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Ecological studies on families Veneridae and Mactridae (Mollusca: Bivalvia) inhabiting the western coasts of the Suez Gulf, Egypt

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ABSTRACT

The faunal composition, abundance, distribution, population density and diversity of bivalve species of families Mactridae and Veneridae were investigated from 11 sites along the western coasts of the Gulf of Suez during the period from summer 2017 to summer 2019. A total of 13 bivalve species belonging to 5 subfamilies within 9 genera of the two families were recorded. Family Veneridae was the dominant and represented by 11species (84.62%) compared with only 2 species of family Mactridae represented 15.38% of all recorded species. *Mactra olorina* (family Mactridae), *Gafrarium pectinatum, Callista florida* and *Circe rugifera* (family Veneridae) were the most frequent species at sites II (Kabanon), III (Adabia) and IV (Ain Sokhna) during this study. Site III accommodated all recorded bivalves (13 species), followed by 8 species at site II, decreased to 6, 4, 4 and 3 species at sites IV, V (Monte Galala), XI (Al Azazia – north Ras Gharib) and I (Suez Bay), respectively. A total of 1208 individuals were collected from the study sites, 842 individuals (69.70%) are venerids and 366 individuals (30.30%) are mactrids. The majority of individuals (1179) were collected from sites III, II and IV, which accommodated 599, 546 and 34 individuals, respectively. The values of Simpson's diversity index, Shannon-Weaver index, evenness, and Margalef´s Species richness were calculated at each site. The annual values of these indices averaged 0.42, 1.70, 0.21 and 1.11(site II), 0.30, 2.13, 0.16 and 1.88 (site III) and 0.20, 2.35, 0.39 and 1.42 (site IV), for these indices, respectively. The highest values for Simpson's index of similarity recorded 76.19 % and 71.43 % between site II and both of sites III, and IV, respectively.

INTRODUCTION

Phylum Mollusca is one of the largest, and most diverse and important groups in the animal kingdom. There are over 50000 described species of mollusks, about 30000 of these are found in the marine environments (Gosling, 2004), which in turn are the second largest animal phylum and the largest in the marine realm (Sharabati, 1984; FAO, 2016; Rusmore-Villaume, 2008), but a great number of these species occur in fresh and brackish waters and several numbers of species are terrestrial and live different land habitats. Ecologically, mollusks are one of the most important elements within food chains and consider among the most prominent members of marine faunal ecosystems. Certain species have direct or indirect commercial

importance and even medical importance to humans (Vine, 1986; Mastaller, 1987; Rusmore-Villaume, 2008).

Class Bivalvia comprises mollusks enclosed in two shell valves as mussels, oysters, scallops and clams. It constitutes the second largest class of Mollusca after Gastropoda, and comprises about 7500 species (Sharabati, 1984; FAO, 2016; Rusmore-Villaume, 2008). Family Mactridae comprises about 180 species with shells are commonly known as "surf clams", or "trough clams" (Huber, 2010) and have important ecological and economic roles in marine environments. Members of this family occupy the sandy and muddy bottoms (Lamprell & Whitehead, 1992) and some of them act as suspension filter-feeding animals in the soft bottom ecosystem (Poutiers, 1998). Species of genus *Mactra* can also be found in mangrove zones (Masagca *et al.*, 2010) and seagrass beds (Mudjiono *et al.*, 1992). Some of mactrid bivalves have economic importance in some countries. They are edible; hence they are actively collected and consumed in the Philippines. On the other hand, members of family Veneridae are the most diverse recent bivalves, comprising over 800 extant, presumably valid species in approximately 170 genera (Mikkelsen *et al.*, 2006). According to Ansell (1961), members of the Veneridae are suspension feeders and shallow burrowing in relatively soft substrata. 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 (Ketchen *et al.*, 1983).

Along the entire Red Sea including the Egyptian coasts and coasts of associated gulfs (Suez and Aqaba), taxonomy, ecology, and fisheries, of the mollusks had treated in several studies (Hasan, 1983; Sharabati, 1984; Vine, 1986; Head, 1987; Mastaller, 1987; Rusmore-Villaume, 2008). The Suez Gulf mollusks had treated in few detailed studies, particularly ecology, biology and economic importance including Hasan (1983), Ismail (2005), Gab-Allah *et al.* (2007), Radwan (2014), and El-Mekawy (2016), in addition to studies carried out on mollusks at the neighboring areas including Suez Canal Lakes (Fouda and Abou Zied, 1990; Abou- Zied, 1991; Mohammed, 1992, 1997; Kandeel, 2002). However, all these studies covered certain species or dealt with general distribution or taxonomy of certain families.

Therefore, this study aims at through light on the ecology of the intertidal and shallow subtidal species of families Mactridae and Veneridae at the western coasts of the Gulf of Suez.

MATERIALS AND METHODS

Field studies:

Study sites:

Eleven sites were chosen at certain localities between Suez City (north) and Ras Gharib (south) covering all different habitats along the western coastal plain of the Gulf of Suez (Figure 1) during the period from summer 2017 to summer 2019. The accurate position of each site was determined using the GPS (Global Positioning System) and local name was recorded and given in Table (1). All field observations on the sites topography, tides, types of habitats, vegetation, accumulated onshore dead shells, date and time of visit, pollution and human activities were recorded.

Sample collection

At each site 3, line intercept transects (LIT) extended from 30-50 m length at upper and intertidal zones and shallow subtidal zone were taken perpendicular on the shoreline and at 100 m distance.

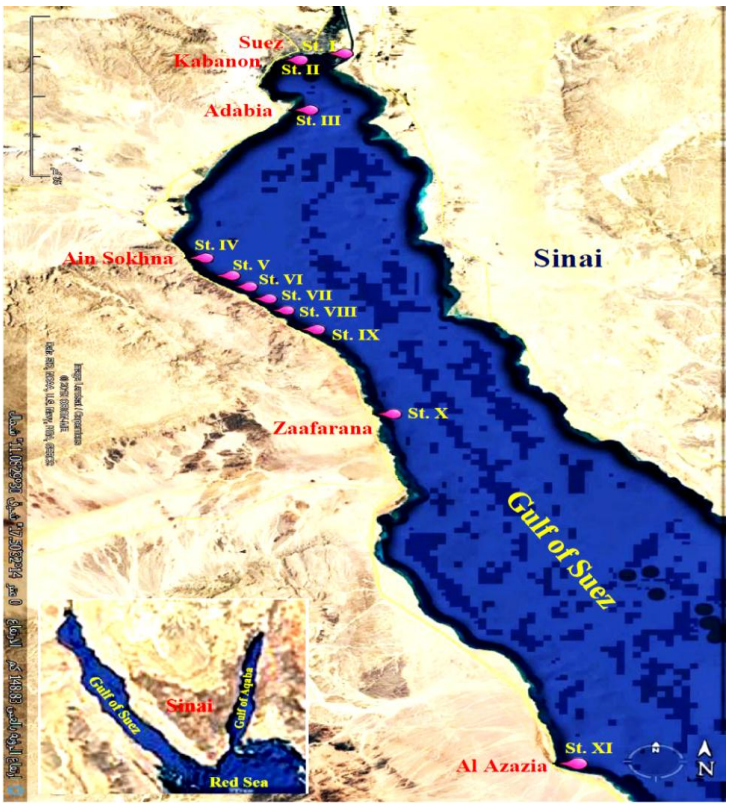

Fig. 1: Map shows sites of study at the western coasts of the Suez Gulf.

