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# Ecological and Biological Studies on Some Economic Bivalves in Suez Bay, Gulf of Suez, Red Sea, Egypt

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**Abstract:** A study was made from April 1999 to June 2000 of the economic clams in Suez Bay located in the northern part of the Gulf of Suez. Two species were investigated; *Gafrarium pectinatum* belong to family Veneridae and *Mactra olorina* belong to family Mactridae. The two species are dioecious, the sex ratio not varying significantly from 1:1 and no hermaphrodites were obtained. *G. pectinatum* matures at shell length of between 10-13 mm, while *M. olorina* matures at shell length of between 26.3-31.5 mm. Length frequency analysis revealed three cohorts in the two species with monthly growth rates of about 3.5-6 mm for *G. pectinatum* and 2.4-3.5 mm for *M. olorina*. The relationships between shell length and several growth parameters for both species were significant and reflected isometric growth in most cases. Spawning period for the two species extends from March to June.

**Key words:** Bivalves, *Gafrarium pectinatum*, *Mactra olorina*, Suez Bay, Gulf of Suez, Red Sea

## INTRODUCTION

Suez Bay is a shallow extension of Gulf of Suez, roughly elliptic in shape, with its major axis in NE SW direction and extends from 29°51 N to 30°N (Fig. 1). Average length along the minor axis of the bay is 18.8 km, while the mean depth 10 m and its surface area is 77.13 km$^2$ (Meshal, 1970). It is connected to Suez Canal by a dredged channel and to the Gulf of Suez through most of its southeastern side. City of Suez occupies the northern part of the bay.

In common with other taxa of the bay, two clams belonging to the families Veneridae and Mactridae, which are *Gafrarium pectinatum* (Linnaeus) and *Mactra olorina* (Philippi) are of great economic importance as sea food. Generally, these bivalves are a traditional food resource for most coastal populations, in the tropics as in temperate areas (Davy and Graham, 1983; Broom, 1985). Many species of the two families are commercially marketed and cultured as an essential source of protein in various countries of the world e.g., Japan, China, Korea, North America, Europe, Southeast Asia and Indonesia (Valli *et al*., 1981, 1982; Ketchen *et al*., 1983; Bourne, 1986).

These clams usually live in the surf zone of exposed sandy beaches and occur in densities that usually support fisheries. They usually attract commercial interest of fishermen and are the focus of some scientific investigations, dealing with their distribution (Chung *et al*., 1987; Baron and Clavier, 1992; Cranfield *et al*., 1992; Conroy *et al*., 1993). The reproductive biology of these species of clams has not been studied in Egyptian waters; however, there are some studies on both genera of the target species in other areas of the world especially Far East, e.g., *Gafrarium tumidum* (Baron, 1992), *Gafrarium pectinatum* (Morton, 1990), *Mactra chinensis* (Chung *et al*., 1987; Sakurai *et al*., 1992; Sakura, 1993).

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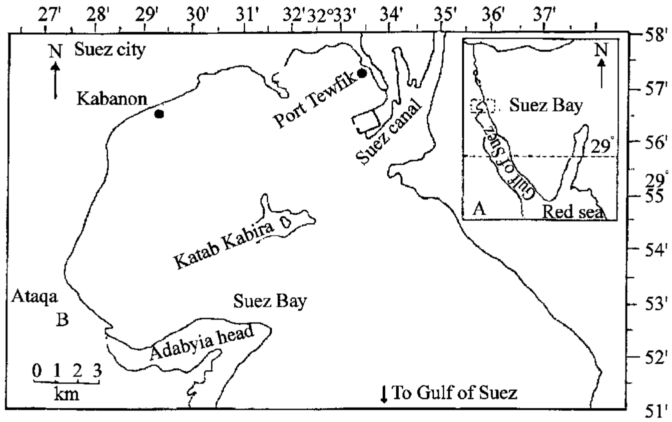


Fig. 1: Map of Suez Bay showing: (A) Suez Bay as a part from Gulf of Suez and Red Sea. (B) Suez Bay and the sites of investigation

The growing demand and the high consumption of the two species by inhabitants of coastal cities in Egypt, lead to their over fishing in Suez Bay. Nevertheless, data on both species are very scarce and dissipated and knowledge remains quite limited. This lack of knowledge is particularly impairing for efficient management of their fisheries.

So, this study deals with the fishery biology of these economic clams *Gafrarium pectinatum* and *Mactera olorina* in the Suez Bay. It could be helpful in management of their fisheries, also, in the mariculture of both species.

## MATERIALS AND METHODS

Monthly sampling of clams *Gafrarium pectinatum* and *Mactera olorina* at two sites (Kabanon and Port Tawfik) of Suez Bay (Fig. 1) was conducted using 50×50 cm quadrat from April 1999 to March 2000. In four replicates at each site, live specimens were counted in each quadrat and the mean density of each species was calculated as number individuals $m^{-2}$. The animals were preserved in 6% neutral formalin for subsequent biological investigated. Apart of these preserved samples (about 300 individuals for each species) were sexed and examined for the following measurements (1) Shell length or the anterior-posterior dimensions measured parallel to the line of the hinge; (2) shell width (the maximum width or convexity of the valves) measured perpendicular to the plane of the commissure and shell highest; (3) the shell height measured at right angles to shell length. These parameters were measured to the nearest 0.1 mm using vernier calipers. The shell length was considered as an index of animal size (2)The flesh parts was carefully removed by hand and drained off excess water and weighted then dried in an oven at 100°C for 24 h and weighed. The wet flesh weight, dry weight, hard shell (without tissues) weight and the total weight (hard shell and flesh) were weighed using Sartorious analytical balance readout 0.01 g. The total length measurements were used to produce monthly length-frequency histograms for the two species Table 1. A series of modes was discriminated by eye and the progression of these modes from month to month was used to generate growth rates.

