Chapter 13
Egyptian Nile Delta Coastal Lagoons: Alteration and Subsequent Restoration

Ayman A. El-Gamal

Abstract Wetlands and coastal lagoons are valuable and sensitive environments as recognized by Ramsar Convention. Egypt has many forms of wetlands. Mariout, Edku, Burullus and Manzala are considered as the most important lagoons and wetlands in the Egyptian Mediterranean coastal area. The Egyptian Ministry of Environmental Affairs (MENA) updated the National Biodiversity, Strategy and Action plan (NBSAP) for the years (2015–2030). One of the goals of this strategy is to minimize the rate of wetlands loss by 50%. The challenges of the Egyptian coastal lagoons were summarized to include pollution, water deterioration, lake of management, reduction of area, aquatic plants, habitat loss, climate change, siltation of the outlets, eutrophication, awareness, illegal fish practice, over fishing and decline of fish yield. Egyptian Environmental Affairs Agency (EEAA) initiate monitoring program to check the water quality of the coastal lakes and its adjacent marine area. The northern lakes have discussed to describe their morphology, environmental status & stress and their water quality according to recent measurements of the EEAA. Many efforts have been done for environmental conservation and socioeconomic development to the coastal lagoon such as El-Burullus Lake is protected by the Egyptian Prime Ministerial Decree 1444/1998 and is a Ramsar Site. Edku and Mariout Lagoons still need more efforts to environment conservation for sustainable development. In order to improvement of coastal lagoons resilience, periodical monitoring of water quality and pollution sources, quantities and type of discharges from these sources became perquisite to determine its impacts of these lakes.

Keywords Coastal wetlands • Lagoons • Nile Delta • Water quality • Environment resilience

A.A. El-Gamal (✉)
Coastal Research Institute, National Water Research Center,
15, El-Pharaana Street, El-Shallalat, 21514 Alexandria, Egypt
e-mail: ayman_elgamal@yahoo.com

C.W. Finkl, C. Makowski (eds.), *Coastal Wetlands: Alteration and Remediation*,
Coastal Research Library 21, DOI 10.1007/978-3-319-56179-0_13

13.1 Introduction

Wetlands can be defined as the areas of marsh, fen, peat-land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6 m. It includes also areas, which may incorporate riparian and coastal zones adjacent to the wetlands, and islands at low tide lying within the wetlands (Fahmy et al. 2007). The key is the presence of water for some significant period of time, which changes the soils, the microorganisms and the plant and animal communities, such that the land functions in a different way from either aquatic or dry habitats (Barbier et al. 1997).

Wetlands are amongst the Earth's most productive ecosystems (Barbier et al. 1997). Wetlands and coastal lagoons are valuable and sensitive environments and their important role has been widely recognized at the international level within the framework of the Convention on Wetlands, which known as Ramsar Convention. The Ramsar Convention is an international treaty for the conservation and sustainable use of wetlands (Ramsar 2014). Historically, many wetlands have been treated as wastelands and drained or otherwise degraded. The Ramsar Convention on Wetlands of International Importance was created to promote the conservation of wetlands and their wise use and management. Ramsar is promoting new methods of economic valuation to demonstrate that wetlands are valuable and should be conserved and wisely used (Barbier et al. 1997).

Wetlands have an imperious bio-ecological function through maintaining everlasting fit place for distinctive groups of biodiversity, especially migratory water birds (EEAA 2016a). Wetlands have been described as "the kidneys of the landscape", because of the functions they perform in the hydrological and chemical cycles, and as "biological supermarkets" because of the extensive food webs and rich biodiversity they support (Mitsch and Gosselink 1993).

Scott (1989) defined 30 groups of natural wetlands and nine manmade ones. However, It can be categorize into five broad wetland systems:

- Estuaries – where rivers meet the sea and salinity is intermediate between salt and freshwater (e.g., deltas, mudflats, salt marshes)
- Marine – coastal water not influenced by river flows (e.g., shorelines and coral reefs)
- Riverine – land periodically inundated by river overtopping (e.g., water meadows, flooded forests, oxbow lakes)
- Palustrine – where there is more or less permanent water (e.g., papyrus swamp, marshes, fen)
- Lacustrine – areas of permanent water with little flow (e.g., ponds, kettle lakes, volcanic crater lakes)

Wetlands continue to decline globally, both in area and in quality. As a result, the ecosystem services that wetlands provide to society are diminished. Contracting Parties and their policymakers are urged to take immediate action to meet the

Ramsar Convention's objective to stop and reverse the loss and degradation of wetlands and services to people (Ramsar 2015).

13.2 Wetlands in Egypt

Wetlands are some of Egypt's most important habitats in terms of biodiversity. Wetlands in Egypt can be classified according to its location as demonstrated by Baha El-Din (2002) as coastal wetlands either in the Mediterranean or Red sea and as inland wetlands. Concerning the Mediterranean coastal wetlands, the most important are the six major coastal lagoons on the Mediterranean: Bardawil, Malaha, Manzala, Burullus, Edku and Mariout. The remainder of the Egyptian Mediterranean coast is of rather limited importance. The Red Sea coastal habitats and wetlands include mudflats, reefs, mangroves and marine islands. There are six major inland wetland areas in Egypt: the Bitter Lakes, Wadi El Natrun, Lake Qarun, Wadi El Rayan Lakes, Nile River and Lake Nasser. In addition, there are many smaller wetlands dispersed in the Nile delta and valley, and in oases in the Western Desert (Baha El-Din 2002).

Wetlands in Egypt can be recognized into 14 generic types (MedwetCoast 2004):

1. The Bardawil-Manzala-Burullus-Idku, Mareotis-Mallah of Port Fouad. These are lakes of North Egypt of different origins and ecology. They all are bird sites and have access to the Mediterranean.
2. The Matrouh lagoons, close to the Mediterranean, and receive their water through the narrow limestone barriers.
3. The Moghra-wadi Natrun Lakes. These are shallow depression in the northern sector of the West Desert. They receive water from underground seepage. It is the eastern lobe of the Qattara Depression and is lied on the western outskirts of the Nile Delta.
4. The Qarun-Wadi Rayan lakes. These are two depressions of the West Desert. Lake Qarun receives drainage water of the Fayoum area. Evaporation makes it hypersaline. Wadi Rayan depression was connected to the agriculture drainage system of the Fayoum Governorate.
5. A number of small lakes scatter in the Delta and its outskirts. Abasa in the east and Dahshoor in the west. Abasa accommodates a fish-farming research and training center. Dahshoor become reed swamps.
6. The Moses Springs site in south-western Sinai form patches of saline moist soil with small ephemeral ponds, reed and rush swamps.
7. The main channel of the Nile between Aswan and Cairo embraces numerous islands.
8. Lake Nasser is the Egyptian part of the Aswan High Dam reservoir-lake (496 km long – total area 5000 km^2).
9. The Mediterranean coast outside the Delta provides little room for developed littoral salt marches.

