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LONG-TERM CHANGES AND COMMUNITY STRUCTURE OF MACROBENTHIC ARTHROPODA AND MOLLUSCA IN BARDAWIL LAGOON

SUMMARY

Lagoons are among the most productive aquatic ecosystems which for thousands of years have been exploited by man. Bardawil Lagoon is a small, hyper saline lagoon in an arid area located in the middle of Sinai's Mediterranean coast. Long-term changes, community structure, biodiversity, biomass and abundance of Arthropoda and Mollusca were studied. *Orchestia gammarella,* Chironomidae larvae and *Balanus perfera* were recorded as dominant taxa within 15 identified Arthropoda species. The western area of the lagoon maintained the highest standing crop as a result of the flourishing of Chironomidae larvae. Arthropoda are weakly represented in the middle and eastern areas. The standing crop of the total Arthropoda shows an obvious increase from 253 and 298 indiv.m^{-2} during 1984 and 1986 to 711 indiv.m^{-2} during the present study. *Branchiodonta variabilis* was the dominant of 9 molluscan species. Spatially there was a tendency towards a decrease in abundance westwards. The population density of Mollusca had highly reduced from 1028 indiv.m^{-2} in 1984 to 671 indiv. m^{-2} during the present study.

The present study shows that Arthropoda and Mollusca assemblages undergo dramatic changes. There is no sign of presence of 20 previously listed species in the lagoon. On the other hand, 9 species have been recorded for the first time.

INTRODUCTION

Lagoons and their characteristic coastal bay-mouth bars represent 51% of the world's coastal zones (Fouda *et al.,* 1985). They can be found from the equator to the poles. They are among the most productive ecosystems in the biosphere.

Mediterranean lagoons are hyposaline being influenced by river, drainage and precipitation. Salinities in these ecosystems are lower or much lower than in the sea-water. Contrarily, the hyper-saline Bardawil Lagoon has higher salinities than the adjacent eastern Mediterranean Sea. In this respect, it is a unique water body which requires special consideration. The organisms inhabiting the lagoon originated from Mediterranean. However, the pronounced fluctuation in the hydrographic, chemical and biological conditions affect the distribution, standing crop and biomasses of organisms inhabiting the lagoon. Macrobenthic invertebrates represent one of the most important resident animal groups in coastal wetlands. Because of their sedentary life style, the distribution and abundance of benthic invertebrates are particularly sensitive to local environmental condition (LUCKENBACH *et al.,* 1990). Macrobenthos therefore, are often used as indicators in environmental monitoring (MATRICARDI *et al.,* 1980). The structure of macrobenthic assemblages is complex and seems to be strongly influenced by site specific processes and conditions. Different factors could have significant effects on the macrobenthic assemblage but non-significant effects elsewhere (LUI *et al.,* 2002).

Bardawil Lagoon is located in an arid, semi-desert area, where rainfall is very scarce. The annual average value of rainfall in the middle of the lagoon is 82 mm. On the other hand, the evaporation values fluctuated between 72 mm in December and 246 mm in July (TAHA, 1990).

The bottom of the lagoon is sandy on the periphery, clay sand covers most of its area and silty clay is found in its deepest part (LEVY, 1974). POR (1971) mentioned that the basic element of the marine flora is *Ruppia cirrhosa.*

The physical and chemical features of the lagoon water were studied by POR (1971); BEN-TUVIA and GILBOVA (1975); KRUMAGALZ *et al.,* (1980); SILIEM (1988; 1989), TAHA (1990), and SHABANA (1999). The community composition of phytoplankton has been studied by KIMOR (1975), and TAHA (1990), while EHRLICH (1975) studied the lagoon benthic algae. The macrophyte assemblage of Bardawil Lagoon is poorly diverse *Ruppia cirrhosa* seems to be the highly dominant taxa (LEPKIN, 1977).

The importance of macrobenthic fauna lies on its position in the food chain. Fish biomass and yield are strongly correlated with macro-invertebrates biomass or production (EGGERS *et al.,* 1978; WISSMAR and WETZEL, 1987). Soil texture plays an important role in benthic distribution (WINNEL and JUDE, 1984).

