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Invertebrate Assemblages Associated with Seaweeds at Different locations in the Red Sea, Egypt

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ABSTRACT

The epiphytic organisms play an important role in nutrient cycles and the diversity of the ecosystem in which they occur. The present study investigated the abundance and community structure of invertebrates associated with seaweeds in the Red Sea, Egypt. Six species of seaweeds; *Caulerpa racemosa, Sargassum cinereum, Cystoseira myrica, Halimeda tuna, Hormophysa cuneiformis* and *Digenia simplex* were collected from three different locations; Kalawy Bay, Mangrove area and the National Institute of Oceanography and Fisheries (NIOF) at Hurghada. The study was carried out in winter. The distribution of seaweed was different in the investigated locations. Twenty-six invertebrate species were identified from three locations. At the Mangrove area station, amphipods were the most abundant fauna associated with C. *myrica* and *H. cuneiformis*, while nematode was the most abundant group associated with *C. myrica, H. cuneiformis* and *S. cinereum* at Kalawy Bay. At NIOF station, the most abundant organisms on *C. racemosa* and *S. cinereum* were nematode species, while amphipods were the most abundant organisms on *C. myrica*. The diversity indices revealed that the highest value of species richness was recorded for *C. myrica* at the Mangrove station, while the highest species richness values for *Sargassum cinereum* were recorded at Kalawy Bay and NIOF stations. *D. simplex* and *S. cinereum* showed the highest similarity according to the abundances of associated epiphytic fauna.

INTRODUCTION

Macroalgae are essential as a living space and asset of nourishment for macrofauna **(Österling & Pihl, 2001; Salovius & Kraufvelin, 2004; Salovius *et al*., 2005).** Crustaceans, molluscs, and polychaetes are the major animal taxa associated with macrophytes **(Taylor & Cole, 1994)**, and information considering their spatial and temporal patterns of abundance is necessary to properly understand marine biological systems. The presence of vegetation permits a greater species diversity and an abundance of individuals than the un-vegetated habitats (**Sánchez-Moyano *et al*., 2007)** providing suitable microhabitats, nutritional resources, and protection from predators.

Lots of arguments have been specified for the perception of how the community structure of most benthic marine organisms is reliant on the physical structure given by living beings such as seagrasses by **Heck and Crowder (1991)**, mangroves by **Ellison *et al.* (1996),** reef-building corals by **Done *et al*. (1997)**, kelps by **Graham (2004)**, and clams by **Grabow- ski *et al*. (2005)**. Most habitat-forming species harbour diverse assemblages of associated organisms that profit by such refuges from predators or cruel physical conditions **(Bracken *et al*., 2007).** A few attempts have been made to detect the connection between geographical changes in algae composition and the patterns of macroinvertebrate diversity and abundance **(Russo, 1997; Pereira *et al*., 2006).**

The current study was conducted to investigate the abundance and community structures of invertebrates associated with the marine seaweeds at three locations in the Red Sea, Egypt, comparing the obtained data of the six dominant seaweed species of the studied locations.

MATERIALS AND METHODS

Study locations: Three sampling locations were selected for the study; Kalawy Bay, 50 km south Safaga, Mangrove area at 17 km south Safaga and the National Institute for Oceanography and Fisheries (NIOF), Hurghada branch. Six dominant species of seaweeds were collected from those locations to estimate the abundance and community structures of invertebrates associated with those seaweeds. The sampling was done in winter (2017). The seaweed species under examination were, namely; *Hormophysa cuneiformis, Cystoseira myrica, Halimeda tuna, Sargassum cinereum, Digenia simplex* and *Caulerpa racemosa.*

