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SYSTEMATIC, ONTOGENETIC VARIATIONS, POPULATION OF MOLLUSCAN FAUNA AND THEIR ENVIRONMENTAL IMPACT ON THE ISLANDS OF THE EL BURULLUS LAGOON, NORTH NILE DELTA, EGYPT

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ABSTRACT

Twenty-three surface, ditch and core samples were collected from a number of islands in the El Burullus Lagoon to define Holocene Molluscan biofacies present in these islands, determine their spatial and geographic distribution and to assess the environmental impact on the habitat of the fauna. In addition, the chemical analysis of the trace elements of the shells is studied to show the relation between the shell composition and the enclosing sediments.

The quantitative examination and statistical analysis of faunal data were undertaken to refine interpretations of the present environmental conditions affecting these islands. This is important because all modern Nile lagoons are undergoing very rapid change (reduction in size, pollution) because of accelerated human activity.

A total of eight Molluscan bivalve and gastropod species represented by 1123 specimens was identified and described. Four identified bivalve species are assigned to Ostrea edulis, Cerastoderma glaucum, Abra ovata and Corbicula fluminalis. The gastropods belong to Theodoxus niloticus, Melanoides tuberculata, Bittium reticulatum and Hinia reticulate species. The ontogeny of most studied species is dealt with through plots of measurements of a number of specimens.

INTRODUCTION

Many workers have studied stratigraphy, geomorphology, tectonic history, pollution and geologic history of the El Burullus Lagoon (Abu Al-Izz, 1971; Saad, 1976; El-Fishawi and El-Askary, 1981; El Sabrouti, 1984; El Askary and Frihy; 1986; Kerambrun, 1986; El-Khidr, 1988; Amany, 1989; El Fishawi and Badr, 1989; Sestini, 1989; Arbouille and Stanley, 1991; Toubar, 1991; Mohamed et al., 1991 & 1992; Mohamed, 1992 & 1993; Gheith et al., 1992, 1993 and 1994; Zaghloul et al., 1999; El-Shinnawy et al., 2000; Appleby et al., 2001; Birks et al., 2001; Flower & Flower et al., 2001; Diab et al., 2006 and Khalil et al. 2007). Few palentological studies were carried out on El Burullus Lagoon as El Beialy et al., 2006 and Ayyad et al., 2010. Nevertheless, little or no studies have been carried out on the islands in the El Burullus Lagoon.

Nearly twenty-three islands occupy the central and northeastern parts of the El Burullus Lagoon and eight of them were selected and studied in detail (Fig. 1). The biggest ones occupy the central part whereas the smallest ones occur in the northeastern part of the lagoon. These islands include Aradat Al-Maqraah, Al-Gharbiyah, Al-Dakhlah, Al Kom-Al Akhdar, Az-Zanqah, Al-Ghariq Al-Qibli, Ibsak and Sinjar Islands. These islands are of different shapes and most of them extend in the NE and NW directions. Other islands such as Al-Dakhlah and Sinjar islands are perpendicular to the coastline. The location of the studied eight islands have been located by GPS as shown in Table (1).

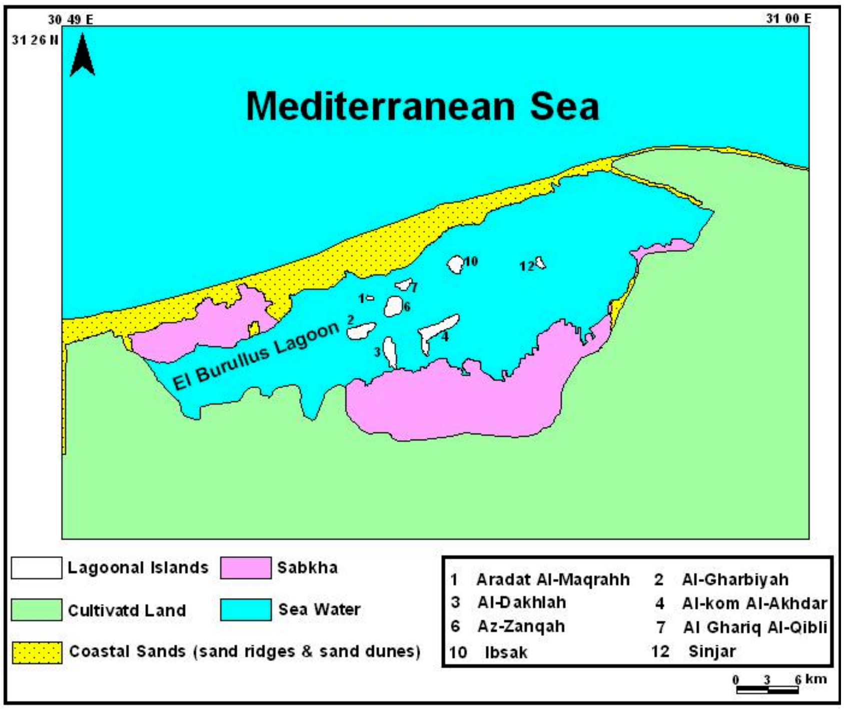


Fig. (1): Location of the studied islands in the El Burullus Lagoon (www.eeaa.gov.eg).

Table (1): Longitudes and latitudes of the studied islands.

Name of Island	Longitude	Latitude
Aradat Al-Maqraah	31° 28′ 9″ E	30° 45′ 45″ N
Al-Gharbiyah	31° 26′ 57″ E	30° 44′ 44″ N
Al-Dakhlah	31° 26′ 36″ E	31° 48′ 0″ N
Al-Kom Al-Akhdar	31° 26′ 55″ E	30° 50′ 10″ N
Az-Zanqah	31° 28′ 38″ E	30° 48′ 8″ N
Al-Ghariq Al-Qibli	31° 29′ 45″ E	30° 48′ 16″ N
Ibsak	31° 30′ 35″ E	30° 51′ 30″ N
Sinjar	31° 30′ 9″ E	30° 56′ 16″ N

MATERIAL AND METHODS

Four bivalve and four gastropod species represented by 1123 specimens were identified. The lithology of boreholes and trenches from which the fauna are collected is given in Fig (2). The lengths of both the cores and trenches dug in the studied islands range from 40 cm to 120 cm. All the studied islands are nearly muddy except the Al-Kom Al-Akhdar Island, which is sandy.

The sands of the Al-Kom Al-Akhdar Island are yellow in color, loose, fine to medium-grained and sub-rounded to rounded. The thickness of the sand beds is up to 80 cm. Some halophytes are growing on the surface of this island. No tests were encountered. The other islands are composed mainly of mud, clays and carbonates. The mud is calcareous or sandy. These sediments are grey, yellowish grey and black. Some shell fragments and whole tests of bivalves and gastropods were recorded as shell banks or mixed with argillaceous sediments. The thickness of the shell fragments bed ranges between 10 and 60 cm. Some variegated colored intensive halophytes are grown on the surface of these islands.

Great numbers of molluscs' specimens were collected from the bottom and the shallow boreholes. These specimens are washed and photographed. The attributed of the shells are measured and graphically plotted in scatter diagram to describe and study the ontogeny of the identified species. Moreover, contour maps showing the distribution of the fauna are drawn. Six samples representing four species of molluscs [*Cerastoderma glaucum* (Poiret, 1789), *Melanoides tuberculata* (Müller, 1774), *Bittium reticulatum* (Da Costa, 1778) and *Ostrea edulis* Linnaeus, 1758] were chosen for chemical analysis. Initially the shells were crushed to powder and then the thirteen trace elements (Cr, Ni, Cu, Zn, Zr, Rb, Y, Ba, Pb, Sr, Ga, V and Nb) were determined by using the X-ray fluorescence spectrometer (Model X-Unique spectrometer) (XRF) technique. The analyses were made in the laboratory of the Egyptian Nuclear Material Authority. The systematic taxonomy is adopted after More, R.c. in Treatise of invertebrate paleontology, 1969.

RESULTS

Relative abundance :

The identified molluscs are represented by four bivalve species and four gastropod species. The bivalves include *Ostrea edulis* Linnaeus, 1758, *Cerastoderma glaucum* (Poiret, 1789), *Abra ovata* Philippi, 1893 and *Corbicula fluminalis* (Müller, 1774), whereas the gastropods include *Theodoxus niloticus* (Reeve, 1856), *Melanoides tuberculata* (Müller, 1774), *Bittium reticulatum* (Da Costa, 1778) and *Hinia reticulata* (Linnaeus, 1758). The average percentage and numbers of specimens of the molluscs recorded in the studied islands are given in Tables (2 and 4) and is graphically represented in Fig. (3). it appears that C*erastoderma glaucum* and *Bittium reticulatum* represent the most abundant species among the molluscs. The two species constitute shell banks in the islands of Sinjar, Ibsak and Al-Ghariq Al-Qibli. None of the identified species except *Cerastoderma glaucum* is found in the Az-Zanqah Island. In general, the *Cerastoderma glaucum* dominates in all the studied islands. Probably the reason for this abundance of such species is due to brackish environment suitable for flourishing of it. The abundance of this species leads to poverty of the three identified bivalves. On the other hand, the gastropods are probably not affected by the dominance of *Cerastoderma glaucum.* Among the gastropods, *Bittium reticulatum dominates* in islands of Sinjar, Al Dakhlah and Ibsak respectively. However, the gastropod species *Melanoides tuberculata* attained a reasonable abundance in Al-Gharbiyah Island.

