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Ecological Impact of Restoration on Water Quality and Macrophyte Diversity in Lake Manzala, Nile Delta

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Shallow lakes shift rapidly worldwide from clear-water to turbid-water conditions and degradation, with poor water quality. Coastal wetlands play a crucial role in supporting biodiversity, leading to the resilience of coastal ecosystems. Therefore, rehabilitation of Egyptian wetlands has been of prime importance in Egyptian considerations since 2017, as they are important fish sources, contributing more than 60 % of the total protein provider. The objective of this research is to measure the effectiveness of the governmental development plan, particularly Lake Manzala, which is the largest wetland and most productive of all. This research attempts to follow the abundance of aquatic plant biodiversity, along with water quality, as tools to investigate the real development process sustained. This is done through investigation of water quality and macrophyte long-term variability, before and after developmental work, which can help mitigate the degradation. The investigation showed positive signs of improvement of water quality in Manzala water during the post-development phase, as it transitioned from a poor to a moderate state. Extinctions of native species and/or excessive growth of macrophytes cause the biological diversity to decline. The free-floating vegetation, Salvinia, Nympheae, and other populations are facing threats and were classified as critically endangered a long time ago due to loss of healthy habitats. Therefore, they have never been recorded in this investigation. On the other hand, the free-floating vegetation, water hyacinths (Eichhornia crassipes) and water cress (Pistia stratiotes) remained in front of the heavily polluted drains from 2010 until 2022. Some submerged vegetations disappeared; others showed new records during the investigation periods. After the rehabilitation project, the community structure showed the presence of two free-floating species, four floating herbs, six submerged vegetation, four emergent halophytes and one filamentous green alga.

Keywords: *Lake Manzala, wetland restoration, water quality, macrophytes, biodiversity*

Introduction

Wetlands are important ecosystems on this earth because they provide refuge and food to different aquatic biodiversity. Mariout, Idku, Burullus, and Manzala lakes are the four most important wetlands on the northern coast of the Nile Delta in Egypt. The areas of these lakes (2,449 km²) contribute <0.003 of the total area of Egypt (one million km²) (Shaltout et al., 2017). The latter authors continued that these lakes are inhabited by 19% of the total Egyptian flora. Therefore, they are regarded as important hotspots for the Egyptian flora, particularly the aquatic

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macrophytes. Economically, Lake Manzala is considered the largest Northern Delta Lake and the most productive overall; it lies on the eastern north coast of Egypt. The northern lakes of Egypt are among the most important sources of fish wealth, as they annually contribute no less than 60% of fish production from natural sources in Egypt (Kafrawy et al., 2018).

Lake Manzala is heavily impacted by human activities and suffers from exposure to high inputs of industrial, domestic, and agricultural pollutants that can degrade water quality, causing eutrophication. It exhibited progressive shrinkage of its water body due to excessive fish farms area uses, increased macrophyte growth and land reclamation. Over the past few decades, the surface area of Manzala Lake has steadily decreased from 1709 km^2 in 1907 to 565.91 km^2 in 2016 (El Sayed et al., 2025). Therefore, the Egyptian Government has launched an extensive program for the restoration of Egyptian lakes, of which Lake Manzala was a high priority. Recently, the project began with intensive national dredging on the lake bottom to enhance the lake's properties and productivity. The plan also included deepening the inlet connection between the lake and the Mediterranean Sea, to let brackish water biodiversity develop, in addition to the removal of weeds from several areas of the lake. This reflects the increase in the area of the Lake to 1011.36 km2 in 2020, according to a remote sensing picture (GAFRD, 2020).

During 2020, the Bahr El Baqar (a heavily polluted drain) wastewater treatment plant was constructed, located in the northern governorate of Port Said city, with a daily output capacity of 5.6 million cubic meters. It serves a population of 11.5 million people. The plant is the world's largest of its kind, holding three Guinness World Records (McFarland, 2021). This world's largest treatment facility processes 64.8 m3 of water per second, is the largest sludge treatment plant, and the largest single-operator ozone generating plant.

Therefore, the new situation of the current L. Manzala urges many scientists to investigate water quality and all biodiversity in the water budget. The goal of this study was to examine long-term trends in the trophic state and water quality of Lake Manzala, based on physicochemical parameters and macrophyte biodiversity. This is to provide baseline information for monitoring the lake after the development plans and carrying out mitigation processes of water quality and biodiversity for sustainable uses for fish production. Also, to provide recommendations that would make the results of water quality and trophic status assessment useful for management strategies.

