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BENTHIC ASSEMBLAGES FOR ECOLOGICAL EVALUATION OF BARDAWIL LAGOON, MEDITERRANEAN SEA, EGYPT

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ABSTRACT: Bardawil Lagoon is the only highly saline oligotrophic lagoon in Egypt, has an area of ca. 650 km^2 with water depths ranged 0.3m to 3m and economically important in terms of fish production. It is the optimum zone getting migratory birds in winter. It is separated from the Mediterranean Sea by a narrow sandy shelf (90 km length, and 22 km width). Ecological evaluation of benthic communities in Bardawil Lagoon to f*ollow-up study of the distribution of benthic study at 12 selected sampling sites representing different environmental habitats for long periods through the project of Environmental Study Wetlands OF North Egyptians Lakes where samples were collected seasonally (2010-2015) and semi-annually (2015 - 2019). The results and data analysis indicated that the distribution, composition and dominance of macro benthic organisms in Lake Bardawil were composed mainly of* Ostracoda, Polychaeta, Sea grasses, Bivalvia, Insecta larvae *communities and dominated the constituent of bottom fauna.* The variations in the benthic biomass were the heaviest at sites elRaodh and meddle elRaodh representing 1354 and 1105 g/m^2 which corresponding respectively to 18.2 % and 14.9% of the annual average of benthic biomass (619 g/m^2). Regional variations abundance of the benthic structure was highest at sites elTelol and elRaodh representing 3486 ind/m^2 and 3635 ind/m^2 which corresponding respectively to 14.8% and 15.3% of the annual average of benthic density (1978 ind/m^2). Sites of sampling study were evenly spread (J' > 0.8) at most sites except at elTelol and elRaodh also, high diversity (H' > 3.00) was at the most sites and show lower value at sites elTelol, elGals, Boughaz I, elNaser, and Raba`a while, Swartz Dominance indexes of number of 5 species over 75% showed low values at sites elGals, Boughaz I, elNaser, and Raba`a. The abiotic environmental effects in the Bardawil Lagoon are general to those generally observed in other areas influenced by organic wastes, namely, changed in the physic-chemical properties of the sediments and low oxygen concentrations in the bottom water due to decomposition of organic materials.

KEYWORDS: benthic assemblages; environmental evaluation; biodiversity; dominance species; Bardawil Lagoon

INTRODUCTION

Noticeably, increasing moderation in environmental conditions leads to increased abundances, more complex trophic structure, and increased influence of species interactions on structure (Menge 2000; Menge and Branch 2001). Widely, comparing spatial distributions of species diversity in different geographical locations, is one of the approaches to the overalls in community formation or habitat use (MacArthur, 1972; Warwick *et al.*, 2016; Gaston, 2000; Thrush *et al.*, 2005), where environmental conditions are closely related to biological features (biotic), following ecological action (abiotic)) (Olff *et al.*, 2009). Moreover, macrobenthic functional approaches employed in biodiversity and their community's structures along different environmental gradients to know the trend of their nonstudents can vary in diversity are composed and their relative selection pressures (McGill *et al.*, 2006). He argued that the general principle of community ecology may not be achieved if research continues to focus on binary species interactions independently of the environment.

The impact on the characteristics of community structures will affect the characteristics of the ecosystem is the result of weakness in the processes between the characteristics of individuals (Weiher *et al.*, 1998; Grime 2006). Appropriate qualities in direct response can include these qualities that respond to environmental change, or through compensatory. This is due to the resulting changes in interactions between species function (Garnier *et al.*, 2004). These will affect society by changing the processes of the ecosystem through changes in the representation of characteristics and the impact of the ecosystem (Diaz *et al.* 2004; Kremen 2005). These characteristics of changes, ecosystem variables, are reliable predictions on the qualities of ecosystem functions (Suding*et al.*, 2008). On the other hand, direct bottom-based biodiversity indicators of the community structure have recently been developed along the environmental regression to predict responses (Poff, 1997; Purvis *et al.*, 2000), including studies on traits related to the probability of extinction (e.g. Williams *et al.*, 2005) and invasion (e.g. Grotkopp *et al.*, 2002; Olden *et al.*, 2006). In addition to the models proposed to understand the dynamics of society include environmental stress models and nutrient/food productivity models (Hamilton *et al.*, 2005) chain dynamics hypothesis (Menge, 2000; Menge *et al.*, 2001)the two hypothetical models that societies can be ordered along the environmental gradient.

Globally, the magnitude of impacts of the activities on the marine environment is increasing over the last 5 decades and most pollutant wastes on the bottom. Studying benthic assemblages, therefore, are important to emphasize their impacts. This study sought to determine the community structure of the macrobenthic of Bradawl Lagoon. Through the qualitative, biomass, and numerical density configuration assessments of benthic communities in aquatic environments can estimate and determine the biological index of biosafety for the study area. In assessing the ecological impacts of certain known groups were based upon their response to environmental stress and termed initially as opportunistic and equilibrium species groups (El-Komi, 2017a, b). This functional assemblage is widely adopted using, macrobenthos, particularly in closed and semi-closed aquatic areas. Represent an easily understood depiction of biological data as community biomass, the abundance of individuals, species diversity, and depth distribution of biomass within the sediment. Besides which some of the more mobile species can wander far from their ‘home' ground and so their absence or presence can be the source of ambiguity. Therefore, it is necessary to identify the so-called indicator species the presence or absence of which is a direct reflection of water quality and not due simply to the vagaries of chance (Dauer *et al.*, 1992 and Weisberg *et al.*, 1997).

Also, these species must be easily observed and counted. Possible groups of organisms that can be examined are vertebrates, including fish and microorganisms including invertebrates; meiofauna, zooplankton and aquatic plants (phytoplankton, seaweed and algae). In general, these indicators do not make pollution and damage to the ecosystem. They are affected by pollutants and disturbances but most of them are difficult to catch, and are less abundant than small organisms in addition to their own movement. Egypt's Mediterranean basin comprises five northern lakes, arranged from west to east (Mariut – Edko – Borolus - Manzala - Bardawil), and these lakes are economically important in terms of fish production which amounts to more than 75% of the total fish production in Egypt. Khairy *et al.*, (2015) noted that the diversity of species in the five lakes can be arranged as follows: Manzala (383 spp.) > Mariut (376 spp.) > Bardawil (333 spp.) > Borolus (247 spp.) > Edku (183 spp.). This may be attributed to its excessively nature compared to other lakes that do not affect minorities, due to the low human impact around them associated with low water pollution. El-Komi (2017a) indicates that the clear differences in population density and species in the areas of study for the types and totals of most of the deep bottom compared to previous reports during the 2010-2015 and the results indicate that Bardawil Lagoon is relatively high diversity is the high salinity of the lake It is directly connected to the Mediterranean Sea and they do not have fresh water sources as a lake down load like the rest of the Nile Delta lakes. The benthic organisms are high compared to the rest of the Nile Delta lakes, due to the lack of sources of pollution and the nature of the lower sediments, which must continue to study the annual and maintain the ecosystem and optimize the improvement of fish wealth. Lake Bardwell is the only salty lake with an upper limit.

It is connected to the Mediterranean Sea through the three artificial entrances called "Boughaz" and the sandy coast. 100-1000 meters width range from sandy although the Agriculture Ministry routinely expels sand coming due to the development of the waves to not close the entrances. Bardawil is the finest area that gets migratory birds in winter. The investigation has been intensive over the past 50 years. Several scientific publications are being reviewed on: the morphological and hydro chemical properties of Lake Bardawil (Abdel-Daiem, 2000;Barbary *et al.*, 2004; Fouda *et al.*, 1985 El-Komi, 2017a, c); water quality in Bardawil Lagoon (Abdel-Satar, 2005, Ali *et al.*, 2006); distribution of bottom fauna Bardawil Lagoon (Khalil *et al.*, 2013, El-komi, 2017c, 2015, 2014); fisheries research in the Bardawil Lagoon (Ben-Tuvia, 1979;Ibrahim *et al.*, 1987); distribution of benthic flora of Bradawl Lagoon (Ehrlich, 1975 ; Lepkin, 1977) and ecological survey of Bardawil nature protectorate (El-Ganainy *et al.*, 2002; Variy, 1990 and Ragheb, 2018).It is biologically classified as highly saline oligotrophic environment (Por,1971and Ehrlich,1975).

The Environmental Monitoring Program in The Egyptian Lakes aims to identify environmental pollutants that affect, stop the continuous degradation, and protect its plans and sustainable development. It compares the annual averages of some current variables (pH, dissolved oxygen, nitrogen compounds) compared to those for water surveying at international levels. The main objectives of this study are to detect the community structure of the macrobenthic faunal assemblages and assessing their relationship of lagoon bottom habitats assuming that the combined structure of the shallow lake bottom in the depths is significantly affected by environmental conditions. The specific objectives of the study were: to determine the state of the total benthic animal populations in the study area; sediment characteristics; and determine the abundance and species diversity of lagoon bottom habitats macrobenthic faunal assemblages.

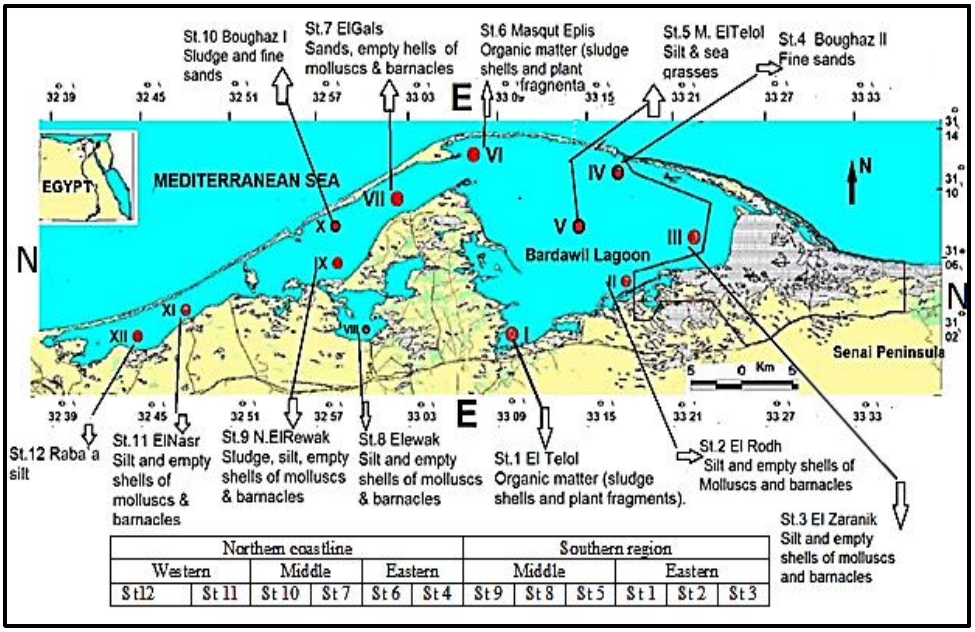

Fig. 1. Locations of sampling study sites at Badawil Lagoon during 2017.