From figure (3), it can be seen that the occurrence and the percentage of the relative abundance of molluscs vary from one island to another. In some islands, only one species is present, in others two or three species are present. No more than five species are encountered together. Such occurrence of molluscs together in the may be due to the similarity of the environmental conditions and habitat of these species.

Table (2): Average percentage of molluscan species in the studied islands.

Island	Name of species								
	Bivalves					Gastropods			
	O. edulis		*C. glaucum*	*A. ovata*	*C. fluminalis*	*T. Niloticus*	*M. tuberculata*	*B. reticulatum*	*H. reticulata*
	Left valve	Right valve							
Al Dakhlah	5.3	2.3	24.5	0.8	0.8	0.3	15	48.9	2.2
Aradat Al-Maqraah	0	0	90	0	0	0	0	0	10
Al-Gharbiyah	3.7	1.1	46.4	3.7	5.5	1.1	25.3	10	3.2
Az-Zanqah	0	0	100	0	0	0	0	0	0
Sinjar	0	0	26.7	0	0	0	0	53.3	20
Ibsak	0	0	65.2	0	0	0	0	30.9	3.9
Al-Ghariq Al-Qibli	3.5	0	67	0	2.6	0	7	17.4	2.6

Note: *O. edulis: Ostrea edulis, C. glaucum: Cerastoderma glaucum, A. ovata: Abra ovata, C. fluminalis: Corbicula fluminalis, T. niloticus: Theodoxus niloticus, M. tuberculata: Melanoides tuberculata, B. reticulatum: Bittium reticulatum and H. reticulata: Hinia reticulata.*

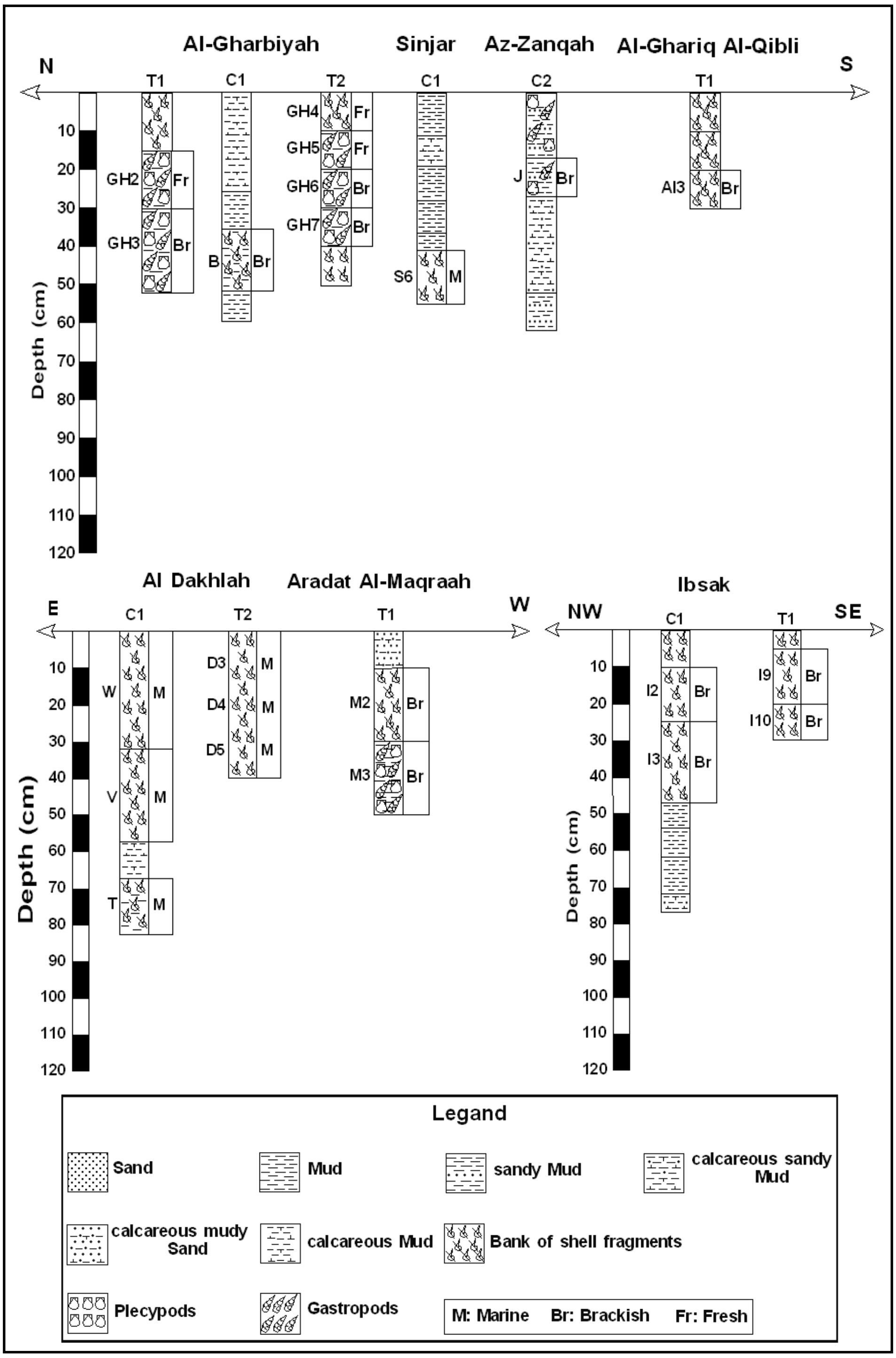


Fig. (2): Lithologic logs of the studied islands showing depth of the samples (left of the log) collected for examination of their macrofaunal content. The depositional environments of the macrofauna are also given (right of the log). (T: Trench, C: Core, M: Marine, Br: Brackish, Fr: Fresh).

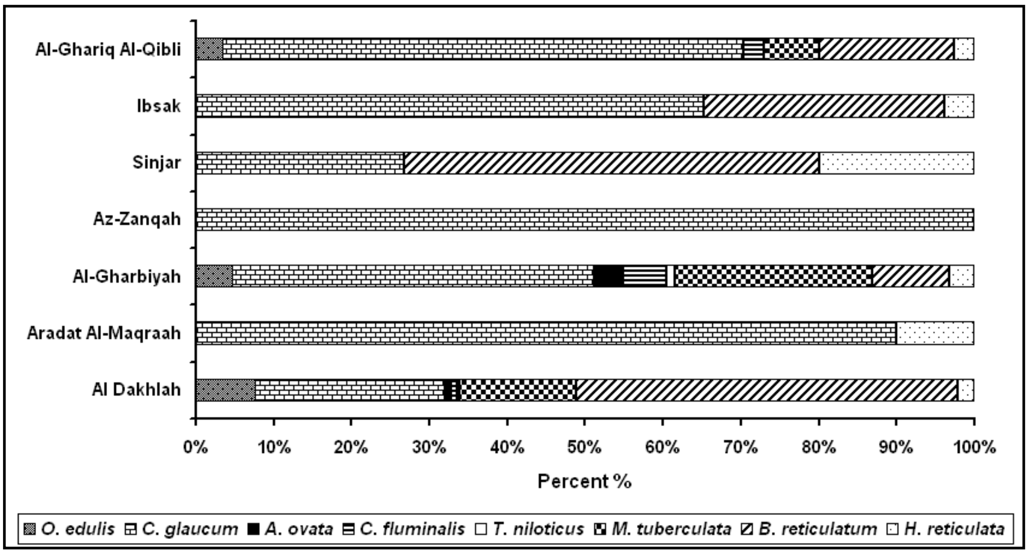


Fig. (3): The relative average percentages of molluscan species in the studied islands.

Systematic taxonomy

Phylum: Mollusca Linnaeus, 1758
Class: Bivalvia Linnaeus, 1758
Family: Ostreidae Rafinesque, 1815
Genus: *Ostrea* Linnaeus, 1758
***Ostrea edulis Linnaeus*, 1758**
(Pl. 1, Figs. 8-13)

Morton et al., 2003: *Ostrea edulis Linnaeus*, 1758, figs. 1, 4 and 5.

Description: The shell is cream-colored, with oval, slender or pear-shaped and is distinctively opisthogyrous. The shell is small, varying in height from 1 cm to 2.5 cm. The left valve is convex and the right one is flat, with tough edges. *O. edulis* has a rough scaly clean surface, sometimes masked with parasitic and some dirty organic matter, with crenulations at the lower ventral part. The outer shell is composed of flaky layers, which may include laminar and hollow chambers. The interior of the shell is white with lightly colored patches on the ventral side. Ligament area is triangular in slender forms, some forms with deep resillium. The adductor muscle scar is white with lightly colored growth lines. This scar is anterio-posteriorly elongate, crescent and tapers posteriorly; it is centrally positioned, slightly near the posterior.

Ontogenetic variation: As we cannot observe the growing animal directly, we use a number of specimens to study the ontogenetic variation of the species. The two attributes of length and height of the shells are plotted against each other (Fig. 4a). In addition, the ratio of these two attributes is plotted against the total numbers of the specimens (Fig. 4b). The left valves are found separately, the right valves are not frequently encountered. All the samples are related to the same species but within two varieties.