Literature Review

The following literature was investigated after governmental developmental projects had begun. About chemical water quality, Serag et al (2021) compared their results with those of the Environmental Protection Agency; they found that the means of temperature and pH are within the permissible limits, while the means of total solids, hardness, BOD, COD, sodium, chloride, total nitrogen, total phosphorus, and Iron are still above the permissible limit. El-Khayat et al. (2023), comparing their results before and after Manzala Lake rehabilitation, indicated a higher water exchange with the sea, accompanied by a significant decrease in Pb, Cd, Cu, and Zn in water samples, and a remarkable decline in Cd and Pb bioaccumulation in all fish and snail samples. Thus, indicating an improvement in chemical water quality, which served the healthy improvement situation of the fish. Although the available literature on macrophyte composition at the different sites of Manzala Lake, Egypt, is scarce, Hafiz et al. (2019) using statistical models, indicated that, by the end of 2042, they gave the assumption that the vegetation cover would disappear. On the other hand, the macrophytes' situation long before the developmental project in Manzala, Khedr (1996), investigations of 100 stands revealed eight vegetation groups, which indicated eleven dominant communities. These were *Phragmites australis*, *Typha domingensis*, *Scirpus maritimus*, *Echinochloa stagnina*, and *Ludwigia stolonifera* as emergent hydrophytes; *Eichhornia crassipes*; and *Azolla filiculoides* as floating hydrophytes. In addition, the dominant submerged hydrophytes were *Potamogeton pectinatus*, *Najas armata*, *Ceratophyllum demersum*, and *Ruppia maritima*. Other authors recorded seven aquatic plants in Lake Manzala (Khedr and Zahran, 1999). These species (*Epilobium hirsutum*, *Myriophyllum spicatum*, *Nymphaea caerulea*, *Nymphaea lotus*, *Persicaria lapathifolia*, *Pistia stratiotes*, and *Saccharum spontaneum*) were restricted to the western section of Lake Manzala. Their records also included *Echinochloa stagnina*, *Panicum repens*, and *Azolla*. Another recent study showed eleven aquatic macrophyte species, dominated by *P. pectinatus*, *E. crassipes*, *P. stratiotes*, *P. australis*, *T. domingensis*, and *E. stagnina*, were recorded in the lake (Haroon, 2022). The current study may show sometimes resemblance to vegetations, compared with previously mentioned authors, but also, deviations from previous records and regeneration of disappearing species, and sometimes registering new records, highlighting a comparable situation of macrophyte biodiversity, before and after the developmental project.

Materials and Methods

Lake Manzala, the largest Egyptian lagoon, lies on the eastern boundary of the Nile Delta; a sandy beach ridge separates the lake from the sea. Around its eastern and southern boundaries, it receives untreated agricultural, industrial, and domestic waste. The polluted water comes from four sources: Bahr El-Baqar Drain, which is a main source of lake pollution with wastewater, and El-Serw Drain, located in Damietta; Hadous Drain, both of which are agricultural drainage channels; and Ramses Drain, which is an agricultural drainage channel located in Dakahlia (Elmorsi et al., 2017), as shown in Figure 1. The first developmental plan removed $24x10^3$ feddans of aquatic grasses. As a result of dredging activities in Lake Manzala, there was a slight change in its surface area, and most aquatic macrophyte was removed. Sampling was carried out seasonally at eleven GPS fixed stations, covering the surface area of the lake. Sampling was carried out seasonally from the year 2010 to 2022, using the Ruttiner Sampler. Temperature, salinity, and pH were measured in situ using a calibrated portable Xylem EC300A – YSI 300-4. Physicochemical parameters, in water samples of Lake Manzala pre- and post-development plan, means of replicating samples were taken seasonally, and measured according to APHA (1989). Trophic state was estimated depending on inorganic nutrient data (P-

PO4, N-NH4). Ammonia and reactive Orthophosphate were determined using the phenate method and the ascorbic acid method, respectively. DO and COD were determined according to the Winkler titration method, modified by Carritt and Carpenter (1966). COD was measured using the potassium permanganate method.

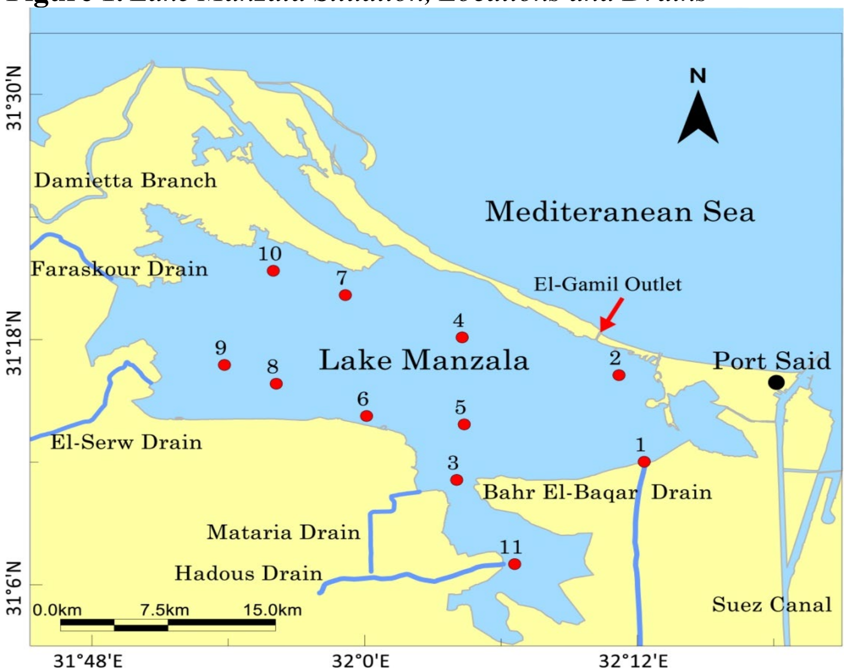
The aquatic system has been categorized into oligotrophic, mesotrophic, and eutrophic water types according to Gupta (2014).

Water Quality Index (WQI)

A simple and concise method for expressing the ambient water quality of streams for general recreational use, including fishing (Cude, 2021). It is a single number that expresses water quality by integrating measurements of water quality variables, such as temperature, dissolved oxygen, biochemical oxygen demand, pH, ammonia nitrogen and total phosphorus, as well as phytoplankton abundance. WQI scores range from 10 (worst case) to 100 (ideal water quality).

