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STUDY OF MOLLUSCAN SHELLS AND THEIR ENCLOSED BOTTOM SEDIMENTS IN MANZALA LAGOON, NILE DELTA, EGYPT

BY

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ABSTRACT

Manzala lagoon is in grave danger of suffering irrecoverable loss of ecosystem quality, largely as a result of over-exploitation and land-use changes and modifications to catchments hydrology. Knowledge of the environmental processes involved. in regulating these lagoonal systems together with an understanding of how Manzala lagoon interact can make a valuable contribution to management and to the development of future mitigation strategies. In order to make a constructive contribution to future management plans and policies, several essential lines of research need to be instigated particularly microfaunal study.

The Present study deals with the study of bottom sediments and molluscan shells in Manzala Lagoon. This study revealed that the Manzala Lagoon sediments show a general coarsening trend at the northern side and the western corners of the Lagoon; this is due to the movement of terrestrial materials of sand from sea toward the lagoon. The general picture of the bottom fauna is the empty shells of mollusca. Most of the molluscs are of marine origin, which are derived to the lagoon from the Mediterranean Sea. The fresh water molluscs invaded the lagoon from the southern drains. The shell wall structure of molluscan shells revealed that the composite prismatic structure characterizes class Gastropoda, while the foliated and cross foliated structure characterize class Bivalvia.

INTRODUCTION

Coastal lagoons occupy as much as 13% of the world's coastlines. Beside their importance for fisheries they could be used as fishing harbors and recreational areas. Their chemistry is a combination of land and marine derived materials. The sensitivity of these specific water structures to pollutants mainly rely on their flushing period and retention time of pollutants in the water system. The northern delta lakes in Egypt constituted a proximate reservoir for fresh and brackish waters discharged to the Mediterranean. They are the sites of the last Egyptian use of drain and agricultural waters. These lakes produce more than 50% of the total fish landings in Egypt.

Because the coastal lagoons of Egypt generally occur at the termini of terrestrial drainage systems as well as at the margin of the marine coastal system, they constitute a finely balanced ecotonal environment. In such environments, the ecological effects of small inter-annual fluctuations in salinity and other natural variables can be exacerbated by land-use activities and climate change and transformed into major environmental change trends.

These trends are now underway at virtually all coastal water resources and yet, at the aquatic ecosystem level of organization, they are largely unrecognized and poorly monitored. Hence a major attribute of this study is to establish reliable spatially data concerning microfauna changes over more than one year at Manzala lagoon.

Manzala lagoon is the largest of the northern Nile Delta coastal lagoons. It occupies the region between Damietta branch of the Nile to the west, and Suez Canal and Port Said to the east (Fig. 1). It is an important and valuable natural resource area for fish catch, wildlife, hydrologic and biologic regime and table salt production. It produces about 50 percent of the fish catch of the northern coastal lagoons and fresh water fisheries.

Manzala Lagoon is characterized by special sensitive environments. Human activities including discharge of sewage and industrial wastes and the impact of canal and road networks have a serious impact on the Lagoon. Image processing techniques as enhancements were applied to help the identification and discrimination of the different features and classes in and around the Lagoon. In the present study, a multi-temporal data sets of images, topographic maps and tabular data supported by field checks have been analyzed by GIS functions and operations to asses, monitor and model the environmental conditions of the Manzala Lagoon. The impacts of the natural and human activities play a key role in changing the morphological features of the lagoon such as the spit systems, beach ridges, water body, etc. One of the serious changes is its change from a connected water body to semi-closed sub-basins. Landuse/Land cover of the area surrounding the lake has undergone a considerable land transformation especially after the construction of Al-Salaam canal, Ahmed *et al.* (2000).

The present study aims to identify the micro faunal species and studying shell wall microstructures in the bottom sediment of Manzala lagoon. Besides the main sediment physical and chemical characteristics such as grain size, organic carbon and carbonate contents. This can help to develop a tool to aid in understanding the future management of Manzala Lagoon. This Lagoon has been aching from a wide variety of natural and human impacts.

Bernasconit and Stanely, (1994) defines molluscan assemblages and interprets their origin in modern and Holocene lagoon deposits in the northern Nile delta of Egypt. Special attention is paid herein to Mariut, Idku, Burullus and Manzala, the four brackish water bodies of variable size which cover a large area of the lower delta plain.

The study of the shell wall structure of the molluscan shells was recently dealt with in detail by several authors, with the aim of solving problems concerned with the systematic position, physiology and ecology. Dodd (1964) mentioned that the shells of Mytilus californianus is composed of four layers, namely, periostracum, nacreous and outer and inner prismatic layers. Hudson (1967), concluded that recent molluscan shells of nacro-prismatic structure normally contain more organic fractions than the fossil molluscan shells. Kennedy et al. (1970) concluded that the shell wall structure of super family Chamacea, is composed of an outer crossed-lamellar and inner complex crossed-lamellar layers. Maslov (1973) indicated that the shells of Mytilus edulis consist of an external prismatic calcite and an internal nacreous aragonite. Abdalla Hegab (1982) indicated that the outer shell layer of the recent shells of genus Modiolus consists of aragonitic nacreous structure, while the internal layer consists of calcitic prismatic structure. Abdalla Hegab (1983) mentioned that the presence of aragonitic structure in shell wall of the Red Sea Quaternary gastropods is probably related to the water temperature or to exogenic factor. Abdel Aal (1983) indicated that the shells of Ostrea edulis and Chlamys varia are composed of foliated calcite. Abdel Aal and Frihy (1984) indicated that the shells of Pinctada radiate consist of an external calcitic prismatic layer and an internal aragonitic nacreous layer. Abdel Aal and Hasan (1988) concluded that the species of family Muricidae and family Strombidae are consisting of two or three layers of the following structural types: prismatic, composite prismatic and nacreous. Abdel Aal (1988) concluded that the shell wall structure of the fresh-water species Corbicula (Corbiculina) angasi is composed of an external calcitic prismatic layer and an internal aragointic nacreous layer. Ebaid Alla (1988) concluded that the shells of Anadara antiquata are composed of aragontic complex cross lamellar and the shells of Tellina rugosa are composed of alternating cross lamellar aragointic structure. Abdel Aal (1991) indicated that the Cretaceous and Eocene oyster shells are composed of crossed-lamellar and complex crossed-lamellar structure, while the Miocene up to recent oyster shells are composed of foliated calcite. Marei (2003) indicated that the Upper Cretaceous Oscillopha dichotoma and Curvostrea heinzi are composed of regularly foliated and cross-foliated layers.