Table 1: Local names and coordinates of study sites at the western coasts of Suez Gulf.

Sites	GPS Coordinates		Habitat types
	Longitudes (E)	Latitudes (N)	
I- Suez Bay (Suez City north)	32°32'51.03"	29°57'22.92"	Sandy-mud habitat with scattered rocks.
II- Kabanon (Suez City south)	32°29'12.02"	29°56'37.20"	Muddy-sand habitats.
III- Adabia	32°30'3.84"	29°50'46.41"	Sandy habitat with few rocks and stones.
IV- Ain Sokhna (65 Km south Suez City)	32°21'39.30"	29°33'29.40"	Mixed habitats: Rocky, corals and sandy bottom.
V- Monte Galala (70 Km South Suez City).	32°25'2.7"	29°30'4.5"	Mixed habitats: sandy, rocks and corals.
VI- 72 Km south Suez City	32°25'54.77"	29°29'27.58"	Mixed habitats: sandy-rocks and corals (moderate pollution).
VII- 75 Km south Suez City	32°27'18.90"	29°28'16.80"	Mixed habitats: sandy- rocks, with heavy polluted shore.
VIII- Porto Sokhna	32°28'28.64"	29°27'24.42"	Mixed habitats: sandy, rocks and corals.
IX – 85 Km South Suez City	32°30'46.83"	29°25'12.50"	Sandy habitat with few rocks.
X- Zaafarana	32°37'0.47"	29°15'23.56"	Sandy- gravel and few rock flats.
XI-Al Azazia (20 Km north Ras Gharib)	32°51'46.44"	28°34'39.00"	Mixed habitat: rocky and sandy.

All live and dead shells of bivalves belong to families Mactridae and Veneridae were surveyed and representative samples from each species were collected by hand from different habitats. A corer was used for collection of soft bottom subtidal and upper intertidal inhabiting species. While sediments within three quadrates of 25 X 25cm at each side of the line transects at the upper intertidal zones were collected and sieved using manual sieve of 0.5 mm, and all bivalves were collected and recorded. The burrowing specimens from the shallow subtidal zones were collected by hand, or using a hand-made manual dredge, supporting with metal frame of 30 x 15 cm along the same LIT. A total of 1208 specimens of bivalve species were collected seasonally during the period of study. Collected specimens were put in

a tightly closed plastic bag, provided with date and place of collection, preserved immediately in 10 % seawater formalin solution and transported to the laboratory for examination.

Laboratory studies:

At the laboratory, the collected samples of bivalves were firstly cleaned from the attached sediments and the extraneous bio-fouling organisms were removed by scraping from the ventral and dorsal shell, then sorted, and counted, followed by identification to the specific level using identification keys of Oliver (1992) and FAO (2016), as well as to available books and literatures including Sharabati (1984) and Rusmore-Villaume (2008) and a list for recorded species were constructed. Representative specimens for each identified species had been deposited among the Reference Collection of Al Azhar University, Egypt (RCAUZE), at the Invertebrates Laboratory, Section of Marine Biology, Department of Zoology, Al-Azhar University, Cairo, Egypt.

Population dynamic

The population dynamics for bivalve species were studied, particularly at intensive study sites. The values of abundance, relative abundance, status, diversity indices, and species richness were calculated as following:

Shannon and Weaver index (H)

Species diversity was calculated according to the formula described by Shannon and Weaver (1963) and Pielou (1977) which is called the "general diversity" or Shannon - Weaver Index (H) as in the following formula:

$$H = 3.3219 \left[\text{Log } N - \frac{1}{N} (\sum n_i \text{ Log } n_i)\right]$$

Where H= Shannon-Weaver index, N= Total number of individuals of all collected species, ni= number of individuals of "i^{th}" species

The value of this index varies from 0 (community contains only a single species) to high values for communities containing several species.

Evenness (E)

To overcome the low number of species and high number of individuals during study, the evenness or Pielou's index (E) was calculated according to Pielou (1966) according to the following formula:

$$E = H'/ S$$

Where E= Evenness, H'= the value of Shannon Weaver index and S= Number of species. An evenness value of "1" would indicate that all species had exactly the same number of individuals.

Simpson index of diversity (D):

This index was also used according to the following formula:

$$D = \frac{\sum ni\,(ni - 1)}{N\,(N - 1)}$$

Where N= sum of all collected individuals, n_i= No. of individuals of i^{th} species.

Species richness (SR):

This index was calculated according Margalef (1968), and called as Margalef's species index as in the following formula:

$$SR = S\text{-}1/\text{Lin } N$$

Where SR= Species richness, S= No. of species, and N= Total number of individuals for all collected species.

Similarity index (S):

This index is used to compare between different sites and was calculated according to formula described by Morton and Davidson (1988) as following:

$$S= 2C/A+B$$

Where A= No. of species in the first area, B= No. of species in the second area, and C= No. of common species in both A and B areas.

Status of collected species:

The status of each species at each site was recorded using the terms of: Frequent (F): more than 10 individuals each visit; Common (C): from 4- 9 individuals; and rare (R): less than 3 individuals.

Population density:

The individual's number of each species was counted I a quadrate of 25x25 cm at each zone, and the population density was estimated as the number of individuals per square meter according to the following formula:

$$D= \sum N / (n \times a^2) \times 10000$$

Where: N= Sum of number of all collected individuals; n= number of replicates; a^2 = Square area in cm.

Statistical analyses:

All obtained data were treated with statistical computing program using Excel, version 2016.

RESULTS

Faunal composition:

General faunal composition:

A total of 13 bivalve species belong to families Veneridae and Mactridae were recorded from the eleven (11) study sites along the western coast of the Suez Gulf. These species belong to 5 subfamilies and 9 genera as shown in Table (2). Family Veneridae was the dominant and represented by 11species (84.62% of all recorded species) belong to 4 subfamilies and distributed within 8 genera. Genus *Circe* comprised 3 species followed by two species in genus *Dosinia*, while other genera were represented by only one species for each. On the other hand, subfamily Circinae comprised the greatest number of species (5) within three genera, while other subfamilies were represented with only two species, either within one genus (subfamily Dosiniinae) or two genera as (subfamilies Callocardiinae and Tapetinae). In contrast, Family Mactridae comprised only two species (15.38% of all) belong to subfamily Mactrinae.

Table 2: Species distribution with status at different sites during the period of study.