Macrophyte samples were collected and characterized from 11 selected stations (Figure 1), representing different drained water sources reaching Lake Manzala. The shrub rake was used to sweep just above the bottom substrate for one meter using a continuous motion, and then lift it with the collected vegetation out of the water. Identification of the vegetation species was done in the lab.

Figure 1. *Lake Manzala Situation, Locations and Drains*



Statistics

Standard Deviation: https://www.basic-mathematics.com › standard-deviation-formula.html

Correlation coefficient: https://www.statisticshowto.com › probability-and-statistics › correlation...

Results

Water quality determined during pre and post development plan are shown in Table 1 and Figures 2, 3.

Table 1. *Mean Values of Environmental Parameters of Lake Manzala in Pre- and Post Development Plan*

Season	T ºC	Tran. cm.	Salinity ‰	DO ml O_2 l^{-1}	BOD Mg/l	COD Mg/l	NH4 -N µM l^{-1}	PO4-P µM l^{-1}
Pre- Development Plan								
Winter 2011	15.6	26.0	2.8	7.4	4.8	79.2	2.0	335.3
Spring 2011	21.8	17.0	3.3	5.0	16.7	168.2	1.1	198.3
Summer 2011	29.4	23.1	7.1	2.7	24.5	83.2	0.4	173.0
Autumn2011	23.2	32.5	5.3	6.2	15.3	130.8	0.4	157.6
Winter 2012	14.2	23.8	2.0	15.7	11.5	0.2	2.3	357.8
Spring 2012	25.1	30.0	4.0	8.3	14.9	192.0	0.7	224.9
Summer 2012	27.9	30.6	4.0	4.0	37.9	22.7	0.8	155.6
Autumn 2012	22.3	28.8	4.4	5.8	29.5	249.8	0.7	85.8
Winter 2013	18.1	76.5	2.3	4.4	24.6	117.8	3.3	358.8
Spring 2013	23.1	47.5	3.7	6.6	88.0	146.1	0.4	93.3
Summer 2013	26.0	35.8	3.1	5.6	25.7	62.5	0.7	131.7
Autumn 2013	19.1	54.0	2.6	5.4	85.1	254.2	1.5	141.5
Winter 2014	17.5	53.3	2.3	4.7	73.4	121.0	1.2	179.4
Spring 2014	24.8	29.6	2.9	6.1	71.7	157.8	0.4	124.0
Summer 2014	26.1	30.0	5.2	5.2	43.9	60.6	0.4	106.8
Winter 2015	15.0	25.8	2.9	6.9	29.6	113.2	3.0	354.1
Summer 2015	28.6	27.3	3.9	4.5	24.6	101.9	0.2	213.7
Winter 2016	16.6	49.2	3.1	7.5	53.6	262.6	1.8	403.6
Summer 2016	28.9	30.4	5.8	4.6	23.0	452.1	0.6	193.4
Winter 2017	16.7	34.2	7.3	7.6	15.5	148.2	1.5	676.2
Average	**22.0**	**35.3**	**3.9**	**6.2**	**35.7**	**146.2**	**1.2**	**233.2**
St. Dev.	5.0	14.1	1.5	2.6	25.3	101.6	0.9	143.5
Summer 2017	27.4	100.0	11.6	7.4	8.5	71.3	0.4	3.5
Winter 2018	24.6	n.r.	n.r.	6.8	8.2	54.7	1.9	29.8
Summer 2018	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Winter 2019	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Summer 2019	30.6	n.r.	8.2	n.r.	n.r.	n.r.	0.6	13.5
Winter 2020	16.3	15.9	3.7	7.5	37.5	56.8	6.7	58.1
Summer 2020	31.2	27.5	6.3	7.5	41.2	60.1	2.8	34.4
Summer 2021	31.4	n.r.	15.4	n.r.	n.r.	n.r.	1.2	22.8

n.r. = not recorded, *Source*: Zaghloul et al (2024)

According to Zaghloul *et al* (2024), the predevelopment period indicated the mean values of DO varied from 2.02 ml O_2 l^{-1} (summer 2011) to 8.33 ml O2 l^{-1} (spring 2012), with an average of 6.2±2.64 ml O_2 l^{-1}. NH_4 ranged between 0.43 µM

l^{-1} (summer and autumn, 2011) and 3.27 μM l^{-1} in winter 2013, with an average of 1.17±0.9 μM l^{-1}. PO4 ranged from 85.83 μM l^{-1} (autumn 2012) to 676.21 μM l^{-1} (winter 2017), with an average of 233.24 ±143.46 μM l^{-1}.

In the post-development period, mean DO increased to around 7.50 mlO_2 l^{-1}. NH_4 ranged between 0.39 μM l^{-1} (summer 2017) and 6.7 μM l^{-1} (winter 2020). However, PO_4 varied within a wide range, from 3.50 μM l^{-1} (summer 2017) to 58.08 μM l^{-1} (winter 2020).

The seasonal distribution of water temperature and water salinity showed a parallel distribution, with low values recorded during the winter season and higher values recorded during the summer season. This is confirmed by a positive correlation between them ($r = 0.484$, $p < 0.05$). The opposite case was recorded with water temperature and dissolved oxygen, since a high water temperature is met with a low value of dissolved oxygen. This is confirmed by a negative correlation between them ($r = - 0.571$, $p < 0.05$).