The sex and gonads conditions were determined by microscopic examination of smears of the gonads. The maturity of the ovary was estimated and divided into three categories. (1) Undeveloped ovaries: transparent ova with obvious nuclei occupying most of the volume and transparent cytoplasm; spent ovaries could not be discriminated and are included in this category. (2) Developing ovaries with ova have nuclei my be obscured, cytoplasm granulated. (3) Ripe, or almost ripe; ova completely opaque. Gonad index was calculated by determining the wet weight of the gonad relative to the wet weight of the soft parts.

Table 1: *G. pectinatum* and *M. olorina*. Percentage of males and females in monthly samples

| | *G. pectinatum* | | *M. olorina* | |
|---|---|---|---|---|
| Date | Males | Females | Males | Females |
| **1999** | | | | |
| April | 51.24 | 48.76 | 51.28 | 48.72 |
| May | 51.03 | 48.97 | 50.83 | 49.17 |
| June | 46.63 | 53.37 | 53.49 | 46.51 |
| July | 49.53 | 50.47 | 48.65 | 51.35 |
| August | 50.50 | 49.50 | 51.06 | 48.94 |
| September | 48.57 | 51.43 | 48.67 | 51.33 |
| October | 51.03 | 48.97 | 48.78 | 51.22 |
| November | 52.15 | 47.85 | 48.22 | 51.78 |
| December | 51.74 | 48.26 | 49.75 | 50.25 |
| **2000** | | | | |
| January | 49.04 | 50.96 | 47.34 | 52.66 |
| Februaruy | 52.50 | 47.50 | 46.48 | 53.52 |
| March | 51.14 | 48.86 | 52.83 | 47.17 |
| April | 51.43 | 48.57 | ND | ND |
| May | 51.26 | 48.74 | ND | ND |
| June | 51.20 | 48.80 | ND | ND |
| Mean | 50.60 | 49.40 | 49.78 | 50.22 |

ND = Not Detected

We examined our data for evidence of differential growth between the various size parameters measured by testing each pair of size variables y and x for their fit to the allometric equation $y = A x^b$ where A and b are constants. This equation can be rewritten in logarithmic form as

$$\log y = \log A + b \log x$$

Gonad index can be determined by the following methods:-Determination of the wet weight of the gonad relative to the total wet weight of soft parts (Ansell *et al*., 1963).

$$GI = \frac{\text{Gonsd wet weigh}}{\text{Soft body wet weight}} \times 100$$

Condition index can be determined by the following methods:-
Determination of the dry weight of the tissue relative to the total wet weight (Ansell *et al*., 1964).

$$CI = \frac{\text{Dry weigh}}{\text{Total wet weight}} \times 100$$

Hydrographic parameters were measured monthly at the collection sites. Surface water salinity (S%) was measured to nearest 0.5% by a calibrated digital refractometer. Surface water temperature was measured using a standard thermometer graduated to 0.1°C. Surface water hydrogen ion concentration (pH) was measured *in situ* using a calibrated digital pH meter. For each parameter, three readings were taken and their mean value±SD were calculated.

## RESULTS

### Density

*Gafrarium pectinatum* showed high density (No. $m^{-2}$) at Port Tawfik than Kabanon with similar trends of increase and decrease with maximum during the winter. Also, *Mactra olorina* showed the same trend (Fig. 2). The lowest densities for both species could be attributed to the overfishing during

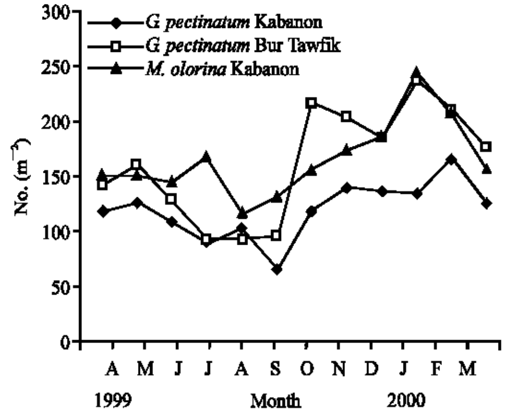


Fig. 2: The mean abundance of *G. pectinatum*, at the two sites and *M. olorina* at Kabanon from April, 1999 to March 2000

summer months. For *Gafrarium pectinatum*, the size less than 20 mm was representing 7.5% of all clams at Kabanon, however it was representing 8.2% at Port Tawfik. Large size individuals (20-40 mm) were representing not less than 60% of the catch, while very big size >40 mm was representing not less than 30% of the catch at both sites. For *Mactra olorina*, the size less than 20 mm was representing 11.9% of the catch. Large size 20-40 mm was representing 52.9% of the total catch. Very big size >40 mm was representing 35.2% of all clams collected.

**Sex Ratio**

In both studied species the sexes can not be distinguished by gonad appearance or shell morphology but only by microscopic examinations of the gonads. 2,995 and 2,512 specimens of *G. pectinatum* and *M. olorina* examined microscopically from April 1999 to June 2000. The results for both species and percentage of both sexes in different months are presented in Table 1. The mean proportions of male to female were 50.60 to 49.40% in case of *G. pectinatum* and 49.8 to 50.2% for *M. olorina*. In both species the departure proportions from equal of males and females was tested separately by a Chi-square ($\chi^2$) test with one degree of freedom and found to be insignificant $\chi^2$ value was nearly equal to zero. This strongly indicates that the sex ratio is even (1:1) and these variations are probably not of any real biological importance. No hermaphroditic individuals were found among the animals examined for both species.

**Morphometric Relationships**

A series of morphometric relationships were investigated by fitting regressions. Length-length, length-weight and weight-weight relationships have been determined for both species. The regression equations, coefficients of correlation and size ranges for different sexes in different areas, are summarized in Table 2 and 3. The curves show linear model for length-length and weight-weight relationships and power models for length-weight relationships. The following were examined: shell length on all shell height; shell width; total weight; tissue weight; shell weight and dry weight; total weight on all tissue weight; shell weight; dry weight; tissue weight on both shell weight and dry weight and shell weight on tissue weight. The regression was determined separately for the samples from the two areas.

