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**Research Article**

# The impact of some anthropogenic activities on river Nile delta wetland ecosystems

## Abstract

The River Nile delta shallow lakes namely, Edku, Burullus and Manzala are natural wetland ecosystems, connected to fresh water sources at the south and to the open sea at the north. Throughout their relatively short geological and hydrological history, the lakes received unpolluted fresh water from the river Nile. Egyptians have begun practicing some form of water management for agriculture and transportation since about 5,000 years ago. As a result of agricultural and industrial development over the last century, the lagoons have been the end points of the last Egyptian use of the Nile water before flowing to the Mediterranean Sea; currently, the lakes receive fresh water from polluted drains inflow. In the present investigation, we studied some common characters of the lakes; including the accumulation of Cu, Zn, Cd, Pb, Mn, Fe, and Al in water, surface sediments, *Tilapia zillii* fish, and the common reed, *Phragmites austrlis*. Sampling was undertaken in May 2017. Six to 9 water samples were withdrawn from locations close to drains - lake and lake-sea connections for each of the three lakes. Surface sediments, tilapia fishes and *P. australis* specimens were sampled from three different localities along the southern edge of each of the studied lakes, where most of the anthropogenic activities occur. Analysis of variance (ANOVA) was carried out to compare the chemical properties of the water among the three lagoons. The lowest concentrations of all the tested metals were found in water, while the highest concentrations of the tested metals (except Zn) were detected in surface sediments. The highest concentration of Zn was found in tilapia fish muscles. However, the magnitudes of heavy metal concentrations in the living components of the lagoons (tilapia fish and the common reed) didn't follow the same pattern as in the nonliving components (water and sediments). *In situ* measurements demonstrated pH values in the alkaline side. The horizontal salinity gradient between northern and southern edges of the lakes is quite obvious. The concentrations of inorganic anions were measured at both lagoons – sea, and drains – lagoons connections. Some of the major chemical characters of lake waters were also analyzed. Accumulation of N-NO$_3$ at the mouths of the drains connected to the lagoons indicated a poor autotrophic activity. The history of area degradation of the lagoons indicated that their area reduction had occurred before the construction of the oldest dam in Egypt. The current management of the lagoons was discussed.

## Abbreviations

TEQ: Toxic Equivalence Quotient; EC: Electrical Conductivity; SWERI: Soil Water & Environment Research Institute; APHA: American Public Health Association; ds/m: deciSiemens/m; TDS: Total Dissolved Salts; mg/L: milligram per liter; mEq/L: milliequivalents per liter; T year$^{-1}$: Tons per year; µmole l$^{-1}$: Micromole per liter

## Introduction

The origin of the northern river Nile delta lagoons wetland ecosystem is connected with the building of the postglacial Nile Delta [1]. Around 20 000 y BP, the river Nile had incised a valley deep below its current surface. After deglaciation, the sea level had risen to about 5 m above the present, and the Mediterranean invaded Lower Egypt. Modern delta building have probably begun only after the sea had stabilized around its present level, some 6000 years ago as a result of the Nile depositing on average 20 cm of alluvium per century. Water management in Egypt has been started since the early human history. The earliest evidence of water control in ancient Egypt was presented by Butzer [2]. Egyptians have begun water management for agriculture and transport since about 5,000 years ago.

The climatic conditions in Northern Egypt, where Nile river delta lagoons have been formed, are warm summer (20–30°C) and mild winter (10–20°C). The aridity index ranges between 0.03 and 0.2 in the northern areas and less than 0.03 in the south, indicting a typically hyper-arid region [3]. However,

