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Macrobenthos Diversity Assessment in the Delta Wetlands, Egypt

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ABSTRACT

Macrobenthos serve as ecological pointers for pollution, as well as indicators of sediment and water quality in marine and sub-marine ecosystems. The primary aim of this study was to shed light on macrobenthic diversity in relation to water and sediment quality in the North Delta wetlands of Egypt (Manzala, Burullus, and Idku). A total of 45 sampling spots were selected—15 at each site—to examine the physicochemical characteristics of water and sediment, along with macrobenthos diversity. Twenty-eight species of the benthic fauna were recorded in the sediments of the North Delta wetlands during 2023 and 2024. Among these, 21 species belong to Gastropoda, 3 to Bivalvia, 2 to Amphipoda, and one species each to Insecta and Cirripedia. Twenty-eight species were identified in both Manzala and Burullus, while only 25 species were recorded in Idku. Six species were not found in the sediments of Idku: *Helisoma duryi*, *Physa acuta*, *Macoma bathica*, *Pisidium pirothi*, *Valvata nilotica*, and *Vanthina nitens*. It was generally observed that the majority of mollusks were distributed as empty shells across the wetland bottoms. The benthic fauna can be effectively used as bioindicators of pollution and habitat type. For instance, *Tendipes tentans* may serve as an indicator of oxygen depletion, while *Nereis succinea* and *Gammarus lacustris* may indicate the presence of fine sediment deposition. Notably, two species of benthic fauna—*Pila ovata* and *Pila wernei*—were recorded for the first time in the northern wetlands. This research contributes to achieving the Sustainable Development Goals (SDGs) and supports sustainable management of wetland ecosystems.

INTRODUCTION

The Mediterranean littoral land of Egypt extends for about 970km, from Sallum to Rafah. This narrow, arid littoral belt is divided into three sections: the western (from Sallum to Abu Qir), the middle (from Abu Qir to Port Said), and the eastern (from Port Said to Rafah). The middle or delta section is characterized by three shallow lagoons: Manzala in the east, Burullus in the middle, and Idku in the west. These lagoons receive almost all the drainage water from the Nile Delta and are considered approximate budgets of the Nile water flowing into the Mediterranean Sea **(Ahmed *et al.*, 2001)**.

They play an important role in the nation's economy, not only because they produce more than 50% of the total fish yield from all Delta wetlands, but also because they have suffered—and continue to suffer—from man-made activities. Agricultural, industrial, and sewage discharges; land reclamation; illegal fishing; and increasing pollution are the main contributing factors. **Ahmed *et al.* (2000)**, **Zyadah *et al.* (2004)**, **Mosleh *et al.* (2021, 2023, 2025)** and **Zyadah (2005)** stated that the abundance and distribution of benthic fauna in Manzala wetlands, in relation to environmental factors, are significantly affected by salinity, nutrients, and pollutants in both water and sediments.

The general condition of the benthic fauna was characterized by empty calcareous shells of mollusks. Twenty different species were identified. The low number of species may be attributed to water pollution and/or habitat degradation. Some freshwater species invaded the lake through rainwater channels. It has been demonstrated that the species composition of macrobenthos may reflect changes in environmental conditions over time. The number of species present in a given niche can serve as a biological pollution index. Many oceanographic organisms can be used to estimate the quality of water and sediments. For example, larvae of chironomids and oligochaetes can be regarded as natural indicators of water purity and the trophic state of the lagoon.

Benthos is considered a better indicator of both historical and present environmental conditions of an ecosystem than physical and chemical indicators of water and sediments. They are considered the best indicators of pollution due to their sedentary, sessile, and long-lived nature, as well as their ease of collection **(Radwan, 2000; Radwan & Lotfy, 2002; Kosari *et al.*, 2021)**.

These researchers studied heavy metal pollution in the water and sediments of the Burullus wetland and found that the concentrations of heavy metals in water exceeded internationally acceptable limits. The distribution of trace elements in the sediments is largely controlled by the mineral composition of the bottom deposits, as well as by pollutants introduced through agriculture and domestic waste.

Samaan *et al.* (1989) studied the oceanographic fauna of the Burullus wetland and identified eleven communities dominated by *Chaetogaster limnei*, *Corophium volutator*, *Gammarus lacustris*, *Mesanthera* spp., and *Corbicula consobrina*. The highest biomass appeared in the western section, mainly due to the abundance of *Corbicula consobrina*. The variation in benthic standing crop in Burullus is largely related to ecological conditions, the nature of bottom sediments, and the fertility of the wetland waters. Eleven elements in both water and sediment were found to be higher than standard levels.

Marine macrofauna in aquatic ecosystems contribute to diverse sediment structures, effective solute transport into burrows, increased oxygen uptake in sediments, stimulation of microbial communities, and enhanced decomposition rates **(Jones *et al.*, 1994)**. These traits demonstrate that macrobenthos are both ecological indicators and ecosystem engineers in aquatic environments. **Rahman *et al.* (2021)** confirmed that oceanographic species can function as ecosystem engineers **(Gogina & Zettler, 2010; Al-Asif *et al.*, 2020)**. These infaunal species live within sediments and exhibit relatively low mobility, making them susceptible to stress from pollutants, low dissolved oxygen, limited nutrients, and physical disturbances **(Dauer *et al.*, 1992; Weisberg *et al.*, 1997)**.

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MATERIALS AND METHODS

Study area

The study was conducted during the summer of 2023 and winter of 2024 at 45 stations across three wetland locations in the northern Nile Delta of Egypt, namely Manzala, Burullus, and Idku. Fifteen stations were selected at each site (Fig. 1).

Manzala Lagoon is located between longitudes 31°50′ and 32°15′ E and latitudes 31°60′ and 31°30′ N. It is the largest of the deltaic wetlands in Egypt, with an approximate area of 1,000km². The lagoon is shallow, with depths ranging between 0.4 and 1.5 meters. It receives three types of water: freshwater, seawater, and drainage water **(Nafea, 2005)**.

Burullus Lagoon lies between longitudes 30°31′ and 31°10′ E and latitudes 31°21′ and 31°35′ N. It is considered the second largest coastal lagoon in Egypt, with an area of approximately 420km², of which about 370km² is open water **(Ahmed *et al.*, 2001)**. The lagoon is connected to the sea through a narrow channel, Boughaz El-Burullus. Its eastern and southern borders are irregular and are surrounded by agricultural lands and fish farms **(Nafea, 2005, 2019)**.