The graph in Fig. 4a is based on measurements of approximately 40 specimens of *Ostrea edulis*. The scatter of points forms somewhat length-shape pattern. This may be interpreted as the rate of width growth is high when the test becomes larger. This can be confirmed in Fig. 4b, as both of the two rates of growth run harmonious in some way. A line drawn at 45^{o} is included in the plots in Fig. 4a. All points above this line represent individuals whose length exceeds their height, while points below the line represent individuals whose height exceeds their length. Such tendency towards the length may be used as an indicator for the separation of the species into two varieties: Variety (a): includes forms with convex shell and strongly ornamented surface (Pl.1 figs. 11 & 13), although the preservation is not so good, and Variety (b): which includes more or less flattened individuals with cavity under resillium (Pl.1 figs.8,9&11).

Since both length and height grow precisely at the same rate, the growth relationship is isometric. The isometric growth means that the plotted line is straight passing through the origin (Raup and Stanley, 1978).

Habitat: The European flat oyster *Ostrea edulis* Linnaeus, 1758 is native to Europe and the Mediterranean. It has long been harvested for food. It prefers the firm bottoms of mud, muddy sand, muddy gravel with shells and hard silt. *Ostrea edulis* Linnaeus, 1758 can be found on estuaries, and it tolerates salinities up to 23%. In the area under study, the species is encountered in the islands of Al - Dakhlah, Al-Gharbiyah and Al-Ghariq Al-Qibli where the mud is dominant and the sand is negligible. The favorable conditions and nutrient make the species outnumbers all molluscs of the El Burullus Lagoon.

All the encountered individuals of *Ostrea edulis* in the studied islands have small shell size, no more than 25 mm, although the *Ostrea edulis* can grow up to 20 cm or more. Such diminution probably reflects extensive mortality due to diseases (Mirella da Silva et al. 2005). The disease *Bonamia Ostrae* (bonamiosis) was contracted by *O. edulis* shortly after its introduction to the northwest Atlantic coast. For the last 25 years, *O. edulis* has caused extensive mortalities among populations of the European flat oyster. *O. edulis* was eventually re-introduced to Europe where the disease was transferred to other established populations. The disease may be responsible for the mortality of the individuals of such species, preventing them to reach the maximum size.

Occurrence: The species is abundant in the west of the area studied (fig. 5).

Geographic distribution: The species is found naturally from the Norwegian Sea south (Hayward and Ryland, 1990) through the North Sea down to the Iberian Peninsula and the Atlantic coast of Morocco. It has also been found in the Mediterranean Sea and extends into the Black Sea (Mirella da Silva et al. 2005). **Age:** Holocene.

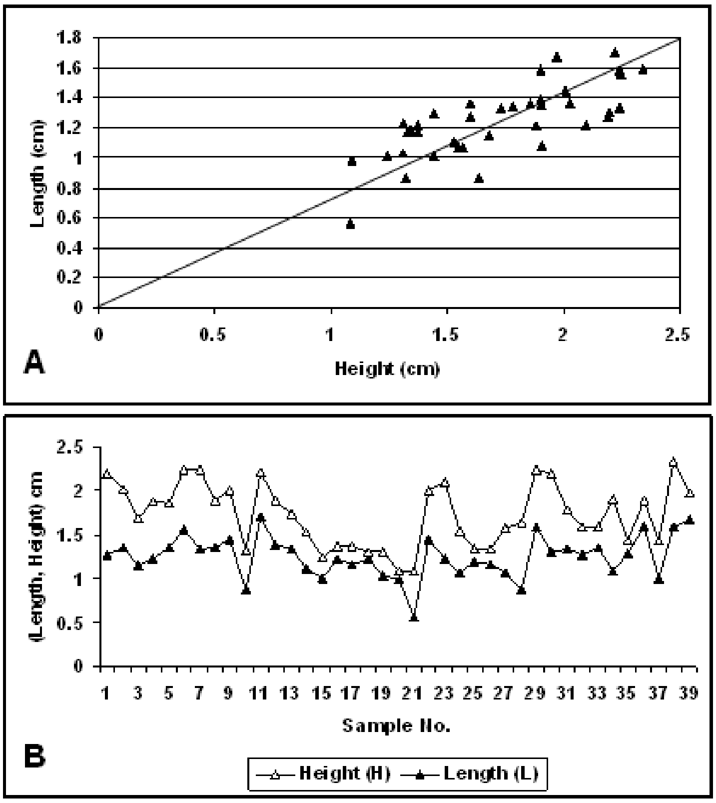


Fig. (4): A- Ontogenetic change in shape (height and length) in specimens of *Ostrea edulis*. **B-** Length / height ratio against total numbers of specimens. Measurements are taken for the left valve of *Ostrea edulis* encountered in the studied islands.

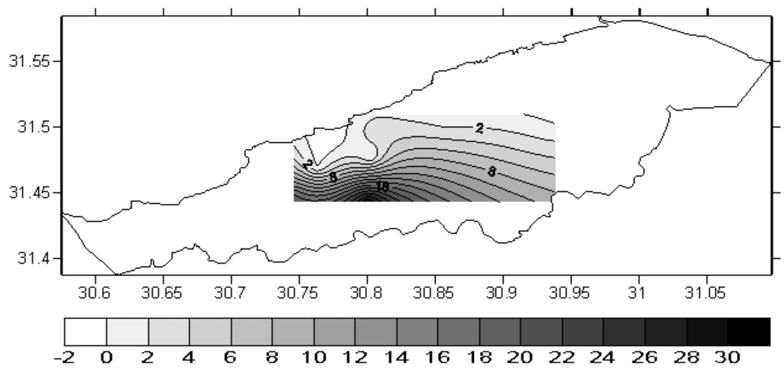


Fig. (5): Spatial distribution of *O. edulis* in the El Burullus Lagoon islands.

Order : Veneroida H. Adams and A. Adams, 1856

Family: Cardiidae Lamarck, 1809

Genus: *Cerastoderma* Poli, 1795

***Cerastoderma glaucum* (Poiret, 1789)**

(Pl. 1, Figs. 1-2)

Barens, 1980 : *Cerastoderma glaucum* (Poiret, 1789), fig. (5.1 a).

Description : The shell is small, thin, oval, fan - shaped and convex. Umbo is prosogyral. The surface is sculptured with 20-22 radiating ribs decorated with scale like spines. The growth lines become distinct at the margin. The lateral teeth are distinct.

Ontogenetic variation : *Cerastoderma glaucum* specimens were counted in the studied samples. The relationship between the length of *Cerastoderma glaucum* against its height is given in (Fig. 6).The plotted dimensions are linear. The scatter of points in the new plot falls quite rigorously on the straight line with slope angle of 45 degree. Such relation indicates that the shape remains constant throughout ontogeny. The growth is isometric i.e. the rate of increase of the length equals the rate of increase of the height.

Habitat & ecology: The cockle, C*erastoderma glaucum* is a filter-feeding bivalve, which burrows shallow in soft sediments. The species exists in a typical thin-shelled variety, which is found in brackish lagoon habitats. The El- Burullus lagoon is one of the saline marshlands that form an interface between the marine, freshwater and terrestrial environments. Saline marshlands support highly specialized biota that are only present in this habitat. Adults usually burrow shallow in muddy soft substratum. Although several species are common in all local marshlands, yet each site has its own peculiar habitat characteristics and suite of species.

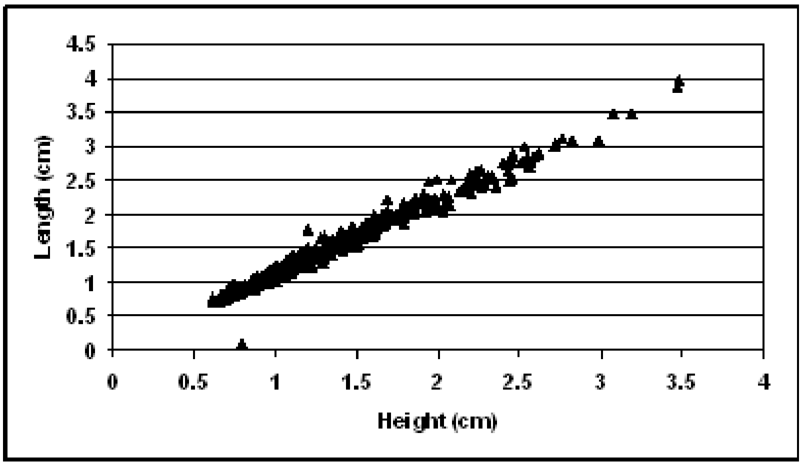


Fig. (6): A plot showing the relationship between height and length in samples of *Cerastoderma glaucum* recorded in the studied islands.

Occurrence: The species is found in Al Dakhlah Island (98 specimens), Aradat Al-Maqraah Island (9 specimens), Al-Gharbiyah Island (176 specimens), Az-Zanqah Island (1 specimen), Sinjar Island (4 specimens), Ibsak Island (133 specimens) and Al-Ghariq Al-Qibli Island (77 specimens). It is noticed that this species has a wide distribution in the studied islands (Fig. 7).

Geographic distribution: It is widely distributed in north-west Europe and found naturally from Norway and the Baltic to the Mediterranean and Black Seas (Hayward and Ryland, 1990).

Age: Holocene.