Figure 2. *Physicochemical Variables estimated during the Predevelopment Period*

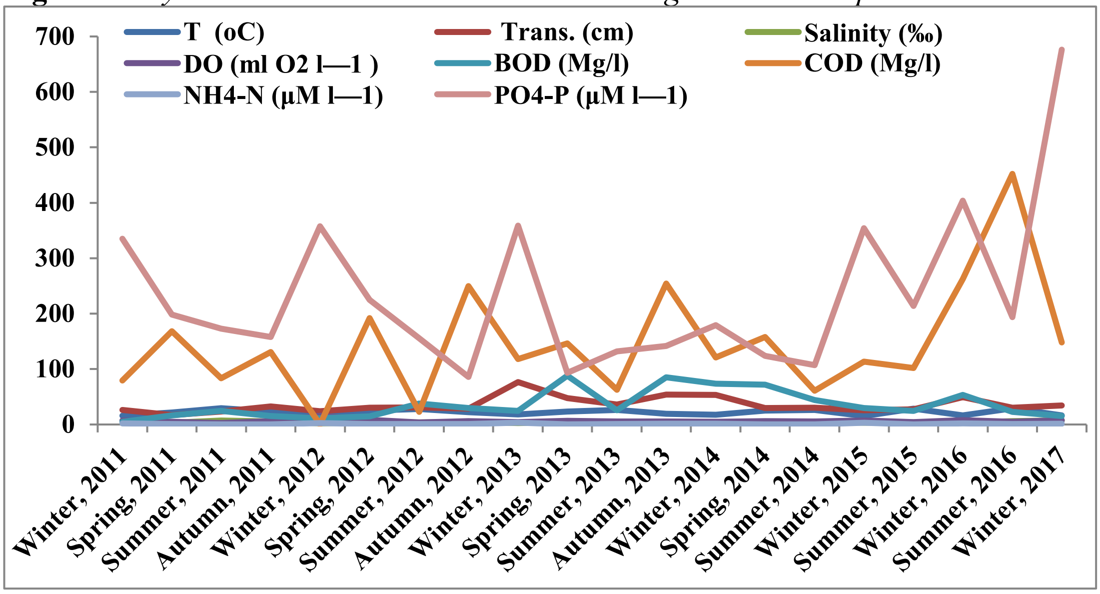
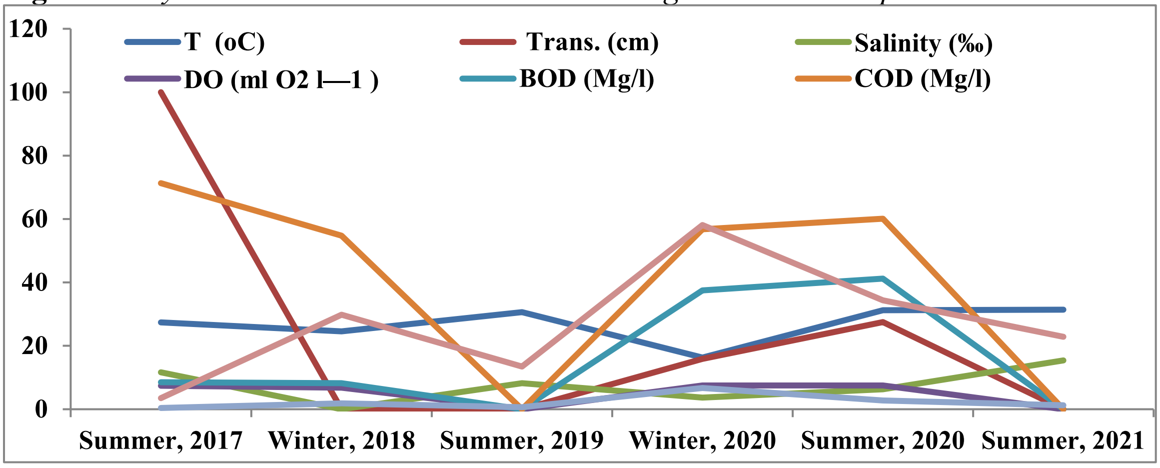
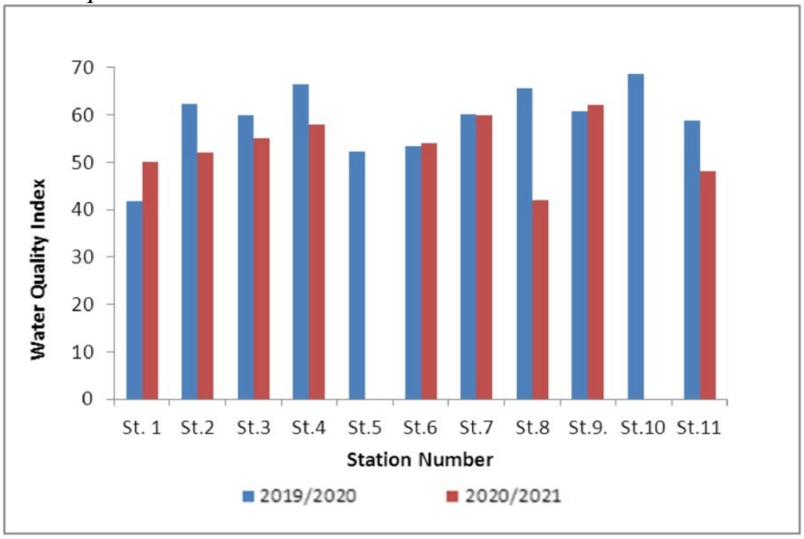


Figure 3. *Physicochemical Variables estimated during the Post Development Plan*



Referring to the Water Quality Index (Gupta, 2014) during the post- development plan (Fig. 4), water quality, in relation to physicochemical parameters, in front of Bahar El Baqar Drain was slightly improved during 2020/2021 from 41.8% to 50% (Zaghloul et al, 2024). Generally, the lake water became a medium state, with an average of 59.1 and 53.4 during 2019/2020 and 2020/2021, respectively.