Shell length-tissue weight relationships showed that the tissue weight of bivalves examined at Bur Tawfik was heavier than that at Kabanon, with a curve power function of 3. It also shows that the Tissues are heavier in spring (March April May and June) than in remaining of the year period

Table 2: *Gafrarium pectinatum*. Regression for morphometric relationships for females (F) and males (M) from Kabanon and Port Tawfik. SL: Shell Length, SH: Shell Height, SWi: Shell Width, TW: Total Weight, TiW: Tissue Weight, SW: Shell Weight, DW: Dry Weight. All lengths in mm, all weight in g. Each equation based on 300 individuals

| x | y | Sex | Area | Slope | Intercept | $r^2$ | $x_{max}$ |
|---|---|---|---|---|---|---|---|
| SL | SH | F | Kabanon | 0.6279 | 5.8443 | 0.92 | 54.30 |
| | | | Port Tawfik | 0.6548 | 3.1017 | 0.94 | 55.70 |
| | | M | Kabanon | 0.6468 | 1.2779 | 0.96 | 56.10 |
| | | | Port Tawfik | 0.6423 | 3.6350 | 0.94 | 56.70 |
| SL | SWi | F | Kabanon | 0.3564 | 4.5490 | 0.90 | 54.30 |
| | | | Port Tawfik | 0.4060 | 2.3783 | 0.91 | 55.70 |
| | | M | Kabanon | 0.3745 | 1.2779 | 0.87 | 56.10 |
| | | | Port Tawfik | 0.3845 | 2.0154 | 0.87 | 56.70 |
| $\log_e$ SL | $\log_e$ TW | F | Kabanon | 2.2864 | -5.5727 | 0.96 | -- |
| | | | Port Tawfik | 2.4980 | -6.7254 | 0.92 | -- |
| | | M | Kabanon | 2.7144 | -7.6009 | 0.94 | -- |
| | | | Port Tawfik | 2.4940 | -6.7254 | 0.94 | -- |
| $\log_e$ SL | $\log_e$ TiW | F | Kabanon | 2.6500 | -8.5172 | 0.93 | -- |
| | | | Port Tawfik | 2.9366 | -9.2103 | 0.90 | -- |
| | | M | Kabanon | 2.8777 | -9.7212 | 0.94 | -- |
| | | | Port Tawfik | 2.7099 | -8.5171 | 0.91 | -- |
| $\log_e$ SL | $\log_e$ SW | F | Kabanon | 2.1525 | -5.3185 | 0.92 | -- |
| | | | Port Tawfik | 1.9317 | -5.3601 | 0.87 | -- |
| | | M | Kabanon | 2.6151 | -7.4186 | 0.95 | -- |
| | | | Port Tawfik | 2.3899 | -6.8124 | 0.89 | -- |
| $\log_e$ SL | $\log_e$ DW | F | Kabanon | 2.8938 | -10.2000 | 0.90 | -- |
| | | | Port Tawfik | 2.8445 | -10.8200 | 0.91 | -- |
| | | M | Kabanon | 3.0775 | -11.8700 | 0.91 | -- |
| | | | Port Tawfik | 2.8554 | -11.5130 | 0.87 | -- |
| TW | TiW | F | Kabanon | 0.2267 | -0.2378 | 0.96 | 37.80 |
| | | | Port Tawfik | 0.5220 | 0.2191 | 0.91 | 31.60 |
| | | M | Kabanon | 0.2451 | -0.0968 | 0.93 | 29.00 |
| | | | Port Tawfik | 0.4116 | 0.3143 | 0.92 | 29.30 |
| TW | SW | F | Kabanon | 0.7704 | 0.3002 | 0.99 | 37.80 |
| | | | Port Tawfik | 0.3928 | 1.1766 | 0.92 | 31.60 |
| | | M | Kabanon | 0.7437 | 0.3424 | 0.98 | 29.00 |
| | | | Port Tawfik | 0.5508 | 0.3566 | 0.94 | 29.30 |
| TW | DW | F | Kabanon | 0.0593 | -0.1631 | 0.76 | 37.80 |
| | | | Port Tawfik | 0.0526 | -0.0684 | 0.90 | 31.60 |
| | | M | Kabanon | 0.0654 | -0.0878 | 0.86 | 29.00 |
| | | | Port Tawfik | 0.0579 | -0.0656 | 0.91 | 29.30 |
| TiW | SW | F | Kabanon | 3.2299 | -1.6844 | 0.92 | 9.10 |
| | | | Port Tawfik | 0.6414 | 1.4176 | 0.76 | 16.90 |
| | | M | Kabanon | 2.8326 | 1.2166 | 0.92 | 7.70 |
| | | | Port Tawfik | 1.2549 | 0.3676 | 0.91 | 11.90 |
| TiW | DW | F | Kabanon | 0.2465 | -0.0676 | 0.77 | 9.10 |
| | | | Port Tawfik | 0.0942 | -0.0441 | 0.89 | 16.90 |
| | | M | Kabanon | 0.2731 | -0.0650 | 0.90 | 7.77 |
| | | | Port Tawfik | 0.1364 | -0.0848 | 0.90 | 11.90 |
| SW | TiW | F | Kabanon | 0.2860 | -0.2237 | 0.92 | 28.80 |
| | | | Port Tawfik | 1.1395 | -0.0333 | 0.83 | 16.90 |
| | | M | Kabanon | 0.3241 | -0.1569 | 0.92 | 20.90 |
| | | | Port Tawfik | 0.7300 | -0.1716 | 0.92 | 16.40 |

which corresponds to the ripening of the gonads in spring. Total weight-shell weight relationship showed that the increase in total weight is mostly associated to shell weight increase. Shell weight considers the heavier part in the animal formed more than 70% from total weight. This ratio decreases in case of *M. olorina* especially in large clams. For the same total weight, shell weight were more heavier in *G. pectinatum* clams form Bur Tawfik than from Kabanon and than that of *M. olorina* clams.