Idku Lagoon is located west of the Rosetta branch, between longitudes 30°08′ and 30°23′ E and latitudes 31°11′ and 31°18′ N. It is the third largest coastal lagoon in Egypt, covering an area of approximately 12,000 feddans (equivalent to 50.4km²). The lagoon is characterized as a shallow brackish water body **(Khadr *et al.*, 1992)**.

Table 1. The sites selected in the three studied wetlands

Site No	Manzala wetland		Burullus wetland		Idku wetland	
1	El-Ghamil	N=31º 9´ E=32º 15´	El-Boughaz area	N=31º 34´ E=30º 59´	El-Maadiya	N: 31º 16´ E: 30º 10´
2	Tenis	N=31º 30´ E=32º 14´	Emade	N=31º 33´ E=30º 59´	El-Nakha	N: 31º 15´ E: 30º 10´
3	El-Bashtir	N=31º 12´ E=32º 10´	Mouth of drain El-Burullus	N=31º 33´ E=31º 04´	Western zone	N: 31º 15´ E: 30º 10´
4	Legan	N=31º 16 ´ E= 32º 20´	Mouth of El-Gharbia drain	N= 31º 31´ E=31º 04´	Near Qarn Diab	N: 31º 13´ E: 30º 11´
5	Dishdy	N=31º 13´ E=32º 5´	Mouth of Nasser Drain	N=31º 31´ E= 31º 31´	Western zone	N: 31º 12´ E: 30º 12´
6	El-Nassima	N=31º 13´	Mishkhilah	N=31º 30´	Southern	N: 31º 9´

		E= 32º 3´		E=30º 57´	zone	E: 30º 14´
7	El-Gamalyia	N=31º 13´ E=32º 18´	Mouth of Drain 7	N=31º 27´ E=30º 56´	Southern zone	N: 31º 10´ E: 30º 15´
8	Tolmpat fahim	N=31º 20´ E= 31º 51´	Mid. of eastern section	N=31º 32´ E=30º 58´	Middle zone	N: 31º 12´ E: 30º 15´
9	Abwat 1	N=31º 20´ E=31º 50´	El-Kom El-Akhder	N=31º 24´ E=30º 43´	Middle zone	N: 31º 15´ E: 30º 15´
10	Hemir	N=31º 20´ E=31º 15´	Kodaa	N=31º 36 ´ E=31º 01´	Northern zone	N: 30 º 16´ E: 30º 16´
11	El-Midah	N=31º 21´ E=31º 51´	El-Maksabah	N=31º 29´ E=30º 45´	Northern zone	N: 31º 15´ E: 30º 14´
12	El-Serew 1	N=31º 21´ E=31º 52´	Deshemi	N=31º 20´ E=30º 37 ´	Eastern zone	N: 31º 15´ E: 30º 20´
13	El-Rodah 2	N=31º 21´ E=31 25 29	El-Tawilla	N=31º 26´ E=30º 44´	Eastern zone	N: 31º 16´ E: 30º 19´
14	Shatta	N=31º 20´ E=31º 15´	Sakkarana	N=31º 24´ E=30º 37´	Eastern zone	N: 31º 15´ E: 30º 19´
15	El-Baghdadi	N=31º 80´ E=32º 5´	Brimbal canal	N=31º 24 ´ E=30º 35´	Eastern zone	N: 31º 16´ E: 30 º 21´

2.2. Physico-chemical characteristics

2.2.1. Water analysis

Water samples were collected from 45 sites across the Manzala, Burullus, and Idku wetlands, with 15 locations sampled at each site. The physico-chemical characteristics of the water samples were determined according to the methods described by **Sawyer and McCarty (1978)**, **Walker (1982)**, **APHA (1985, 1992)**, **Adams (1990)** and **Standard Methods (1992)**.

2.2.2. Sediment analysis

The pH was determined using a pH meter model 5995 in a 1:5 sediment-water extract **(Piper, 1947)**.

Total organic carbon (TOC) was measured using the Dichromate Method according to **Adams (1990)**.

Total phosphorus was analyzed by the Persulfate Digestion Method, as described by **APHA (1989)** and **Adams (1990)**.

Total nitrogen was also measured, although the specific method was not detailed here.

Sediment texture was determined using the hydrometer method as described by **Piper (1947)**.

2.2.3. Fauna in sediment

Bottom sediment samples were collected using a modified Ekman bottom sampler. The samples were washed over a small hand net made of bolting silk with a mesh size of 23 meshes/cm, and then examined **(Cairns, 1971; Ibrahim *et al.*, 1997b; Ibrahim *et al.*, 1999)**.

3. Statistical analysis

All statistical analyses were conducted on an IBM mainframe computer using the Statistical Package for the Social Sciences (SPSS). Analysis of variance (ANOVA) was performed to assess group differences in the concentrations of the studied elements. Means ± Standard Errors (M ± SE) were calculated for all recorded data.

3.1. Multivariate analysis

3.1.1. cluster analysis

Cluster analysis was performed using the SYSTAT 7.0 software **(Wilkinson, 1997)**. The analysis employed Euclidean distances and the centroid linkage method to classify the biological data into distinct groups.

3.1.2. Canonical correspondence analysis (CCA)

A matrix of biological parameters and environmental variables from the samples was subjected to Canonical Correspondence Analysis using the CANOCO (Canonical Community Ordination) program **(Ter Braak, 1987)**.

RESULTS

1. Physico-chemical characteristics of the water of the lakes

Tables (2, 3) show the results of the physico-chemical analysis of the water in the three studied wetlands.

Water translucency varied widely among the sites, with maximum values recorded at 100 cm in Manzala, 39cm in Burullus, and 40cm in Idku. Translucency was generally higher in summer than in winter, with Manzala exhibiting the lowest values across both seasons. The average pH values across all wetlands remained within a narrow range of 8.1 to 8.3 during both summer and winter seasons (Tables 2, 3).

Electrical conductivity and total dissolved solids (TDS) were closely related. Manzala recorded the highest TDS value (14.6g/ L) during summer, while Idku recorded the lowest values during winter. Overall, TDS values were higher in summer than in winter.