Figure 4. *Water Quality Index in Front of Bahar El Baqar drain during Post Development Plan*



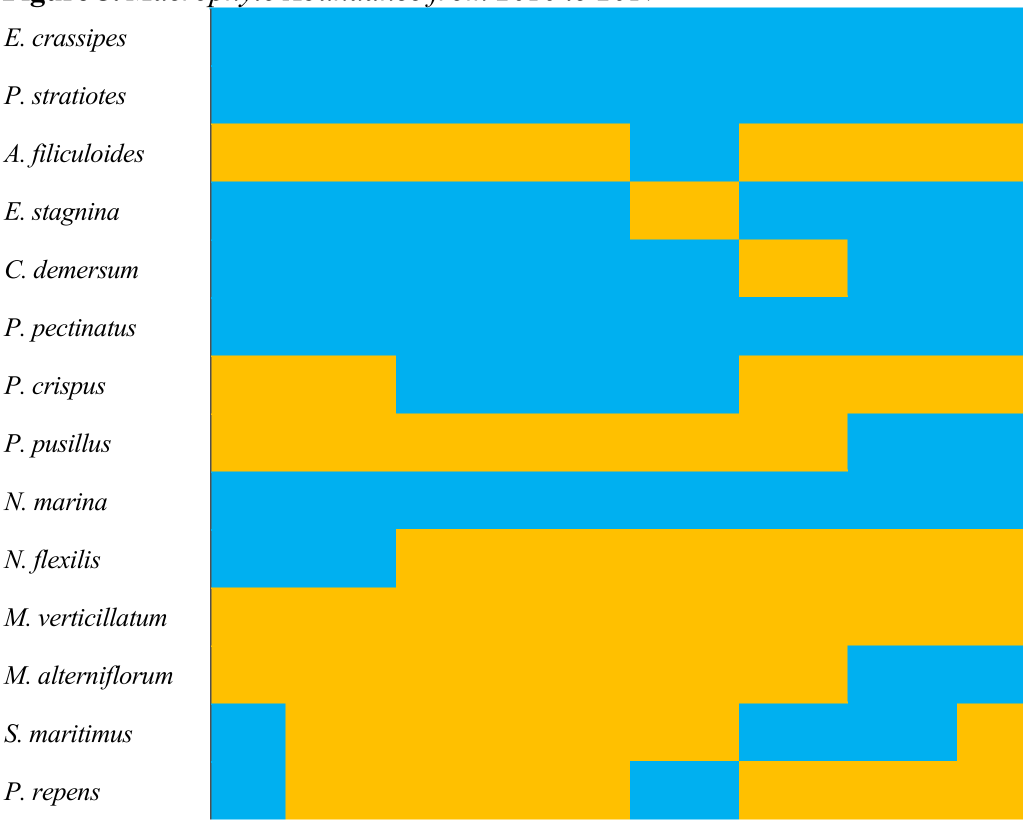
Source: Zaghloul et al, 2024

Tables 4 and 5: Distribution of different macrophytes species along pre and post development plans.

Table 4. *Macrophytes Abundance before Development Plan (2010-2017)*

Macrophyte sp.	2010	2011	2012	2013	2014	2015	2016	2017
E. crassipes	+	+	+	+	+	+	+	+
P. stratiotes	+	+	+	+	+	+	+	+
A. filiculoides					+			
E. stagnina	+	+	+	+		+	+	+
C. demersum	+	+	+	+	+		+	+
P. pectinatus	+		+	+	+	+	+	+
P. crispus			+	+	+			
P. pusillus							+	+
N. marina	+	+	+	+	+	+	+	+
N. flexilis	+	+						
M. verticillatum								
M. alterniflorum							+	+
S. maritimus	+					+	+	
P. repens	+				+			
P. australis		+			+			
T. capensis					+		+	
Polygonum sp.							+	+
E. ramosissimum	+							
R. aquatilis						+	+	
Cladophora sp.								
Alternanthera								
Schoenoplectus sp.								
L. stolonifera								
P. geminatum								

