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DISTRIBUTION PATTERN AND ENVIRONMENTAL CONTROLS ON BENTHIC FORAMINIFERA IN EL-BURULLUS LAKE, NORTH OF THE NILE DELTA, EGYPT

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ABSTRACT

El-Burullus Lake is one of the northern lakes of the Nile Delta, connected with the Mediterranean Sea through El-Boughaz opening. Sixty three surface bottom sediment samples were collected, as possible, from all niches of the lake during summer 2006 and spring 2007. Also, forty one stations were assigned for lake water analyses (variables) such as salinity (TDS), temperature, dissolved oxygen and pH. The main objective of the present study is to discuss the distribution pattern of benthic foraminifera in the El-Burullus Lake sediments and their relationship with bottom sediment environmental variables such as sediment grain size, carbonate content, water depth, organic carbon, as well as with the lake water variables.

The result of the present study indicated that the bottom sediments of the El-Burullus Lake are very rich in benthic foraminifera, with high faunal density, but with very low diversity. Although the modern bottom sediments of the lake contain high numbers of dead benthic foraminifera, living forms are very low increasing somewhere in the lake toward El-Boughaz, especially during the spring season. Environmental conditions in the lake may be stressful on the living bottom habitats as indicated by dominance of monospecies of benthic foraminifera "Ammonia tepida". This species is euryhaline (2-67‰), representing more than 90% of the total foraminiferal assemblages in the surface sediments of El-Burullus Lake. The present El-Burullus Lake water salinity varies from 2 to 14.5 g/l. Therefore, dominance of A. tepida in the surface bottom sediments is likely related to the occurrence of low salinity in the present El-Burullus Lake. Such conditions are not favorable for other benthic foraminiferal species to proliferate.

INTRODUCTION

El-Burullus Lake is located in the northern central part of the Nile Delta, specifically in Kafr El-Sheikh Governorate. It occurs, generally, in a central position between Damietta Branch of the Nile to the east, and Rosetta Branch of the Nile to the west. It is centered between latitudes 30° 33' and 31° 07' N and longitudes 31° 22' and 31° 26' E (Fig. 1). The El-Burullus Lake has an elongated shape parallel to the Nile Delta shoreline, with total area of 410 km^2 (100,000 feddan), of which 370 km^2 is open waters.

The water body of the El-Burullus Lake is interrupted by many islets, of which some are composed of mud, while others are composed of sand. They were considered as relicts of deltaic features, beach ridges, dunes and river banks of former distributaries (ARE-UNEP, 2002). These islets have a total area of 2860 Fadden, representing 2% of the total area of the lake (Wendorf et al., 1976).

The El-Burullus Lake receives agricultural drainage water mostly from 8 drains and Brimbal Canal (Fig. 1). This drainage water is estimated of about 4 billion m^3y^{-1}. The maximum amount of water discharge into the lake takes place in summer months (July-September) during the season of rice cultivation in the catchment area.

The El-Burullus Lake is densely vegetated by about 13 groups of plant communities (Shaltout and Al-Sodany, 2008). These vegetations cover more than 25% of the lake area and grow mostly in the shallower part of the lake and islets. Six groups are dominated by the common reed, so called '*Phragmites australis*'.

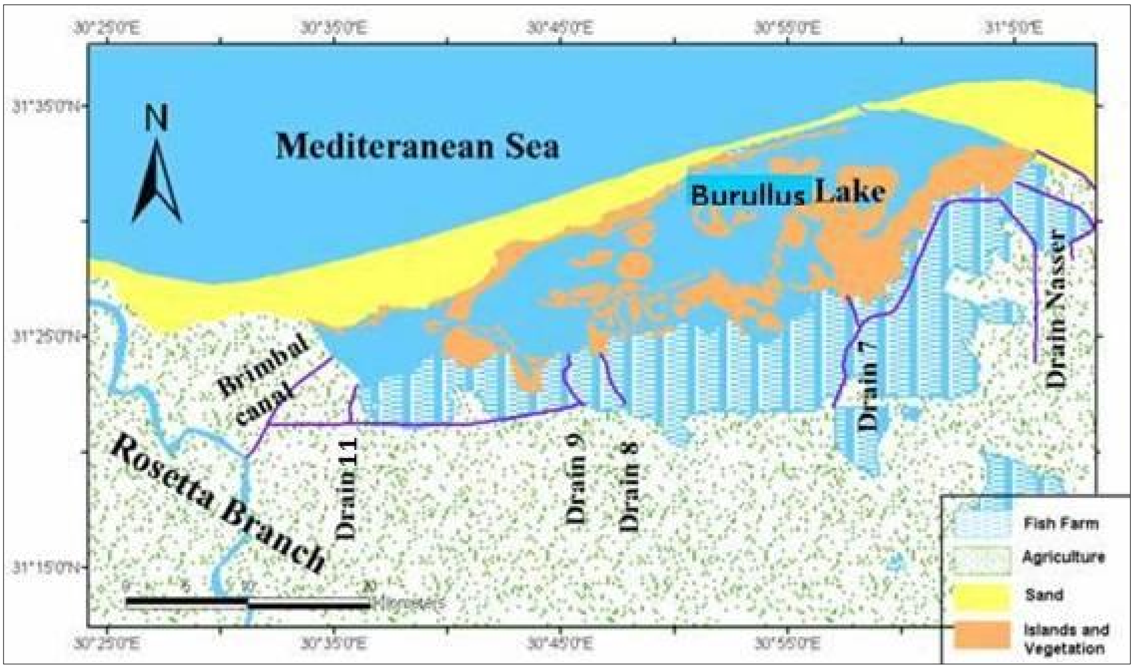

Fig. 1 : Location map of El-Burullus Lake.

MATERIALS AND METHODS

Sediment and foraminiferal analyses :

The materials of this study consist of 63 surface bottom sediment samples, collected during summer 2006 and spring 2007 (Fig. 2). These sediment samples were collected using a small gravity corer on board a fishing boat. Their coordinates and water depths are listed in Table 1. On board, sediment samples were immediately placed in numbered plastic jars and stained by rose Bengal stain (each 1.5 g of rose Bengal powder was diluted in 1 liter of 95% ethyl alcohol). Rose Bengal stain is used to distinguish living from dead foraminiferal specimens. Then, stained samples were taken to the laboratory and left in stain for a week to be ready for micropaleontologic analyses. After that, they were left to dry in room temperature, weighted and disaggregated by soaking in hot water. Samples were washed over sieves with 63-500 μm and >500 μm openings. The 63-500 μm and >500 μm fractions were dried and weighed again and kept for faunal analysis. The 63-500 μm fractions were split using a microsplitter to reduce the amount of sediments and number of foraminifera to approximately 200 individual per sample. The recovered foraminiferal specimens were picked and mounted on faunal slides, identified, counted and presented as total number per gram of dry weight and as percentages of the total dead foraminiferal assemblages. Live foraminiferal tests that have dark red globules of stained protoplasm were separately counted and were not lumped with the dead assemblage in any statistical work. They were only used to determine Live/Dead ratio of benthic foraminifera in El-Burullus Lake. Most of the recorded foraminiferal species were photographed using a scanning electron microscope (SEM) at the Archaeological Department, University College London (UCL), and displayed in Plates 1-2.

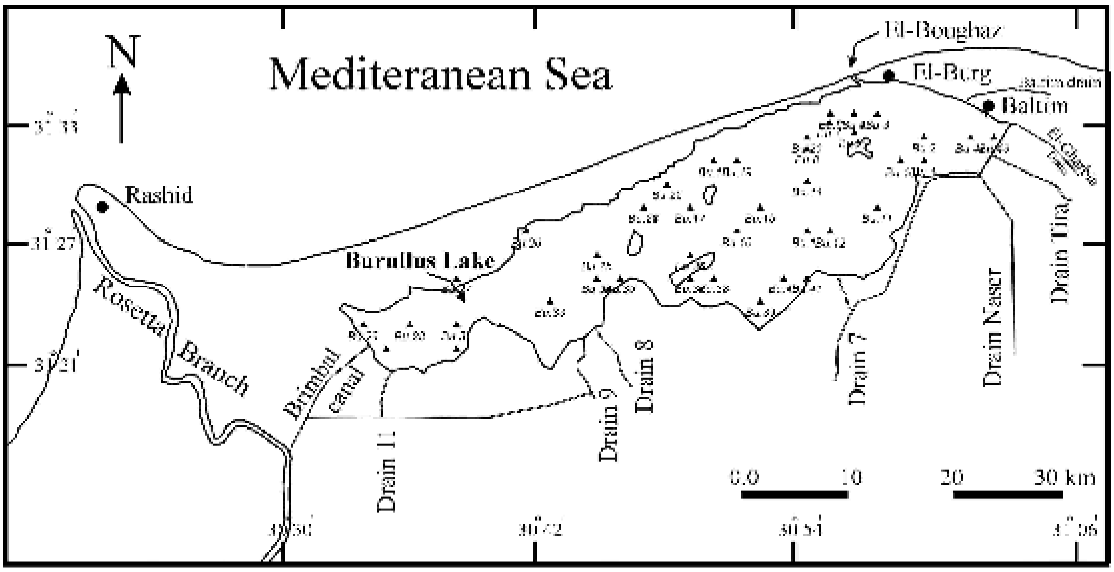

Fig. 2 : The studied sites (sediments and water samples) in El-Burullus Lake. Site location is indicated by solid triangular.

Table 1: Coordinates of the studied samples (sites) and their measured environmental parameters in El-Burullus Lake.