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nowadays, Northern Nile delta lagoons are among the most important and productive wetland ecosystems in the country; they are also considered internationally important staging, wintering and breeding areas for water birds [4]. Meanwhile, Egypt's wetlands have been intensively subjected to a variety of man-made threats, including land reclamation and other natural and anthropogenic factors. A drainage network have been constructed to gather agricultural waste effluents from the delta toward delta coastal lakes, making them final destinations for the main drainage instead of being terminated at the sea, which eventually caused severe deterioration of these lakes. Consequently, sedimentation rates, nutrient levels, and heavy metal concentration increased. This deterioration has been accompanied by severe water body degradation to the extent that one of them, Edku lagoon, is about to vanish [5]. On the other hand, El-Shazly et al. [6] documented that cytotoxicity testing of Manzala lagoon water exhibited inhibition of cell viability; while Dioxin analysis indicated that the average concentrations of some of these toxic compounds were higher than the toxic equivalence quotients (TEQs) set by the World Health Organization (WHO) in water and fish muscle samples.

The quality and quantity of fresh water enriching the lakes are controlled by two main factors; the upriver activities as well as the social and economic requirements of the local population, inhabiting the neighbouring land, including uncontrolled drying for housing and cultivation as well as primitive fishing and fish farming activities. These facts simply summarize the huge pressures of anthropogenic activities on the River Nile delta wetland ecosystems. The aims of the present work are to present an overview of the environmental status of the Nile delta lagoons and to study some of common characters of these lagoons; including the major chemical features of the water, as well as, the accumulation of some heavy metals in some living and non-living components of these ecosystems (water, surface sediments, the bony fish, *T. zillii* and the common reed, *P. australis*).

## Materials and Methods

### Description of the lakes

The Nile Delta is a part of the Egyptian Mediterranean coast, extending approximately 240 km from Abukir headland at Alexandria in the west, to Port Said in the east. The delta is under the arid climate with annual precipitation of <100 mm [7]. The most conspicuous features of its margin are the Rosetta and Damietta promontories (figure 1), which emanate from a point of bifurcation 23 km north of Cairo. Between these promontories lies a broad headland composed of Nile sediments deposited since 6,500 years ago [8-10]. The river Nile delta wetland ecosystem comprised three brackish lagoons.The three lakes share several common characteristics. Each lake is separated from the open Mediterranean Sea by a sand bar along its northern edge, but remains connected to the sea by one or more outlets locally known as 'boghaz'; recent maps are given by El-Shazly et al. [5]. The lakes are extremely shallow, with an average depth ranging between 0.4 and 2.0 m. There are also several large and small islands disrupting the water body of each lake. The reported island numbers were 1000, 75 and 7 for Manzala, Burullus and Edku lagoons, respectively [11,12]. Large sectors of the lakes are occupied by emergent, floating and submerged water plants. The most common plant surrounding the lakes from all directions is the common reed, *Phragmites australis.* The lagoons serve as collection basins for agriculture drainage, municipal sewage and industrial wastewater. It was estimated that an annual drainage influx of approximately 4060 × 106 $m^3$, 2460 × 10 h6 $m^3$ and 1836 × 106 $m^3$ enters Manzala, Burullus and Edku lagoons, respectively [13-16]. However, till now, the three lagoons are important wetland reserves for the maintenance of biodiversity in Egypt. The lakes, especially Lake Burullus, are considering wintering areas of international significance for water birds. Economically, the lagoons provide Egypt with a considerable quantity of the annual fish yield [17].

### Water and trace metal analysis

Electrical conductivity (EC) and water pH values were determined in situ. Water analysis was conducted in "Soil, Water & Environment Research Institute (SWERI)"- Ministry of Agriculture- Egypt. The following anions and cations were determined: $N\text{-}NH^{4+}$, $N\text{-}NO^{3-}$, $CO_3{-}^{2}$, $Cl^-$, $SO4^{-2}$, $Ca^{+2}$, $Mg^{+2}$, $Na^+$, $K^+$, and total phosphorous. Water samples were obtained during May 2017. Six to 9 water samples were withdrawn from locations close to drains - lake and lake-sea connections for each of the three lakes. Water was sampled in sterile glass jars and samples were transferred in the same day to SWERI water analysis laboratory. Trace metal analysis in surface sediments, *P. australis* shoots and *T. zillii* fish muscles was performed as follows: Sampling was undertaken in May 2017. Surface water, sediment, tilapia fishes and *P. australis* were obtained from three different localities along the southern edge of each of the studied lakes, where most of the anthropogenic activities occur. Prior to analysis, sediment and edible fish tissues were prepared according to Hseu [18]. Concentrations of trace metals (Cu, Zn, Mn, Cd, Pb, Fe and Al) were determined in water, sediment and edible fish tissues using flame atomic absorption spectrophotometer (Thermo Scientific ICE 3300, UK, equipped with double beam and deuterium background corrector) according to APHA [19]. Analysis of variance (ANOVA) was carried out to compare the chemical properties of the water among the three lagoons.