The available data dealing with the macrobenthos in Bardawil Lagoon are scarce. FOUDA *et al.* (1985) included macrobenthos in their study on ecology of Bardawil Lagoon. ABOUL-EZZ (1988) mentioned that the Arthropoda and Mollusca contributed 32.7 and 12.6 % of total macrobenthos density. The amphipods *Corophium* and *Gammarus,* the chironomid larvae of insects, and the molluscs *Brachiodontes* and *Cerithium* are the main components within the groups.

The main purpose of present study is to verify the existence of long term changes in community structure, biodiversity, biomass and abundance of Arthropoda and Mollusca in the lagoon in relation to changes in some abiotic and biotic variables.

MATERIAL AND METHODS

the study site (Bardawil lagoon)

The Sinai Peninsula, bordered southerly by the Red Sea (Suez Gulf and Aqaba Gulf) and northerly by the Mediterranean Sea, has been a passage way for centuries between the Nile Valley and the middle east territories, a land bridge between Africa and Asia. Bardawil lagoon is located in the middle of the Mediterranean coast of Sinai. The surface of the lagoon is 1-3 m below the sea level, out from the sea by a narrow sand bar 300-1000 m wide, often covered by sea water. Spreads from 32° 40' and 33° 30' Long. East, and 31° 03' and 31° 14' Lat. North. The flooded area is approximately 650 km^2, extended for about 75 Km long with a maximum width of 22 km (PISANTY, 1980; VARIY, 1990). Three openings, locally term Boughaz, connected the lagoon with the sea. Two of them, the Western Boughaz I and the middle Eastern Boughaz II are man-made, whilst the third, the extreme Eastern Boughaz III at El-Zaranik is natural.

Bardawil Lagoon has been identified as one of the most important wetland for water birds in the whole of the Mediterranean region since it has been suggested as a major breeding site for little tern (*Sterna albiforns*) and Kentish plover (*Charadrius alexandrinus*) (FRY *et al*., 1985).

sampling

Benthos samples were collected in October 2002, and March 2003, using Ekman grab (225cm^2 opening area). Benthos samples were collected from 12 different stations representing the different microhabitats of the lagoon (Table, 1, Fig. 1). The samples were sieved by hand sieve of 0.4 mm mesh diameter then washed with lake water to remove mud or other fine particles. The organisms retained in the sieve were preserved in 10% neutral formaline. In the laboratory, the samples were re-washed with tap water to remove any silt remains. Sorting of the specimens was carried out by taking successive small sub-samples and examining them under stereoscopic microscope at 40X. The bottom organisms were sorted into main groups. Each group was examined and sorted into genera or species. Both the abundance and fresh weight of each species were measured after retaining the organism on filter paper for 3 minutes. All mollusc species were measured with shells. Additional qualitative benthic samples were collected from fouling and macrophytes for detecting benthic species associated with them.

The references used for identification of the collected species are: CAMPBELL (1982) and RUFFO (1982).

Station	Location	Station	Location
I	31° 09′ 18″ N 33° 19′ 25″ E	VII	31° 05′ 35″ N 32° 59′ 18″ E
II	31° 12′ 27″ N 33° 15′ 43″ E	VIII	31° 08′ 11″ N 32° 55′ 75″ E
III	31° 11′ 78″ N 33° 06′ 24″ E	IX	31° 06′12″ N 32° 53′ 30″ E
IV	31° 08′ 96″ N 33° 07′ 92″ E	X	31° 05′ 67″ N 32° 51′ 18″ E
V	31° 04′ 50″ N 33° 10′ 13″ E	XI	31° 04′ 20″ N 32° 48′ 36″ E
VI	31° 05′ 81″ N 33° 13′ 65″ E	XII	31° 03′ 51″ N 32° 46′ 75″ E

Table 1 - Location of selected stations (latitude and longitude).

