IMPACT OF WATER QUALITY ON MACROFAUNA ABUNDANCE IN MANGROVE ECOSYSTEM OF GULF OF KACHCHH

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Abstract: Mangrove ecosystem of Gulf of Kachchh is unique for its semi-arid climate with extremely low rainfall, high variability in seasonal temperature and high rate of evaporation and high sediment and water salinity with tidal amplitude. Mangrove ecosystem serves and plays a vital role for the coastal fauna, such as birds and macroinvertebrates. It constitutes a complex ecosystem that offers opportunities for free living, climbing, burrowing organisms and plays a significant role for the increasing nutrient load in the soil and water by detritus matters. The present study deals with the investigation of birds and macrofauna abundance in mangroves with reference to the water quality in one of the important mangrove creeks at Jakhau. A total of 65 bird species, 27 macroinvertebrate species have been recorded responding to the water quality at Jakhau mangroves. The study has indicated that the water quality shows significant impact on the faunal abundance; several parameters like temperature, DO, PO_4, N are negatively correlated**,** while such elements as pH, SO_4, BOD, Ca, Mg are positively correlated with the faunal abundance and activities. The study reveals that macrofauna**,** like birds and benthic invertebrates**,** can be used as key indicators to know the status and quality of coastal ecosystems.

Keywords: Gulf of Kachchh, macrofauna, mangrove ecosystem, water quality

Introduction:

Mangrove areas are ecologically important coastal environments and act as a buffer zone between the marine and terrestrial ecosystems, characterized by high variation of physicochemical, morphological and hydrological conditions (Carter 1988; Ysebaert et al. 2002). Mangrove ecosystems have a considerable amount of organic compounds and hence are known as a biologically rich ecosystem with a variety of living organisms attracting other life forms for various purposes. The mangrove habitat plays a host role to a moderate number of bird species around the globe. Hundreds of bird species migrate to the mangrove forest for feeding, roosting, nesting and breeding (Florida Fish and Wildlife Commission 2003). The shallow waters and exposed mudflats of the mangroves make this habitat ideal for probing shoreline birds such as plovers and sandpipers. Long-legged wading birds utilize these as well as the deeper waters along mangrove-lined waterways.

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Herons, egrets, bitterns, spoonbills and ibises are among the wading birds that visit mangroves in search of food. Certain species of bird are dependent on the mangrove ecosystem in with regard to roosting, food, breeding etc.**,** and they also play a vital role in maintaining the mangrove ecosystem through several activities mainly those of pollinator, seed disperser, and pollution regulation providing food for other animal predators and also contributing to nutrient recycling processes. Not only are birds important for a mangrove**,** but the mangrove is also important for birds. They are completely reliant on their habitat for supplying rich food resources. The habitat type, size of the area, plant community structure and landscape pattern can have a great effect on the bird community structure (Wijesekara 1999). However few animals have been reported to feed on mangrove trees directly**,** whereas other parts of the mangrove, like dead leaves, stems and roots are progressively broken down into detritus because microbes are not active to decompose them. This detritus is consumed by a variety of invertebrate species (Day et al. 1975). The benthic animals are responsible for secondary productivity and they are very good pollution indicators. The fertility and healthiness of the mangrove ecosystem depends upon the primary productivity of birds and macrobenthos. The present paper is an attempt to correlate productivity, such as the physical and chemical property of water, and macrofauna abundance in one of the creek systems of Kachchh Gulf, Western India.

Materials and methods:

Study area

The present study has been carried out on the Jakhau coast, also known as the Jakhau creek system of Kachchh Gulf located between 23^{o} 13' N and 68^{o} 43' E of the extreme western border of Kachchh district on the coastline of the Arabian Sea (Fig. 1). It is one of the oldest ports on the Kachchh coast and well-known for very productive salt pans, dense mangrove forest, coastal bird diversity, and prawn and fishery industry. The district has a total mangrove cover of 23.76 sq. km, of which the Jakhau areas covered approximately 10 sq. km (MAGS 2009).

The shoreline of Jakhau which is covered by mangrove vegetation and extensive mudflats was selected for the study area. The bird point count and macroinvertebrate sampling were done within this area. The point count was observed using a straight line of 700 m and designing two points with a 300 m radius at both the ends of the line (Mojiol et al. 2008).