Description of collection's Locations: The first Location was Kalawy Bay located at 50 km south Safaga (26°31' 53.232 " N, 34° 03' 17.334" E) which is a sandy and little rocky beach. Activities there include diving and snorkeling. During the sampling period, three species of seaweed were recorded, namely, *H. uneiformis*, *C. myrica* and *S. cinereum.* The second was the Mangrove area located at 17 km south Safaga City (26° 37' 06.030" N, 34° 00' 26.808" E). It is distinguished by Mangrove trees (*Avicennia marina*) and the tidal zone reaching about 100 m width. A collection of three species of seaweeds (*C. myrica, H. cuneiformis* and *H. tuna*) was gathered from the second site. The third station was in front of NIOF located at the northern tip of the Red Sea, 5 km away from the center of Hurghada City (27° 17' 6.39" N, 33° 46' 28.93" E). NIOF location is characterized by a long patchy reef, representing the front edge of a wide and shallow reef which is flat with many depressions and lagoons. Four species of seaweeds *C. racemosa*, *S. cinereum, C. myrica* and *D. simplex* were found in that location.

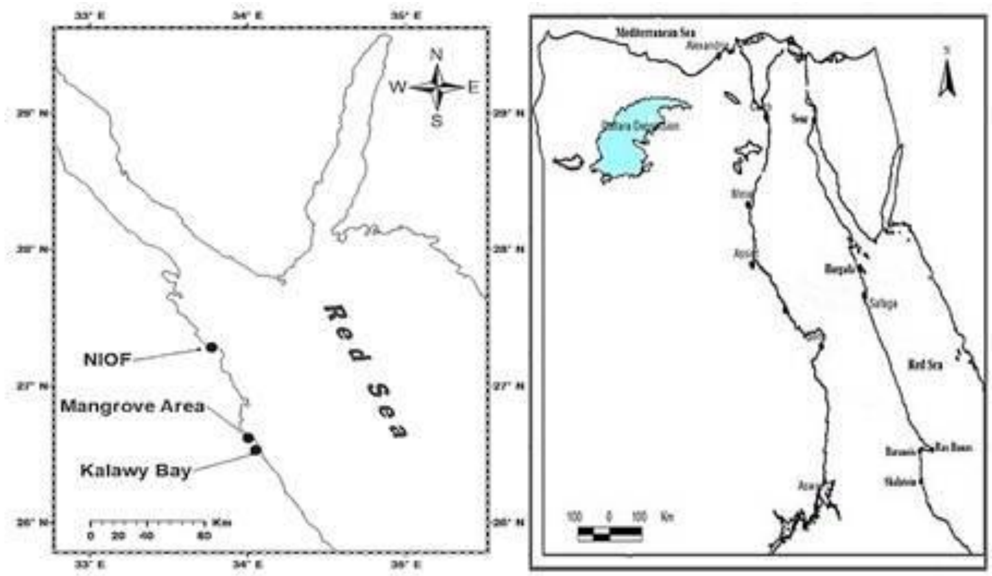

Fig. 1. A map showing the sampling locations; NIOF, Mangrove area and Kalawy Bay

Each of the fresh seaweed thallus was weighed and washed carefully with water in a plastic dish. The water was filtered with 55µ plankton net for each algae species. Fine forceps were used to pick macro invertebrates. The volume of filtered water was reduced to 100 ml and preserved with 5% formalin solution. Sorting and identification were performed using a dissecting microscope. Each zooplankter was counted separately using a binocular microscope (40X). The collected zooplankton species were identified according to the method of **Tregouboff and Rose (1957), Mori (1964), Gonzalez and Bowman (1965), Williamson (1967), Bradford-Grieve (1972a, 1994b), Newell and Newell (1977), Bradford-Grieve and Jillett (1980), Bradford *et al*. (1983), Michel *et al*. (1986),** and **Heron and Bradford-Grieve (1995).**

Physicochemical parameters of water were measured during sampling. Water temperature, pH, conductivity, dissolved oxygen (DO), salinity, turbidity and conductivity were all measured using "YSI multimetre", while pH was measured by using Jenway Ltd., Model 350-pH-metre. Surface water samples were collected for chemical analysis. Chemical parameters measured include ammonia (NH_4), nitrate (NO_3), nitrite (NO_2), phosphate (PO_4) and silicate (SiO_2). All chemical analytical methods were carried out according to **APHA. (2005).**

