Brazilian Journal of Biology
ISSN 1519-6984 (Print)
ISSN 1678-4375 (Online)

https://doi.org/10.1590/1519-6984.234129
Original Article

Linking fish and crustacean taxonomic composition with seasonal contrasts in the soft-bottom intertidal zone

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Received: February 17, 2020 – Accepted: April 24, 2020
(With 3 figures)

Abstract

The primary objective of this study was to investigate the seasonal fish and crustacean variations concerning taxonomic composition, species richness, and diversity in sandy beach habitat. For this purpose, we investigated the Sonmiani Hor lagoon area during four distinct seasons, i.e., northeast (NE) monsoon, pre-monsoon, south-west (SW) monsoon, and post-monsoon for one year. During each haul, the net was pulled about 100m along the beach in 0.5m depth. The results showed a strong linear correlation between the diversity index and equitability in fishes (r = 0.978). The diversity index was strong negatively correlated with the abundance and biomass (r = -0.978, -0.972, respectively). The physical attributes like sea surface water temperature and salinity showed a strong negative effect on species assemblages (r = -0.981 and -0.943, respectively). The mean air and water temperature illustrated approximately 3°C difference during NE and pre-monsoon seasons. However, salinity, pH, and electrical conductivity did not show any significant seasonal variabilities. Under the ecological indices, the fish species displayed higher diversity (*H'* = 3.19) during SW monsoon, whereas the lowest diversity was observed during pre-monsoon (*H'* = 1.58). The equitability and species richness, however, remained more noticeable during SW monsoon (*J'* = 0.81). The total number of individuals of fish and crustaceans reached 4799 with 3813 fish individuals and 986 individuals of crustaceans. A total of 27 families of fish while five crustacean families comprising of 30 genera and 38 fish species while ten genera and 17 species of crustaceans were recorded. *Liza subviridis* displayed the highest abundance among the sampled fish species. In conclusion, fish species constituted a significant part of the coastal fauna in the study area. The seasonal variations displayed distinct variations in fish species composition and diversity.

Keywords: seasonal variations, soft bottom, intertidal zone, Sonmiani Bay, species diversity, Mangroves.

Ligação da composição taxonômica de peixes e crustáceos com contrastes sazonais na zona intertidal de fundo macio

Resumo

O objetivo principal deste estudo foi investigar as variações sazonais de peixes e crustáceos em relação à composição taxonômica, riqueza de espécies e diversidade no habitat de praias arenosas. Para esse fim, investigamos a área da lagoa Sonmiani Hor durante quatro estações distintas, ou seja, monção nordeste (NE), pré-monção, monção sudoeste (SW) e pós-monção, por um ano. Durante cada transporte, a rede foi puxada cerca de 100 m ao longo da praia, a 0,5 m de profundidade. Os resultados mostraram uma forte correlação linear entre o índice de diversidade e a equitabilidade de peixes (r = 0,978). O índice de diversidade apresentou forte correlação negativa com a abundância e a biomassa (r = -0,978 e -0,972, respectivamente). Os atributos físicos, como temperatura da água da superfície do mar e salinidade, apresentaram forte efeito negativo sobre o conjunto de espécies (r = -0,981 e -0,943, respectivamente). A temperatura média do ar e da água teve uma diferença de aproximadamente 3 °C durante a monção NE e a pré-monção. No entanto, salinidade, pH e condutividade elétrica não apresentaram variabilidade sazonal significativa. A respeito dos índices ecológicos, as espécies de peixes apresentaram maior diversidade (H' = 3,19) durante a monção SW, enquanto a menor diversidade observada foi na pré-monção (H' = 1,58). A equitabilidade e a riqueza de espécies, no entanto, permaneceram mais perceptíveis durante a monção SW (J' = 0,81). O número total de peixes e crustáceos foi de 4.799, com 3.813 peixes e 986 crustáceos. Foram registradas 27 famílias de peixes e 5 famílias de crustáceos, com 30 gêneros e 38 espécies de peixes, além de 10 gêneros e 17 espécies de crustáceos. Liza subviridis apresentou a maior abundância entre as espécies de peixes amostradas. Em conclusão, as espécies de peixes constituíram uma parte significativa da fauna costeira na área de estudo. As variações sazonais apresentaram variações distintas na composição e diversidade das espécies de peixes.

Palavras-chave: variações sazonais, fundo macio, zona entremarés, Baía de Sonmiani, diversidade de espécies, Manguezais.

1. Introduction

The patterns of the spatial distribution of fish and crustaceans along the sandy beaches often allude to the degree of disturbance as shallow bays and beaches are the coastal ecosystems most threatened by the anthropogenic activities and habitat changes (Omena et al., 2012; Equbal et al., 2018). The fish and crustacean ecology have been studied in the backdrop of sandy beaches on a global scale. The two main groups of coastal populations constitute a vital component of the sandy intertidal zones in tropical and temperate regions (Brown and McLachlan, 1991; Nicolaidou et al., 2006a; Hernández-Guevara et al., 2008). However, the fish species display relatively fewer variations with seasonal and temporal fluctuations (Kim et al., 2019; Saeed et al., 2020; Atique et al., 2020a; Khanom et al., 2020), particularly shallow intertidal zone fish communities. The crustaceans, such as crabs, are considered for research to reflect upon seasonal and temporal changes (Post et al., 2006; El Asri et al., 2018; Rahman et al., 2020). Most of the studies report benthic invertebrates, whereas sampled fish species are mostly those of commercial importance (Kouadio et al., 2008; Cuéllar-Mercado et al., 2019). Gibson et al. (1993) alluded to the community variations in the sandy beaches in Scotland linked with environmental changes that unfold the annual and seasonal distribution patterns in fish and macro crustacean populations.