Sample/Site number	Latitude (N)	Longitude (E)	Water depth (m)	Temperature (°C)	Electrical conductivity	pH	Salinity (g/l)	Dissolved oxygen (surface)	Dissolved oxygen (bottom)
1-04	31.56°	31.04°	0.75	30	6500	9.22	4	-	-
2-04	31.57°	31.03°	0.95	31	8000	9.2	5	-	-
3-04	31.58°	31.01°	1	29.8	10500	8.86	6.5	-	-
4-04	31.57°	30.99°	0.72	30	12500	8.76	7.5	-	-
5-04	31.57°	30.96°	0.72	29.8	7900	9.27	4.75	-	-
6-04	31.56°	30.93°	1	29	6000	9.25	3.5	-	-
7-04	31.55°	30.95°	1.1	29.5	6000	9.17	3.5	-	-
8-04	31.55°	30.97°	1.12	29	7000	9.26	4.1	-	-
9-04	31.55°	30.99°	1.07	28.5	7900	9.29	4.6	-	-
10-04	31.52°	30.98°	1.05	29	8500	9.2	5	-	-
11-04	31.55°	31.04°	1.07	30	8000	8.86	4.7	-	-
12-04	31.54°	30.94°	1.16	28	6000	9.4	3.5	-	-
13-04	31.52°	30.92°	1.38	29	5000	9.33	3	-	-
14-04	31.51°	30.90°	1.2	30	7500	9.33	4.5	-	-
15-04	31.52°	30.90°	1.25	28	7500	9.27	4.3	-	-
16-04	31.52°	30.88°	1.2	29.3	5000	9.27	2.9	-	-
17-04	31.52°	30.86°	1.19	29	4500	9.35	2.5	-	-
18-04	31.53°	30.88°	1.45	27	4000	9.19	2.4	-	-
19-04	31.54°	30.92°	1.15	30	4900	9.33	2.9	-	-
20-04	31.56°	30.95°	1.17	30	5500	9.32	3.2	-	-
21-04	31.55°	30.99°	1.25	30	11000	9.12	7	-	-
1-07	31.04°	31.53°	0.8	21	3600	7.35	3	5.5	4.8
2-07	31.03°	31.55°	0.75	20	32000	8.03	14.5	9.3	7.1
3-07	31.00°	31.57°	0.76	19.5	13000	8.34	8	9.1	6
4-07	30.98°	31.57°	0.76	20	900	8.44	5.5	11.5	8.5
5-07	30.98°	31.57°	0.72	19	6000	8.52	4	11.9	7.5
6-07	30.97°	31.56°	2.73	20	5500	8.54	3.25	11.1	6.5
7-07	30.96°	31.6°	0.98	19.5	4250	8.61	2.25	10.8	6
8-07	30.95°	31.5°	0.6	20	4400	8.4	2.5	10.6	8.8
9-07	32.42°	31.54°	0.41	21.5	3900	7.61	2	4.4	3.2
10-07	31.01°	31.53°	0.84	21	11000	7.96	6.5	6.9	5.5
11-07	31.00°	31.50°	0.91	22	15000	8.04	8.75	6.4	4.2
12-07	30.97°	31.48°	0.76	21	6500	8.41	4	8.6	6.6
13-07	30.95°	31.48°	0.75	20	5000	7.82	3	6.8	4.4
14-07	30.95°	31.52°	0.91	20	6500	8.34	4	9.2	7.1
15-07	30.92°	31.50°	1.07	20	4900	8.39	2.75	9	7.1
16-07	30.9°	31.48°	0.97	20	4500	8.59	2.5	9.8	6.8
17-07	30.87°	31.50°	0.85	20	3600	8.62	2	11.2	10.5
18-07	30.88°	31.53°	1	19	7500	8.74	4.75	11.8	7.4
19-07	30.90°	31.53°	0.88	19.5	4200	8.62	2.25	10.6	7.1
20-07	30.95°	31.55°	0.74	19	4600	8.74	2.75	10.2	6.2
21-07	30.98°	31.55°	1.03	19.5	15500	8.52	10	10	6.4
22-07	30.85°	31.52°	1.15	21	3850	8.63	2	9.5	6.8
23-07	30.83°	31.50°	1.22	21	3250	8.36	1.5	8	6.1
24-07	30.83°	31.50°	1.07	21.5	3500	8.76	1.75	9	8.1
25-07	30.80°	31.46°	1.1	20	3100	8.42	1.75	7.1	5.6
26-07	30.75°	31.48°	1.28	21	3200	8.62	2	9	6.3
27-07	30.70°	31.45°	1.38	21	3100	8.75	1.75	10.6	7.2
28-07	30.67°	31.41°	0.85	20	30000	8.91	1.75	11.5	8.3
29-07	30.63°	31.42°	0.76	19	3350	8.94	1.8	12.4	12
30-07	30.65°	31.40°	0.88	19	3100	9.03	2.5	13.7	10.5
31-07	30.70°	31.42°	1.23	19	21000	8.86	1.25	12.3	8.3
32-07	30.7°	31.40°	1.1	18.5	1900	8.5	1	8.1	6
33-07	30.76°	31.43°	0.88	19	2500	8.08	1.25	10.9	7.8
34-07	30.80°	31.45°	0.88	19	3050	8.36	2.5	8.4	6.4
35-07	30.81°	31.45°	0.94	18	5000	8.29	3.75	11	7.5
36-04	30.87°	31.47°	0.94	20	39000	8.67	3.25	10	-
37-04	30.86°	31.45°	0.9	19	4800	8.27	3	5.7	-
38-07	30.88°	31.45°	1.06	19	4400	8.28	3	5.3	-
39-07	30.92°	31.43°	0.71	18	5000	7.42	3	4.3	-
40-07	30.93°	31.45°	0.44	18	4200	8.32	2.75	4.7	-
41-07	30.95°	31.45°	0.57	19	3100	7.75	2	6.8	-
42-07	31.07°	31.55°	0.75	19	5000	-	3	-	-
43-07	31.08°	31.55°	1.3	18	6000	-	4.25	-	-

Field measurements :

At each sediment sample site, several ecological variables were measured during the field work such as surface water electrical conductivity (EC), pH, surface and bottom water dissolved oxygen, temperature and water depth. The location of each site was determined by using a GPS (Magellan GPS 315). Coordinates of these sites and their ecological variables are listed in Table 1. The pH of the lake water was measured using Microprocessor pH Meter (HANNA instruments pH 211). The dissolved oxygen content of lake water was measured using a portable Dissolved Oxygen Meter D0-5509. Surface water temperature, water salinity and electrical conductivity (EC) were measured using an YSI Model 33 S-C-T Meter.

Geochemistry analysis :

Total organic carbon and carbonates were determined using loss on ignition (LOI) technique, following Heiri et al. (2001) and Abu-Zied et al. (2007). About one gram of sediment was dried in an oven overnight at 105°C and then weighted to determine total dry weight. After that, they were placed in the oven (Thermolyne-type 47900 furnace) twice: for 4 hours at 550°C and for 2.5 hours at 950°C to determine the total organic carbon and carbonate, respectively. After each heat treatment, samples were cooled in a glass desiccator with $CaCl_2$ to absorb all water vapor, weighted to determine percentages of both organic carbon and carbonate from the total dry weight.

RESULTS AND DISCUSSION

Environmental parameters variability in El-Burulles Lake

Sediment :

Bottom sediments (substrates) of El-Burullus Lake consist mainly of dark to grey mud except in some places (central and far west parts) firm substrates occur. These firm substrates consist of compacted shell fragments and complete shells of pelecypods (e.g. Cerastoderma glaucum and Abra ovate) and gastropods (e.g. Melanoides tuberculata and Bittium reticulatum). These observations are also indicated by the grain size analysis. It shows that mud-dominated (<0.063) substrates occur, in general, in the deepest parts of the lake, whereas the sand-dominated (>0.063) substrates occur in the central and far-west parts of the lake (Fig. 3. Microscopic examination is indicated that the sand fraction (>0.063) is mainly composed of bioclastic materials such as foraminiferal tests, ostracod carapaces, bivalves, gastropods and tubes of polychaetes.

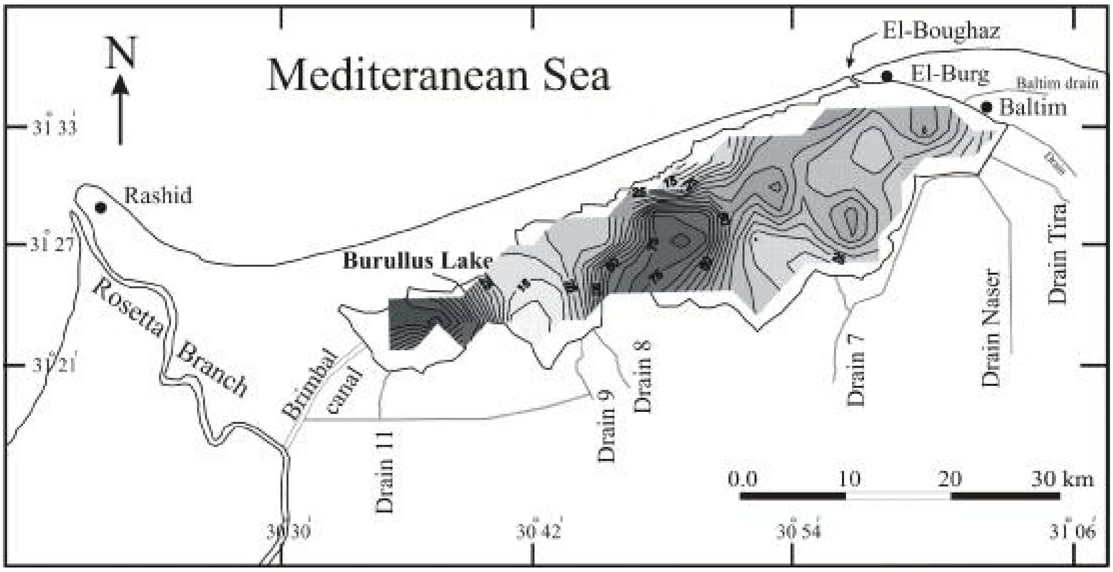

Fig. 3 : Distribution of sandy substrates (dark color) in El-Burullus Lake. Contour interval is every 5%.
interval is every 5%.

Water depth :

Water depths of El-Burullus Lake vary from 0.4 to 2.7 m (Fig. 4). Maximum water depth (2.7 m) is recorded towards El-Boughaz inlet, whereas shallow depths occur towards the south-eastern part of the lake (Fig. 4). In general, lake water depth increases towards the northern side of the lake and decreases towards the southern side of the lake where dense vegetations occur leading likely to occurrence of high sedimentation rates at this side. These conditions encouraged local people to reclaim lands from the shallowest parts of the lake for agriculture and fish farming purposes. Therefore, further study should be undertaken to prevent the closure of the lake in the future due to occurrence of high accumulation rates of organic matters.