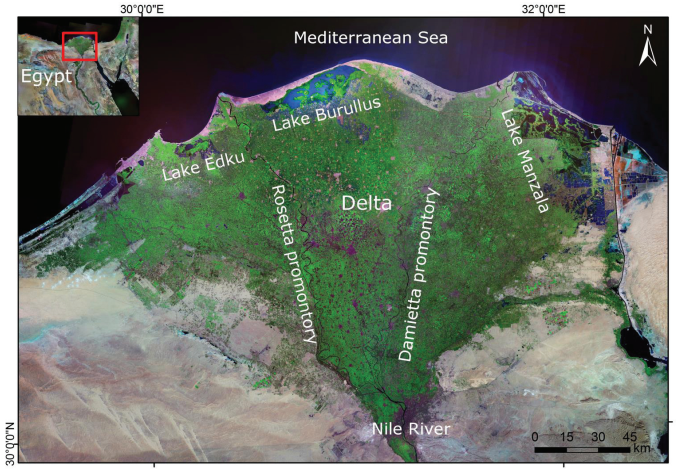

**Figure 1:** Satellite image of River Nile delta showing locations of delta coastal lakes (source: satellite image, LANDSAT 8, 2015).

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**Table 1:** Comparison of Physical and Chemical Properties* of Water Samples from all Lakes.

| Character | Connection with sea | | | Connection with drains | | |
|---|---|---|---|---|---|---|
| | Manzala | Burullus | Edku | Manzala | Burullus | Edku |
| Physical properties | | | | | | |
| **EC (ds/m)** | 17.8±0.11a | 50.2±0.13b | 2.9±0.05c | 4.3±0.28a | 3.7±0.79a | 1.7±0.04b |
| **TDS (ppm)** | 14225±90.8a | 401866±109.3b | 1915.7±34.5c | 2766.8±184.9a | 2416±506.2a | 1120±27.7b |
| Chemical properties | | | | | | |
| **Anions(mEq/L)** | | | | | | |
| $CO_3^-$ | 3.5±0.26a | 5.7±0.42b | 2.3±0.29c | 2.2±1.0a | 1.5±0.10a | 1.4±0.48a |
| $(Cl^-)$ | 155.0±15.4a | 477.6±17.5b | 2500.5±210.6c | 35.9±4.1a | 32.0±8.2a | 13.0±0.99b |
| $SO_4^{-2}$ | 12.2±2.3a | 18.4±1.0b | 2.2±0.11c | 3.5±1.9a | 1.7±0.47b | 2.2±0.16ab |
| **Cations (mEq/L)** | | | | | | |
| $Ca^{+2}$ | 41.3±6.6a | 128.3±9.4b | 8.5±0.77c | 11.6±1.9a | 10.7±1.7a | 4.4±0.90b |
| $Mg^{+2}$ | 38.6±6.5a | 118.0±6.6b | 7.5±0.73c | 10.5±1.6a | 8.7±2.8a | 3.5±0.48b |
| $Na^+$ | 88.5±7.5a | 253.6±16.8b | 13.2±1.7c | 18.8±2.4a | 15.1±3.8a | 8.2±0.40b |
| $K^+$ | 2.4±0.8a | 2.1±0.30a | 0.53±0.11b | 0.73±0.14a | 0.47±0.09b | 0.32±0.10b |
| **N-$NH_4^+$ (mg/L)** | 5.0±0.05a | 8.6±7.1b | 11.3±0.86c | 9.4±3.5a | 9.6±2.0a | 10.0±0.73a |
| **N-$NO_3^-$ (mg/L)** | 189.1±7.4a | 149.9±7.0b | 22.7±0.60c | 76.5±17.0a | 123.7±22.6a | 74.5±7.7a |
| **P (mg/L)** | 0a | 0a | 0.05±0.009b | 0.36±0.34a | 0.06±0.02a | 0.07±0.01a |