Figure 5. *Macrophyte Abundance from 2010 to 2017*



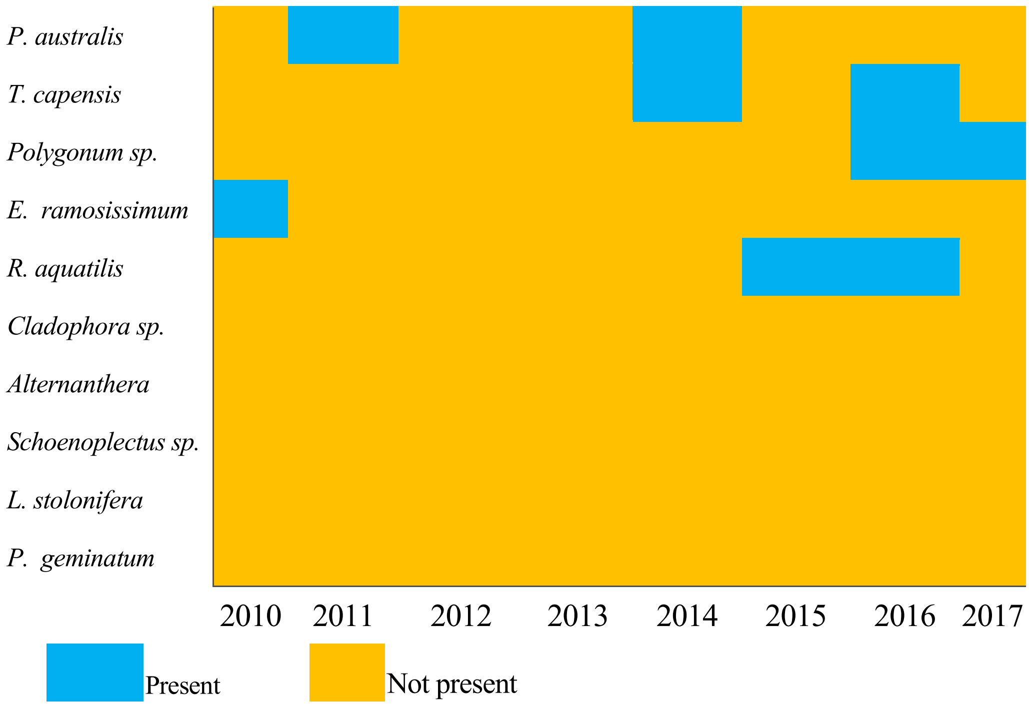
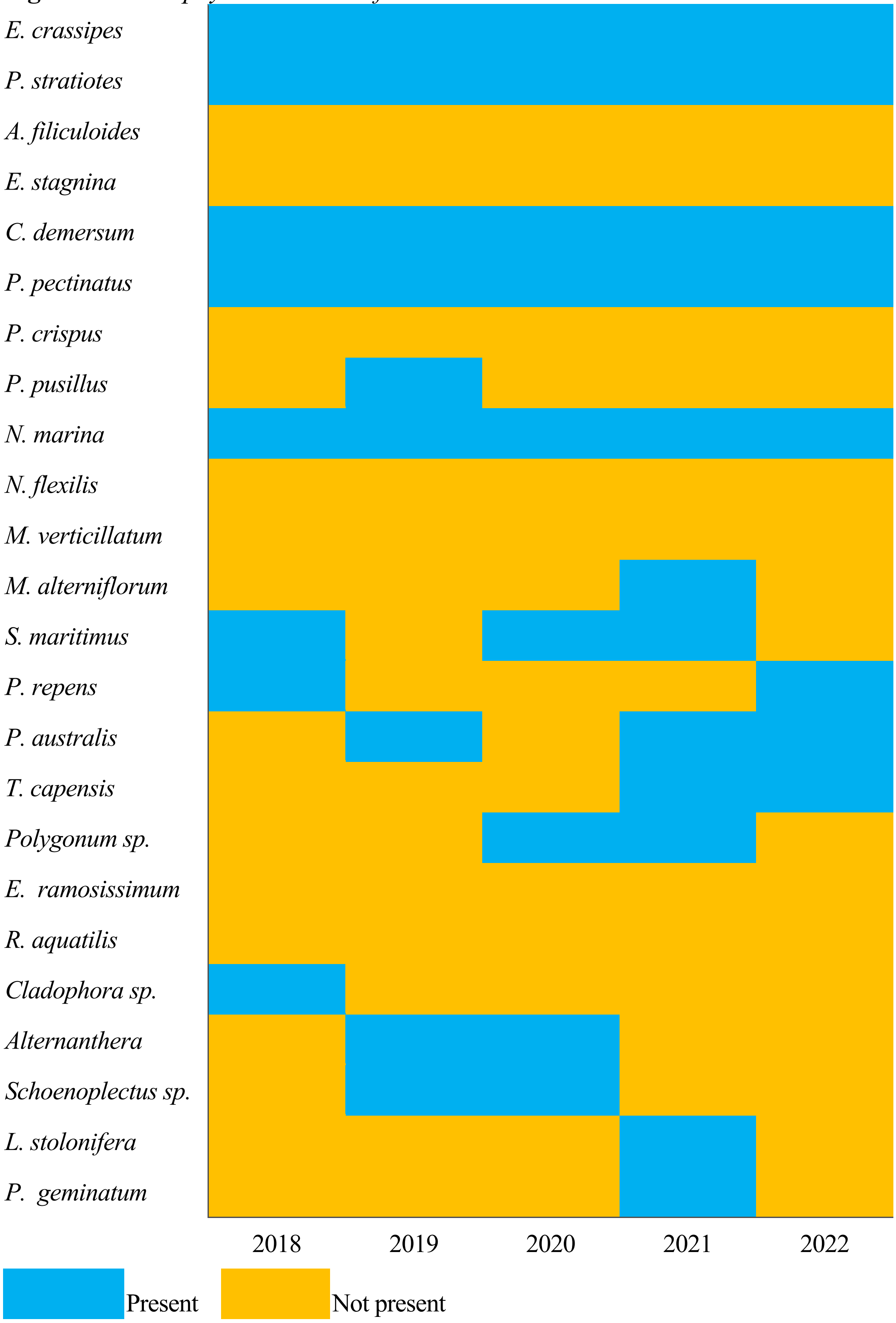