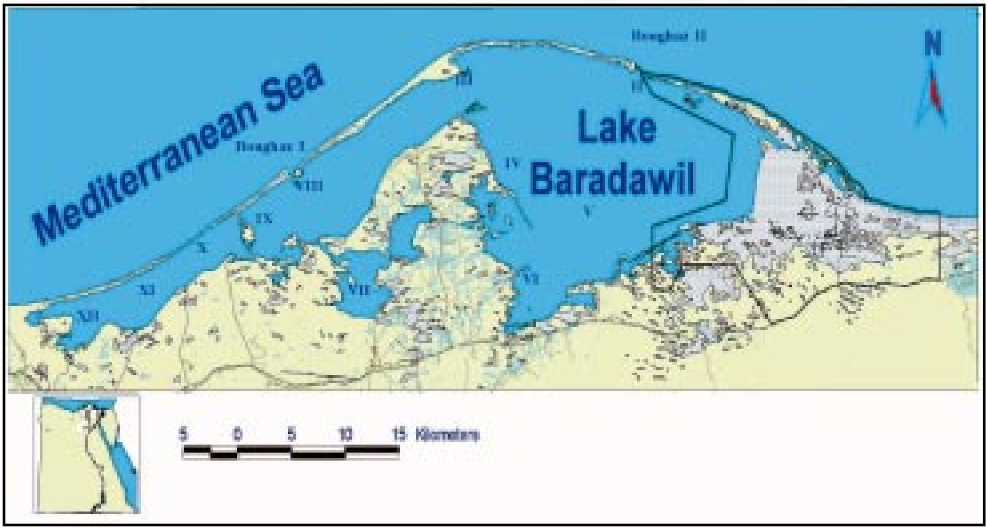

Fig. 1 - Map of the northern side of Egypt showing the location of Bardawil lagoon and the selected station.

abiotic variables:

* SOIL TEXTURE

Sediments were analyzed mechanically according to Folk and Word (1957). Types of sediment were determined according to Bettijhon (1975).

* ORGANIC MATTER

Organic matter were determined according to Hanna (1965).

RESULTS AND DISCUSSION

organic matter

Organic matter shows a negligible variation during October and March (Av. 8.04 and 8.1 %). Spatially, station VIII (in front of Boughaz I) sustained to lowest mean of

5.93 %, while stations I, II and IX maintained the highest means of 9.25, 9.33 and 9.22 %, respectively (Table, 2).

soil texture

The nature of sediment is muddy and muddy sand at stations I and VIII. The rest of stations are characterized by sand sediment (Table, 2).

salinity

Salinity fluctuated between 38 ‰ at stations II and VIII (in front of Boughaz I and II) in March and 63 ‰ at stations III and XII in October

Arthropoda

15 species were recorded, *Orchestia gammarella*, and Chironomidae larvae proved to be the common taxa (Table, 3 and Fig. 2). The western area of the lagoon had the highest standing crop owing to flourishing of Chironomidae larvae. Arthropoda weakly occurred at the eastern and middle area (Fig. 3). The comparison with 1984-87 showed an increase from 253 and 298 indiv.m^{-2} (FOUDA *et al.* 1985; ABOUL-EZZ, 1988) to 711 indiv.m^{-2} during the present study (Fig. 4). Concurrently with the population density, the diversity within Arthropoda has been increased from 12 - 8 species to 15 species (Fig. 5). The biomass increased from 3.5 g fresh wt.m^{-2} in 1987 to 8.6 g fresh wt.m^{-2} during the present study. Five arthropod species, mostly associated with fouling have been recorded for the first time in the lagoon.

Parameter / Stations	Salinity ‰		Organic Matter %		Composition of Sediment %				Type of the Sediment
	Oct-02	Mar-03	Oct-02	Mar-03	Granules	Coarse Sand	Fine Sand	Mud	
I	49.00	48.00	9.47	9.02	5.00	0.00	5.00	90.00	muddy
II	40.00	38.00	9.47	9.19	9.44	39.40	37.96	13.20	sandy
III	58.00	52.00	8.38	8.18	12.00	38.92	26.20	22.80	sandy
IV	51.00	50.00	9.24	9.14	12.16	44.64	32.88	10.24	sandy
V	47.00	47.00	7.30	7.24	24.08	25.28	34.88	15.60	sandy granules
VI	59.00	52.00	6.09	6.02	8.00	43.36	38.48	10.00	sandy
VII	63.00	54.00	8.13	8.55	8.00	26.12	61.04	4.76	sandy
VIII	39.00	38.00	5.90	5.96	0.00	5.32	65.40	29.16	muddy sand
IX	41.00	44.00	9.22	9.23	16.80	46.56	36.36	0.24	sandy
X	55.00	42.00	6.97	6.90	5.20	50.52	37.60	6.68	sandy
XI	57.00	47.00	8.47	8.73	6.56	50.72	32.08	10.44	sandy
XII	63.00	54.00	7.91	8.00	4.96	27.24	64.24	3.36	sandy

Table. 2 - Salinity, Organic matter, Soil texture and type of sediment of Bardawil lagoon during the studied period.