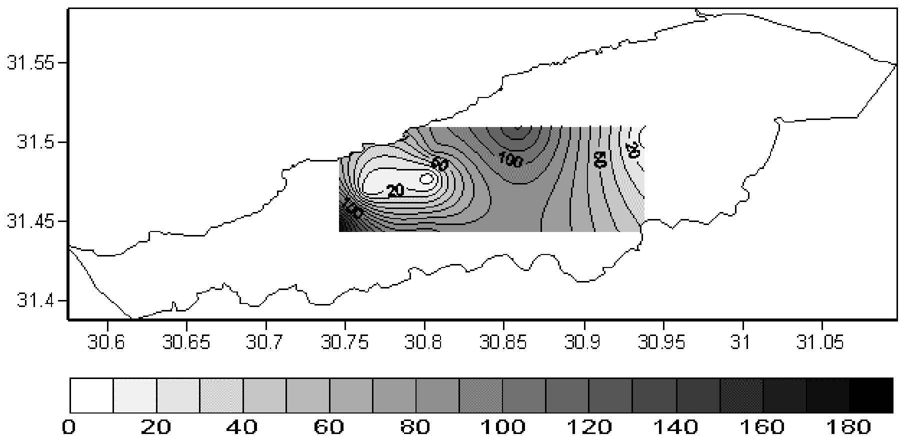


Fig. (7): Spatial distribution of the *Cerastoderma glaucum* recorded in the El Burullus Lagoon.

Order : Veneroida H. & A. Adams, 1856
Family: Semelidae Stoliczka, 1870
Genus: *Abra Lamarck, 1818*
***Abra (Syndesmya) ovata* Philippi, 1893**
(Pl.5, Figs. 5-7)

Zhadin, 1952: *Abra (Syndesmya) ovata* Philippi, fig. 2.

Description: The shell is thin, small, dwarf, fragile, translucent, and equivalved, rounded-triangular, and more or less flat. The anterior margin is rounded, the posterior one is tapering than the anterior. The umbo is very narrow, less pronounced. The surface is covered with thin lines of accretion. The cardinal area of the right valve consists of two small cardinal and two lateral teeth. In the left valve, there is a small cardinal tooth.

Habitat: The thin wall of the species reflects quite calm conditions prevailing during the deposition of mud. *Abra ovata* occurs in almost all bottoms but typically inhabits sandy mud and is characteristic of areas featuring strong salinity changes such as semi-enclosed areas such as coastal lagoons (Gremare et al., 2004). It is found in brackish lagoon habitats dominated by calcareous mud facies and high salinity.

Occurrence: It is found in Al Dakhlah Island (3 specimens) and Al-Gharbiyah Island (14 specimens), western area of the lagoon (Fig. 8).

Geographic distribution: The horizontal distribution of *Abra ovata* goes from northern France to the Atlantic Coast of Morocco and to the Mediterranean Sea (Gremare et al., 2004).

Age: Holocene.

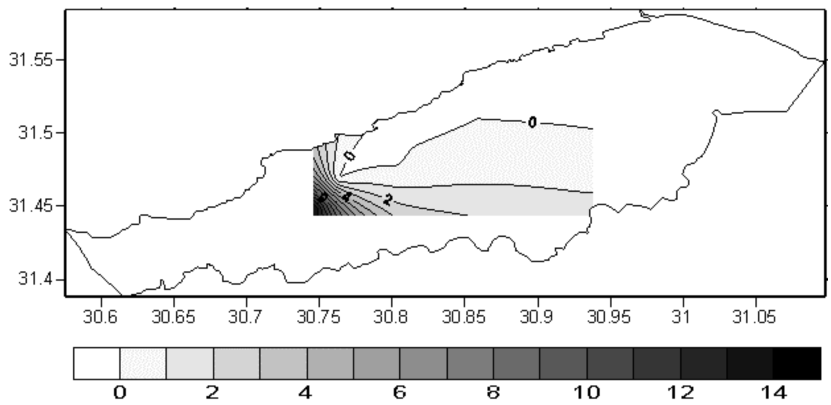


Fig. (8): Spatial distribution of Abra ovata recorded in the El Burullus Lagoon showing a pocket in the west.

Order : Veneroida H. Adams and A. Adams, 1856

Family: *Corbicula* Mergele von Muhlfeld, 1811

***Corbicula fluminalis* (Müller, 1774)**

(Pl. 1, Figs. 3-4)

Ciutti and Cappelletti, 2009: C*orbicula fluminalis* (Müller, 1774), fig.1 (a).

Description: Shell is small, triangular, with rounded margins, reddish brown, and umbo orthogyrate. The surface is covered with concentric weak and very regularly spaced ribs. It has highly convex, smooth umbonal area with indistinct growth lines. Lateral teeth elongated, three short and thicker cardinal teeth in each valve. Pallial line is integrepalliate and adductor muscles are heteromayrian.

Habitat: *Corbicula fluminalis* is found in lakes and streams of all sizes with silt, mud, sand, and gravel substrates. It prefers fine, clean sand, clay, and coarse sand substrates (Aguirre and Poss 1999). The bivalve *Corbicula fluminalis* is perhaps the most famous interglacial mollusc known from north-west Europe, found in freshwater habitats.

The occurrence of the species in the area of study refers to coastal wetlands, transitional between freshwater wetlands and saline marshlands in the sense that the biotic assemblages they support consist of species typical of both freshwater and saline habitats. Such wetlands have been termed 'transitional coastal wetlands'. Such wetlands arise when rainwater collects in depressions close to the sea. Under appropriate conditions, these pools become colonized by species typical of freshwater and which have some degree of tolerance to maritime influence. During the dry period, the only water arriving in these depressions is seawater carried by wind and wave action; conditions therefore favor brackish water species.

Occurrence: It is found in Al Dakhlah Island (3 specimens), Al-Gharbiyah Island (21 specimens), (Fig. 9).

Geographic distribution: It is found in Atlantic Europe, North Sea (Streftaris et al. 2005) and Germany (Gollash and Nehring, 2006).

Age: Holocene.

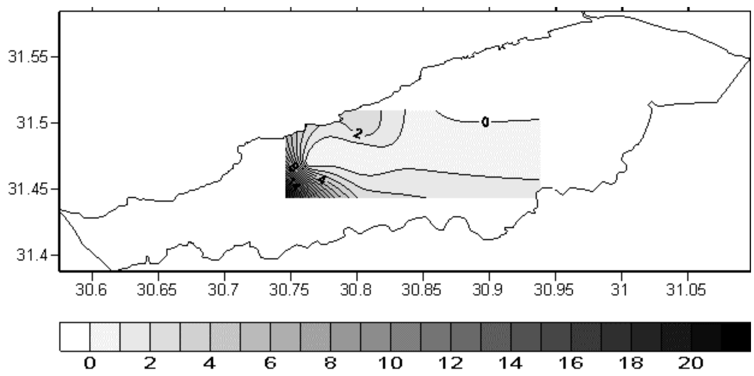


Fig. (9): The spatial distribution of *Corbicula fluminalis* in the studied islands showing a spot in the west side of the lagoon.

Class: Gastropoda Cuvier, 1797
Order: Neritopsina Cox & Knight, 1960
Family: Neritidae Rafinesque, 1815
Genus: *Theodoxus* Montfort, 1810
Theodoxus niloticus **(Reeve, 1856)**
(Pl. 2, Figs 11-13)

Brown, 1994: *Theodoxus niloticus* (Reeve, 1856): fig. 16 (b, c).

Description: The shell is small, obliquely ovate, and more or less turbinate. The color of the whorls of the spire is yellow, whereas the body whorl has alternatively patches of brown and pale yellow. Last whorl elongates with rounded and oblique dextral base. Spire is very short and the apical angle obtuse. The shell has three spirally coiled whorls, which are more rounded at the periphery and separated by a flush suture. The aperture is semicircular in outline. It takes exactly the shape of letter D. The aperture is limited by an outer delicate lip sloping down at a very acute angle to the columella. The shell is without umbilicus, so the inner lip or columellar margin is twisted. The sculpture includes more or less faint wavy oblique axial narrow stripes.

Habitat: live in fresh water and slowly flowing water in Northern Egypt, tolerant of some salinity and abundant in the extinct fauna of aquatic molluscs in the Fayum Depression (Gardner, 1932).

Occurrence: It is found in Al Dakhlah Island (1 specimen), Al-Gharbiyah Island (4 specimens), (Fig. 10).

Geographic distribution: *Theodoxus niloticus* inhabits along the River Nile and its tributaries from Lake Nasser (Southern Egypt) to Rosetta and Damietta branches (Northern Egypt). It is recorded In Ethiopia, The Blue Nile below Lake Tana and near Massawa (Brown, 1994). **Age**: Holocene.

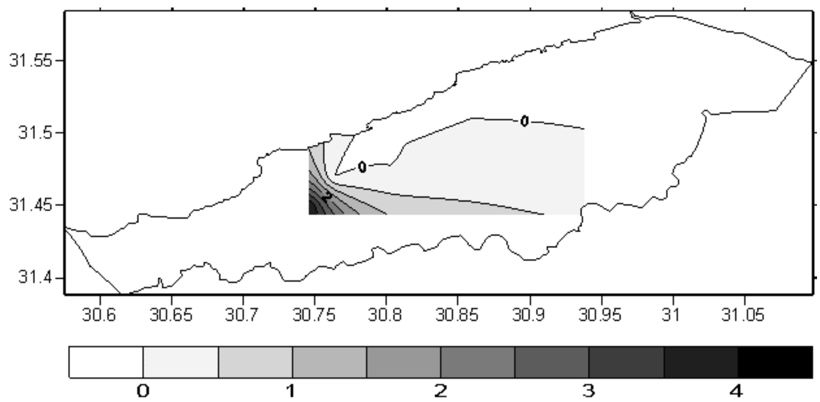


Fig. (10): The spatial distribution of *Theodoxus niloticus* recorded in the studied islands showing a spot in the west.