*Data are presented as mean ± SD. Means followed by the same letter within each row are not significantly different (ANOVA, Tukey test, P > 0.05).

## Results and Discussion

### Water chemistry

*In situ* measurements demonstrated pH values in the alkaline side, with wide range of fluctuation (7.15–8.5,). The horizontal salinity gradient is quite significant, where the (EC) at drains-lakes connections ranged between 1.7±0.04 and 4.3±0.28 for Edku and Manzala lagoons, respectively; while EC values at lakes – sea connections were 17.8±0.11and 50.2±0.1, for Manzala and Burullus lagoons, respectively (Table 1). However the low value of EC at Manzala – sea connection is attributed to the huge inflow of the agricultural wastewater, while Lake Burullus receives less polluted drain loads, as most of the eastern area of this lagoon is declared as a national wetland ecosystem protectorate. On the other hand, the extremely low value of EC of Edku Lake (2.9 ds/m, Table 1) could be due to the small area of the lagoon, together with the huge agricultural drains inflow into the lake, and this may account also for the significantly low TDS value at its connection with the sea.

TDS is a measure of all constituents dissolved in water. The inorganic anions dissolved in water include carbonates, chlorides, sulfates and nitrates. The inorganic cations include sodium, potassium, calcium and magnesium (Table 1). The concentration of inorganic anions can be arranged in a descending order of $Cl^- > SO_4^{-2} > CO_3^{,}$ and the concentration of inorganic anions can be arranged in a descending order of $Na^+ > Ca^{+2} > Mg^{+2} > K^+$ in both lagoons – sea, and lagoons –drains connections (Table 1). The concentration of sulfate ranged between 1.7±0 mEq/L at the connections of drain canals with Burullus lagoon and 18.4±1 mEq/L at the connection of the same lagoon with open sea. Sulfate is a constituent of TDS and may form salts with sodium, potassium, magnesium and other cations. Sulfate ($SO4^{2-}$) is widely distributed in nature and may be present in natural waters at concentrations ranging from a few to several hundred milligrams per liter. The concentration of sulfates at the connection with drains is much below the sulfate criteria for livestock watering, which is 2.000 mg/L (= 41.6 mEq/L). The guideline values of livestock watering for other ions will remain the same.

### Nutrients

Phosphate wasn't detected at lagoons –sea connections in Manzala and Burullus, but its average concentration at the mouths of drains-lagoons connections were 0.36±0.34, 0.06±0.02and 0.07±0.01 mg/L for Manzala, Burullus and Edku respectively. This suggests that Burullus lagoon is less polluted than Manzala. Okbah and Hussein [20], reported that phosphate concentration in Burullus ranged between 0.63–14.83 µmole $l^{-1}$; however, it is generally accepted that a TP >0.1 mg/L represents hypereutrophic conditions.

Concerning N content, the concentrations on N-$NH_4$ at drain- lagoons connections were 9.4±3.5, 9.6±2.0 and 10.0±0.73 mg. /L for Manzala, Burullus and Edku respectively; the corresponding values at the connection to the sea were 5.0±0.05, 8.6±7.1 and 11.3±0.86 mg. /L for the three lagoons, respectively. The concentrations of N-$NH_3$ at the mouths of drains connected to the lagoons were 189.1±7.4, 149.9±7.0 and 22.7±0.60 mg./L for Manzala, Burullus and Edku respectively; the corresponding values at the connections to the sea were 76.5±17.0, 123.7±22.6 and 74.5±7.7for the three lagoons, respectively.