Chironomidae larvae

On standing crop basis, Chironomidae larvae (Diptera) occupied the first position among the different arthropod categories in Bardawil lagoon. It contributed collectively about 75.1 and 54.2 % of total arthropod numbers with a standing crop of 588 and 346 indiv.m^{-2} during October 2002 and March 2003, respectively.

The participation of Chironomidae larvae in arthropod biomass was 18.9 and 24.3% of total. The occurrence of these larvae is highly confined to the Western part of the lagoon (Stations, IX-XII), while it was totally missed from benthic hauls at the Eastern area (Fig. 6). Chironomidae larvae are known to inhabit the littoral zone of both oligotrophic and eutrophic lakes (Mundi, 1955). These larvae are the most important component of benthic fauna of the majority of aquatic habitats (Paterson and Fernando, 1970).

Wirth and Stone (1968) mentioned that Chironomidae larvae are favored by a heavy growth of aquatic macrophytes. The chironomid larvae (*Cricotopus mediterraneus*) were predominant in high salinities and isolated area of Bardawil Lagoon. They were also found among food items in the stomach of some lagoon fishes (Fouda *et al.,* 1985).

Orchestia gammarella

O. gammarella is widely spread in Bardawil lagoon but not abundant anywhere. It is well represented in March, with a mean standing crop value of 217 indiv.m^{-2}, weighted 0.8 g fresh wt.m^{-2}, forming 34.0 and 14.6 % of total arthropod number and biomass. The population density of this species is remarkably decreased in October (Fig. 7). Station V maintained the highest occurrence (600 indiv.m^{-2}, weighted 2.4 g fresh wt.m^{-2}) in March, while it was totally disappeared at station XII. *O. gammarella* was previously recorded and associated with macrophytes (*Ruppia cirrhosa*) in the lagoon (Fouda *et al.,* 1985).

Mollusca

Nine mollusc species dominated mainly by *Brachiodonta variabilis,* were recorded (Fig. 8). Generally, there was a tendency towards a decrease in abundance westwards. Stations IV, V and VI were characterized by a relatively low standing crop with a heavy biomass and vice versa for station II (Fig. 9). On long term changes base, the population density sharply decreased from 1028 indiv.m^{-2} in 1984 (Fouda *et al.,* 1985) to 591 indiv.m^{-2} in 1987 (Aboul-Ezz, 1988). Mollusca occurred in density of 671 indiv.m^{-2} during the present study. The biomass was sharply increased from 28.8 g fresh wt.m^{-2} in 1987 to 128.2 g fresh wt.m^{-2} during the present study (Fig. 4). The diversity within Mollusca increased from 10 species in 1984 to 13 species in 1987, only 9 species were recorded during present study (Fig. 5). It is worth mention that 2 mollusc species were newly recorded.

Species	1984 [1]	1987 [2]	2002 [3] - 2003	present status
ARTHROPODA				
Orchestia gammarella (Pallas)	*		*	C
Ampithoe remondi Audouin	*		*	M.C.
Gammarus locusta (Linnaeus)		*	*	R
Corophium sp.	*	*	*	R
Caprella acanthifera (Leach) #			*	VR
Sphaeroma serratum (Fabricius) #			*	VR
Dynamena bidentata (Adams) #			*	R
Idotea baltica (Pallas) #			*	R
Balanus perforatus Bruguiere	*		*	R
Balanus amphitrite (Darwin)		*		
Anthura gracilis (Montagu)		*		
Lepas anatifera (Linnaeus)	*	*		
Lupa pelagicus (Linnaeus)	*		*	R
Palaemon sp.		*		
Anchialina agilis G. O. Sars	*			
Mysis relicts (Lovan)		*		
Metapenaeus stebbing (Nobili)	*		*	R
Penaeus semisulcatus (De Haan)			*	R
Penaeus japonicus (Bate)			*	R
Nymphon gracile (Leach) #			*	VR
Chironomidae larvae	*	*	*	M.C.
Squilla desmaresti Risso	*			
MOLLUSCA				
GASTROPODA				
Cerithium vulgatum (Brugiere)		*	*	R
Cerithium reticulatum (Da Costa)		*		
Cerithium scabridum Philippi	*			
Cerithium kochi Philippi	*			
Pirenella conica (Linnaeus)	*	*	*	R
Murex tribulus (Linnaeus)		*		
Murex brandaris (Linnaeus)	*			
Murex trunculus (Linnaeus)	*			
Hydrobia ventrosa (Montagu) #			*	VR
Patella sp. #			*	R
BIVALVIA				
Brachiodontus variabilis (Linnaeus)	*	*	*	C
Cerastoderma edule (Linnaeus)		*		
Cerastoderma lamarcki (Reeve)	*		*	R
Mactra corallina (Linnaeus)	*			
Mactra glauca (Born)		*	*	VR
Mytilus galloprovincialis (Lamarcki)		*		
Donax trunculus (Linnaeus)		*		
Dosinia lupinus (Linnaeus)	*		*	R
Gari depressa (Pennant)	*		*	R
Tellina edentula (Linnaeus)		*		
Arca lactea (Linnaeus)		*		
Barnea candida (Linnaeus)		*		
Cerastoderma sp.		*		