Tissue weight-shell weight relationship and vs explain that those from Bur Tawfik population had consistently thicker and heavier shells for any given weight of tissue than those from Kabanon population. When clams of similar size are compared, those from the high shore generally have higher

Table 3: *Mactra olorina*. Regression for morphometric relationships for females (F) and males (M) from Kabanon SL: Shell Length SH: Shell Height, SW: Shell Width, TW: Total Weight, TiW: Tissue Weight, SW: Shell Weight, DW: Dry Weight, All lengths in mm, all weight in g. Each equation based on 300 individuals

| x | y | Sex | Area | Slope | Intercept | $r^2$ | $x_{max}$ |
|---|---|---|---|---|---|---|---|
| SL | SH | F | Kabanon | 0.5652 | 1.1444 | 0.95 | 58.80 |
| | | M | | 0.6231 | 2.6023 | 0.95 | 57.90 |
| SL | SWi | F | Kabanon | 0.3747 | 1.2181 | 0.96 | 58.80 |
| | | M | | 0.4636 | 0.5015 | 0.96 | 57.90 |
| $\log_e$ SL | $\log_e$ TW | F | Kabanon | 3.0454 | -9.4334 | 0.95 | -- |
| | | M | | 2.8217 | -8.5171 | 0.95 | -- |
| $\log_e$ SL | $\log_e$ TiW | F | Kabanon | 3.3194 | -11.5129 | 0.93 | -- |
| | | M | | 3.1044 | -10.4143 | 0.93 | -- |
| $\log_e$ SL | $\log_e$ SW | F | Kabanon | 2.8424 | -9.2104 | 0.92 | -- |
| | | M | | 2.5858 | -8.1117 | 0.91 | -- |
| $\log_e$ SL | $\log_e$ DW | F | Kabanon | 3.4751 | -13.8155 | 0.91 | -- |
| | | M | | 3.2526 | -12.7169 | 0.92 | -- |
| TW | TiW | F | Kabanon | 0.3625 | -0.0542 | 0.96 | 17.89 |
| | | M | | 0.3989 | -0.1406 | 0.93 | 18.96 |
| TW | SW | F | Kabanon | 0.6118 | 0.1713 | 0.97 | 17.89 |
| | | M | | 0.6192 | 0.1346 | 0.98 | 18.96 |
| TW | DW | F | Kabanon | 0.0645 | 0.00027 | 0.92 | 17.89 |
| | | M | | 0.0724 | -0.0101 | 0.90 | 18.96 |
| TiW | SW | F | Kabanon | 1.5539 | 0.4994 | 0.89 | 7.35 |
| | | M | | 1.4334 | 0.6252 | 0.89 | 8.08 |
| TiW | DW | F | Kabanon | 0.1719 | 0.0242 | 0.90 | 7.35 |
| | | M | | 0.1751 | 0.0296 | 0.90 | 8.08 |
| SW | TiW | F | Kabanon | 0.5654 | -0.0560 | 0.90 | 12.40 |
| | | M | | 0.6233 | -0.1453 | 0.90 | 12.82 |

shell weights and lower tissue weights than those from the low shore. There is further reflected in the higher shell/Tissue ratios in clams from the high shore, which show a general increase with increasing size suggesting that, as the clams grow, so their shells become progressively heavier relative to their Tissue.

**Length Frequency Analysis**

Length frequency distribution from Kabanon revealed about three mode groups of *G. pectinatum* over the course of the year. Shell collected in April 1999 appeared to be unimodal with a peak around 26 mm. This mode could be followed through to November 1999 when this sample had a size of 56 mm. This means that this bivalve had growth rate of about 4.2 mm month. A second mode appeared in August at about 24 mm shell length which reached around 54 mm in February 2000 (i.e., growth rate 6 mm month). The third pulse appeared in October 1999 at about 18 mm shell length and could be traced through to the final sample of March 2000 at about 48 mm (i.e., growth rate 6 mm month) (Fig. 3).

Length frequency distribution of *G. pectinatum* from Bur Tawfik revealed to annual cohorts with recruitment to the commercial population in May-June and October-December. The first cohort in April 1999 had a mode of 30 mm which could be traced in through the following months and ended in September 1999 (i.e., growth rate 3.6 mm). A second cohort appeared in August 1999 at 22 mm and could be followed through to March, 2000 with a mode of 48 mm (i.e., growth rate 3.7 mm $month^{-1}$) (Fig. 4).

The size frequency distribution of *M. olorina* revealed three peaks over the course of the year. Shells collected in April 1999 appeared to be unimodal with a peak around 48 mm. This could be traced with some uncertainty in May 1999 at about 42 mm shell length which could be traced with uncertainty to a mode of 54 mm in February, 2000 (i.e., growth rate 2.4 mm month). The third pulse appeared in July 1999 with a modal size at 12 mm and could be followed through to March 2000 with a mode of 40 mm (growth rate 3.5 mm) (Fig. 5).

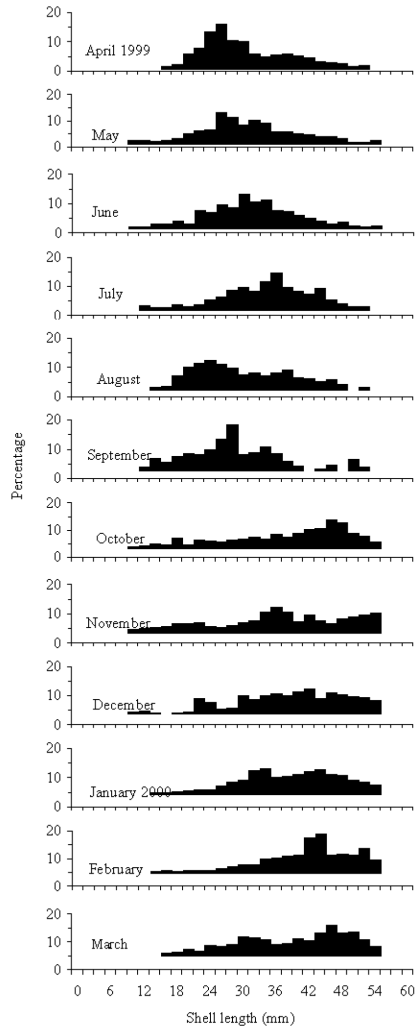


Fig. 3: *Gafrarium pectinatum*. Size frequency histogram at Kabanon site; sampled monthly from April 1999 to March 2000

**Size at Sexual Maturity**

The shell length at which the gonad begins to develop from rudimentary virgin state (undifferentiated or juvenile gonad) to the state in which the gonad is sexually differentiated is taken to be the size at first sexual maturity. Microscopic examinations were carried out for all individuals of clams starting from 10 mm shell length (minimum collected size) and continued up to the maximum sizes collected which were 56.7 and 58.5 mm shell length for *G. pectinatum* and *M. olorina*, respectively.

