Biodiversity in Relation To Water Quality at Different Sites along the Red Sea Coast of Jeddah, KSA

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Abstract: The present investigation aims to study the abundance and distribution of some flora and fauna, from intertidal and shallow subtidal waters in four different sites along the Red Sea coast of Jeddah, KSA Thirty one species were collected during this study. Mean values of density and relative abundance for the collected species were tabulated. The data declared that site 1 is characterized by a noticeable higher total number of individuals with high values of species richness and Shannon diversity in comparison to other sites. *Sargassum* sp. shows the highest percentages of all collected species in site 1 while *Balanus* sp. is the highest of fauna. In site 4 which is the more polluted site, *Mytilus galloprovincialia* is the more dominant species, this may indicate that this species could be considered as a bioindicator for pollution and other human activities.
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1. Introduction

The Red Sea is blessed with natural beauty and outstanding biological diversity. Coral reefs, mangrove forests, sea grass beds, salt marshes are distributed throughout the region. These unique habitats support a diverse range of marine life. Coral reefs are mainly distributed along the northern and central coasts and decrease in abundance towards the southern region as the water becomes more turbid. The most extensive areas of coral reefs are found along the Saudi coast, with over 194 recorded coral species. While mangrove forests are scattered along much of the Red Sea coast, the main concentration is in the southern region, due to the soft bottomed substrate. Eleven species of sea grass are widespread in the Red Sea, but are most common in the lagoons and embayment of the southern region (UNEP, 1997; PERSGA, 1998, 2000).

Although, The Red Sea region has remained relatively free of pollution, the environment is currently under increasing threat from a wide range of human activities (Garay-Narváez *et al.,* 2013). Also, in contrast to other regional seas around the world where most pollution comes from land-based activities, marine-based activities such as shipping and oil exploitation are becoming a significant source of marine pollution in the Red Sea. Industrial effluents, in the form of thermal pollution from power and desalination plants, hypersaline brine water from desalination plants, particulate matter and mineral dust from fertilizer and cement factories, and chemicals, and organic wastes from food processing factories have contributed to the degradation of water quality in the Red Sea ((NPA, 2003).

Natural habitats, such as coral reefs, mangroves and sea grass beds, have been physically altered and destroyed through dredging and land filling operations associated with urban expansion, industrial development and tourism, especially in Saudi Arabia, Egypt and Yemen (Wilkinson, 2008).

In the 1970's, the Arab League Educational, Cultural and Scientific Organization (ALECSO) brought together the countries bordering the Red Sea and Gulf of Aden to discuss shared marine environmental issues. The outcome of these meetings culminated in the signing of an international agreement in 1982, the Jeddah Convention, and formally entitled the "Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment". This agreement focuses on the prevention, reduction and fight against pollution, and is significant because it provides the first regional legal framework for cooperation in marine issues between the member countries. Subsequently, an official intergovernmental organization known as the "Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA)" was established in 1995 as an implementation body of the Jeddah Convention and is dedicated to the conservation of the coastal and marine environment. Since then PERSGA has prepared a Strategic Action Plan (SAP) for the Red Sea and Gulf of Aden, which was implemented as a major new environmental initiative in 1998 through cooperation from the Global Environment Facility and other international organizations.

Marine waters in general and coastal areas in particular suffer globally from stressing events. These events can be largely attributed to higher levels of human-induced eutrophication, contamination by pollutant, and siltation (Desrosiers *et al.,* 2013). The features that make the Red Sea so valuable ecologically and economically are also leading to its demise through the demands of oil exploration shipping and tourism. The resulting loss of biodiversity and marine pollution is not affecting the quality of the red sea itself, but also the well-being of people in the seven nations who claim it shores. The increase of our interest in environment care, make it be worthy to mention that diversity of flora and fauna are also of great help from this aspect, because some of them can be used as indicator of environmental health.

Recently, there has been an increasing interest in using biological indicators such as plants for monitoring soil, air and water pollution (Pyatt, 1999; Peng *et al.,* 2008 ; Bonanno and Giudice, 2010 ; Ruiz and Velasco, 2010, Al-Yemni *et al.,* 2011 and Eid *et al.,* 2012). Some aquatic plants such as *Eichhornia crassipes* (C. Mart.) Solms, *Phragmites australis* (Cav.) Trin. ex Steud., *Potamogeton pectinatus* L. and *Typha domingensis* (Pers.) Poir. ex Steud. have been used to indicate, monitor and purify water pollution (Wolverton and McDonald, 1978; Peng *et al.,* 2008 ; Bonanno and Giudice, 2010; Abdel-Ghani *et al.,* 2009; Eid *et al.,* 2010, 2012a&b).