$NH_4$-N is produced by heterotrophic bacteria as an end product of decomposition of organic matter, and is readily assimilated by plants in the trophogenic zone; $NH_4$-N concentrations is commonly low in oxygenated waters of oligo- to mesotrophic deep lakes because of utilization by plants in the photic zone and nitrification to N oxidized forms [21]. Nitrification of ammonia is decelerated in response to the depletion of the dissolved oxygen in the water; the absorptive

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capacity of the sediments is reduced, and a marked increase of the release of NH$_4$-N from the sediments then occurs. As a result, the NH$_4$-N concentration would increase. NO$_3$-N is the common form of inorganic nitrogen entering lakes with the drainage water; in relatively aerobic waters nitrification prevails [21]. Thus, when NO$_3$-N from external sources reaches lakes it is consumed by autotrophs and bacteria, transformed in organic matter that on decay and food web transmission ultimately goes to the NH$_4$-N pool [22]. Accumulation of N-NO$_3$ in at the mouths of the drains connected to the lagoons (76.5±17.0 and 123.7±22.61, 74.5±7.7mEq/L for Manzala and Burullus, and Edku, respectively, table 1) indicates a poor autotrophic activity, and consequently, low oxygen contents, which may account for the mass mortality of fishes in the highly polluted basins of the lagoons. In general, the nutrient loads was reported to be 205.44, 25.80 T year$^{-1}$ for N and P, respectively in Manzala lagoon; 87.14, 10..94 T year$^{-1}$ for N and P, respectively in Burullus lagoon and 16.16, 2.03 T year$^{-1}$ for N and P, respectively in Edku lagoon [10], while Rasmussen et al. [23], suggested that the total yearly inputs of nitrogen and phosphorus from drainage canals to Manzala lake were 42,091 and 3,116 T year$^{-1}$, respectively.

## Trace metal analysis

Trace metals in the major constitutes of living (*T. zillii* and *P. australis*), and non-living (water and surface sediments) of the lakes are given in table 2. The lowest concentrations of all the tested metals were found in water in all lagoons, while their highest concentrations were detected in sediments. The only exception was Zn, where the highest concentration of this trace metal was found in the bony fishes, *T. zillii*, in the three lakes.

The average concentrations of the majority of heavy metals in nonliving components of lake ecosystems, water and sediments, can be arranged in a similar descending order of Al> Mn> Zn> Pb> Cu> Cd (Table 2). Cadmium concentrations in lake sediments were found to exhibit the lowest values of the detected metals in previous literature [24]. However, various records of the most concentrated metal varied in different literatures, e.g. [25].

**Table 2:** Average concentrations* of heavy metals in living and non- living components of the three lagoons.

| Metals | Sediments | Water | T. zillii | P.australis |
|---|---|---|---|---|
| Cu | 3.8±0.07**<br>(3.6-3.8)*** | 0.023±0.0007<br>(0.022-0.024) | 5.1±1.2<br>(3.8-6.8) | 6.8±0.04<br>(6.7-6.8) |
| Zn | 23.5±0.65<br>(21.7-23.7) | 0.041±0.002<br>(0.040-0.047) | 47.4±1.0<br>(46.0-48.6) | 18.6±0.03<br>(18.5-18.7) |
| Mn | 314.7±0.20<br>(314.2-315) | 0.07±0.001<br>(0.069-0.073) | 1.8±0.02<br>(1.7-1.8) | 337.9±2.6<br>(331.5-339.0) |
| Cd | 0.01±0.0001<br>(0.01-0.01) | 0.003±0.0004<br>(0.003-0.004) | 0.11±0.07<br>(0.04-0.21) | 0.06±0.01<br>(0.03-0.09) |
| Pb | 4.4±0.13<br>(4.4-4.8) | 0.04±0.008<br>(0.03-0.046) | 2.8±0.09<br>(2.7-2.9) | 2.9±0.05<br>(2.7-2.9) |
| Fe | 4175.8±4.8<br>(4173.7-4188.1) | 0.23±0.005<br>(0.22-0.24) | 51.9±10.3<br>(41.1-65.7) | 544.6±2.3<br>(542.7-550.3) |
| Al | 5279.6±136<br>(5218.9-5623.3) | 0.12±0.001<br>(0.120-0.125) | 11.6±4.0<br>(6.0-15.9) | 657.8±1.9<br>(656.9-662.2) |