Dissolved oxygen (DO) levels ranged from 2.6 to 9.4mg/ L in summer and from 3.9 to 9.6mg/ L in winter. Surprisingly, winter generally exhibited lower DO concentrations, while summer values were slightly higher. Manzala consistently showed lower DO levels compared to the other two wetlands (Tables 2, 3).

Concentrations of phosphate, ammonia, nitrate, nitrite, and silica were the highest in Idku during both seasons. Silica values showed a slight increase in summer relative to winter.

2.4. Physico-chemical characteristics of bottom sediments

The recorded total organic matter (TOM) ranged between 1.1–4.1% in Manzala, 0.61–2.9% in Burullus, and 0.6–11.6% in Idku (Tables 4, 5), with Idku exhibiting the highest TOM values among the three sites.

Total nitrogen (TN) concentrations in sediments varied widely, ranging from 3.1 to 100 µg/g dry weight. The lowest values were observed in Manzala, while the highest were found in Idku and Burullus (Tables 4, 5).

Total phosphorus (TP) concentrations ranged between 40– 113µg/ g dry weight. Burullus had the lowest phosphorus concentrations, while winter values across all sites were generally higher than in summer.

Sediment texture analysis revealed the following:

- **Manzala**: Sandy-silty deposits with average composition of 56.5% sand, 32.5% silt, and 9–11% clay.
- **Burullus**: Silty-muddy texture with 20.7–22% sand, 41–48.6% silt, and 30.8–37% clay.
- **Idku**: Loamy deposits, averaging 36–45% sand, 36–39.2% silt, and 19–24.8% clay (Tables 4, 5).

3. Bottom dauna

A total of 28 benthic species were identified in the sediments of the North Delta wetlands during summer 2023 and winter 2024 (Tables 6, **7**). These include:

- **21 species** of *Gastropoda*
- **3 species** of *Bivalvia*
- **2 species** of *Amphipoda*
- **1 species** of *Insecta*
- **1 species** of *Cirripedia*

Recorded Gastropoda include: *Bulinus truncatus, Biomphalaria alexandrina, Cleopatra bulimoides, Bellamya unicolor, Lanistes carinatus, Melanoides tuberculata*, *Planorbis planorbis*, *Pilla ovata*, *Pilla wernei*, *Lymnaea columella*, *Hydrobia ventrosa*, *Etheria elliptica*, *Theodoxus niloticus, Vanthina nitens, Helisoma duryi, Physa acuta, Gyraulus ehrenbergi, Valvata nilotica,* and *Pisidium pirothi*.

Bivalvia include: *Corbicula consobrina*, *Cardium edule*, and *Macoma bathico*.

Amphipoda: *Gammarus lacustris* and *Corophium volutator*.

Insecta: *Tendipes tentans*.
Cirripedia: *Balanus improvisus*.

All 28 species were recorded in both Manzala and Burullus, while Idku contained only 25 species. The species *Helisoma duryi, Physa acuta, Macoma bathico, Pisidium pirothi, Valvata nilotica*, and *Vanthina nitens* were absent from Idku.

The most abundant species across the three wetlands included *Cardium edule, Lanistes carinatus, Bellamya unicolor, Melanoides tuberculata, Corbicula consobrina*, and *Biomphalaria alexandrina*, with presence frequencies of 100, 90, 100, 85, and 90%, respectively (Table 8).

The less abundant species included *Pilla ovata*, *Pilla wernei*, *Macoma bathico*, and *Pisidium pirothi* with presence rates of 45, 30, 20, and 15%, respectively.

3.1. Cluster analysis of faunal communities

In Manzala (Fig. 2), cluster analysis revealed three faunal groups among the 28 recorded species:

- **Group A**: Dominated by *Nereis succinea* and co-dominated by *Balanus improvisus*. Indicator species: *Etheria elliptica*.
- **Group B**: Dominated by *Tendipes tentans, Corophium volutator*, and *Cardium edule*. Co-dominant: *Planorbis planorbis*. Indicator species: *Vanthina nitens*.
- **Group C**: Dominated by *Lanistes carinatus, Biomphalaria alexandrina, Bulinus truncatus, Corbicula consobrina, Theodoxus niloticus*, and *Melanoides tuberculata*. Co-dominants: *Lymnaea columella* and *Valvata nilotica*. Indicator species: *Physa acuta, Pilla wernei, Pilla ovata*, and *Helisoma duryi*.

In Burullus (Fig. 3)

- **Group A**: Dominated by *Nereis succinea* and *Balanus improvisus*. Co-dominants: *Planorbis planorbis* and *Tubi worms*. Indicator: *Gammarus lacustris*.
- **Group B**: Dominated by *Lanistes carinatus, Theodoxus niloticus, Biomphalaria alexandrina*, and *Corbicula consobrina*. Co-dominants: *Lymnaea columella* and *Cardium edule*. Indicators: *Pilla ovata* and *Physa acuta*.
- **Group C**: Dominated by *Melanoides tuberculata, Corophium volutator, Tendipes tentans*, and *Bulinus truncatus*. Indicators: *Hydrobia ventrosa* and *Valvata nilotica*.

In Idku (Fig. 4)

- **Group A**: Dominated by *Lanistes carinatus, Gammarus lacustris, Nereis succinea, Corophium volutator, Balanus improvisus*, and *Tubi worms*.
- **Group B**: Dominated by *Lymnaea columella, Cleopatra bulimoides, Theodoxus niloticus, Melanoides tuberculata, Bellamya unicolor, Planorbis planorbis*, and *Bulinus truncatus*.
- **Group C**: Dominated by *Biomphalaria alexandrina, Corbicula consobrina*, and *Tendipes tentans*. Indicator species: *Pilla wernei*.

DISCUSSION

1. Water and sediments characteristics

The Northern Delta wetlands are affected by multiple sources of pollution, including domestic, agricultural, and industrial drainage. Seasonal variations in water temperature are significant and are primarily influenced by solar radiation, which causes seasonal changes in air temperature **(Nafea, 2005, 2024)**. This physical factor, in turn, affects other biotic and abiotic components of the wetlands.

Water transparency varied considerably among sites, with maximum values recorded at 100cm in Manzala, 39cm in Burullus, and 40cm in Idku. Transparency was generally higher in summer than in winter. Manzala had the lowest values overall (Tables 2, 3). The high transparency in Manzala (100cm) may be attributed to the dense growth of *Potamogeton pectinatus* and other hydrophytes, which trap and settle suspended clay particles. This observation agrees with findings by **Radwan *et al.* (2001)** in Burullus and **Nafea (2005)** in Manzala.