The biodiversity and its distribution patterns are conspicuous in the tropical regions and manifested in the seasonal variations of the population and community structures of the intertidal organisms (Nicolaidou et al., 2006b; Equbal et al., 2018). Monsoon patterns equally influence the freshwater and marine biodiversity (Atique and An, 2018; Atique et al., 2019; Hara et al., 2020; Atique et al., 2020b; Haque et al., 2020). Tropical estuarine ecosystems are dependable indicators of environmental change (Dauvin, 2007); therefore, species composition and structure are the sensitive community features that modify in reaction to habitat level changes (Post et al., 2006; Lefrere et al., 2015; Atique and An, 2020). The higher the species diversity and abundance, the higher productivity and available feeding resources ensured (Day et al. 1989; Atique and An, 2019; Iqbal et al., 2017; Iqbal et al., 2020; Moon et al., 2020; Bae et al., 2020). For instance, the temporal variations in benthic macrofauna composition in response to seasonal variation in a tropical coastal lagoon of the Gulf of Mexico are reflected in the community compositions (Hernández-Guevara et al., 2008). Several studies have shown that the temporal community structure in shallow marine zones resulted in seasonal settling or progressive migration tendencies at the early life stages (Beukema, 1992; Bazaïri et al., 2003; Nicolaidou et al., 2006a; Chaouti and Bayed, 2008).

The species spawn in deeper salty waters and relocate as post-larvae or sub-adults in the depthless marginal zones throughout spring and summer seasons for warm temperatures and food availability (Edwards and Steele, 1968; Marchand, 1991). Amara and Paul (2003) published that some species evolve the ability to thrive in the intertidal zone during high tides. Hence, the intertidal species, as opposed to subtidal or shore (line) species, could be distinguished as the species effectively utilizing the intertidal territory for the fulfillment of all or a part of their life stages (Gibson, 1982). Equivalent reasons for prolonged exposure of these organisms to environmental stress (fluctuating salinity, extreme temperature events, and solar radiations) are the characteristics of temporal displacements (Berghahn, 2000). Though generally recognized, the movement of juveniles and other mobile organisms across the intertidal zone is meant for feeding and exploiting resources that could only be accessed when immersed. Blaber and Blaber (1980) proposed that irregular exploitation of the intertidal zone by fish and epibenthic organisms with occasional usage of the nearshore environment as an evasion from predation and extended food availability. Therefore, the intertidal zone, specifically the sandy habitats, are more preferred by juveniles for feeding and shelter. Selleslagh and Amara (2007) stated the seasonality in density, and composition of fish and epibenthic community in the intertidal zone primarily reflects diverse recruitment of distinctive species, further influenced by temperature, turbidity, and dissolved oxygen. A study was conducted to investigate the seasonal changes in the taxonomic composition of mobile fauna, either visiting or permanently inhabiting the shallow intertidal zone. Several studies have been conducted in the Sonmiani Hor (our study area) to investigate the abundance and biodiversity of the intertidal zone (Ahmed et al., 1982; Hassan, 1989; Ahmed and Abbas, 1999; Ayub and Miuzamimiil, 2001). However, these investigations lacked comprehensive research and showed random patterns while dealing only with commercially valuable shell and finfish species. Therefore, a comprehensive study of species diversity (fish and crustaceans) in the sandy habitats of Miani Hor was inevitable while recognizing its grander importance as a hub of commercial fishing nested in a large mangrove area. The leading aims of this investigation included the study of fish and crustacean species diversity, linking the species abundance with the hydrographic factors, taxonomic identification of fish and crustacean species, seasonal variations of hydrographic observations, application of species diversity indices, fish and crustaceans assemblage structure and estimation of biomass in Sonmiani Bay, Baluchistan, Pakistan.

2. Material and Methods

2.1. Study area

Pakistan falls in the subtropical zone, and its coastal regions undergo mixed semidiurnal tides. Therefore, a clear difference in tidal heights alternatively inundates the intertidal zone twice a day. Consequently, the intertidal zone receives abundant and nutrient-laden waters with equal chances of squandering the salubrious nutrients to the open waters. On the other hand, fine sediments get ensnared by mangrove trees that further stabilize the coastline, along with nutrients that support the endemic and visiting organisms in the intertidal zone.

The Miani Hor is a lagoon in Sonmiani Bay, situated approximately 90 km from Karachi Metropolitan on the easternmost coast of Baluchistan. The bay spreads on 60 km length and 7 km width with a tortuous and contorted body of water and is connected to the sea on the southeastern end by a 4 km wide mouth. It takes a western turn by a short distance from its mouth. It then runs parallel to the shoreline in the shape of an arc, with an endpoint in the same line as its mouth (Rasool et al., 2002). The Hor is fed by Sonmiani bay lying outside in the Arabian Sea. Two seasonal rivers enter the bay; the Porali River that drains through the Bela region and empties into the central part of the bay, and the Windor River that enters near the mouth. The total area of the bay is 125.5 km^2 and is characterized by the sandy beach, intertidal mudflats, and the muddy beach adjacent to mangrove forests (Figure 1). Based on the seasonal precipitation intensity and related factors, we divided the study area climate into four distinct seasons: northeastern (NE) monsoon, pre-monsoon, southwest (SW) monsoon, post-monsoon.

Damb is a small coastal town with an estimated population of 15,000 inhabitants, located along Miani Hor. Most of the inhabitants depend on the capture fisheries, either directly or indirectly. However, Damb is more famous for its trash fish and shrimp production. There is an informal fishing jetty that entertains all sorts of outboard fishing engines used in fishing boats. This part of the coastline is predominantly sandy with few patches of sandy cum muddy and sparse patches of black mangrove (*Avicennia marina*). The coastline area covered by Damb is approximately five km long.

2.2. Field sampling

We identified two sampling stations on the sandy beach along the coast of Miani Hor. All the sampling events were conducted by employing the seine net (10 m x 2.5 m and 0.5 cm mesh size) operated by two persons in the shallow surfing zone and covering 100 m of the beach in each haul. The sampling events were conducted on a seasonal basis (northeast monsoon, pre-monsoon, south-west monsoon, and post-monsoon) at each study station from January to December 2003.