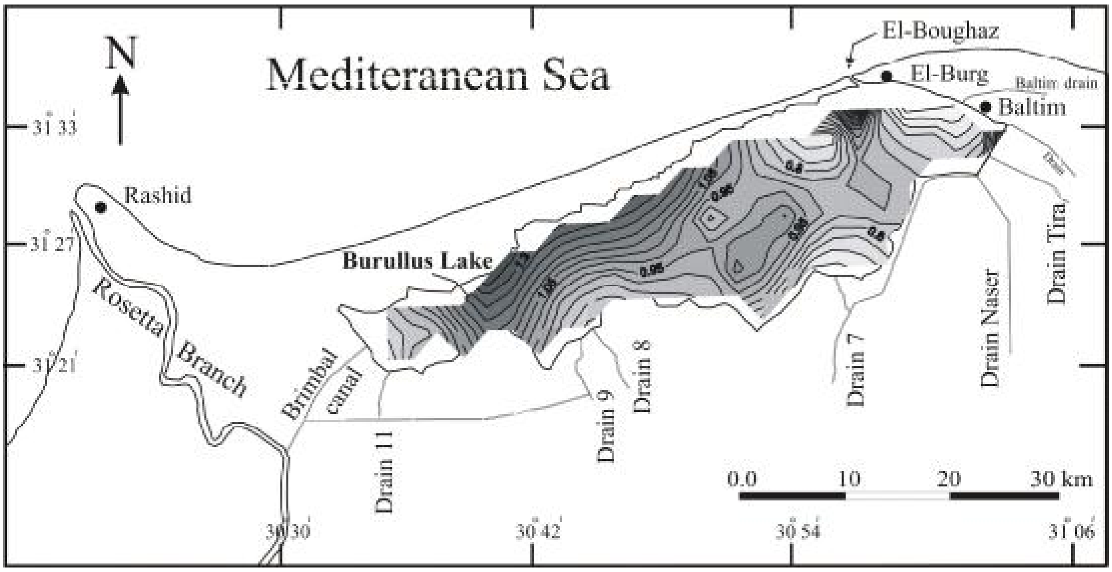

Fig. 4 : Bathymetric map of El-Burullus Lake. Deepest parts of the lake are indicated by dark color. Contour interval is every 0.05 m.

Salinity (TDS) :

El-Burullus Lake water salinity varies from 2 to 14.5 g/l during spring 2007 (Fig. 5). It becomes high near El-Boughaz Inlet due to the influence of the Mediterranean Sea water entering the lake by action of tides. It is noted that lake water salinity is higher in the spring than in the summer (1 to 12 g/l), see Fig. 6. This lowest salinity in summer is attributed to high influx of fresh water to the lake via drainage systems of rice lands, as well as to the Nile flood during this time. This lowest salinity leads to absence of live foraminiferal specimens during summer.

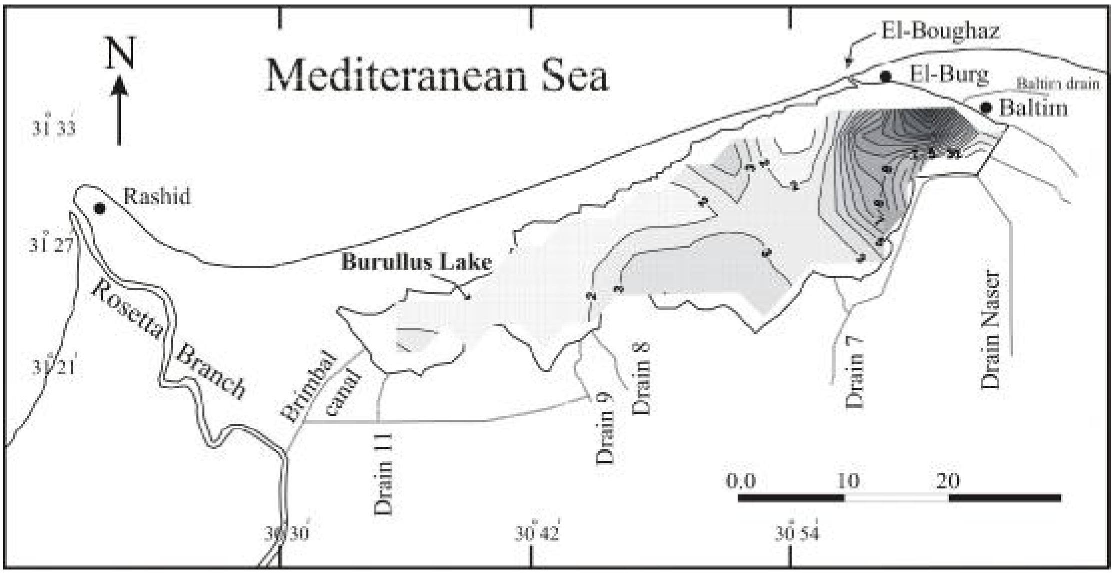

Fig. 5 : El-Burullus Lake water salinity (g/l) during spring 2007. High salinity areas are indicated by dark color. Contour interval is every 1.0 g/l.

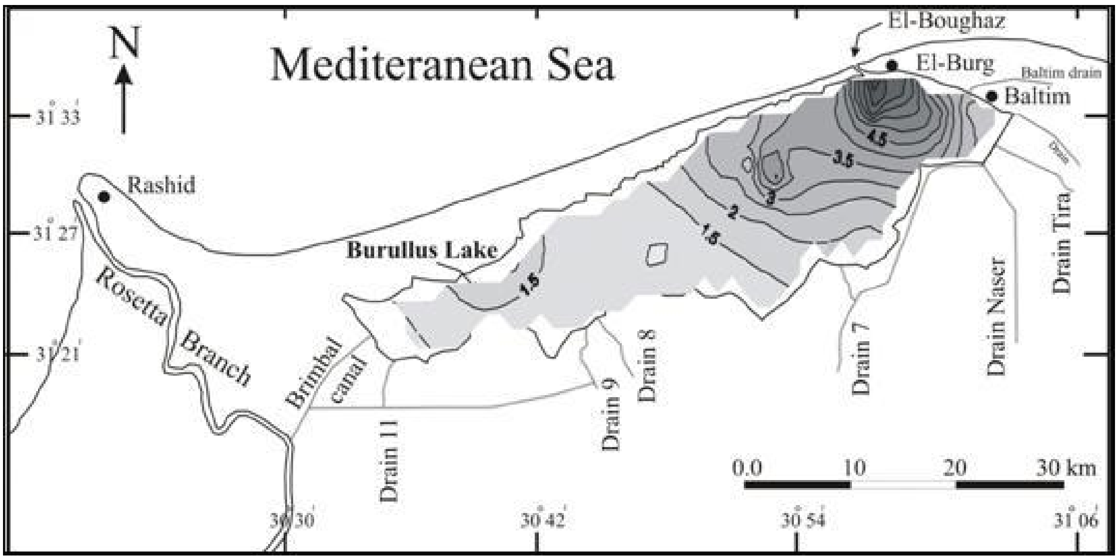

Fig. 6 : El-Burullus Lake water salinity (g/l) during summer 2006. High salinity areas are indicated by dark color. Contour interval is every 0.5 g/l.

Alkalinity (pH) :

El-Burullus Lake water alkalinity (pH) has an average value of 8.3, indicating that the lake water is alkaline (Fig. 7). The pH increases towards the north-western side of the lake reaching a maximum value of 9.0 and decreases towards south-eastern parts of the lake, reaching value of 7.4. The iso-pH line is parallel to the longitudinal axis of the lake (Fig. 7). This variability of pH in the lake water is attributed to interaction of many factors such as respiration, photosynthesis and decomposition of dead organic matters which release more CO_2 in the water column leading possibly to alkalinity decrease at south-eastern parts of the lake.

Dissolved oxygen :

Bottom water dissolved oxygen averages 7 ml/l (Fig. 8), whereas surface water dissolved oxygen averages 9.0 ml/l (Fig. 9). This high amount of dissolved oxygen in the El-Burullus Lake water is attributed to high photosynthesis by water plants that occupy c. 25% of the total area of the lake. These findings indicate that El-Burullus Lake water is well ventilated and no anoxia or dysoxic conditions occur in the present lake.

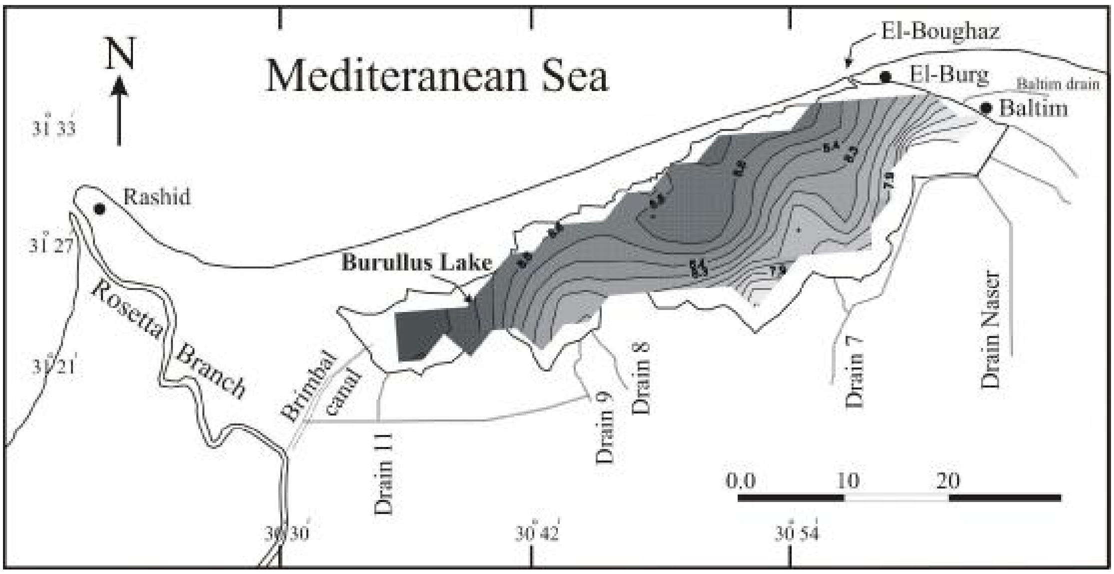

Fig. 7 : Alkalinity (pH) of El-Burullus Lake water during spring 2007. Dark color areas indicate high pH value. Contour interval is every 0.1.