Water Sampling and analysis

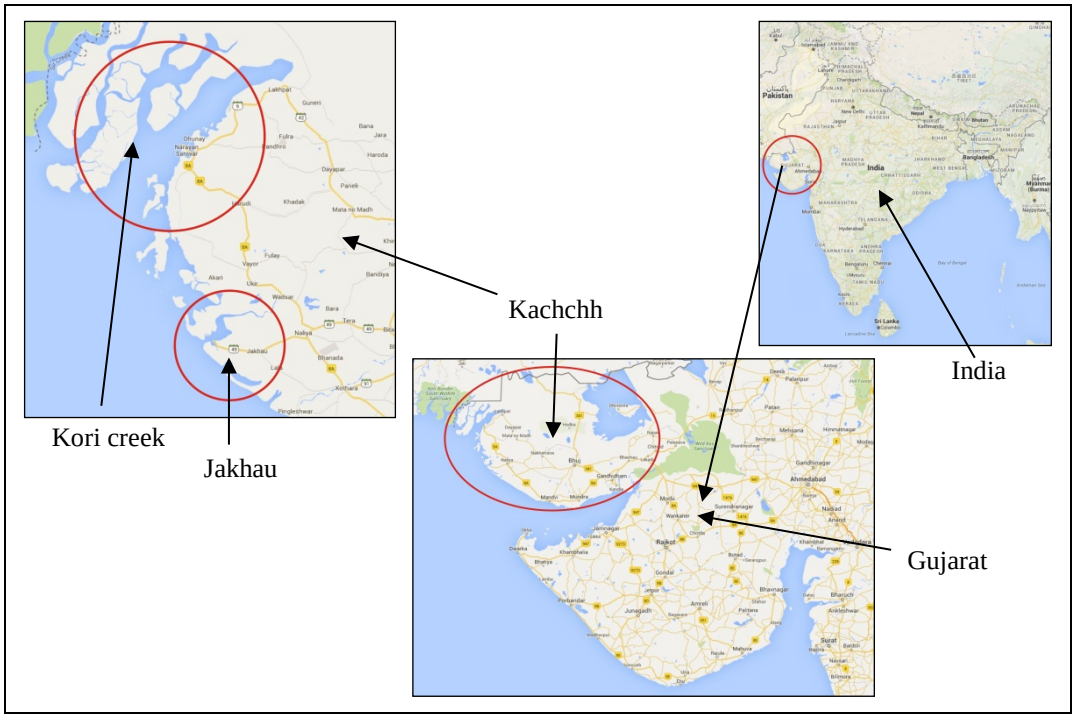
Water samples were collected systematically at each bird count point. Temperature and pH were measured on the spot by thermometer and pH strips respectively, where as DO was fixed using the Winkler method (Sajish 2012). 2 litres of water sample was collected for further laboratory analysis to estimate BOD, Ca, Mg, SO_4, PO_4 and N. All chemical analyses were carried out using standard methods as described in APHA et al. (2005).

Bird identification

Bird count was undertaken using the point count method (Mark and Martin 2011) during the migratory season (December to May, 2013) for this place is known as a feeding ground of migratory birds because it falls under the international migratory route (Ali 1945). Bird count points were selected as circular observation of 300 m radius at the start and the end point of a straight line of 700 m; a total of eight bird count points was carried out throughout the study site for bird observation, identification and count. Bird counts were done on each point from 8:00 to 13:00hrs and from 16:00 to 18:00hrs in a day during the study period. Birds were observed with a pair of binoculars and identified with the help of a standard book (Grimmette et al.

1999). Birds were further categorized by their residential and IUCN redlist status.

Figure no. 1 Map of study area



Source of images: https://www.google.co.in/maps/

Sampling and identification of macroinvertebrates

Sediment samples for macrobenthos were taken from the point count area using a core sampler - of 10 cm diameter and 10 cm depth - in order to collect the macroinvertebrate. The total three cores from 1 m interval were designed, so sediment samples were passed through 1 mm^2 mesh size sieves. The majority of the animals were identified on the site. However a few unidentified animals were placed in a wide-mouth plastic container and preserved in 10% formalin with Rose Bengal (Dye) to be carried to the laboratory for microscopic observation and identification by some reference key (Claudiu et al. 1979; Zabbey 2002; Idowu and Ugwumba 2005).