MATERIALS AND METHOD

a- Area of Study:

30′36``E) as shown in Fig 1. The pattern of the study sampling sites in Bardawil Lagoon can be divided into two main sides namely: the northern coastline and the southern region and each of them were divided into western, middle and eastern. It is associated with the Mediterranean Sea through the two artificial inlets called the Boughaz (I and II) and the 3rd nature Boughaz (elZaranik) and a coastline ca. 100-1000 meters. It is subjected to a scope of difficulties including the decrease of its zone achieves a length of 85 km coming about because of the extension of agricultural and fish farm's activities and achieving a most extreme width of 22 km and has an area of around 650 km^2.

b- Sampling collection:

- Sampling was carried out during two periods, the 1st during January 2017 representing the winter season and the 2nd during August representing the summer season 2017.
- Benthos and bottom sediment samples were collected from 12 sites representing the different habitats in the Bardawil Lagoon. The positions of the selected sites, as well as the nurture of the bottom sediments, are shown in Fig 1. The location of the sampling sites is detected by using GPS. At each site, the bottom sediment sample was collected by Van veen grab sampler size 15cm x 15cm (an equivalent area to 0.02 m^2) which each sample was placed in plastic containers, labeled and preserved in 8-10 diluted formalin solution.

c- Water depth and transparency:

The lagoon water depth was greatly varied among the different sampling sites ranging between 1.0 to 3 meters and an average of 1.8m. The maximum depth 3 meters was only measured at St4 (Boughaz II); 2 meters at Sts 12, 11, 9, 8, and 5 (41.7% of sampling sites); 1.5 meters at Sts 10, 7, and 1 (25%); 1.3 meters at Sts 2, and 3 (16.7%) and one meter at St6. Therefore, the degree of transparency of lagoon water in many stations expressed one of the high transparent regions.

d- The nature of the benthic sediment:

Sediments in a few zones are comprised of organic materials (sludge) is made out of waste sewage and agricultural and industrial particularly at the southern region and others of sandy silt, sands, and shells in the northern region. Consequently, it can decide a few conditions prevailing in lagoon environments. Nature of bottom sediment as illustrated in Table 1 is characterized by some deposits of organic material (sludge) and is composed of sewage waste of agricultural, industrial and others of sandy silt and shells.

e- Physic-chemical Parameters (after Final report, EEAA, 2017):

- The annual average water temperature ran (16°C) in the lagoon water was low in mid-winter 2017; while great value (28°C) registered in summer 2017 (annual average 22°C).
- The degree of transparency of water in many stations expressed one of the high transparent regions.
- Water salinity ranged from less value 38‰ at St3 (elZaranik) at the most eastern region. The highest value of salinity reached 58‰ was recorded at St2 (elRoadh) at the most western region estimating an annual average of 46‰.
- Hydrogen ion concentration (pH) situated in the alkaline side, most reduced value 7.90 at St8 (elRewak) in summer and higher value of 8.46 at St3 in summer (annual average 7.99).
- Dissolved oxygen in the water ranged between less worth 4.05 mg/l in central lagoon settlement M. elTelol) in summer and highest value 7.48 mg/l at St7 (elGals) in winter (annual average 5.95 mg/l).
- Compare the annual averages for some variables present to those hydrographical survey of international levels found as cited in final Report EEAA (2017): pH levels are found in the allowed limits (9.0-6.0) of average (7.99); dissolved oxygen levels (4.2-12.6 mg/l) average (0.95 mg/l); consumer under biology oxygen levels (0.3-6.0 mg/l); in all stations the lack of nutrient in lagoon water (average of 0.95 mg/l).

f- Laboratory Analyses (El-komi, 2017b):

Bottom sediment samples were washed through 100 and 300 µm mesh-sized sieves thoroughly with fresh water to remove the formaldehyde and other fine sediments (lesser than 300 µm). During sorting, stained matter or organisms identified were placed into broad taxa, including polychaetes, molluscs, and to the species, level using a binocular stereomicroscope has a power magnification of 20x and 40x. Acceptable taxonomic keys were used from different branches of taxonomical sources.

The following descriptive measurements were computed at each site:

- S is the species number per sample
- A is the abundance of individuals and it is expressed as sum ind/m^2

- B is the biomass of individuals and it is expressed as wet weight of individuals in g/m^2 the ratio A/B and A/S were plotted for the samples at the different sites.

Table 1. Nature of the sampling bottom sediments and benthos constituent's assemblages.

Northern coastline	Western	St 12 (Raba`a)	most western region of lagoon	fine silt	Low diversity of polychaetes, ostracods, amphipods.bivalves.
		St 11 (elNaser)	most western region of lagoon	fine silt	Low diversity of polychaetes, ostracods, amphipods, bivalves.
	Middle	St 10 (Boughaz I)	eastern region of lagoon	Sandy	Low diversity of polychaetes, ostracods, amphipods, bivalves.
		St 7 (ElGals)	northern region nearby the narrow sandy shelf	coarse sands	Moderate diversity of sea grasses, polychaetes, ostracods, amphipods, bivalves.
	Eastern	St 6 (Masqut Eplis)	northern region	sludge (organic matter)	Moderate diversity of sea grasses, polychaetes, ostracods, amphipods, bivalves.
		St 4 (Boughaz II)	middle region of the lagoon	fine sands	Moderate diversity of sea grasses, polychaetes, ostracods, amphipods, bivalves.
Southern region	Middle	St 9 (N-elRewak)	east side of St 10	sludge (organic matter)	High diversity of sea grasses, polychaetes, ostracods, amphipods, bivalves.
		St 8 (elRewak)	southern west side	silty	High diversity of sea grasses, polychaetes, ostracods, amphipods, bivalves.
		St 5 (M.elTelol)	middle of the eastern region	fine sands	High diversity of sea grasses, polychaetes, ostracods, amphipods, bivalves.
	Eastern	St 1 (elTelol)	southernmost site	sludge (organic matter)	High diversity of sea grasses, polychaetes, ostracods, amphipods, bivalves.
		St 2 (elRoadh)	near St 1 (ElTelol)	silt	High diversity of sea grasses, polychaetes, ostracods, amphipods, bivalves.
		St 3 (elZaranik)	most eastern part, declared as a Ramsar protected area, in 1985	silt	Moderate diversity of sea grasses, polychaetes, ostracods, amphipods, bivalves.

g- Diversity Indices:

Diversity indices that serve as an indication of community health on area scales can be measured using several indices as Magurran, (1955), Goodall, (1973), Magurran and McGill, (2011) El-komi, (2017b) and DIVERSE-Univariate diversity indices using PRIMER 5 (Plymouth Routines In Multivariate Ecological Research) including Margalef's species Richness, Pielou's Evenness index, Shannon-Weiner species diversity, and Simpson's diversity index was applied in this study.

-Margalef's species richness (d):

Species richness refers to the total number of different species present (without taking into account the proportion and distribution of each species) within the sample. Margalef index (Margalef, 1958) is represented by the equation: $d = (S-1)/lnN$ where S = the total number of species, and N = the total number of individuals in the sample.

- Pielou's Evenness (J`):

Evenness, with the assumption that all species were accounted for in the sample. This aids in qualifying organism distribution among sampled assemblages. The higher the attained value, the more evenly individuals are spread among the species. Species evenness is dependent on species richness and species diversity. The evenness measure is a ratio of the observed diversity to the maximum possible in a sample having the same number of species. The equation used was:

$$J` = H/H`max = H`/\log S$$

where H` = the Shannon-Wiener diversity index, S = the total number of species.

- Shannon-Wiener's species diversity index (H`);

The Shannon-Wiener diversity index (also referred to as the Shannon diversity), characterizes the state of an assemblage per the species richness and species abundance. It assumes all species are represented in the sample and that individuals are randomly sampled from an independently large population. The community diversity is defined by the obtained value; 0 to 1.5 for poor, 1.5 to 2.5 for moderate and > 2.5 for highly diverse. The Shannon-Wiener diversity value often falls between 1.5 and 3.5 but can exceed 4. The index increases as the community richness and evenness increase (Shannon and Weaver 1949).

The equation used is:

$$H' = -\sum_{i=1}^{S} pi \ln pi$$

where pi = the proportion of individuals found in species i ln = natural logarithm S = the total number of species.

- Simpson's diversity index (D):

Simpson (1949, 1951)introduced this measure to determine the degree of concentration when species are classed. The values of Simpson's diversity index range from 0 to 1, where 0 represents no diversity and 1 represents infinite diversity. The index is directly related to species evenness and richness. The Simpson index gives more weight to common or dominant species; therefore, a few rare species with only a few representatives will not affect the diversity.

The equation used to measure it was: $D = \Sigma\ [((n-1) / (N-1))]$

where n = the total number of organisms of a particular species N = the total number of organisms of all species. D is a measure of dominance, so as D increases, diversity (in the sense of evenness) decreases. Thus, Simpson's index is usually reported as its complement 1-D. This provides an intuitive proportional measure of diversity that is much less sensitive to species richness.

h- Statistical analyses:

- Statistical tools used in Univariate and Multivariate analyses were Microsoft Excel tool PCA and PRIMER (Plymouth Routines In Multivariate Ecological Research) version 5 respectively. The analysis of variance (ANOVA) using the simple linear regression (FAO, 1991) was calculated. This method is based on determining the significant differences at the 95 confidence limits between the variables of sites (abundance, biomass, and groups of benthos) and physic-chemical variables.

- The triangular matrix of similarities between samples leading to hierarchical classification (cluster analysis) (FAO, 1991). This is based on a Bray-Curtis similarity matrix of appropriately transformed species abundance or biomass data.

- Principal component and factor analyses PCA are multivariate techniques, which generate a sequence of varieties known as components of factors in a correlation matrix. These analytical methods have been successfully used in marine ecology. It is based on extracting information on the regional patterns of species from complex correlation matrices. The basic difference between PCA and factor analyses FA is that the PCA is assumed that all the variance is common and its orthogonal components can be extracted, whereas in the FA the variance common in all variables is separated from the specific and error (residual) variances. The analysis is based on the data of the abundance (no. ind/m^2) of the most common species or the main high taxa groups of benthos using the numerical data.

- **Swartz's dominance index**, which measured the number of species whose combined abundance comprised 75 of the total sample abundance (if index value > 5 indicating that the area has no stress community). According to PTI 1993, the values less than 5 usually indicate a stressed community (PTI, 1993 as cited by Laetz, 1998). The Swartz's dominance index values ranged from one to six at the sampling sites, where most western sites were significant of less stress than the previous sites.

RESULTS AND DISCUSSION

1- Species composition of benthos structure:

1. 1 Species composition:

This study reviewed the benthic structure and its distribution in Bardawil Lagoon. Results show for inspecting arrangement subjective macrobenthic communities during the study period were recorded 62 species as listed in Tables 2 in which including a total of 36 species were identified as benthic livening communities in the addition to many un-living composed mainly from empty shells of bivalves, gastropods, barnacles and fragments of aquatic plants. These include 14 groups belong to nine main higher taxonomic levels namely;

- Sea grasses (class Angiosperms),
- Marine algae (class Chlorophyta, class Rhodophyta).
- Phylum Nematoda (class Enoplea); Phylum Annelida (class Oligochaeta, class Polychaeta);
- Sub Phylum Crustacea, class Ostracoda, order Myodocopida), (class Malacostraca,

order Amphipoda, order Isopoda, order Cirripedia);
- Phylum Mollusca (class Bivalvia),
- Phylum Echinodermata (class Holothuroidea), and
- Phylum Chordata (class Ascidiacea).

Table 2. the list of taxa and the occurrence in the sampling sites.