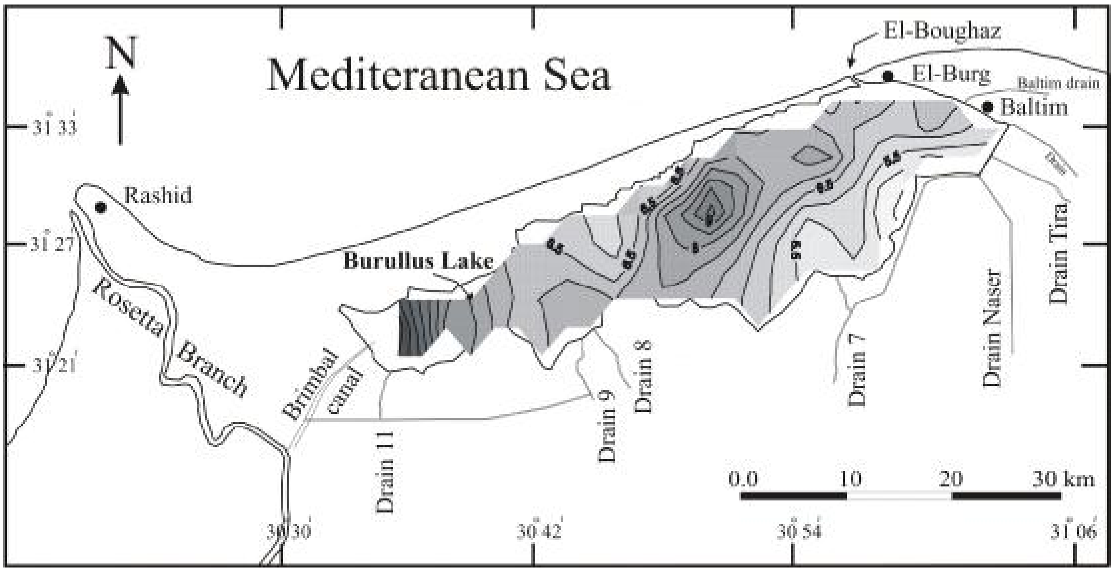

Fig. 8 : Bottom water dissolved oxygen of El-Burullus Lake water in spring 2007. High dissolved oxygen is indicated by dark color. Contour interval is every 0.5 m/l.

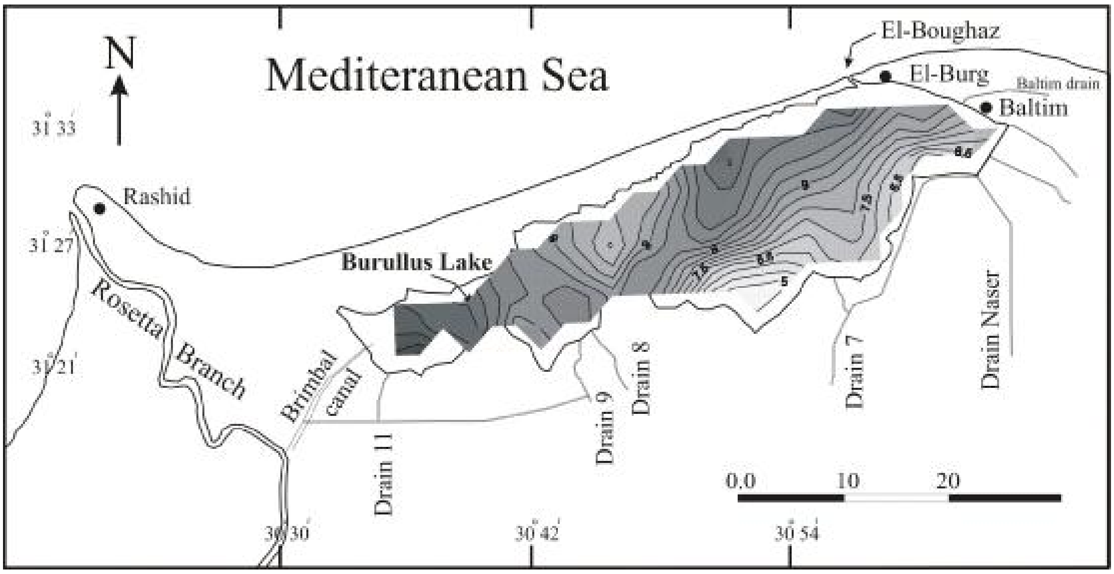

Fig. 9 : Surface water dissolved oxygen of El-Burullus Lake water in spring 2007. High dissolved oxygen is indicated by dark color. Contour interval is every 0.5 m/l.

LOI carbonates :

Total carbonates in El-Burullus Lake have mean value of 10%. They dominate (up to 57%) the bottom sediments of the central and far west parts of the lake (Fig. 10). They decrease (c. 2%) in the bottom sediments of eastern part of the lake. Distribution of carbonates in the El-Burullus Lake co-varies, more or less, with the distribution of sandy substrates which increase due to high concentration of calcareous shells of foraminifera and molluscs, indicating a biological origin for these carbonates.

Organic carbon (OC) :

Organic carbon (OC) is relatively high in El-Burullus Lake bottom sediments, varying from 4.5% to 39% (mean value = 14%) (Fig. 11). Highest organic carbon occurs in the deepest parts of the lake, which have calm environments for organic matter accumulation after death. It increases in northwestern and southeastern parts of the lake (Fig. 11).

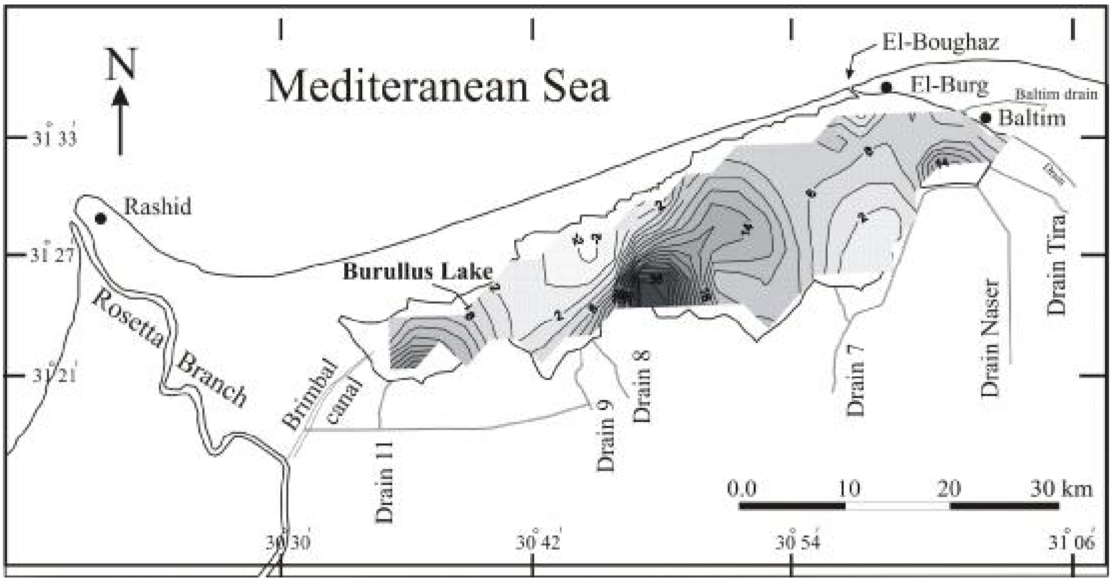

Fig. 10 : Carbonate distribution in the bottom sediments of El-Burullus Lake.

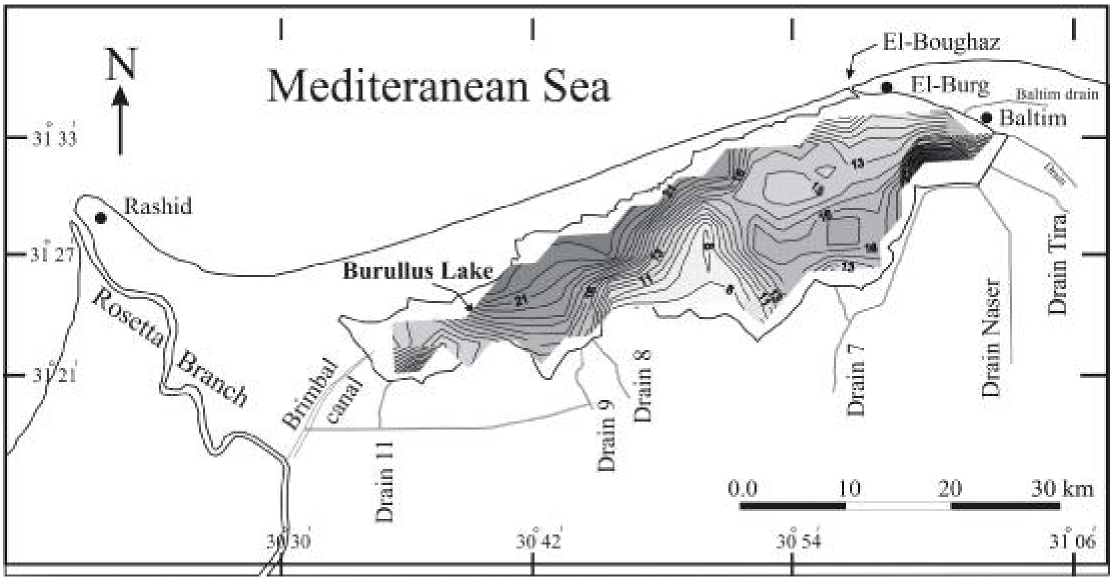

Fig. 11 : Distribution of organic carbon (OC) in El-Burullus Lake bottom sediments.