Data analysis

Bird and macroinvertebrate abundance were calculated using the formula:

$$\text{Density} = N / A$$

where:

N = total number of individual observed;

A = area surveyed.

The physico-chemical parameters were further correlated with bird and macroinvertebrate density to know the relationship among these.

The Pearson correlation analysis was undertaken using the statistical SPSS® software to verify if there was any significant relationship between biotic and abiotic components.

Results and discussion:

The water temperature remained between 22 °C and 30 °C and the pH ranged between 7 and 9. Table 1 shows the results of laboratory analysis of different water quality parameters such as DO, BOD, minerals and macronutrients.

Table no. 1 Water quality parameter ranges at the study area

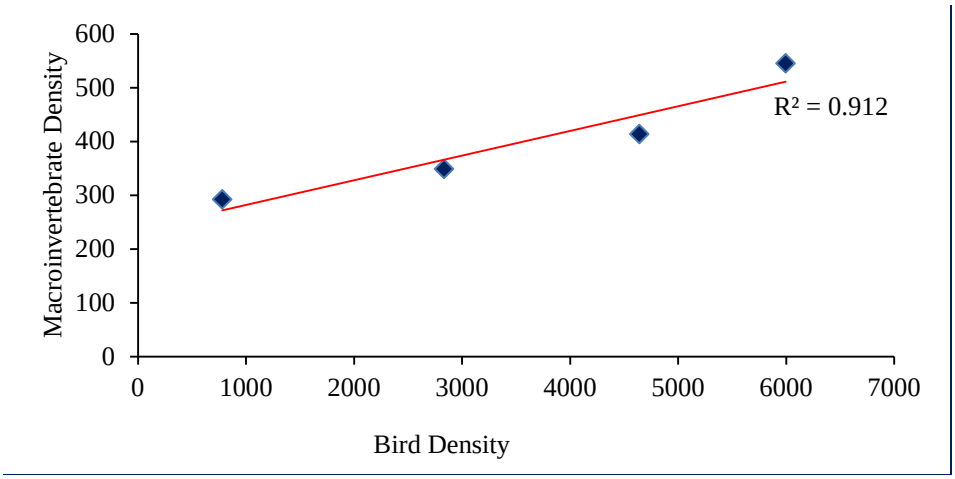
Water parameter	Ranges (mg/l)
DO	9 to 10
BOD	52 to 59
Ca	560 to 574
Mg	451 to 460
SO_4	728 to 734
PO_4	6 to 7
N	72 to 79

65 bird species belonging to 17 families representing 38 different genera were recorded during the study period, out of which, 49% were migratory, 34% were residential and 17% were resident migratory. Moreover, seven IUCN red listed species were also recorded, among them where six species which were near-threatened and one was recorded as vulnerable.

27 macroinvertebrate species belonging to five major groups, viz. polychaetes (30%), crustaceans (30%), gastropods (26%), bivalves (7%) and fishes (7%), were recorded during the study period.

With respect to the density of birds and macroinvertebrates, bird density ranges between 780 to 5995 birds per km^2 and the density of macroinvertebrate are ranges between 292 to 545 animals per m^3. The results show the strong significant positive correlation between the bird and macroinvertebrate densities (Fig. 2, Tab. 2).

Figure no. 2 Correlation between birds and macroinvertebrate density



Correlation between water nutrient, macrofauna abundance and temperature gives strong negative correlation, where as SO_4 and Ca gives strong positive correlation with the bird density occurred in the study site (Fig. 3, Tab. 2).

Benthic macroinvertebrate also gives strong negative correlation with temperature, DO and nitrogen and positive with SO_4 (Fig. 4, Tab. 2).

The correlation among bird and macroinvertebrate density and water physicochemical qualities show some significant relationships. Table 2 depicts a positive correlation between bird and macroinvertebrates; the water temperature is

negatively correlated with the bird and macroinvertebrate, while water hardness is positively correlated with bird and macroinvertebrate density.