Families	Subfamilies	Species \ Sites	I	II	III	IV	V	VI-X	XI
Mactridae	Mactrinae	*Mactra lilacea*	-	-	+	-	+	-	-
		Mactra olorina	+	+++	+++	+	+	-	-
Veneridae	Callocardiinae	*Callista florida*	+	+++	+++	+	+	-	-
		Pitar hebraea	-	-	+	-	-	-	-
	Circinae	*Circe corcea*	-	-	+	-	-	-	+
		Circe rugifera	-	++	+++	-	-	-	-
		Circe scripta	-	+	+	-	-	-	-
		Circenita callipyga	-	+	+	+	-	-	+
		Gafrarium pectinatum	+	+++	++	+	-	-	+
	Dosiniinae	*Dosinia erythraea*	-	++	++	+	-	-	-
		Dosinia hepatica	-	-	+	+	-	-	-
	Tapetinae	*Paphia textile*	-	+	+	-	-	-	+
		Tapes deshayesii	-	-	+	-	+	-	-
Total	**5**	**13**	**3**	**8**	**13**	**6**	**4**	**-**	**4**

* Note that: (-) = Absent, (+) = Rare, (++) = common and (+++) = Frequent.

Spatial fluctuations in faunal composition:

The results in Table (2) show that, all bivalve species (13species) were recorded at site III (Adabia), followed by 8 species at site II (Kabanon) comprised only *Mactra olorina* from Mactridae and by 7 species of Family Veneridae. Site IV (Ain Sokhna) came in the third order with 6 species of Veneridae (5 species) and only *M. olorina* from Mactridae; then sites V (Monte Galala) and XI (Al Azazia- Ras Gharib) in the fourth order with 4 species for each and site I (Suez Bay) in the last with only 3 species. However, no evidence for occurrence of bivalve species of the two families was detecting at sites VI, VII, VIII, IX and X, in spite of three surveys were carried out at sites VI-IX during this study.

Seasonal variations in faunal composition:

The results in Table (3) and Figure (2) indicated that, the maximum number of all recorded bivalve species from all sites was 12, recorded during summer, declined to 8 species during autumn. It was found that, 7 species were recorded during all seasons, represented 53.85 % of all; while both of *Circe crocea* and *Dosinia hepatica* disappeared in autumn and winter, respectively. On the other hand, *Mactra lilacea*, *Circe scripta* and *Paphia textile* were recorded in winter- spring, summer- spring and summer- winter, respectively; while, *Pitar hebraea* detected in summer only.

At site III (Adabia), the same pattern in seasonal fluctuations was observed, with high number of species (12) in summer, and the lowest number (7 species) in autumn. But at site II (Kabanon), the highest number of species (7) was recorded in summer and spring, declined to 5 species during both autumn and winter. While at site IV (Ain Sokhna), only 5 species of bivalves were recorded in summer and spring, declined to 4 species in autumn and disappeared completely in winter. Other sites were occupied with few numbers of species according to time of visit, so, they did not indicate in Table (3) and Figure (2).

Table 3: Seasonal fluctuations in number of bivalve species and individuals at the study sites of the Suez Gulf.

Sites	Species / Seasons	*M. lilacea*	*M. olorina*	*C. florida*	*P. hebraea*	*C. corcea*	*C. rugifera*	*C. scripta*	*C. callipyga*	*G. pectinatum*	*D. erythraea*	*D. hepatica*	*P. textile*	*T. deshayesii*	Total number of individuals	Total number of species
II-Kabanon	Summer	0	20	27	0	0	9	0	1	109	9	0	1	0	176	7
	Autumn	0	13	16	0	0	2	0	0	81	3	0	0	0	115	5
	Winter	0	12	14	0	0	3	0	0	4	3	0	0	0	36	5
	Spring	0	33	25	0	0	12	1	1	140	7	0	0	0	219	7
	Total	0	78	82	0	0	26	1	2	334	22	0	1	0	546	8
III- Adabia	Summer	0	57	78	1	1	28	1	2	7	6	2	1	1	185	12
	Autumn	0	64	17	0	0	21	0	2	7	3	0	0	1	115	7
	Winter	1	80	45	0	0	17	0	2	8	4	0	0	1	158	8
	Spring	4	64	34	0	1	17	0	3	12	3	2	0	1	141	10
	Total	5	265	174	1	2	83	1	9	34	16	4	1	4	599	13
IV-Ain Sokhna	Summer	0	3	1	0	0	0	0	0	1	1	1	0	0	7	5
	Autumn	0	5	0	0	0	0	0	5	5	0	2	0	0	17	4
	Winter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Spring	0	3	2	0	0	0	0	2	2	1	0	0	0	10	5
	Total	0	11	3	0	0	0	0	7	8	2	3	0	0	34	6
Sites (I,V& XI)		1	6	7	0	1	0	0	3	9	0	0	1	1	29	8
Total	Summer	0	83	109	1	1	37	1	4	121	16	3	2	1	379	12
	Autumn	0	82	33	0	0	23	0	7	93	6	2	0	1	247	8
	Winter	1	92	59	0	1	20	0	5	17	7	0	1	1	204	10
	Spring	5	103	65	0	1	29	1	5	154	11	2	0	2	378	11
	Totals	6	360	266	1	3	109	2	21	385	40	7	3	5	1208	13

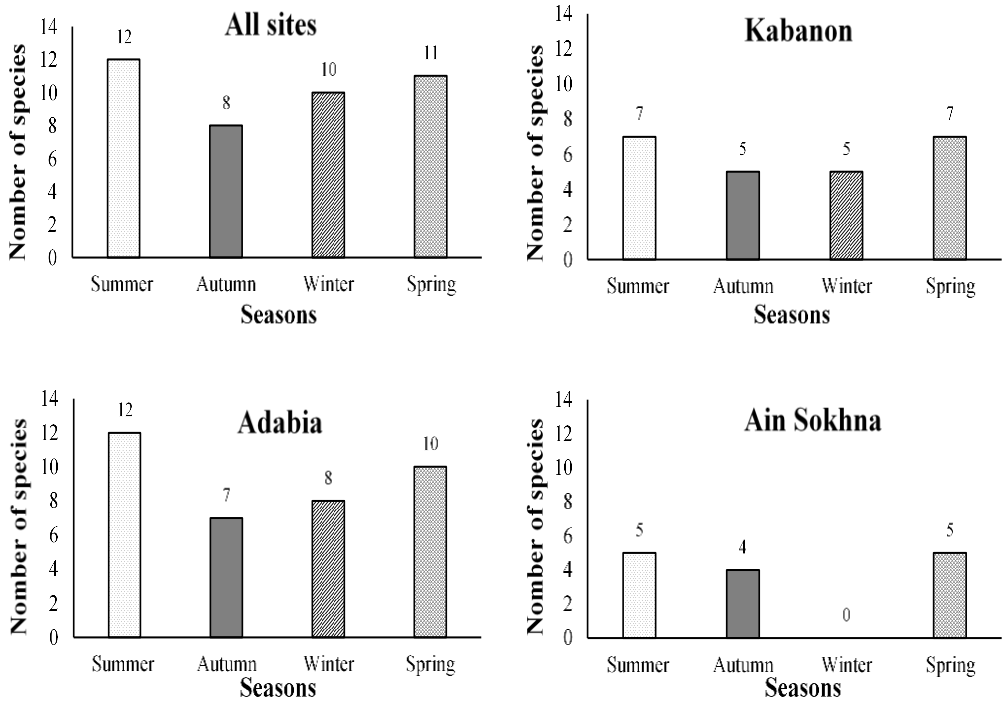

Fig. 2: Seasonal fluctuations in number of bivalve species at the study sites, western coasts of Suez Gulf.