Additionally, the low clay content in Manzala sediments contributes to high water transparency and low turbidity **(Younis & Nafea, 2012; Nafea, 2020)**. Conversely, the low transparency in Burullus (40cm) may be due to strong wind activity that stirs the water, combined with the discharge of drainage water carrying suspended materials **(Sayed, 2003)**.

Water pH ranged from 8.1 to 8.3 across seasons, with extreme values of 9.2 and 7.3 recorded in Manzala during winter and summer, respectively. High pH in summer is primarily linked to photosynthetic activity of phytoplankton and aquatic vegetation **(Sayed, 2003)**. Low pH values are often a result of decomposition of organic matter, releasing CO_2 and H_2S **(Abbas *et al.*, 2001; Sayed, 2003)**. According to **Nafea (2005)**, pH variation is mainly driven by phytoplankton photosynthesis. Lower pH values were recorded near drain outlets.

Manzala recorded the highest Total Dissolved Solids (TDS) (14.6g/ L) in summer, while Idku recorded the lowest during winter. TDS levels were generally higher in summer. TDS and electrical conductivity are strongly correlated. TDS values are influenced by saline water intrusion from the sea, particularly in Manzala, through the El-Gamil and El-Borg inlets. In contrast, Burullus and Idku showed lower TDS values, likely due to their smaller sea connections and sediment buildup from increased drainage input **(Younis & Nafea, 2012; Nafea, 2020)**.

Dissolved Oxygen (DO) levels ranged from 2.6– 9.4mg/ L in summer and 3.9–9.6mg/ L in winter. Higher DO values in winter are likely due to lower temperatures and stronger wind-induced mixing, which enhances oxygen solubility **(Braga *et al.*, 2011)**. DO was at its lowest value in Manzala, likely a result of eutrophication **(Ghrib & Soliman, 1998)**. The drainage sector at Idku was also heavily impacted by poorly oxygenated drainage water. There is a known inverse relationship between temperature and DO **(Nafea, 2020)**, as well as between DO and Biological Oxygen Demand (BOD).

Concentrations of phosphate, ammonia, nitrate, nitrite, and silica were the highest in Idku, particularly due to the heavy load of drainage water from sewage and agriculture via Berzik, El-Bosily, and El-Tabia drains **(Younis & Nafea, 2012)**. Nitrate concentrations reached 13.3µg/ L in Idku, attributed to runoff from Beheira Province **(Abbas *et al.*, 2001)**. Silica concentrations were also the highest in Idku (93 µg/L) due to inputs from Berzik and El-Khairy drains. Burullus showed slightly lower values (91µg/ L), consistent with those recorded in previous study **(Radwan *et al.*, 2001)**. Silica is an essential nutrient for diatoms, which dominate phytoplankton communities.

Phosphorus plays a critical ecological role as a major nutrient for plants and microorganisms **(Vanloon & Duffy, 2000)**.

2. Sediment chemistry and bottom fauna

Total Organic Carbon (TOC) in sediments ranged between 1–1.4% in Manzala, 0.4–2.9% in Burullus, and 0.6–11.6% in Idku (Tables 4, 5). Idku exhibited the highest TOC, likely due to sewage discharge and decaying aquatic vegetation **(Sayed, 2003)**. Elevated organic content may also result from industrial cellulose waste from the Racta Paper Mills in Abu Qir Bay.

Total Nitrogen (TN) concentrations in sediments ranged from 3.1 to 100µg/ g dry weight, with the lowest in Manzala and highest in Idku—likely due to high wastewater discharge. Total phosphorus (TP) ranged from 40– 113µg/ g dry weight, with Burullus showing the lowest values.

Heavy metals in sediments showed concerning levels:

- **Copper (Cu):** 13.8– 28.1µg/ g in Manzala; up to 40µg/ g in Burullus and 34µg/ g in Idku.
- **Zinc (Zn):** 20– 131µg/ g. Highest values were recorded in Manzala (130µg/ g), Burullus (121µg/ g), and Idku (90µg/ g).
- **Lead (Pb):** 6.2– 42µg/ g. Manzala recorded the highest values due to domestic, industrial, and agricultural discharges via Bahr El-Baqar and Hadous drains **(Zyadah *et al.*, 2004; Zyadah, 2005)**.
- **Cadmium (Cd):** 3.5– 15.6µg/ g in Manzala, 0.95– 6.3µg/ g in Burullus, and 3.5– 9.3µg/ g in Idku. Higher Cd levels are correlated with higher organic carbon **(Wong & Chiu, 1993; Azrina *et al.*, 2006)**.

3. Bottom fauna

Sediment type varied among sites: sandy-shell fractions in Manzala; sandy-muddy with shells in Burullus and Idku. A total of 28 species were recorded in Manzala and Burullus, and 22 species in Idku. Dominant species included *Cardium edule, Lanistes carinatus, Bellamya unicolor, Melanoides tuberculata, Corbicula consobrina, Biomphalaria alexandrina,* and *Tendipes tentans*—similar to the findings of **Samaan and Aleem (1972)**, **Samaan *et al.* (1989)** and **Basu *et al.*, 2013, 2018)**.

Tendipes tentans was the most dominant species. It is common in both oligotrophic and eutrophic waters and is a reliable pollution indicator. It feeds on plant matter, particularly *Potamogeton pectinatus*, which is widespread in the wetlands **(Nafea, 2005)**. It prefers low salinity and high organic matter and serves as an indicator of low oxygen levels.

The reduced species diversity in Idku likely results from high pollution and/or water recession, consistent with **(Ibrahim *et al.*, 1997a; Ramadan *et al.*, 2000)**. *Nereis succinea* was the most significant benthic polychaete species in the Delta wetlands **(Guerguess, 1979)**. *Balanus improvisus* was abundant, especially near Boughaz areas, forming dense patches on hard surfaces and shells.

Corophium volutator and *Gammarus lacustris* were found in vegetation-free areas and feed on organic debris. This agrees with previous works **(Samaan, 1974; Samaan *et al.*, 1989)**.