Table 5. *Macrophytes Abundance after Development Plan (2018-2022)*

Macrophyte Sp.	2018	2019	2020	2021	2022
E. crassipes	+	+	+	+	+
P. stratiotes	+	+	+	+	+
A. filiculoides					
E. stagnina					
C. demersum	+	+	+	+	+
P. pectinatus	+	+	+	+	+
P. crispus					
P. pusillus		+			
N. marina	+	+	+	+	+
N. flexilis					
M. verticillatum					
M. alterniflorum				+	
S. maritimus	+		+	+	
P. repens	+				+
P. australis		+		+	+
T. capensis				+	+
Polygonum sp.			+	+	
E. ramosissimum					
R. aquatilis					
Cladophora sp.	+				
Alternanthera		+	+		
Schoenoplectus sp.		+	+		
L. stolonifera				+	
P. geminatum				+	

Figure 6. *Macrophyte Abundance from 2018 to 2022*



The free-floating vegetation, water hyacinths (*Eichhornia crassipes*) and water cress (*Pistia stratiotes)* have prevailed in front of the heavily polluted drains, from 2010 until 2022, as they are considered pollution indicators and can withstand pollution stress (Table 4 & Figure 5). The submerged grasses *Echinochloa stagnina*, *Potamogeton pectinatus*, the cattail *Ceratophyllum demersum,* and the cosmopolitan water nymphs *Najas armata* and *N. flexilis* were recorded in the middle-deepest part of the lake, known as the most productive area. The recorded emergent macrophyte is the native - branched horsetail *Equisetum ramosissimum*, which thrives in damp environments; its robust root system stabilizes soil in wet areas, preventing erosion. The emergent halophyte *Phragmites australis,* the grasses like sedge *Scirpus maritimus* and torpedo grass *Panicum repens*, all of which can withstand high salinity changes, resist pollution hazards, and are important for the protection of the lake from erosion. Lake Manzala investigation years 2012, 13, 14, 15, and 16, i.e., pre-development, recorded the same vegetation as before, in addition to the water fern *Azolla filiculoides*, which invades countries where the presence of eutrophic waters and lack of natural enemies. The perennial herb *Runnunculus aquatilis* (common water crowfoot), recorded in front of polluted drains, grows well on soils of different chemical and granulometric composition. The emergent *Typha capensis*, a cosmopolitan inhabitant, is shown along lake edges, provides habitat for wildlife species. In 2018 (Table 5 & Figure 6), the submerged macrophyte *Potamogeton pusillus* (small ponweed) and cosmopolitan occur in standing and slow-flowing freshwater habitats, with the whorled water milfoil *Myriophyllum verticillatum*, which is an excellent oxygenator for freshwater ecosystems and flourishes in tranquil waters with alkaline soil; therefore they were recorded in the vegetative part, middle of the lake. Macrophyte samples in 2022 didn't register new vegetation; after the governmental sustainable development, still water hyacinths and water cress were recorded in all investigated stations, as were also *Phragmites* on lake edges, in addition to the common cattail *Typha domingensis.*

Discussion

Lake Manzala, the largest and most productive overall, turned into a sewage reservoir due to the dumping of sewage, especially in the regions of Hadous and Bahr El-Baqar drains, loaded with polluted drains (Fig. 1). The lake was highly eutrophic, with both macrophyte and planktonic algae, contributing to extensive carbon fixation. The nutrient input comes from fresh water inflows, such that productivity decreases as salinity decreases nearer the Mediterranean Sea Boughaz (opening) due to dune precipitation.

Hereher (2014) mentioned that Lake Manzala has witnessed an alteration in its aquatic vegetation composition as a consequence of the change in the hydraulic regime of the Nile and the conversion from an annual to a perennial irrigation system in the late 1960s, constructing numerous irrigation and drainage canals. As mentioned earlier, the salinity of the lake has decreased drastically due to the dilution of the freshwater from agricultural drainage (Bernhardt et al, 2011), which led to the decline of salt-marsh vegetation in the lake, as proved by the pollen analysis.

The investigation from 2010 until 2016 revealed low biodiversity as pollution indicator species covered most of the lake regions, particularly in front of polluted drains. The disappearance of some of the vegetation (extinct) recorded in table 4 was due to excessive pollution discharges, while they have newly appeared in the post-development survey. Between the years 2016 – 2017, submerged *Myriophyllum alterniflorum* was recorded for the first time. It probably prefers salt and freshwater mixed. However, Haroon (2022) explained that the low diversity was probably because the lake faced many environmental problems and intensive pressure, which resulted in changing its ecological features, including the decrease in both bare land (from 52.45 to 45.50%) and water bodies (from 28.19 to 19.32%).

The vegetative cover, during such period, was dominated by pollution indicator species; water hyacinths, water cress, and *Azolla* (free-floating), in addition to submerged *Potamogeton* spp., *Ceratophyllum* and *Najas* spp., *Myriophyllum* and *Echinochloa* (which always appeared faded and wilted as it is salt-tolerant). Also, the emergent pollution and salinity-resistant *Phragmites* and *Typha* existed permanently around lake edges, protecting it from erosion and share in improving water quality. All above-mentioned vegetation, in addition to other vegetation species shown in Table 4, existed long before restoration activities covering the years from 2010 to 2017. However, the distribution of macrophytes in Manzala investigated by Zahran et al. (1989) and Khedr (1997), linked their presence to variables such as water depth, salinity, oxygen levels, pH, chloride, nitrate(NO_3), and phosphate (PO_4). The author's results supported the present macrophyte species dominance.