Groups	Species	Groups	Species
Sea grasses	*Cymodocea nodosa*	Amphipoda	*Elasmopus pectenicrus*
	Halophila stipulacea		*Corophium volutator*
Green algae	*Chaetomorpha* sp.	Isopoda	*Sphaeroma serratum*
Brown Algae	*Laurencia obtusa*		*Apseudes latreillei*
Red algae	*Jania rubins*	Barnacles	*Amphibalanus amphitrite*
	Gracilaria armata		*Balanus eburneus*
Nematoda	*Enoplis mersdionalis*	Decapoda	*Trachypenaeus curvirostria*
Bryozoa	*Bowerbankia imbricata*		*Portunus hastatus*
	Bugula neritina	Gastropoda	*Gibbula magus***
Oligochaeta	*Chaetogaster lirnnaei*		*Bolinus brandaris* **
Polychaeta	*Capitella capitata*		*Monodonta articulata***
	Armandia polyophthalma		*Cerithium vulgatum***
	Lumbricorneis laterili		*Bullria striata***
	Nereis irrorata		*Bittium reticulatum***
	Nereis pelagica		*Bullria striata***
	Prionospis cirrifera		*Planorbis planorbis***
	Clymene palermilana	Bivalvia	*Cerastoderma glaucum***
	Glycera convolata		*Crista pectinata*
	Onuphis eremita		*Donax variegatus*
	Cirratulus ciratus		*Donax trunculus*
	Syllis sp.		*Loripes lucinalis*
	Hydroides sp.		*Venus* sp.**
	Pectinaria auricoma		*Tellina ablicans*
	Nymphon gracile		*Mactra cummana*
	Serpula sp.**		*Brachiodontes variabilis*
Insecta larvae	*Cricotopus mediterranous*		*Modiolus adraticus***
	Nymphon gracile		*Pinctada margaritifera*
Ostracoda	*Sclerochilus contortus*		*Gastrana fragilis***
			*Gafrarium pectinatum***
		Echinodermata	*Holothuria* sp.
			Amphipholis squamata
		Ascidian	*Ciona intestinalis*

** Empty shells

Table 3. Yearly annual averages of abundance (no.ind/m^2), biomass (wet weight in g/m^2) and the number of species recorded in benthos groups in bottom sediments collected from Bardawil Lagoon during 2017.

Abundance 2017 no.ind/m^2	Ave	%	Biomass 2017 wet weight in g//m^2	Ave	%	Groups	No. species	%
Ostracoda	408	20.9	Sea grasses	370	59.5	Polychaeta	13	36
Sea grasses	373	18.6	Bivalvia	153	23.5	Bivalvia	6	16.7
Polychaeta	320	16.3	Polychaeta	45.1	8.2	Insecta larvae	2	5.6
Bivalvia	298	14.8	Cirripedia	14.5	2.2	Amphipoda	2	5.6
Insecta larvae	189	10.0	Echinodermata	7.4	1.4	Sea grasses	2	5.6
Amphipoda	121	5.9	Green algae	3.1	0.6	*Cirripedia*	2	5.6
Cirripedia	68	3.4	Red algae	4.3	0.8	Red algae	2	5.6
Oligochaeta	65	3.2	Amphipoda	7.3	1.0	Green algae	1	2.8
Nematoda	61	3.0	Ascidian	6.4	1.2	Nematoda	1	2.8
Echinoder-mata	14	0.7	Oligochaeta	5.8	1.1	Bryozoa	1	2.8
Ascidians	14	0.7	Bryozoa	2.1	0.4	Oligochaeta	1	2.8
Green algae	8	0.4	Insecta larvae	0.8	0.1	Ostracoda	1	2.8
Red algae	10	0.5	Isopoda	0.1	0.001	Isopoda	1	2.8
Bryozoa	18	0.9	Nematoda	0.00	0.001	Echinodermata	1	2.8
Isopoda	12	0.6	Ostracoda	0.00	0.001	Ascidians	1	2.8
Total no. ind/m^2	1978	100	Total bio g./m2	619	100	Total no. spp.	36	100

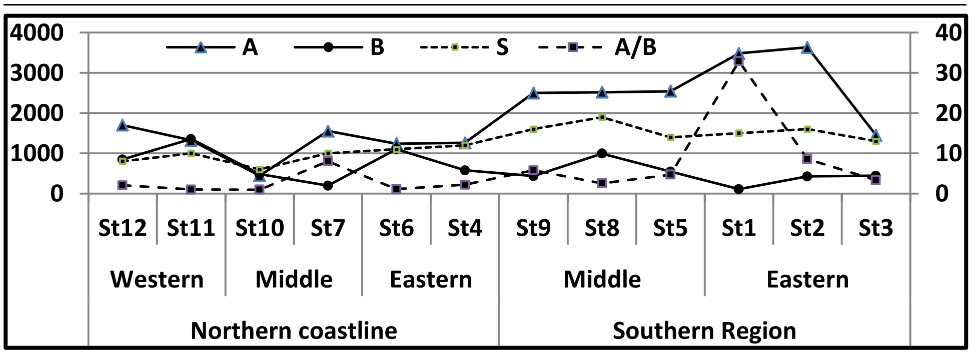

Fig. 2. Regional changes of Species (S), Abundance (A), Biomass (B) and A/B ratio were calculted for benthic constituents at the study sampling sites in Bardawil Lagoon during 2017.

Table 4. Dominance species (ind/m^2) and relative abundance (%) of benthic species recorded in the sampling sites in Bardawil

Dominance Species	St 1	%	Dominance Species	St 2	%	Dominance Species	St 3	%
Sclerochilus contortus	1533	44	*Sclerochilus contortus*	672	19	*Sclerochilus contortus*	588	38
Halophila stipulacea	315	9	*Cymodocea nodosa*	546	15	*Cymodocea nodosa*	168	11
Cymodocea nodosa	252	7	*Halophila stipulacea*	548	15	*Halophila stipulacea*	126	8
Brachiodontes variabilis	252	7	*Brachiodontes variabilis*	462	13	*Capitella capitata*	105	7
Cricotopus mediterranous	231	7	*Nereis pelagica*	189	5	*Brachiodontes variabilis*	84	6
T. abund. ind/m^2	3486	14.8	T. abund. ind/m^2	3635	15.3	T. abund. ind/m^2	1533	6.5
Dominance Species	**St 4**	**%**	**Dominance Species**	**St 5**	**%**	**Dominance Species**	**St 6**	**%**
Sclerochilus contortus	231	18	*Halophila stipulacea*	630	25	*Halophila stipulacea*	336	27
Corophium volutator	168	13	*Elasmopus pectenicrus*	378	15	*Cymodocea nodosa*	189	15
Ciona intestinalis	168	13	*Enoplis mersdionalis*	273	11	*Armandia polyophthalma*	126	10
Elasmopus pectenicrus	126	10	*Capitella capitata*	168	7	*Donax trunculus*	105	9
Cymodocea nodosa	105	8	*Cirratulus ciratus*	168	7	*Donax variegatus*	84	7
T. abund. ind/m^2	1260	5.3	T. abund. ind/m^2	2541	10.7	T. abund. ind/m^2	1239	5.2
Dominance Species	**St 7**	**%**	**Dominance Species**	**St 8**	**%**	**Dominance Species**	**St 9**	**%**
Sclerochilus contortus	420	27	*Brachiodontes variabilis*	672	27	*Halophila stipulacea*	399	16
Cymodocea nodosa	294	19	*Cymodocea nodosa*	231	9	*Sclerochilus contortus*	357	14
Cricotopus mediterranous	231	15	*Chaetogaster lirnnaei*	189	8	*Amphibalanus amphitrite*	336	13
Halophila stipulacea	168	11	*Sclerochilus contortus*	189	8	*Enoplis mersdionalis*	252	10
Tellina ablicans	168	11	*Cricotopus mediterranous*	168	7	*Capitella capitata*	231	9
T. abund. ind/m^2	1544	6.6	T. abund. ind/m^2	2520	10.6	T. abund. ind/m^2	2499	10.5
Dominance Species	**St 10**	**%**	**Dominance Species**	**St 11**	**%**	**Dominance Species**	**St 12**	**%**
Cricotopus mediterranous	149	34	*Brachiodontes variabilis*	504	38	*Sclerochilus contortus*	504	30
Lumbricorneis gracilis	63	14	*Nereis irrorata*	168	13	*Brachiodontes variabilis*	294	17
Nymphon gracile	63	14	*Nereis pelagica*	147	11	*Loripes lucinalis*	273	16
Sclerochilus contortus	63	14	*Loripes lucinalis*	105	8	*Amphibalanus amphitrite*	252	15
Nereis pelagica	63	14	*Chaetogaster lirnnaei*	84	6	*Cricotopus mediterranous*	168	10
T. abund. ind/m^2	443	1.9	T. abund. ind/m^2	1323	5.5	T. abund. ind/m^2	1707	7.1

Table 5. The yearly annual average of abundance (no.ind/m^2) and relative abundance (%) of the main groups of benthic species recorded in bottom sediments collected from Bardawil Lagoon during 2017.

Abun-dance/ 2017	**Northern coastline**						**Southern Region**							
	Western		**Middle**		**Eastern**		**Middle**			**Eastern**				
Stations	**St12**	**St11**	**St10**	**St7**	**St6**	**St4**	**St9**	**St8**	**St5**	**St1**	**St2**	**St3**	**Ave**	**%**
Sea grasses	0	0	0	462	525	147	462	294	630	567	1094	294	373	18.6
Algae	84	0	0	0	0	0	42	0	0	0	84	0	18	0.9
Nematoda	0	0	0	0	0	84	252	126	273	0	0	0	61	3.0
Bryozoa	0	0	0	0	0	0	210	0	0	0	0	0	18	0.9
Oligochaeta	0	84	0	42	0	0	63	189	63	126	147	63	65	3.2
Polychaeta	63	357	168	105	126	189	504	420	483	378	714	336	320	16.3
Insecta larvae	231	105	212	294	126	147	126	273	147	273	231	105	189	10.0
Ostracoda	504	84	63	420	84	231	357	189	168	1533	672	588	408	20.9
Amphipoda	0	0	0	0	0	294	147	147	378	189	231	63	121	5.9
Isopoda	0	0	0	63	42	0	0	42	0	0	0	0	12	0.6
Cirripedia	252	0	0	0	0	0	336	168	63	0	0	0	68	3.4
Bivalvia	567	693	0	168	336	0	0	672	336	252	462	84	298	14.8
Echino-dermata	0	0	0	0	0	0	0	0	0	168	0	0	14	0.7
Ascidians	0	0	0	0	0	168	0	0	0	0	0	0	14	0.7
T. abund ind /m^2	1701	1323	443	1554	1239	1260	2499	2520	2541	3486	3635	1449	1978	
%	14.8	15.3	6.5	5.3	10.7	5.2	6.6	10.6	10.5	1.9	5.5	7.1		
no. sp.	8	10	6	10	11	12	16	19	14	15	16	13		
no. groups	6	6	3	7	6	7	10	10	9	8	8	7		

1. 2 Species number (S):

The structure of species number of benthos groups at the different sites (as shown in Table 3 and Fig. 2) emphasized that two groups from a total of 14 were highly predominate namely; group Polychaeta were the most common comprising 13 spp. (where 9 species were as errant form and 4 species were as sedentary form) of the total number 36 species, representing 36% and Bivalves 6 species (representing 16.7%) and the rest groups were by represented by only one to two species.