Status of recorded species:

Table (2) indicated that, out of the 13 recorded species, only 2 species (*M. olorina, C. florida*) were frequent at sites II and III and only *Dosinia erythraea* was common at those sites. In contrast, *Circe rugifera* was frequent at site II and common at site III, while *Gafrarium pectinatum* was common at site III and frequent at site II. The other remaining 8 species were rare at all surveyed sites.

Abundance:

Overall abundance:

During the present study, a total of 1208 individuals of all recorded species of families Mactridae and Veneridae were collected; out of them 842 individuals (69.70 % of all) were Veneridae compared with 366 individuals of Mactridae represent 30.30 % of all (Tables 4 and Figure 3).

Spatial variations in abundance:

The majority of collected individuals (1145) were obtained from sites II and III (Tables, 3&4 and Figure, 3). It was noticed that, a total of 599 individuals (49.59 % of all) were collected form site III (Adabia), comprised 270 of mactrids (45.08 %) and 329 of venerids (54.92 %). This number declined slightly to 546 individuals (45.20 % of all) at site II (Kabanon) and included 78 mactrids (14.29 %) and 468 venerids (85.71 %). A sharp decline in individuals number to 34 (2.81 % of all) was recorded at site IV (Ain Sokhna) with 11 mactrids and 23 venerids, and showed more decline to 10 individuals (0.83 %) at both sites I and X (Suez Bay and Al Azazia, north Ras Gharib) and 9 individuals (0.75 %) at site V.

Seasonal variations in abundance:

The numbers of obtained individuals of all species were seasonally fluctuated (Tables 3&4 and Figures 4&5). The higher numbers were 379 and 378 individuals (31 % for each) recorded in summer and spring, respectively, declined to 247 individuals (21%) in autumn and reached the minimum, 204 individuals (17%) in winter.

Table 4: Numbers and percentages of families Mactridae and Veneridae individuals at the study sites, Suez Gulf, summer 2017-spring 2018.

Sites	Families / Seasons	Mactridae		Veneridae		Total	%
		Total	%	Total	%		
II Kabanon	Summer	20	11.36	156	88.64	176	32.23
	Autumn	13	11.30	102	88.70	115	21.06
	Winter	12	33.34	24	66.67	36	6.59
	Spring	33	15.07	186	84.93	219	40.11
	Total	**78**	**14.29**	**468**	**85.71**	**546**	**45.20**
III Adabia	Summer	57	30.81	128	69.19	185	30.88
	Autumn	64	55.65	51	44.35	115	19.20
	Winter	81	51.26	77	48.74	158	26.38
	Spring	68	48.22	73	51.78	141	23.54
	Total	**270**	**45.08**	**329**	**54.92**	**599**	**49.59**
IV Ain Sokhna	Summer	3	42.86	4	57.14	7	20.59
	Autumn	5	29.41	12	70.59	17	50.0
	Winter	0	0	0	0	0	0
	Spring	3	30	7	70	10	29.41
	Total	**11**	**32.35**	**23**	**67.65**	**34**	**2.81**
Other sites (I,V& XI)		**7**	**24.14**	**22**	**75.86**	**29**	**2.4**
Total and %		**366**	**30.30**	**842**	**69.70**	**1208**	

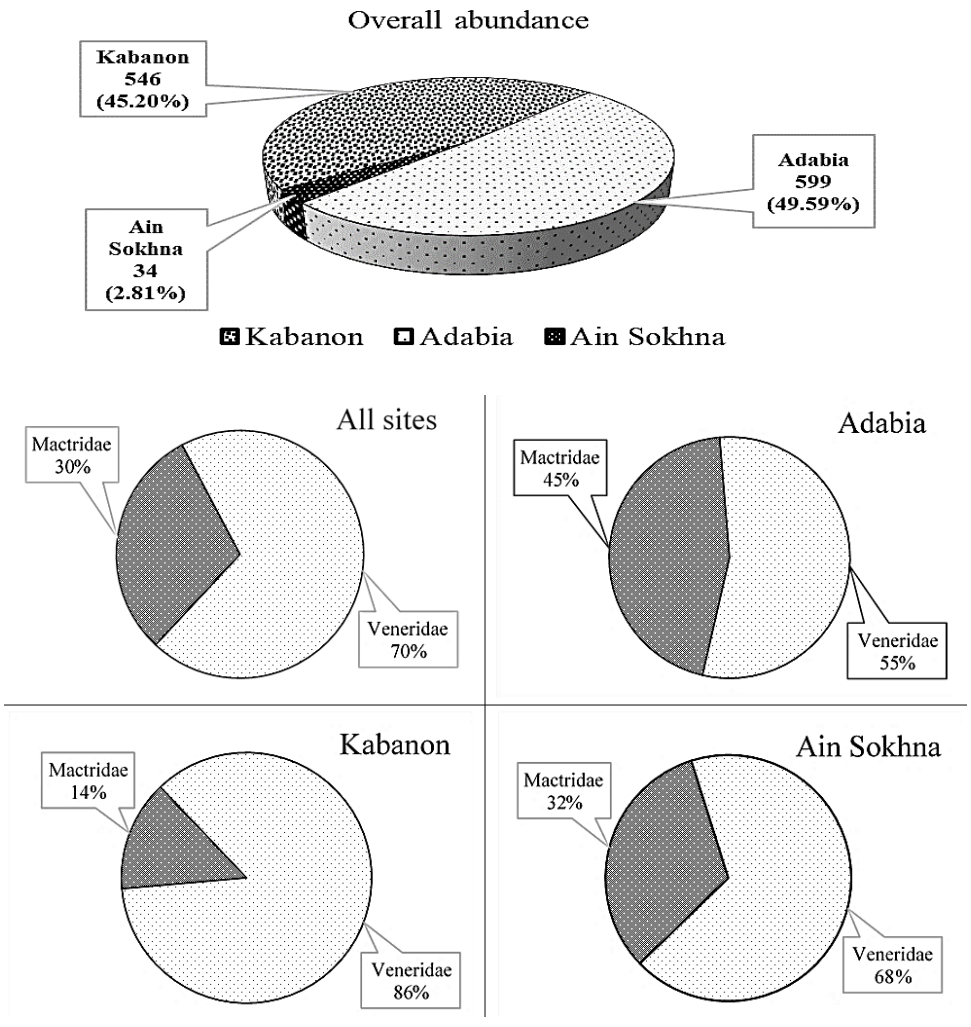

Fig. 3: Percentages of recorded individuals of families Mactridae and Veneridae during this study.