10. The Red Sea and the Gulf of Suez has extensive littoral salt march formations all along the coast.
11. The Red Sea and the Gulf of Aqaba coastal lands have extensive patches of mangroves (c. 400 ha). It is an elaborate ecosystem with rich biota.
12. The Red Sea coral reefs form long stretches parallel to the shoreline, and comprise diversities of coral species with associated biota.
13. The Red Sea islands with the Egyptian exclusive economic zone comprise coral formation and volcanic islands.
14. The Suez Canal system includes a small Lake Temsah and a larger, further south, Bitter Lake. The whole system connects the Red Sea and the Mediterranean, and provides a causeway for migration of biota

Cataudella and his group (2015) divided the Mediterranean coastal area of Egypt into three sectors, according to the coastal lagoons presence and typology. The western sector from west of Salloum to Alexandria, the central area from Alexandria to Port Said and the third sector from Port Said to Rafah. The second and the central area contains the most important lagoons and wetlands: from west to east Mariout, Edku, Burullus and Manzala as shown in Figs. 13.1 and 13.2 (Cataudella et al. 2015).

The Egyptian Mediterranean coastal area has different categories of water, which mainly affected by Nile water and through coastal lake outlets and various drainage effluents. These effluents continuously discharge water with a complex of varied waste materials into the sea (Hamza 2006; El-Gamal 2016).

The Nile Delta has different kinds of water such as:

1. Fresh water as in the Nile River branches (Rosetta and Damietta).
2. Estuarine water, which is mixed between fresh and marine water.
3. Brackish water as in the northern lakes in the Nile Delta regions such as Edku, Elburullus, Marioute and Manzala Lakes.
4. Marine Water as the water of the Nile Delta coastal area.

The Ministry of Environment of Egypt updated the National Biodiversity, Strategy and Action plan (NBSAP) for the years (2015–2030) (MENA 2016). This report discuss the wetlands habitats in Egypt. Strategic Goal number 2 concerning the sustainable use of natural resources stated that by 2021 the rate of wetland loss is reduced by 50%, water efficiency in farming is improved by 50%, and BMP in development of inland water ecosystems are available to policy makers. The main topics of the National Plan and programs of action are as following (MedwetCoast 2004; UNEP-MAP RAC/SPA 2009):

1. Establishment of the national council for wetlands.
2. Survey of wetlands in Egypt.
3. Selection of sites for wetland nature.
4. Research program in representative wetland sites.
5. Program of studies for formulating management plans for each of the selected sites.
6. Program for materials for education

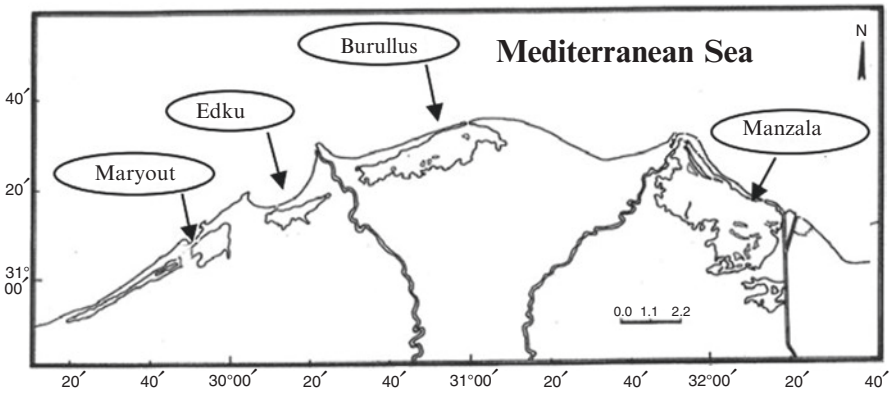

Fig. 13.1 The Mediterranean coastal lagoons in Egypt. The brackish water lagoons under investigation are located in the Nile Delta coastal area Maryout, Edku, El-Burullus and Manzala Lakes

7. Establishment of national wetland databank.
8. Program for training man power capacity building.
9. Program for inventories of cultural heritage and indigenous knowledge of wetlands of Egypt.
10. Consolidated national law for wetlands.

Egypt's wetlands are subject to a variety of human induced threats that are leading to the degradation of this valuable national resource. The main threat facing Egyptian Northern coastal lakes and their vulnerability to climate change is habitat loss and degradation driven by significant reduction in area. This reduction is a result of agriculture and settlements, abstraction of water for irrigation, coastal erosion, water pollution, over fishing and illegal fishing activities, introduction of alien species, spreading of aquatic plants and the blockage of their connections with the sea. Different kinds of pollution among various lakes from untreated or partially treated industrial and domestic wastewater in addition to the agricultural wastes, which loaded with eutrophication parameters (N and P), fertilizer, pesticide and herbicide residues.

The Egyptian Ministry of Environmental Affairs stated that wetlands in Egypt are facing many threats that lead to their degradation (MENA 2016), such as:

- Excessive expansion in scooping coastal lakes for implementing development projects.
- Intrude of different kinds of pollutants discharged to the coastal lakes from domestic, agricultural and industrial wastes generated from cities and villages located along coastal lakes such as El-Burullus, Edku and El-Manzala that affect biota and decrease services and resources of these lakes.
- Accretion and sand creep are natural threats exposed the wetlands, which may play an important part for siltation of the outlets of the lakes.

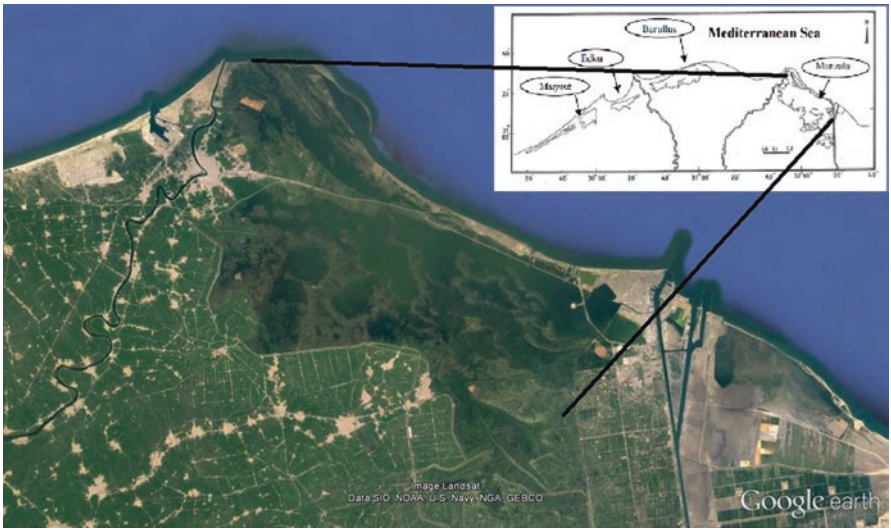

Fig. 13.2 Google earth image of El-Manzala Lagoon during 2016

- Climate change, mainly sea level rise.
- Overgrazing and erosion of vegetation coverage, in addition to drought episodes associated with low rainfall and poor management of rangelands.
- Mines spread along large areas of North Coast and Western Desert, left from the II World War in El-Alamein area, this area (more than quarter million feddans) is suitable for agriculture.

In this chapter, we will discuss the Nile Delta lagoons, which are the most important Mediterranean coastal lagoons Manzala, Burullus, Edku and Mariout. Morphology, environmental parameters and water quality of the four lakes under investigation with its adjacent Mediterranean water are discuss. Vulnerability and environmental stress of these wetlands will be presented with its conservation and sustainable development.