On the other hand, many fauna are used as pollution bioindicators. For example, Dunbar *et al*. (2003) reported that Lyla and Ajmal Khan (1996) used the estuarine hermit crab, *Clibanarius longitarsus* (De Hann) as an indicator of changes in heavy metals (iron and manganese) in the Vellar estuary, India. Benthic invertebrates are used frequently as bioindicators of marine monitoring, because they respond relatively rapidly to stress (Pearson and Rosenberg, 1978; Dauer, 1993; Borja *et al*., 2000 and Sharma *et al*., 2010). Cheraghi *et al*. (2013), illustrated that bivalves considered as good biomonitor agents for heavy metal monitoring in aquatic ecosystems (Elfwing & Tedengreen, 2002; Yap *et al*., 2003; Zelika *et al*., 2003; Nicholson *et al*., 2005; Zorita *et al*., 2006; Vlahogianni *et al*., 2007; Maanan, 2008).

The coastal regions present a wide variety of habitats, including: muddy, sandy, boulder and rocky shores and mangrove forests. These types of habitats provide a variety of ecological niches for the biodiversity. Therefore, the present work aims to study the biodiversity of Jeddah sector of the Red Sea in terms of flora and fauna marine species composition inhabitant intertidal and shallow subtidal waters in four different sites.

2.Material and Methods

Sites of collections:

The present research was carried out in the city of Jeddah which is located on the west coast of the Kingdom of Saudi Arabia (latitude 21°32′36″N & longitude 39°10′22″E), in the middle of the eastern shore of the Red Sea south of the Tropic of Cancer. Four sites were be established along the Red Sea shore at Jeddah region to study the biodiversity in relation to water quality (Fig. 1).

Site 1:

This site located for about 25 km south to Jeddah Islamic Port. The area is located under the influence of organic and inorganic pollution of the port because of the main direction of the sea current from the north to the south. The area is flat plateau of fine sand extends for about 50 meters towards the sea, followed by a rocky reef with a very gentle sloop with small swamps forming the intertidal zoon. On the sandy shore a young and healthy mangrove trees about one meter tall (*Avicennia marina*).

Site 2:

This site is close to Jeddah Islamic Port (about 5 km far from the port). It is located on the eastern side of a semiclosed lake at the end of Palestine st. The islands in front of this station forming a barrier between the main land and the main water current from the north. Because of that, the surface water moves around the southern part of these islands to inter the lake from the south carrying some of the wastes of the port. Thus the water in this station have a dirty green color which reflect the heavy load of organic matter. Therefore, this site is suffering from pollution because of its location closed to Jeddah Islamic port.

Site 3:

This site is far to the north from the port. Most probably this area is a clean and clear, it is facing the open sea, receiving fresh waves and water all the time. The shore is forming of coarse sand, gravels of different sizes and blocks of cement for protection of shore from wave action. Behind the shore line there are several inland lakes of different sizes.

Site 4:

This site is called Sharm Abhor and is located north of Jeddah. This site is suffering from a lot of human activities such as shipping, digging turbidity and land filling …… etc. Filed observation declared bleaching of corals which indicate that this site is the most polluted site.

Sampling:

Random quantitative samples (meter square) were collected from different localities of each study sites (Fig. 1). Each site was divided into five definite localities. Macro flora and fauna were located visually, counted and some specimens collected by hand for identification. During the sampling water pH, conductivity and total dissolved salts (TDS) were measured. The collected specimens were preserved in 10% sea water formalin and kept in glass bottles. until they were examined for identification purposes. Water samples were taken for water quality parameters analysis.

In laboratory, specimens were examined under a binocular microscope. Several published papers and keys were used to identify the collected species. Some water quality parameters were measured with the unit of mg/liter: concentrations of Cd, Se, As, Ag, Zn, Cu, Ca, Mg and K.

Species richness of the collected communities were calculated. Shannon wiener diversity index (H\`) was calculated to show the biodiversity within the collected communities by using shannon-wiener equation H\`= -∑*pi* (ln*pi*), where ***pi*** is the proportion of individuals belonging to the i^{th} species. Analysis of Variance on SPSS software package (version 17) (SYSTAT statistical program) was used to test the present data. The program Canoco for windows 4.5 was used for canonical corresponded analysis (CCA) as a unimodal method to analyze the response of the benthic community composition to environmental variables.

