Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 2403 – 4104
Vol. 28(3): 427 – 437 (2024)
www.ejabf.journals.ekb.eg

The Impact of Rehabilitation Projects on the Taxonomic Composition and Economics of Fishing Activities in Burullus Wetland, Egypt

Amal M. Faragallah, Sherif A. Fattouh, Ahmed F. EL-Karashily, Shaimaa M. Haggag*
National Institute of Oceanography and Fisheries (NIOF), Fisheries Division, Egypt
[*]**Corresponding Author: Sh_haggag@yahoo.com**

ARTICLE INFO

Article History:
Received: March 2, 2024
Accepted: April 3, 2024
Online: May 27, 2024

Keywords:
Northern Delta Wetlands,
Burullus Wetland,
Catch composition,
Tilapia,
Economic evaluation

ABSTRACT

This study aimed to analyze the impact of rehabilitation projects on the taxonomic composition of Burullus Wetland. Published secondary data covering the lake's production from 1998 to 2021 underwent descriptive analysis. The primary data were collected and analyzed through a cost-benefit analysis. The findings revealed a significant increase in the total production of Burullus Wetland, particularly in key species such as tilapia and grass carp, accompanied by a noteworthy decrease in catfish production after rehabilitation. This indicates a negative impact on certain fish speciesBased on the evaluation results, all fishing nets generate positive net income. Moreover, legal nets demonstrate superior efficiency when compared to their illegal counterparts. The results underscore the considerable relative importance of tilapia production in Burullus Wetland, emphasizing the need to balance development and environmental preservation to enhance lake efficiency and maintain species diversity. Preserving the class composition of fish is similarly crucial. Further studies are needed after the completion of this phase to precisely determine the impact of disinfection and development operations.

INTRODUCTION

Five lakes are situated along the Egyptian Mediterranean coast, playing a vital role in the national economy not only due to their fish production but also as resting areas for migratory birds. They hold great ecological importance, hosting a diverse range of biodiversity **(Shalby *et al.*, 2020; Mehanna *et al*., 2023)**. Lake Burullus, the second-largest lake in the Nile Delta, is connected to the Mediterranean Sea through a natural outlet called the Bogaz **(El-Shinnawy, 2002; Shalby *et al.*, 2020; Hany *et al.*, 2021; Mehanna *et al.*, 2023)**. Covering an area of approximately 410km^2, the lake has a rectangular shape bordered by agricultural lands in the South and a wetland separating it from the Mediterranean Sea in the North. The lake's depth ranges from 20cm close to the shore of the eastern basin to 200cm in the central basin and near the sea outlet. Lake Burullus is a primary recipient of agricultural wastewater, receiving about 4 billion cubic meters annually **(El-Shinnawy, 2002)**. Numerous drains allow many effluents, including significant quantities of pesticides and fertilizers, to enter the lake, resulting in serious mineral and microbiological pollution **(Al-Afify *et al.*, 2023)**. Satellite data analysis also revealed a 16% decrease in the Wetland's water bodies and a 52% decrease in floating vegetation area between 1984 and 2019 **(Abd el-sadek *et al.*, 2022)**. In addition to the previously mentioned data, overfishing, illegal fishing methods, the spread of aquatic plants, siltation of the Burullus inlet, and illegal seed collection were reported **(Mehanna, 2008)**.

The Egyptian government has recently made substantial efforts to rehabilitate and restore the northern lakes and wetlands to improve their environmental conditions and restore their economic value. The process of developing and purifying the Egyptian lakes began in February 2010 and has continued until now. These operations occurred after the political leadership instructed officials to prepare the 'Rehabilitation of Egyptian Lakes' program, including the Burullus Wetland rehabilitation project. The project aims to improve water quality and fish production in the lake, primarily by enhancing water exchange between the lake and the sea through dredging and lateral protective actions **(Hany *et al.*, 2021, 2022; Mehanna *et al.*, 2023)**.