2- Predominate benthic groups:

Tables 3, 4, 5 and Fig. 2 emphasized that the data analysis of benthic groups were the highest predominate benthic meiofauna Ostracoda constituent (408 ind/m^2, representing 20.9% of the total annual average of 1978 ind/m^2) which recorded at the most sampling sites in the lagoon and living among the sand bottom sediments. Also, sea grasses

(*Cymodocea nodosa* and *Halophila stipulacea)* were the **2nd** highest abundant rather (373 tufts/m^2, representing 18.9% of the total annual average) which recorded at the most sampling sites in the lagoon. Polycleitus showed the **3rd** highest density of individual's numbers in which essential polychaetes were relatively abundant rather (9.1%, 180 ind/m^2) than the sedentary forms (7.1%, 140 ind/m^2) of polychaetes which live inside muddy or calcareous building tubes and attaching to any submerged objects. Bivalves showed the **4th** highest density of individual's numbers accounting for 14.8% of the total number of individuals estimated by an annual average abundance 298 ind/m^2 which most species live inside sandy bottom sediments expect one species (*Brachiodontes varia*bilis) attaching temporally by abysses hairs on hard objects. Contrarily, the insect larvae represented the **5th** dominant groups floating on the water surface representing 9.6% of the total annual average reaching 189 ind/m^2. The **6th** dominant groups Amphipoda (*Elasmopus pectenicrus* and *Corophium volutator*) reached an annual average abundance of 121 ind/m^2 and representing 6.1% of the total annual average of benthos abundance which lives inside muddy building tubes. The other benthic groups were less frequent ranging from 0.6% to 3.5% where the number of individuals ranged from 12 - 68 ind/m^2. On the other word, the density of bottom fauna groups within higher taxonomic levels at the sampling sites can be arranged in the following sequence: Ostracoda (20.6%) > sea grasses (18.9%) > polychaetes (16.2%) > Bivalves (15.0%) > Insect larvae (9.6%) > Amphipoda (6.1%) > Cirripedia (3.5%) > Oligochaeta (3.3%) > Nematoda (3.1%) > other groups (3.8%) of the total number of individuals.

3- Biomass g/m^2 (B):

As shown in Tables 3, 6 and Fig. 2 sea grasses (*Cymodocea nodosa* and *Halophila stipulacea)* have the largest biomass among the bulk of benthos collected at the different sites yielding 370 g/m^2 representing 59.5% of the total biomass 619 g/m^2. The **2nd** more weight was bivalves attained 153 g/m^2, representing 23.5% of the total annual average). While polychaetes species have relatively high biomass among the bulk of benthos collected at the different sites yielding 45 g/m^2 representing 8.2% of the total biomass. Cirripedia species were sustained only14.5 g/m^2 and representing by 2.2% of the total biomass. The other benthic groups were less frequent ranging from 1.4% to less than 0.01% of the total annual average biomass of individuals which their biomass was ranged from 7.4 g/m^2 to less than 0.01 g/m^2. On the other side, the percentage of biomass of benthic groups at higher taxonomic levels at the different sampling sites can also be ranked as following: seagrasses (59.5%) > bivalves (23.5%) > Polychaeta (8.2%) > Cirripedia (2.2%) > Echinodermata (1.4%) > Algae (1.4%) > Amphipoda (1.0%) > other groups ranged from 1.2% to less than 0.01%.

4- The pattern of benthic assemblages:

4.1 Regional variations of benthic fauna during 2017:

4.1.1 Species number (S):

Regional variations in the species number as shown in Table 3 and Fig. 2 the highest number of species was found at the following sites: St8 (elRewak) 19 spp, St9 (N. elRewak) 16 spp, St2 (elRoadh) 16 spp, St1 (elTelol) 15 sp., St5 (M. elTelol) 14 spp, St3 (elZaranik) 13 spp, St4 (Boughaz II) 12 spp, St6 (Masqut Eplis) 11 spp, St7 (elGals) 10 spp, St11 (elNaser) 10 spp, St12 (Raba`a) 8 spp. The abundance of benthic fauna in Bardawil Lagoon at all sites is noticed. Values of sample abundance were highest at sites St2 (elRoadh, St1 (elTelol), St5 (St5 (M. elTelol)), St8 (elRewak) and St9 (N. elRewak)

Table 6. Yearly annual average of biomass (wet weight in g/m2) and relative of biomass (%) of the main groups of benthic species recorded in bottom sediments collected from Bardawil Lagoon during 2017.

	Northern coastline						Southern Region							
Biomass/2017	**Western**		**Middle**		**Eastern**		**Middle**			**Eastern**				
	St 12	St 11	St 10	St 7	St 6	St 4	St 9	St 8	St 5	St 1	St 2	St 3	Average	%
Sea grasses	0.00	0.00	0.00	363.30	424.20	94.50	409.92	491.40	693.00	512.40	1096.20	350.70	370	59.5
Algae	21.84	0.00	0.00	0.00	0.00	0.00	42.00	0.00	0.00	0.00	25.20	0.00	7.4	1.4
Nematoda	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.23	0.00	0.00	0.00	0.0	0.004
Bryozoa	0.00	0.00	0.00	0.00	0.00	0.00	24.99	0.00	0.00	0.00	0.00	0.00	2.1	0.4
Oligochaeta	0.00	0.84	0.00	0.21	0.00	0.00	0.25	1.11	1.47	1.26	1.05	63.00	5.8	1.1
Polychaeta	0.06	32.97	105.21	0.23	0.67	5.29	1.74	52.92	171.23	91.60	14.93	64.16	45	8.2
Insecta larvae	0.48	0.42	0.44	0.55	0.50	0.46	0.46	0.50	0.50	3.82	0.61	0.50	0.8	0.1
Ostracoda	0.04	0.02	0.02	0.04	0.02	0.02	0.04	0.02	0.02	0.04	0.04	0.04	0.03	0.01
Amphipoda	0.00	0.00	0.00	0.00	0.00	16.80	11.76	7.35	18.80	16.59	16.17	0.08	7.3	1.0
Isopoda	0.00	0.00	0.00	0.42	0.42	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.1	0.02
Cirripedia	65.31	0.00	0.00	0.00	0.00	0.00	53.34	33.81	21.42	0.00	0.00	0.00	14.5	2.2
Bivalvia	350.9	392.1	0.00	69.30	150.6	0.00	0.00	403.2	136.9	130.2	199.5	0.00	153	23.5
Echinodermata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.4	1.4
Ascidian	0.00	0.00	0.00	0.00	0.00	76.86	0.00	0.00	0.00	0.00	0.00	0.00	6.4	1.2
T.biomass g/m^2	439	426	106	434	576	194	545	991	1105	845	1354	478	619	
%	11.4	18.2	6.4	2.6	14.9	7.8	5.8	13.3	7.3	1.4	5.7	5.9		
no. sp	8	10	6	10	11	12	16	19	14	15	16	13		
no. groups	6	6	3	7	6	7	10	10	9	8	8	7		

representing 3635, 3486, 2541, 2520 and 2499 ind/m2 and corresponding respectively percentage of 15.3%, 14.8%, 10.7%, 10.6% and 10.5% of the total annual average abundance of benthic fauna (1978 ind/m^2).

4.1.2 Abundance of benthic fauna (as shown in Table 3 and Fig. 2):

1- Sea grasses species *Cymodocea nodosa* and *Halophila stipulacea* species were more frequent at most sites except at St10 (Boughaz II), St11 (elNaser) and St12 (Raba`a). *Cymodocea nodosa* abundance was recorded in high density at St1, St2, St7, and St8 ranging from 546 to 231 tufts/m^2, whereas *Halophila stipulacea* was recorded in high density at sites St1, St2, St6 and St9 which ranged from 630 to 315 tufts/m^2.

2- Oligochaeta: *Chaetogaster lirnnaei* was more frequent at most sites are characterized by inhabiting inside muddy tubes and representing as pollution species indicator were recorded in moderate numbers at different sampling sites which the species ranged from 42 to 189 ind/m^2 individuals.

3- Polychaeta: the dominant species were calcareous sedentary form *Serpula* sp. (recorded at all sites ranged from 231 to 63 ind/m^2) and other 3 species of muddy sedentary form namely *Armandia polyophthalma*, *Capitella capitata* and *Cirratulus ciratus* as pollution species indicator were recorded in moderate numbers at different sampling sites which the species ranged from 42 to 126 ind/m^2 (at St2, St6, and St8), the 2^{nd} species varied from 63 to 231 ind/m^2 (St1-St3, St5, St8, St9 and St12) while the 3rd species ranged from 42 to 168 ind/m^2 (at St1-St3, St5, and St8). The other 9 errant polychaetes species namely each of *Lumbricorneis gracilis*, *Nereis irrorata*, *Nereis pelagica*, *Clymene lumbricoides*, *Glycera convolata*, *Amphitrite aftinis*, *Onuphis eremita*, and *Pectinaria auricoma* have little occurrence at different sites yielding a total of the annual average density of only 5 to 54 ind/m^2.

4-Phylum Euarthropoda: (subphylum Hexapoda, class Insecta) in which the Insecta larvae *Cricotopus mediterranous* and *Nymphon gracile* were more flourished at all sampling sites yielding density varied from 63 to 231 ind/m^2 and little annual average of 133 ind/m^2 representing 6.7% of total benthic abundance for the **1^{st}** species and contrary the **2^{nd}** species indicating lower density attained from 42 to 105 individual and annual average of 56 ind/m^2 representing 2.8% of the of total benthic abundance. Crustaceans Ostracoda *Sclerochilus contortus* were dominated at most sampling sites reaching the highest annual average of 408 ind/m^2 representing 20.6% of the total benthic abundance at all sites. This species sustaining high density varied from 63 to 1533 ind/m^2.

5-**Other Crustaceans:** orders (Amphipoda, Isopoda, and Cirripedia) in which were frequently recorded at sampling sites yielding little an annual average of 201 individuals representing 10.2% of total benthic abundance at all sites and the species abundance at sites were varied from 42 to 336 ind/m^2.

6-Bivalve species: *Brachiodontes variabilis* has maximum occurrence at 6 sites yielding a total of 203 ind/m^2 (10.3%). It was recorded at St1, St2, St3, St5, St8, and St12 comprising 252, 462, 168, 672, 504 and 294 ind/m^2 respectively. While *Donax variegatus* and *Donax trunculus* were recorded only at St6 yielded 84 (4%) and 105 (4%) individuals respectively. *Loripes lucinalis* was recorded at 4 sites St5, St6, St11, and St12 yielded 84 to 273 ind/m^2 (annual average 53 ind/m^2, 2.7%). *Tellina ablicans* was recorded at St7 (63 individuals) and St8 (168 individuals). *Crista pectinata* was recorded at St11 yielded 84 ind/m^2.

7-Echinodermata: *Holothuria* sp. was recorded only at St1 comprising 168 individuals (0.7%).

8- Ascidians *Ciona intestinalis* was recorded only at St4 comprises 168 ind/m^2 (0.7%).

4.1.3 Biomass of benthic fauna (as shown in Tables 3, 4 and Fig. 2):

1) The sea grasses species *Cymodocea nodosa,* and *Halophila stipulacea* species were more frequent at the most sites except at St10 (Boughaz I), St11 (elNaser) and St12 (Raba`a). They were recorded in high weight ranged from 351 to 1069 g/m^2 whereas it was recorded in low biomass at site St4 (Boughaz II) yielded only 95 g/m^2.

2) Polychaetes species was relatively less frequent at most sites and characterized by low weight at different sampling sites which the species biomass yielded an annual average biomass 45 g/m^2 representing 8.2% of the total annual average biomass. Oligochaeta species was also recorded in little biomass reached 5.8 g/m^2 and estimated by 1.1% of the annual average biomass.

3) Phylum Euarthropoda (subphylum Hexapoda, class Insecta) in which the insect larvae *Cricotopusmediterranous* and *Nymphon gracile* were more flourished at all sampling sites but yielding less than 0.8 g/m^2 and representing less than 0.1 %.

4) Crustaceans orders (Amphipoda, Isopoda, and Cirripedia) in which were frequently recorded at sampling sites yielding little an annual average biomass 7.3-14.5 g/m^2 representing 1.0%-2.2% of the total benthic biomass.