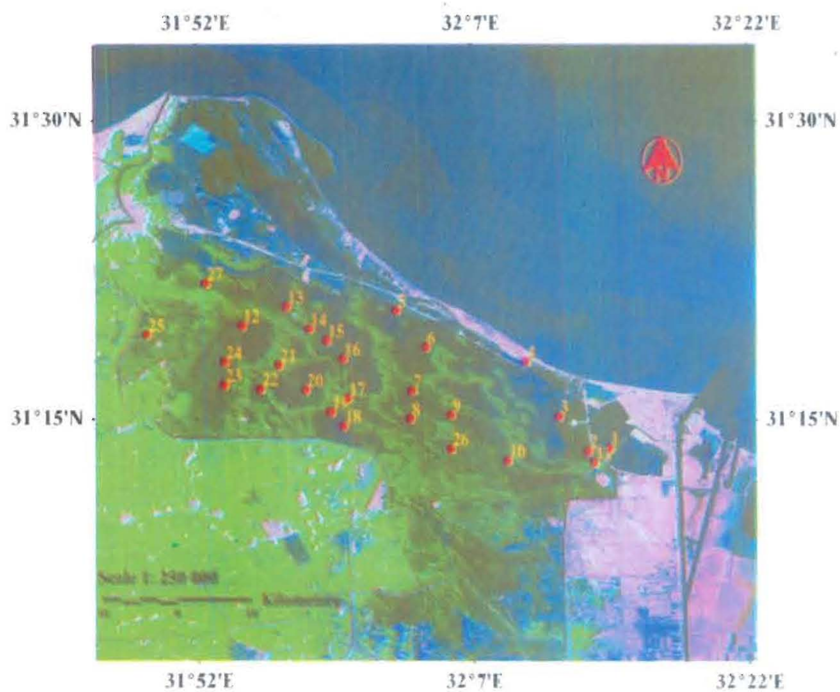

Fig.1: The study area of Manzala Lagoon showing the locations of samples

MATERIAL AND METHODS

Sampling

Twenty seven surface sediment samples were collected at Manzala Lagoon during April 2003. The Lagoon survey team undertook a programme of water and sediment sampling throughout the Lagoon. The geographic positions of these samples were determined using GPS and at the same time information about the water depth and quality were collected.

The dataset of collected samples are geographically distributed as shown in (Fig. 1). Depending on the nature of the surface sediment, two sediment samples were collected using Petersen grab. Sample (A) was weighed and passed through two sieves (5 and 0.2 mm) and biological remains identified, counted and collected into labelled bags. Where difficulties occur in identifying species in the field, taxa were coded and returned (in 10% isopropyl alcohol) to the laboratory for determination. Sample (B) was placed in a labelled bag for laboratory analysis. Sediment samples were divided into several sub-samples for later laboratory analyses for sediment texture, organic carbon, and carbonates contents.

Each individual sediment sample was treated separately for grain size analysis using standard sieve and pipette techniques. Mean grain size was calculated using the graphical method adopted by Folk and Ward (1957). The total organic carbon content was obtained as percentage loss of weight of the dried sediment sample after ignition 550°C. The followed ignition loss procedure is that described by Dean (1974). The total carbonate of the sediment samples was determined by the technique of Molnia (1974). Duplicate analysis for organic carbon and total carbonate percent showed a precision of 0.2%.

Faunal Analysis

A total of 27 bulk samples were examined in the present study. All surfacial sediment samples were kept in 4°C at freeze. Faunal components were separated from the terrigenous fraction using a 2 mm sieve. With respect to molluscan material separated from these surfacial samples, this study focuses on the Gastropoda and Bivalvia because of their higher proportions in most samples. The faunal analysis is divided into two main parts; 1) Species identification and 2) Shell wall microstructures.

RESUL TS AND DISCUSSIONS

1- Mean grain size (Mz):

The geographical distribution of the mean grain size (Mz) is illustrated in (Fig. 2), the texture distribution revealed that the sediments consist of strongly polymodal mixture of fine sand and silt. Mean grain size (Mz) ranged from a minimum of 4.93φ to a maximum of 8.21φ with an average value of 5.32φ. The pattern distribution ofMz in the Manzala lagoon sediments shows a general coarsening trend at the northern side whereas the sand islands were found and the western corners of the lagoon; this is due to the movement of sand from sea toward the lagoon.

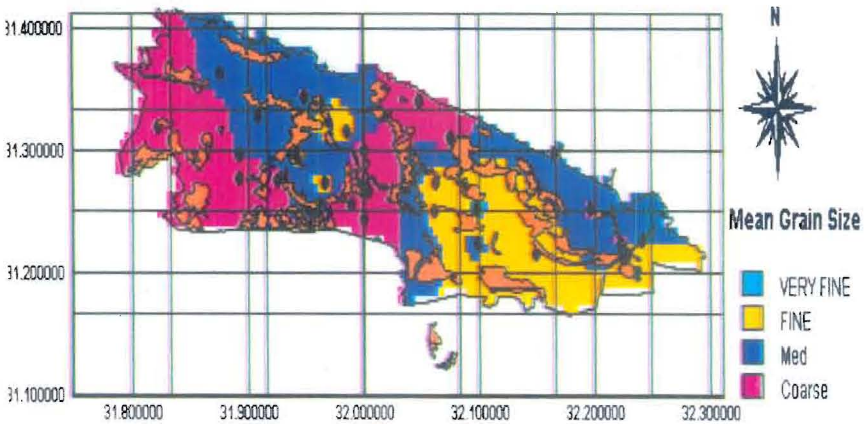

Fig. 2: The spatial distribution of mean grain size of bottom sediments ofManzala lagoon.