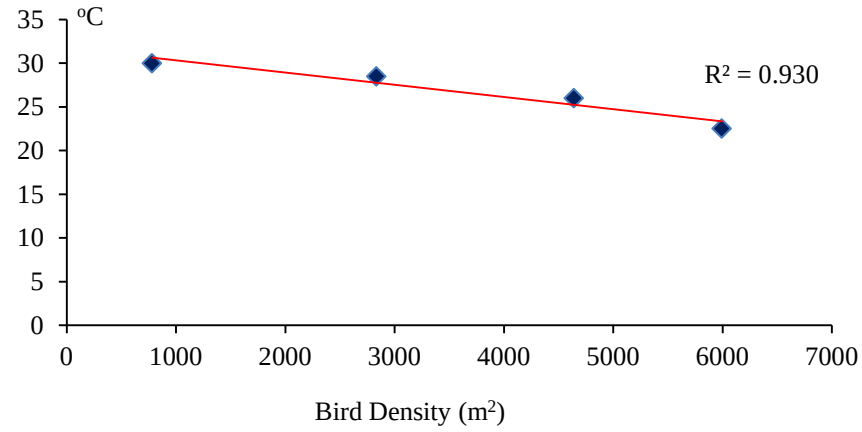
Table no. 2 Pearson correlation analysis of macrofauna and water quality

	Bird Density	Inv. Density	Temperature	pH	DO	BOD	Ca	Mg	SO_4	PO_4	N
Bird Density	1										
Inv. Density	.955*	1									
	.045										
Temp.	-.965*	-.997**	1								
	.035	.003									
pH	.497	.677	-.687	1							
	.503	.323	.313								
DO	-.755	-.908	.880	-.713	1						
	.245	.092	.120	.287							
BOD	.759	.678	-.730	.606	-.362	1					
	.241	.322	.270	.394	.638						
Ca	.975*	.991**	-.987*	.572	-.879	.651	1				
	.025	.009	.013	.428	.121	.349					
Mg	-.125	.148	-.087	.337	-.549	-.497	.096	1			
	.875	.852	.913	.663	.451	.503	.904				
SO_4	.998**	.938	-.951*	.478	-.715	.788	.960*	-.186	1		
	.002	.062	.049	.522	.285	.212	.040	.814			
PO_4	-.238	-.511	.466	-.685	.813	.075	-.439	-.903	-.182	1	
	.762	.489	.534	.315	.187	.925	.561	.097	.818		
N	-.666	-.848	.814	-.710	.992**	-.262	-.812	-.649	-.621	.878	1
	.334	.152	.186	.290	.008	.738	.188	.351	.379	.122	

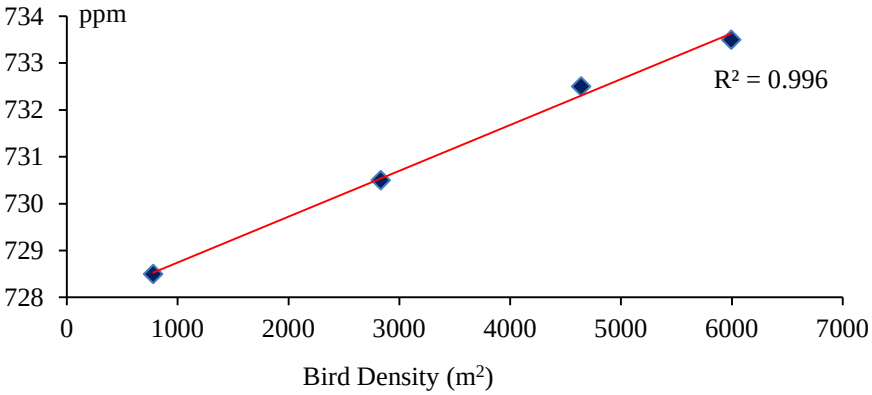
Note: *-significant at 0.05 level; **-significant at 0.01 level.