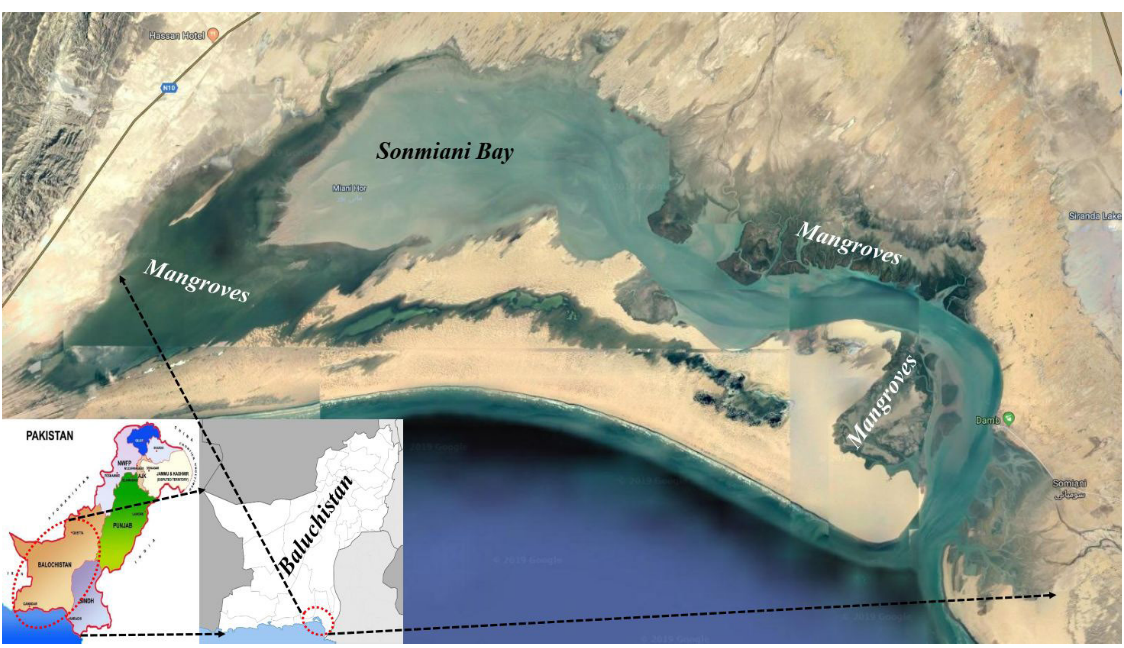

Figure 1. Coastline map showing Sonmiani bay (Miani Hor/lagoon).

2.3. Hydrographic observations

The hydrographic observations include water salinity, air temperature, water temperature, pH, and electrical conductivity (EC). We used a handheld refractometer (ATAGO-S-Mill, $0^{o}/_{oo}$- $100^{o}/_{oo}$; USA) for salinity measurement while air and water temperatures, pH, and EC were estimated by a handheld thermometer (HANNA instruments HI-8314) before each sampling event.

2.4. Taxonomic identification, diversity indices

For ex-situ taxonomic identification and classification, all sampled organisms were sorted into each faunal group, separately preserved in 5-10% formalin, and identified up to the species level. We sued the field guide by Bianchi (1985) to identify and classify the fish, shrimps, and crab species.

The estimates for percent occurrence and relative numerical abundance of each species were carried out before applying the Shannon-Weaver index (Shannon and Weaver, 1963) and the Margalef index (Margalef,, 1958) to calculate the diversity, similarity, and species richness.

The Shannon-Weaver index is expressed as Equation 1:

$$Hs = \sum Ni / N \; Log \; 2 \; Ni / N \quad (1)$$

Where:
Hs = Shannon-Weaver index
N = total number of individuals in the sample
Ni = the number of individuals of species in the sample

The Margalef index value is calculated for species richness by the following Equation 2:

$$D = S - 1 / Log \; iN \quad (2)$$

Where:
D = Margalef Value
S = Number of species collected
N = total number of individuals in the sample

2.5. Statistical analyses

For statistical analyses, we used the Pearson correlation to find out the links between the abiotic variables and biotic factors. Two-way ANOVA was used to analyze the effect of seasonal and faunal assemblage on various ecological attributes like diversity, equitability, species richness, abundance, and biomass of the population in specific time durations (season). We used the MS Minitab (ver.13.0) software and MS Excel to perform the statistical analyses and preparation of illustrations.

3. Results

3.1. Seasonal variations of hydrographic parameters

3.1.1. Air and water temperature

The mean air temperature (AT) and water temperature (WT) displayed roughly 3°C difference during NE and pre-monsoon seasons while no distinct differentiations between AT and WT during SW and post-monsoon months (Table 1). The lowest mean AT (18.18°C) was observed during NE monsoon, while the highest mean WT was (30.37±0.74) during the NW monsoon. The Sonmiani area endures an arid atmosphere that sustains less than 200 mm of annual precipitation. During summers, the mainland areas experience more than 35°C from May to August. However, the SW winds blowing from the northern Arabian Sea towards the Sonmiani decrease the impact of a raised temperature. The WT has a strong association with AT; therefore, the mean lowest temperature was recorded during NE monsoon (15.68°C). The post-monsoon and pre-monsoon registered the temperature range between 26°C - 28°C through this study duration.

3.1.2. Salinity

SW and post-monsoon seasonal salinity levels remained almost similar, while the highest mean salinity level was recorded during NE monsoon (39.53±1.43 ppt) followed by pre-monsoon (37.67±2.54 ppt) seasons (Table 1). The single highest salinity level was recorded as 42.5 ppt, and the lowest values remained as 33.5 ppt during pre-monsoon season. Salinity has a noticeable impact on the distribution of fish and crustacean assemblages in specific habitats. Therefore, the impact of salinity level and its fluctuations could help to determine the niche and habitats of aquatic organisms.

3.1.3. pH and Electrical Conductivity (EC)

The highest mean pH level was taped during pre-monsoon (7.5±0.41) and post-monsoon (7.5±0.18), while the overall highest value remained equal to 8.2 during pre-monsoon. However, in the case of EC, the highest mean value reached 74.55±3.39 mS/cm in pre-monsoon, while the lowest mean recorded as equal to 60.76±4.57 during the NE monsoon (Table 1). The mean pH level fluctuated between 7.4 to 7.5 during this study. However,

Table 1. Descriptive statistics of hydrographical observations of Sonmiani Bay (Miani Hor).