*mg/kg dry wt. for sediments, fishes and aquatic plants, mg/L for water
**Data are presented as mean ± SD. ***Range.

It seems that the magnitudes of heavy metal concentrations in the living components of an ecosystem don't necessarily follow the same pattern in nonliving components. Thus, in *P. australis* stem tissues the concentration of heavy metals (mg/kg dry wt.) can be arranged in a descending order of Al (657.8±1.9) > Fe (544.6±2.3) > Mn (337.9±2.6) > Zn (18.6±0.03) > Cu (6.8±0.04) > Pb (2.9±0.05) > Cd (0.06±0.01); while, the average concentrations (mg/kg dry wt.) of heavy metals in *T. zillii* muscles could be arranged in a descending order of Fe (51.9±10.3 )> Zn (47.4±1.0) > Al (11.6±4.0) > Cu (6.8±0.04) > Pb (2.8±0.09) > Mn (1.8±0.02) > Cd (0.11±0.07) (Table 2). Some previous records documented the highest concentration of Fe, and the lowest concentration of Cd in 6 fish species [26]. However, metals exhibit variable affinities not only to different fish species, but also to different organs of the same species [27]. This can be attributed to the innumerable variations in the metabolic roots of different chemicals in living organisms, which in turn, direct the bioaccumulation rates in different species, as well as the bio- magnification rates of different elements of the food web in a given ecosystem.

## Anthropogenic activities and lakes management

**The high Dam:** While dams building decisions would rely upon solid environmental impact assessment studies, these constructions have mostly been raised on economic rather than ecological basis. The hydrology of Nile River has not been properly managed after the construction of water barrages which were accelerated during the twentieth century with the construction of the first Aswan dam in 1902. Additional reservoirs were built in1902, 1903, 1909, 1930 and 1951. These reservoirs smoothed out the peaks and sags in the amount of water reaching the delta lakes. However, full control of the Nile floods was achieved with the commissioning of the Aswan high dam in 1964. After the filling the Aswan High dam, during the last third of the 20th century, there was a year round irrigation system instead of a short flooding season that predominated throughout the previous history of the region. Meanwhile, a group of drains have been constructed to gather agricultural waste effluents from the delta toward the Mediterranean Sea. The occurrence of the delta coastal lakes made them a final destination for the main drainage instead of being terminated at the sea, which eventually caused severe deterioration of these lakes [28]. We have followed the history of area degradation and represented the data in figure 2 for Manzala, Edku and Burullus lagoons, respectively. The figure indicates that water body areas of Manzala has decreased from 3035 mk$^2$ in 1800 to 1983 km$^2$ in 1889, meanwhile, the lagoonal area of Edku lake has decreased from 336.4 km$^2$ in 1826 to 210 km$^2$ in 1889; this reduction had occurred before the construction of the oldest dam, as the construction of the first Aswan dam was in 1902. Furthermore, the area of Manzala lake had increased from 1323 km$^2$ in 1953 to 1441 km$^2$ in 1973 [5], while the High Dam was constructed in 1964.on the other hand, no significant reduction in Edku lake area has been reported since 1973 (Figure 2). Concerning Burullus lagoon, we have no available information about its area change before 1949. However, it was suggested that current anthropogenic nutrient load to the coastal zone exceeds that of pre – Aswan High Dam conditions [23]. Thus, the increase in sedimentation rate and nutrient levels can be attributed to the poor periodic monitoring of the environmental health of the lakes as well as the absence of the proper hydrological management.