5) Bivalve species ranked the 2nd benthic groups have maximum occurrence and biomass yielding annual average 153 g/m^2 (corresponding to 23.5 of annual average biomass.

6) Echinodermata *Holothuria* sp. was recorded only at St1 comprising 89 g/m^2 representing 1.4 of annual average biomass).

7) Ascidians *Ciona intestinalis* was recorded only at St4 yielded a biomass 6.4 g/m^2 (1.2% of annual average biomass).

8) The percentage of the biomass of the bottom constituents at different sampling sites along the lagoon can be arranged in the following rank: 10.5% - 15.3% (St1, St2, St5, St8 and St9), 5.1% - 7.1% (St3, St4, St6, St7, St11 and St12) and only 1.9% at St10 of the total abundance of the individuals yielding an annual average density attaining 1978 ind/m^2.

9) Also the percentage of biomass of bottom fauna at the sampling sites can be arranged as follows: 11.4% - 18.2% (St1, St2, St5 and St8), 5.7% - 7.8% (St3, St6, St7, St9, St11 and St12) and from 1.4% to 2.6% at St10 and St4. of the total wet weight of the individuals yielding an annual average biomass attaining 619 g/m^2.

10) The percentage of the abundance of the bottom fauna at different sampling sites along the lagoon can be arranged in the following rank: 10.5 - 15.3 (St1, St2, St5, St8 and St9), 5.1% - 7.1% (St3, St4, St6, St7, St11 and St12) and only 1.9 at St10 of the total abundance of the individuals yielding an annual average density attaining 1978 ind/m^2.

11) Errantia polychaetes: *Lumbricorneis gracilis, Nereis irrorata, Nereis pelagica, Clymene lumbricoides, Glycera convolata, Nephylus caeca, Amphitrite aftinis, Onuphis eremita,* and *Pectinaria auricoma*.

12) Sedentary polychaetes: *Armandiapolyophthalma*, *Capitella capitata, Cirratulus ciratus*, and *Serpula* sp.

13) Quantitative analysis of bottom of the collected samples is less diversity in species in all sites as shown in Tables 3 ,4 and Fig. 2 that the numerical density percentage reached the highest density at St2, St1, St9, St8, St5 estimated numerical density respectively preparing 3906, 3192, 2898, 2856 and 2646 ind/m^2 and corresponding to 15.8%, 12.9%, 11.8%, 11.6%, and 10.7% respectively while stocking the rest stations set up between 1890 to 126 ind/m^2 estimated percentages 7.7% to 0.5%, respectively.

14) Results demonstrate amid various seasons that the examination zones more diverse number of species and numerical abundance was most noteworthy at the St1 (elTelol) and St2 (elRoadh), where the annual average of abundance and biomass were estimated respectively by 3486 ind/m^2 and 3635 ind/m^2 (representing 14.7% of the total abundance of living macrobenthic organisms 1978 ind/m^2) and less numerical density at each of St5 (m. elTelol), St8 (elRewak) and St9 (N. elRewak) by 2541 - 2449 ind/m^2 diminished by 10.7% - 10.5% as a result of the presence of large numbers of sea grasses (18.6%), Polychaetes (16.3%), Insect larvae (10%), Ostracoda (20.9%) and Bivalves (14.8%).

15) Thirty-six species were identified in the lagoon during the two seasons of 2017 attaining an annual average benthic abundance of 1978 ind/m^2 and the annual average biomass sustained in a wet weight of 619 g/m^2. Though the exclusive number of species reached 10-11 species at St1, St2 and St8 and less number recorded were ranged from just a single species at St10 (Boughaz I), 8 species at St8 and 4-7 species at the rest stations. During winter season accomplishing annual benthic abundance of 2055 ind/m^2 and the total biomasses were highest at St1, St2, St5 and St8 attaining respectively 11.4, 18.2, 14.9 and 13.3 of the total crop stock density corresponding to wet weights of 845, 1354, 1105 and 991 g/m^2.

16) The assessed level of the yearly biomass measured in wet weight the predominated macrobenthos communities during the seasons of 2017 reaching an annual average biomass 619 g/m2 and were highest at stations St1, St2, St5 and St8 attaining respectively 11.4%, 18.2%, 14.9% and 13.3% of the total stock density crop corresponding to wet weights of 845, 1354, 1105 and 991 g/m^2.

17) Results indicate four groups predominantly sampling seasons as follows; The **1st**group, sea grasses biomass with an annual average of 370 g/m^2 and a higher rate of up to 59.5%; the **2nd**group, class Polychaeta ranging biomass density with an annual average of 45 g/m2 and a rate of up to 8.2%; the **3rd**group class Crustacea ranging biomass density with an annual average of 22 g/m2 and a lower rate of 3.2% and the 4th group class Bivalvia yielding an annual average of 153 g/m2 and a relatively a high rate up of 23.5%.

18) On the other side, the estimated annual average numerical abundance and stock crop biomass of different populations of macrobenthos was relatively higher in comparing to other northern lagoons in Egypt. Due to the water quality in the lagoon is good quality class, reflecting the pressures acting in their watersheds.

19) In perspective of the present outcomes, management measures ought to be embraced, particularly for Bardawil Lagoon. Variations in the biomass of benthic fauna at the sampling sites are recognized as shown in Table 6 and Fig. 2. Values of sample

biomass were the heaviest at sites St1 (elTelol), St2 (elRaodh), St5 (St5 (M.elTelol)), St6 (Masqut Eplis), St8 (elRewak) and St9 (N. elRewak) representing 845, 1354, 1105, 576, 991, and 454 g/m^2 and corresponding respectively percentage of 11.4%, 18.2%, 14.9%, 7.8%, 13.3% and 7.3% of the total annual average biomass of benthic fauna (619 g/m^2).

5- Diversity Indices (as shown in Table 7 and Fig. 3):

The diversity indices which serve as an indication of community health on spatial and temporal scales can be measured using several indices [47, 58]. However, diversity indices including Swartz Dominance, d species Richness, j` Pielou`s Evenness, H` (ln) Shannon-Weaver species diversity, and 1-Lambda` Simpson's diversity index were applied in this study.

Table 7. Results of diversity indices estimated for benthic constituents at the study sampling sites in Bardawil Lagoon during 2017.

	Northern coastline						**Southern region**					
	Western		**Middle**		**Eastern**		**Middle**			**Eastern**		
Stations	**st12**	**st11**	**st10**	**st7**	**st6**	**st4**	**st9**	**st8**	**st5**	**st1**	**st2**	**st3**
Abundance ind/m^2	1701	1323	443	1554	1239	1260	2499	2520	2541	3486	3635	1533
% abundance	7.1	5.5	1.9	6.6	5.2	5.3	10.5	10.6	10.7	14.8	15.3	6.5
Biomass g/m^2	439	426	106	434	576	194	545	991	1105	845	1354	478
% biomass	5.9	5.7	1.4	5.8	7.8	2.6	7.3	13.3	14.9	11.4	18.2	6.4
A/B	3.87	3.11	4.18	3.58	2.15	6.49	4.59	2.54	2.30	4.13	2.68	3.21
Depth m	2.0	2.0	1.5	1.5	1.0	3.0	2.0	2.0	2.0	1.5	1.3	1.3
no. sp.	8	10	6	10	11	12	16	19	14	15	16	13
no. groups	6	6	3	7	6	7	10	10	9	8	8	7
E(H`)	1.021	1.237	0.934	1.218	1.331	1.409	1.591	1.757	1.462	2.064	1.543	1.458
E(H`)	1.021	1.237	0.934	1.218	1.331	1.409	1.591	1.757	1.462	2.064	1.543	1.458
SD[H']	0.341	0.3295	0.3184	0.3329	0.3231	0.3181	0.3135	0.2987	0.324	0.3258	0.3218	0.3175
V(N.D.)	2.465	2.206	2.404	2.403	2.669	2.97	2.873	2.796	2.737	1.766	2.778	2.156
F-ratio	8.857	4.996	16.89	6.312	8.586	13.69	6.581	4.977	6.519	2.625	5.793	3.848
Degrees of Freedom for F	8.149	11.97	7.195	11.56	13.99	15.85	20.80	26.71	17.06	17.70	19.28	17.06
	8.443	10.31	6.608	10.29	11.22	12.11	15.46	18.04	13.72	14.51	15.35	12.96
Swartz Dominance	4	4	3	5	6	6	7	8	7	6	8	6
d species Richness	0.941	1.252	0.821	1.225	1.404	1.541	1.917	2.298	1.658	1.716	1.83	1.636
j` Pielou`s Evenness	0.895	0.853	0.948	0.876	0.915	0.947	0.899	0.881	0.89	0.762	0.879	0.835
H`(ln) Shannon-Weaver	2.686	2.834	2.452	2.911	3.164	3.396	3.594	3.74	3.389	2.977	3.517	3.09
1-Lambda` Simpson	0.82	0.804	0.797	0.839	0.862	0.893	0.901	0.89	0.878	0.776	0.89	0.815

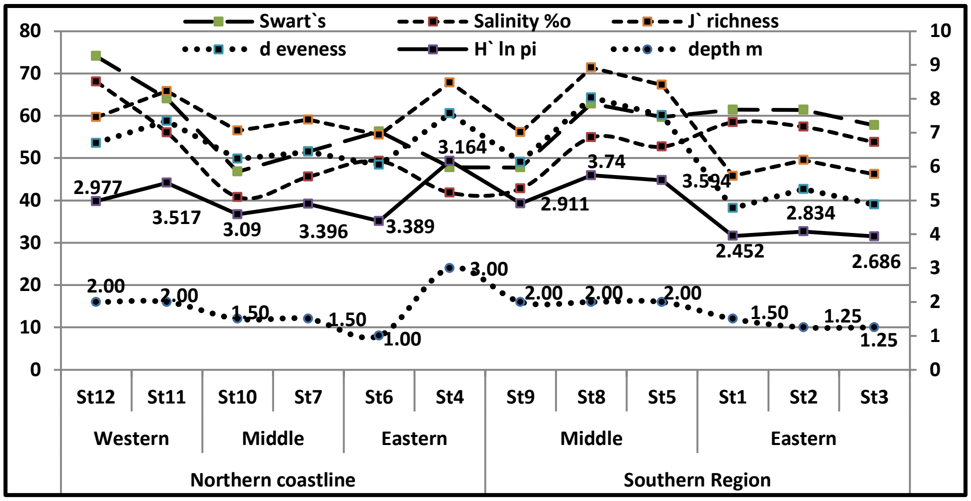

Fig. 3. Results of diversity indices estimated for benthic constituents at the study sampling sites in Bardawil Lagoon during 2017.

5.1 Swartz Dominance index:

Swartz's dominance index, which measured the number of species whose combined abundance comprised 75 of the total sample abundance (if index value > 5 indicating that the area has no stress community). The values ranged from 3 to 5 at the sampling sites St12, St11, and St10, whereas, at most western sites were significant of less stress than the previous sites ranging from 6 to 8.

5.2 Margalef's species richness (d):

Species richness refers to the total number of different species present (without taking into account the proportion and distribution of each species) within the sample. The calculated values species richness (d) were low of species richness of values less than one at St12 and St10 and high of species richness of value 2.298 at St8 and were moderate ranging from 1.252 -1.917 at the rest sites.

5.3 Pielou's evenness (J'):

Pielou's evenness used the ratio of the expected number of species against the recorded number of species as an index of evenness, with the assumption that all species were accounted for in the sample. The higher the attained value was estimated by values of 0.915-0.948 at St10, St6 and St4 meaning the more evenly individuals are spread among the species. Species evenness is dependent on species richness and species diversity. The evenness measure is a ratio of the observed diversity to the maximum possible in a sample having the same number of species.