Figure no. 3 Correlation between bird density and physico-chemical parameters

a. Temperature



b. SO_4



c. Ca

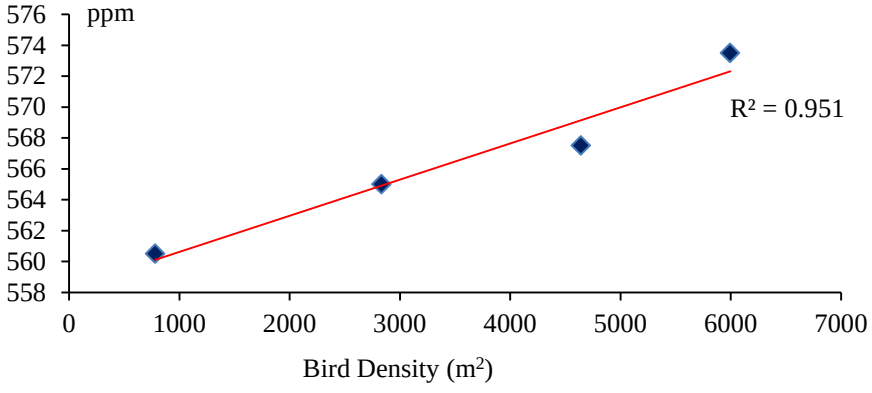
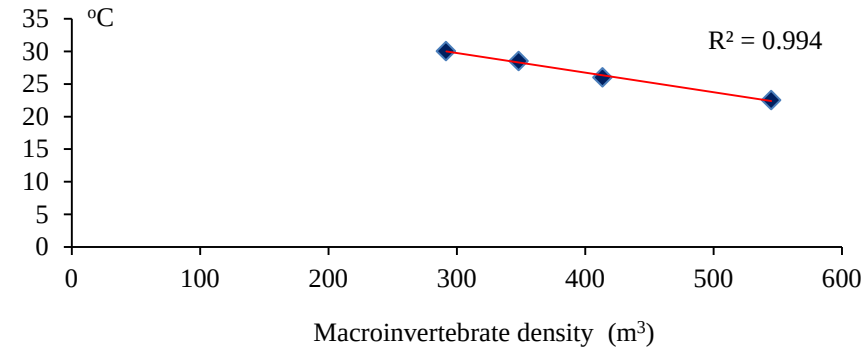
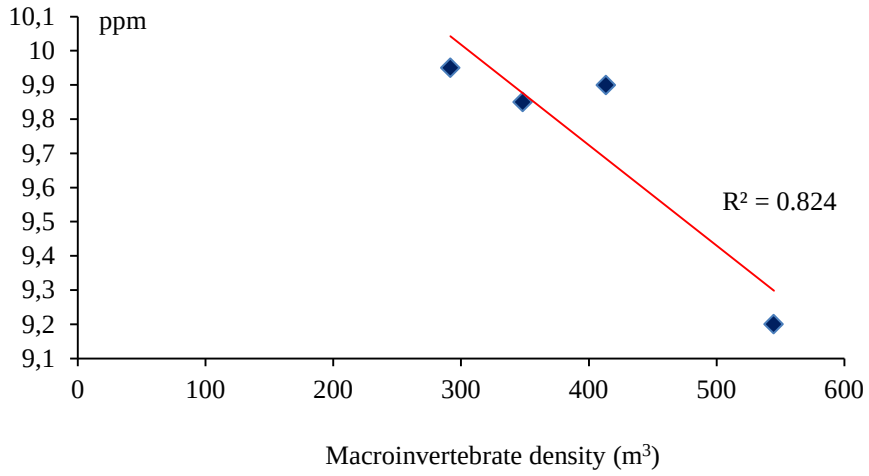