Macrobenthic fauna are strong indicators of water quality **(Samaan, 1977; El-Sherif & Aboul-Ezz, 1988; Ibrahim *et al.*, 1997; Nafea, 2005)**. They feed on detritus and microfauna, converting them into biomass for higher trophic levels, including fish. The wetlands' shallow depths allow for high productivity of benthic organisms **(Ghrib & Soliman, 1998; Kosari *et al.*, 2021)**.

Several factors affect benthic fauna distribution:

1. **Sediment type:** Silty or muddy-sandy sediments support more fauna than coarse or rocky ones **(Cohen, 1986; Ramadan *et al.*, 2000)**.
2. **Organic content:** Higher organic carbon enhances benthic abundance.
3. **Pollution levels:** Heavily polluted areas support fewer species **(Abdel-Salam, 1995)**.

Empty mollusk shells were widely observed, indicating dominance of mollusks in recent decades. This shift may be linked to salinity changes after the construction of the Aswan High Dam, which decreased salinity levels **(Guerguess, 1979; Braga *et al.*, 2011)**. Several freshwater species invaded the lagoons via drains, including *Biomphalaria alexandrina, Melanoides tuberculata, Theodoxus niloticus*, *Bulinus truncatus, Lymnaea columella, Physa acuta, Cleopatra bulimoides*, and *Bellamya unicolor*.

The living bivalve observed was *Cardium edule*. Living gastropods included *Cleopatra bulimoides, Lanistes carinatus, Pilla wernei, Pilla ovata*, and *Bellamya unicolor*. Notably, *Pilla wernei* and *Pilla ovata* were recorded for the first time in the northern wetlands during this study. These species were previously observed in the Nile and Siwa Oasis **(Ibrahim *et al.*, 1999; Asadujjaman *et al.*, 2012)**, highlighting their ecological significance.

Lastly, *Biomphalaria alexandrina* and *Bulinus truncatus*, vectors of bilharzia, can serve as indicators of domestic pollution **(Noman *et al.*, 2019)**.

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APPENDIX

Table 2. Physico-chemical characteristics of water in Delta wetlands, summer 2023

Parameters	Manzala wetland			Burullus wetland			Idku wetland		
	Min.	Max	X±SE	Min.	Max	X±SE	Min.	Max.	X±SE
Depth cm	20	180	82±42	60	160	99.4±9	51	103	76.4±19
Temperature °C	30	32	31±6	28	31	29.5±1	29	33	30.7±3
Transparency cm	15	100	36.3±30	20	39	26.2±4	20	40	30.9±11
pH	7.3	9.1	8.3±1	7.5	8.6	8.1±0.3	7.8	8.6	8.2±1
EC g/ l	0.6	29	6.3±13	1.0	8.5	3.2±3	1.1	2.6	1.7±1
TDS g/ l	0.3	14.6	3.6±6	1.2	2.8	1.6±1	0.6	1.0	0.8±0.2
DO mg/ l	2.6	8.5	6.1±5	6.3	9.4	8.9±2	6.8	9.4	9.1±2
BOD mg/ l	1.2	6.8	3.3±3	1.3	6.9	2.9±1.8	1.2	5.6	2.1±2
PO_4 µg/ l	2.7	9.8	5.4±2	1.4	13	5.1±2	16.5	43	29.8±4
NH_4 µg/ l	10.1	26.0	16.3±6	1.1	20.1	8.6±4	12	40.5	29.8±3
NO_3 µg/ l	4.2	13.0	8.7±4	1.3	13.9	6.0±5	11.3	42.0	24.6±8
NO_2 µg/ l	1.2	5.0	2.8±1	0.4	9.0	3.1±3	9.0	13.3	10.4±2
SiO_2 µg/ l	19	93	58.6±19	40.1	91	70.7±11	34	92.4	70.1±5
Cu. µg/ l	9	43	21.5±7	8.4	20.1	13.5±5	20.2	40.2	28.8±6
Zn µg/ l	46.5	116	99.3±8	6.3	41.2	19.9±9	10.5	126	60.6±20
Pb µg/ l	16	23	21.9±2	3.9	16.2	8.2±5	8.6	100	56.4±18
Cd µg/ l	11.6	40	21.8±10	1.3	8.1	4.7±3	4.1	16.2	11.5±3

Where: X = Average Min.= values Minimum Max. = Maximum SE = Standard Error

Table 3. Physico-chemical characteristics of water in Delta wetlands, summer 2024

Parameters	Manzala wetland			Burullus wetland			Idku wetland		
	Min.	Max.	X±SE.	Min.	Max.	X±SE.	Min.	Max.	X±SE.
Depth cm	26	160	90±40	45	166	90 ± 30	45	110	77.5±30.5
Temperature C^0	16	19	18 ± 1	15	17	16 ± 1	16	20	18 ± 3.5
Transparency cm	16	50	35±10	22	38.6	35±3	18	36	28±7.3
pH	7.5	9.2	8.3±0.6	7.6	8.8	8.3±0.2	7.6	8.9	8.3± 0.6
EC g/ l	0.5	26	5.9±1.4	0.9	7.8	3±2	0.7	2.4	1.4±1.1
TDS g/ l	0.3	14.3	2.8±2	0.42	2.57	1.1±0.5	0.2	1.6	1.3±0.4
DO mg/ l	3.9	9	6.3±4	5.9	9.6	9.1±3	7.2	9.7	9.3±1.3
BOD mg/ l	1.1	4.8	3±1	1.5	5	2.4±2	1.8	5.2	1.9±1
PO_4 µg/ l	2.3	8.4	6±2	1	13.2	8±2	19	43	31±6
NH_4 µg/ l	10.3	28	25±4	8.3	38.1	23±6	11	43	28±10
NO_3 µg/ l	3.2	12.9	8±2	1.8	11.5	7.5±3	13	43.6	30±11
NO_2 µg/ l	1.4	5.1	3.2±1	0.63	5.8	4±2	9.5	22	17±4
SiO_2 µg/ l	24	91	64±17	21.6	66.5	51±10	37	93	80±20
Cu µg/ l	11	33	22±4	13.5	28.3	26±6	21.6	39.1	29±8
Zn µg/ l	30	63	51±9	16.2	44.1	33±10	11.6	124	66±15
Pb µg/ l	14	32	26±4	3.5	15.6	10±3	18.7	105	70±17
Cd µg/ l	36	50	43±10	4.1	20.2	14±3	4.3	17	12±3