5.4 Shannon-Wiener's diversity index (H`):

The Shannon-Wiener diversity index refers to the state of an assemblage per the species richness and species abundance. The estimated values 2.452 to 2.977 were moderate diverse at northern coastline sites (Sts12, 11, 10, 7, and 1) and highly diverse at the rest sites varied from 3.09 to 3.594.

Table 8. Results of diversity indices estimated for benthic constituents at the study sampling sites in Bardawil Lagoon during 2017.

Groups	Mean	Mini-mum	Maxi-mum	Std. Dev.	Groups	Mean	Mini-mum	Maxi-mum	Std. Dev.
Sea Grass	372.9	0	1094	322.4	Isopoda	12.3	0	63	22.8
Algae	17.5	0	84	33.3	Cirriped	68.3	0	336	117.8
Nematoda	61.3	0	273	102.7	Bivalvia	297.5	0	693	257.5
Bryozoa	17.5	0	210	60.6	Echinodermata	14	0	168	48.5
Oligochaeta	64.8	0	189	63	Ascidian	14	0	168	48.5
Polychaeta	320.3	63	714	195.6	Abundance	1978	443	3635	963
Insecta	189.2	105	294	70.6	Biomass	624	106	1354	374
Ostracod	407.8	63	1533	409.6	No Group	7.3	3	10	2
Amphipod	120.8	0	378	131.6	No spp.	12.5	6	19	3.7

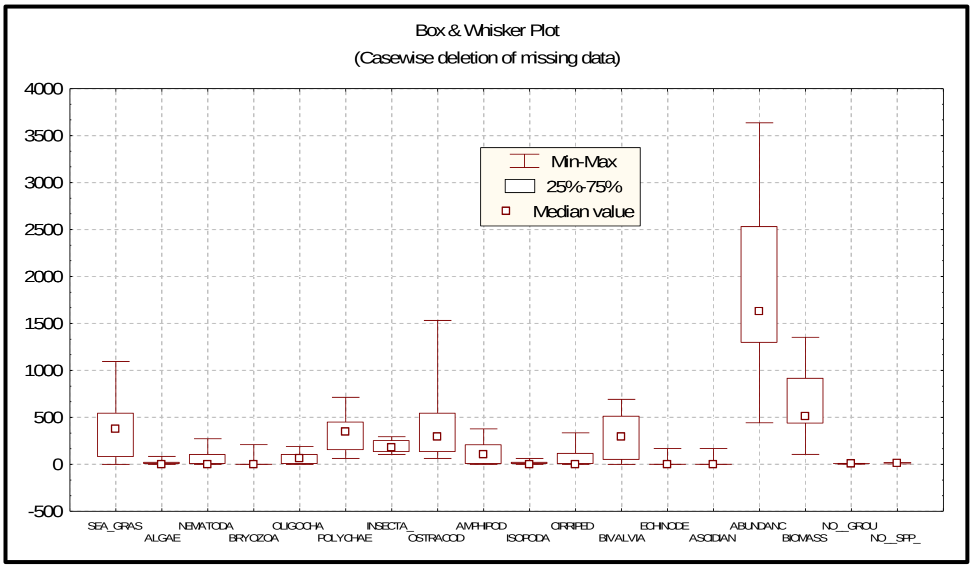

Fig. 4. Descriptive Statistics (Casewise Deletion of Missing Data) Valid N = 12.

5.5 Simpson's diversity index (D):

Simpson's diversity indexes aimed to measure and determine the degree of concentration when species are classed. The values of Simpson's diversity index at the studied sites were ranged from 0.776 - 0.901. This provides an intuitive proportional measure of diversity that is much less sensitive to species richness.

6- Statistical analyses (as shown in Table 8 and Fig. 4):

6.1 Casewise Deletion of Missing Data:

Descriptive Statistics (Casewise Deletion of Missing Data) which species numerical abundance for the different environment sampling sites in Bardawil Lagoon showed annual abundance was 1978 ind/m^2, with minimum, maximum and standard deviation 106, 1354 and 374, respectively. The annual biomass was 624 g/m^2, with minimum, maximum and standard deviation 443, 3635 and 963, respectively. Numerical abundance of main benthic group's in dominance orders were respectively ostracods, sea grasses, polychaetes, bivalves, insects, amphipods and oligochaets 408, 373, 320, 298, 189, 121 and 65 ind/m^2. In respect to respective dominance orders, the taxa dominance showed: ostracods> sea grasses >polychaetes>bivalves>insects>amphipods >oligochaetes >others.

6.2 Caswell's V statistics:

The Caswell's V statistics assessment between-site, and variables species show two groups of highly species diversity: more than 3 (at stations 1-6, and 8, 9) and less than 3 (at the rest sites); SD (H\`), V (N.D.), and F-ratio and degrees of freedom for F supports the same results was estimated (Table **9**).

Table 9. Caswell's V statistics- Sample selection: All - Variable selection: All.

Sample	N	S	H`log2	E(H`)	SD[H']	V(N.D.)	F-ratio	Degrees of	freedom for F
St1	3486	15	3.004	2.064	0.3258	1.766	2.625	17.7	14.51
St2	3635	16	3.542	1.543	0.3218	2.778	5.793	19.28	15.35
St3	1533	13	3.135	1.458	0.3175	2.156	3.848	17.06	12.96
St4	1260	12	3.440	1.409	0.3181	2.970	13.69	15.85	12.11
St5	2541	14	3.537	1.462	0.3240	2.737	6.519	17.06	13.72
St6	1239	11	3.209	1.331	0.3231	2.669	8.586	13.99	11.22
St7	1554	10	2.949	1.218	0.3329	2.403	6.312	11.56	10.29
St8	2520	19	3.776	1.757	0.2987	2.796	4.977	26.71	18.04
St9	2499	16	3.627	1.591	0.3135	2.873	6.581	20.8	15.46
St10	443	6	2.521	0.934	0.3184	2.404	16.89	7.195	6.608
St11	1323	10	2.876	1.237	0.3295	2.206	4.996	11.97	10.31
St12	1701	8	2.716	1.021	0.3410	2.465	8.857	8.149	8.443

Table 10 and Fig.5 reveal PCA Principal Component Analysis ordination between all variables and samples which the Eigenvalues Eigenvectors and (Coefficients in the linear combinations of variables making up PC's) and Principal Component Scores indicating one main of highly score St6, St7 and St10 of 3.854, 2.664 and 2.773 respectively that stations located at north coastal stations of low depth and less polluted areas. While, the pattern at other sites are indicative tend to values of PCA suggest the influence of surrogate abiotic water conditions.

6.4 Cluster Analysis Similarity:

A Bray-Curtis similarity cluster assessment between-species (Fig. 6) are displayed as dendrograms. Between-species similarity showed 6 groups were average at 95% to 80% namely; *Donax variegatus-D. trunculus; Nereis irrorata-N. pelagica; Ciona intestinalis-*

Table 10. PCA Principal Component Analysis within different studied sites of benthic species.

PCA Principal Component Analysis Benthic species
Sample selection: All
Variable selection: All

Eigenvalues			
PC	Eigenvalues %	Variation Cum %	Variation
1	6.93	18.7	18.7
2	6.37	17.2	35.9
3	3.98	10.8	46.7
4	3.74	10.1	56.8
5	3.48	9.4	66.2

Eigenvectors
(Coefficients in the linear combinations of variables making up PC's)

Variable				
PC 1	**PC 2**	**PC 3**	**PC 4**	**PC 5**
Cymodocea nodosa				
-0.132	0.251	0.178	0.228	0.004
Halophila stipulacea				
-0.220	-0.100	0.139	0.306	-0.113
Chaetomorpha sp.				
-0.081	0.127	0.028	-0.034	-0.192
Gracilaria armata				
-0.140	-0.227	-0.243	0.097	0.099
Enoplis mersdionalis				
-0.193	-0.275	-0.043	0.070	0.192
Bowerbankia imbricata				
-0.140	-0.227	-0.243	0.097	0.099
Chaetogaster lirnnaei				
-0.301	0.195	-0.033	0.021	0.053
Armandia polyophthalma				
0.077	0.125	-0.044	0.396	-0.077
Capitella capitata				
-0.319	-0.160	0.001	0.099	-0.105
Lumbricorneis gracilis				
0.126	0.015	-0.073	-0.168	-0.038
Nereis irrorata				
-0.196	0.197	-0.227	-0.132	-0.027
Nereis pelagica				
-0.214	0.257	-0.129	-0.098	-0.047
Clymene lumbricoides				
-0.191	-0.153	-0.249	0.071	0.204

Variable				
PC 1	**PC 2**	**PC 3**	**PC 4**	**PC 5**
Balanus eburneus				
-0.107	0.156	-0.125	0.019	0.261
Loripes lucinalis				
0.064	-0.088	-0.087	-0.056	-0.183
Tellina ablicans				
0.180	0.062	0.015	0.250	0.166
Crista pectinata				
0.022	0.057	-0.224	-0.220	0.096
Donax variegatus				
0.175	0.019	-0.046	0.381	-0.118
Donax trunculus				
0.175	0.019	-0.046	0.381	-0.118
Brachiodontes variabilis				
-0.199	0.241	-0.125	-0.122	-0.015
Holothuria sp.				
-0.098	0.087	0.112	-0.006	-0.040
Ciona intestinalis				
0.001	-0.189	0.309	-0.093	0.182
No. species				
-0.309	0.029	0.048	0.165	0.133
Principal Component Scores				
Sample				
SCORE 1	**SCORE 2**	**SCORE 3**	**SCORE 4**	**SCORE 5**
St 1				
-2.167	1.763	1.411	-0.074	-0.438

Continued…….

Variable	PC 1	PC 2	PC 3	PC 4	PC 5	Sample	SCORE 1	SCORE 2	SCORE 3	SCORE 4	SCORE 5
Glycera convolata	0.113	-0.337	0.148	0.000	-0.020	St 2	-3.961	3.588	1.585	0.879	-1.650
Cirratulus ciratus	-0.256	0.010	0.256	0.064	-0.172	St 3	0,539	-1.394	1.524	-0.745	-2.697
Amphitrite aftinis	0.025	-0.069	0.121	-0.063	-0.244	St 4	1.855	-1.389	3.330	-1.753	2.876
Nephylus caeca	0.084	-0.069	0.264	-0.148	0.260	St 5	-2.187	-4.022	1.828	0.452	-0.450
Onuphis eremita	0.152	-0.008	0.220	-0.023	0.353	St 6	3.854	0.389	-0.584	4.518	-1.299
Pectinaria auricoma	-0.180	0.178	0.126	0.074	-0.149	St 7	2.664	1.157	0.419	1.379	2.384
Serpula sp.	0.025	-0.069	0.121	-0.063	-0.244	St 8	-2.344	3.156	-1.584	0.224	2.881
Cricotopus mediterranous	-0.046	0.217	0.068	0.046	0.141	St 9	-3.082	-4.593	-3.068	1.149	1.090
Nymphon gracile	-0.032	0.209	-0.037	-0.062	0.312	St 10	2.773	0.302	-0.927	-2.000	-0.421
Sclerochilus contortus	-0.151	0.099	0.172	0.004	-0.107	St 11	0.492	3.854	1.160	-2.825	-2.608
Elasmopus pectenicrus	-0.222	-0.218	0.205	0.043	0.029	St 12	1.565	-0.118	1.110	-1.421	-1.210
Corophium volutator	-0.116	0.141	0.282	-0.078	0.220						
Sphaeroma serratum	0.133	0.139	-0.065	0.306	0.249						
Amphibalanus amphitrite	-0.118	-0.187	-0.272	0.017	0.077						