Figure no. 4 Correlation between macroinvertebrates and water quality

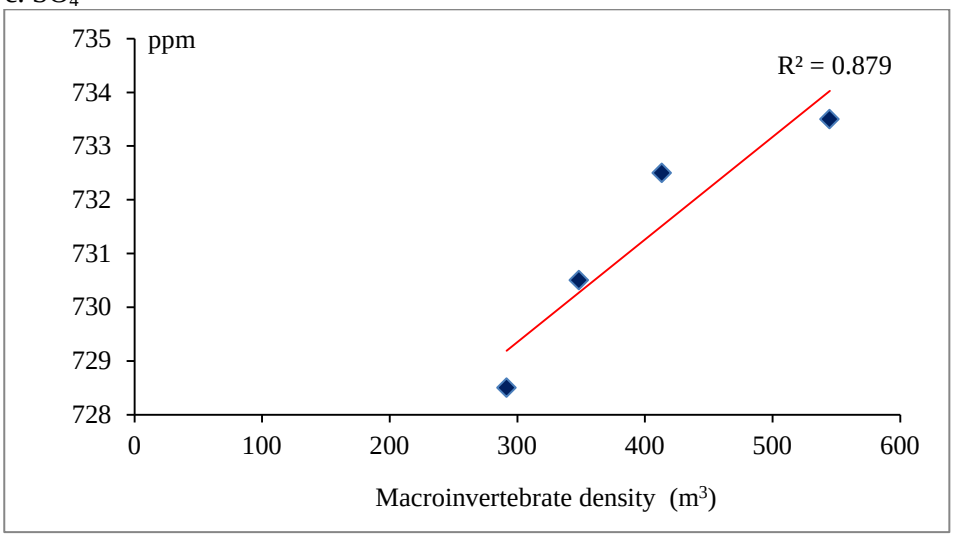
a. Temperature



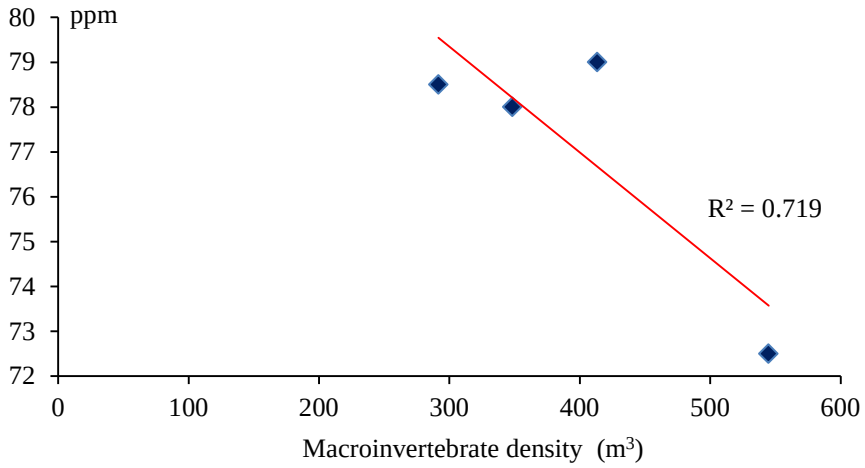
b. DO



c. SO_4



d. N



Conservation and restoration of mangroves, it seems, are a requirement for maintaining the faunal distribution associated with the mangrove habitat**.** This aspect is also helpful in protecting the coast against flooding and erosion. There are many mud-dweller faunal species inhabiting there which attract many predator species. Mudflats and mangroves play a significant role as nursery ground, roosting, nesting and feeding ground for a variety of fauna. 65 bird species and 27 species of benthic macroinvertebrates vary from other reports and research described as below. A total of 65 birds and 27 macroinvertebrate species were recorded in the mangrove creek system. Mangroves have often been supportive of abundant bird congregations during the migratory seasons; Zockler et al. (2005) found 62 bird species in the Indian Sunderbans. Out of 80 bird species recorded in the Gulf of Kachchh during the migratory season (Gadhvi 2011), 65 were recorded in Jakhau creek, the present study indicating the importance of mangroves for bird congregations. Similarly, 62 species of macroinvertebrates were recorded by Saravankumar et al. (2007) in the same region; however this study includes the macroinvertebrates only during the migratory season. The reduced number of species found in the study area could be the result of restricted methodology, season and limited sampling area (Cheal et al. 1993). The group of wader was more abundant than others; this is because of extensive mudflats and food availability in a predominantly mangrove habitat.