Data Analysis

Range, mean and standard deviation of data were estimated using Microsoft Office Excel (2019). Diversity indices, which includes Shannon–Wiener diversity index and species richness, were used to estimate the species diversity across the study locations (equation 1):

$$H = -\sum_{i=1}^{s} Pi\ LnPi$$

Where pi = The total number of species; LnPi = The natural logarithm of this proportion, according to **Shannon (1948).**

The similarity of the invertebrate community, that was found attached to the studied seaweed species, was estimated using the Bray-Curtis similarity metric index, applied after log10(x+1) transformation of the data to reduce the influence of the few high abundant taxa. To explore the effect of the physicochemical parameters on the invertebrate species, the canonical correspondence analysis (CCA) was used.

RESULTS

Table 1 shows summarized data of the physicochemical parameters at the three investigated locations.

Table 1. Mean, standard deviation (SD) and range (minimum and maximum) of the water physicochemical parameters at the three studied locations at the Red Sea.

Parameters	Locations	Mean	SD	Minimum	Maximum
Temperature	Mangrove	17.59	0.01	17.58	17.60
	Kalawy Bay	20.51	0.01	20.50	20.52
	NIOF	20.93	0.06	20.90	21.00
pH	Mangrove	7.82	0.05	7.76	7.86
	Kalawy Bay	8.29	0.04	8.25	8.32
	NIOF	8.40	0.02	8.38	8.42
Conductivity	Mangrove	62.11	0.01	62.10	62.12
	Kalawy Bay	62.81	0.01	62.80	62.82
	NIOF	62.71	0.01	62.70	62.72
TDS	Mangrove	40.36	0.01	40.36	40.37
	Kalawy Bay	40.82	0.01	40.81	40.82
	NIOF	40.85	0.01	40.84	40.86
Sal.	Mangrove	41.81	0.01	41.80	41.82
	Kalawy Bay	42.38	0.01	42.37	42.39
	NIOF	42.61	0.01	42.60	42.62

Turb	Mangrove	7.94	0.74	7.24	8.71
	Kalawy Bay	7.25	0.07	7.17	7.30
	NIOF	8.30	0.85	7.32	8.86
DO	Mangrove	7.20	0.10	7.10	7.30
	Kalawy Bay	6.67	0.15	6.50	6.80
	NIOF	7.30	0.10	7.20	7.40
	Total	7.06	0.31	6.50	7.40
NH_4	Mangrove	0.54	0.24	0.32	0.80
	Kalawy Bay	0.83	0.18	0.65	1.01
	NIOF	0.52	0.19	0.37	0.73
NO_3	Mangrove	0.17	0.21	0.04	0.41
	Kalawy Bay	0.04	0.01	0.04	0.05
	NIOF	0.04	0.02	0.03	0.06
NO_2	Mangrove	0.02	0.01	0.02	0.03
	Kalawy Bay	0.03	0.01	0.02	0.03
	NIOF	0.03	0.01	0.02	0.03
PO_4	Mangrove	3.44	0.61	3.00	4.14
	Kalawy Bay	3.31	0.66	2.76	4.04
	NIOF	2.85	0.15	2.71	3.00
SiO_2	Mangrove	3.57	0.66	3.11	4.33
	Kalawy Bay	4.46	0.49	4.00	4.98
	NIOF	5.39	0.14	5.23	5.49

***(TDS)** Total Dissolved Salts, (Sal) Salinity, (Turb) Turbidity

Invertebrates Community Composition

A total of 26 invertebrate species were collected from three locations at the Red Sea namely; *Caulerpa racemosa, Sargassum cinereum, Cystoseira myrica*, *Halimeda tuna*, *Hormophysa cuneiformis,* and *Digenia simplex.* At NIOF station, 18 invertebrate species were recorded, while both Kalawy bay and Mangrove area recorded 17 species. Amphipods larvae were the most abundant organisms at the Mangrove area, which were associated with *C. myrica* and *H. cuneiformis*, comprising 34% and 25%, respectively, of the total species encountered, while the most abundant species on *H. tuna* was nematodes, *which* amounted to 38% as shown in Table (2). The most abundant species on