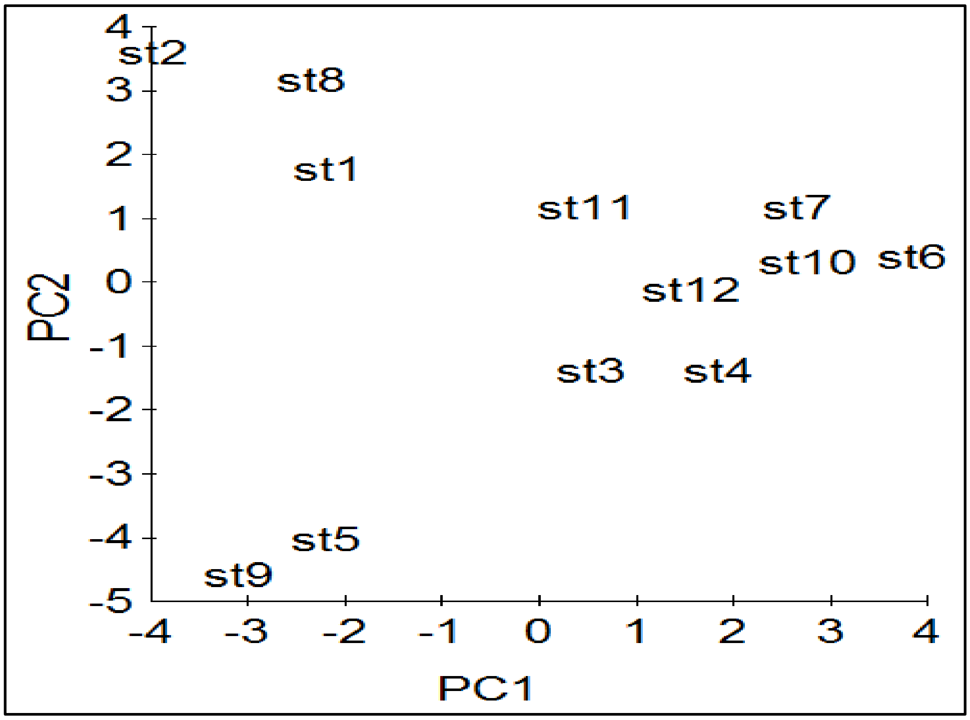

Fig. 5. PCA Principal Component Analysis within different studied sites of benthic species.

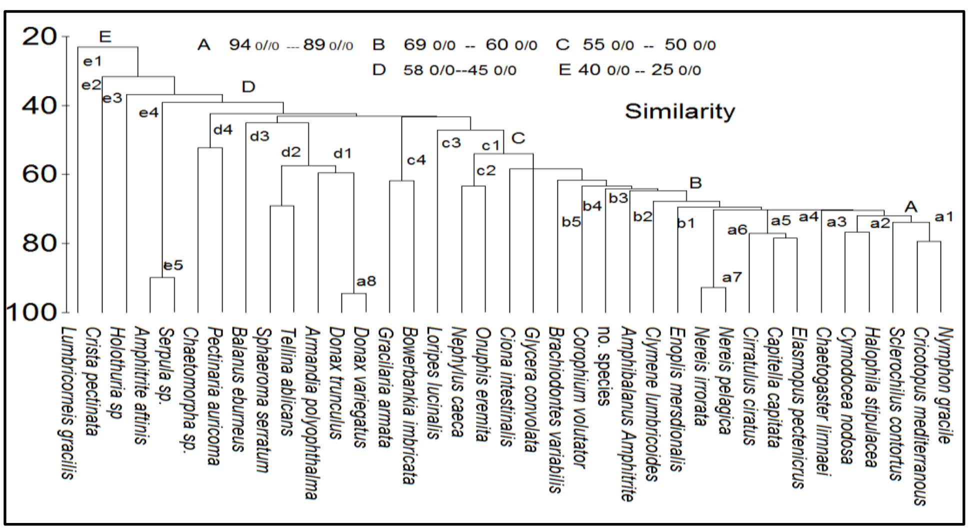

Fig. 6. Bray-Curtis similarity (%) dendrogram within of benthic species at different studied sites.

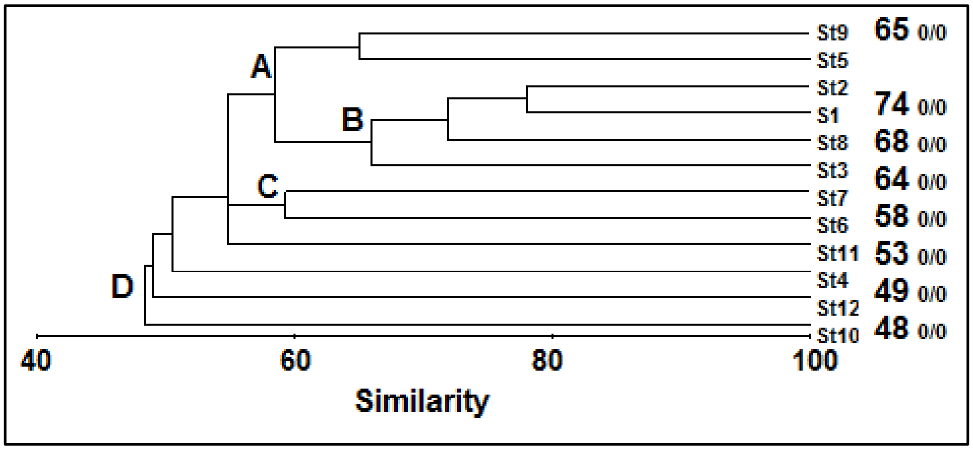

Fig. 7. Bray-Curtis similarity (%) dendrogram within of benthic species at different studied sites.

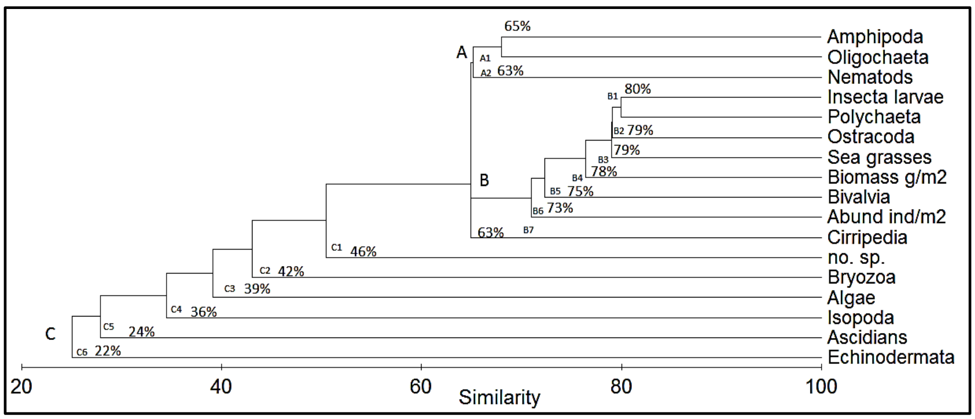

Fig. 8. Bray-Curtis similarity (%) dendrogram within of benthic groups and diversity indices at different studied sites.

Nephylus caeca; Serpula sp.-*Amphitrite aftinis; Ciona intestinalis*-*Nephylus caeca* and*Nymphongracile*, *Cricotopusmediterranous.*The rest species have approximately 40 % to 70% similarity was observed within-species. Combining of 37 groups are illustrated as their parentage of similarity.

On the other side, the Bray-Curtis similarity cluster assessment between-site (Fig. 5) shows three groups show high similarity at sites namely; class 1 (St2, St1); class 2 (St8) and class 3 (St9, St5) were reached similarity 65%-78%. The rest sites have similarity were averaged 45% and 60%. The detail of Combining between the 12 sites is illustrated as their parentage of similarity.

The Bray-Curtis similarity cluster assessment between-group (Fig. 8) shows three class groups show high similarity namely; class A at similarity 65% - 63%

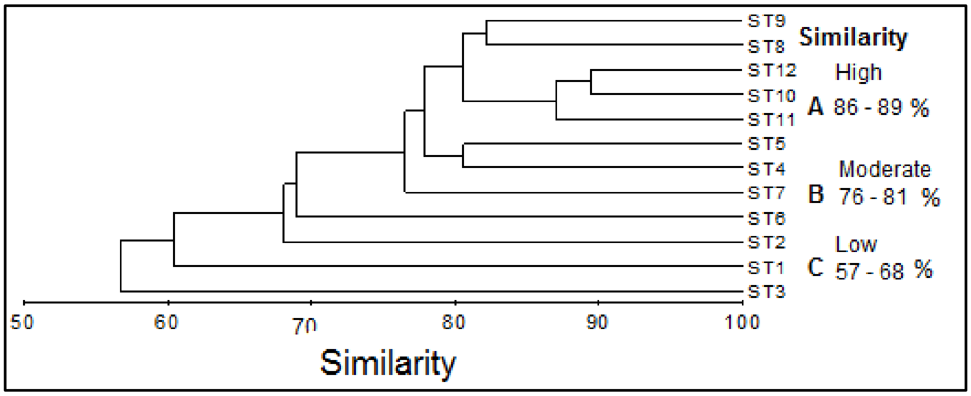

Fig. 9. Bray-Curtis similarity (%) dendrogram within different studied sites of benthic groups.

(A1-amphpoda-oligochaeta and A2-nematoda); class B at 80%-63% (including 7 subclasses B1 to B7) and the least similarity 22%-46% were at rest groups including 6 subclasses C1 to C6). The detail of Combining between the 12 sites is illustrated as their parentage of similarity.

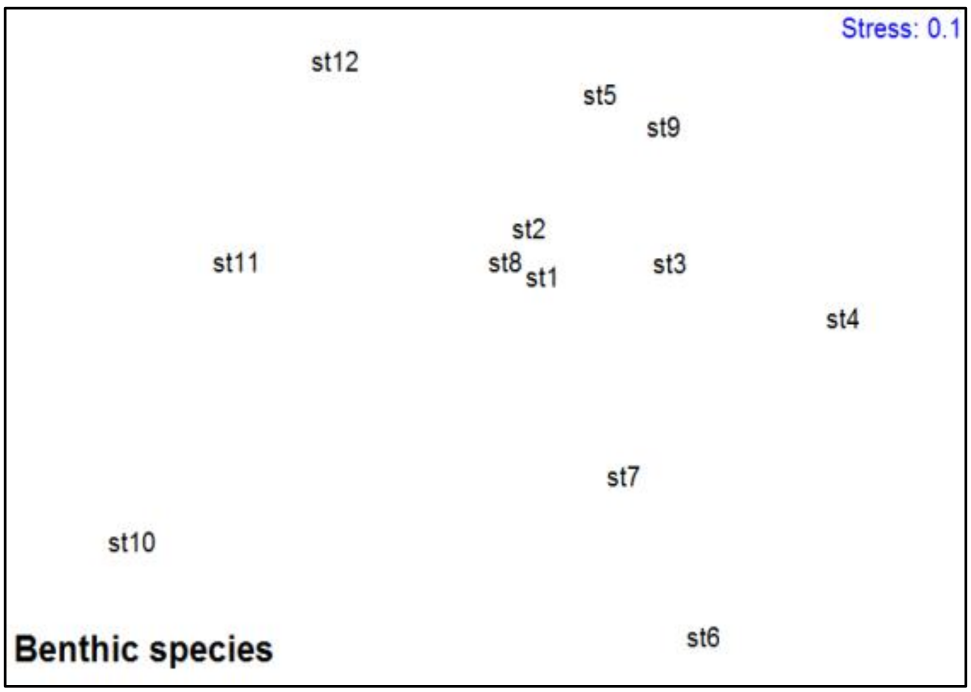

Fig. 10. MDS non-metric Multi-Dimensional Scaling analyses Similarity Matrix Data type: Similarities Sample selection: All.