Order: Sorbeoconcha Ponder & Lindberg, 1997
Family: Thiaridae Troschel, 1857
Genus: *Melanoides* Olivier, 1804
Melanoides tuberculata **(Muller, 1774)**
(Pl. 2, Figs. 6-10)

Paz, et al., 1995 & Duggan, 2002: *Melanoides tuberculata* (Muller, 1774), fig. (2).

Description: The shell is small; ranging from 0.46 cm to 1.81 cm, thin, transparent. The shell is elongate and conical with regularly increasing whorl, typically seven in number, with Light brown color. The body whorl occupies one third of the shell. Aperture is oval with the nucleus near to the base. The sculpture is evenly distributed all over the whorl, being composed of weakly curved ribs and much finer spiral striations The surface is frequently mottled with rust colored spots.

Ontogenetic variations: *Melanoides tuberculata specimens* were counted in all the samples. The relationship between the heights of *Melanoides tuberculata* against its height of aperture is given in (Fig. 11). It is noticed that the growth relationship is isometric i.e. as the height increases the height of the aperture increases (proportional relationship). The rate of variation of the diameter of the aperture is proportionate with the rate of the shell height. However, the shell has a tendency to be high in the expense, of whorl width. Such perfect growth relation between the spire and the aperture is expressed in the line sloping by 45 degree (Fig. 11).

Habitat description: *Melanoides tuberculata* is typically found in freshwater, shallow slow running water (0.6-1.2m in depth), on a substrate consisting of soft mud, or soft mud and sand (Neck, 1985). Dundee and Paine (1999) reported areas rich in detritus and silt behind overhanging stems and protruding roots of bank vegetation.

Occurrence: *Melanoides tuberculata* is found in Al Dakhlah Island (60 specimens), Al-Gharbiyah Island (96 specimens), Al-Ghariq Al-Qibli Island (8 specimens), Fig. (12).

Geographic distribution: This species is native to a large part of Africa , the Mediterranean region (Schutt, 1983), and throughout India (Dutt & Bali 1980). It is also found in Southeast Asia (Brandt 1974), Malaysia, Arabian Peninsula (Brown and Wright 1980), southern China north to the Ryukyu Islands of Japan and south and east through the Pacific Islands to northern Australia and the New Hebrides (Pace 1973).

Age: Holocene.

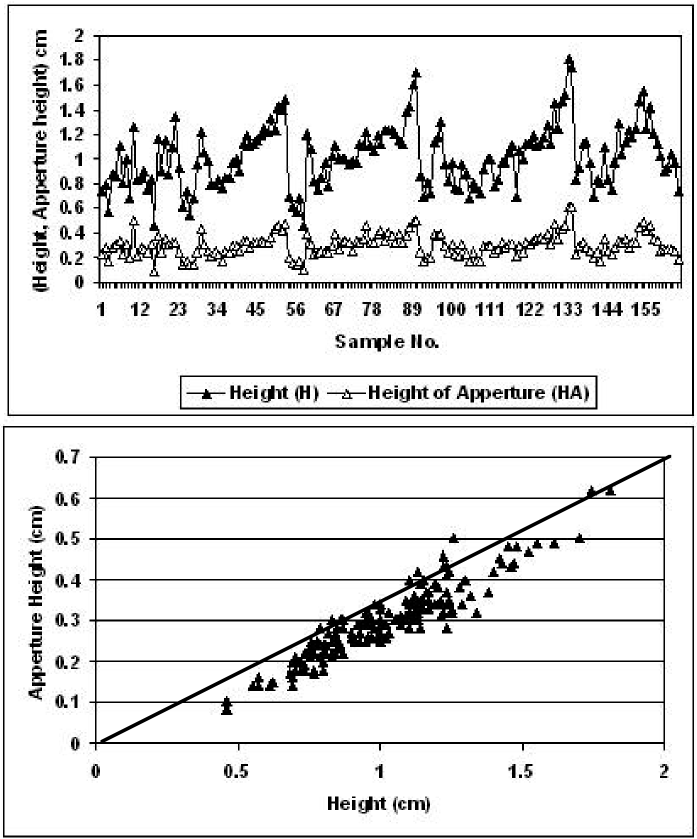


Fig. (11): Plots showing the relationship between height and aperture height of *Melanoides tuberculata* recorded in the studied islands.

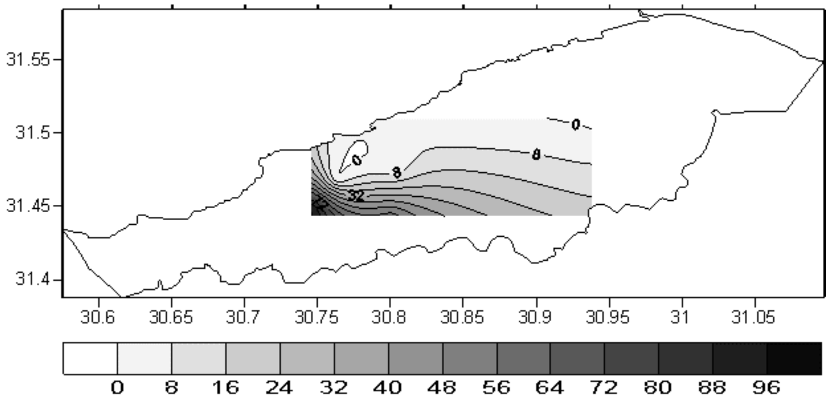


Fig. (12): The spatial distribution of *Melanoides tuberculata* in the studied islands.

Order: Caenogastropoda Ponder & Lindberg, 1997

Family: Cerithiidae Fleming, 1828

Genus: *Bittium* Gray, 1847

Bittium reticulatum **(Da Costa, 1778)**

(Pl. 2, Figs 1- 3)

Fish & Fish, 1996: *Bittium reticulatum* (Da Costa, 1778), fig. 136 (b).

Description: The shell is small, varying in size from 0.5 to up to 2 cm, turreted in shape with acute apical angle and rounded whorls .The body chamber occupies 25% of the spire. The aperture is siphostomatus. The sutures are depressed. The ornamentation is reticulate with slightly raised axial nodes.

Remarks: The described specimens have a rounded aperture related to slightly oval ones described by Da Costa (1778).

Ontogenetic variations: *Bittium reticulatum* specimens were counted in all the samples. The relationship between the height of *Bittium reticulatum* against its height of aperture is given in Fig. 13. It is noticed that the growth relationship is isometric i.e. as the height increases the height of the aperture increases (proportional relationship). Again, the growth is isometric. However, the rate of variation of the two-plotted attributes shows slight difference.

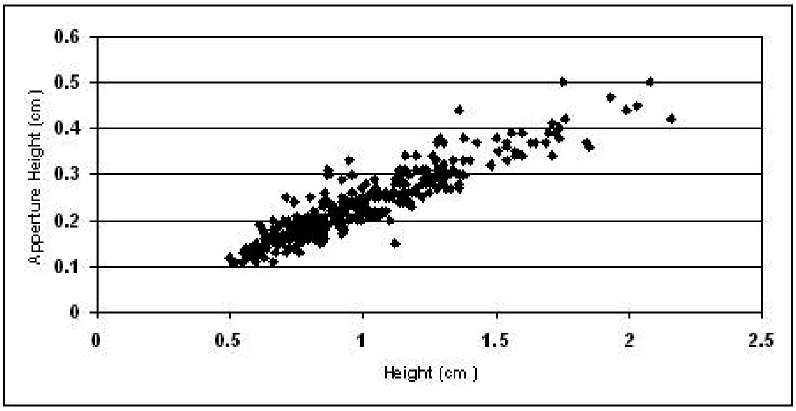


Fig. (13): Plots showing the relationship between the height of *Bittium reticulatum* and height of its aperture recorded in the studied islands.

Habitat: *Bittium reticulatum* was the most abundant species, being especially abundant in the sea grass habitat (Almeida et al. 2008). It is associated with sandy and muddy shores, and on rocks and stones.

Occurrence: *Bittium reticulatum* is found in Al Dakhlah Island (195 specimens), Al-Gharbiyah Island (38 specimens), Sinjar Island (8 specimens), Ibsak Island (63 specimens), Al-Ghariq Al-Qibli Island (20 specimens). It is noticed that this species has a wide distribution in the studied islands, (Fig. 14).

Geographic distribution: This species inhabits Atlantic coast of Europe (north of England) Mediterranean, Aegean, Marmara, Black and Azov Seas (Hayward, and Ryland, 1990).
Age: Holocene

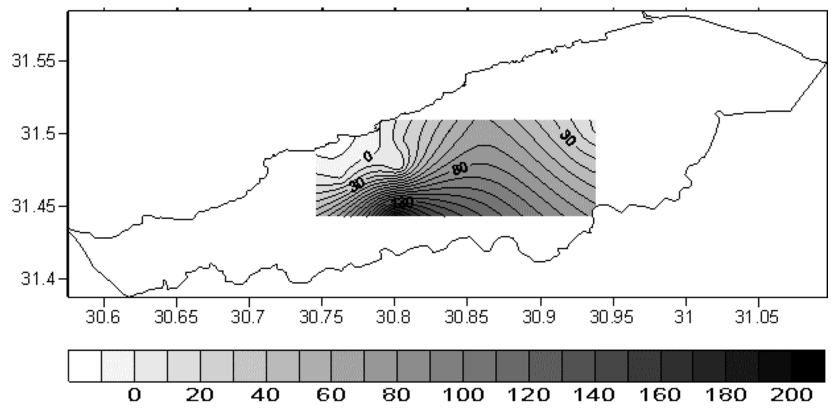


Fig. (14): The spatial distribution of *Bittium reticulatum* recorded in the studied islands showing a spot in the southwest.