2- Total carbonates (TCO_3):

The total carbonate content (TC03) is certainly the most important environmental factor and one of the equilibria systems in the marine environment. It plays an important role in constructing the shells in all species. The weight percentages of acid soluble material ($CaCO_3$) in bottom sediments of the Manzala lagoon were found to vary from about (30.7-92.1%). The geographical distribution of total carbonate percentages (TCO_3) in Manzala lagoon is presented in (Fig. 3). Low concentrations of (TCO_3) ranged between (30%-45%) were recorded at the northern side in small patches, and closed to Bagdady outlet. Dominated carbonate percent ranged between (60%-75%) was recorded to cover most of bottom sediments of the lagoon.

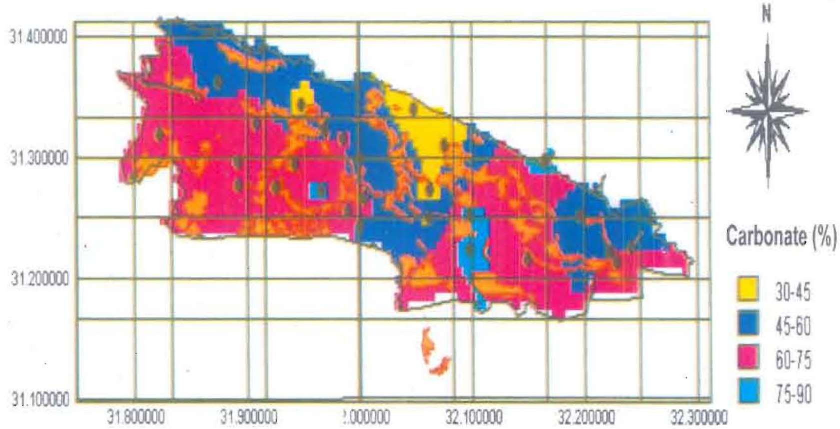

Fig.3: The spatial distribution of carbonate percent of bottom sediments of Manzala lagoon.

3- Organic Matter (OM):

The organic matter in sediments can be quantified as total organic compound (TOC) and it plays an important role in the accumulation and release of pollutants in lagoon water, also it is a source of nutrient for the living fauna in the lagoon. For this reasons, it is important to have a clear picture about the distribution of the organic matter on bottom sediments in the Manzala lagoon.

Distribution of organic matter concentrations in the original sediment samples has been illustrated in (Fig 4). The descriptive statistics of organic matter (OM) showed that the minimum concentration value 3.69% found at station no. 18 is located at the far southern side of the lagoon, while the maximum concentration 31.86% is recorded at station 12 at the north western side of the lagoon, with overall mean value of about 12.17%.

It is clear from the distribution of the organic matter concentration in the Manzala lagoon that there exist two remarkable areas; the organic matter concentration areas were represented in the southern and western side of the lagoon (cyan color) because of the drainage water that entering the lagoon from the south, while very rare patches of high organic carbon content (blue color) was found in the middle area of the lagoon at El-Rawda area due to abuse of aquatic plants for fishing by firing the plants. Moderate organic matter concentration areas (yellow color) were dominated along the northern and eastern side area of the lagoon as well were closed to seawater outlets which is considered as a source of nutrients for the aquatic resources in the seawater.

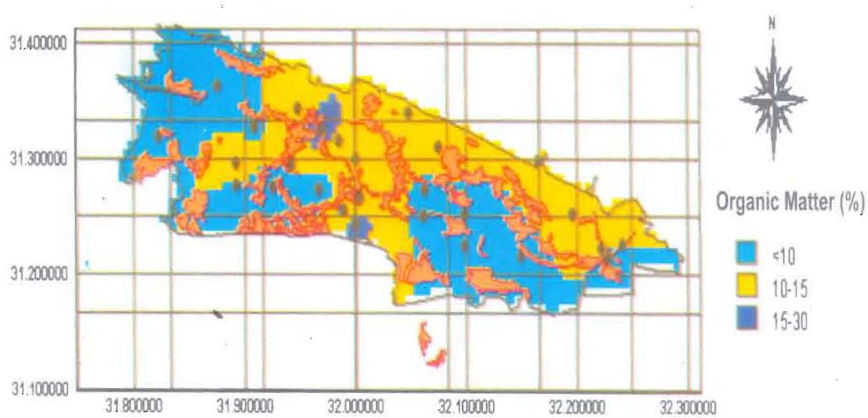

Fig. 4: The spatial distribution of organic matter content of bottom sediments of Manzala lagoon.

4- Species Identification:

The present work deals with the identification, distribution, and ecology of molluscan shells collected form twenty-seven stations covering Manzala Lagoon. Thirty species of class Bivalvia and twenty-six species of class Gastropoda were identified and the number of specimens in each taxon is counted. The classification of Bivalvia is mainly introduced by Moore et al (1969), while the classification of Gastropoda is mainly introduced by Moore et al (1960). Results of the species identification are shown in Tables (1 and 2), and presented in Figs (5 and 6).

Molluscan shells indicate that Manzala is fresh water influenced lagoon, and also records greatest incursion of marine waters via its outlet. Modern Nile delta molluscan biofacios comprise a somewhat larger proportion of freshwater species than in many other Mediterranean lagoons. This is largely a function of important River Nile water discharge and consequent relatively low salinity. Delta projects have considerably reduced the size of Nile delta lagoons, and this presently results in a proportionally higher fresh-water input in these water bodies, Bernasconit and Stanely, (1994; 1997).

