Indian Journal of Geo Marine Sciences
Vol. 50 (03), March 2021, pp. 228-235

Seasonal variation in the abundance and species diversity of penaeid shrimps from the coastal area of Sonmiani Bay Lagoon, Balochistan, Pakistan

Z Amanat*[,a], N U Saher[a] & N A Qureshi[b]

[a]Centre of Excellence in Marine Biology, University of Karachi, Karachi – 75270, Pakistan

[b]Department of Fisheries and Wildlife, University of Veterinary and Animal Sciences, Syed Abdul Qadir Jillani Road, Lahore – 54000, Pakistan

*[E-mail: zunairaamanat@gmail.com]

Received 15 April 2016: revised 16 December 2020

Shrimp communities of the coastal habitat of the Sonmiani Lagoon were shown to be dominated by family Penaeidae. Seasonal variation in the relative abundance and species diversity of penaeid shrimps was derived from sampling of 2554 individuals representing twelve species of three genera. The results showed that species of the genus *Penaeus* dominated over those of the other two genera of penaeid shrimps *i.e. Metapenaeus* and *Parapenaeopsis.* The most abundant species of penaeid shrimps were *Penaeus indicus* (67.50 %), *Metapenaeus affinis* (13.31 %), *Penaeus merguiensis* (12.02 %), *Metapenaeus brevicornis* (4.26 %) and *Metapenaeus stebbingi* (1.60 %), respectively. Relative abundance varied seasonally within the species and between the seasons. Highest species richness in the lagoon was observed in the period of SW monsoon and the lowest in pre-monsoon season, whereas Diversity *(H')* was found to be highest in post-monsoon, and appeared to be influenced by the equitability (*J*) of distribution of individuals among the species. Temperature, salinity and pH influenced both the abundance and the diversity of shrimp fauna in the lagoon.

[**Keywords**: Diversity, Equitability, Seasonal abundance, Species richness]

Introduction

Decapods serves as an important fish resource and also act as a trophic link between benthic microorganisms and fishes in the food chain/web of coastal waters[1,2]. The shrimp family, Penaeidae covers almost 70 % of the world's prawn (shrimps) catch[3] and due to their nutritional value they support a very valuable trade and export market. Penaeid shrimps are fast-growing and short-lived; their life cycle can be completed in about one year. The genus *Penaeus* commonly occurs in tropical and subtropical waters, between 40º N to 40º S and is the most commercial important species in the fauna of estuaries and coastal waters. Coastal penaeid shrimp hoard have been studied extensively over the past four decades as their importance in tropical fisheries has increased. The significant progress has been made in biological research since the FAO World Science Conference on biology and culture of penaeid shrimps in 1967(ref. 4).

Pakistan is among the top ten major shrimp producing countries of the world[5]. Its shrimp industry is primarily an export industry and its stock is the backbone of important capture fisheries. These fisheries are a major foreign exchange earner for Pakistan, with high profit margins, and are the source of livelihood for thousands of local fishermen. Most of the aquaculture practices are based on species of penaeid shrimps especially members of the genus *Penaeus*, due to their hatchery production, rapid growth and large population sizes. Northern Arabian Sea waters off the coast of Pakistan are very rich in penaeid shrimp populations. However, the environmental as well as the geomorphologic characteristics have substantially increased the ecological pressure on the shrimp stocks, along with continued fishing pressure. This would be expected to have an adverse effect on the shrimp populations diversity, harvest size of target species and size at maturity due to fishing pressure.

Sonmiani Bay Lagoon *i.e.* Miani Hor is one of the important fishing hub on the coast of Pakistan, where shrimp is the target fishery; and fishing is done at the depth of 10-50 m(ref. 6). Various types of nets were used mainly to catch fishes, shrimps and crabs from lagoon waters by a moderate-sized fishing fleets operating from the fishing jetty located in the town of Damb. Sonmiani Bay Lagoon exhibits depth bounded by mangrove vegetation such that the life cycle of the shrimp is sustained. Mangroves serve as nursery grounds and provide protection and food for the juveniles of shrimps, crabs and fishes[7-9].