Order: Sorbeoconcha Ponder & Lindberg, 1997
Family: Nassariidae Iredale, 1916
Genus: *Hinia* Leach, 1847
Hinia reticulata (Linnaeus, 1758)
(Pl. 2, Figs. 4- 5)

Fish, & Fish, 1996: Hinia reticulata (Linnaeus, 1758), fig. 153 (a).

Description: Creamy whelk, small size, trochoid with straight sided spine, body whorl half of the spire, apical angle acute, about 5 whorls, ornamentation reticulate with a raised axial one, become very feeble around the aperture with clear axial ornamentation, aperture oval with outer lip, inner lip extending over the body-whorl, siphon canal deep and at an oblique angle.

Habitat: Hinia reticulata is found in sedimentary areas of the lower rocky shore and on soft sediments, where it often buries itself and lives in brackish water.

Occurrence: It is found in Al Dakhlah Island (9 specimens), Aradat Al-Maqraah Island (1 specimen), Al-Gharbiyah Island (12 specimens), Sinjar Island (3 specimens), Ibsak Island (3 specimens), Al-Ghariq Al-Qibli Island (3 specimens).

Geographic distribution: Inhabits Azores, British Isles, Canaries, North East Atlantic, Norwegian Exclusive Economic Zone (Hayward, and Ryland, 1990), Belgian Exclusive Economic Zone (Eneman, 1984), Grevelingen, Wadden Sea (Leewis, 2002) and Sas van Goes (Annys, 1984). **Age:** Holocene.

DISCUSSION AND CONCLUSIONS

I- Environmental impact

a- Mixed environments:

This study shows the occurrence of marine, brackish and fresh molluscan species. The brackish species are dominant in most of the studied islands (Fig. 3). Moreover, the marine molluscan species are dominant in Al Dakhlah and Ibsak islands, whereas the fresh molluscan species occur in Al- Gharbiyah Island. It is worthy to mention that in the lithologic log of Al- Gharbiyah Island, the brackish Molluscan fauna occupy its lower part, whereas its upper part is occupied by the fresh species (Fig. 2). Bernasconi and Stanley, 1994 used the Molluscan fauna to deduce the paleoenvironmental and paleobathymetrical interpretations of the Nile Delta during the past 7500 years. They found that there is a variation in the molluscan fauna content in the Nile Delta Holocene coarsening upward sequence i.e., from lower prodelta and delta front lithofacies to upper coastal and lagoon lithofacies.

A summary of distribution, habitat and environment of the identified species are given in table (3)

Table (3): Summary of the distribution and habitat of the mollusks.

Macrofauna	Habitat & ecology	Islands
Ostrea edulis	Muddy areas – marine water	Al-Dakhlah, Al-Gharbiyah & Al-
Cerastoderma glaucum	Soft sediments – brackish water	All
Abra ovata	Soft grounds cover with silt and sand – brackish lagoons	Al-Dakhlah & Al-Gharbiyah
Corbicula fluminalis	Fresh water	Al-Dakhlah & Al-Gharbiyah
Theodoxus niloticus	Fresh water (River Nile)	Al-Dakhlah & Al-Gharbiyah
Melanoides tuberculata	Soft mud and sand – fresh water	Al-Dakhlah, Al-Gharbiyah & Al-Ghariq Al-Qibli
Bittium reticulatum	Sandy & muddy shores – marine water	All except Az-Zanqah & Aradat Al-Maqraah
Hinia reticulata	Soft sediments – brackish water	All except Az-Zanqah

b- Facies control and faunal distribution

The distribution of the fossils in any water body depends on its salinity, temperature, water depth, chemical composition and nutrients. To some extent, the facies, the chemistry of the water body and the sediments affect the distribution of the molluscan species encountered in the studied islands. The sediment components of the studied islands play an important role in distribution of the Molluscan species (Table 6).

Table (4): List of eight of Molluscan species retrieved from the studied islands. Numbers of specimens recorded for each species in the 33 samples refers to actual specimen counts.

Name of Species		Name of Island / Name of Sample																						
		Al Dakhlah						Aradat Al-Maqraah		Al-Gharbiyah								Az-Zanqah	Sinjar	Ibsak				Al-Ghariq Al-Qibli
		D3	D4	D5	W	V	T	m2	m3	GH2	GH3	GH4	GH5	GH6	GH7	B	GH 9	J	S6	I2	I3	I9	I10	AI3
Bivalves	Ostrea edulis	–	15	15	–	–	–	–	–	8	–	–	5	2	3	–	–	–	–	–	–	–	–	4
	Cerastoderma glaucum	–	40	56	1	–	1	2	7	27	100	–	–	6	19	6	18	1	4	11	34	26	62	77
	Abra ovata	–	–	2	1	–	–	–	–	–	13	–	–	–	1	–	–	–	–	–	–	–	–	–
	Corbicula fluminalis	–	1	2	–	–	–	–	–	2	–	–	13	3	3	–	–	–	–	–	–	–	–	3
Gastropodes	Theodoxus niloticus	–	1	–	–	–	–	–	–	–	–	1	3	–	–	–	–	–	–	–	–	–	–	–
	Melanoides tuberculata	3	21	29	7	–	–	–	–	30	7	–	37	4	18	–	–	–	–	–	–	–	–	8
	Bittium reticulatum	4	66	114	9	1	1	–	–	18	10	–	–	4	4	2	–	–	8	3	30	12	18	20
	Hinia reticulata	–	–	9	–	–	–	1	–	6	2	1	1	–	1	1	–	–	3		5		3	3

Table (5): Vertical distribution of Molluscan species retrieved from the T2 of Al-Gharbiyah Island and C1 in the Al-Dakhlah Island.

Island		Bivalves				Gastropods			
		Ostrea edulis	Cerastoderma glaucum	Abra ovata	Corbicula fluminalis	Theodoxus niloticus	Melanoides tuberculata	Bittium reticulatum	Hinia reticulata
Al-Gharbiyah	GH4	-	-	-	-	1	-	-	1
	GH5	5	-	-	13	3	37	-	1
	GH6	2	6	-	3	-	4	4	
	GH7	3	19	1	3	-	18	4	1
Al-Dakhlah	W	-	1	1	-	-	7	9	-
	V	-	-	-	-	-	-	1	-
	T	-	1	-	-	-	-	1	-

Al Kom-Al Akhdar Island is barren in fauna, as it is composed mainly of sand. In addition, the other islands such as Aradat Al-Maqraah and Az –Zanqah islands contain a little amount of mollusc due to the dominance of the sands. Scarcity of fauna could also be due to the low percentage of the carbonates, mud and total dissolved salts as reported from the (Hayward, and Ryland, 1990), Aradat Al-Maqraah, Az-Zanqah, Sinjar and Ibsak islands. Macrofossils are only found in the muddy facies for which three varieties could be differentiated in the studied islands. They are:

B1- Mud facies: These include sediments with high percentages of mud over than 69% are reported in Az-Zanqah and Sinjar islands. They contain a relatively low percentage of total dissolved salts and fresh water Molluscan species dominate this facies.

B2- Salty mud facies: This mud facies contains a high percentage of total dissolved salts up to an average of 25% associated with high amounts of carbonates, dominated by marine Molluscan fauna tolerant of high salinity as reported in the Al Dakhlah Island.

B3- Calcareous mud and carbonate facies: This is a high diversity facies,(Table 5) mainly composed of a large amount of carbonates resulting from a large accumulation of shells adapted to live in salt-water as reported in the Al-Gharbiyah, Al Dakhlah, Ibsak and Al-Ghariq Al-Qibli Islands.

II- Chemistry of molluscan shells :

Nine trace elements are determined for six samples representing the shells of four Molluscan species (Table 7). The concentration of Ni (range; 4-8 ppm), Rb (range; 3-10 ppm), V (range; 2-9 ppm), Cu (range; 15-20 ppm), Zn (range; 12-25 ppm) and Cr (range; 10-28 ppm) is low. The concentration of Zr (range;

28-52 ppm) and Ba (range; 23-98 ppm) are moderate. The concentration of Sr is high and ranges between 1181 ppm (shells of *Bittium reticulatum*) and 2183 ppm (shells of *Cerastoderma glaucum*). Such high variation in Sr values may reflect the different salinity regime in the El Burullus Lagoon (Nossier, 1986). A combined strontium isotopic ($^{87}Sr/^{86}Sr$) and paleontological method is applied to a modern lagoon in Egypt's Nile River delta to test its applicability as a paleosalinity proxy (Reinhardt et al., 1998). It is worthy to mention that the contents of most trace elements are lower in the shells (Table 6) than those recorded in the sediments of the studied islands. However, the Sr content in the Molluscan fauna is higher than that reported in the sediments. A comparison between the most abundant elements in the shells and those of the sediments of the islands is given in Fig. (15). Such comparison reveals a proportional relationship.

Table (6): The relationship between the facies and distribution of the molluscan species in the studied islands.