13.3 Morphology and Environmental Parameters

Lagoons are an integral part of the coastal landscape and have peculiar ecological conditions that characterize its ecosystems (Cataudella et al. 2015). It recognized by significant environmental heterogeneity, highly resilient, productive ecosystems and efficient trophic transfer (Cataudella et al. 2015). The delta contains a network of irrigation canals and drainage systems. Drainage waters finally flow into several

Table 13.1 State and water characteristics of Egyptian coastal lagoons during 2008

Lagoon	Area (ha)	Water sources	Water characteristics
Edku	8000	Drainage + sea	Freshwater- brackish
Burullus	41,000	Drainage + sea	Freshwater- brackish
Manzala	78,000	Drainage + sea	Freshwater- brackish

Abdel Rahman (2008)

wetlands and lagoons that face the Mediterranean Sea. These lagoons contribute significantly to the economics, environmental aspects and fishery production of the country (Cataudella et al. 2015).

The three delta lagoons (Edku, Burullus and Manzala) have almost the same pattern of water salinity. Each of them receives large volumes of drainage water and has one or more narrow connections to the sea (Table 13.1) (Cataudella et al. 2015). During the year except at the winter enclosure period, freshwater enters the lagoons in order to keep the water level in the lagoons higher than the sea level and preventing the intrusion of seawater. All lagoons are shallow water bodies with average depth ranging between 0.8 and 1.0 m (Shaltout and Khalil 2005).

13.4 The Northern Lakes: Manzala, Brullus, Edku and Mariout

The Northern Lakes under investigation are Manzala, Brullus, Edku and Mariout. These lakes are in contact with the Mediterranean Sea and have a direct or indirect relation with the Nile River. These lakes are natural environment for fauna and flora and a home for emigrant birds.

13.4.1 Manzala Lagoon

13.4.1.1 Site Description

Lake Manzala, the largest of Egypt's Mediterranean wetlands. Located within the boundaries of five governorates: Dakahliya, Damietta, Port Said, Ismailia and Sharkia, and bordered from the east by Suez Canal and from the west by Damietta Branch and the Mediterranean from the north (EEAA 2010). The importance of this lake is not only dependent on its size but also on its high productivity (Zakaria et al. 2007). It is shallow lake with average depth 1.3 m and located in the northeastern corner of the Nile delta. They reported that the area had drastically reduced from 1100 km^2 in 1973 to 1052 km^2 in 1984 and finally became 720 km^2 in 2003. They

attributed this shrinking to the reclamation activities and to the construction of the coastal highway (Hereher 2014). It is predicted that existing reclamation plans will reduce its area further. Manzala is generally rectangular, about 60 km long and 40 km wide (Baha El-Din 2002). Its coastal line is about 293 km, with maximum width of 30 km (EEAA 2010). It is separated from the Mediterranean Sea by a narrow sandy fringe (Shakweer 2005), through which it is connected to the sea by four channels (bughaz) (El-Gamil, Ashtom El-Gamil, El-Diba and El-Baghdadi). Bughaz El Gamil is the main connection between the lake and the Mediterranean. The lake is connected to Suez Canal through Boughaz Alkaboty and Damietta branch through El-Ratama and El-Safra Canals (EEAA 2010).

Large areas in the north-west of the lake have been turned into fish farms. 3.7 km^3 of fresh water flow annually into Lake Manzala from nine major drains and canals. The most important of these are Faraskur, Al Sarw, Baghous, Abu Garida and Bahr El Baqar. Of all the drains discharging into Lake Manzala, the Bahr El Baqar drain is the most polluted (Baha El-Din 2002). Artificial wetland has been established to reduce the pollution of this drain (El-Quosy 2005).

13.4.2 Burullus Lagoon

13.4.2.1 Site Description

Lake Burullus, the second largest Delta lakes, with total area of about 70,000 feddans. It is elongate in shape extending for c.54 km from east to west with a width of 6–21 km and an estimated average depth of 75–100 cm. The mean annual fish production from the lake is 48,000 (Baha El-Din 2002). Lake Burullus is a shallow brackish water basin. The lake lies in the north of the Nile Delta, along the Mediterranean Coast of Egypt between Long. 30°30′ & 31°10′ E and Lat. 31°35′ N (Fig. 13.3). The lake is separated from the sea by to 5.5 km. The lake is connected directly to the Mediterranean Sea through El-Burullus outlet, which is about 250 m wide and 5 m deep. There are some 50 islands scattered throughout the lake with a total area of 0.7 km^2. The lake receives drainage waters with anthropogenic materials from agricultural areas through seven drains in addition to the fresh water from Brembal Canal (El-Sammak and El-Sabrouti 1995). The amount of the drainage water discharged annually into the lake fluctuates from 1 year to the other (Samaam et al. 1989).

The north shores of the lake are dominated by saltmarshes and mudflats, while the southern shore is bordered by an extensive fringe of reed-swamps (mainly Phragmites and Typha), which currently covers more than 25% of the lake area. Lake Burullus has abundant submerged vegetation, dominated by Potamogeton, which is densest in the southern portion of the lake (Baha El-Din 2002).

Fig. 13.3 Google earth image of El-Burullus Lagoon during 2016

13.4.3 Edku Lagoon

13.4.3.1 Site Description

Edku Lake is coastal wetland located in the north of the Nile Delta west of the Rosetta Nile branch and approximately 35 km east of Alexandria. It extends for about 17 km in the east-west direction. It lies between latitudes of 31°10′ and 31°18′ N, and longitudes of 30° 8′ and 30° 22′ E (Fig. 13.4) (Youssef and Masoud 2004). It is a shallow inland eutrophic lake with an average depth of 1 m. The mean annual fish production from the lake is 9000 ton. The width of the lake (N-S direction) is about 11 km at its widest part, where the narrowest part is only about 5 km (Masoud et al. 2005). The lake is connected to the sea by El-Maadia outlet. The total area of the lake is decreased from 30.000 to about 12.000 ha as a result of agricultural reclamation (Masoud et al. 2005). Two main drains namely Magrour Edku and Barsiek discharge huge volumes of drainage water to the Lake. Magrour Edku Drain is joined to different sources of drains. These Drains carry mainly agricultural, domestic and to less extent industrial effluents. The drainage water of more than 300 fish farms is also disposed to El-Khaiy Drain directly before being connected with the Lake. Barsiek Drain transports mainly agricultural drainage water to the Lake as well as the waste of Barsiek fishing ponds (Youssef and Masoud 2004). The water in the lake is mainly fresh (brackish), but increases in salinity towards the Bughaz and during the summer (Baha El-Din 2002).

Fig. 13.4 Google earth image of Edku Lagoon during 2016

13.4.4 Mariout Lake

13.4.4.1 Site Description

Lake Mariout is situated along the Mediterranean coast of Egypt south of Alexandria city (long. 29°51′ 00″–29° 56′ 15″E, lat. 31°04′ 15″–31° 10′ 45″ N) as shown in Fig. 13.5. It has been divided artificially by international roads and railway lines into four basins; the fish farm, the north-western, the south-western, and the main basins (EEAA 2010). The main basin is the heavily polluted part of the lake. The major water sources of the lake are El-Omoum Drainage, El-Kalaa Drainage and Nubaria Canal. The most important of these drains is the Kalaa Drain, as well as large quantities of municipal and industrial effluent from the city of Alexandria. El-Kalaa Drain disposes of an average of 920,000 m^3 wastewater per day in the main basin of the Lake Mariout. Since 1993 El-Kalaa Drain has received partially treated wastes from the Eastern Treatment Plant as well as mixed sewage from El-Kalaa tributary drains (Youssef 1999; Youssef and Masoud 2004).