5- Shell Wall Microstructure :

Forty thin sections were prepared across the different parts of the studied species was examined under microscope. The shell wall structure revealed the following:

a. The shell wall structure of Bivalvia:

1) Corbicula (Corbicula) angasi (p1. I, Fig.1): Is composed of two layers; the external is calcitic prismatic, while the internal is aragonitic nacreous layer.

2) Circe scripata (p1. I, Fig .2): Is composed of two layers; the external is aragonitic nacreous, while the internal is calcitic prismatic.

3) Acanthocardia tuberculata (p1. I, Fig .3): Is composed of cross foliated aragonitic structure.

4) Cardium edule (p1. I, Fig .4): Is composed of cross foliated aragonitic structure.

5) Arca noae (p1. I, Fig.5): Is composed of two layers; an external foliated aragonitic layer and an internal cross foliated layer.

6) Tellina rugosa (p1. II, Fig.1): Is composed of two layers; an external foliated aragonitic layer and an internal cross-lamellar layer.

7) Glycymeris (Glycymeris) glycymeris (p1. II, Fig.2) Is composed of cross lamellar structure.

8) Lima (Lima) lima (p1. II, Fig.3): Is composed of foliated aragonite with lenticular chambers. The lenticular chambers are hollow cavities of lenticular outline surrounded

by normal shell material. These chambers are originally empty or filled with chalky deposits.

9) Barbatia barbata (pl. II, Fig.4): Is composed of foliated aragonitic with elongated lenticular chamber.

10) Nucula (Nucula) nucleus (pl.III,Fig.1): Is composed of complex cross lamellar structure separated by organic material.

11) Ostrea edulis (pl. III, Fig.2): Is composed of foliated aragonitic with organic material

b. The shell wall structure of Gastropoda:

1) Helix sp. (pl. III, Fig.3): Is composed of three layers: an external and an internal nacreous (aragonitic) layers, while the middle layer is formed of aragonitic composite prismatic structure making an angle of about 60°-75° with the shell surface

2) Vulgocerithium vulgatum (pl. III, Fig.4): Is composed of three layers; the external layer is formed of long prismatic structure, the internal layer is formed of nearly equal length prisms, while the middle layer is formed of aragonitic nacreous type of lenticular shape.

3) Terebra crenulata (pl. III, Fig.5): Is composed of two layers: an external prismatic layer and an internal composite prismatic aragonitic layer.

4) Gibbula magus (pl. III, Fig.6): Is composed of three layers: the external one is an aragonitic nacreous layer, the middle layer is formed of composite prisms, and the internal layer is formed of fine-grained aragnitic nacreous structure.

5) Terebra crenulata (pl. III, Fig.7): Is formed of two layers, the external one is a simple prismatic structure, while the internal layer is formed of composite prisms.

6) Viviparus, vivipara (pl. IV, Fig.1): Is formed of two aragonitic layers, the external one is formed of long and simple prisms, perpendicular to the shell surface, while the internal layer is composed of fine-grained nacreous structure

7) Turritella communis (pl. IV, Fig.2): Is completely formed of composite prisms, oriented in different directions and tuncated on one another.

8) Turritella triplicata (pl. IV, Fig.3): Is completely formed of composite aragonitic prisms. They were separated by organic material.

9) Polinices tumidus (pl. IV, Fig.4): Is composed of two aragonitic layers the external one is formed of composite prisms perpendicular to the shell surface, while the internal layer is composed of complex cross lamellar structure.

Table (1): Frequency distribution of Bivalvia species in Manzala Lagoon

	Species \ Station No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	Nucula (N) nucleus				R	R		R	R	R			R	R												R	R	
2	Nucula nitida			R				R					R	R		R										R	R	
3	Nucula decussata					R		R					R	R												R		
4	Arca noae					R			R	R																R		R
5	Barbatia barbata		R						R					R		R		R				R		R		R		
6	Anadara (A.) antiquata	R	R		R	R		R	R	R				R					R		R	R		R	R	R	R	R
7	Glycymeris (G) glycymeris		R						R	R				R					R							R	R	
8	Glycymeris pectunculus							R	R					R		R											R	
9	Lithophaga (L) lithophaga					R									R													
10	Modiolus auriculatus	F			R										R			R										
11	Chlamys varia				R		R	R	R	R			R	R		R												
12	Lima(L) lima			R		R	R	R	R																			
13	Limaria (L) tubercualata			R		R			R																			
14	Limatula (L) subauriculata			R				R											R						R	R		R
15	Limatula nivea							R	R	R									R							R		
16	Ostrea edulis	F	R	F	F	F	R	F	R	R		R	F	F		F					F					R	F	
17	Acanthocardia tubercualata	A	A	A		A	A	A	F	F	F	F		F	A	F		A	A	A	A	A	R	R	R	R		A
18	Acanthocardia paucicostatum	A	A	A		F	F	A	F	F	F			F	F	F	A		A		A	A			F			
19	Cardium edule	A	F	A	F	F	F	A	F	F	A	F	A	F	A	A	A		A	A	A	A	A		A		F	A
20	Cardium (C.)costatum					F	F	A	F				A	F	A		A	F					A	F	A	A		
21	Cardium sp										F	F	A		A			F		A		A		F	F			A
22	tellina rugosa			A	F	A	F	F	F	F			F	F		F			R			F				A	F	A
23	tellina sp												F	F				F										F
24	Donax trunculus	R		R		R	R	R	R	R			R	R		R			R			R		R	R	R	R	
25	Asaphis deflorata												R	R													R	
26	Venerupis aurea			R			R		R			R	R	R														
27	Corbicula (C.) angasi	A						A	A	A	A																	
28	Venus reticulata	F			F	R	F	F	F	F			F	R		R			R							R	R	
29	Circe scripata						R		R				R	R		R										R	R	
30	Circe pectinata											R		R														