3.Results and Discussion

In the present study, several variables have been estimated in the four different sites. Such variables include water analysis factors and biological variables that include the flora and macro fauna (Plant, algae, birds, fish and macro-invertebrate) and community structure of the study sites. Regarding the evaluated ecological factors, the collected data show considerable variation in water quality parameters (Table 1). Site 2 and site 4 show a slightly higher pH that may indicate that flora and fauna inhabiting these sites should be able to tolerate the alkaline environment. The conductivity is relatively high in sites 1, 3 while total dissolved salts was higher in sites 1 & 2. Regarding the concentration of studied metals site 3 shows the highest concentration for Cd, Se, As, Ag, Zn, Cu and Mg but the concentrations of Ca and K in this site were the lowest values.

These variations between study sites may be due to pollution and human impact since these sites suffer from anthropogenic impact. Groga *et al*. (2012) concluded that the high conductivity observed during their study cannot be explained by the granite type rocky substratum (Leblond, 1984) and must, therefore, be attributed to inputs linked to human activities, such as untreated waste water (Helena, *et al.*, 2000). Garay-Narváez *et al*. (2013), mentioned that Human activities may produce serious disturbances to ecosystems on earth, including habitat destruction and fragmentation, climate change, overexploitation of natural resources, invasion of exotic species and pollution. These disturbances threaten natural communities, driving the loss of species and their interactions (Primack, 2008). They illustrated that research on the effects that species richness and interactions have on the stability of ecological communities is of increasing interest (McCann, 2007, Bascompte, 2009). However, the functional consequences of these losses are still debated and not well understood (Stouffer and Bascompte, 2011, McCann, 2012, Rooney and McCann, 2012).

Thirty one species were collected during this study. Mean values of density (Indv/m^2) and relative abundance (%) for the collected species at the investigated sites are shown in Table (2). It is clear that site 1 is characterized by a noticeable higher total number of individuals representing different flora and fauna groups in comparison to other sites. Different flora and fauna groups collected from the four studied sites show different densities. In site 1 *Sargassum sp.* show the highest percentages of all collected species while *Balanus* sp. is the highest fauna. The situation is completely different for other sites. They are characterized by the dominance of filament algae. In case of fauna species, *Narita* spp. is the dominate species in site 3 while *Mytilus galloprovincialia* is the dominate species in site 4. It could be concluded that the high dominate density of *M. galloprovincialia* at the most polluted site (site 4) may indicate that this species could be considered as a bioindictor for pollution and other human activities. The same conclusion was also reported by Sureda *et al.* (2012).

Figure (2) summarize the collected species richness and Shannon diversity at the studied sites. It shows differences among sites in these variables. In case of total collected species and flora species, site1 shows the high values of species richness and Shannon diversity. Whereas in case of fauna species site 3 have the high values of species richness and Shannon diversity. These differences of the community structure between the four study sites could be explained by the varied habitats of the four sites. It seems that the biodiversity of study sites communities were enhanced as pollutant stress. Garay-Narváez *et al.* (2013), found that the positive effect of complexity on stability of community was enhanced as pollutant stress increased. Additionally they showed that the number of basal species and the maximum trophic level shape the complexity stability relationship in polluted systems, and that in degree of consumers determines species extinction in polluted environments. Their study indicates that the form of biodiversity and the complexity of interaction networks are essential to understand the effects of pollution and other ecosystem threats.

The results of canonical correspondence analysis (CCA) ordination was performed on the recorded flora and fauna species and the corresponding studied environmental variables (water characters) for the collected samples from the four studied sites. Diagram of canonical correspondence analyses of flora species are shown in Figure (3). The results of CCA reveal that the flora species mostly related to water TDS, conductivity and pH followed by Mg, As, Ca, Zn and K concentrations. The rest of metal concentrations have relatively small effects in flora. Diagram of canonical correspondence analyses of fauna species are shown in Figure (4). The results of CCA reveal that the fauna composition mostly related to metal concentrations of water. While TDS, conductivity and pH has relatively small effects on fauna. The impact of metals on the aquatic biodiversity was confirmed as important factors regulatory the community structure by Zyadah *et al.* (2004).

Table 1: Mean ± SD values of some water quality parameters for the study sites and statistical results.