## Threats to Mediterranean sea

Nile discharge to the Mediterranean has been restricted to the Rosetta promontory. The Damietta promontory is blocked 12 km upstream from its mouth by a dam at the city of Faraskur. The water flowing through the mouth of the Rosetta promontory is controlled by another barrage, the Edfina Barrage located 35 km south of the river mouth. Restriction of the Nile flow through the Nile promontories to the Mediterranean is due to the almost total dependence of Egypt on the Nile (95% dependent) as the main freshwater source to satisfy the fast increase in its population growth. As a result of these restriction controls, the quantity of water released to the Mediterranean is no longer determined by Nile flooding, but is composed of wastewater that considered unsuitable for recycling. In his review, Hamza [17], indicated the actual quantity of Nile surplus reaching the Mediterranean annually amounts to 2.5–4 $km^3$. Almost all of this water passes through the northern delta lakes and other land effluents connected to the sea. Thus, Lake Manzala, for example, is a current threat to the Mediterranean Sea [29], approximately 6000 tons of N and 1300 tons of P are exported to the Mediterranean through the two main lake–sea connections.

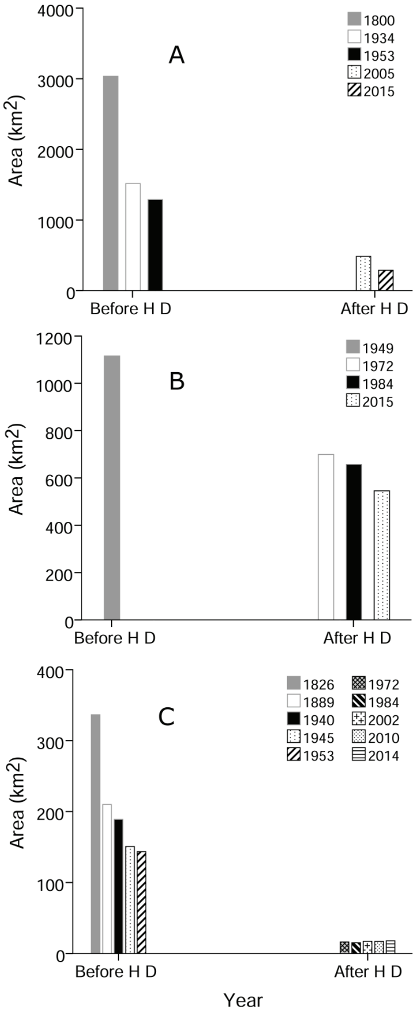

**Figure 2:** Area reduction of three wetland ecosystems before and after the construction of the high dam (H D); (A) Lake Manzala; (B) Lake Burullus; (C) Lake Edku.

## Fish production

The sewage discharges into the coastal lakes and other land run-offs have become the alternative source of nutrients for coastal fisheries. Not only are biodiversity aspects and coastal lagoons wetland ecosystems are at risk, but the goods and services that affect human welfare are also generally in decline. Currently, fishing and fish culturing are important economic activities in northern delta lagoons and provide a livelihood for fishermen and their families. Social problems, including health care shortage and security problems, especially in Manzala district have led to economic collapse in the last decades [30]. Although fish production from delta lakes has increased in the last two decades [31], the accumulation of dioxins and heavy metals in fishes reduced the fish quality [6]. In addition, the average size of the edible fish, tilapiines decreased by 30%, due to overfishing [32].