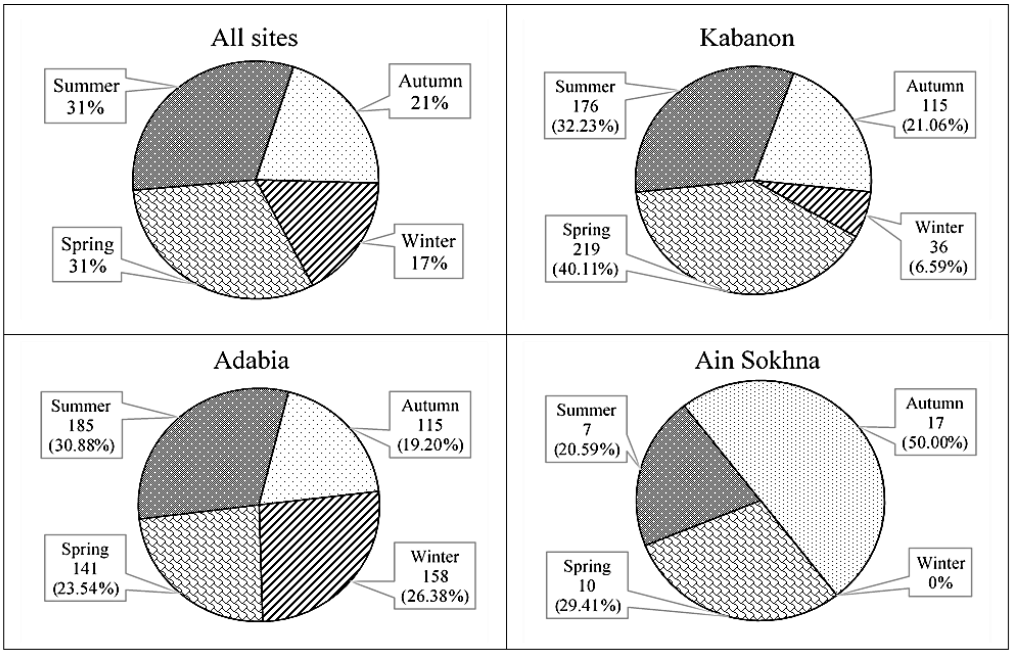

Fig. 4: Seasonal number and percentages of bivalve individuals at the study sites, Suez Gulf.

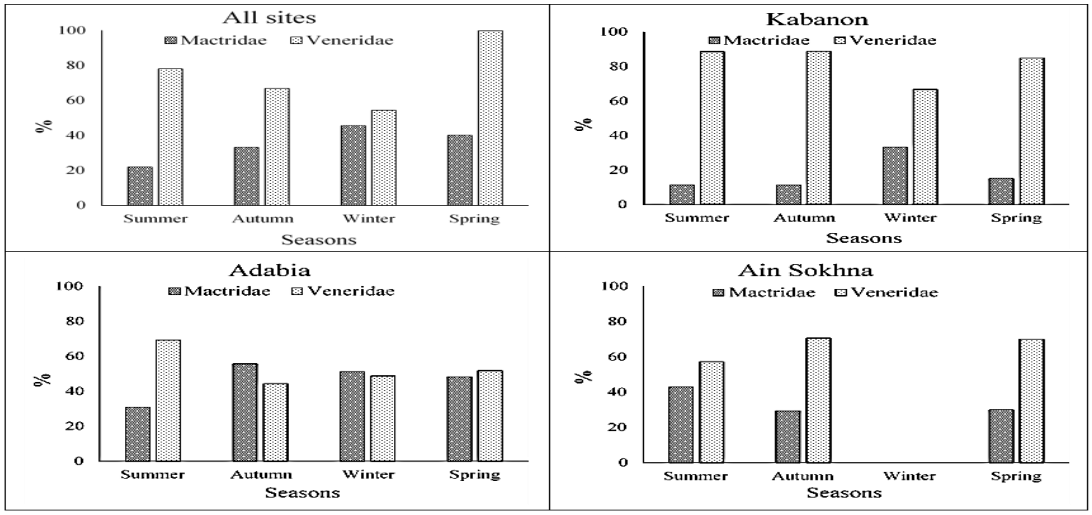

Fig. 5: Seasonal percentages of individuals of bivalves Mactridae and Veneridae at study sites, Suez Gulf.

Relative abundance:

The results in Table (5) denote that, the majority of collected individuals was restricted to the most frequent species comprised *G. pectinatum*, *M. olorina* and *C. florida* which amounted totally 1011 individuals, represent 83.70 % of all collected specimens. These species were represented by 385, 360 and 266 individuals, represent 31.87%, 29.80% and 22.02 %, respectively. *Circe rugifera* and *Dosinia erythraea* came in the 4th and 5th orders with 109 and 40 individuals, represented 9.02% and 3.31 % of all, respectively. The remaining 8 species were represented by 48 individuals, represent 3.97 % of all.

There are seasonal fluctuations in the number of the most frequent species during this study at different sites. The maximum number of collected individuals was 140, 80 and 78, for *G. pectinatum*, *M. olorina*, and *C. florida* obtained during spring (site II), winter (site III) and summer (site III), respectively. The number of these

species declined remarkably into only 1, 3 and 1 individuals, respectively, during summer at site IV (Table 5).

Table 5: Seasonal fluctuations in numbers of frequent and most common species during study period at Kabanon, Adabia and Ain Sokhna, Gulf of Suez.

Sites	Species \ Seasons	Summer	Autumn	Winter	Spring	Total	%
II- Kabanon	*Gafrarium pectinatum*	109	81	4	140	334	61.17
	Callista florida	27	16	14	25	82	15.02
	Mactra olorina	20	13	12	33	78	14.29
	Circe rugifera	9	2	3	12	26	4.76
	Dosinia erythraea	9	3	3	7	22	4.03
	Other species	2			2	4	0.73
III- Adabia	*Mactra olorina*	57	64	80	64	265	44.24
	Callista florida	78	17	45	34	174	29.05
	Circe rugifera	28	21	17	17	83	13.86
	Gafrarium pectinatum	7	7	8	12	34	5.68
	Dosinia erythraea	6	3	4	3	16	2.67
	Other species	9	3	4	11	27	4.51
IV-Ain Sokhna	*Mactra olorina*	3	5		3	11	32.35
	Gafrarium pectinatum	1	5		2	8	23.53
	Circenita callipyga		5		2	7	20.59
	Callista florida	1			2	3	8.82
	Dosinia hepatica	1	2			3	8.82
	Dosinia erythraea	1			1	2	5.88
Total		369	247	194	369	1179	

Diversity

Species diversity:

Results in Table (6) show the seasonal and mean annual values of bivalve species diversity indices during the study period at sites II, III and IV. The annual values of Simpson's diversity index declined gradually southwards from the highest of 0.42, recorded at site II, to 0.30 at site III, and reached lowest value of 0.20, at site IV.