R = Raro (1-4 specimens) F = Frequent (5-15 specimens) A = Abundant (over 15 specimens)

Table (2): Frequency distribution of Gastropoda species in Manzala Lagoon

	Species \ Station No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	Turritella communis	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A		A	A	A	A	A		A
2	Turritella triplicota	A		A	A	A	A	A			A	A	A	A		A	A		A	A		A	A	A	A	A		A
3	Turritella sp					A		F	F				F															
4	Gibbula magus	A	A		F	F	A		F	F		F	A	A	F	F	F		A			F	A	A	A	F	F	
5	Gibbula umbilicoris				F		F		F						F				F			F	A	A	F	F		
6	Gibbula ardens							F	A			A	A	A	F				F			F				F	F	
7	Terebra crenulata			A		F		F							F	A		F										
8	Terebra consobrina	F	F	A		F	F	F	F	A					F	A	F	F		A		F	F	F	F	F	F	
9	Terebra nebulosa								F	A										A		F	A	F	F			F
10	Terebra SP														F				R									
11	Bittium reticulatum				F		F		F			F	R	F		F	F		F	F		F	F		F	R	F	
12	Bittium sp				R								R						F									
13	cerithium ruppili				F	F											F											
14	Vulgocerithium Vulgatum	A	A				A		F	F							F			F						F	F	F
15	Nassarius arularius													F														
16	polinices maurus														R											R		
17	polinices tumidus		R					R						F												R	F	
18	Viviparus vivipara	F										F						A		A		F	F	F			F	F
19	Alvania costata							R																				
20	Turbonilla lacteal						A	A	R	A			F	F														
21	Macluritella (Euomphalopsis)														F													
22	Liljevallospira sp		A						A							A	F		A		F	F						F
23	Planorbis sp								F				A	F				F			A	F	A	A	F	F	F	F
24	Helix sp												F			F					R							F
25	atica sp																								R			
26	Scaevogyra sp	F							F		F		F	F	F					F				F	F	F	F	F

R = Rare (1-4 specimens) F = Frequent (5-15 specimens) A = Abundant (over 15 specimens)

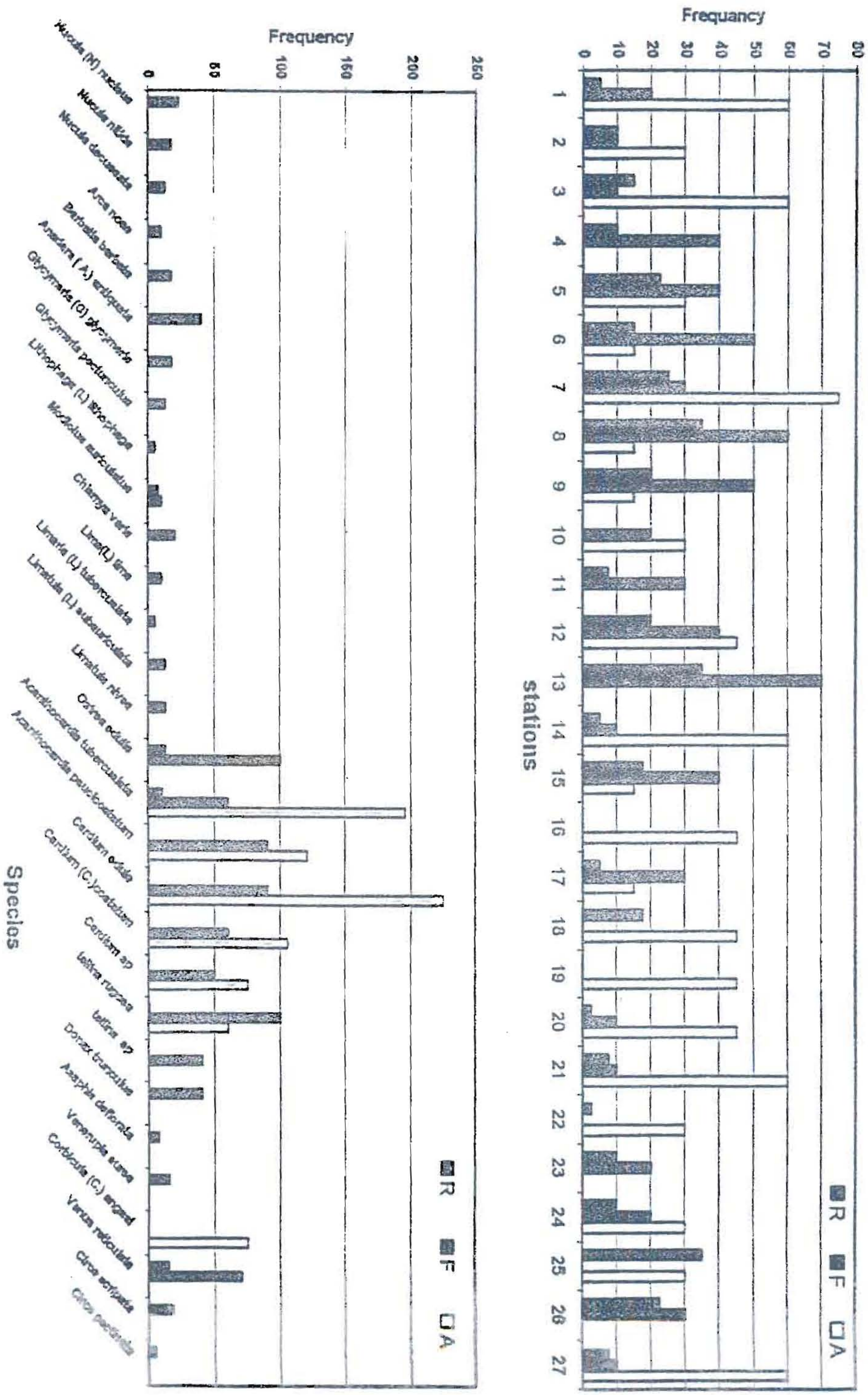

Fig. (5) : The histogram shows the Bivalvia Species frequency in the 27 collected bottom sediments samples of Manzala lagoon