Island	Carbonate %	Sand %	Mud %	TDS %	OM %	Bivalves				Gastropods			
						O. edulis	C. glaucum	A. ovata	C. fluminalis	T. niloticus	M. tuberculata	B. reticulatum	H. reticulata
Al Dakhlah	13.67	2.82	54.35	25.50	3.67	■	■	■	■	■	■	■	■
Aradat Al-Maqraah	37.5	39.80	9.20	10.00	3.50		■						■
Al-Gharbiyah	37.83	0.41	42.01	13.83	5.92	■	■	■	■	■	■	■	■
Az-Zanqah	5.75	9.84	69.95	8.83	5.63		■						
Sinjar	6.19	3.33	70.41	15.84	4.23		■					■	■
Ibsak	30.40	7.41	51.76	4.37	6.06		■					■	■
Al-Ghariq Al-Qibli	74.37	1.54	14.75	6.24	3.10	■	■		■		■	■	■

TDS: Total Dissolved Salts, OM: Organic Matter, *O. edulis: Ostrea edulis, C. glaucum: Cerastoderma glaucum, A. ovata: Abra ovata, C. fluminalis: Corbicula fluminalis, T. niloticus: Theodoxus niloticus, M. tuberculata: Melanoides tuberculata, B. reticulatum: Bittium reticulatum and H. reticulata: Hinia reticulata*

Table (7): Trace elements in shells of some molluscan species found in the sediments of the studied islands.

Island	Sample No.	Species	Trace elements (ppm)								
			Cr	Ni	Cu	Zn	Zr	Rb	Ba	Sr	V
Al Dakhlah	D 4	*Bittium reticulatum*	20	7	17	19	37	7	47	1414	6
	D 5	*Cerastoderma glaucum*	11	5	16	12	41	7	43	1924	u.d
		Melanoides tuberculata	28	8	20	25	52	6	98	1639	9
Al-Gharbiyah	GH 2	*Cerastoderma glaucum*	14	6	15	12	46	3	63	2183	u.d
		Ostrea edulis	12	6	16	16	32	8	57	1133	6
Ibsak	I10	*Cerastoderma glaucum*	10	u.d	16	13	39	6	23	1823	2
	I3	*Bittium reticulatum*	16	5	19	17	37	10	50	1181	7

(u.d): means under detection limit which is 2 ppm

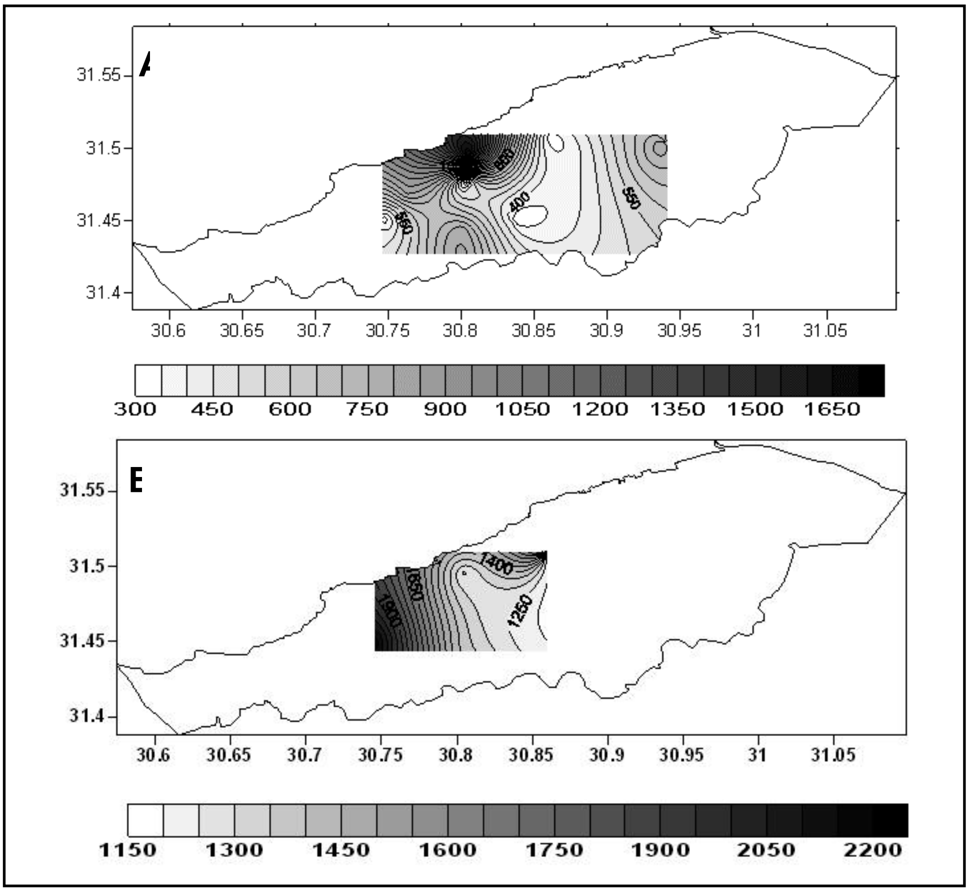


Fig. (15): (A): The spatial distribution of Sr content in sediments and **(B):** The spatial distribution of Sr content in shells in the studied islands.

Explanation of Plate 1 (Bivalves)

Figs. (1 - 2) : *Cerastoderma glaucum* (Poiret, 1789).

Fig. 1 : Al-Ghariq Al-Qibli Island, trench 1, Al3, brackish, Holocene, 0.78 X.

Fig. 2: Al-Ghariq Al-Qibli Island, trench 1, Al3, brackish, Holocene, 0.79 X.

Figs. (3 - 4) : *Corbicula fluminalis* (Müller, 1774).

Fig. 3 : Al-Gharbiyah Island, trench 2, GH5, freshwater, Holocene, 0.78 X.

Fig. 4 : Al-Gharbiyah Island, trench 2, GH5, freshwater, Holocene, 0.78 X.

Figs. (5 - 7) : *Abra ovata* Philippi, 1893.

Fig. 5: Al-Gharbiyah Island, trench 1, GH3, brackish, Holocene, 0.78 X.

Fig. 6: Al-Gharbiyah Island, trench 1, GH3, brackish, Holocene, 0.78 X.

Fig. 7: Al-Gharbiyah Island, trench 1, GH3, brackish, Holocene, 0.78 X.

Figs. (10-16) : *Ostrea edulis* Linnaeus, 1758.

Fig. 8: Al-Gharbiyah Island, trench 2, GH5, marine, Holocene, 1.4 X.

Fig. 9: Al-Gharbiyah Island, trench 2, GH5, marine, Holocene, 1.04 X.

Fig. 10: Al Dakhlah Island, trench 2, D5, marine, Holocene, 1 X.

Fig. 11: Al-Gharbiyah Island, trench 2, GH5, marine, Holocene, 1.07 X.

Fig. 12: Al Dakhlah Island, trench 2, D4, marine, Holocene, 1.4 X.

Fig. 13: Al Dakhlah Island, trench 2, D5, marine, Holocene, 1.14 X.

Explanation of Plate 2 (Gastropods)

Figs. (1-3) : *Bittium reticulatum* (Da Costa, 1778).

Fig. 1: Al Dakhlah Island, trench 2, D5, marine, Holocene, 1.6 X.

Fig. 2: Al Dakhlah Island, trench 2, D5, marine, Holocene, 1.6 X.

Fig. 3: Al Dakhlah Island, trench 2, D5, marine, Holocene, 1.5 X.

Figs. (4-5) : *Hinia reticulata* (Linnaeus, 1758).

Fig. 4: Sinjar Island, core 1, S6, brackish, Holocene, 1.7 X.

Fig. 5: Al Dakhlah Island, trench 2, D5, brackish, Holocene, 1.9 X.

Figs. (6-10): *Melanoides tuberculata* (Müller, 1774).

Fig. 6: Al-Gharbiyah Island, trench 1, GH2, freshwater, Holocene, 1.8 X.

Fig. 7: Al-Gharbiyah Island, trench 1, GH2, freshwater, Holocene, 1.9 X.

Fig. 8: Al-Gharbiyah Island, trench 1, GH2, freshwater, Holocene, 1.9 X.

Fig. 9: Al-Gharbiyah Island, trench 1, GH2, freshwater, Holocene, 1.7 X.