Generally, the diversity and abundance of plenty of these plants are extensively affected by changes in environmental factors, including water physicochemical characteristics. In addition, competitive interactions between the increases in vegetation cover (from 19.36 to 35.18%) throughout the period from 1992 to 2019 with different organisms, and sediment texture (Haroon, 2022) were mainly due to the developmental project.

On the other hand, Shaltout et al. (2017) mentioned that parts of Lake Manzala are managed as protected areas, with the highest number of aquatic weeds (35 species) recorded. This is due to the unsettled situation and pollutants still being transported to the lake through the main drains, accompanied by minimal salinity. Changes in macrophyte species diversity and distribution, in the post-development survey, can be attributed to the influence of the Egyptian government's development process on this Lake (Abd Ellah, 2021). In addition, Shaltout et al. (2017) recorded 13 threatened species including, *Nymphaea lotus* L., referring to the IUCN Red List categories (El-Hadidi and Hosny, 2000). Although they recorded *Nymphaea caerulea*, which is native to Northern and Tropical Africa, especially along the Nile River, it is classified as Critically Endangered (Ali, 2010). Therefore, it was not recorded in the present investigation. A long time before, Khedr and Hegazy (1998) and Hegazy et al. (2001) recorded the floating-leafed lotus (*Nymphaea lotus* L.) in irrigation canals and rice fields, due to climatic factors and soil components, but never recorded during the present long-term investigation.

Many vegetation species, recorded after restoration activities (from 2018 to 2022), were missing (Tables 3 and 4), probably due to removal of vegetation cover accompanied by the elimination of submerged plants.

Although the lake water during the post-development plan is not in a stable state yet, its water quality is better than before, but needs more time to follow up. Generally, the eutrophic state of Manzala Lake showed signs of improvement in terms of phytoplankton abundance and the number of recorded species (Zaghloul et al. 2024). The nutrient input, particularly through the heavily polluted Bahr El Baqar Drain, has a relative excess of phosphorus compared to nitrogen.

The years from 2017 to 2021 showed two free-floating species; water hyacinths (*E. crassipes*) and watercress (*P. stratiotes*), constantly recorded in most selected stations during the two seasons (summer and winter) throughout the 5 years, particularly in front of all polluted drains. These pollution indicator species dominated due to uncontrolled phosphates and ammonia enhancement, resulting also in phytoplankton dominance (Zaghloul et al., 2024).

By 2018 (after the start of the development plan), it indicated low biodiversity, since most of the submerged, emergent vegetation had disappeared, except for the submerged pollution indicators, *P. pectinatus*, *Ceratophyllum demersum,* and *Najas armata,* in addition to the emergent *P. australis* and the sedge *S. maritimus*, mostly due to ineffectiveness of wastewater treatment. On the other hand, the filamentous reticulated green alga *Cladophora* sp. appeared in front of a polluted drain, probably intruding from the Mediterranean through openings. A newly recorded African aquatic sub-shrub, the creeping herb *Alternanthera littoralis,* and the rhizome herb lake-shore bulrush, salt-tolerant *Schoenoplectus lacustris* sp., were recorded for the first time in front of polluted drains. The latter macrophyte probably emerged after the enhancement of the openings, which permitted saline water from the Mediterranean to be introduced. Most of the recorded species are capable of withstanding unstable conditions of organic matter, but are also acclimated to changing water quality.

In 2022, the native *Ludwigia stolonifera* was recorded is one of the most dominant species recorded in watercourses in Egypt, as confirmed previously by Bidak & Marzouk (2005), who observed a high degree of acclimation and plasticity accompanied by *L. stolonifera* populations in Lake Manzala. This herb sometimes appears in the present investigation, but most of the identified species disappeared due to pollution or dredging activities. Generally, the current biodiversity cannot be, yet, considered a recovery situation, because it needs a time course to develop buried seeds.

In terms of phytoplankton abundance and number of recorded species, Zaghloul et al. (2024) mentioned that Manzala showed improvement as themesotrophic state reached 60% in the post-development period instead of 39% in the pre-development one, and the eutrophic state decreased from 61% in the pre-development period to 31.6% in the next one. In addition, the production of marine fish species in Lake Manzala increased noticeably, especially mullets and sea bream. By 2020, the total yearly catch rose to 82,547 from 59,779 million tons in 2011 (GAFRD, 2020).

Conclusion

The effects of environmental pressure and subsequent impacts are evident in Lake Manzala. The lake ecosystem is still under disturbance, as evidenced by water quality and phytoplankton bloom, as well as macrophyte diversity levels. The intensive national dredging project on the lake bottom that has been conducted by the Egyptian government could have enhanced new macrophyte development as well as fish biodiversity and productivity. Lake Manzala needs continuous monitoring by assessment of water physicochemical variables, along with surveying the biodiversity of macrophytes, phytoplankton and fisheries. This will allow decision makers to apply policy governance to meet restoration targets.

Recommendations

Still, Lake Manzala needs some time to develop new vegetation of native origin to enhance sustainable water biodiversity, or it probably needs to derive seeds from seed banks. On the other hand, this study is considered a baseline and monitoring study for future implementation of lagoon management to investigate the health of the lake, through support across sectors contributing to restoration activities. Creating, thus, a scientific database as well as an official agreement on priorities for using the lake, while securing sufficient tools, scientists, and environmental managers to develop support for effective management actions.

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