Table. 3 - Long term changes in arthropods and molluscs, C: Common; MC Moderately Common; R: Rare and VR: Very Rare.

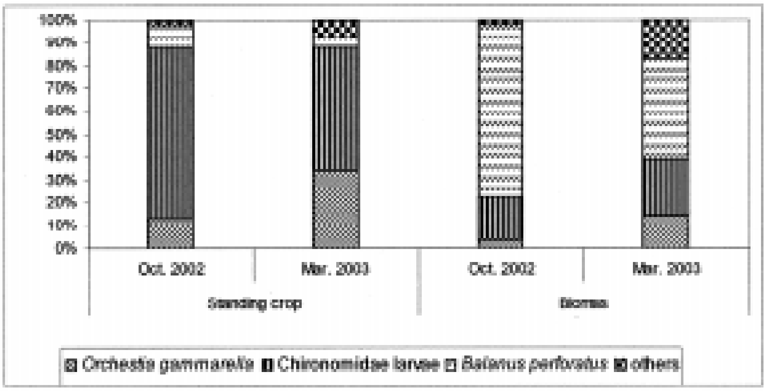

Fig. 2 - Percentage frequency of different arthropod species.

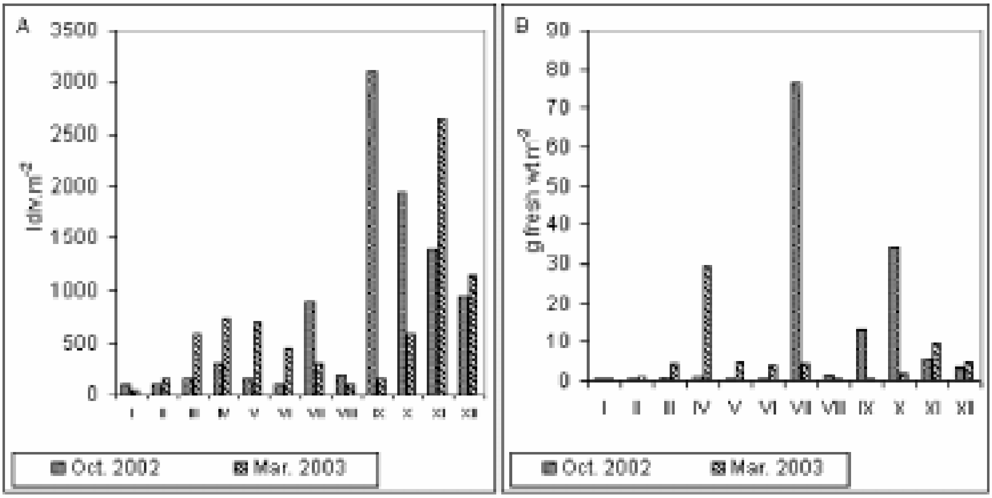

Fig. 3 - Standing crop and biomass of total Arthropoda a) Standing crop b) Biomass.