C. myrica, H. cuneiformis and *S. cinereum* at Kalawy Bay area was nematode, which amounted to 39%, 26%, and 27%, respectively, of the total encountered species (Table 3). At NIOF area, nematode was the most abundant species on *C. racemosa* and *S. cinereum,* which comprised 31% and 14% of the total encountered species. Moreover, the most abundant species on *C. myrica* and *D. simplex* were amphipod larvae and *Cypridina* species, which comprised 42% and 23%, respectively (Table 5). Invertebrate assemblage similarity was high within the seaweed species; *D. simplex* and *S. cinereum* (> 75%) came from a pool of 26 invertebrate taxa (Fig. 2).

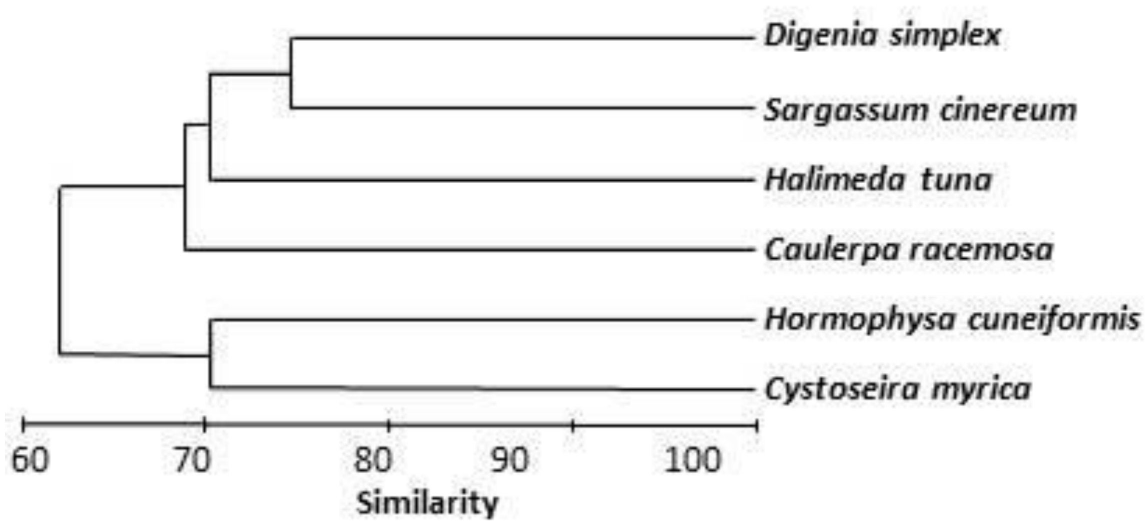

Fig. 2. Dendrogram of seaweed species clusters identified from the Bray-Curtis similarity matrix.

The invertebrate species that contributed most to similarity within clusters were; *Acrocalanus* sp, and *Stenosemella ventricosa* (100%) within all other invertebrate groups (Fig. 2).