Quality parameters	**Site 1**			**Site 2**			**Site 3**			**Site 4**			**F**	**P value**
pH	7.73	±	0.03	8.02	±	0.015	7.94	±	0.06	8.15	±	0.035	63.47	<0.001
Conductivity (ms)	159.9	±	1.75	157.4	±	2	158.1	±	0.35	154.4	±	1.5	6.62	0.015
TDS (mg/l)	96.2	±	1.6	94.4	±	1.45	92.2	±	1.2	92.8	±	0.35	6.13	0.018
Cd (mg/l)	0			0			0.001	±	0.0006	0			16.00	0.001
Se (mg/l)	0.001	±	0	0			0.008	±	0.0015	0.001	±	0	58.29	<0.001
As (mg/l)	0.002	±	0.0006	0.011	±	0.005	0.019	±	0.003	0.004	±	0.002	21.47	<0.001
Ag (mg/l)	0			0			0.381	±	0.01	0.01	±	0	4217.84	<0.001
Zn (mg/l)	0			0			0.063	±	0.003	0.03	±	0	1726.32	<0.001
Cu (mg/l)	0			0			0.382	±	0.007	0			8418.69	<0.001
Ca (mg/l)	300.4	±	20.65	266.7	±	12.53	221.7	±	17.32	311	±	7.015	20.79	<0.001
Mg (mg/l)	424.1	±	44.09	342.1	±	18.68	490.4	±	14.67	521.4	±	11.14	28.74	<0.001
K (mg/l)	629.6	±	43.59	648.7	±	8.83	383.7	±	12.17	549.5	±	27.25	60.94	<0.001

Table 2: Mean values of density (Indv/m^2) and relative abundance (%) for the collected species at investigated sites.

Species	**Site 1**		**Site 2**		**Site 3**		**Site 4**	
	Indv/m^2	**%**	**Indv/m^2**	**%**	**Indv/m^2**	**%**	**Indv/m^2**	**%**
Avicennia marina	2	0.49	0	0	0	0	0	0
Rhizophora mucronata	1	0.24	0	0	0	0	0	0
Asparagopsis sp.	25	6.08	0	0	0	0	0	0
Padina pavonia	45	10.95	0	0	0	0	40	4.25
Sargassum sp.	240	58.39	0	0	0	0	0	0
Turbinaria sp.	30	7.30	0	0	0	0	0	0
Ulva sp.	0	0	450	41.78	0	0	0	0
Filament algae	0	0	500	46.43	400	91.12	450	47.82
Posidonia sp.	0	0	0	0	0	0	400	42.51
Egretta gularis	2	0.49	0	0	0	0	3	0.32
Ardea purpurea	1	0.24	0	0	0	0	0	0
Himantopus himantopus	1	0.24	2	0.19	0	0	0	0
Columba livia	2	0.49	1	0.09	0	0	0	0
Larus modestus	3	0.73	0	0	0	0	0	0
Himantopus himantopus	15	3.65	15	1.39	0	0	0	0
Egretta gularis	3	0.73	2	0.19	0	0	0	0
Atticus kirkii magnusi	0	0	0	0	5	1.14	0	0
Fungia sp.	0	0	0	0	2	0.46	0	0
Stylophora pistillata	0	0	0	0	2	0.46	0	0
Platyhelminthes	0	0	0	0	2	0.46	0	0
Balanus sp.	17	4.14	102	9.47	0	0.00	0	0
Grapsus albolineatus	0	0	0	0	2	0.46	0	0
Mytilus galloprovincialia	12	2.92	0	0	0	0	27	2.87
Narita spp.	10	2.43	5	0.46	10	2.28	21	2.23
Conus sp.	2	0.49	0	0	0	0	0	0
Morula granulate	0	0	0	0	2	0.46	0	0
Patella sp.	0	0	0	0	7	1.59	0	0
Vermatidae species	0	0	0	0	1	0.23	0	0
Ophiocoma scolopendrina	0	0	0	0	3	0.68	0	0
Holothuriacuriosa curiosa	0	0	0	0	2	0.46	0	0
Heterocentrotus mammillatus	0	0	0	0	1	0.23	0	0

Fig. 1: A map showing sites of collection. Satellite image showing the selected sites along the Red Sea shore at Jeddah region.