The correlation coefficient matrix (Pearson correlation) among bird density, invertebrate density and abiotic components of the mangrove ecosystem studied are presented in Table 1. The result revealed that some abiotic components conveyed a significant correlation with macrofauna population. Bird density has a positive significant relationship with the invertebrates' density, both components being somehow inter-related. The temperature showed a highly prominent role in regulating bird and invertebrate density. Water temperature is invaluable as it regulates various abiotic characteristics, the biotic activity of aquatic life forms and handles the functions of the aquatic ecosystem. Sajish (2012), McCombie (1953), Radhika et al. (2004) suggested that the variability in temperature plays a key role regarding variation in marine and estuarine ecosystems at all levels of the food chain from primary productivity to top level predators including fisheries. The results also revealed that macroinvertebrates were controlled by temperature, whenever the

temperature was low simultaneously the density of macroinvertebrates was high. The study also shows the inverse correlation between water temperature and dissolved oxygen which regulate the tactile activities of macroinvertebrates and indirectly regulate the density of birds feeding on such macroinvertebrates. The total hardness of water depends on the concentration of minerals like calcium and magnesium. The major contribution of hardness is usually due to the amount of calcium present in the water. This study highlights the significant positive correlation of the Ca concentration with macrofauna density. Both phosphate and sulphate are the micronutrients considered to be critical limiting nutrients, an over-amount of this nutrient being triggered by eutrophication and required by algae in small quantity (Rabalais 2002; Bandela et al. 1999). The influence of the phosphate and sulphate concentration is due to the concentration of fresh water mixed with seawater in the estuarine ecosystem. Significant relationships between physicochemical qualities, density of birds and macroinvertebrates are comprised in the findings of the present study. This is an indication of the ability of organisms to survive, adapt, migrate and die under favorable and unfavorable environmental conditions respectively. The similar role of water properties in regulating aquatic biodiversity was also reported by Tyokumbur et al. (2002).

Finally, the result indicated spatial and temporal variation in the occurrence, distribution and density, composition of macroinvertebrates and bird abundance with respect to water quality in a mangrove ecosystem. Saravankumar et al. (2007) reported that lower temperature and stability of environmental factors such as salinity leads to an increase of density and diversity of macrofauna in mangrove forest of Kachchh. Ravera (1999) and Ikomi et al. (2005) reported that macrobenthic invertebrates are useful bio-indicators providing more accurate understanding of changing aquatic conditions than chemical and microbiological data, which at least do provide short-term fluctuation. Odiete (1999) stated that the most popular biological method in the monitoring and assessment of aquatic ecosystem is the use of birds and macroinvertebrates.

Conclusions:

Macrofauna density plays a significant role to assess the water qualities. Apart from minerals and nutrients, water temperature and hardness also affect the macrofauna density. The density of macrofauna can be used for the monitoring and assessment of coastal change. The paper shows that long-term monitoring of coastal wetlands through this type of study may enhance the rapid assessment and management of coastal wetlands and their biodiversity.

Rezumat:

IMPACTUL CALITĂȚII APEI ASUPRA ABUNDENȚEI MACROFAUNEI ÎN ECOSISTEMUL DE MANGROVE DIN GOLFUL KACHCHH

Ecosistemul de mangrove din Golful Kachchh este unic pentru climatul său semiarid, cu precipitații extrem de scăzute, mari variații de temperatură sezonieră, o înaltă rată de evaporare, precum și o salinitate a apei dar și o cantitate mare de sedimente în directă legătură cu amploarea fluxului. Ecosistemul de mangrove joacă un rol vital pentru fauna de coastă, precum păsări și macronevertebrate. Constituie un ecosistem complex care oferă condiții de viață pentru numeroase organisme libere, cățărătoare sau de vizuină și contribuie semnificativ la creșterea cantității de nutrienți din sol și apă prin materiile aflate în descompunere. Acest studiu prezintă rezultatul cercetărilor privind abundența păsărilor și a macrofaunei din mangrove în strânsă legătură cu calitatea apei, într-unul din cele mai importante golfuri cu păduri de

mangrove de la Jakhau. Au fost semnalate un număr de 65 de specii de păsări și 26 de specii de macronevertebrate. Rezultatele obținute susțin impactul semnificativ al calității apei asupra abundenței faunei; unii parametri, precum temperatura, DO, PO_4 și N, influențează negativ, în timp ce pH-ul, SO_4, BOD, Ca, Mg au o corelație pozitivă cu activitățile și abundența faunei. Studiul dezvăluie faptul că macrofauna, precum păsări și nevertebrate bentice, poate fi utilizată drept indicator cheie pentru a afla statutul și calitatea ecosistemelor de coastă.

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