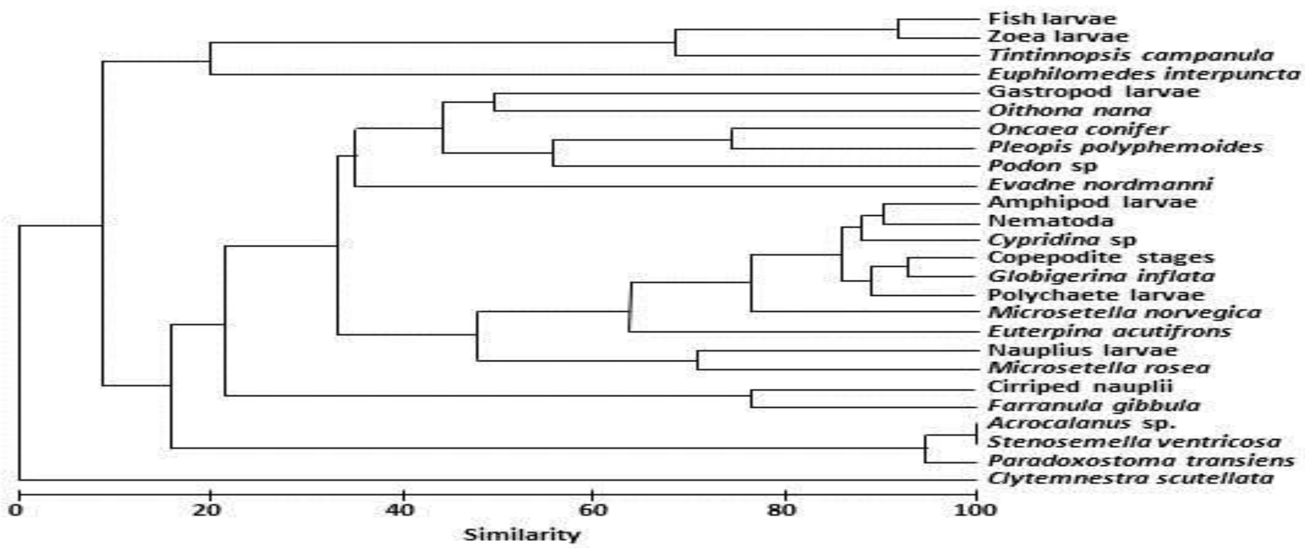

Fig. 3. Dendrogram of invertebrate species clusters identified from the Bray-Curtis similarity matrix of log10 (x11) transformed invertebrate abundance data, using unweighted pair group average sorting.

Table 2. Density, (Indv. /g: individual per gram) and relative abundance (RA) of the recorded invertebrate attached to *Cystoseira myrica*, *Hormophysa cuneiformis* and *Halimeda tuna* at the Mangrove area.

Seaweed species		*C.myrica*	RA	*H.cuneiformis*	RA	*H.tuna*	RA
Invertebrate Taxa		**Indv. / g**	**%**	**Indv. / g**	**%**	**Indv. / g**	**%**
1	*Stenosemella ventricosa*	42	1.75	0	0.00	0	0.00
2	*Globigerina inflata*	63	2.62	74	8.52	61	10.63
3	*Nematoda* sp.	167	6.96	88	10.13	217	37.80
4	*Pleopis polyphemoides*	63	2.62	44	5.06	0	0.00
5	*Podon* sp.	0	0.00	15	1.73	0	0.00
6	*Evadne nordmanni*	0	0.00	44	5.06	0	0.00
7	*Acrocalanus* sp.	42	1.75	0	0.00	0	0.00
8	*Paradox ostomatransiens*	63	2.62	0	0.00	0	0.00
9	*Oithona nana*	63	2.62	29	3.34	17	2.96
10	*Oncaea conifer*	0	0.00	29	3.34	0	0.00
11	*Euterpina acutifrons*	63	2.62	59	6.79	0	0.00
12	*Microsetella norvegica*	375	15.62	0	0.00	61	10.63
13	Copepodite stages	167	6.96	74	8.52	35	6.10
14	*Cypridina* sp.	354	14.74	103	11.85	87	15.16
15	Amphipod larvae	813	33.86	221	25.43	61	10.63
16	Polychaeta larvae	63	2.62	74	8.52	35	6.10
17	Gastropod larvae	63	2.62	15	1.73	0	0.00

Table 3. The mean density of the recorded invertebrate attached to *Hormophysa uneiformis*, *Cystoseira myrica* and *Sargassum cinereum* at the Kalawy Bay area.