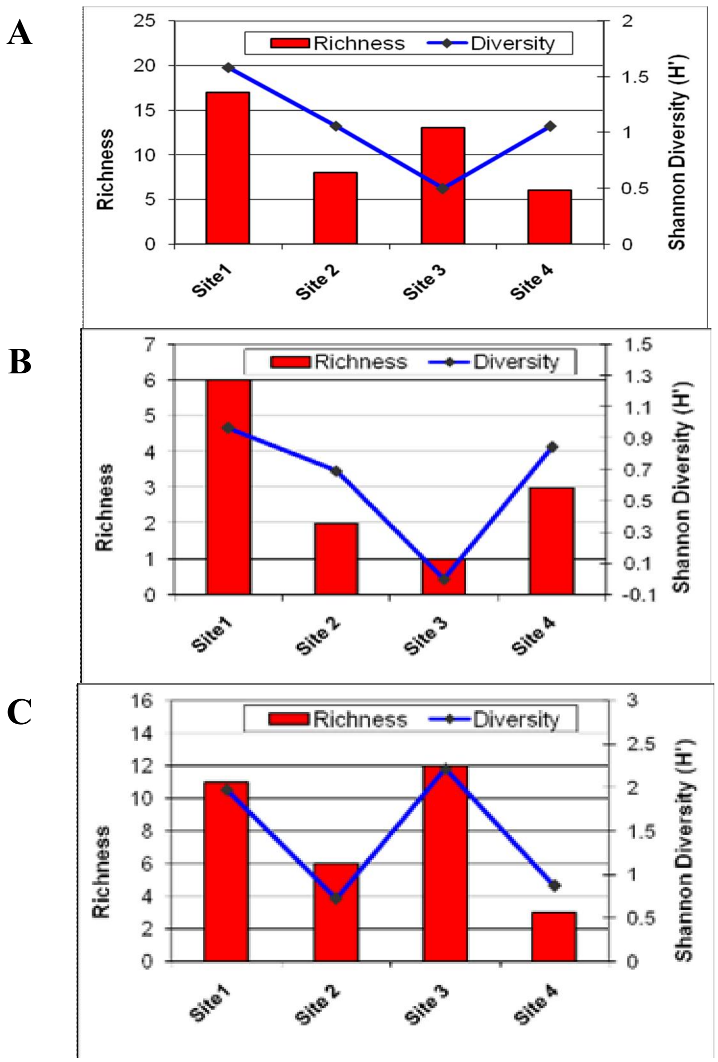

Fig. 2: Species richness (S) and Shannon-Wiener's index of general diversity (H) of (A) all collected samples, (B) plant samples and (C) animal samples.

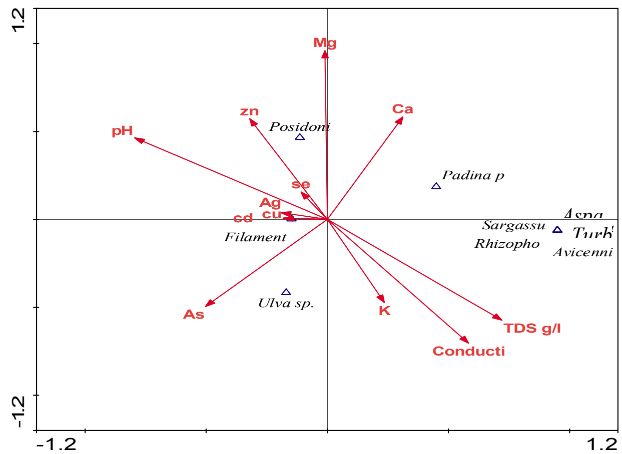

Fig. 3: Ordination diagrams of canonical correspondence analyses (CCA) of flora abundance data (9 species) and corresponding water quality parameters sampled form study sites.

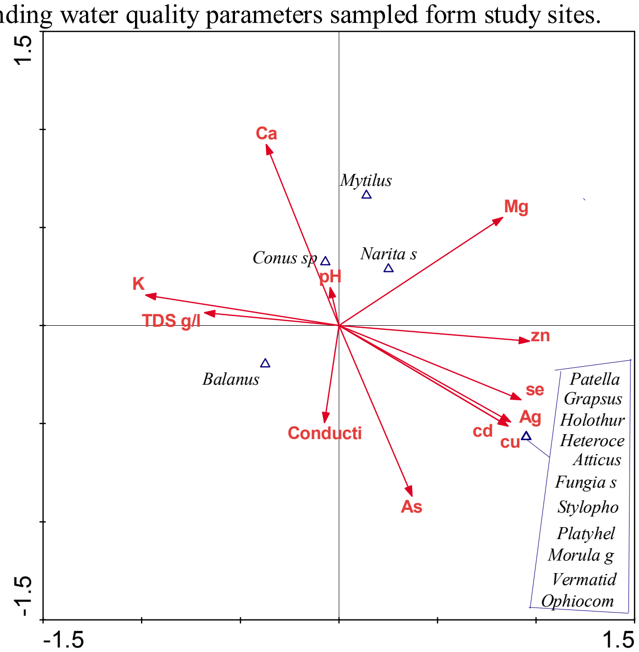

Fig. 4: Ordination diagrams of canonical correspondence analyses (CCA) of fauna abundance data (15 species) and corresponding water quality parameters sampled form study sites.

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