Season	N	Salinity (ppt)	AT (°C)	WT (°C)	pH	EC (mS/cm)
NE Monsoon	16	39.53±1.43	18.18±1.09	15.68±3.17	7.4±0.18	60.76±4.57
Range (Min-Max)		(36.5-42.5)	(17.0-20.5)	(13.0-22.0)	(7.2-7.8)	(55.40-75.1)
Pre Monsoon	12	37.67±2.54	31.79±2.02	28.37±0.98	7.5±0.41	74.55±3.39
Range (Min-Max)		(33.5-42.0)	(28.0-35.0)	(26.5-30.0)	(7.1-8.2)	(68.50-79.7)
SW Monsoon	8	36.87±0.58	30.50±1.43	30.37±0.74	7.4±0.08	68.37±2.99
Range (Min-Max)		(36.0-37.5)	(29.0-32.5)	(29.0-31.0)	(7.3-7.6)	(62.40-71.6)
Post Monsoon	16	36.34±1.22	26.93±3.73	26.59±2.75	7.5±0.18	72.86±6.84
Range (Min-Max)		(36.5-42.5)	(17.0-20.5)	(13.0-22.0)	(7.2-7.8)	(55.40-75.1)

NE = North-east, SW = South-west, Min = Minimum, Max = Maximum, AT = Air Temperature, WT = Water Temperature, EC = Electrical conductivity.

the degree of displacement of EC in the SW monsoon and post-monsoon manifested higher variations as 68.37 and 72.86 mS/cm, respectively.

3.2. Ecological indices

There is a comparison of the percent abundance of fish and crustacean species in the study area in Figure 2, showing the diversity among the two animal groups varied throughout different seasons in the study period. Fish species displayed higher diversity (*H'* = 3.19) during SW monsoon, whereas the lowest diversity was observed during pre-monsoon (*H'* = 1.58). The other ecological indices, e.g., equitability and species richness, remained more noticeable during SW monsoon (*J'* = 0.81) except for a little increase in species richness of fish during the NW monsoon (*S* = 0.26). In the case of crustaceans, however, the diversity was the highest in NE monsoon (*H'* = 2.23), where equitability and species richness were more elevated in NW monsoon and post-monsoon (*J'* = 0.70; *S* = 0.40, respectively).

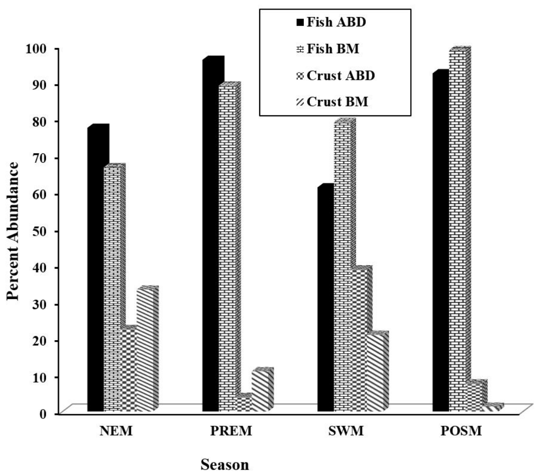

Figure 2. Seasonal comparison between percentage abundance and biomass of fishes and crustaceans along the coast of Miani Hor, *(ABD = Abundance, BM = Biomass, Crust = Crustacean, NEM = North-east monsoon, PREM = Pre-monsoon, SWM = South-west monsoon, POSM = Post-monsoon*).

The diversity and equitability indices displayed a robust linear correlation displayed (r = 0.978) in the fish species. The diversity index significantly correlated with the abundance and biomass (r = -0.978, -0.972, respectively), whereas the number of species exhibited significantly higher species richness and biomass (r = -0.996, 0.954, respectively). On the other hand, the physical attributes such as sea surface WT and salinity displayed a strong relationship with the fish assemblage (r = -0.981 and -0.943, respectively; Table 2). However, most of the physical and biological characteristics of crustacean assemblages did not explain any significant correlation except for species richness was found to be correlated with the number of individuals of various species that occurred at the same time (Table 2). Two-way ANOVA did not show any significant differences in diversity index, equitability between seasons, and groups except for species richness within groups (p = 0.018) when α = 0.05.

3.3. Assemblage structure, number of species and specimens

Over twelve months, the total number of individuals (TNI) of collected amounted to 4,799 with fish TNI 3,813, and crustaceans TNI 986 from Miani Hor intertidal sandy substratum. When we further breakdown the catch statistics of our study, a total of 27 fish families and five crustacean

Table 2. Pearson correlation matrix showing the relationships between biotic and abiotic parameters of the Fish (A) and Crustaceans (B) community structure.

Parameters	D	E	SR	% ABD	% BM	Species	Ind	TW
E	0.95*							**(A)**
SR	0.61	0.53						
% ABD	-0.97*	-0.88	-0.72					
% BM	-0.53	-0.51	-0.97*	0.61				
Species	-0.58	-0.48	0.99*	0.70	0.95*			
Ind	0.02	0.18	0.58	-0.04	-0.75	-0.54		
TW	-0.006	-0.21	-0.45	-0.01	0.65	0.40	-0.98*	
Salinity	-0.001	0.06	0.71	-0.08	-0.83	-0.70	-.94*	-0.86*
E	0.05							**(B)**
SR	-0.79	-0.008						
% ABD	-0.46	0.33	-0.10					
% BM	0.41	0.42	-0.80	0.61				
Speceis	0.75	-0.25	-0.96*	0.01	0.66			
Ind	-0.26	0.44	-0.28	0.97*	0.76	0.15		
TW	-0.73	-0.71	0.61	0.01	-0.65	-0.41	-0.19	
Sal	0.84	0.34	-0.93*	0.08	0.83	0.81	0.29	-0.86*

D = Diversity; E = Equability; SR = Species Richness; ABD = Abundance; BM = Biomass; Ind = Individuals; TW = Total Weight. Asterix sign indicates very strong correlation.

families were sampled that further comprised of 30 genera and 38 fish species, and ten genera with 17 species of crustaceans. Most of the samples were collected during the post-monsoon (27) and pre-monsoon (26), whereas SW monsoon and NE monsoon showed a lower number of individuals. We noticed an evident variation in fishes over the study period. For instance, in NE monsoon and pre-monsoon, 14 fish species were caught in each season, while for SW monsoon and post-monsoon, 15 and 21 fish species were caught, respectively. However, we noticed a different situation in the crustacean assemblage, where NE monsoon and pre-monsoon revealed a higher number of species; nine and eight, respectively. The other two seasons, i.e., SW monsoon and post-monsoon, exhibited a lower number of species, seven and six, respectively (Table 3).

A significant difference in the number of species and specimens revealed among animal groups (p = 0.019 and p = 0.016), but no variation was detected between seasons. There was a close link between the assemblage of various families representing the marine groups along the soft bottom sandy coast in Miani Hor, and the fish species constituted the significant number pelagic organisms shaping the underwater community of the shallow intertidal zone.