Seaweed species		*C.myrica*	RA	*H. uneiformis*	RA	*S.cinereum*	RA
NO.	**Invertebrate Taxa**	**Indv. /g**	**%**	**Indv. /g**	**%**	**Indv. /g**	**%**
1	*Tintinnopsis campanula*	29	3.98	0	0.00	0	0.00
2	*Globigerina inflata*	43	5.90	36	3.77	71	6.99
3	*Nematoda* sp.	286	39.23	250	26.18	271	26.67
4	*Pleopis polyphemoides*	0	0.00	24	2.51	0	0.00
5	*Podon* sp.	0	0.00	24	2.51	0	0.00
6	*Evadne nordmanni*	0	0.00	0	0.00	29	2.85
7	*Oncaea conifer*	0	0.00	24	2.51	0	0.00
8	*Euterpina acutifrons*	114	15.64	179	18.74	29	2.85
9	*Microsetella norvegica*	0	0.00	0	0.00	100	9.84
10	*Microsetella rosea*	0	0.00	0	0.00	43	4.23
11	Nauplius larvae	0	0.00	0	0.00	29	2.85
12	Copepodite stages	57	7.82	24	2.51	29	2.85
13	*Cypridina* sp.	71	9.74	167	17.49	243	23.92
14	*Euphilomedes interpuncta*	29	3.98	0	0.00	0	0.00
15	Amphipod larvae	71	9.74	179	18.74	86	8.46
16	Polychaetae larvae	0	0.00	48	5.03	86	8.46
17	Gastropod larvae	29	3.98	0	0.00	0	0.00

Table 4. The mean density of the recorded invertebrate attached to *Caulerpa racemosa*, *Sargassum cinereum*, *Cystoseira myrica* and *Digenia simplex* at the NIOF area.

Seaweed species		*C. myrica*	RA	*C. racemosa*	RA	*S. cinereum*	RA	*D. simplex*
NO.	**Invertebrate Taxa**	**Indv. /g**	**%**	**Indv. /g**	**%**	**Indv. /g**	**%**	**Indv. /g**
1	*Tintinnopsis campanula*	0	0.000	82	6.376	0	0.000	0
2	*Globigerina inflata*	52	5.014	96	7.465	31	4.324	94
3	*Nematoda* sp.	134	12.922	397	30.871	99	13.808	89
4	*Podon* sp.	45	4.339	0	0.000	0	0.000	20
5	*Oithona nana*	30	2.893	0	0.000	0	0.000	0
6	*Farranula gibbula*	15	1.446	0	0.000	15	2.092	0
7	*Euterpina acutifrons*	0	0.000	0	0.000	92	12.831	0
8	*Microsetella norvegica*	67	6.461	110	8.554	76	10.600	168
9	*Microsetella rosea*	0	0.000	82	6.376	61	8.508	54
10	Nauplius larvae	7	0.675	0	0.000	23	3.208	35
11	Copepodite stages	15	1.446	68	5.288	61	8.508	59
12	*Cypridina* sp.	0	0.000	178	13.841	61	8.508	198

13	Amphipod larvae	433	41.755	68	5.288	84	11.715	64
14	Polychaetae larvae	112	10.800	82	6.376	53	7.392	35
15	Gastropod larvae	0	0.000	0	0.000	0	0.000	40
16	Zoea larvae	0	0.000	82	6.376	0	0.000	0
17	Cirripede nauplii	127	12.247	0	0.000	61	8.508	0
18	Fish larvae	0	0.000	41	3.188	0	0.000	0

Richness and Shannon-Wiener diversity of the recorded invertebrate taxa

The highest peak value of the taxa richness was recorded in *C. myrica* at the Mangrove area (14 taxa), while 11 taxa and 12 taxa were recorded in *S. cinereum* at Kalawy Bay and NIOF areas, respectively. Shannon-Wiener's diversity index ranged between 1.67 in *H. tuna* to 2.94 in *H. cuneiformis* at the Mangrove area. At Kalawy Bay, Shannon-Wiener's diversity index ranged between 2.03 and 2.35 in *C. myrica* and *S. cinereum*, respectively. Additionally, at NIOF area, the Shannon-Wiener's diversity index ranged between 1.76 and 2.42 in *D. simplex* and *S. cinereum*, respectively. Taxa richness and the Shannon-Wiener diversity index (H') of the recorded invertebrate are presented in Fig. 4.