Benthic foraminiferal density and diversity variations :

Benthic foraminiferal density is relatively high in the bottom sediments of El-Burullus Lake. It ranges from 26 to 16,100 specimens/g with mean of 2,800 specimens/g (Fig. 12). Faunal density shows highest values in the central and eastern areas of the lake. This is likely related to occurrence of high salinity in these areas where the influence of Mediterranean water occurs. Nutrients (food) do not seem to be a limiting factor, since the lake bottom sediments are very rich in the organic carbon.

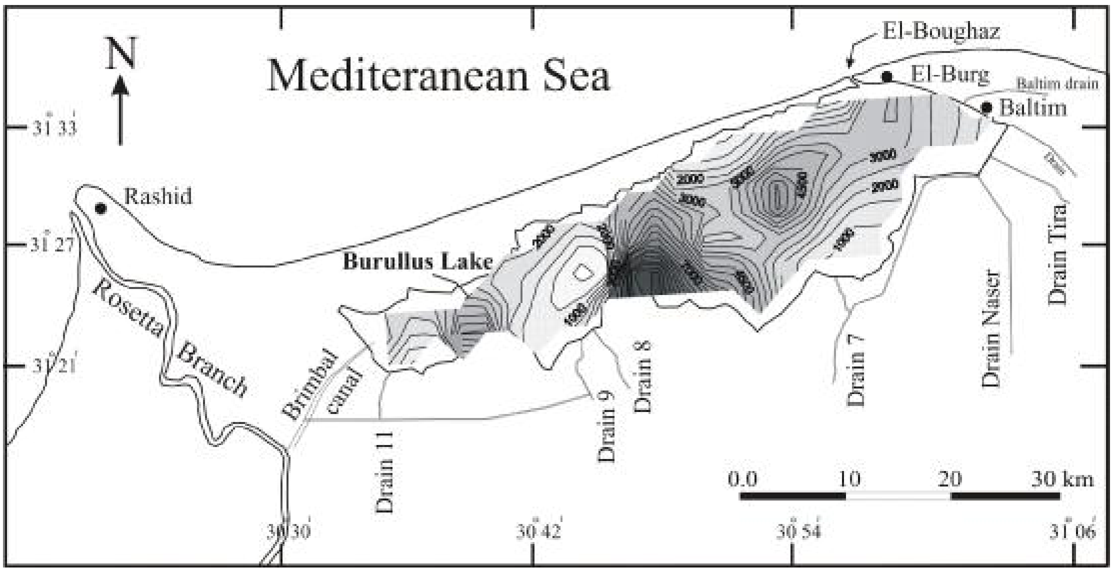

Fig. 12 : Benthic foraminiferal density (per gram dry weight) in El-Burullus Lake bottom sediments during spring 2007.

Benthic foraminiferal diversity (S) is calculated by counting the total number of species in each sample. It is very low representing only of 1 to 3 species among them *Ammonia tepida* and *Cribroelphidium excavatum* are the dominant ones. *Ammonia tepida* attains more than 90% of the total foraminiferal assemblages in the bottom sediments of El-Burullus Lake.

Live benthic foraminifera (Live/Dead ratio) are very low (almost 0.0) in the bottom sediments of El-Burullus Lake, especially during the summer. In the spring, the Live/Dead ratio is almost 0.0 throughout the whole lake except at area that is very close to El-Boughaz inlet where the ratio increases to about 9 (Fig. 13). These findings indicate that the summer is not favorable time for the living foraminifera as a result probably to high influx of fresh water into the lake from the cultivated lands (rice land). This influx of fresh water into the lake seems to decrease in the spring season, consequently lake water salinity increases due to evaporation and an increase of sea water inflow to the lake via El-Boughaz inlet. This rising salinity during the spring may allow the benthic foraminifera to survive and proliferate as indicated by the occurrence of high Live/Dead ratio during this time.

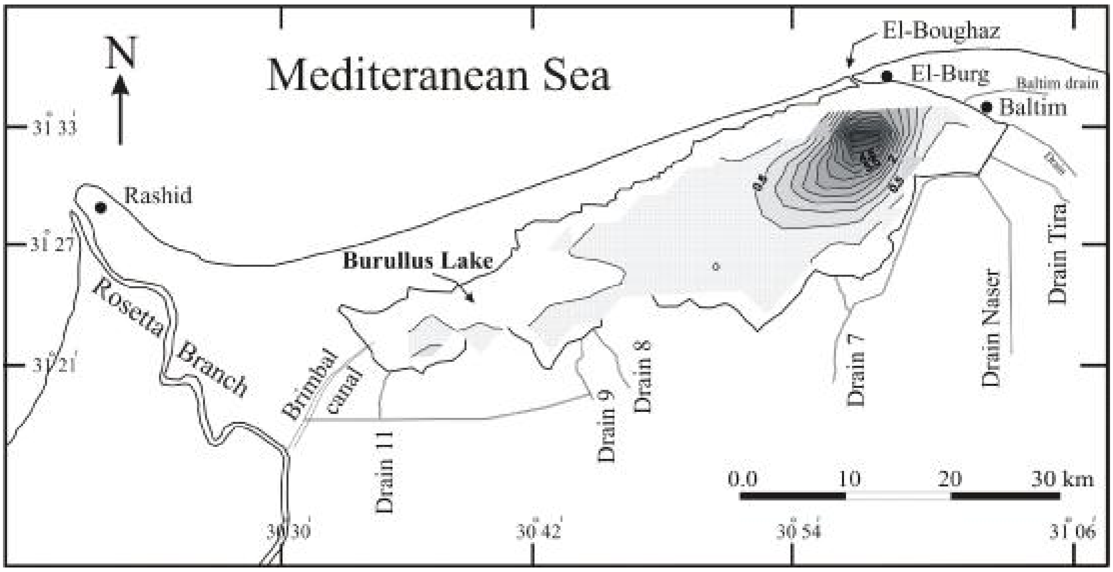

Fig. 13 : Live / Dead ratio of benthic foraminifera in El-Burullus Lake bottom sediments during spring 2007.

Benthic foraminiferal species distribution :

Ammonia tepida is the most dominant species in the bottom sediments of El-Burullus Lake. It represents more than 90% of the total benthic foraminiferal assemblages in the lake (Fig. 14). Its frequency, in general, varies from 60 to 100%, showing maximum numbers in the central and western parts of the lake (Fig. 14). *Ammonia tepida* shows more or less stable values throughout the whole area of the central and western parts of the lake (Fig. 14), but it decreases towards El-Boughaz and the eastern side of the lake. The reason for this finding is elusive. However, this may be related to occurrence of rapidly changing environments at El-Boughaz and the eastern side of the lake. *Ammonia tepida* is euryhaline species and can live under very low salinity conditions. Bradshaw (1957) indicated that *A. tepida* normally reproduces within salinity ranges of 13‰ and 34‰, whereas its other activities occur within salinities ranges of 2‰ and 67‰. The present El-Burullus Lake water salinity varies from 2 to 14.5 g/l. Therefore, dominance of *A. tepida* in the surface bottom sediments is likely related to occurrence of low salinity in the present El-Burullus Lake. This low salinity is probably favorable for *A. tepida* and detrimental on the other species. Bradshaw (1957) also reported that reproduction of *Ammonia tepida* take place at temperatures between approximately 20-30°C. Temperature also affects the duration of each generation. At 20°C, this duration may take four times as long to reach reproductive maturity as at temperatures of 25-30°C. Although *Ammonia tepida* occurs all over the lake, it is recorded alive only near El-Boughaz inlet where the salinity is higher than any other places in the lake.

Cribroelphidium excavatum occurs with very low numbers in bottom sediments of

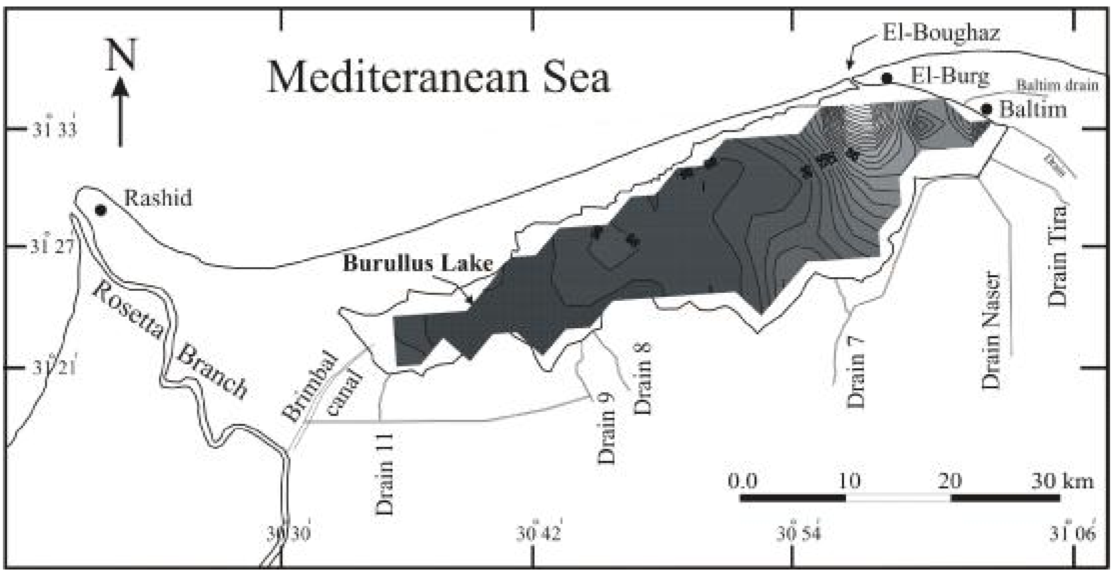

Fig. 14 : Distribution of Ammonia tepida in El-Burullus Lake bottom sediments during spring 2007.

El-Burullus Lake (Fig. 15). It is nearly absent from the central and western parts of the lake, showing only about 1% of the total benthic foraminiferal assemblages (Fig. 15). It shows the highest values (c. 37%) near El-Boughaz inlet and at the eastern side of the lake, indicating its preference to high salinity water in El-Burullus Lake. Belford (1981) reported that presence of *Cribroelphidium* indicates deposition within shallow water (i.e. photic zone). Its presence also indicates a warm lake water, calm environments, high salinity and past transgression of the sea into the lake (Butt, 1980; Abdou and Zazou,1989).