3.4. Taxonomic abundance and biomass

Here we give a detailed account of the taxonomic abundance and percent biomass of the crustaceans and fish species in the study area in four distinct seasons, i.e., NE monsoon, premonsoon, SW monsoon and post-monsoon. The total abundance of fish and crustaceans species recorded during NE monsoon was equal to 77.48%, out of which, the family Sillaginidae, represented by *Sillago sihama* scored the highest abundance (23.64%) and constituted the most significant share (39.33%) of the total biomass (2389.01 g), followed by *Liza subviridis* (21.15%) from family Mugilidae (Table 4). However,

Table 3. Presence dynamics of fish and crustacean species and families based on seasonal changes at Miani Hor (Sonmiani Bay).

Season	Fish		Crustacea	
	Family	Species	Family	Species
NE monsoon	11	14	5	9
Pre-monsoon	18	14	4	8
SW monsoon	11	15	2	7
Post-monsoon	14	21	3	6

NE = Northeast, SW: Southwest.

Table 4. Abundance and biomass estimation of various intertidal soft-bottom taxonomic groups collected from Miani Hor (Sonmiani Bay) during northeast monsoon season.

Family	Species	N	Abundance (%)	Biomass(g)	Biomass (%)
Mugillidae	L. subviridis	358	21.15	80.07	3.35
	L. carinata	176	10.4	267.61	11.2
Sillaginidae	S. sihama	400	23.64	939.81	39.33
Soleidae	S. elongate	7	0.41	10.31	0.43
	E. orientalis	1	0.05	3.32	0.13
Gobiidae	B. dussumeiri	198	11.7	105.36	4.41
Scienidae	Scienidae juveniles	55	3.25	25.47	1.06
	O. cuverii	74	4.37	67.61	2.83
Platycephalidae	P. indicus	1	0.05	0.31	0.01
Bothidae	P. elevates	3	0.17	2.04	0.08
Scorpaenidae	S. maculata	3	0.17	59.24	2.47
Teraponidae	Terapon jarbua	7	0.41	2.08	0.087
Stegostomatidae	S. commersonii	25	1.47	20.82	0.87
Leignathidae	L. daura	3	0.17	9.1	0.38
Portunidae	P. pelagicus	89	5.26	480.56	20.11
	P. sanguinolentus	2	0.11	7.31	0.3
	C. cruciata	1	0.05	3.26	0.13
Leucosiidae	P. globosa	1	0.05	0.78	0.03
Calappidae	A. lunaris	67	3.95	71.44	2.99
Penaeidae	M. stebbingi	141	8.33	127.96	5.35
	M. brevicornis	52	3.07	33.57	1.4
	M. affinis	27	1.59	51.83	2.16
Diogenidae	C. padavensis	1	0.05	19.15	0.8
	Total	**1692**		**2389.01**	

L. carinata contributed 11.20% of the total biomass as well. The mudskippers (Family: Gobiidae) were also found in the same season with abundance and biomass of 11.70% and 4.41%, respectively. The overall biomass of fish species was more than double (66.68%) of the same for crustaceans (33.27%). The crustacean species persisted lower in abundance (22.51%). However, crustaceans were represented by five families with *Metapenaeus stebbingi* abundance as 8.33% and *Portunus pelagicus* as 5.26%. However, concerning biomass, the *Portunus pelagicus* alone accounted for higher biomass (20.11%) in the shellfish group.

The ensuing season (pre-monsoon) revealed the highest abundance (96.05%) of fish species and the lowest for crustaceans (3.94%) during this investigation. *Liza subviridis* (Family: Mugilidae), was the species showing the highest abundance (71.19%) with convincing share in biomass (40.98%) as well when compared with all other finfish catch (Table 5). However, *Leiognathus berbis* (5.80%) and *Secutor insidiator* (5.14%) were detected in relatively less abundance while other fish species even <1%. Although crustaceans were much lower in abundance, *Penaeus indicus* (family: Penaeidae) abundance (2.19%) remained the highest of all the crustaceans during pre-monsoon. The *P. pelagicus* contributed 4.66% in the overall biomass of the season as well (Table 5).

Linked with increasing sea surface WT and salinity, a comparatively lowered abundance of fish species (61.21%) and higher seasonal abundance of crustaceans (38.78%) indicated a paradigm shift in the species composition during the SW monsoon season (Table 6), as compared to the NE monsoon and pre-monsoon seasons. Further, the species displayed even distribution with an overall smaller number of species sampled during this season (≤ 10% in abundance). For sample, only *Secutor insidiator* (10.31%) was the most abundant as well as higher in sharing the 10.86% of the total seasonal biomass sampled, followed by *Escualosa thoracata* (8.61%) and juveniles of carangids and *Thryssa spp.*(7.75% each), which constituted the central part of overall biomass of fish species (79.05%). However, *L. subviridis* turned to be one of the dominant species in biomass contribution (13.05%) besides *E. thoracata* (16.17%). An essential assemblage in the SW monsoon existed in the abundance of post-larvae (PLs) of penaeid shrimps (31.10%). *M. stebbingyi* secured a higher place in biomass (11.32%) of the crustacean species on the overall biomass distribution during the SW monsoon season (Table 6).

Table 5. Abundance and biomass estimation of various intertidal soft-bottom taxonomic groups collected from Miani Hor (Sonmiani Bay) during premonsoon season.

Family	Species	N	Abundance (%)	Biomass	Biomass (%)
Mugillidae	*L. subviridis*	650	71.19	1177.37	40.98
Sillaginidae	*S. sihama*	10	1.09	188.5	6.56
Soleidae	*S. elongata*	3	0.32	25.26	0.87
Gobiidae	*B. dussueiri*	2	0.21	1.63	0.56
Lactariidae	*L. lactarius*	8	0.87	27.96	0.97
Leignathidae	*L. blochi*	8	0.87	15.01	0.52
	L. berbis	53	5.8	333.04	11.59
	S. insidiator	47	5.14	60.36	2.1
Tetradontidae	*L. lagocephalus*	1	0.1	7.87	0.27
Scatophagidae	*S. argus*	2	0.21	627.25	21.83
Clupeidae	*E. thoracata*	39	4.27	26.67	0.92
	N. nasus	3	0.32	13.79	0.47
Carangidae	*A. melanoptera*	2	0.21	15.55	0.54
	C. talamproides	1	0.1	9.19	0.31
Belonidae	*S. strongylura*	1	0.1	0.13	0.004
Engrualidae	*T. mystax*	2	0.21	2.93	0.1
Serranidae	*E. fasciatus*	44	4.81	24.49	0.85
Fistularidae	*F. commersonii*	1	0.1	0.61	0.02
Portunidae	*P. pelagicus*	1	0.1	134.04	4.66
	C. cruciata	1	0.1	3.34	0.11
Calappidae	*A. lunaris*	7	0.76	29.2	1.01
Penaeidae	*P. indicus*	20	2.19	36.26	1.26
	P. merguiensis	1	0.1	0.97	0.033
	M. stebbingi	1	0.1	1.45	0.05
Diogenidae	*C. padavensis*	4	0.43	88.43	3.07
	C. avarus	1	0.1	21.67	0.75
	Total	**913**		**2872.97**	