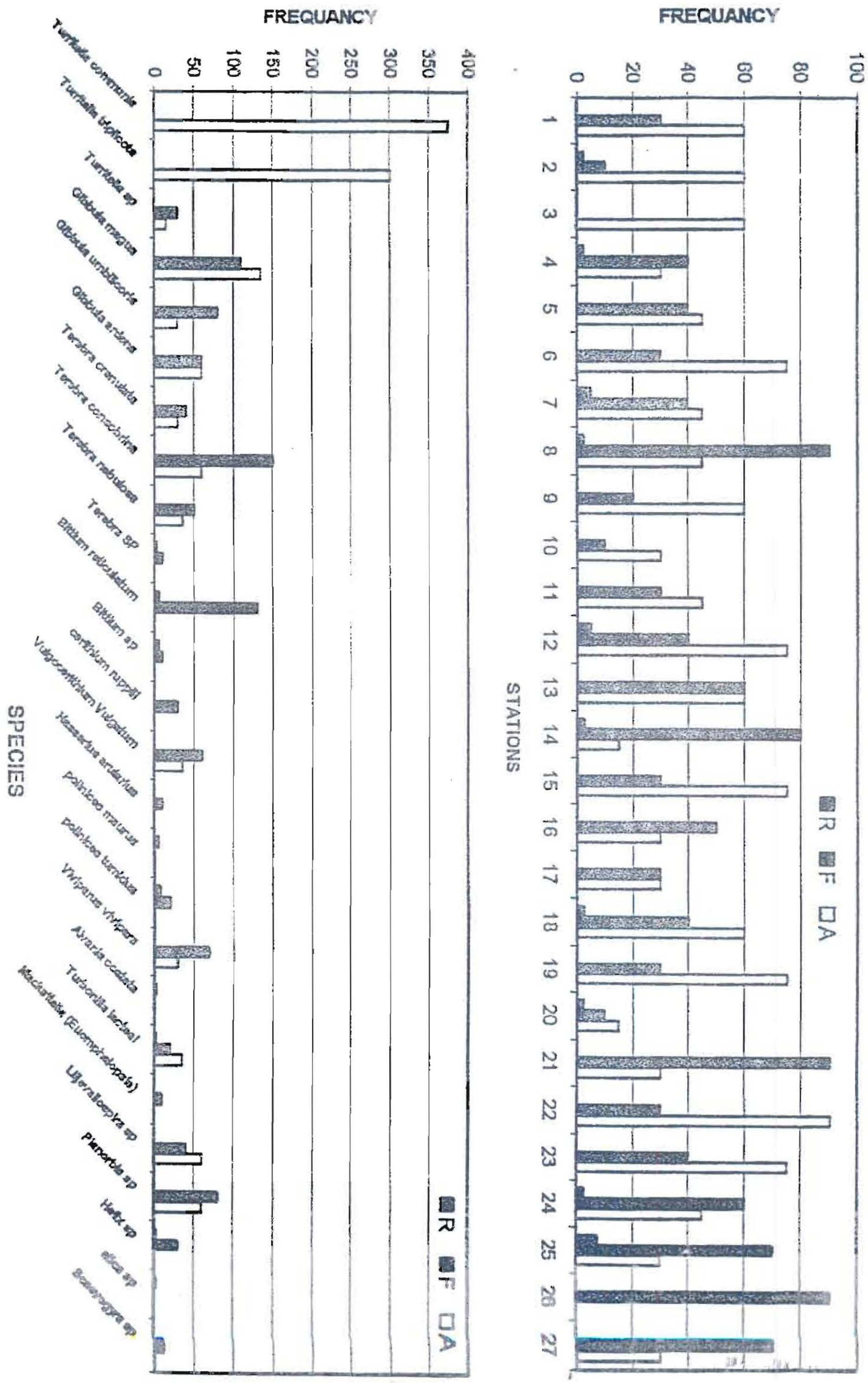

Fig. (6) : The histogram shows the Gastropoda Species frequency in the 27 collected bottom sediments samples of Manzala lagoon