Table 6: Seasonal values of diversity indices for bivalves of family Mactridae and Veneridae at the study sites, during the study period, Gulf of Suez.

Sites	**Seasons \ Indices**	**No. Species**	**No. Individuals**	**Simpson's index (S)**	**Shannon index (H')**	**Evenness index (E)**	**Species richness (SR)**
II (Kabanon)	Summer	7	176	0.42	1.72	0.25	1.16
	Autumn	5	115	0.53	1.35	0.27	0.48
	Winter	5	36	0.27	2.01	0.40	1.12
	Spring	7	219	0.45	1.64	0.23	1.11
	Annual	**8**	**546**	**0.42**	**1.70**	**0.21**	**1.11**
III (Adabia)	Summer	12	185	0.29	2.14	0.18	2.11
	Autumn	7	115	0.36	1.87	0.27	1.26
	Winter	8	158	0.35	1.88	0.24	1.38
	Spring	10	141	0.28	2.25	0.23	1.82
	Annual	**13**	**599**	**0.30**	**2.13**	**0.16**	**1.88**
IV (Ain Sokhna)	Summer	5	7	0.14	2.13	0.43	2.06
	Autumn	4	17	0.23	1.92	0.48	1.06
	Winter	0	0	0.00	0.0	0.0	0.0
	Spring	5	10	0.13	2.25	0.45	1.74
	Annual	**6**	**34**	**0.20**	**2.35**	**0.39**	**1.42**

In contrast, Shannon- Weiner index (H'), increased from the lowest value of 1.70 at site II to 2.13 at site III and reached the maximum value of 2.35 at site IV,

while Evenness index (E) reached the highest values of 0.39 at site IV, and the lowest one of 0.16 at site III and had moderate value of 0.21 at site II. On the other hand, species richness reached the highest value of 1.88 at site III and the lowest one of 1.11 at site II and was moderate with 1.42 at site IV (Table 6).

Seasonal fluctuations in species diversity:

The calculated values of diversity indices showed also seasonal fluctuations at the studied sites (Table 6). For Simpson diversity index, the highest values were recorded in autumn at all sites; while the lowest values were recorded in winter at site II and spring at sites III and IV.

For Shannon- Weiner Index, the highest values were recorded during winter at site II and in spring at sites III and IV. In contrast, the lowest values were recorded during autumn at all sites.

On the other hand, Evenness recorded its higher values in winter at site II and in autumn at sites III and IV. It reached the lowest values in spring at site II and in summer at sites III and IV.

For Margalef´s Species Richness, it recorded higher values in summer, but declined to the lowest values in autumn at all sites (Table 6).

Similarity index

Results of Simpsons Similarity Index between different sites are presented in Table (7). This index recorded its highest values, 76.19 % and 71.43%, between sites II versus site III, and site II versus site IV, respectively. Its values declined to 66.67% between sites I and IV, and recorded the lowest value of 28.57% between sites I and XI, but reached to 0 between sites V and IX, where no common species were detected. However, its values were moderate between other sites (Table 7).

Table 7: Shows the values of Simpsons Similarity Index between the studied sites from Suez Gulf (data are expressed as percentage, %).

Sites	Site I	Site II	Site III	Site IV	Site V
Site II	54.55	-	-	-	
Site III	37.50	76.19	-	-	
Site IV	66.67	71.43	63.16	-	
Site V	57.14	33.34	47.06	40.00	
Site XI	28.57	50.00	47.06	40.00	0.00

Distribution of bivalve species within preferable habitats:

Table (8) indicated that, all 13 recorded species of families Mactridae and Veneridae were collected from sandy habitat (site III).

Table 8: Occurrence of bivalves within their natural habitats during the period of this study.

Families	Habitats / Species	Rocky-Sand	Sandy	Muddy	Coral reefs
Mactridae	*Mactra lilacea*	(+)	+	-	-
	Mactra olorina	(+)	+	-	(+)
	Callista florida	(+)	+	+	(+)
	Pitar hebraea	-	+	-	-
	Circe corcea	(+)	+	-	-
	Circe rugifera	-	+	+	-
	Circe scripta	-	+	-	-
Veneridae	*Circenita callipyga*	(+)	+	+	(+)
	Gafrarium pectinatum	(+)	+	+	(+)
	Dosinia erythraea	-	+	+	(+)
	Dosinia hepatica	-	+	-	(+)
	Paphia textile	(+)	+	+	-
	Tapes deshayesii	(+)	+	-	-
	Total	**(8)**	**13**	**6**	**(6)**

However, there are 6 species, represented 46.15%, belong to family Veneridae were also occurring in muddy habitats in addition to their occurrence in sandy bottom areas. Field observation indicated that, all collected species were burrowing in their soft bottom habitats. However, all individuals recorded from both mixed rocky-sand and coral reefs habitats were obtained from sand depressions or muddy substrates at those habitats.

Population density:

The population density of *G. pectinatum*, *M. olorina,* and *C. florida,* in addition to *C. rugifera* were estimated at sites II (Kabanon), and III (Adabia) and presented in Table (9). It was obvious that, at site II, *G. pectinatum* has the highest density, recorded annual average density of 44±41 ind./ m2. It followed by *M. olorina* averaged density of 14± 16 ind./ m2, then *C. rugifera* with 5± 7 ind./ m2; while *C. florida* was represented by the lowest density, averaged 1±2 ind./ m2, and appeared only during spring.

In contrast, at site III (Adabia), *M. olorina* had the highest density averaged 20±17 ind/m2, followed by *C. florida* with 15±16 ind./m2 and *C. rugifera* with 8±11 ind/m2, while all individuals of *G. pectinatum* were dead and no live individuals were detected.

The population density of these species showed obvious seasonal fluctuations at the two studied areas. At site II, the high densities of *G. pectinatum* and *M. olorina* were recorded in spring, but declined to the minimum density averaged 4± 8 ind./m2 for *G. pectinatum* in winter and to 10± 15 ind./m2 in autumn for *M. olorina*, but recorded similar values for *C. rugifera* during all seasons (Table 9).

On the other hand, at site III, *M. olorina* recorded the highest density in spring and lowest density in winter. While *C. florida* and *C. rugifera* showed highest density in summer and lowest densities in autumn and spring, respectively (Table 9).

Table 9: Seasonal variations in population density of bivalve species at the study sites during period of this study (Density= No. of individuals /m^2).