Fishermen frequently observe floating dead fishes early in the morning. Accumulation of $N-NO_3$ at the mouths of the drains connected to the lagoons (76.5±17.0 and 123.7±22.61mEq/L for Manzala and Burullus, respectively, table 1) indicates a poor autotrophic activity, and consequently, a low oxygen content, which may account for the mass mortality of fishes in the highly polluted basins of the lagoons. The values of dissolved oxygen between 4-8, 2-4 and less than 2 (mg/L) in a water body indicate low risk of effects, possible effects and probable effects, respectively. On the other hand, the average value of dissolved oxygen in one of Manzala lagoon basins was 1.5 mg/L (El-Shazly, unpublished data); this value was detected in the southern area of the lake adjacent to the drains inlets, where the nutrient concentration is very high. Oxidation of such organic matter as well as respiration of aquatic organisms (phytoplankton, aquatic plants and fishes) consumes the dissolved oxygen. Because sampling was undertaken at the mid-day where photosynthesis process is peaked, this value is considered very critical at night where respiration is the dominant process, reducing the oxygen to minimum values. This could account for the observed mass mortality of fishes. On the other hand, the reduction of lake area has forced fishermen to harvest fingerlings and dredge the lake bottom in search for adult fish in their breeding grounds. Dredging the bottom sediments re-suspends particulate organic matter, which consumes oxygen and results in fish kills. Also, turbid water reduces the photosynthetic capacity of algal cells, making re-oxygenation more difficult.

## Management policy

Water management in Egypt has been started since the early human history. The earliest evidence of water control in ancient Egypt were presented by Butzer [2], who has mentioned that

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Egyptians began practicing some form of water management for agriculture about 5,000 years ago. Indeed, the River Nile was managed not only for large-scale agricultural production, but also as a means of transport connecting the whole empire in a strong, coherent and a long living state; today this country is the Arab Republic of Egypt. The reconstructed landscape maps of the north-west Nile Delta in Egypt [33], suggests that in antiquity (c. 300 BC to the ninth century AD), the lagoons, marshes and river channels provided a watery environment that was exploited to the maximum to support the major political power centers of the time.

In Egypt, and probably in many other countries, great support was given to industrial development during the 1 950's, while inadequate attention was paid to the long-term imacts on the environment. Egyptian regulations and standards were not enforced, and untreated waste waters have been discharged ever since into the Nile, Lakes, Canals, and the Mediterranean Sea [34]. Integrated environmental law presented by the Egyptian Environmental Affairs Agency (EEAA) was approved by the National Assembly in 1 993. However, the impacts of global climate change, especially temperature change and sea level rise on Egypt's Mediterranean coastal zone including northern delta lagoons are considered as challenges facing the management and sustainable development of these productive natural ecosystems. The impacts of sea level rise on Egypt's coastal zone and the adaptive management of northern delta lakes have been discussed by Malm [35] and Omran and Negm [36].

There are more than eight Administrative Agencies Concerned with the Protection of the Water Environment, namely, The Egyptian Environmental Affairs Agency (EEAA),The Department of Ports and Lighthouses, The Suez Canal Authority, Port Authorities in ARE, The General Egyptian Organization for the Protection of the Coast. Egyptian General Petroleum Corporation. (EGPC), General Department of Surface Water Police, Tourism Development Authority, and Other agencies designated by a Prime Ministerial Decree. According to the Egyptian environmental law number 4 of (1994), Environmental Monitoring Networks includes the above mentioned agencies "which undertake, within their spheres of competence and through their stations and work units, to monitor the components and pollutants of the environment and relay their results and data to the competent authorities periodically". In spite of the above mentioned administrative agencies concerned with the protection of the water environment, the poor management is obvious as the increase in sedimentation rate, pollutant concentration and nutrient levels can be attributed to the poor periodic monitoring of the environmental health of the lakes as well as the absence of the proper hydrological management. It was suggested that current anthropogenic nutrient load to the coastal zone exceeds That of pre – Aswan High Dam conditions despite the large reduction in the annual pulse of water and nutrients brought about by the dam lake. Consequently, a regular survey of the environmental status of the lakes through a unified environmental monitoring checklist is recommended to avoid overlapping and confusion of duties and responsibility among administrative agencies; provided that environmental monitoring is undertaken regularly by a technical independent authority and the checklist is designed to include all the possible environmental health variables.

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