A highly positive correlation existed between shell length and the percentage of mature clam. In other words, the proportion of mature clams increased rapidly with the increase in shell length.

In case of *G. pectinatum*, the minimum size of mature clam ranged from 10.0-13.0 mm shell length. The estimated size at $SM_{50}$ ranged from 16.6-19.1 mm shell length, The percentage of clams that reached sexual maturity was approx 100% for those more than 23.8 mm (Fig. 6). For *M. olorina* the

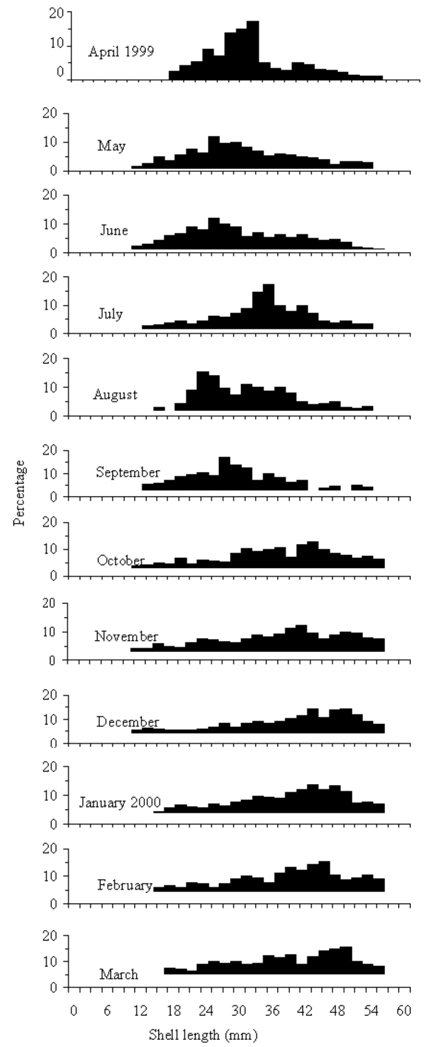


Fig. 4: *Gafrarium pectinatum*. Size frequency histogram at Bur Tawfik site; sampled monthly from April 1999 to March 2000

minimum size of mature clam varied from 26.3 to 31.5. mm shell length, the estimated size at $SM_{50}$ ranged from 35.2 to 38.0 mm shell length, 100% of clams that reached sexual maturity was approx for those more than 48.0 mm (Fig. 6 and 7).

## Gonad Maturation and Gonad Index

Stages of gonad maturation of the two species were investigated throughout the period of study using smear method. Annual variations in the percentage of *G. pectinatum* and *M. olorina* at the various sexual stages are shown in Fig. 8 and 9.

In *G. pectinatum* clams (Fig. 8). Immature phase dominated the sample all year around particularly from July 1999 to January 2000 and ranged from 50% in June to 100% in September, mature phase takes place in the period from April to July 1999 and from February to June 2000, ranged from 25% to 40% and occur in low percentage in the period from August to December, 1999

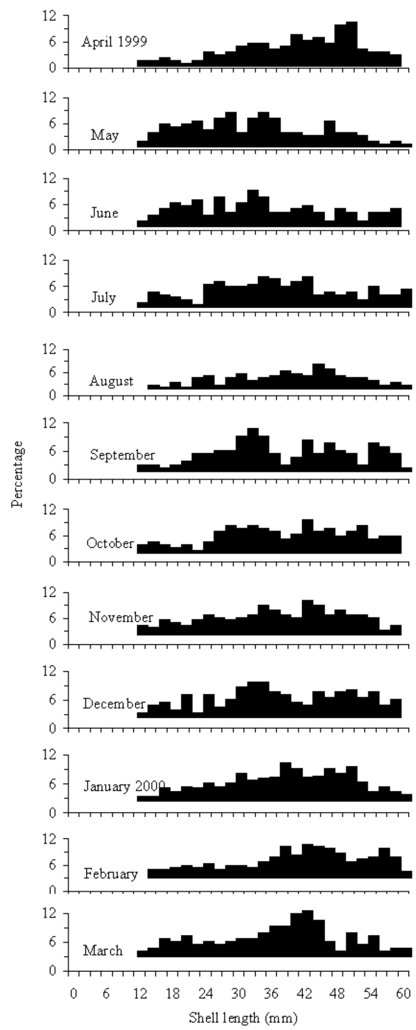


Fig. 5: *Mactra olorina*. Size frequency histogram in Kananon site; sampled monthly from April 1999 to March 2000

and January 2000 and ripe phase that was represented very well in the periods from April to June 1999 and from February to May 2000. It ranged from 40 to 60%. The ripe phase did not occur at all during the period from September to November 1999.

In *M. olorina*, immature phase occurred all year around and dominated particularly from June to December, 1999 and January-February, 2000 which ranged from 46 to 100%. Mature phase had a low frequent appearance with percentage varied between 5% and 38% and ripe phase was dominated during April-May 1999 and March 2000 (65-75%) and has low appearance during June-August 1999 and December-February, 2000 period (Fig. 9).