In the nineteenth century, the western half was cut off by a railway embankment and transformed into an extensive salina, now known as Malahet (Brine) Mariout. What remains of the lake proper is brackish, receiving agricultural drainage-water through several drains. The lake has no direct connection with the Mediterranean, and is maintained at a level of c.2.8 m below sea level and discharge its water to the Mediterranean by a pumping station at El Max. Much of the lakeshore is fringed by extensive Typha/Phragmites marshes. The lake still supports a fishery, with Tilapia sp. making up most of the production (Baha El-Din 2002).

Fig. 13.5 Google earth image of Mariout Lagoon during 2016

13.4.5 Water Quality of the Coastal Lakes

The aquatic ecosystem of the coastal lakes is a major concern since good ecosystem health is essential not only for sustaining lake services to local populations but also for maintaining biodiversity (Zakaria et al. 2007). Egyptian Environmental Affairs Agency (EEAA) initiate monitoring program to check the water quality of the coastal lakes. The results of the monitoring of water quality of the lakes under investigation during August 2009 carried out by Central Department for Water Quality-the national program for monitoring the Egyptian Lakes-EEAA are listed in Table 13.2 as reported in EEAA report of Egypt state of Environment of year 2012 (EEAA 2015). Table 13.3 listed the maximum and minimum values of annual average of the chemical parameters of water and sediments of Edku Lake according to Masoud et al. (2005).

13.5 Environmental Indicators

13.5.1 Monitoring Dissolved Oxygen

Dissolved oxygen (DO) levels in lake water are influenced by many factors, including water temperature, the concentration of algae and other plants in the water, and the amount of nutrients and organic matter that flow into the water body from the watershed. Oxygen is produced through plant metabolism (photosynthesis), and it

Table 13.2 Ranges of water quality parameters of the coastal lakes under investigation during 2012

Parameter	Manzala	Burullus	Edku	Mariout
pH	7.85–8.6	7.9–8.89	8.08–8.68	7.82–8.37
Salinity (ppt)	1.75–22.6	0.9–13.93	1.01–3.81	1.63–5.89
DO (mg/L)	1.9–13.03	2.6–13.96	3.4–11.5	3.75–8
Ammonia (mg/L)	0.14–3.77	0.08–2.65	0.06–1.93	0.27–11.92
Total nitrogen (mg/L)	3.36–8.26	2.77–7.51	3.62–5.82	2.8–18.5
Total phosphorus (mg/L)	63.61–881.96	247.14–1059.03	485.8–1055.86	57.9–2184.7
BOD (mg/L)	13.27–45.13	6.68–22.77	10.91–19.94	24.21–63.29
COD (mg/L)	72.28–329.1	102.67–243.88	125.28–294.13	93.5–414.12
Total coliform bacteria (cells/100 ml)	48–65,825	120–4700	157–2875	498–1,053,500
Polychlorinated biphenyls (ng/L)	2.29–15.13	4.02–25.8	6.47–18.94	2.1–13.82
Pesticides (ng/L)	1.27–4.93	2.46–13.4	4.56–9.9	1.33–14.95
Hydrocarbons/petroleum origin (μg/L)	0.71–1.46	0.86–2.66	0.68–1.98	0.83–3

Table 13.3 Maximum and minimum values of annual average of the chemical parameters of water and sediments of Edku Lake

Type		Fe	Mn	Zn	Cu	Cd	Cr	Co	Pb	Ni
Water		mg/L	μg/L	μg/L	μg/L	μg/L	μg/L	μg/L	μg/L	μg/L
	Max	0.82	75.25	57.55	31.5	11.75	16.50	14.00	95.50	51.50
	Min	0.30	28.83	8.85	20.00	11.25	2.5	5.00	18.50	26.25
Sediments		g/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
	Max	36.29	273.17	71.25	2.57	1.56	60.31	2.65	2.41	18.35
	Min	27.40	226.35	52.00	1.83	0.62	45.83	9.73	1.15	13.79

Masoud et al. (2005)

is consumed during respiration and decomposition. Oxygen in lake water is also influenced by wind and wave action through weather events and the exposure of surface water to atmospheric sources.

An adequate supply of dissolved oxygen in lake water is essential to fish and other aquatic life forms. DO is also a sensitive indicator of change in water quality, and of the ability of a water body to support aquatic life. The loss, over time, of DO in the deep areas of a lake, especially during summer months, may indicate that the ecosystem is stressed and changing (VLMP 2016).

13.5.2 Temperature Profile

Water temperature plays an important role in determining the amount of oxygen found in the lake. Oxygen is more soluble in cold than warm water. Most lakes over 20 ft deep stratify during the summer into a warm, lighted upper layer (epilimnion) and a cold, dark lower layer (hypolimnion). Thus, the cold lower layer can potentially hold more oxygen than the warmer upper layer. it is important to define the thermal layers in a lake when characterizing dissolved oxygen conditions (USEPA 2002).

13.5.3 Salinity

Coastal seawater salinity affected by the discharge of the fresh or low saline water from inland source such as the coastal lakes.

13.5.4 Monitoring Sedimentation

Sedimentation problems occur when erosion is taking place in the watershed. Surface runoff washes sand and silt into the lake where it settles to the bottom and creates shallow areas that interfere with lake use and enjoyment. In addition, sediments often carry significant amounts of nutrients that can fertilize rooted aquatic plants and algae.

Concerning the suspended solids, some of the silt and organic matter that enters a lake does not settle to the lake bottom. Instead, it remains suspended in the water. These suspended solids decrease water transparency and can affect the suitability of the lake habitat for some species. One can monitor the suspended sediment condition by measuring two parameters: water transparency using a Secchi disk; and total suspended solids (USEPA 2002).

13.5.5 Monitoring Acidification

The measurement of pH is the detection of lake acidity and alkalinity status. The pH is measured on a scale of 0–14. The lower the pH, the higher the concentration of hydrogen ions and the more acidic the solution. Acid rain typically has a pH of 4.0–4.5. In contrast, most lakes have a natural pH of about 6.0–9.0. The pH of a lake sample can be easily determined by using a portable, battery-powered pH meter.

13.5.6 Monitoring Bacteria

The indicator organisms most often used to indicate sanitary conditions at bathing beaches are fecal coliform bacteria and enterococcus bacteria. Coliforms belong to the enteric bacteria group, Enterobacteriaceae, which consists of various species found in the environment and in the intestinal tract of warm-blooded animals. Fecal coliforms are the part of the coliform group that are derived from the feces of warm-blooded animals. The fecal test differentiates between coliforms of fecal origin and those from other sources (USEPA 2002).

13.6 Adjacent Marine Area and Their Outlets

Water quality of the adjacent marine area of the coastal lakes under investigation was monitored under the national program "The Environmental Information and Monitoring Program" (EIMP) which operate through the Egyptian Environmental Affairs Authority (EEAA). The purpose of the Coastal Water Monitoring Program is to obtain baseline knowledge of the quality of the Egyptian coastal waters and to establish a continuous survey of these waters. The outputs is also used to establish quantitative and causal relations between pollution sources and pollution impacts. The proposed water sampling Program focuses on measurements of marine water samples and the outlets from the river Nile and the major lakes are sites of interest in this program (EEAA 2016b). Continuous bimonthly and annual reports were presented the main results of this program such as EEAA (2016c, 2015). Figure 13.6 shows the dissolved oxygen values at the adjacent marine water of the lakes under investigation during May 2016. It shows that all the values are accepted as higher than accepted limit of 4 mg/L. Effect of water salinity of the coastal lakes under investigation to the adjacent marine area during May 2016 is presented in Fig. 13.7. The salinity in front of the outlets are decreased than the normal ambient seawater in this area. The water of El-Gamil outlet is the relatively higher effects of the adjacent seawater. The domestic wastewater discharged from the coastal lake outlets to the adjacent seawater was detected by coliform bacterial indicator. Figure 13.8 shows the counts of the Coliform bacteria in front of the coastal lakes outlet. Mariout Lake was recognized as the most polluted lake from the domestic pollution during May 2016. Moreover, scientific articles in specific journals and conference were submitted from the program output such as Haslund and his group (Haslund et al. 1999).