PLATE 1

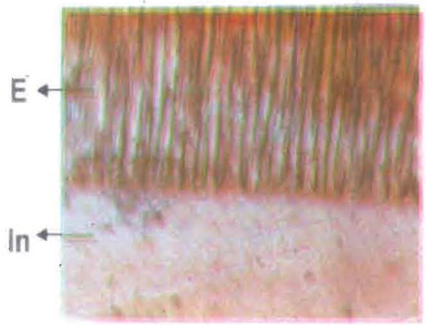

Fig.1

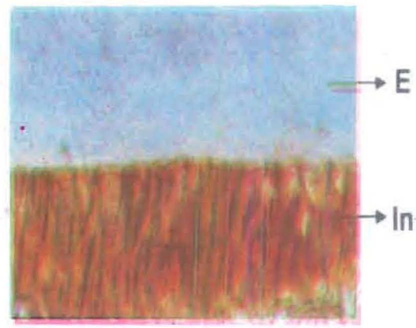

Fig.2

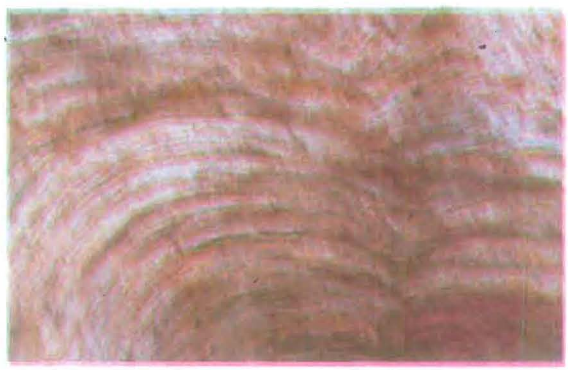

Fig.3

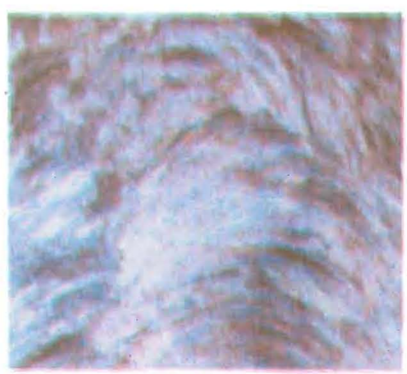

Fig.4

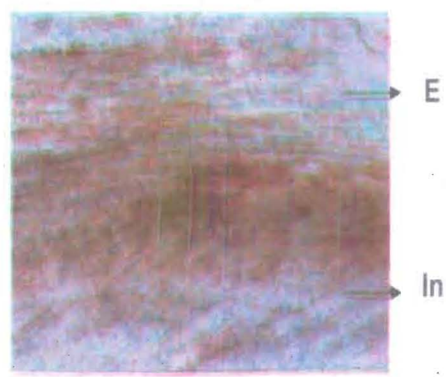

Fig.5

PLATE II

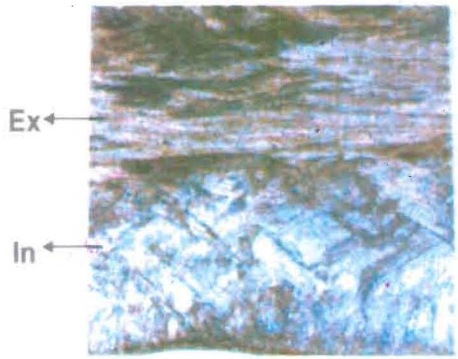

Fig.1

Fig.2

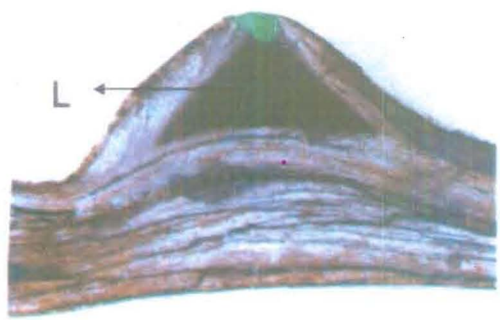

Fig.3

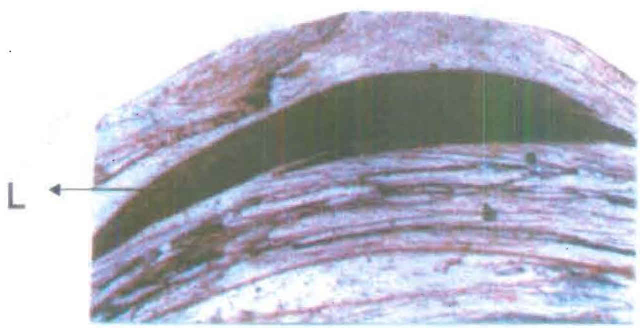

Fig. 4

PLATE III

Fig. 1

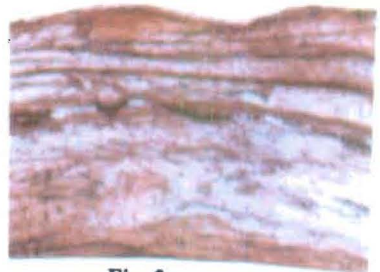

Fig. 2

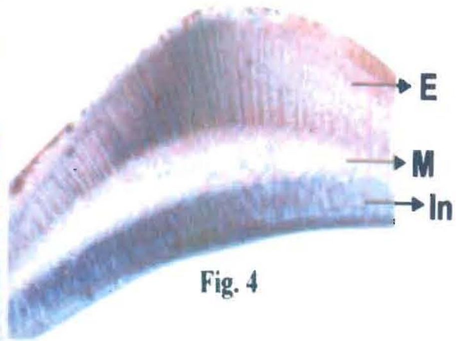

Fig. 4

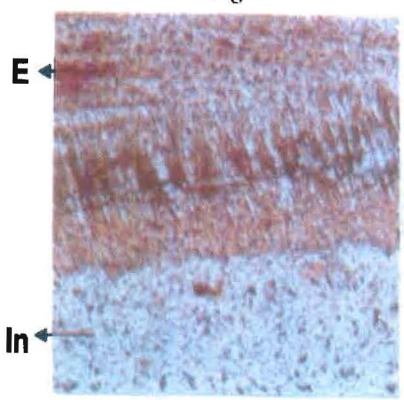

Fig. 3

Fig. 5

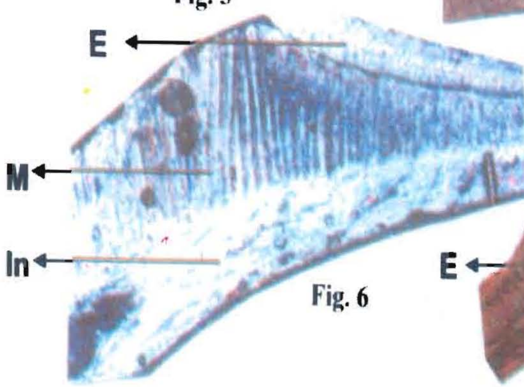

Fig. 6

Fig. 7

PLATE IV

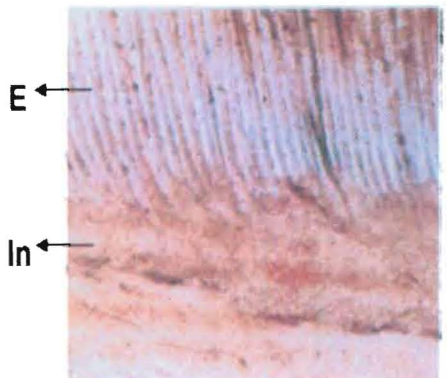

Fig. 1

Fig. 2

Fig. 3

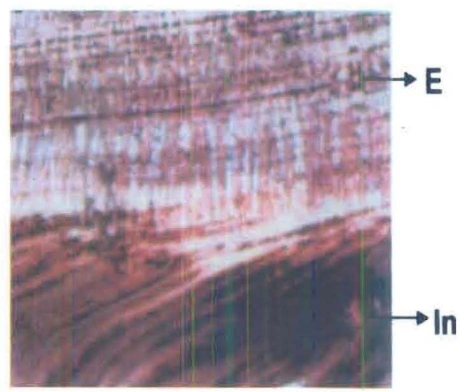

Fig. 4

Explanation of Plate I

Fig.1: Axial Section in corbicula (corbiculina) angasi (x80).

ex= external calcitic prismatic layer

in= internal aragonitic nacreous layer.

Fig.2: Axial section in circe scripata (x80).

ex = external aragonitic nacreous layer.

in = internal calcitic prismatic layer

Fig.3: Axial Section in Acanthocardia tuberculata (x 100).

Is completely composed of cross foliated aragonitic layers.

Fig.4: Axial Section in Cardium edule (x100).

Is completely composed of cross foliated aragonitic layers.

Fig.5: Axial section in Arca noae (x100).

ex = external foliated aragonitic layer.

in = internal cross foliated layer.

Explanation of Plate II

Fig.1: Axial Section in Tellina rugosa (x100).

ex= external foliated aragonitic layer

in= internal cross lamellar layer.

Fig.2: Axial section in Glycymeris (G.) glycymeris (x120).

Is completely composed of cross lamellar structure

Fig.3: Axial Section in Lima (L.) Lima (x 100).

Is composed of foliated aragonite with lenticular chambers (L)

Fig.4: Axial Section in Barbatia barbata (x120).

Is composed of foliated aragonite with lenticular chambers (L).

Explanation of Plate III

Fig.1: Axial Section in Nucula (N) nucleus (x120).
Is composed of complex cross lamellar
Fig.2: Axial section in Ostrea edulis (x 80).
Is composed of foliated aragonitic Layers.
Fig.3: Spiral Section in Helix sp. (x 120).
ex= external nacreous aragonitic layer
m= middle aragonitic composite prismatic layer
in= internal nacreous aragonitic layer.
Fig.4: Spiral Section in Vulgocerithium vulgatum (x80).
ex= external long prismatic layer
m= middle nacreous layer
in= internal equal length prismatic layer.
Fig.5: Spiral Section in Terebra crenulata (x60).
ex= external prismatic layer
in= internal composite prismatic layer.
Fig.6: Spiral Section in Gibbula magus (x80).
ex= external nacreous layer
m= middle layer formed of composite prisms
in= internal nacreous layer.
Fig.7: Spiral Section in Terebra crenulata (x60).
ex= external prismatic layer
in= internal composite prismatic layer.

Explanation of Plate IV

Fig.1: Spiral Section in Viviparus vivipara (x120).
ex= external simple prismatic layer
in= internal nacreous layer.