Following this development, several studies have been conducted, with some addressing the impact of development on water quality, revealing a significant improvement in water quality standards **(Hany *et al.*, 2022; Al-Afify *et al.*, 2023)**. A study examined fishermen's opinions after development, indicating that the majority of fishermen agreed that some problems continued to exist despite development **(Hassan & Mohamed, 2023)**. The impact of these efforts on the quantity and value of fish production in the lake was also measured **(Mehanna *et al.*, 2023)**. However, no studies have been conducted to clarify the impact of this development on the catch composition before and during development. Therefore, this research mainly aimed to study the clearing and development processes and their impact on the lake's fish production in general, as well as on the species composition and relative importance of fish species in the lake's production in particular.

MATERIALS AND METHODS

Data sources

This study relied on published secondary statistical data from 1998 to 2021, sourced from the Central Agency for Public Mobilization and Statistics (CAPMAS) Fish Production Annual Statistics, specifically focusing on Lake Burullus' production and its taxonomic composition. Additionally, preliminary data included a random sample of 240 fishermen working with different nets in Burullus Wetland. Furthermore, pertinent research studies and literature on the subject were referenced to provide a comprehensive understanding of the context and background.

Data analysis

Both descriptive and quantitative economic analyses were employed for the study variables, utilizing standard statistical and economic models, including the estimation of the change rate in lake production by applying a growth model. Pre- and post-production differences were assessed using a Paired Samples T-test analysis. Additionally, cost-benefit analysis was utilized to evaluate the economic returns from the fishing activities in the wetland.

RESULTS

1. A general description of projects for the rehabilitation and enhancement

The rehabilitation projects, aiming to clear and develop the wetland commenced in early 2010. These initiatives included the removal of aquatic plants, such as reeds and hay, and the deepening of the lake by at least one meter in the Baltim area. Additionally, radial canals were constructed from the sea to the lake, enhancing water flow and consequently improving water quality. This effort contributed to an increase in the lake's production of high-value marine fish, viz. bream, sea bass, and crab. The 11-km Bermbal Canal was also cleared and deepened, boosting nutrient levels in Lake Burullus, and improving the flow of agricultural wastewater into the Burullus Wetland. Furthermore, an equipped dock was established for the water bodies police near the Bogaz area to enhance their efficiency in carrying out tasks, including combating the wielding seed mafia to preserve the lake's seed sources.

1. 2. Evolution in Burullus' Wetland significance for North Delta Wetlands' production

Table (1) indicates a decline in the first period in Lake Burullus production, dropping from 59 thousand tons in 1998 to approximately 53 thousand tons in 2009. This shows a non-significant annual decrease of 0.09%, which was not statistically proven. However, during the second period, production surged from around 60 thousand tons in 2010 to 104 thousand tons in 2021, with an annual statistically significant increase of approximately 6%. Consequently, there was a rise in its relative importance to the total production of the northern Delta Lakes (Manzala - Burullus - Edku - Mariout) from 44% in the first period to 46% in the second period.

Table 1. Evolution of the relative significance of Burullus Wetland production (1000t) to the total production of the Northern Delta Wetlands

Before rehabilitation				After rehabilitation			
Year	**Burullus**	**Northern Delta**	**%**	**Year**	**Burullus**	**Northern Delta**	**%**
1998	59	152.2	38.8	2010	59.5	133	44.7
1999	55.3	135.3	41.0	2011	45.5	117.1	38.8
2000	51.8	141.2	36.7	2012	52.1	128.3	40.6
2001	59.2	144.7	40.9	2013	49.7	144.8	34.3
2002	59.8	133.8	44.7	2014	63.8	132.3	48.4
2003	55.5	135.6	40.9	2015	65.1	132.6	49.1
2004	55	132.8	41.4	2016	67.6	123.5	54.7
2005	53.9	108.6	49.6	2017	69.3	146.1	47.4
2006	53	108.3	48.9	2018	71.4	152.5	46.8
2007	58.3	106.1	54.9	2019	81.1	179.6	45.2
2008	52.3	108.9	48.0	2020	91.9	198	46.4
2009	53.4	113.1	47.2	2021	103.8	206.2	50.3
Mean	55.5	127.2	43.6	Mean	68.4	150.1	45.6