The Bray-Curtis similarity cluster assessment between-site (Fig. 9) shows three class groups show high similarity namely; class A at similarity 86%-89% (St9-St8; St10-St12 and St11); class B moderate similarity at 76%-81% (including 2 subclasses St4-St5 and St7) and the least similarity 57%-68% were at rest sites including 4 subclasses St6, St1, St2 and St3). The detail of Combining between the 12 sites is illustrated as their parentage of similarity.

6.5 Distribution pattern of the stations in the MDS:

MDS non-metric Multi-Dimensional Scaling analyses ordination as shown in Fig.10 between the benthos species and sample sites which the similarity was measured at Bray Curtis without standardize and with transform square root showed a relative separation of shallow depth stations (stations 10, 7, 6, 1, 2, and 3) and deep depth stations (stations 12, 11, 4, 9, and 8). The spatial pattern is indicative that stations located in each specific sampled northern coastline tend to cluster together, which also suggest the influence of surrogate abiotic water conditions.

On the other side, MDS non-metric Multi-Dimensional Scaling analyses ordination as shown in Fig.11 between the benthos groups and sample sites which the similarity was measured at Bray Curtis without standardize and with transform square root showed a less relative separation of shallow depth stations (stations 10, 7, 6, 1, 2, and 3) and deep depth stations (stations 12, 11, 4, 9, and 8). The spatial pattern is indicative that stations located in each specific sampled northern coastline tend to cluster together, which also suggest the influence of surrogate abiotic water conditions

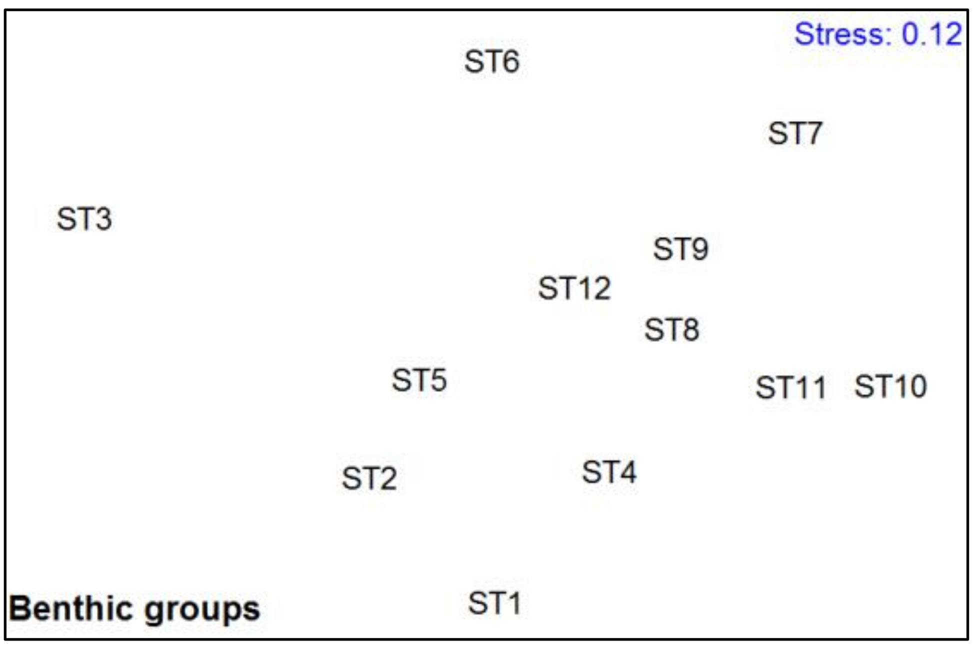

Fig. 11. MDS non-metric Multi-Dimensional Scaling analyses Similarity Matrix Data type: Similarities Sample selection: All.

Bardawil Lagoon is classified as flat shallow coastal water "Lagoon" where the neighbor area of the east Boughaz I in the middle of lagoon represents in the deeper zone. Fronts and edges of the lagoon represent the region characterized by shallow areas with low water depth due to the migration on the tides to raise water in the lagoon. The water resources of the lagoon are received from two main sources namely from the Boughaz I (in the eastern region) and Boughaz II (in the western region) in addition to rain waters in the winter season and agricultural drainage from newly reclaimed land in the north Sinai. Data analysis made during this statistical study indicated the water depth of the lagoon water area was the largest 36% (0.5 to one meter), 26% (one to 1.5 meters), and 11.5% (2 to 2.5 meters). This influence is more clearly in areas near the Boughazes. As noted the influence in the depths of the lagoon from region to region. The lagoon is characterized as having depth does not exceed 3 meters and the degree of transparency of water is high in most areas of study, and some areas are characterized by high fertility degree due to the relative increase of the degree of pollution and with limited impact on the presence of some benthic species. Given the low depth of the water in the lagoon and higher evaporation rate which is leading to rising in salinity in some areas where salinity it about 60‰ and the lowest level of salinity in some areas is estimated at 38‰. On the other side, some physic-chemical parameters are affected by the increase in nitrogen concentrations of mineral salts and generally on the benthic flora and fauna in particular fisheries. For seasonal variation in temperature in a clear factor is not considered aquatic distribution in terms of qualitative difference to the number of dominant species and numerical density and quantity and seasonally in the study areas of the lagoon for its location in the moderate tropical region.

It is well known the water temperature of the most important factors affecting the whole aquatic environment in-water surveys of fish, phytoplankton, zooplankton, aquatic plants, and benthic faunas in addition to its impacts on all physic-chemical properties. In Bardawil lagoon the water is characteristic by a narrow variation between the low temperature in winter (24^{o}C) and a high degree in the summer period reaching 30^{o}C. Reflect the degree of transparency of the water over the ability of light to penetrate the water column, making transparency an important factor affecting the dynamic processes within aquatic surveys, the degree of transparency of lagoon water in most months of the year faulty distribution transformers to the bottom of the lagoon which makes it water more transparency.

Bardawil water feature with high salinity of seawater due to increased evaporation process with few waves action and the increase the distances and low depths of shallowness and subjected to constant evaporation waters leading to a significant increase to about 60‰ and less salty areas near outlet to enter the waters of the sea where up to about 40‰. The concentration of pH ion is the most important factor affecting the aquatic environment where participate in all dynamic processes within aquatic surveys focus also it has an important role in precipitation or melting metals in-water surveys. The results showed the lagoon located in the alkaline side where the average concentration values ranged between 8.02-8.42. Dissolved oxygen in water has a larger role and affecting all the chemical and physical characteristics and vitality within aquatic surveys as one of the main reasons for the survival of all living organisms as without it will die. The mean concentration of dissolved oxygen ranged from low 4.39 mg/l and the highest of value 6.34 mg/l.

It is clear from the nature of sediments that the occurrences of mud (silt and clay) represented the highest percentage of about 98% in the addition to the percentage of organic matter in sediment was varied from 6.6% to 0.2% and averaged of 2%. Reflecting that lagoon exposed to the entrance of freshwater or drainage water from newly reclaimed land in the north Sinai and increase fish farms particularly in the southern region of the lagoon. From a public health point of view with the result especially when applying international mentioned of water quality found that at all stations located within the limits of preparation and bacteria Interior valid are referred to this time of year according to Egyptian Ministry of Health, 1996 which are not contaminated except at st11 (elNaser).

The results indicate an average annual stocking 1968 ind/m^2 density is in terms of numerical density and the number of species is relatively small compared with previous studies of the Lagoon during the successive monitoring yearly studies from 2010 to 2017 (El-Komi, 2017). Numerical density estimated the highest density of stations numbers 2, 5, 6, 8 and 9 with annual average respectively 2310, 4284, 2310, 2073 and 2121 ind/m^2 and the corresponding percentage 10.7%, 19.8%, 10.7%, 9.6%, and 9.8% of average annual stocking 1968 ind/m^2 and lower density estimated at other stations where the annual average numerical density ranged between 525 to1827 ind/m^2 and a percentage between 2.4%-8.4% of average annual stocking. And also for the number of species varied number of 7-9 species at the station numbers 4-7 and less diverse with the rest of the stations where the number of species ranged between 3-6 species, on the other hand, the results indicated that there is a clear variation between numerical density during the average numerical density semesters during summer and winter 2016 and 2017 estimated respectively 1786 and 2150 ind/m^2. The statistical analysis shows the quantitative and qualitative appreciation of the numerical density of benthic species living macro lack a certain Style explains the degree of increase or decrease in numerical density during sampling periods. And the presence of high numerical density from the previous year as is evident with the previous report on monthly changes to numerical benthic density.

Previous studies conducted in the Lake during the years 1979 and a, b 1992-1993 and 2001-2002 and 1997 and 2004 and previous studies during the first year of the project 2009-2010 and during the second year 2011-2012 and 2012-2013 (El-Komi, 2014) and prior year 2014-2015 (El-Komi, 2015), the current study for the 8th year 2016-2017 (El-Komi, 2017a) reflect some changes in the qualitative diversity of benthic and numerical density of equal distribution between species and between study areas due to different environments, depending on the type and physical and chemical properties of aqueous than direct and indirect impact on the qualitative composition of benthic.

The abiotic environmental effects in the Bardawil Lagoon are general to those generally observed in other areas influenced by organic wastes, namely, changed in the Physic-chemical properties of the sediments and low oxygen concentrations in the bottom water due to decomposition of organic materials. According to Pearson and Rosenberg, (1978) the effects are most pronounced in the vicinity of the outlets and decreased progressively with increasing the distance from the discharged points. As mentioned in many lectures, Snelgrove (2001) indicated that abiotic variables such as temperature, salinity, oxygen concentration, light availability, and sediment composition mainly have

been historically ascribed the greatest direct influence over benthic organisms distributions. In the present work thee environmental variables in Bardawil Lagoon such as sediment structure, organic matter content, temperature, salinity, dissolved oxygen, nutrient concentrations, pH, turbidity, water transparency, and depth may be more correlated with abundance, density and diversity of macrobenthic assemblages but some of these variables may vary seasonally (Nicolaidou *et al.*, 1988; Arvanitidis *et al.*, 1999; Hagberg and Tunberg , 2000; Mistri *et al.*, 2000).
On the other side, another factor as natural and anthropogenic may be disturbance and influence on the disruption of the system‘s stability in an enclosed environment in lagoons and reflecting the variable of the benthic organisms distributions. Raffaelli and Hawkins (1996) mentioned that the anthropogenic stresses are superimposed on stresses caused by natural environmental factors. Generally, marine biodiversity changes may be directly resulted by habitat structure, pollution, exploitation, or indirectly through climate change and related bio-geochemistry changes. Stress can be any factor that negatively affects the physiology, growth, reproduction, and survival of an organism or that has consequences affecting populations or communities (Shiel, 2009). Stress at one level of organization (e.g. individual, population) may also have an impact on other levels, for example, causing alterations in community structure. However, it is sometimes difficult to detect the effects of anthropogenic stress at the level of individual organisms, and impacts are more often investigated at a population or community level (Crowe *et al.*, 2000). There is little doubt that anthropogenic disturbance has extensively altered the global environment, leading to a decrease in biodiversity.

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