The water quality parameters of the drains discharged to Edku Lake and the lake water with its outlet have been summarized by Gharib and Soliman (1998) and listed in Tables 13.3 and 13.4. The quality of the adjacent marine water to the lake outlet is also presented during 1995–1996.

Coastal Research Institute (National Water Research Center, Egypt) established monitoring program for the water quality of the coastal lakes outlets since 16 years.

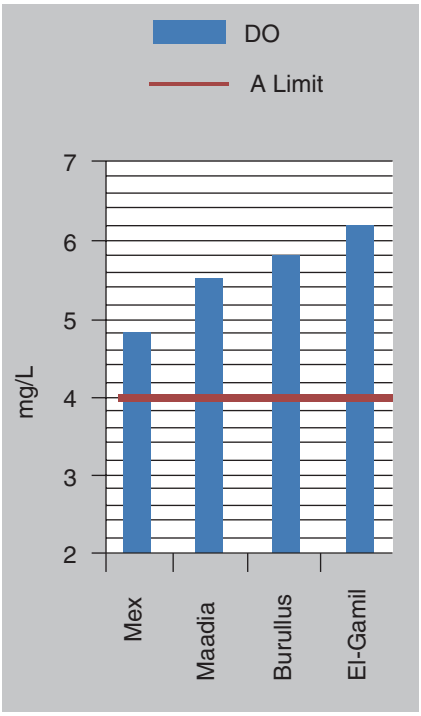

Fig. 13.6 Dissolved oxygen (DO) during May 2016 of the Mediterranean Sea Water adjacent to the coastal lakes under investigation against the accepted limit (Mex = Mariout Lake, Maadia = Edku Lake, Burullus = Burullus Lake and El-Gamil = Manzala Lake) (Data from EEAA 2016c)

The monitoring parameters includes the critical and the important water quality parameters such as water temperature, salinity, conductivity, pH, Dissolved oxygen, turbidity, transparency, TSS, NH_3, NO_2, NO_3, TN, PO_4, TP, SiO_2 and Coliform bacteria. Water quality index was calculated for the Mediterranean water adjacent to the coastal lakes outlets and it revealed temporal enhancement of their water quality (El-Gamal 2009). This is due to the governmental efforts to reduce the pollution through the establishment of the environmental law 4/1994 and his upgrading version 9/2009.

13.7 Vulnerability and Environmental Stresses

The rapid population growth in Egypt, especially in the Nile Delta covered by several wetlands, poses serious problems. Recently, coastal lagoons have become a matter of concern due to the detrimental impact of several human activities. There is close relationship between lagoons with terrestrial ecosystem from different environmental conditions. These conditions are hydrological modifications (freshwater diversions or drainage discharges), water pollution and habitat loss (Gamito et al. 2005; Pérez-Ruzafa et al. 2005). Finally, it make a deep change of the structure dynamic of the lagoons ecology (Cataudella et al. 2015). Accordingly, conservation

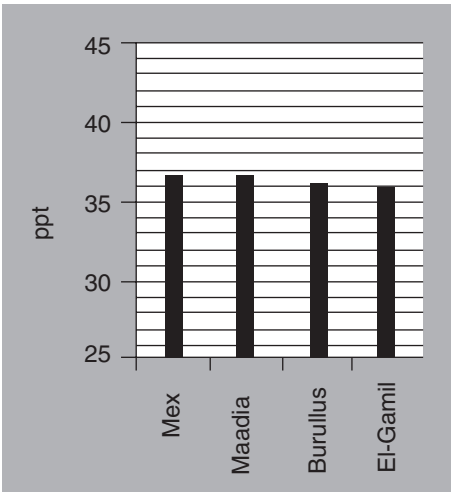

Fig. 13.7 Salinity during May 2016 of the Mediterranean Sea Water adjacent to the coastal lakes under investigation (Mex = Mariout Lake, Maadia = Edku Lake, Burullus = Burullus Lake and El-Gamil = Manzala Lake) (Data from EEAA 2016c)

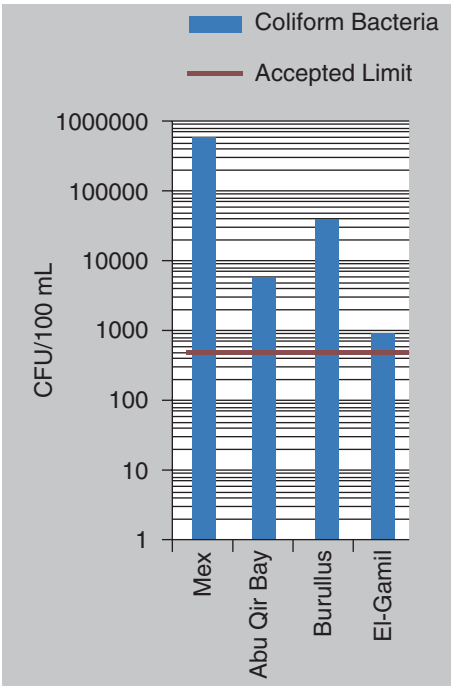

Fig. 13.8 Coliform Bacteria during May 2016 of the Mediterranean Sea Water adjacent to the coastal lakes under investigation against the accepted limit (Mex = Mariout Lake, Abu Qir Bay = Edku Lake, Burullus = Burullus Lake and El-Gamil = Manzala Lake) (Data from EEAA 2016c)

of these water bodies is important and became necessary for better management, mainly for the benefit of the Egyptian economy and public health. The Nile Delta lakes, as transitional zone between land and sea, are considered as the most productive natural systems in Egypt (Saad 2003).