Table 4. Physico-chemical characteristics of the sediment in Delta wetlands, winter 2023

Parameters	Manzala wetland			Burullus wetland			Idku wetland		
	Min.	X±SE	Max.	Min.	X±SE	Max.	Min	X±SE	Max.
PH	7.5	8.2±1	9.2	6.9	8.2±1	9.3	7.7	8.1±0.3	8.7
TOC %	1.1	1.7±1	3	0.82	2±1	2.9	0.8	5.2±6	11.3
TN µg/g dry Wt.	3.1	7.8±2	11.2	30	59±10	95	11.8	27.4±10	50
TP µg/g dry Wt.	75	93±7	99	40	73.4±15	101	61.5	82.5±9	109
Cu µg/g dry Wt.	13.8	19±4	28.1	10.3	26.3±10	40	12.1	20±5	34
Zn µg/g dry Wt.	26.6	54±10	81.3	23	81.6±10	121	36.2	64±10	90
Pb µg/g dry Wt.	25	31.4±3	35.2	6.2	16.8±8	42	12.1	17.1±5	23
Cd µg/g dry Wt.	4.5	8.7±4	15.1	1.2	3.1±2	6.3	5.1	12.3±3	16
Sand %	21	58.5±15	85	3	20.7±6	40	6	36.0±10	86
Silt %	14	32.5±19	73	3	48.6±10	65	9	39.2±6	63
Clay %	1	9±10	27	0	30.8±15	69	4	24.8±8	44

T M: Total organic matter T N: Total nitrogen T P: Total phosphorus

Table 5. Physico-chemical characteristics of the sediments in Delta wetlands, summer 2024

Parameters	Manzala wetland			Burullus wetland			Idku wetland		
	Min.	Max	X±SE.	Min.	Max.	X±SE.	Min.	Max.	X±SE.
PH	7.3	8.9	8.2±0.5	7.1	8.6	7.8±0.6	7.6	8.6	8.2±1
TOC %	1.3	4.1	2.6±0.4	0.61	2.7	1.6±0.5	0.61	11.6	6.1±5.1
TN µg/g dry Wt.	3.6	11.5	8±3	38	100	65±30	12	63	36±16
TP µg/g dry Wt.	73	110	94±13	50.1	111	81±19	61	113	87±30
Cu µg/g dry Wt.	14.2	26.2	20±4	10	40.5	25±10	11.4	33.8	21±10
Zn µg/g dry Wt.	24.2	81	50.4±19	20	110	67±30	40.1	82	63±19
Pb µg/g dry Wt.	23.1	36	31±10	6.5	33.1	21±6	10.6	22.1	16±6
Cd µg/g dry Wt.	3.5	15.6	13.3±4	0.95	5.9	3.5±2	9.3	11.8	10±1
Sand %	20	91	56.5±20	3	41	22±16	6	88	45±20
Silt %	8	75	32.5±19	5	75	41±19	6	63	36±16
Clay %	1	30	11±19	1	62	37±22	2	50	19±10

Table 6. Abundance (%) of bottom fauna in the sediment of the Delta, winter 2023

Species / presence %		Delta wetlands		
		Manzala	Burullus	Idku
1	*Balanus improvisus*	80	45	25
2	*Bellamya unicolor*	75	75	90
3	*Biomphalaria alexandrina*	80	90	100
4	*Bulinus truncatus*	70	90	95
5	*Cardium edule*	100	100	100
6	*Cleopatra bulimoides*	65	80	75
7	*Corbicula consobrina*	75	80	100
8	*Corophium volutator*	100	65	40
9	*Etheria elliptica*	75	25	50
10	*Gammarus lacustris*	70	40	70
11	*Gyraulus ehrenbergi*	35	20	55
12	*Helisoma duryi*	60	75	10
13	*Hydrobia ventrosa*	90	55	85
14	*Lanistes carinatus*	95	85	90
15	*Lymnaea columella*	65	70	60
16	*Macoma bathico*	20	15	-
17	*Melanoides tuberculata*	95	100	100
18	*Nereis succinea*	60	40	35
19	*Physa acuta*	65	60	15
20	*Pilla ovata*	15	50	50
21	*Pilla wernei*	30	40	30
22	*Pisidium pirothi*	45	10	-
23	*Planorbis planorbis*	90	55	100
24	*Tendipes tentans*	75	90	65
25	*Theodoxus niloticus*	80	90	95
26	Tubi worms	60	70	25
27	*Valvata nilotica*	80	75	15
28	*Vanthina nitens*	20	30	-

Table 7. Occurrence (%) of bottom fauna in sediment of Delta wetlands, summer 2024

Species \ presence %		Delta wetlands		
		Manzala	Burullus	Idku
1	*Cardium edule*	100	100	100
2	*Lanistes carinatus*	73	65	90
3	*Bellamya unicolor*	75	75	90
4	*Melanoides tuberculata*	95	100	100
5	*Corbicula consobrina*	80	65	100
6	*Cleopatra bulimoides*	65	80	75
7	*Biomphalaria alexandrina*	80	90	100
8	*Bulinus truncatus*	70	90	95
9	*Planorbis planorbis*	90	65	100
10	*Pilla ovata*	15	30	25
11	*Pilla wernei*	15	10	5
12	*Gammarus lacustris*	70	40	62
13	*Theodoxus niloticus*	95	90	95
14	*Lymnaea columella*	65	70	60
15	*Hydrobia ventrosa*	75	40	60
16	*Etheria elliptica*	55	20	40
17	*Neris succinea*	60	50	30
18	*Corophium volutator*	100	65	60
19	*Vanthina nitens*	10	25	-
20	*Gyraulus ehrenbergi*	35	20	40
21	*Balanus improvisus*	80	45	25
22	*Tubi worms*	60	70	25
23	*Valvata nilotica*	75	60	15
24	*Helisoma duryi*	60	60	20
25	*Physa acuta*	50	60	30
26	*Tendipes tentans*	80	90	75
27	*Macoma bathico*	20	15	-
28	*Pisidium pirothi*	45	10	-