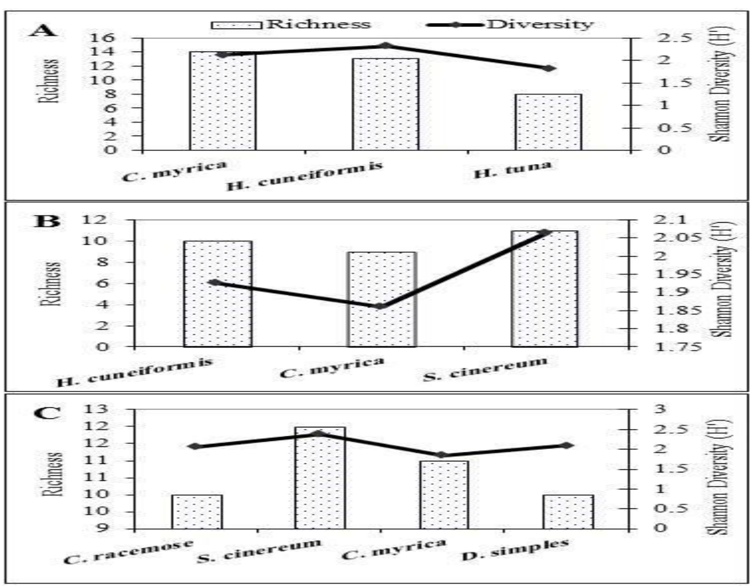

Fig. 4. Richness and Shannon-Wiener diversity Index (H') of recorded invertebrate at the three studied locations. A: Mangrove Area.B: Kalawy Bay Area C: NIOF area.

Effect of physicochemical parameters on invertebrate abundance

The results of canonical correspondence analysis (CCA) revealed that an abundance of the collected invertebrate groups was mostly related to the physicochemical parameters (Fig. 5). Water temperature, pH, TDS, conductivity, salinity and SiO_2 had positive effect on the abundance of the annelids and protozoan, and negative effect on the amphipods and ostracods. PO_4 and NO_3 had a positive effect on amphipods and Ostracoda, Mollusca, and Copepoda. DO and turbidity had positive effect on the abundance of Platyhelminthes, while they had a negative effect on the cladocerans, molluscans and copepods groups. NH_4 had a positive effect only on Cladocerans.

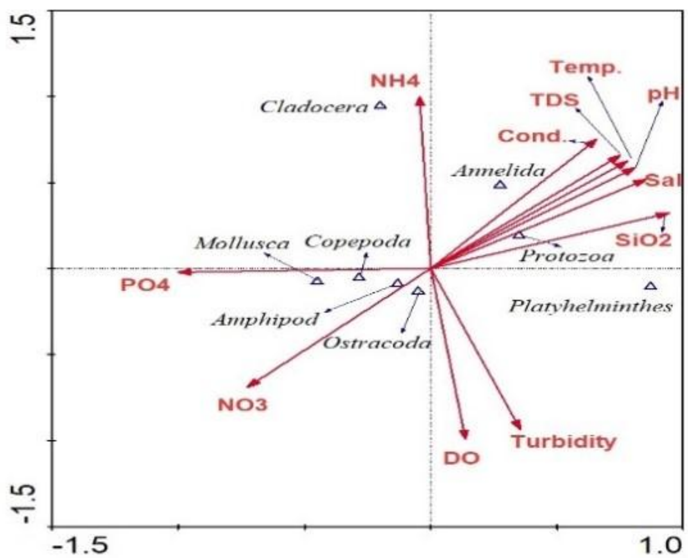

Fig. 5. The canonical correspondence analysis (CCA) results on physicochemical parameters and invertebrate group abundances in study sites. Physicochemical parameters notation: Temp= water temperature, Cond= Conductivity, Sal=Salinity, Turb= Turbidity, DO=Dissolved Oxygen, NH_4= Ammonia, NO_3= Nitrate, NO_2=Nitrite, PO_4= Phosphate and SIO_2= Silicate.