Source: **CAPMAS (2000- 2023).**

Table (2) illustrates various shifts in the relative importance of fish species in Burullus Wetland across two distinct periods: the initial phase (1998- 2009) preceding rehabilitation initiatives, and the subsequent phase (2010- 2021) concurrent with these operations. Notably, the relative importance of tilapia increased from 52.3% in the first period to 59.7% in the second period. Conversely, the Mugilidae family experienced a decline in relative importance, dropping from 20.6 to 17.1%. Additionally, catfish witnessed a decrease from 9.5 to 3.4%, while the relative importance of grass carp shifted from 3 to 3.5%. In the case of other species, relative importance rose from 14.5 to 16.3% between the two periods.

Table 2. Evolution of the production of captured species (1000t) from Burullus Wetland before and during rehabilitation operations

Rehabilitation	Year	Tilapia	Mugilidae	Catfish	Carp	Other	Total
	1998	40.2	2.8	5.0	0.5	10.5	59.0
	1999	33.9	3.1	5.9	0.3	12.1	55.3
	2000	32.1	8.9	2.6	0.9	7.3	51.8
	2001	38.5	12.3	2.2	1.9	4.2	59.2
	2002	39.9	12.8	1.9	1.4	3.8	59.8
	2003	38.4	9.7	2.1	1.5	3.9	55.5
Before	2004	35.6	10.6	2.2	1.8	4.8	55.0
	2005	28.3	14.9	2.9	1.7	6.1	53.9
	2006	1.7	26.1	9.3	2.1	13.7	53.0
	2007	21.4	16.3	8.4	1.7	10.5	58.3
	2008	19.1	11.6	10.0	1.9	9.6	52.3
	2009	20.7	7.7	11.6	2.9	10.4	53.4
	Mean	29.2	11.5	5.3	1.7	8.1	55.5
	%	52.3	20.6	9.5	3.0	14.5	100
	2010	37.5	12.2	2.3	2.5	5.0	59.5
	2011	32.2	4.5	2.5	2.4	4.1	45.5
	2012	27.6	9.8	2.1	2.0	10.5	52.1
	2013	26.8	9.8	2.1	2.0	9.0	49.7
	2014	39.8	10.0	2.3	2.4	9.4	63.8
	2015	40.4	10.4	2.3	2.4	9.7	65.1
During	2016	41.3	11.5	2.3	2.4	10.0	67.6
	2017	42.3	11.1	2.4	2.4	11.1	69.3
	2018	42.7	11.6	2.6	2.6	11.8	71.4
	2019	46.8	13.5	2.7	2.9	15.2	81.1
	2020	55.5	16.7	2.8	2.9	14.0	91.9
	2021	57.5	18.1	2.5	2.6	23.1	103.8
	Mean	40.8	11.7	2.3	2.4	11.1	68.4
	%	59.7	17.1	3.4	3.5	16.3	100

Source: **CAPMAS (2000- 2023)**.

3. The relative importance of the taxonomic composition

Table (3) provides regression results detailing the relationship between fish production (y) and time (T) before and during rehabilitation projects, with each equation representing the models for the respective periods. Before rehabilitation, the total fish production (Ln(y)) was modeled as Ln(y) = 4.05 - 0.006T, resulting in an F-statistic of 1.971, an R-squared value of 0.165, and a *P*-value of 0.191. During rehabilitation, the equation changed to Ln(y) = 3.797 + 0.062T, yielding a significantly higher F-statistic of 50.37, an R-squared value of 0.834, and a highly significant *P*-value of < 0.001.