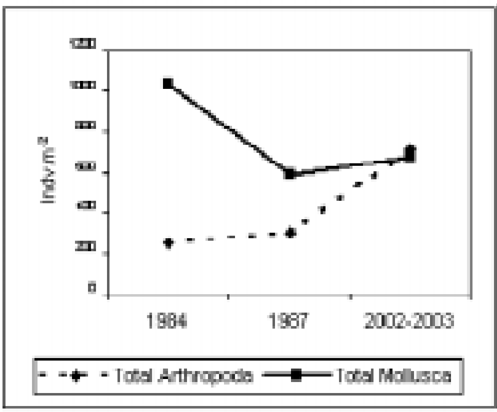

Fig. 4 - Long Term changes in standing crop of arthropoda and mollusca.

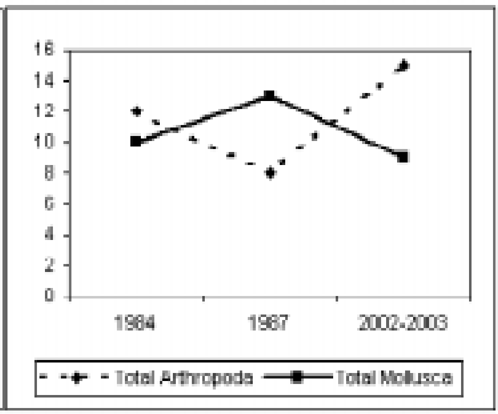

Fig. 5 - Diversity within arthropoda and mollusca.

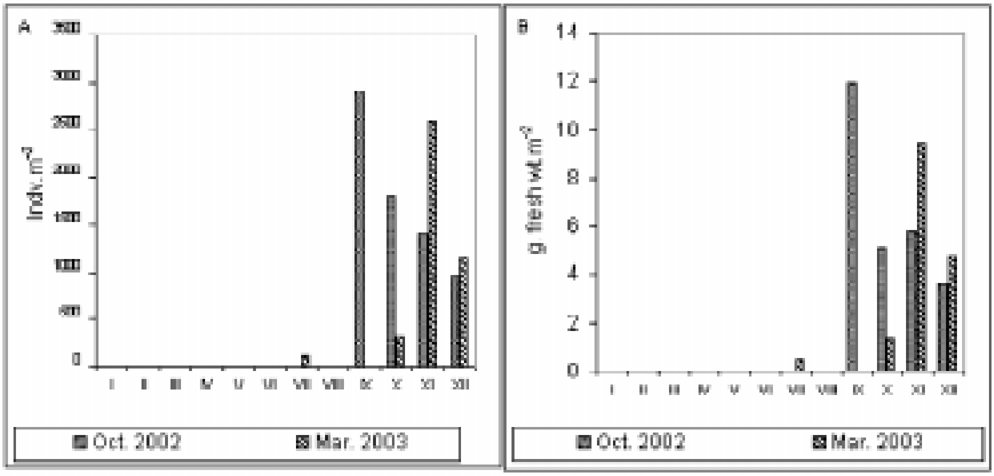

Fig. 6 - Standing crop and biomass of *Chironomidae larvae* a) Standing crop b) Biomass.

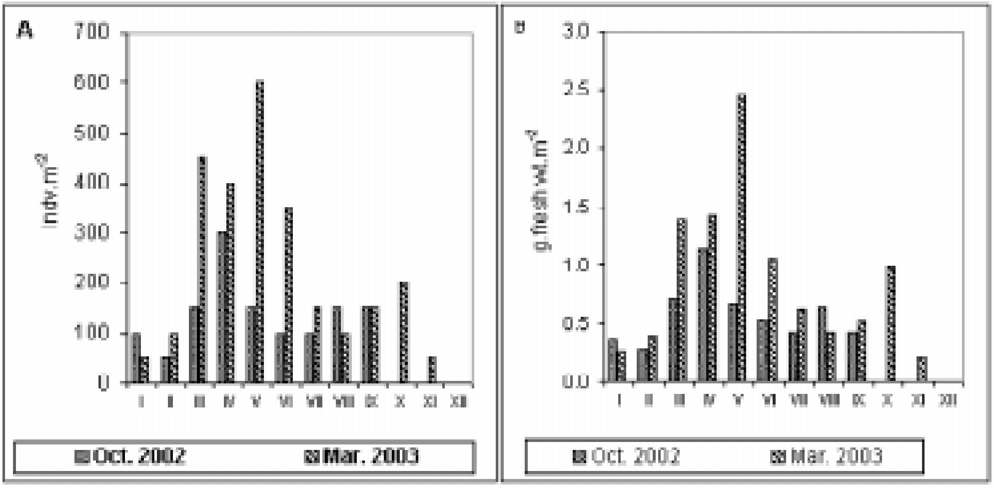

Fig. 7 - Standing crop and biomass of *Orchestia gammarella* a) Standing crop b) Biomass.