Gonad index of mature clams (>10 mm shell length) showed no significant correlation (r = 0.1664, 0.1269; 0.2546, 0.3785) to both species, for males and females, respectively. Female clams of *G. pectinatum* (Fig. 10) showed slightly higher values of gonad indices than that of males during the period of study except in January, 2000. The males showed high values in April 1999 (33.2±7.2) and

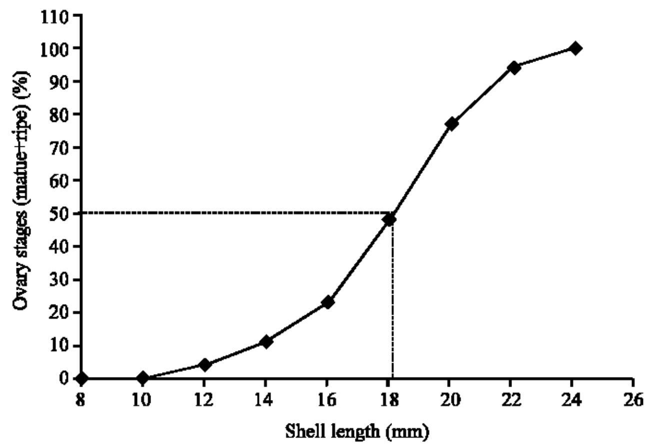


Fig. 6: Relationship between ovary maturation (mature+ripe stages) of female *G. pectinatum* and shell length during the period of maturation

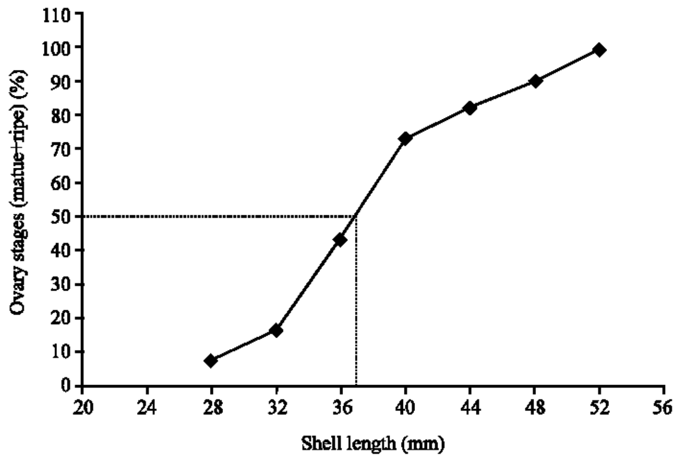


Fig. 7: Relationship between ovary maturation (mature+ripe stages) of female *Mactra olorina* and shell length during the period of maturation

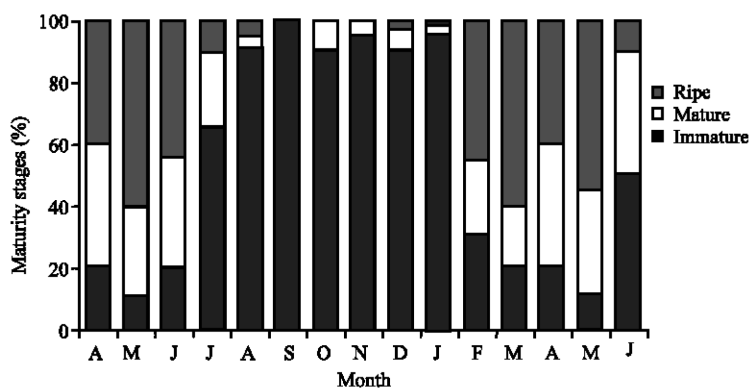


Fig. 8: *Gafrarium pectinatum*. The monthly variations of maturity stages throughout the period of study in Suez Bay

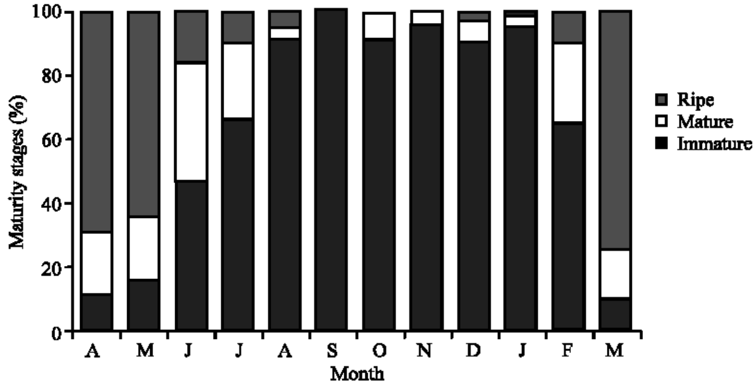


Fig. 9: *Mactra olorina*: The monthly variations of maturity stages throughout the period of study in Suez Bay

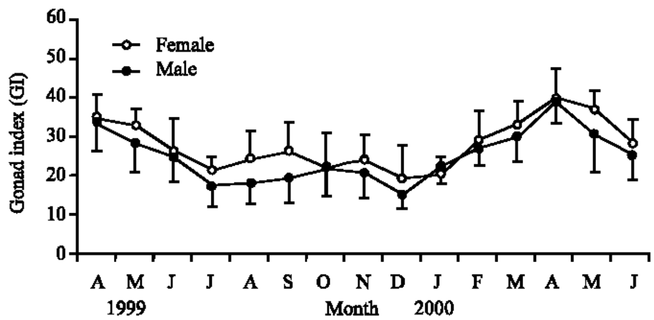


Fig. 10: *Gafrarium pectinatum*. Monthly variations in mean gonad index±SD for males and females from April 1999 to June 2000

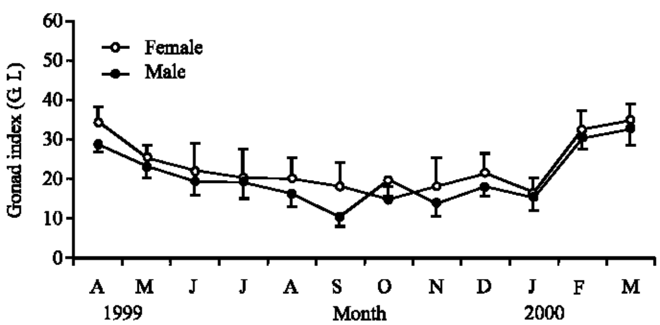


Fig. 11: *Mactra olorina*: Monthly variations in mean gonad index±SD for males and females from April 1999 to March 2000

April 2000 (39.6±5.2) and low one in July 1999 (17.1±5.4) and December 1999 (15.0±3.1). On the other hand, females had also two major values in April 2000 (40.4±8.0) and May 2000, (37.6±5.2) and two minor values in July 1999 (21.2±4.0) and December, 1999 (19.4±8.5). The decline in gonad index of both males and females attributed mainly to spawning which assumed to take place from June 1999 to January, 2000.