Table 6. Abundance and biomass estimation of various intertidal soft-bottom taxonomic groups collected from Miani Hor (Sonmiani Bay) during the southwest monsoon season.

Family	Species	N	Abundance (%)	Biomass	Biomass (%)
Mugillidae	L. subviridis	38	2.94	124.06	13.05
	L. carinata	37	2.87	51.62	5.43
Sillaginidae	S. sihama	5	0.38	14.91	1.56
Teraponidae	T. jarboa	2	0.15	10.17	1.07
Leiognathidae	S. insidiator	133	10.31	103.22	10.86
Hemiramphidae	H. dussumerii	66	5.12	30.52	3.21
Carangidae	Carangidae Juveniles	100	7.75	12.6	1.32
	S. leptolepis	2	0.15	25.19	2.65
Engraulidae	Thryssa Juveniles	100	7.75	34.69	3.65
	S. gibbosa	4	0.31	9.89	2.65
Gerridae	G. filamentosus	2	0.15	4.99	0.52
Lactaridae	L. lactarius	88	6.82	83.58	8.79
Clupeidae	Clupeide Juveniles	100	7.75	90.52	9.52
	E. thoracata	111	8.61	153.7	16.17
Tetradontidae	L. lagocephalus	1	0.07	1.42	0.14
Calappidae	A. lunaris	2	0.15	20.54	2.16
	M. planipes	23	1.78	12.52	1.31
Penaeidae	M. stebbingi	58	4.49	107.57	11.32
	M. brevicornis	13	1	8.16	0.85
	P. penicillatus	2	0.15	7.86	0.82
	P. merguiensis	1	0.07	2.94	0.3
	PLs of Penaeidae	401	31.1	39.44	4.15
	Total	**1289**		**950.13**	

PLs = Post larvae.

The post-monsoon season displayed the highest species variation, with a total species count to 27 species in fish and crustaceans that belonged to 17 families. However, the occurrence of fish species was higher (92.37%) than crustaceans (7.62%) during the pre-monsoon season (Table 7). *Liza subviridis* (51.49%) was found as the most abundant among the species caught during this season. The continuously resident *L. subviridis* contributed 35.0% in overall biomass of the sample that could be compared with other benthopelagic *Platycephalus indicus* (27.76%). Other highly abundant fish species included *Sillago sihama* (19.11%), juveniles of *Thryssa spp*. (7.29%) Furthermore, *Liza carinata* (4.75%) appeared to have been there following the suitable environmental conditions for growth and survival in the intertidal zone. Although very few (6) crustacean species were recorded in the post-monsoon, simply PLs of the penaeid shrimp were found in abundance (5.41%). However, the hermit crab (*Clibanarius spp*) biomass was estimated as the highest (0.66%) in the sample within the crustaceans group (Table 7). The abundance and biomass significantly varied within groups ($p = 0.028$ and $p = 0.017$, respectively) but did not display a significant seasonal difference.

The seasonal contrasts in the three ecological variables (diversity, equitability, and species richness) connecting NE monsoon, pre-monsoon, SW monsoon, and post-monsoon were found during the study as shown in Figure 3. The most observed variation in fish species diversity was recognized during the SW monsoon, while the same for crustacean species calculated during the NE monsoon. Similar was the case with the species equitability. Nonetheless, the species richness did not illustrate any significant pattern during the study duration.

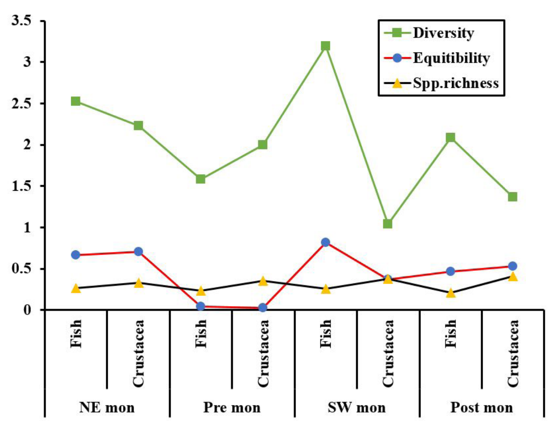

Figure 3. Seasonal comparison between fish and crustaceans based on three ecological variables at Miani Hor (NE = North-east, SW = South-west).

4. Discussion

There was a discrete variance in the species diversity, abundance, and richness in Miani Hor sandy beach zone

Table 7. Abundance and biomass estimation of various intertidal soft-bottom taxonomic groups collected from Miani Hor (Sonmiani Bay) during post monsoon season.

Serial No.	Taxonomic Group	N	Abundance (%)	Biomass	Biomass (%)
Mugillidae	L. subviridis	466	51.49	1167.89	35
	L. carinata	43	4.75	38.42	1.15
	L. vaigiensis	1	0.11	17.55	0.52
Sillaginidae	S. sihama	176	19.44	447.58	13.41
Leiognathidae	L. splendens	1	0.11	34.39	1.03
Teraponidae	T. jarboa	10	1.1	81.03	2.42
Carangidae	A. melanoptera	1	0.11	36.27	1.08
Engrualidae	S. sindensis	1	0.11	1.74	0.05
	Thryssa Juveniles	66	7.29	16.35	0.49
	Engraulidae Juveniles	19	2.09	2.28	0.06
Mullidae	U. vittatus	8	0.88	126.22	3.78
Hemiramphidae	H. limbatus	30	3.31	66.55	1.99
	H. dussumerii	1	0.11	25.14	0.75
Bothidae	P. arsius	2	0.22	91.68	2.74
	P. elevates	1	0.11	102	3.05
Stegostomidae	S. commersonii	2	0.22	5.11	0.15
Lutjanidae	L. fulviflammus	1	0.11	16.1	0..48
Pomadasydidae	P. olivaceaum	1	0.11	8.14	0.24
Clupeidae	I. melastoma	2	0.22	6.84	0.2
Platycephalidae	C. crocodilla	1	0.11	64.63	1.93
	P. indicus	2	0.22	926.41	27.76
Calappidae	A. lunaris	2	0.22	8.72	0.26
Penaeidae	P. sculptilis	3	0.33	0.28	0.008
	PLs of shrimps	49	5.41	5.64	0.16
	M.. monoceros	12	1.32	5.62	0.16
Diogenidae	C. padavensis	2	0.22	22.15	0.66
	D. diogenes	1	0.11	0.89	0.02
	Total	**905**		**3336.67**	