Total miliolids also occurs with very low values (0.0-5%) in El-Burullus Lake bottom sediments, showing a similar distribution to that of the *C. excavatum* (Fig. 16). They are very rare or completely absent from the west-

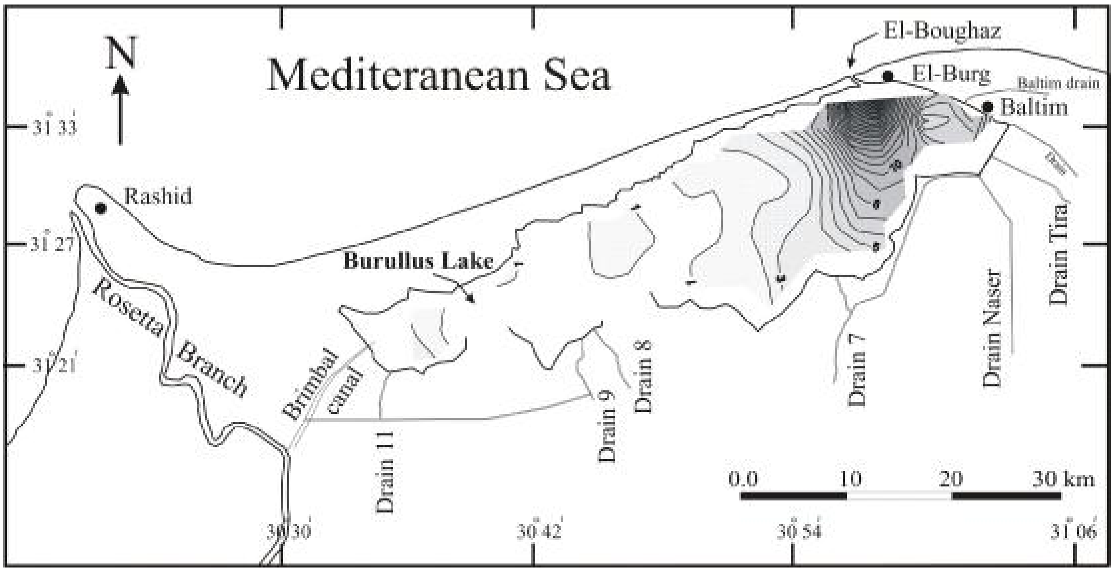

Fig. 15 : Distribution of Cribroelphidium excavatum in El-Burullus Lake bottom sediments during spring 2007.

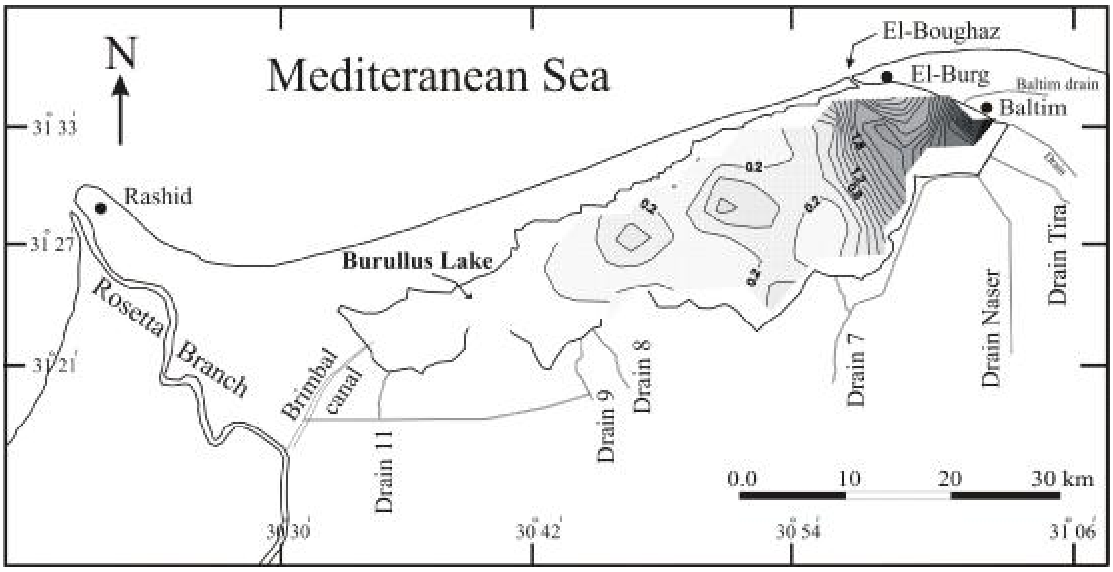

Fig. 16 : Distribution of miliolids in El-Burullus Lake bottom sediments during spring 2007.

ern and central parts of the lake (Fig. 16), displaying only highest frequency at the far east part of the lake or nearly close to El-Boughaz inlet. This also indicates its preference to high salinity water in El-Burullus Lake. These miliolids include species such as *Triloculina trigonula*, *Quinqueloculina bosciana, Q. lata, Q. poeyana, Q. seminulum* and *Sigmoilina distorta*.

Bolivina sp. (*B. striatula, B. spathulata*, and *B. variabilis*) is very rare in the El-Burullus Lake bottom sediments (Fig. 17). Its frequency varies from 0 to 0.8%, showing maximum value at the central and south-eastern parts of the lake (Fig. 17). Their occurrence may indicate organic-rich sediments (Abu-Zied, 2001).

Rosalina globularis and Haynesina depressula also occur in the bottom sediments of El-Burullus Lake, but with undetectable values (see Figs. 18-19). They, in general, occur sporadically in lake sediments with frequen-

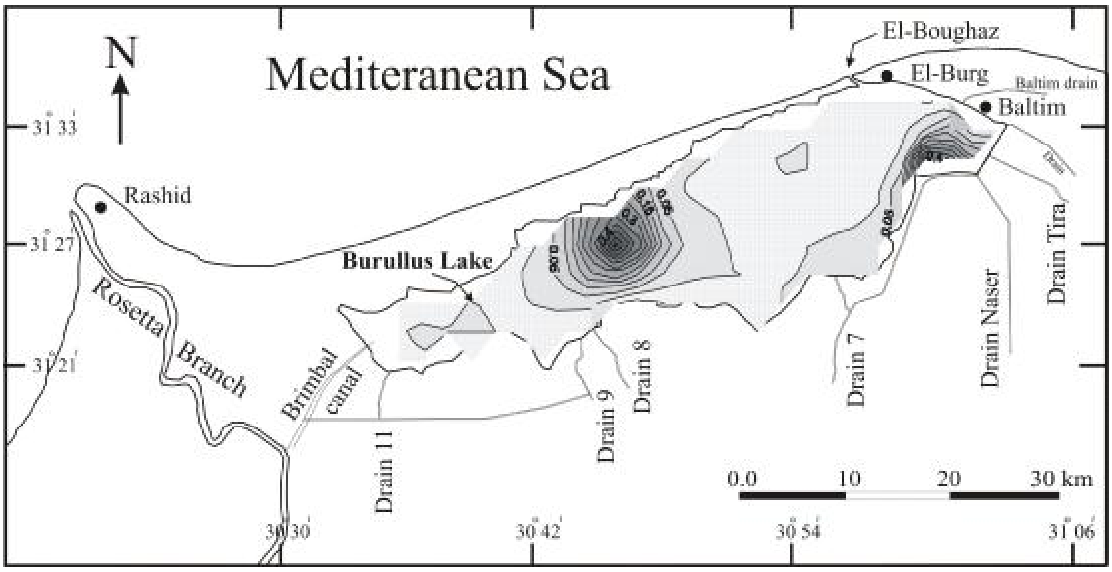

Fig. 17. Distribution of *Bolivina* sp. in El-Burullus Lake bottom sediments during spring 2007.

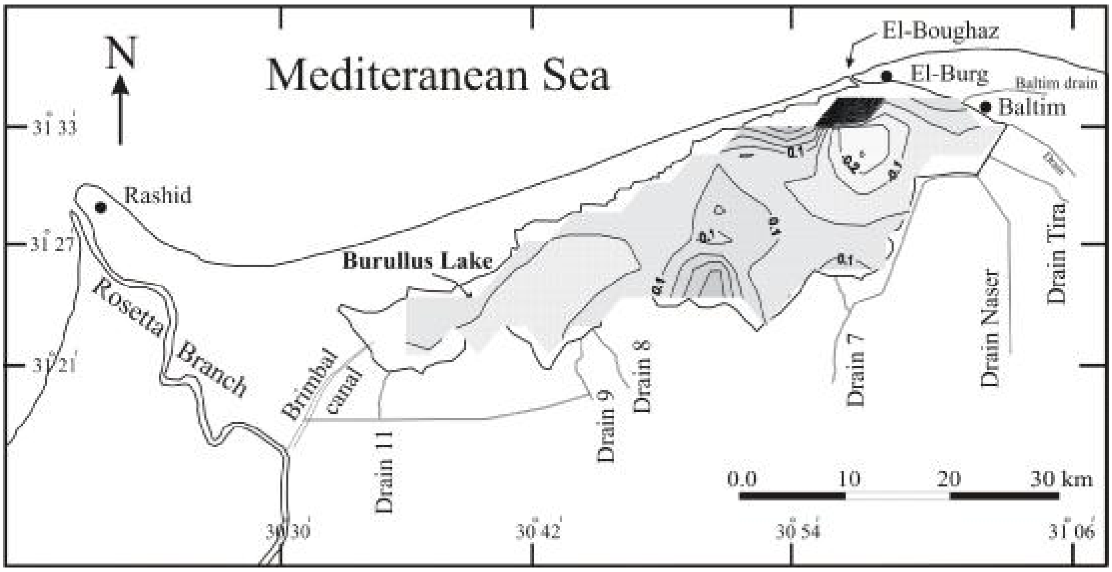

Fig. 18. : Distribution of *Rosalina globularis* in El-Burullus Lake bottom sediments during spring 2007.