Similar patterns were observed for tilapia, Mugilidae, Catfish, and other fish species. Before the operations, each species had its own model, and during the operations, a new model emerged. In all cases, the models during the operations demonstrated higher F-statistics, R-squared values, and lower *P*-values compared to the models before the operations. These findings suggest a significant impact of the rehabilitation projects on fish production, with notable improvements in the model's explanatory power and statistical significance during the specified period. The exception is grass carp, which did not follow the same pattern.

Table 3. Estimating the time trend equation for fish production catch before and during rehabilitation in Burullus Wetland

Statement	The equation	Model	F	R^2	*P*-value
Total	Ln(y)= 4.05- 0.006T	Before	1.971	0.165	0.191
	Ln(y)= 3.79+ 0.062T	During	50.37	0.834	< 0.001
Tilapia	Ln(y)= 3.90- 0.109T	Before	2.886	0.225	0.12
	Ln(y)= 3.33+ 0.054T	During	23.56	0.702	0.001
Mugilidae	Ln(y)= 1.56+0.110T	Before	6.635	0.399	0.028
	Ln(y)= 1.91+0.074T	During	10.02	0.501	0.01
Catfish	Ln(y)= 0.77+0.104T	Before	4.012	0.286	0.073
	Ln(y)= 0.60+0.030T	During	5.213	0.343	0.046
Grass carp	Ln(y)= -1.07+0.88T	Before	22.11	0.689	0.001
	Ln(y)= 0.66+0.030T	During	3.953	0.264	0.087
Other	Ln(y)= 1.78+0.032T	Before	0.062	0.66	0.436
	Ln(y)= 1.58+0.113T	During	33.54	0.77	< 0.001

Source: Data analysis using SPSS.

The presented Paired Samples T-test analysis in Table (4) illuminates the repercussions of rehabilitation operations on the composition of species in Burullus Wetland. Notably, the total fish production witnessed a statistically significant increase during rehabilitation (**P*< 0.05), underscoring a positive impact on overall fish abundance. While the change in tilapia production exhibited marginal significance (*P*= 0.050), implying a potential influence on tilapia abundance, the Mugilidae family production remained relatively stable with no statistically significant difference (*P* = 0.929). On the contrary, catfish production experienced a highly significant decrease (***P*< 0.01), suggesting a substantial negative impact during rehabilitation. Conversely, the production of grass carp displayed statistically significant negative changes (**P*< 0.05). The production of other fish species, while not statistically significant (*P*= 0.088), hinted at a potential increase during rehabilitation. In conclusion, the Paired Samples T-test underscores the diverse and species-specific effects of rehabilitation operations on the fish population in Lake Burullus, emphasizing both positive and negative outcomes for different species.

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Table 4. Paired Samples T-test for changes in fish species composition in Burullus Wetland before and during rehabilitation operations

Statement		Mean	SD	T	*P*-value
Total	Before	55.5	2.855	2.437	0.033
	During	68.4	17.131		
Tilapia	Before	29.2	11.535	2.201	0.050
	During	40.8	9.292		
Mugilidae	Before	11.5	5,272	0.092	0.929
	During	11.7	2.413		
Catfish	Before	5.3	3.601	-3.195	0.009
	During	2.3	0.452		
Grass Carp	Before	1.7	0.779	3.447	0.005
	During	2.4	0.515		
Other	Before	8.1	3.502	1.875	0.088
	During	11.1	4.907		

Source: Data analysis using SPSS.

4. Economic assessment of the main fishing gears

The following results were extracted from the analysis of data collected through the questionnaire, where Table (5) presents the economic evaluation of the fishing gears used in Burullus Wetland, denominated in Egyptian pounds (EGP). They are as follows: The average monthly net income for the boat-owning fisherman engaged in the trammel net during the 6.5-month fishing season is approximately 2,215 EGP, while the average monthly wage for the hired fisherman working on a trammel net is about 738 EGP. The average monthly income for the owner of the set net for a 4– 5-month fishing season is around 3,911 EGP, and for the hired fisherman in the same net, it's about 1,303 EGP per month. The average monthly income for the owner of the set net/ trammel net during the 2– 5-month fishing season is approximately 2,909 EGP, while the hired fisherman in the same net earns around 969 EGP per month. Regarding the traps, the monthly income for the fisherman is about 1,457 EGP for the 7-month season, and this net doesn't utilize a hired fisherman. The average monthly income for the boat-owning fisherman in diving (illegal) is around 1,733 EGP, and for the hired fisherman, it's about 578 EGP during the 6-month season. As for the trawl net (illegal), the average monthly income for the boat-owning fisherman is around 3,222 EGP, and for the hired fisherman, it's approximately 1,074 EGP during the fishing season.