For *M. olorina,* Female clams, (Fig. 11) showed slightly higher values of gonad indices than that of males during the period of study except in October, 1999. Gonad index of males had higher values in April 1999 (33.7±1.6) and March 2000 (37.7±3.5). The highest gonad indices of females were found

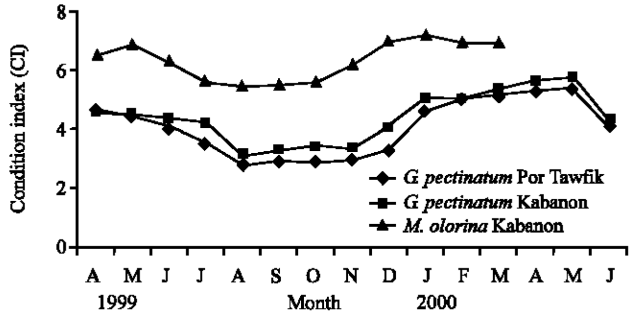


Fig. 12: *Gafrarium pectinatum* and *Mactra olorina*: Monthly changes in condition index for clams collected from Kabanon and Port Tawfik during the study period

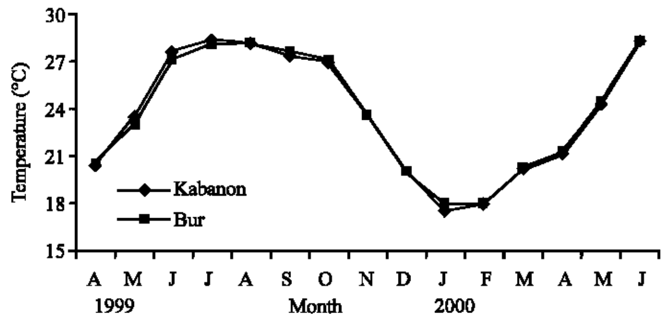


Fig. 13: Monthly temperature in Suez Bay from April 1999 to June 2000 for the two sites

to be in April, 1999 (38.4±3.5) and March 2000 (39.2±3.7). The decrease in gonad index of both males and females due to spawning was evident in the period from June 1999 to January 2000. The lowest gonad indices were recorded in September, 1999 (18.5) and October, 1999 (22.3) for males and females, respectively.

**Condition Index**

The mean dry weight expressed as a percentage of the total shell weight has been used routinely as a measure of condition.

The values for this index for *G. pectinatum* showed a distinct annual cycle during April, 1999 and June 2000. The cycle following that of reproductive activities, being largely based on the development, ripening and emptying of the gonad. August 1999 forms a convenient time at which to start a description of the annual cycle since at this time the index of condition was at its lowest value for the year.

In case of *M. olorina*, a distinct annual cycle appeared at this time, August 1999 forms a time that condition index value is the lowest for the year but January, 2000 shows the maximum value (Fig. 12).

**Hydrographic Parameters**

The measurements of surface water hydrographic parameters (pH, S% and C) made at the same time are represented in Fig. 13, 14 and 15. Each value is the mean of eight measurements taken at each site. Surface water temperature showed a wide variation among months (Fig. 13). Temperature reached to the maximum value of in July 1999 at the 1st station and in June 2000 at the 2nd station. It

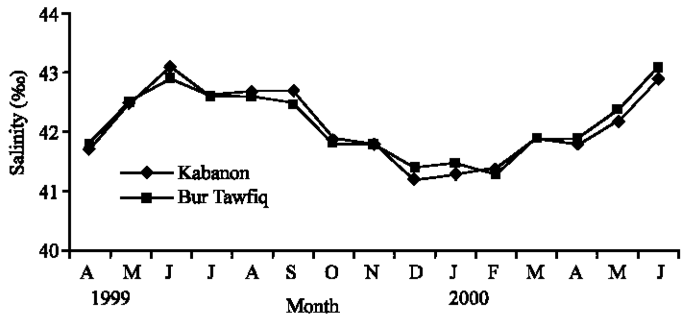


Fig. 14: Monthly salinity in Suez Bay from April 1999 to June 2000 for the two sites

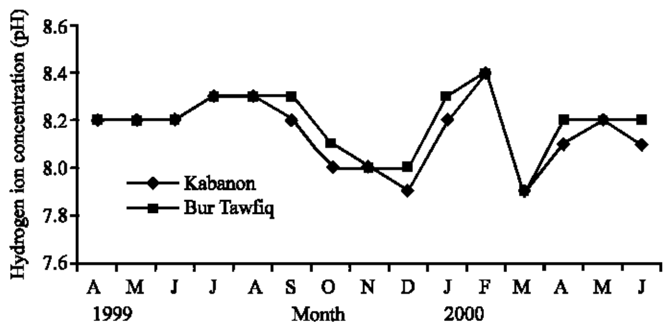


Fig. 15: Monthly hydrogen ion concentration in Suez Bay from April 1999 to June 2000 for the two sites

recorded the minimum value in January, 2000 at the 1st station and at the 2nd station in January and February, 2000. The temperature variation followed a rough sinusoidal curve with maximum in summer and minimum in winter.

Monthly variation of salinity (Fig. 14) over the study period showed no significant difference between sites or months. Salinity reached the maximum value 43.1‰ in June, 1999 and 2000, at the two sites and the minimum value in February, 2000 and in December, 2000 at the 1st and 2nd station, respectively (Fig. 12).