Table 13.4 Range and (mean) values of the physic-chemical in the Edku Lake water and its drains with the adjacent seawater and the outlet water during 1995–1996 (Gharib and Soliman 1998)

Parameter	Sea	Outlet	Lake	Drain
Secchi depth (cm)	12.5–35 (29.6)	15–50 (30.2)	10–32.35 (25)	5–17.20 (15)
pH value	7–8.6 (7.85)	7.91–8.42 (8.05)	7.98–8.67 (8.32)	7.4–8.2 (7.68)
Dissolved oxygen (mg/L)	0.0–9.6 (3.94)	1.5–9.5 (5.25)	4.7–15.7 (10.83)	0.8–10.5 (6.99)
Ammonium (μmol/L)	0.0–22.45 (6.07)	0.0–18.96 (6.97)	0.0–22.99 (7.15)	0.0–34.79 (9.16)
Nitrate (μmol/L)	6–28.17 (11.16)	0.0–47.82 (16.44)	0.0–41.19 (50.2)	0.0–58.71 (26.16)
Nitrite (μmol/L)	0.88–51.44 (6.91)	2.48–28.80 (8.45)	0.64–8.12 (2.13)	2.1–23.60 (11.94)
Phosphate (μmol/L)	0.07–2.23 (1.29)	0.90–8.30 (4.78)	1–6.65 (2.57)	0.7–12.24 (7.99)
Silicate (μmol/L)	14.3–107.56 (47.92)	54.16–159.84 (126.15)	0.16–146.68 (88.1)	54.12–159.20 (140)

All Northern Delta lakes are more or less facing the same challenges according to many researchers as:

1. Pollution (Mehanna 2008; Cataudella et al. 2015), lagoons have even been considered as dumping areas for urban and industrial wastes (De Wit et al. 2011). Nile delta lagoons are the most polluted areas in Egypt. They receive great amounts of industrial, municipal and agricultural wastewaters without treatment.
2. Deterioration and decrease in available healthy water supplies (Saad 2003).
3. Lack of management (Cataudella et al. 2015) have strongly modified both the structure and the functioning of these sensitive coastal ecosystems.
4. Significant reduction in area (Mehanna 2008), most Egyptian wetlands have been degraded drastically during the past 50 years (Baha El-Din 2002). Filling up and drought; which lead to a decrease in size of all delta lagoons by over 70% of their original areas.
5. Spreading of aquatic plants (Mehanna 2008), several kinds of plants are found in the coastal lake such as *Myriophyllum spicatum*, *Potamogeton pectinatus*, *Phragmites australis*, *Typha domingensis* (Younis and Nafea 2012).
6. Habitat loss (Mehanna 2008), through land reclamation.
7. Climate change. Lagoon environmental features such as depth, connections with the sea, sediment dynamics, size, as well as water temperatures and productivity, shall all be affected by global climate change and the rise of sea level (Cataudella et al. 2015; Bianchi and Morri 2004; De Wit 2011; Nicholls et al. 2007).
8. The blockage of Boughazes (Mehanna 2008), siltation of the outlets is one of the important feature resulting from coastal processing and it will affect the ship sailing.

9. Eutrophication. Eutrophication can be accelerated with human consequences in the watershed. If proper controls are not in place, pollutants from agricultural, urban, and residential developments can easily be carried out to lakes and their tributaries (Cataudella et al. 2015; USEPA 2002).
10. Low awareness of fishermen about environmental issues (Mehanna 2008),
11. Declining of fish yield and fish quality, (Mehanna 2008)
12. Over-fishing (Mehanna 2008),
13. Illegal fishing practices and illegal harvesting of fish fry (Mehanna 2008),

13.8 Environmental Conservation and Socioeconomic Development in the Nile Delta Region

13.8.1 Manzala Lagoon

The lake is unprotected, apart from Ashtum El Gamil Protected Area (declared by Prime Ministerial Decree 459/1988), which encompasses a small area (c.35 km^2) located along the sandbar at Bughaz El Gamil, the largest connection between the lake and the sea, near Port Said. The main purpose for creating this protected area was the protection of gravid fish and fry during their passage in and out of Manzala, through Bughaz El Gamil (Baha El-Din 2002).

El-Salam canal is the main land reclamation project in the Eastern Nile Delta and Sinai Peninsula in Egypt (currently mostly destined for Manzala). The project aim is to reuse agricultural drainage water from Bahr Hadous and lower Serw drainage to irrigate about 620,000 feddans through El-Salam canal (EL-Sayed and Omar 2013). This is expected to lead to a significant increase in the salinity of the lake from the current 3–8 ppt, consequently changing its whole ecology (Baha El-Din 2002). Efforts have been done to decrease the water salinity in Bahr Hadous drain in order to increase the amount of the reused drainage water discharged into El-Salam canal (EL-Sayed and Omar 2013).

Lake Manzala serves as a final repository for much of the municipal and agricultural wastewater of the eastern Delta, including the wastewater of most of Cairo. The main contributors to the lake are the Bahr El Bakr Drain, Hadous Drain and the drainage water delivered by some adjacent pumping stations. The Bahr El Bakr Drain carries sewage effluent from Cairo and the polluted drainage water of more than 200,000 ha of agricultural land (Wahab and Badawy 2004). Engineered Wetland was constructed to improve the water quality of Bahr El-Baqar drain, before entering the Lake Manzala (El-Quosy 2005).

13.8.2 El-Burullus Lagoon

Burullus is protected by Prime Ministerial Decree 1444/1998 and is a Ramsar Site. The area of the lake is decreased as a result of ongoing drainage and reclamation of the lake's margins, and also due to the proliferation of emergent and submerged vegetation. It is anticipated that Burullus, along with other coastal delta wetlands, will be further reduced in area because of landward migration of coastal sandbars. Despite being the least polluted of the northern delta lakes, increasing quantities of agricultural drainage-water with heavy fertilizer and pesticide loads are being released into Burullus, contributing significantly to the eutrophication and pollution of the lake (Baha El-Din 2002).

13.8.3 Edku Lagoon

Edku Lake suffers from the same ailments that affect other delta wetlands: drainage and land-claim, pollution, disturbance, water bird catching, etc. Habitat loss through land-claim is certainly the most serious of these threats. Edku Lake has been reduced to less than half its original size (Baha El-Din 2002).

13.8.4 Mariout Lagoon

Lake Mariout has been reduced by more than 75% from its original area, and is still decrease in size. The main causes for the diminishing area today are urban encroachment and solid-waste dumping from the rapidly growing city of Alexandria. The lake is eutrophic and is the most polluted wetland in Egypt. The level of disturbance is particularly high because of the very close proximity of Alexandria's urban and industrial sprawl. The outlook for the future of this wetland is rather grim (Baha El-Din 2002).

13.9 Improvement of Coastal Lagoons Resilience

The Egyptian Ministry of State for Environmental Affairs has set a priority to protect the northern lakes from pollution and to maintain their sustainable development. This carried out within its priorities and strategy for water resources protection. So that periodical monitoring of pollution sources, quantities and type of discharges from these sources; also monitoring water quality and sediments in these lakes became a perquisite to determine impacts of various pollutants, and to set priorities for rehabilitation and development to ensure their sustainability to maximize their benefits (EEAA 2010).

Legal framework and constraints have been set to control the human activities in the coastal lagoons. Law 124/1983 regulates capture fishery and aquaculture activities in Egypt. The Law 4/1994 and its enhanced version 9/2009 on the protection of the environment constitutes the main legislative act in the field of environmental protection and promotion.

Two coastal lagoons in Egypt were designated as Ramsar Sites. The first lagoon is the Burullus wetland, which was declared as a natural protectorate in 1998. The protectorate includes the lake, its islets, as well as the sand bar between the Mediterranean and the lake. This habitat is very important for migrant birds for foraging, refuge and breeding. The second lagoon is the Bardawil lagoon, also designated as a Ramsar Site in 1988. Very limited eco-friendly human activities are allowed in the surroundings of the lagoon. All development activities are forbidden inside the protectorate except salt production. Other coastal lagoons are unprotected, apart from the Ashtum El Gamil Protected Area (declared by Prime Ministerial Decree 459/1988), which encompasses a small area (c.35 km^2) located along the sandbar at Bughaz El Gamil, in the Manzala lagoon. Constrains include land reclamation, pollution and illegal fishing practices (Cataudella et al. 2015).