Variable costs include boat maintenance, nets, fishing tools, and fuel expenses. Fixed costs encompass fishing license renewal and depreciation. Total costs represent the sum of variable and fixed costs. The lowest total costs were associated with the traps, approximately 3.8 thousand pounds, while the illegal trawl net had the highest total costs, reaching about 63 thousand pounds. The return-to-cost ratio indicates that legal fishing nets have higher ratios, approximately 1.8, 2.04, 1.98, and 3.68 compared to illegal nets with ratios of 1.6 and 1.5. This ratio suggests the potential to cover costs with an economic surplus. The higher the ratio above one, the better, making legal nets more favorable in this regard. In terms of the operating ratio, legal nets were nearly equal, with values around 0.52, 0.48, and 0.50, except for the traps, which had an operating ratio of about 0.27. For illegal nets, the ratios were 0.61 and 0.68, indicating an operational efficiency. The lower the ratio from one, the more efficient the use of economic resources, showcasing the efficiency of legal nets over illegal ones.

Table 5. The economic assessment of the main fishing nets in Burullus Wetland during the year 2021 (in thousands of EGP per ton)

Fishing net/Indicator	Trammel net*	Set net*	Set/ Trammel net*	Traps*	Diving net**	Trawel net**
Fishing season (months)	6.5	4.5	5.5	7	6	9
Total production of the Boat	6.8	6	5.2	3.4	4.8	9.2
Total revenue for the boat	30.6	34.4	32.2	14	27.2	92
Variable costs for the Boat	11.6	12.6	11.8	2.6	14.6	48
Fixed costs for the boat	4.6	4.2	4.4	1.2	2.2	15
Total costs for the boat	16.2	16.8	16.2	3.8	16.8	63
Net income of the boat for the fishing season	14.4	17.6	16	10.2	10.4	2.9
Monthly income for the boat owner during the Season	2.2	3.9	2.9	1.5	1.7	3.2
Monthly income for the hired fisherman during the season	0.7	1.3	1.0	-	0.6	1.1
Return to cost ratio	1.8	2.04	1.98	3.68	1.61	1.46
Operating ratio	0.52	0.48	0.50	0.27	0.61	0.68
Net return on revenue	0.47	0.51	0.49	0.72	0.38	0.31
Utilization efficiency	0.88	1.04	0.98	2.68	0.61	0.46
Break-even point	1.6	1.2	1.3	0.4	0.9	3.1
Break-even revenue	7.40	6.62	6.94	1.47	4.74	31.36
Break-even price	2.37	2.8	3.1	1.11	3.49	6.83

Source: Collected and calculated from questionnaire forms.
*Legal method.
**Illegal method.

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The net return on revenue was approximately 0.5 for legal nets, except for the traps, which reached 0.72. Illegal nets had lower ratios, highlighting that legal nets are more efficient administratively.

The utilization efficiency index, reflecting the efficiency of utilizing available resources, was higher for legal nets, with ratios of 0.88, 1.04, 0.98, and 2.68 compared to 0.61, and 0.46 for illegal nets.

The most important of these indicators are the three break-even points, including the quantity break-even point, which determines the quantity at which neither profit nor loss occurs. The break-even quantities for legal nets were close, with approximately 1642, 1200, and 1270kg, except for the traps, which had a break-even quantity of about 850kg. Illegal nets, like the trawl net, had a much higher break-even quantity of around 3120kg, indicating potential overfishing or illegal practices.