between the two locomotory animal groups (fish and crustaceans (), by utilizing the beach seine net and beam trawls. This research sampling resulted in the overall presence of 27 families of fish comprising of 38 species. The seasonal variation in fish was not very characteristic as a lower number of fish species were found in NE monsoon and pre-monsoon (14) in comparison with the highest fish variation during the post-monsoon (21) season. Few ichthyofaunal families could be characterized as native and permanent residents, though one or more fish species continued benefiting from the shallow coast of the Miani Hor. The salient examples incorporate family Mugilidae (*Liza subviridis, L. carinata, and L. vaigiensis);* family Sillaginidae *(Sillago sihama),* family Leiognathidae *(Secutor insidiator, Leiognathus daura, L.blochi, L.berbis),* family Teraponidae *(Terapon jarbua),* Engraulidae *(Thryssa mystax, Sardinella gibbosa, S. sindensis);* Family Clupeidae (*Ilisha melastoma, Escualosa thoracata, Nematolosa nasus*); family Bothidae (*Pseudorhombus arsius, P. elevatus*) and family Platycephalidae (*Platycephalus indicus*).

The expanding diversity during NE monsoon and SW monsoon implied that several fish species are the frequent visitors and utilize the inshore areas as feeding and refuge grounds, as the low mid-tide circumstances favor these opportunities. Moreover, the sea surface WT could be changing while the ebb tides generate turbulence in the semi-enclosed lagoon stretch. Therefore, the species richness was higher as compared to the pre-monsoon and post-monsoon, corresponding to the diversity index. Silva et al. (2011), correlated the low species richness of some benthic groups with specific environmental parameters and physiological stress. According to Kinne (1971), increased salinity worked as a favorable factor to most macrofaunal taxa resulting in boosting their density and diversity. Although the species abundance varied throughout this investigation, however, inter-seasonal species distribution prevailed for higher reflection.

The species abundance and variation could be a function of sea WT. Generally, the estuarine benthic fauna belongs to Polychaeta, Crustacea, and Mollusca, which shows a higher tolerance to the environmental stress and substantial changes in the spatial and temporal structure of the community. Several studies hinted at the temperature as one of the most critical environmental variables that control the marine life (Bhaud et al., 1995), especially during the reproduction and larval stages, recruitment patterns, and metabolism are the essential elements that are directly influenced by the WT (Sinclair, 1988; Bhaud and Cha, 1992). According to another research, predicting long term changes in benthic communities is an elusive goal owing to the exceptionally long duration required to monitor such confounding alterations that could have appeared because of temperature changes (Gray and Christie, 1983). The fish species were small-size and mostly at the juvenile and sub-adult life stages. As the surfing zone is a complex habitat that equally serves as the shelter and feeding zone for several organisms. The higher density of juvenile and small-sized fish species symbolizes that sandy beaches are rendering an alternative nursery habitat to estuaries for many species. Lasiak (1984) proposed that the utilization of the surfing zone by large numbers of juveniles favor the use of shallow sandy beaches as a nursery ground due to the abundant supply of food in the form of zooplankton and avoidance from predation further encourages by shallow waters coupled with higher turbidity and turbulence in the zone. It is also imperative that habitats do not remain constant but vary regularly on a daily and seasonal basis. Therefore, we noticed a characteristic variation in the species distribution, abundance, and diversity in Miani Hor.

Species richness, abundance, and biomass are three of the most frequently investigated ecological attributes of the sandy beach macrobenthic communities at the large-scale comparative studies. Fish species equally share this shallow intertidal zone, therefore, abundant diversity and distribution lessen the equal chances of exploitation of resources available to benthic fauna. Consequently, *P. pelagicus*, *M. stebbingi*, *P. indicus*, and *A. lunaris* were detected to display a striking abundance and biomass in crustacean species. Therefore, the species abundance and biomass remain tightly linked with the density of a population. During the NE monsoon and pre-monsoon seasons, relatively more families of crustaceans were recorded (5 and 4, respectively), which is higher than the other two seasons (SE monsoon: 2, and post-monsoon: 3). Accordingly, the increased values of diversity index (*H'*) were found in NE monsoon and pre-monsoon (2.23 and 2.00, respectively). Though species richness did not corroborate with the corresponding season, the SW monsoon and post-monsoon showed an increased species richness (S=0.37 and S=0.40, respectively).

Among Crustacea, shrimps (Family: Penaeidae, e.g. *Metapenaeus stebbingi, Penaeus merguiensis*), crabs (Family: Portunidae and Family: Calappidae e.g., *Portunus pelagicus and Ashtoret lunaris*) and hermit crabs (Family: Diogenidae e.g., *Clibanarius padavensis*) were the essential populations of intertidal animals discovered in the benthic habitat. McLachlan et al. (1981) demonstrated that the species community features such as richness, density, and total abundance expanded from the steeper beaches with coarse sand to the flatter beaches with fine sands. Subsequent investigation covering a broad range of beaches and geographical areas validated these conclusions by determining that macrotidal dissipative beaches supported communities having higher richness, abundance, and biomass than microtidal reflective beaches (McLachlan, 1990; McLachlan et al., 1993). The distribution and abundance also vary in the intertidal zone affected by tidal phases and tidal states during distinct seasons. The physical structure of the ecosystem belongs to the ocean and sandy beaches and is characterized by three variables: the sand grain size, wave climate, and tidal regime. The resulting interactions among three factors feature an array of beach morphodynamics, that broadly range from microtidal reflective beaches (narrow and steep) to macrotidal dissipative systems (broad and flat, with tidal flats) (Short, 1996). Because beach ecosystems lack biological structures, the intertidal macrofaunal communities have been physically controlled by the Autecological Hypothesis. The infaunal communities respond differently in the presence of monsoon that occurs frequently, and its magnitude varies (Alongi, 1989). George et al. (2009) studied the benthic macroinvertebrate fauna and tried to develop its link with the physicochemical parameters in the Niger Delta and stated that many invertebrates play an essential role in the circulation and recirculation of nutrients in aquatic ecosystems. Besides, there are important links between unavailable nutrients held in detritus and useful protein materials in fish and shellfishes. Most benthic organisms feed on debris that settles on the bottom of the water and in turn, serves as a food source for the full range of fish species (Ajao and Fagade, 1990; Oke, 1990; Idowu and Ugwumba, 2005; Uwadiae, 2009).