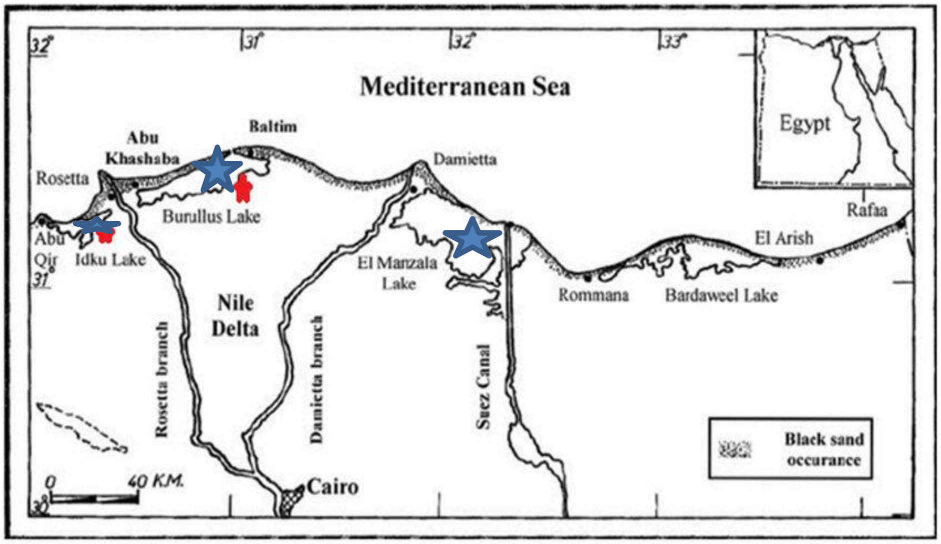
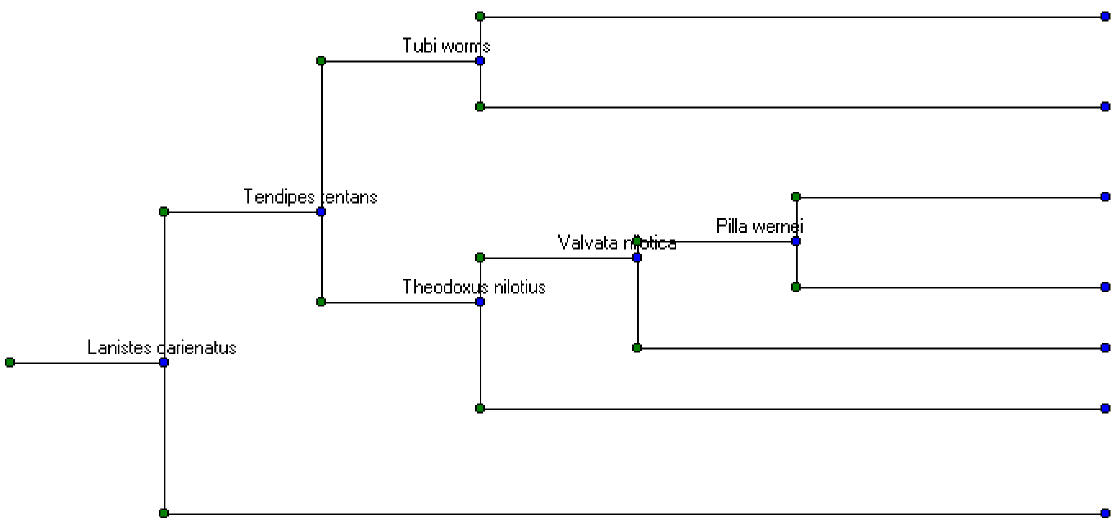


Fig. 1. The locations of the study area



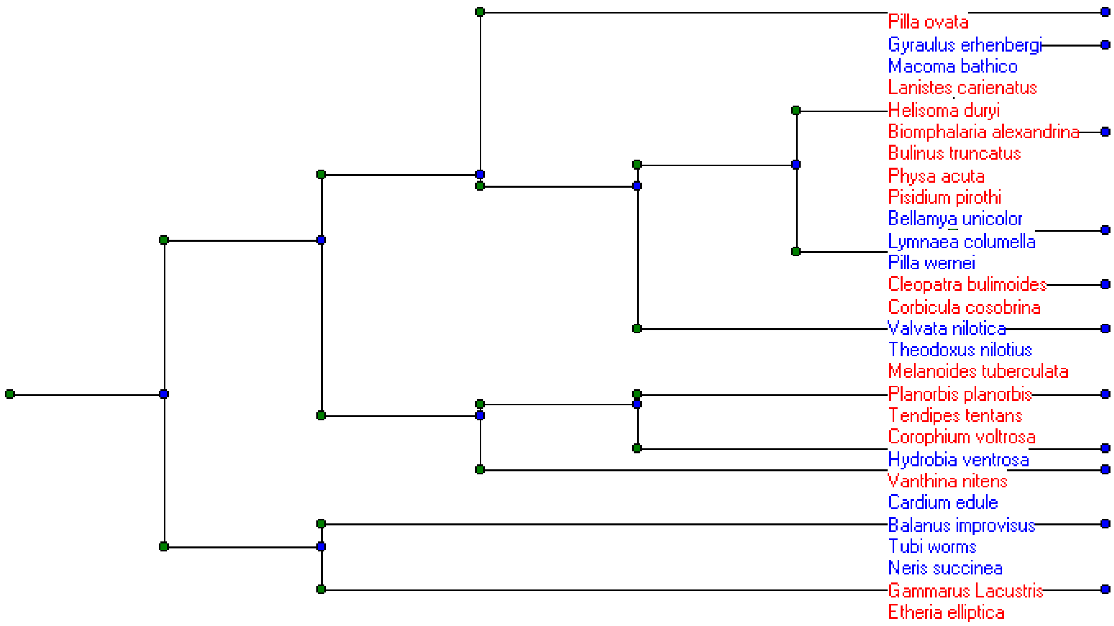
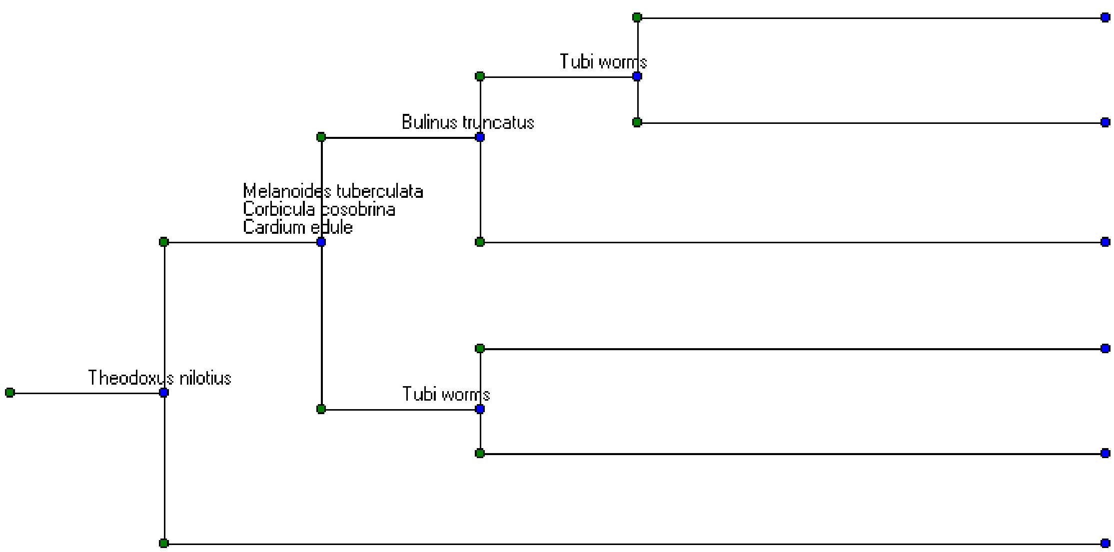