Fig.2: Spiral section in Turritella communis (x 120).

Is formed of composite prisms.

Fig.3: Spiral Section in Turritella triplicate (x 120).

Is formed of composite prisms.

Fig.4: Spiral Section in Polinices tumidus (x120).

ex= external composite prisms

in= internal complex cross lamellar.

CONCLUSION

Molluscan assemblages are sensitive markers of environmental conditions, such as fluctuations of salinity conditions. It is predicted, for example, that fresh-water influenced biofacies will become progressively more wide spread as Manzala lagoon receive relatively substantial fresh-water input but continue to decrease in size. In view of the much-increasing anthropogenic pressures, it is recommended that molluscan faunas should be monitored in baseline studies of Nile delta coastal lagoon.

The general picture of the bottom fauna is the empty shells of mollusca. Most of the mollusks are of marine origin, which are mostly derived to the Manzala Lagoon from the Mediterranean Sea fauna. Corbicula (Corbiculina) angasi is typical fresh water bivalve, was found in stations No. 1,7,8,9,10,21,22,23,and 26 which occupy the southern part of the lagoon this species invaded the lagoon through the southern drains. Viviparus vivipara is typical fresh water gastropod, found in stations No. 1,12,17,19,21,22,23,26 and 27, which occupy the southern, and western parts of the lagoon. This species invaded the lagoon through the southern and western drains. Helix sp and Cardium sp are typical terrestrial fauna, they are independent of water for breeding, and their mantle cavity acts as a lung. They invaded the lake through the southern drains.

Both fresh-water bivalve shell Corbicula (Corbiculina) angasi and gastropod shell Viviparus vivipara are composed of an external prismatic layer and an internal nacreous layer. The shells of Acanthocardia tuberculata and Cardium edule are completely composed of cross-foliated aragonitic structure. The shells of Lima (Lima) lima and Barbatia barbata are composed of foliated aragonite with lenticular chambers. The shells of Ostrea edulis are composed of foliated aragonite with organic materials. The shells of Turritella communis and Turritella triplicata are completely composed of composite aragonitic prisms. The shells of Vulgocerithium vulgatum are composed of three layers; the external and internal layers are formed of prismatic structure, while the middle layer is formed of nacreous structure. The shells of Gibbula magus are formed of three layers; the external and internal layers are formed of nacreous aragonite, while the middle layer is formed of prismatic structure. The shells of the different species of genus Terebra are composed of two layers, an external prismatic and an internal composite prismatic layer. Generally, the composite prismatic structure characterize class Gastropoda, while the foliated and cross foliated structure characterizes class Bivalvia.

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