Sites	Species \ Seasons	Summer	Autumn	Winter	Spring	Average
Kabanon	*Mactra olorina*	12±17	10±15	-	32±33	14±16
	Callista florida	-	-	-	4±8	1±2
	Circe rugifera	6±11	-	6±9	6±10	5±7
	Gafrarium pectinatum	59±65	42±30	4±8	71±61	44±41
Adabia	*Mactra olorina*	24±19	16±12	11±11	26±25	20±17
	Callista florida	47±41	2±5	8±11	3±6	15±16
	Circe rugifera	10±9	10±11	8±13	4±8	8±11
	Gafrarium pectinatum	-	-	-	-	All are dead

DISCUSSION

During this study, a total of 13 bivalve species belong to families Mactridae (2 species) and Veneridae (11 species), distributed in 9 genera and 5 subfamilies were encountered from the sandy and muddy bottoms at the intertidal and shallow subtidal zones along the studied sites. All recorded species are Indo-west Pacific in origin according to several authors (Sharabati, 1984; Vine, 1986; Mastaller, 1987; Lamprell & Whitehead 1992; Oliver, 1992; Zuschin and Oliver, 2003; Rusmore-Villaume, 2008; El-Mekawy, 2016) and no evidence for Mediterranean bivalves was noticed. In contrast, out of these recorded bivalves, 7 species comprised *Mactra olorina*, *Callista*

florida, Circe scripta, C. callipyga, Gafrarium pectinatum, *Dosinia erythraea*, and *Paphia textile*, considered Lessepsian migrants and were recorded from Suez Gulf Lakes (Lamy, 1930; Moazzo, 1939; Barash and Danin, 1972, 1982; Hassan, 1983; El-Gamal, 1988; Dexter, 1989; Fouda and Abou Zied, 1990, Abou-Zied, 1991; Ghobashy *et al.*,1992; EL-Sorogy *et al* 2006), Bardwail Lagoon (Heiman and Mienis, 2010), eastern Mediterranean basin, and even from Aegean Sea comprised coasts of Turkey and Greece (Mienis, 2000c; Heiman and Mienis, 2010; Zenetos *et al*., 2010). However, 3 species comprised *Circe corcea*, *C. rugifera* and *Tapes deshayesi* were restricted in their northward's distribution to Suez Canal Lakes only and did extend northwards behind those lakes (Barash and Danin, 1972; Fouda and Abou Zied, 1990 and Abou Zied, 1991).

On the other hand, *Dosinia hepatica* and *Pitar hebraea* are the only two bivalve species did not extend northwards outside the Suez Gulf (Oliver, 1992; Zuschin and Oliver, 2003; Rusmore- Villaume, 2008; El-Mekawy, 2016); while *M. lilacea* was absent from the Suez Canal but recorded in Bardawail Lagoon (Egypt) (Mienis, 2000c). On the other hand, *Circe scripta* had invaded the Mediterranean Sea and reached the Greek part of the Aegean Sea as reported by Zenetos *et al.*(2010).

According to Oliver (1992) and Rusmore-Villaume (2008) the recorded species of family Veneridae in the studied sites represent at least 50 % of the Gulf's bivalve's fauna belong to this family; but beings higher than those recorded by Sharabati (1984), which recorded only 13 species of Veneridae from the entire Red Sea, of them 5 species were recorded during the present study; however, Sharabati's list did not refer to their accurate localities and not comprise any species of family Mactridae.

Generally, the recorded bivalve species of families Mactridae and Veneridae during the present study over dominated other previous records of these families along the Gulf of Suez and sometimes all bivalves recorded by El- Mekawy (2016) which comprised 9 venerids and 2 mactrids, and other carried out by El- Komi (1996), Emara and Belal (2004), El Sorogy *et al*. (2006), Gab-Allah *et al* (2007), Radwan (2014), Belal and Ghobashy (2014).

The number of recorded bivalve species was varied within different studied sites and was correlated with their preferable habitats. It is well known that, most species of families Mactridae and Veneridae are burrowing and preferred soft substrates (Mastaller, 1987; Zuschin and Oliver, 2003). The present results showed that, the high number of species was recorded at sandy habitats at site III (Adabia), followed by those occur at muddy sand habitats at site II (Kabanon), which reflects an increase of recorded species at that sites. Consequently, all obtained species were recorded at Adabia (site III) associated with extended sandy bottom surface area suitable for sheltering and burrowing behavior. But increasing muddy at the Kabanon lead to decreasing in number of species unfavorable for muddy areas and came in the second order with only 8 species. While at sites IV (Ain Sokhna), site V (Monte Galala) and site XI (Al Azazia), the bottom was mainly rock with variable coral reef colonies, which have very restricted sandy depressions favorable for only 4 species adapted for those habitats. Moreover, the number of species decreased into 3 only at site I (Suez Bay), which was characterized with high ratios of organic matters and extended muddy bottom. On the other hand, sites VI-X were dominated with rocky substrates or affected with oil pollution, and no bivalve species of these families were detected. Consequently, the highest number of individuals and species were recorded at sites III and II compared with sites IV and I.

The present results reflect the better distribution of bivalve species at Adabia and Kabanon, than other sites, which may be attributed to preferable sandy bottom

habitat adapted for burrowing and buried behavior of Veneridae and Mactridae bivalves (Mastaller, 1987; Lamprell & Whitehead 1992; Oliver, 1992; Zuschin and Oliver, 2003; Rusmore- Villaume, 2008; Huber 2010; El-Mekawy, 2016).

The occurrence of *Mactra olorina*, *M. lilacea, Circe corcea, Circenita callipyga*, *Gafrarium pectinatum, Dosinia erythraea*, *D. hepatica*, *Tapes deshayesii* and *Callista florida* at mixed habitats (sites, IV, V and XI) was correlated with their tolerance for living in sand and sediments near or around corals and among sea grasses according to Zuschin and Oliver (2003). Therefore, these species had migrated northwards into Suez Canal and Mediterranean Sea as previously mentioned.

The status of the recorded species during this study was also varied. only *Mactra olorina*, *Gafrarium pectinatum*, *Callista florida* and *Circe rugifera* were frequent, and detected with high number of individuals at sites III(Adabia) and II (Kabanon) due their suitable sandy and muddy bottom habitats as previously mentioned. These results are in a good agreement with that recorded in the Red Sea and Suez Gulf at different habitats by Oliver (1992), Zuschin and Oliver (2003), Gab Allah *et al*. (2007), Rusmore- Villaume (2008) and El-Mekawy (2016). However, some of these species may be appearing as frequent in certain sites but appears rare in others during this study. According to Oliver (1992) and Rusmore- Villaume, (2008), *Mactra olorina* is endemic to the Red Sea and fluctuated from abundant in the Suez Gulf, to occasional in Gulf of Aqaba and not found south Safaga. In contrast, *M. lilacea*, is rare in both Gulfs but common between Marsa Alam-Wadi Lahmi to Shalatein. Generally, many species of family Veneridae are usually represented with low number of individuals along the entire Red Sea and gulfs of Suez and Aqaba as indicated by Rusmore- Villaume (2008), but some of them were fluctuated and appear either common or rare in the intertidal and shallow subtidal zones according to prevailing environmental conditions and extended habitats, which also agree well with that mentioned by El- Komi (1996), Hasan (1983) along the Egyptian coats and Vine (1986) along the entire.