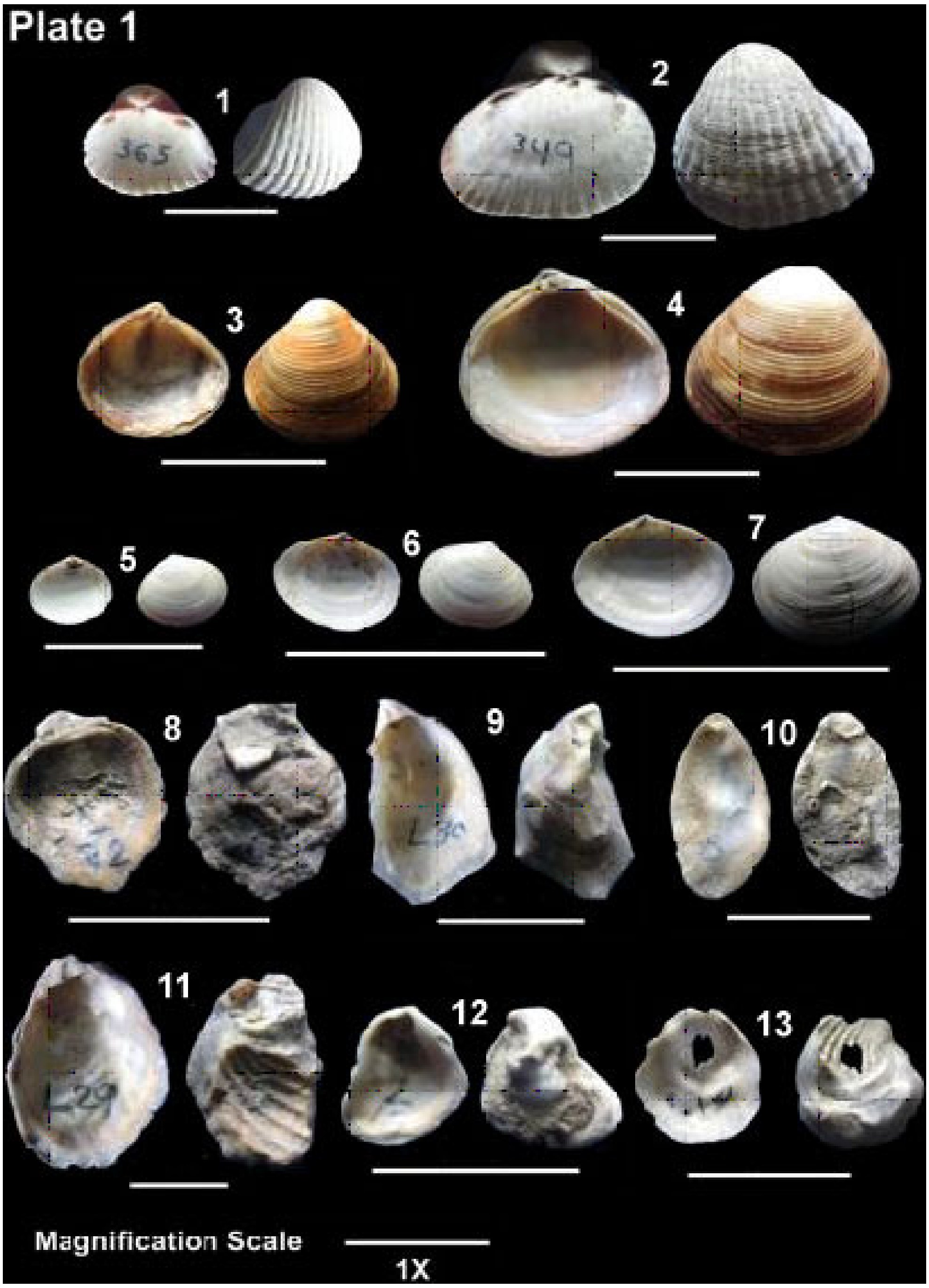
Fig. 10: Al-Gharbiyah Island, trench 1, GH2, freshwater, Holocene, 1.6 X.

Figs. (11-13): *Theodoxus (Neritaea) niloticus* (Reeve, 1856).

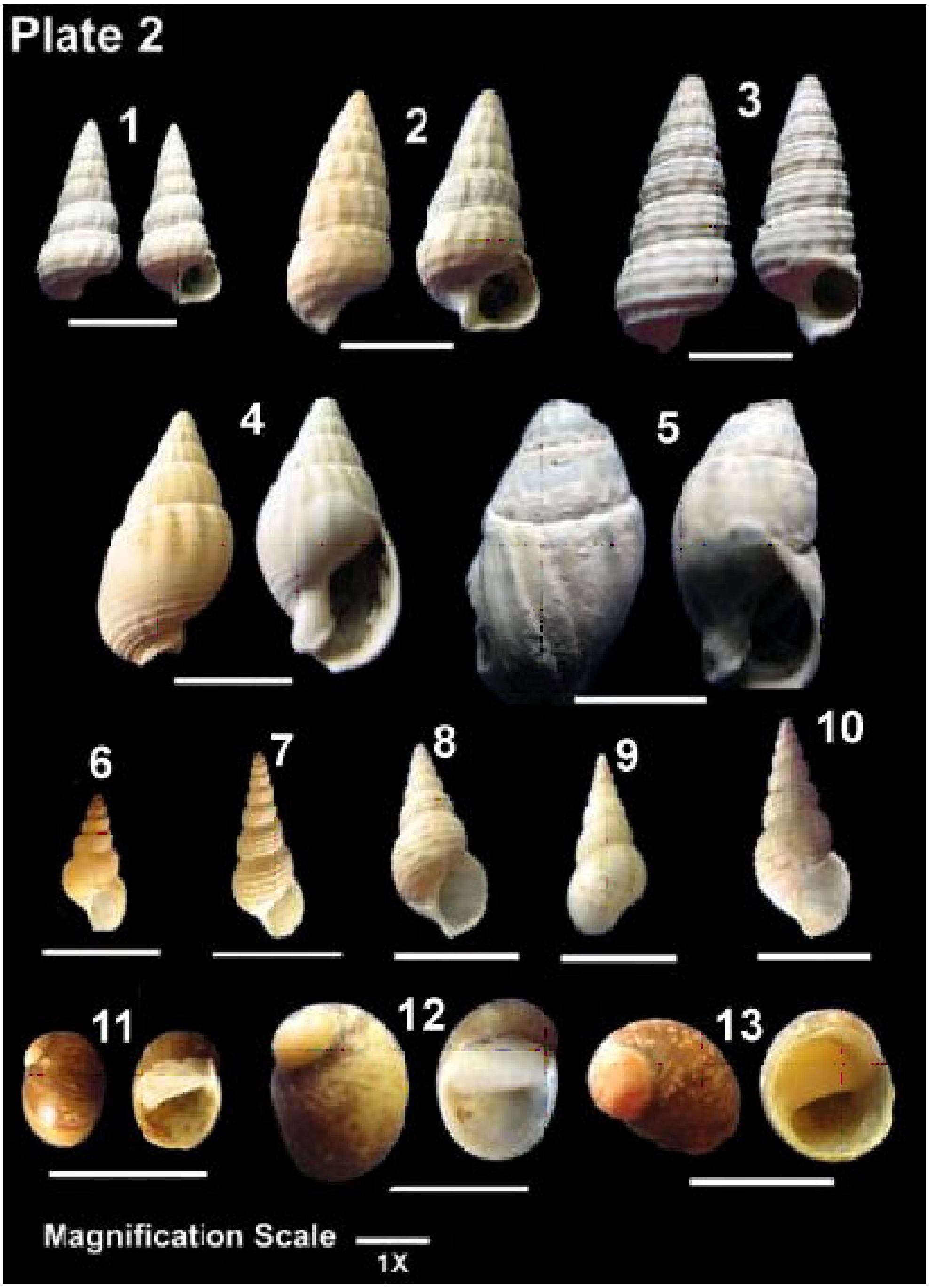
Fig. 11: Al-Gharbiyah Island, trench 2, GH5, freshwater, Holocene, 2.3 X.

Fig. 12: Al-Gharbiyah Island, trench 2, GH5, freshwater, Holocene, 2.1 X.

Fig. 13: Al-Gharbiyah Island, trench 2, GH5, freshwater, Holocene, 2.1 X.



1-2: *Cerastoderma glaucum*, **3-4:** *Corbicula fluminalis*, **5-7:** *Abra ovata* and **8-13:** *Ostrea edulis*] [1X = normal size].



1-3: *Bittium reticulatum*, **4-5:** *Hinia reticulata*, **6-10:** *Melanoides tuberculata* and **11-13:** *Theodoxus (Neritaea) niloticus]* [1X = normal size].

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الملخص العربى

الوضـع التصنيفى وتغـيرات أصـداف الرخويــات والأثــر البيئى لجـزر بحيرة البرلس بشمال دلتــا نهــر النيل بمصــر

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يتناول البحث تتبع مراحل نمو، وتقسيم أصداف الرخويات، التى جمعت من ثلاث وعشرين عينة لبية وسطحية من بحيرة البرلس، ودراسة البيئات المختلفة لتلك الأصداف، وقد تم التعرف على ثمان أنواع : أربعة منها تتبع المحار، وأربعة أخرى تتبع البطنقدميات، هذا وقد صنفت تلك الأنواع، وأجريت عليها قياسات لأبعاد تلك الأصناف وتمثيلها بيانياً بهدف تمام وصفها ودراسة كيفية نموها، وحول نشأة تلك الأصداف فقد تم إستنتاج أن منها ماكان يعيش فى المياه البحرية العذبة نتيجة تأثير مياه نهر النيل قديماً وحديثاً، ومنها مايعيش فى المياه المويلحة، ومنها ماكان يعيش فى المياه البحرية المالحة التى دخلت واستعمرت بحيرة البرلس فى وقت ماض. كما درست العلاقة بين توزيع الأنواع المعرفة وسحنات رواسب بحيرة المنزلة، وتم تحليل العناصرة النادرة المكونة لأصداف الرخويات وعلاقتها بمكونات العناصر النادرة فى رواسب البحيرة، وقد ساهمت الدراسة لحد ما فى فهم أصل بحيرة البرلس.

JOESE 5

SYSTEMATIC, ONTOGENETIC VARIATIONS, POPULATION OF MOLLUSCAN FAUNA AND THEIR ENVIRONMENTAL IMPACT ON THE ISLANDS OF THE EL BURULLUS LAGOON, NORTH NILE DELTA, EGYPT

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