The literature survey could not provide any convincing arguments on the presence of various Molluscs, hermit crabs, and other crab species along the coast of Miani Hor except fewer studies that investigated some commercial shrimp and finfish species. Gondal et al. (2012) proclaimed that 22 fish species belonged to 14 families, while eight crustacean species represented one family (Penaeidae) in Miani Hor. Similarly, Ahmed and Abbas, (1999) studied the abundance of some finfish and shellfish juveniles in the intertidal zone of Miani Hor and ranked some fish species like *L. subviridis, Sillago sihama*, *Coilia dussumieria* for important commercial values. Moreover, the shellfish, species, e.g. *Penaeus merguiensis* and *Metapenaeus stebbingyi* were ranked as two important shrimp species in the coastal Miani Hor. Likewise, Hassan, (1989) worked on the distribution and abundance of juveniles of Penaeid shrimp along the coast of Makran and observed *M. stebbingi*, *P. semisulcatus*, and *P. stylifera* as the most abundant in the coastal waters. However, Ahmed et al. (1982) surveyed the entire Makran coast for distribution and abundance of intertidal organisms on some beaches, but the macrofauna reported were more relevant to rocky intertidal zones.

The distribution of the lower number of intertidal benthic fauna along the coast could be due to the narrow intertidal zones, which also confirmed by the studies carried out by Ahmed et al. (1982). Furthermore, demersal populations tend to be higher because of the shallow sandy bottoms and abundant epibenthic and infaunal surface prey. Although seasonal variations occur in intertidal zones, there are other factors also presented by Aller and Aller (1986) and Seshappa (1953). These factors include the shallow inshore communities in regions of intense wet season activity, and upwelling is frequently smothered by massive ravine sedimentation or by the erosion of estuarine mud banks.

We determine the distribution and abundance of organisms by their intricate responses to environmental and biotic factors. It is argued that the state of tide determines the abundance of species in a marine ecosystem, e.g., low tides favor more species as compared to high tides that would influence the dominant species to remain in the ecosystem (Gibson et al., 1993, 1996; Lasiak, 1984). In Miani Hor, fish species always dominated positions throughout this study in abundance, diversity, and biomass as compared to crustaceans in the benthopelagic zone. The resident species, for instance, *L. subviridis*, *S. sihama* and *S. insidiator* established the dominant status of the fish community. The other species were found as visitors, and their status remained changing during this investigation. Blaber and Whitfield (1977) conceded that the calm waters, turbidity, substratum type, and depth determine the distribution of juvenile fish species in the nearshore areas.

Miani Hor serves as a feeding and shelter ground habitat to a diverse range of sea life. The adjoining mangrove forests further enhance the importance of sandy and mudflats of the lagoon areas. Therefore, we found numerous variations in benthic and pelagic organisms. Quinn and Kojis (1987) inferred that the abundance of species, individuals, and biomass in the evening time linked with the changes in illumination, gear efficiency, and behavior of the aquatic organisms. Further, the tides would have a profound effect on the species composition of the benthopelagic habitat. As the tide is lowered, the organisms tend to seek refuge in sediment, or the nektons migrate to subtidal waters. Rozas and Zimmerman (2000) analyzed the species that frequently utilize the intertidal zone during high tides, migrate back in the shallow subtidal zones. Furthermore, as the intertidal zones immersed, the same pattern was followed. However, Hampel et al. (2003) suggested that most of the species occur during the entire tidal cycle, regardless of day-night or lunar rhythms. Davis (1988) pointed out that higher tides provide considerable aid to the upstream movement of several species, which results in the differences of community structure during the lunar phases. He further claimed that fish species benefit from stronger tides for movement into inundated areas. The former situation prevails in the Miani Hor, where mixed semidiurnal tides provide a suitable opportunity to large numbers of taxa to visit and benefit from the shallowness of the intertidal zone, further enriched by adjacent abundant mangroves. As a result, a range of finfish, hard shellfishes, and soft shellfish species are captured to support the local fisheries. Therefore, a very profitable fishery has been established in the coastal area of Sonmiani Bay, linking the local and distant human populations.

5. Conclusions

In conclusion, this investigation targeted the seasonal species abundance, diversity, and richness in the coastal Miani Hor. We studied the fish and crustacean populations during the NE monsoon, pre-monsoon, SW monsoon and post-monsoon. Mild to lower disparities in the air and water temperature were observed, while salinity and pH did not show any significant seasonal changes. Fish species abundance and diversity displayed higher heterogeneity during SW monsoon, whereas the lowest diversity was observed during pre-monsoon. The fish species diversity and equitability manifested a robust linear correlation. We sampled a total of 4,799 species individuals fish equal to 3813, and crustaceans as 986. We recorded differences of species-based biomass percentage dominated during various seasons, implying thereby seasonal abundance of fish and crustacean species. In conclusion, seasonal abundance and richness of fish and crustacean species are linked with a plethora of environmental factors, tidal regime, type of the habitat, availability of food and shelter, and migration patterns of species.

Acknowledgements

The authors are profoundly grateful for partial financial support from the Higher Education Commission and PARC-ALP program. Besides, all technical and logistic support was provided by the Centre of Excellence in Marine Biology, University of Karachi, Pakistan. The authors (SM, KAH, FAM, and ZA) express their sincere appreciation to the Researchers Supporting Project No. RSP-2020-24 the King Saud University, Riyadh, Saudi Arabia

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