The hydrogen ion concentration of the Suez Bay (Fig. 15) fluctuated within a narrow range with annual average of 8.2. The highest pH values were observed in February, 2000 while the lowest reading appeared in November 1999.

## DISCUSSION

The venerid clams represent the most commercially important and successful group of bivalves in Egyptian waters (Hasan, 1983; Fouda and Abou Zied, 1990; Ghobashy *et al*., 1992; Mohammed *et al*., 1992). The species of interest, *G. pectinatum* distributes originally throughout the tropical Pacific (Cernohorsky, 1972), Indian Ocean and Red Sea (Oliver, 1992). It is first recorded in the Suez Canal by Tillier and Bavay in 1905; the Mediterranean from Egypt: Port Said (Tillier and Bavay, 1905), Alexandria (Pallary, 1913) and El-Arish (Barash and Danin, 1973); and South Turkey: Kizkalezi (Lindner, 1987) and Tasuçu (Buzzurro and Greppi, 1997). While the other species of interest *M. olorina*, which belongs to Mactridae. It distributes originally as endemic in Red Sea (Oliver, 1992). It is first recorded in the Suez Canal (Tillier and Bavay, 1905), the Mediterranean from Egypt: Port Said (Cams, 1889-93), Bardawil Lagoon (Barash and Danin, 1973, 1982) and Lebanon: Beirut (Gruvel and Moazzo, 1931).

*Gafrarium pectinatum* and *Mactra olorina* are most important clams in intertidal sandy shores of Suez Bay in Gulf of Suez. They used as a food in Egypt and usually marketed in Suez Canal cities. Allometric growth and morphometric relationships of both species revealed uniform growth and the gradual changes in body proportions with size and age. Older clams had heavier shells with width often exceeding heights. Tidal heights, substrates and other environmental parameters are the major factors affecting growth in lengths, tissues and its ratios (Lent, 1967; Rhoads and Young, 1970; Bloom *et al*., 1972; Thomassin, 1978; Chardy and Clavier, 1988; Baron and Clavier, 1992). Submergence of mussels for many hours increased the weight of tissues and shell deposition than those in high intertidal zone (Fox and Coe, 1943; Wilbur and Jodrey, 1952). Growth in linear dimensions and weight for males and females of both studied species generally describes curvilinear pattern. The actual rates of increase varied considerably from one population to another as did the rates of various parameters within one population. Similar relationships have been definitely established for many clams all over the world (Chung *et al*., 1987; Baron and Clavier, 1992; Kandeel, 2002).

Length frequency distribution of *G. pectinatum* and *M. olorina* generally revealed polymodal patterns. Cohorts' admission to the population taking place in May-June and October- December. Different cohorts showed different growth rates (varied between 3.6-6 mm month for *G. pectinatum* and between 2.4 and 3.5 mm month for *M. olorina*). Growth of these cohorts depended on the season, site and on the optimisty of the environmental parameters affecting its growth. Kabanon's population seems to be in favorite conditions than in Port Tawfik. Temperature, salinity, pH were similar in both sites, however substrate texture was different. In Kabanon, the texture was muddy and clay, while in Port Tawfik, it was mainly sandy. This could reflect the better growth in Kabanon's population than Port Tawfik's one. Previous studies (Chung *et al*., 1987; Baron and Clavier, 1992) recommended the role of substrate as a control parameter influencing the growth of clams and confirming their preference for muddy and clay substrates.

Data of sex ratios for both species generally regarded as being dioeciously with an approximately 1:1 sex ratio with no hermaphroditism as in other bivalves populations (Walter and Dela Cruz, 1980; Walter, 1982; Brousseau, 1983) and *G. pectinatum* in Hong Kong mangrove (Morton, 1990).

The onset of sexual maturity and the reproductive periods for the studied clams in the present study, reflect the significant role of temperature and other endogenous factors for rapid maturation. Loosanoff and Davis (1952) and Kinne (1963) emphasized the role of exogenous (temperature, salinity, light,..etc) and endogenous factors (nutrient reserves, hormonal cycle, genetic) on the timing and duration of various phases of reproductive cycle and the synchronization of spawning period with these factors. In the present study, *G. pectinatum* attains its first sexual maturity at a mean shell length of 11.4 mm, while *M. olorina* usually has first sexual maturity at a mean shell length of 28.9 mm. At these recorded sizes, the individuals of both species are more or less one year old. Reproduction cycle for both species is characterized by one brood and confined to a specific climatic season, which is spring and early summer. This time of the year reveals the optimum conditions for gametogenesis. Study of Morton (1990) on *G. pectinatum* of Hong Kong mangrove confirmed that it matures at a shell length of between 16-20 mm after one year of life. However, for other species *G. Tumidum* in New Caledonia, it was 20mm. Sakurai *et al.* (1992) revealed that *M. chinensis* begins sexual maturation at shell length of 25-30 mm.

Data of gonad index and condition index reflecting changes of gonad conditions seasonally and with animal size. The highest values of gonadal index were during April, 2000, being 40.0 for *G. pectinatum*; and during March 2000, being 38.5 for *M. olorina*. The lowest values of gonadal index were in December, 1999, 18.5 for *G. pectinatum* and during September, 1999, 21.8 for *M. olorina*. Results of these parameters were mainly confined with the availability of food and with the repining conditions of gonads. Ansell *et al.* (1964), Pekkarinen (1983) and Kluytmans (1985) strongly recommended the role of digestive gland weight (as a food reservoir) and the gonad ripening on the gonad conditions and body conditions of these bivalves. Griffiths (1977) also found that the decline in gonad and body weights of mussels coincided with build-up of gametes cells and gametes. Mature gonads of the two studied species constituted large parts of body weight (between 25.6 and 40% in *G. pectinatum* and 31.4-40.7% in *M. olorina*) reflecting their significant roles in total body weight. Evidence of prolonged breeding is the simultaneous presence within a population of all sexual development stages. The growth of gametes thus varies with individuals suggesting a specific response to the environmental factors. The occurrence of successive individual spawning has been linked to the presence of gametes at all stages of maturity (Shafee and Lucas, 1980; Morten, 1990).

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