Brachiodonta variabilis

The numerically dominant mollusc species is clearly *B. variabilis,* which seldom account for less than 70% of total Mollusca. October showed high numbers of this species (mean 683 indiv. m^{-2}, weighted 62.63 g fresh wt. m^{-2}), while it has been recorded with a relatively low number and heavy biomass in March (mean 383 indiv. m^{-2}, weighted 131.8 g fresh wt. m^{-2}). Spatially, stations II and III maintained highest density, while stations VIII and XII were the poorest (Fig. 10). Fouda *et al.* (1985) mentioned that *B. variabilis* was the most dominant bivalve species collected from Bardawil lagoon and was abundant in places where *Ruppia cirrhosa* was common.

Factors affecting Arthropoda and Mollusca distribution

In Bardawil Lagoon, salinity, organic matter and soil texture were highly correlated with Arthropoda and Mollusca community structure, while total nitrogen and total phosphorus were weakly correlated.

Increased salinity can modify benthic community biomass through reduction of primary production, substrate modification, deoxygenation and other mechanisms (Timms, 1983). Hammer (1986) mentioned that benthic macrofaunal diversity, generally decreases with increasing salinity. The abundance of different macrobenthic species demonstrate different relationships with salinity. Some studies reported a positive correlation between salinity and benthic abundance (Möller *et al.,* 1985 and Jones *et al.,* 1986), while other showed that benthic abundance decreased from estuarine to oceanic habitats (Flint and Kalke, 1985).

These salinity-species abundance relationships are probably determined by the salinity tolerances of oceanic or freshwater species along a low-salinity to high-salinity gradient (Yap and Nacorda, 1993). Salinity shows a positive correlation with total Arthropoda and Chironomidae larvae (r = 0.58 and 0.57), while it shows negative correlation with the rest of species.

Organic matter in sediment is thought to provide food for deposit-feeding and detritivorous macrobenthos. There is usually a higher species abundance and biomass in organically rich environment than in organically poor environment (Taylor, 1993). The weak correlation in the present study may be due to the narrow ranges of this parameter among the different selected stations.

Soil texture plays an important role in the distribution of infauna. Some species prefer sand substrate, while others are abundant at silt or clay substrate. Arthropoda were negatively correlated with sand percentage and *vice versa* for mud.

Fish can affect benthic community structure through disturbance and predation. Fish predation reduces macrofaunal abundance and limits the distribution of favorable macrofaunal organisms (Healy, 1984).

The characteristics of fish catch composition in the lagoon were greatly changed from 1982 to 2000. Contribution of the most economic species sea bream and sea bass sharply decreased from 56.5 % in the 1982-1988 to about 8 % in 2000 of the

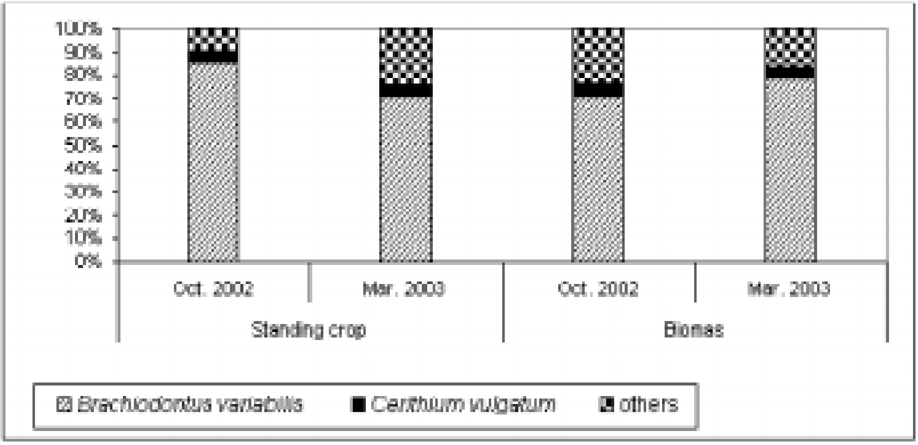

Fig. 8 - Percentage frequency of different molluscan species.