DISCUSSION

An epiphyte is a living being that develops on the outside of a plant and gets its moisture and supplements from the air, rain, water (in marine environments) or from debris conforming to it **(Hickey & King, 2001)**. Epiphytes are different living beings including animals, fungi, bacteria, and myxomycetes with a rich and various living space **(Sydney *et al*., 2009)**. Settlement of epiphytic species is affected by certain components including light, temperature, currents, nutrients, and trophic interactions. Algae are viewed as the most well-known substrates gathering epiphytes in marine biological systems **(Larkum *et al*., 2006).**

The present study was carried out in the winter season, water temperature ranged from 17.59 – 20.93°C. As a result, there was a similar influence of the environmental factors, which were represented by the physicochemical parameters, on the abundance and distribution of the recorded invertebrates. **Dai *et al*. (2014)** reported that some invertebrate species, preferring cold water, could not be detected in the collected assemblages. Moreover, they did not vary among different sampling locations, thus indicating the non-significant differences of environmental factors. Consequently, the effect of the physicochemical parameters on the abundance of the invertebrate taxa group had almost the same influence in all studied locations. **Lemieux and Cusson (2014)** stated that habitat-forming species diversity profiles had a limited short-term function in their study habitat, and this indicated that biological forcing in these intertidal communities is less vital than environmental conditions.

There are other factors that may influence the differences in number of individuals per algal unit. **Lippert *et al.* (2001)** stated that biotic and abiotic factors can affect the invertebrates to attach on different species of macroalgae and these factors may be different for either sessile or mobile fauna. **Hayward (1980)** reported that the structural qualities of algae like size, surface or thallus structure may be considered as an important biotic factor. Previous studies of **Whorff *et al*. (1995)** and **Kelaher (2000)** illustrated that the diversity and abundance of macrofauna frequently vary among patches of algal turf on rocky intertidal shores.

Tavares *et al.* (2013) stated that the main reasons affecting the selection of marine macrophytes by meso-herbivores are not clear, and may incorporate the nutritional nature of algae, the estimation of the living space as shelter, and the accessibility of algae in the environment. The present investigation revealed that there was a distinct relationship between the abundance of invertebrate species and the species of seaweed. **Taylor and Cole (1994)** reported that differences in the morphology of the plants should be considered for most of the variation in epifaunal densities among the investigated algal species.

The present study revealed that the amphipod larvae were the most abundant invertebrates at the Mangrove area. **Klumpp *et al*. (1992)** revealed that the impacts of amphipods and other meso-herbivores on macrophytes are the base elements of these environments supporting the cycling of nutrients. **Wakabara *et al*. (1996)** stated that the density of amphipod predators is higher in the colder months, which would expand the predation stress on the amphipods.

The highest peak value for the taxa richness (14) was recorded in the seaweed species *Cystoseira myrica* at the Mangrove area. **Bouillon *et al*. (2000**) reported that mangrove forests are highly productive tropical ecosystems. **Able (2005)** stated that mangrove forests have an essential role in marine fisheries, such as feeding ground, nursery ground, and spawning ground for different kinds of aquatic biota. This result may conclude that the richness of the taxa is affected only by the difference in seaweed species habitat in this case. **Bates (2007)** manipulates experiments over 2 years to determine the implications of varied combinations of seaweed species richness, functional richness, and species and functional composition on the structure of associated mobile epifaunal assemblages. The aforementioned author reported that invertebrates' epifaunal richness and abundance are not influenced by differences in the biodiversity of seaweeds. **Lemieux and Cusson (2014)** did not notice a remarkable change in habitat-forming species richness, evenness, abundance, or identity of associated species community.

CONCLUSION

The present study focused on the invertebrates associated with some of the dominant macroalgae species at three locations along the Red Sea, Egypt. The study of diversity revealed that the highest value for species richness was recorded for *C. myrica* at the Mangrove area, while the highest values for *Sargassum cinereum* were recorded at Kalawy Bay and NIOF areas. The study was conducted merely in the season of winter; hence, results might have shown slight differences between both species and locations.

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