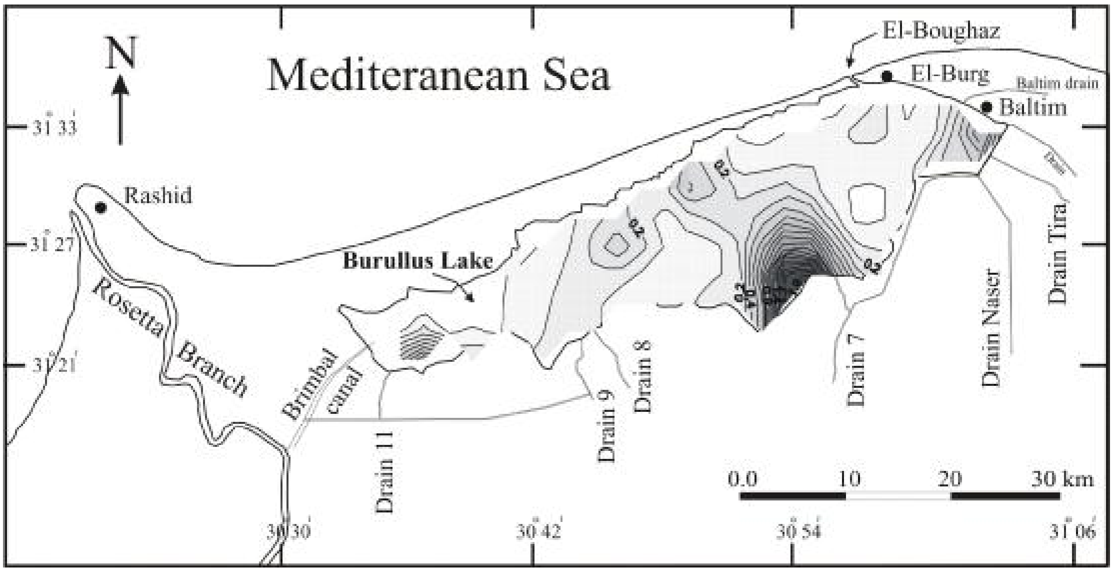

Fig. 19 : Distribution of *Haynesina depressula* in El-Burullus Lake bottom sediments during spring 2007.

cies ranging from 0.0 to c. 4% (Figs. 18-19). They display an insignificant trend, however, they may indicate predominant of epiphytes in the lake (Abu-Zied et al., 2007).

Benthic foraminiferal taxonomy

Thirteen benthic foraminiferal species were recorded from the surface bottom sediments of El-Burullus Lake. They belong to 8 genera, 6 families, 5 superfamilies, and 2 suborders and have been systematically listed below with references.

Order: Foraminiferida Eichwald, 1830.

Suborder: Miliolina Delage and Herouard, 1896.

Superfamily: Cornuspiracea Schultze, 1875.

Family: Hauerinidae Schwager, 1876.

Genus: *Quinqueloculina* d'Orbigny, 1826.

Quinqueloculina bosciana d'Orbigny, 1839

Pl. 1, Figs. 1-2

Quinqueloculina bosciana d'Orbigny, 1839-Cimerman and Langer 1991, p. 36, pl. 33, figs. 5-7.

Quinqueloculina lata Terquem, 1876.

Pl. 1, Figs. 3-4

Quinqueloculina lata Terquem, 1876-Murray, 1971, p.63, pl. 23, figs. 1-3.

Quinqueloculina poeyana d'Orbigny, 1839.

Pl. 1, Figs. 5-7

Quinqueloculina poeyana d'Orbigny, 1839-Sgarrella and Moncharmont-Zei, 1993, vol. 33, no. 2, p. 174, pl. 6, figs. 3-4.

Quinqueloculina seminulum (Linné, 1826)

Pl. 1, Figs. 8-9

Quinqueloculina seminulum (Linné, 1826)-Murray, 1971, p. 63, pl. 23, figs. 1-3.

Genus: *Triloculina* d'Orbigny, 1826.

Triloculina trigonula (Lamarck, 1804).

Pl. 1, Figs. 10-11

Triloculina trigonula (Lamarck, 1804)-Todd and Bronnimann,1957, p.27, pl.3, figs. 18-19.

Genus: *Sigmoilina* Schlumberger, 1887.

Sigmoilina distorta Phleger and Parker, 1951.

Pl. 1, Fig. 12

Sigmoilina distorta Phleger and Parker, 1951-Sgarrella and Moncharmont-Zei, 1993, p. 184, pl. 9, fig. 5.

Suborder: Rotaliina Delage and Heroud, 1896

Superfamily: Bolivinacae Glaessner, 1937.

Family: Bolivinidae Glaessner, 1937.

Genus: *Bolivina* d'Orbigny, 1839.

Bolivina striatula (Cushman, 1922).

Pl. 2, Figs. 1-2

Bolivina striatula (Cushman, 1922)-Cimerman and Langer, 1991, p. 60, pl. 62, figs. 6-9; see also Barmawidjaja et al. (1992), pl. 2, figs. 10-13.

Bolivina spathulata (Williamson, 1858).

Bolivina spathulata (Williamson, 1858)-Murray, 1971, p.110, pl. 45, figs.1-4; see also Lander Rasmussen (1991), P. 376, fig. 6 (12).

Bolivina variabilis (Williamson, 1985).

Pl. 2, Fig. 3

Bolivina variabilis (Williamson, 1985)-Murray, 1971, p.113, pl. 46, figs. 1-3.

Superfamily: Discorbacea Ehrenberg, 1838.

Family: Rosalinidae Reiss, 1963.

Genus: Rosalina d'Orbigny, 1826.

Rosalina globularis d'Orbigny, 1826.

Pl. 1, Figs. 4-5

Rosalina globularis d'Orbigny, 1826-Murray, 1971, p.135, pl. 56, figs. 1-6.

Superfamily: Nonionacae Schultze, 1854

Family: Nonionidae Schultze, 1854

Genus: *Haynesina* Banner & Culver, 1798).

Haynesina depressula (Walker & Jacob, 1798).

Pl. 2, fig 6.

Haynesina depressula (Walker & Jacob, 1798)-Reinhardt et al. 1994, p. 43, pl. 1, figs. 1-2.

Superfamily: Rotaliace Ehrenberg, 1839.

Family: Rotaliidae Ehrenberg, 1839.

Genus: *Ammonia* Brünnich, 1772.

Ammonia tepida (Cushman, 1926).

Pl. 2, Figs. 7-9

Ammonia tepida (Cushman, 1926)-Cimerman and Langer, 1991, p. 76, pl. 87, figs. 10-12.

Family: Elphidiidae Galtowae, 1933

Genus: *Cribroelphidium* de Mortfort, 1808

Cribroelphidium excavatum (Terquem, 1875).

Pl. 2, Figs. 10-12

Cribroelphidium excavatum (Terquem, 1875)-Murray, 1971, p. 159, pl. 66, Figs. 1-7.

CONCLUSIONS

The bottom sediments and water characteristics of El-Burullus Lake were studied with regard of benthic foraminifera and environmental parameters. The environmental parameters include, type of substrates, water depth, pH, dissolved oxygen, organic carbon and carbonates. These parameters indicate that El-Burullus Lake is very shallow basin with mean average water depth of 1m, its deepest part (c. 2.5m) occurs near El-

Boughaz inlet. Muddy substrates contain high amount (~14%) of organic carbon (OC) and dominate most of the bottom sediments of the lake, whereas sandy substrates dominate the central and far west parts of the lake, containing the highest value of carbonates (~10%). Such conditions indicate high accumulation of OC and carbonates in a very shallow basin El-Burullus, encouraging local people to reclaim lands from the shallowest parts of the lake for agriculture and fish farming purposes. Therefore, further study should be undertaken to prevent the closure of the lake in the future.

El-Burullus Lake water salinity varies from 2 to 14 g/l, with alkaline medium (pH = 8.3) and highly ventilated conditions (dissolved oxygen = 7-9 ml/l). These conditions allow only calcareous benthic foraminifera to live in the bottom sediments of the lake. Agglutinated foraminifera were never found in the lake sediments.

The bottom sediments of El-Burullus Lake host high benthic foraminiferal density, consisting mostly of one species *Ammonia tepida,* which is the dominant species in the lake sediments with frequency >90% of the total assemblages. These findings indicate that stressful environmental conditions control the benthic foraminiferal habitats in the bottom sediments of El-Burullus Lake. For example, occurrence of low salinity values in El-Burullus Lake is probably favorable for *A. tepida* and detrimental on the other species *(Cribroelphidium* sp. and miliolids), which occur only near El-Boughaz inlet, indicating their preferences to high salinity water.

Acknowledgments

This paper is part of N. Ameen's M.Sc. thesis (2010). We thank Dr. Elsayed Nafea and Coastal and Waterbodies Guards for their help in the field work of this study and good hospitality at the El-Burullus Protectorate, Baltim City. We are also grateful to Prof. Amin Gheith for his help and support to publish in this journal.