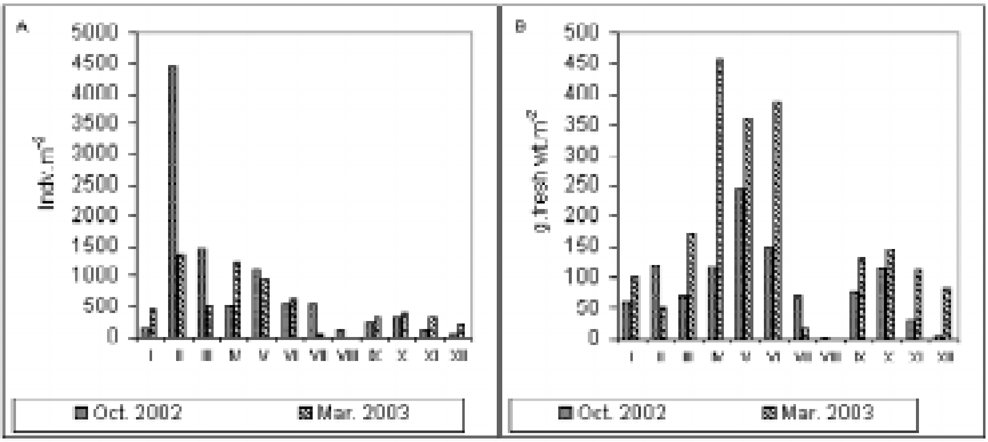

Fig. 9 - Standing crop and of total Mollusca A) Standing crop B) Biomass.

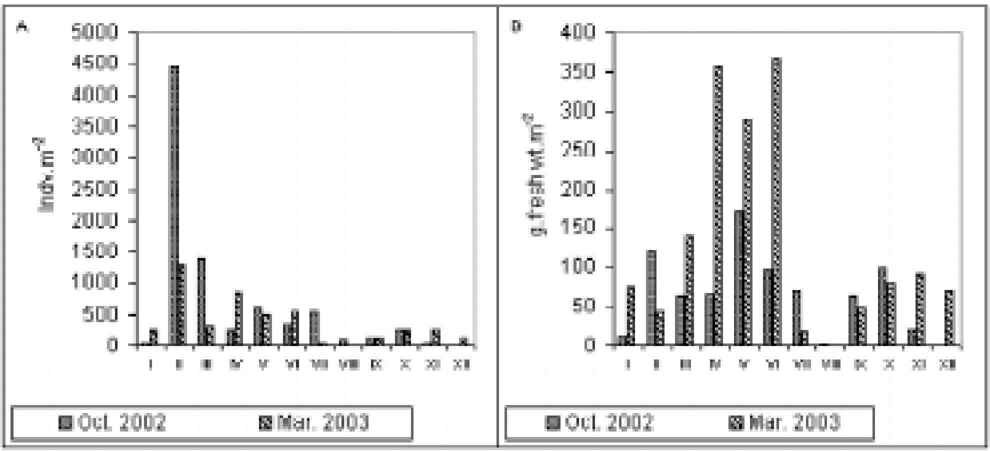

Fig. 10 - Standing crop and biomass *of Brachiodonta variable* A) Standing crop B) Biomass.

total catch. In contrast, other species, such as crabs and shrimps attained an increase percentage in the catch with 26.8 and 25 % for shrimps and 24.2 and 24 % for crabs in 1995 and 2000, respectively (El-Ganainy *et al.*, 2002).

The phenomenon of changes in fish community structure may be mainly related to changes in macrobenthos assemblages since the majority of the dropped fish species are mainly bottom feeders. Mollusca comprised the highest volume of *Sparus aurata* diet, contributing about 33.24% (%composition) of the total diet volume of *Sparus aurata* and was found in 89.63% (%frequency), while Crustacea constituted about 8.11 % of its diet volume(Fouda *et al.*, 1985).

Dredging and Deepings of the two artificial inlets (Boughazs I and II) to about 7 m down water, with continuously maintains would help the exchange of water between the lagoon and Mediterranean, that will maintain the salinity to the optimum level and rebalance the species composition of macrobenthic community, and consequently fish species structure.

The present study urgently recommends a detailed investigation on production of the common arthropods and molluscan species, which constitute the main bulk of food items for Bardawil Lagoon fish.

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