In order to establish a successful volunteer monitoring program, the necessary steps to plan and manage were mentioned in the international guidance of EPA's "Volunteer Water Monitoring: A Guide for State Managers". Topics in this guide include how to establish goals, identify data uses and users, assign staff responsibilities, establish a pilot program, prepare a quality assurance plan, and fund a program (USEPA 2002).

The Egyptian Ministry of Water Resources and Irrigation (MWRI) has a wetlands policy that copes with the Ramsar Convention to strength the objective of protection and enhance water resources management and the overall aquatic environment on a sustainable basis. The policy includes promoting and encouraging fresh water conservation and the efficient water utilization in different water use categories.

Natural wetlands rehabilitation is in the Egyptian policy is worked with the wetlands protection in the process of water resources management (USEPA 2002; Fahmy et al. 2007).

Establishing quality assurance and quality control in many environmental issues was distributed and now well known. There are five major areas of uncertainty that should be evaluated when formulating data quality objectives as listed by USEPA (2002). These areas are accuracy, precision, representativeness, completeness and comparability. Accreditation for environmental laboratory that holding ISO 17025 certificate is recommended.

13.10 Summary and Conclusion

Wetlands and coastal lagoons are valuable and sensitive environments as recognized by Ramsar Convention. They described wetlands as the kidneys of the landscape. Egypt has many forms of wetlands. Different efforts have been done to classify the

Egyptian wetlands. One classified wetlands in Egypt according to its location to be coastal either in the Mediterranean Sea or Red Sea or inland wetlands. Another classification was adopted the wetlands in Egypt into 14 generic types. The northern lakes are grouped in one of these types. Moreover, classification of the northern lakes as coastal wetlands has been performed into three sectors from Salloum to Alexandria to Port Said to Rafah. The second and the central area contains the most important lagoons and wetlands: from west to east Mariout, Edku, Burullus and Manzala.

The Egyptian Ministry of Environmental Affairs updated the National Biodiversity, Strategy and Action plan (NBSAP) for the years (2015–2030). One of the goals of this strategy is to minimize the rate of wetlands loss by 50% and improved the water efficiency for farming by 50%. In general, the wetlands in Egypt are facing many threats to their degradation such as pollution, reduction of its area, accretion and erosion, climate change and overgrazing. Nile Delta coastal lagoons Manzala, Burullus, Edku and Mariout have discussed in some kinds of details to describe their morphology, environmental status & stress and their water quality according to recent measurements of EEAA team work. These coastal wetlands are shallow lakes with direct or indirect contact with the sea.

El-Manzala Lagoon was characterized by enlargement of its size, which reduced with the time, and its high productivity. The lake received its water from different polluted drains. Artificial wetland has been established to reduce the pollution of Bahr Elbakar Drain, which is the most polluted drain discharge its water to El-Manzala Lake. El-Burullus Lake is the second largest coastal lake. El-Burullus Lake receives fluctuated amounts of drainage waters with anthropogenic materials from agricultural areas through seven drains. Edku Lake is coastal wetland located in the north of the Nile Delta west of the Rosetta Nile branch. Two main drains namely Magrour Edku and Barsiek discharge huge volumes of drainage water to the Lake. Lake Mariout is situated south of Alexandria city. It divided artificially into four basins; the fish farm, the north-western, the south-western, and the main basins. The major water sources of Edku lake are El-Omoum Drainage, El-Kalaa Drainage and Nubaria Canal.

EEAA initiated monitoring program to check the coastal lakes water quality. The results of this program are presented in different EEAA publications such as Egypt state of environment and summarized in this chapter. The critical environmental indicators have been identified and monitored in the coastal lagoons under investigation. Dissolved oxygen, water temperature, salinity, sedimentation, acidification, coliform bacteria. This program indicated that hypoxia (dissolved oxygen <4 mg/L) condition has been detected in different sites in the four brackish coastal lagoons (Manzala, El-Burullus, Edku and Mariout). Coliform bacteria was found in parts of the four coastal lagoons under investigation higher than the accepted counts level, which indicated of the domestic pollution.

National program organized by EEAA has been established to monitor water quality of the adjacent marine area of the coastal lakes under investigation to obtain baseline knowledge of the quality of the Egyptian coastal waters. The program focus on the estuaries and outlets of major drains and the coastal lakes. Selected

water quality parameters values were presented. During 2016, dissolved oxygen showed that all the values are accepted as higher than the accepted limit of 4 mg/L. Enhancement of water quality in the adjacent area of the outlets of the coastal lakes under investigation was recognized. This is due to the enrolling of the Egyptian environmental law 4/1994 and its updated version 9/2009. The four coastal lagoon are vulnerable to environmental stresses such as pollution. The challenges of the coastal lakes were summarized to include pollution, water deterioration, lake of management, reduction of area, aquatic plants, habitat loss, climate change, siltation of the outlets, eutrophication, awareness, illegal fish practice, over fishing and decline of fish yield.

Many efforts have been done for environmental conservation and socioeconomic development to the coastal lagoon. El-Manzala Lake is environmentally unprotected, but apart from it at the site Ashtum El Gamil is considered as Protected Area (declared by Prime Ministerial Decree 459/1988). Engineered Wetland was constructed to improve the water quality of the most polluted drain (Bahr El-Bakar drain) which discharge its water into Lake Manzala. El-Burullus Lake is protected by the Egyptian Prime Ministerial Decree 1444/1998 and is a Ramsar Site. Edku and Mariout Lagoons still need more efforts to environment conservation for sustainable development.

In order to improvement of coastal lagoons resilience, periodical monitoring of water quality and pollution sources, quantities and type of discharges from these sources became perquisite to determine its impacts of these lakes. In addition, the setting of the priorities for rehabilitation and development to ensure their sustainability is highly required.

References

Abdel Rahman SH (2008) Fishery resources in Egypt (Present status and future prospective). Presented at the Second International Conference on Aquatic Resources. National Institute of Oceanography and Fisheries, Alexandria, November 2008

Baha El-Din SM (2002) Egypt, important bird areas in Africa and associated islands – Egypt, pp 241–264

Barbier EB, Acreman AM, Knowler D (1997) Economic valuation of wetlands, a guide for policy makers and planners. Ramsar Convention Bureau Department of Environmental Economics and Environmental Management, University of York Institute of Hydrology IUCN-The World Conservation Union

Bianchi CN, Morri C (2004) Climate change and biological response in Mediterranean Sea ecosystems: a need for broad-scale and long-term research. Ocean Chall 13:32–36

Cataudella S, Crosetti D, Massa F 2015 Mediterranean coastal lagoons: sustainable management and interactions among aquaculture, capture fisheries and the environment Studies and Reviews. General Fisheries Commission for the Mediterranean. No 95. FAO, Rome, 278 pp

De Wit R (2011) Biodiversity of coastal lagoon ecosystems and their vulnerability to global change, ecosystems biodiversity, PhD. Grillo O (ed) (also available at www.intechopen.com/books/ecosystems-biodiversity/biodiversity-of-coastal-lagoonecosystems-andtheir-vulnerability-to-global-change)

EEAA (2010) Egypt state of environment report 2009. The Egyptian Environmental Affairs Agency (EEAA)