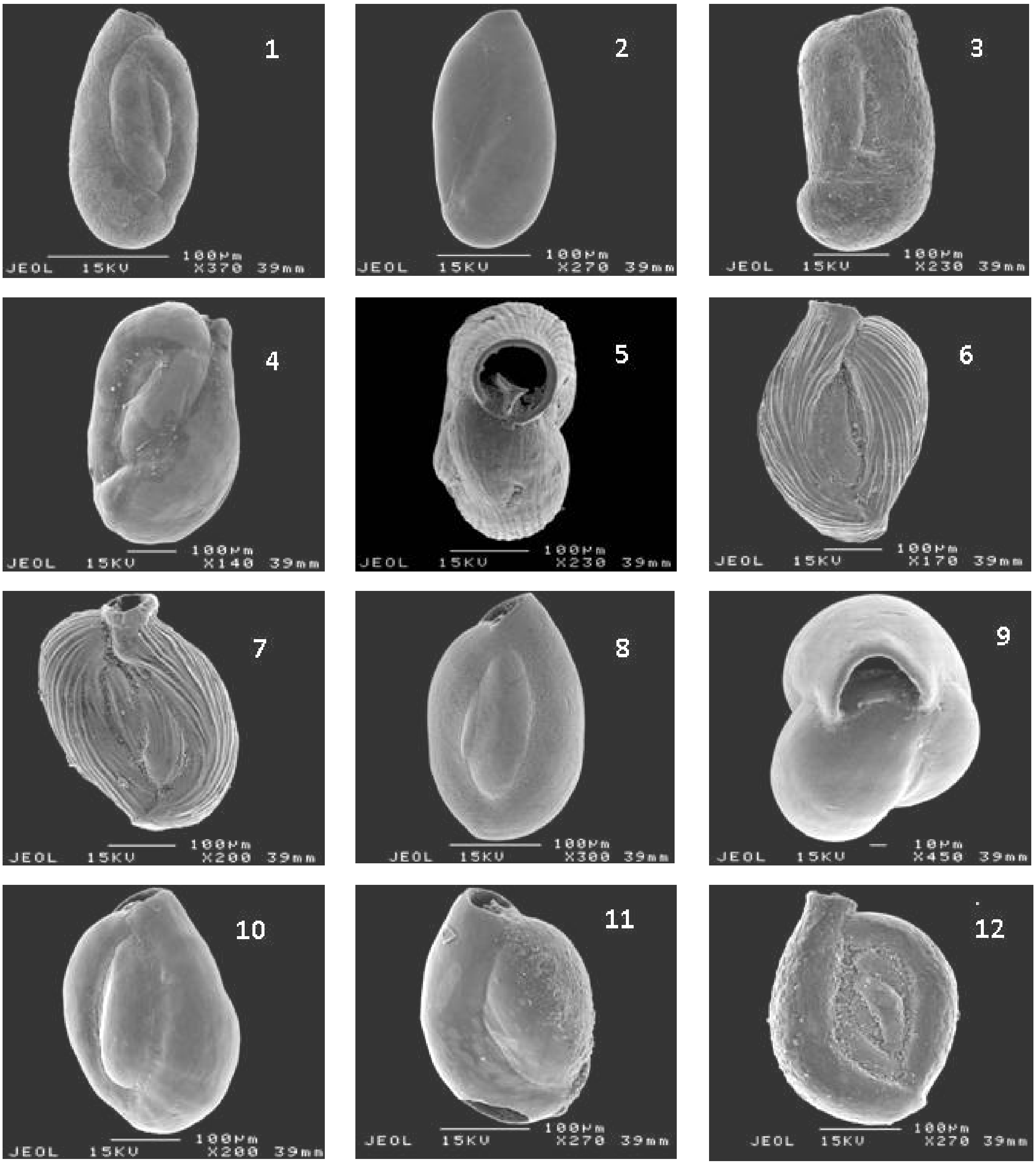

Plate 1. 1-2, *Quinqueloculina bosciana* (d'Orbigny, 1839); 1-2 side views. 3-4, *Quinqueloculina lata* (Terquem, 1876); 3-4 side views. 5-7, *Quinqueloculina poeyana* (d'Orbigny, 1839); 5 aperture view, 6-7 side views. 8-9, *Quinqueloculina seminulum* (Linné); 8 side view, 9 aperture view. 10-11, *Triloculina trigonula* (Lamarck, 1804); 10-11 side views. 12, *Sigmoilina distorta* (Phleger and Parker, 1951); 12 side view.

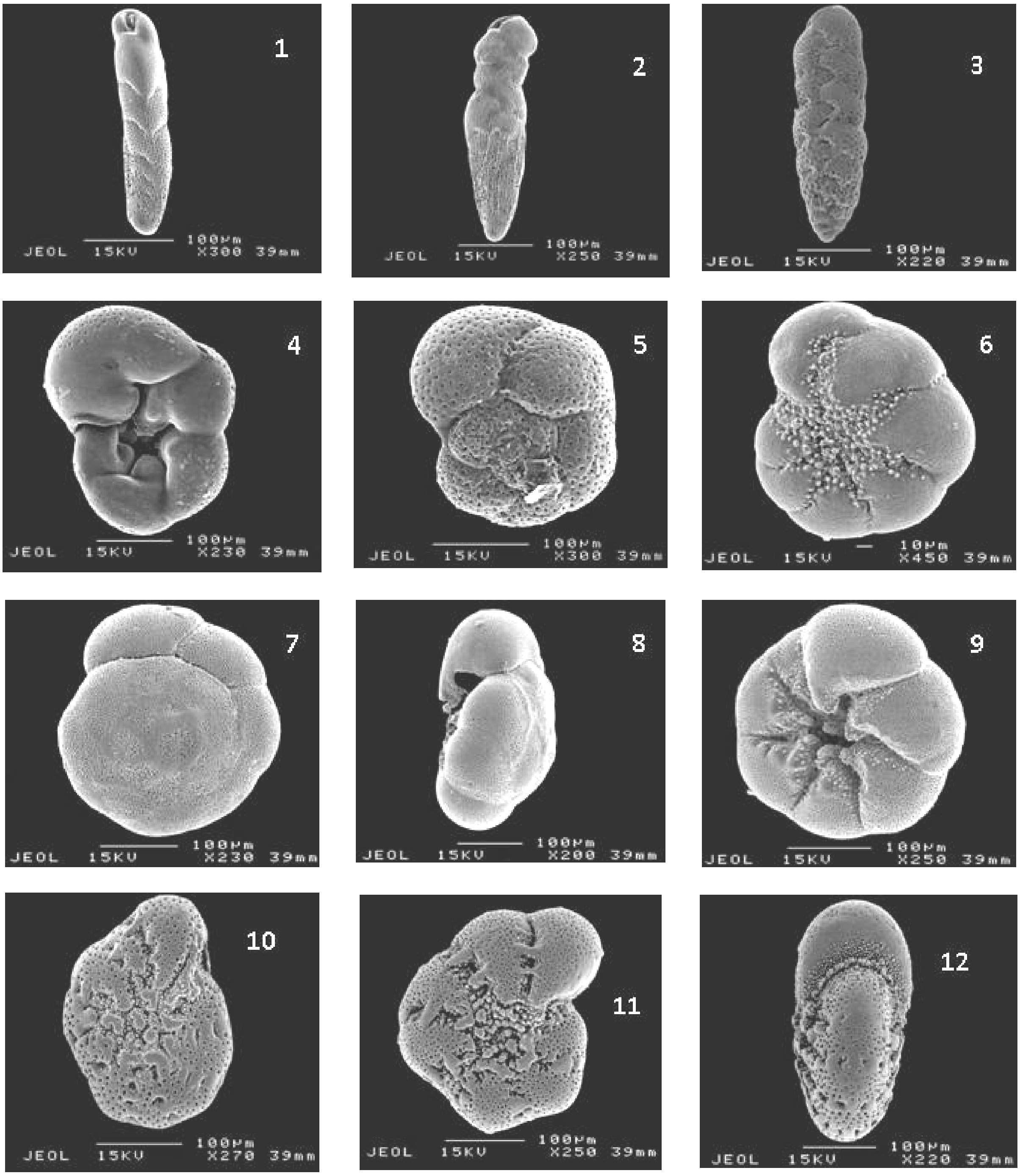

Plate 2. 1-2, *Bolivina striatula* (Cushman, 1922); 1 aperture view, 2 side view. 3, *Bolivina variabilis* (Williamson, 1985); 3 side view. 4-5, *Rosalina globularis* (d'Orbigny, 1826); 4 umbilical view, 5 spiral view. 6, *Haynesina depressula* (Walker & Jacob, 1798); 6 umbilical view. 7-9, *Ammonia tepida* (Cushman, 1926); 7 spiral view, 8 side view, 9 umbilical view. 10-12, *Cribroelphidium excavatum* (Terquem); 10-11 spiral view, 12 side view showing the aperture.

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الملخص العربى

نمط توزيع الفورامنيفرا القاعية والعوامل البيئية المتحكمة فيها فى بحيرة البرلس، شمال دلتا النيل، مصر

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بحيرة البرلس هى واحدة من البحيرات الشمالية لدلتا النيل، تتصل بالبحر المتوسط من خلال مضيق البوغاز، ثلاثة وستين عينة رسوبية سطحية تم جمعها من أماكن مختلفة من البحيرة فى صيف ٢٠٠٦ وربيع ٢٠٠٧م. وكذلك تم تعيين واحد وأربعين محطة لدراسة المتغيرات البيئية لمياه البحيرة مثل الملوحة (المواد الصلبة الذائبة) ودرجة الحرارة ودرجة الحموضة والأكسجين الذائب، الهدف الرئيسى من هذه الدراسة هو مناقشة نمط توزيع الأحافير الدقيقة القاعية فى رواسب القاع لبحيرة البرلس وعلاقتها بالمتغيرات البيئية للرواسب القاعية مثل حجم حبيبات الراسب ومحتوى الكربونات وعمق المياه والكربون العضوى وكذلك مع المتغيرات المائية فى البحيرة.

نتائج هذه الدراسة تشير إلى أن رواسب قاع بحيرة البرلس غنية جداً بالأحافير الدقيقة القاعية ذات الكثافة العالية جداً والتنوع المنخفض جداً، على الرغم من أن رواسب القاع الحديثة للبحيرة تحتوى على أعداد كبيرة من الأحافير الدقيقة القاعية الميتة، إلا أن الأحياء الحية منها منخفض للغاية ولكن يزداد فى مكان ما بالبحيرة فى إتجاه مضيق البوغاز وخاصة خلال موسم الربيع فقط.

ربما تكون الظروف البيئية فى بحيرة البرلس قاسية ومؤثرة على هذه الأحافير الدقيقة القاعية وذلك بسبب سيادة نوع واحد فقط من هذه الأحافير وهو "*Ammonia tepida*". هذا النوع يتحمل مدى واسع من الملوحة (٢-٦٧ جرام/لتر) ومتواجد فى رواسب البحيرة بنسب عالية جداً تصل إلى أكثر من ٩٠٪، الملوحة الحالية لبحيرة البرلس تتفاوت من ٢ إلى٥ر١٤ جرام/لتر، لذلك فإن سيادة ***A. tepida*** للرواسب السطحية لقاع بحيرة البرلس، من المرجح، أن يكون بسبب تواجد نسبة ملوحة منخفضة فى بحيرة البرلس، مثل هذه الظروف ليست مواتية لغيرها من الأنواع القاعية للفورامنيفرا لتتكاثر.

JOESE 5

DISTRIBUTION PATTERN AND ENVIRONMENTAL CONTROLS ON BENTHIC FORAMINIFERA IN EL-BURULLUS LAKE, NORTH OF THE NILE DELTA, EGYPT

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