Revenue break-even point: It represents the point where neither gains nor losses occur. The break-even revenue for illegal nets was around 31.4 thousand pounds, indicating that boat owners might resort to illegal means to surpass this point and achieve profits.

Price break-even point: It helps determine the appropriate selling price. Legal nets had suitable break-even points, while for the illegal trawl net, the break-even price was significantly higher, even though the quality of the production did not differ.

DISCUSSION

The Egyptian government has launched a comprehensive national program for the sustainable development of Egyptian lakes; these plans include dredging and deepening the bottom of the lakes and removing reeds to promote water circulation **(Abd Ellah, 2021; Rifaat *et al.*, 2023)**. This project, based on the current study results, has contributed to the increased production of Burullus Wetland, a focal point of this initiative. Additionally, there is a relative change in the species composition of the lake. Our findings align with previous results indicating that government dredging and cleaning operations in Lake Manzala have a discernible impact on the species composition of the lake **(Shalloof *et al.*, 2023)**. The increase in lake productivity may be attributed to the improvement in waterer quality at the lake inlet and the eastern part, where dredging activities have been implemented **(Hany *et al.*, 2022)**. Moreover, the lake's water quality is most influenced by the interchange of water with the sea and the circulation pattern within the lake **(Hany *et al.*, 2022; Aly-Eldeen *et al.*, 2023; Shalloof *et al.*, 2023)**. According to TSIChl-a, the lake has been converted from being mostly hypereutrophic to eutrophic **(Zaghloul *et al.*, 2022)**. In addition, the expansion of water surfaces due to continuous development in Lake Burullus, represented by the removal of aquatic plants, has led to a decrease in the vegetation cover **(Abd El-Hamid *et al.*, 2023)**.

In addition, the current study results revealed that tilapia fish form the dominant species in Lake Burullus, which is consistent with the findings of **Shalloof *et al.* (2023)** indicating that tilapia species represents 70% of the production of Manzala Wetland. This indicates the significance of the substantial impact of this species on lake production, and therefore, it should be considered in rehabilitation projects to develop solutions for adapting to climate change. It was mentioned that these changes may result in the intrusion of seawater into the lake, leading to an increase in the lake's salinity **(Eid & Shaltout, 2013; Shalby *et al.*, 2020; Ouda, 2022)**. Therefore, understanding the taxonomic composition is critical for sustainable water bodies management **(Baki *et al.*, 2017)**.

In terms of the fishermen's monthly income, the results of this study align closely with those of **Mehanna *et al.* (2023)** concerning fishermen's income in Manzala Wetland. This may elucidate the discontent among fishermen regarding rehabilitation operations, as they did not notably enhance income or offer improved living conditions **(Hassan, 2023)**. Development ultimately should be in favor of human well-being, and thus, further studies should be conducted to assess the impact of these projects on the fishermen's livelihoods. Additionally, these projects should be evaluated upon completion to reveal their effect on the lake's species composition.

CONCLUSION

This study highlighted a positive impact of clearing and development operations on the overall production of Burullus Wetland, particularly on key species such as tilapia and grass carp, with a noticeable increase in the total production. Despite the stability observed in the production of the Mugilidae, catfish production experienced a decline, signaling a negative impact on specific fish species. The results emphasize the considerable relative importance of tilapia production from Burullus Wetland, highlighting the need to consider this significance in future environmental or economic initiatives in the region. While clearing and development operations bring positive benefits to fish production in Lake Burullus, it is crucial to prioritize environmental balance and biodiversity in upcoming efforts aimed at enhancing the lake's efficiency and preserving fish species composition. Further studies are warranted to precisely assess the impact of clearing and development operations and validate the conclusions drawn.

The evaluation results also showed that all fishing nets yield positive net income, highlighting the economic efficiency of this production activity. It has been demonstrated that legal nets exhibit higher efficiency compared to their illegal counterparts. This underscores the significance of guiding fishermen toward legal trade by issuing licenses, thereby eliminating illegal practices.

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