EEAA (2015a) Egypt state of environment report 2012. The Egyptian Environmental Affairs Agency (EEAA)
EEAA (2015b) Annual report of the year 2014 of monitoring of water quality of the Mediterranean coastal water, EIMP, EEAA
EEAA (2016a) Egyptian biodiversity strategy and action plan (2015–2030), Arab Republic of Egypt, Ministry of Environment. https://www.cbd.int/doc/world/eg/eg-nbsap-v2-en.pdf
EEAA (2016b) Coastal Water Monitoring Program, EIMP, EEAA. http://www.eeaa.gov.eg/eimp/cwobj.html
EEAA (2016c) Report of the second campaign of monitoring the water quality of the Mediterranean coastal water during May 2016. EIMP, EEAA
El Sammak AA, El Sabrouti MA (1995) Organic carbon distribution and preservation in sediments of Lake Burullus, S.E. Mediterranean, Egypt. Fresenius Environ Bull 4(8):457–462
El-Gamal A (2009) Spatial and temporal variations of the Egyptian Mediterranean coastal water eutrophication, Water Sciences. Sci J Nat Water Res Cent, NWRC 46:11–24
El-Gamal A (2016) Water and sediments qualities of the Nile River Estuaries, Chapter 8, in The Nile Delta Book (Volume) – edited by Abdelazim M. Negm, in the series of The Handbook of Environmental Chemistry, Project coordinator Dr. Andrea Schlitzberger, Springer
El-Quosy D (2005) Lake Manzala engineered wetland port said, Egypt. www.Phy_10(1)_Lake Manzala Engineered Wetland 29112004.pdf
EL-Sayed EA, Omar M (2013) Investigating the constructed wetlands in the branches of Bahr Hadous Drain to reduce its salinity and increase drainage reuse of El-Salam canal. Int J IT, Eng Appl Sci Res (IJIEASR) 2(5):4–14
Fahmy H, Khalifa E, Rashed A (2007) The role of wetlands in water management – Egypt. Technical Report, January 2007. https://www.researchgate.net/ publication /285056112
Gamito S, Gilabert J, Marcos C, Perez Ruzafa A (2005) Effects on changing environmental conditions on lagoon ecology. In: Gonenc IE, Wolfin JP (eds) Coastal lagoons: ecosystem processes and modeling for sustainable use and development. CRC Press, Boca Raton, pp 193–229
Gharib SM, Soliman AM (1998) Some water characteristics and phyto-zooplankton relationship in Lake Edku (Egypt) and adjacent sea. Bull Fac Sci Alex Univ 38(1, 2):25–44
Hamza W (2006) The Nile estuary. In: Estuaries PW, (ed.) The handbook of environmental chemistry, volume 5 water pollution, part H. Springer Science and Business Media
Haslund OH, Jensen A, Nasr S, Poulsen E, Boisen F, Ebrahim AMM, et al (1999) First results from the Egyptian Coastal Water Monitoring Program. MEDCOAST 99 – EMECS 99 joint conference, land-ocean interactions: managing coastal ecosystems. In: Ozhan E (ed.) 9–13 November 1999: Antalya
Hereher ME (2014) The Lake Manzala of Egypt: an ambiguous future. Environ Earth Sci 72(6):1801–1809
Masoud MS, Alewa AA, Ali AE, Mohamed AE (2005) Distribution of some metal concentrations in water and sediments of Lake Edku, Egypt. Bull Chem Technol Maced 24(1):21–34
MedwetCoast (2004) National wetlands strategy and plan of action for Egypt. http://vinc.s.free.fr/IMG/A21_Egypt_National_Wetlands.pdf
Mehanna SF (2008) Northern delta lakes, Egypt: constraints and challenges, Tropentag, international conference on research for development in Agriculture and Forestry, Food and Natural Resource Management competition for resources in a changing world: new drive for Rural Development, October 7–9, 2008 in Stuttgart-Hohenheim, University of Hohenheim
MENA (2016) Egyptian biodiversity strategy and action plan (2015–2030) January 2016, Arab Republic of Egypt, Ministry of Environmental Affairs
Mitsch WJ, Gosselink JG (1993) Wetlands, 2nd edn. Van Nostrand Reinhold, New York
Nicholls RJ, Wong PP, Burkett VR, Codignotto JO, Hay JE, RF ML et al (2007) Coastal systems and low-lying areas. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) Climate change 2007: impacts, adaptation and vulnerability, Contribution of Working Group II to the fourth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp 315–356

Pérez-Ruzafa A, Marcos C, Gilabert J (2005) The ecology of Mar Menor coastal lagoon: a fast-changing ecosystem under human pressure. In: Gonenc IE, Wolfin JP (eds) Coastal lagoons: ecosystem processes and modeling for the sustainable use and development. CRC Press Boca Raton, Florida, pp 392–422

Ramsar (2014) The Ramsar convention and its mission. http://ramweb-uat.neox24.ch/about/the-ramsar-convention-and-its-mission

Ramsar (2015) State of the world's wetlands and their services to people: A compilation of recent analyses. Ramsar Briefing Note 7, March 2015. http://www.ramsar.org/sites/ default/files/documents/library/bn7e_0.pdf

Saad MAH (2003) Impact of diffuse pollution on the socio-economic development opportunities in the coastal Nile Delta lakes. Diffuse Pollution Conference, Dublin 2003 ECSA 5: Management, 6–81

Samaam AA, AFA G, Aboul-Ezz SM (1989) The benthic fauna of Lake Burullus. 1-community composition and distribution of the total fauna. Bull Nat Inst Oceanogr and Fish, ARE 15(1):217–224

Scott DA (1989) Design of wetland data sheet for database on Ramsar sites. Mimeographed report to Ramsar Convention Bureau, Gland, Switzerland

Shakweer L (2005) Ecological and fisheries development of Lake Manzala, I. Hydrography and chemistry of Lake Manzala. Aquac Res 31(2005):1110–0354

Shaltout KH, Khalil MT (2005) Lake Burullus (Burullus Protected Area), Publication of Biodiversity Unit, vol 13. State Ministry of Environment, Cairo

UNEP-MAP RAC/SPA (2009) Sub-regional report on vulnerability and impacts of climate change on marine and coastal biological diversity in the Mediterranean, Arab Countries. By Ben Haj, S., Cebrian, D., Limam, A., Grimes, S., Halim, Y, Bitar, G., Bazairi, H., Ibrahim, A., Romdhane, M. S., Ed. RAC/SPA, Tunis; 40 pages

USEPA (2002) Office of water volunteer Lake monitoring, EPA44-4-91-002 http://intranet.epa.gov/ow/temp

VLMP (2016) Water quality indicators, Marine Volunteer Lake Monitoring Program, http://www.mainevlmp.org/programs/water-quality-monitoring/water-quality-indicators/

Wahab RA, Badawy MI (2004) Water quality assessment of the river Nile system: an overview. Biomed Environ Sci 17:87–100

Younis AM, Nafea EM (2012) Impact of environmental conditions on the biodiversity of Mediterranean sea lagoon, Burullus protected area, Egypt. World Appl Sci J 19(10):1423–1430

Youssef DH (1999) Behaviour of some heavy metals in sulphidic aquatic conditions, Ph.D. Thesis, Faculty of Science, Alexandria University, Alexandria, 1999

Youssef DH, Masoud MS (2004) Behavior of some acid-base indicators in some Egyptian aquatic environments. Bull Chem Technol Maced 23(1):37–46

Zakaria HY, Ahmed MH, Flower R (2007) Environmental assessment of spatial distribution of zooplankton community in Lake Manzalah, Egypt. Acta Adriat 48(2):161–172