The number of individuals of collected specimens for the recorded species was varied spatially and seasonally. During this study, a total of 1208 individuals of all 13 recorded bivalve species of family Mactridae and Veneridae were collected. In spite of family Veneridae has the highest number of species (11), and was represented with 842 individuals (69.70 %), only one species of Mactridae, *M. olorina*, has relatively considerable number (366), represents 30.30 % of all. This indicates to favorable environmental conditions for occurrence of *M. olorina*, particularly at site II (Kabanon) compared with the reverse obtained results for the occurrence of *G. pectinatum* at site III (Adabia).

Generally, the number of individuals of families Mactridae and Veneridae during the present study was higher than those recorded by El- Komi (1996), Emara and Belal (2004), El Sorogy *et al*. (2006), Gab-Allah *et al* (2007), Radwan (2014), Belal and Ghobashy (2014) and El- Mekawy (2016). However, there are remarkable seasonal fluctuations in number of individuals and variation in population densities reflect the effect of breeding seasons particularly for *G. pectinatum* as reported by Gab Allah *et al*. (2007) at the same studied sites.

On the other hand, the present results exhibited also that, there are obvious variations in values of all diversity indices comprised Shannon-Weaver index, Simpson's index, evenness, and Margalef´s Species richness. The highest value of Simpson's Diversity Index was recorded at site II, and lowest value at site IV. In contrast, Shannon index (H') and Evenness index (E), reached the highest values at site IV, compared with the lowest values at sites II and III, respectively; while species

richness recorded the highest value at site III and the lowest one at site II. In addition, the value of Simpsons Similarity Index recorded highest values between site II (Kabanon) versus both sites III (Adabia) and IV (Ain Sokhna), and recorded moderate values between other sites. The values of these indices are lower than those recorded by Ismail (2005) and El-Mekawy (2016) on the benthic fauna at the same and neighboring sites. Therefore, these results indicate hazard environmental conditions and non-stability and consistency of the intertidal populations at the study areas, which may be attributed to the stressful of the environmental conditions and human impacts which lead to decreasing species diversity. However, the present results in contrast with that carried out by Dexter (1989) on sand beach communities and Fouda *et al.* (2003) on mangroves fauna of the Red Sea.

For population density, *Gafrarium pectinatum* and *Mactra olorina* showed high density at site II (Kabanon) during spring and lowest densities during winter and autumn, respectively. While at site III (Adabia), *M. olorina* recorded the highest density during spring and lowest density during winter. These results are in well agreement with that reported by Gab-Allah *et al.* (2007). They indicated that, *G. pectinatum* and *M. olorina* showed high density at Kabanon during winter and low densities during summer months.

In spite of these information on species of families Mactridae and Veneridae at the studied areas, further studies are necessary to cover other biological features for species and other important species of bivalves along the entire Suez Gulf.

CONCLUSION

Eleven bivalve species of Family Veneridae and two species of family Mactridae were recorded from the western coasts of Suez Gulf. Distribution, diversity, abundance and density were treated and indicated that most species and individuals were collected from Adabia (#III), Kabanon(#II) and Ain Sokhna (# IV).

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ARABIC SUMMARY

دراسات بيئية على عائلتي فينيريدى وماكتريدى (الرخويات: ذوات المصراعين)، خليج السويس، مصر

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٢- كلية العلوم - جامعة الازهر- فرع أسيوط - مصر.

أجريت هذه الدراسة على أنواع المحاريات التي تتبع عائلتي Veneridae، Mactridae (الرخويات: ذوات المصراعين) جمعت موسميا من الشواطئ الغربية لخليج السويس خلال الفترة من صيف ٢٠١٧ الى صيف ٢٠١٩. أسفرت النتائج عن تسجيل ١٣ نوعا من تلك المصراعيات، يتبع منها إحدى عشر نوعا عائلة Veneridae تمثل ٨٤.٦٢% ونوعين فقط من عائلة Mactridae (١٥.٣٨%) وتنتمي الأنواع المعرفة إلى٩ أجناس، منها ٨ من عائلة Veneridae وجنس واحد فقط من عائلة Mactridae .

تباين تواجد تلك الأنواع بالمناطق المختلفة حيث سجلت جميع الأنواع بالموقع الثالث (الأدبية)، مقابل ٨ أنواع بالموقع الثاني (الكابانون)، ٦ أنواع بالموقع الرابع (العين السخنة)، ٤ أنواع بالموقعين الخامس والحادي عشر (٢٠كم شمال رأس غارب)، و٣ أنواع فقط بالموقع الأول (أقصى الشمال بمدينة السويس)، بينما لم يسجل أيا من تلك الأنواع بالمواقع من السادس حتى العاشر. ولقد بينت الدراسة ارتباط توزيع الأنواع المسجلة طبقا لمواطنها الفطرية حيث سجل انتشار وتواجد تلك الأنواع في المواطن الرملية (١٣نوعا) والطينية (٦ أنواع)، ثم المختلطة (٨ أنواع)، واقتصر تواجد الأنواع المسجلة في منطقة الشعاب المرجانية على مدى تواجد المنخفضات الرملية حيث سجل ٦ أنواع. كما أظهرت النتائج توافر أفراد *Callista florida* ، *Mactra olorina* بوفرة عالية بالموقعين الثاني والثالث، بالإضافة إلى أفراد نوع *Gafrarium pectinatum* في الموقع الثاني، بينما سجل نوعي *Circe rugifera* ، *Dosinia erythraea* بشكل ملحوظ بالموقعين الثاني والثالث، أما باقي الأنواع فكانت نادرة التواجد.

ولقد تباينت قيم مؤشرات معاملات التنوع باستخدام شانون ويفر (Shannon-Weaver index)، وسيمبسون (Simpson Index of Diversity)، ومؤشر عدالة التوزيع (Evenness) والوفرة النوعية (Species richness) بين المواقع المختلفة، حيث أظهر معامل شانون ويفر للتنوع زيادة مطردة من الشمال إلى الجنوب ارتفعت من ١.٧٠ بالموقع الثاني إلى ٢.٣٥ بالموقع الرابع، على العكس قيم معامل سيمبسون الذي ارتفع من ٠.٢٠ بالموقع الرابع إلى ٠.٤٢ بالموقع الثاني، أما معامل عدالة التوزيع فقد سجل أعلى قيمة (٠.٣٩) بالموقع الرابع وأقل قيمة (٠.١٦) بالموقع الثالث، على عكس معامل الوفرة النوعية الذي سجل أعلى قيمة (١.٨٨) بالموقع الثالث وانخفض إلى أدنى قيمه (١.١١) بالموقع الثاني. كما سجل أعلى معامل للتشابه وصل إلى ٧٦.١٩% بين الموقعين الثاني والثالث (الكابانون والأدبية) و٧١.٤٣% بين الموقعين الثاني والرابع.