Fig. 2. A dendrogram showing TWINSPAN classification of a) 15 stands and b) 28 epi-fauna and infauna species in Manzala wetland



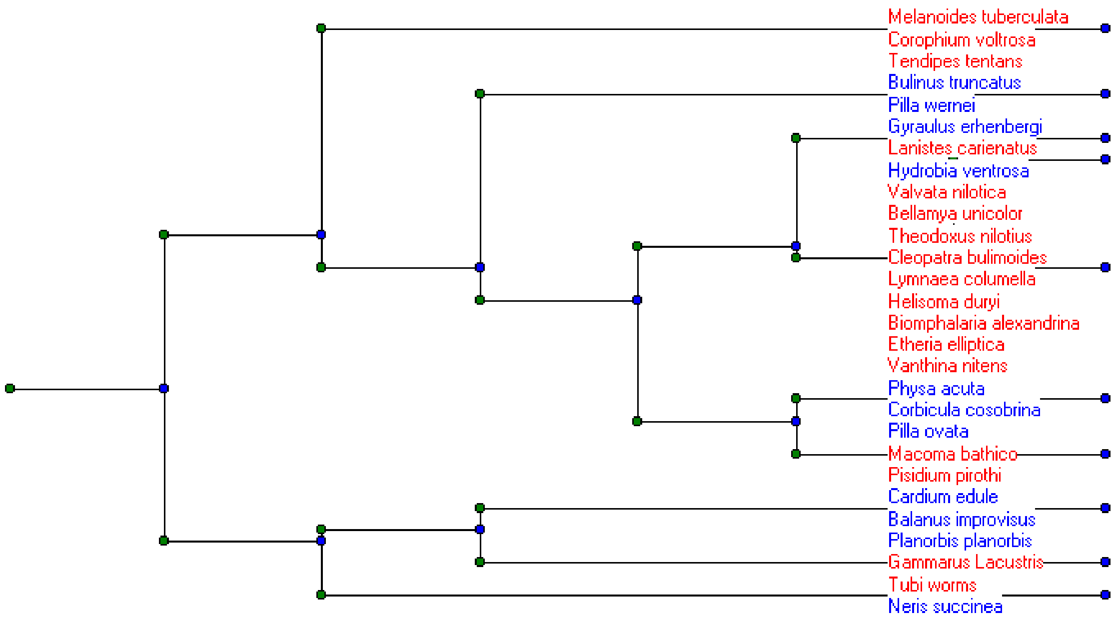


Fig. 3. A dendrogram showing TWINSPAN classification of a) 15 stands and b) 28 epi-fauna and infauna species in Burullus

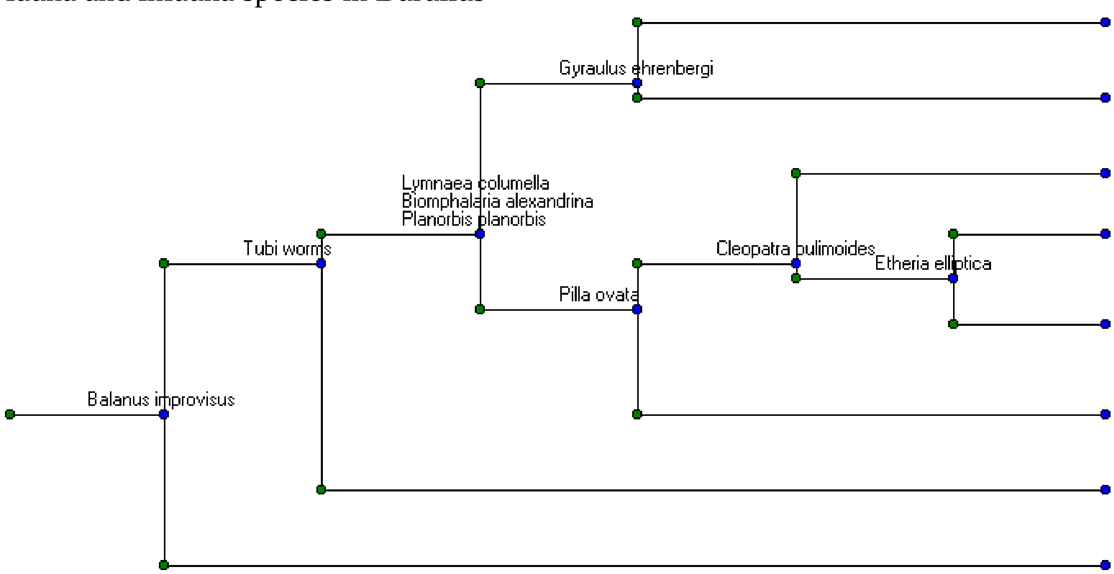


Fig. 4. A dendrogram showing TWINSPAN classification of a) 15 stands and b) 22 epi-fauna and infauna species in Idku wetland