Various workers have published data on the population structure, distribution, abundance, length-frequencies, sex-ratio and gonadal maturity of economically important penaeid shrimps and biology of shrimps along the coast of Pakistan[10,11]. For the management and sustainability of the shrimp industry accurate assessments are of critical importance due to the substantial fishing pressure and high exploitation rates of shrimp stocks. The quantification of the relationships between animal size, density and biomass are of vital importance to both fisheries and ecological studies. Very few information is published on the distribution and population structure of fish and shellfish resources from Sonmiani Bay lagoon, Balochistan, Pakistan. Therefore the present research was formulated to elucidate the species diversity, abundance, population structure, and sex ratio of the commonly occurring penaeid shrimps in Sonmiani Bay.

Materials and Methods

The Pakistan has coastline of about 990 km long that compsises of the province of Sindh (320 km) and the province of Balochistan (670 km), and Exclusive Economic Zone (EEZ) of about 240,000 square km[12]. The coast of Balochistan, running along the North Arabian Sea, includes lagoons, bays, cliffs, alluvial plains, beaches, mudflats and marine terraces. The coast of Balochistan has 40 km wide continental shelf and the is exposed with intense wave action. The costal area of Sonmiani Bay or Miani Hor is located about 95 km from Karachi covering 7.471 ha area[11]. It is approximately located at latitude of 25°27'431" N, and longitude of 66°33'700" E. Miani Hor is one of the swampy lagoon because the weather condition of lagoon is very arid, recorded rain per year is less than 200 mm. The main sources of fresh water for Miani Hor are the two seasonal run-off rivers *i.e*. Porali and Windor river[13,14].

For this study the samples of shrimp species were collected from the Sonmiani Bay in each month between July 2006 to June 2007. For this purpose, a gill net (5 cm mesh size), and a beach seine net (with 0.5 cm mesh size) were used to collect all size class individuals that inhabit different niches of Miani Hor Lagoon, so that the number of species of shrimp found in the Sonmiani could be determined. The fishing nets were deployed with the help of local fishermen from a commercial fishing boat. At least three to four hauls of 20-25 min of the gill nets and two operations of the beach seine net were made at each sampling event. Environmental parameters (temperature, salinity and pH) were also noted at each sampling event. The temperature was recorded using a centigrade thermometer with an accuracy of 0.1 ºC, salinity in parts per thousand (ppt) by using the portable refractometer (ATAGO S/Mill-E) and pH by a portable pH meter (Hanna, HI 8314). All the samples (fish, shrimps, crabs, etc.) collected in each haul were instantly weighed, placed in separate polythene bags and than iced for transfer to the laboratory for further analysis. During this study, approximately 2554 individuals of penaeid shrimps were collected.

In the laboratory, the shrimp samples were sorted and segregated according to sex and were identified to species level according to Tirmizi & Bashir[15] and Bianchi[16]. The weight and lengths (total length, carapace length, rostrum length and the telson length) of the shrimps were then measured. Lengths were measured to the nearest 0.1 centimeter (cm) and weights were measured to the nearest 0.01 gramme (g). To observe the seasonal changes and variability, monthly data were grouped into seasons following Morrison *et al*.[17]. Thus November, December and January were defined as the NE monsoon; February, March and April as the pre-monsoon; May, June and July as the SW monsoon; and August, September and October as the post-monsoon period.

For all species of shrimps that were abundant and common, sex ratios were estimated from the percent distribution of male and female shrimps and the result was tested by using Chi-square (χ^2) test for the differences from the expected ratio of 1:1. The equation used for estimation was:

$$(\chi^2) = \sum (O - E)^2 / E \quad \ldots (1)$$

Where, observed value was denoted by O, and expected value of that species is denoted by E, two-sample *t*-tests were employed to compare sample means.

The following formula were used to calculate the Fulton condition factor (K):

$$K = 100W/L^3 \quad \ldots (2)$$

Where, W represent thebody weight of individual penaeid shrimp in grams, and L is the total length of the shrimp in the centimeters[18-20].

Diversity indices were used to determine the shrimp diversity as stated below:

1. Shannon – Weiner index (H) measures the order or disorder observed with a particular system. This order is characterized by the number of individuals observed for each species at the sample site. The Diversity index was derived by using the formula:

$$H = - \sum (n_i/N)*(\log_2 n_i/N) \quad \ldots (3)$$

Where, n_i = number of individuals in the i^{th} species, N = total number of individuals, log = commonly chosen logarithm with base of 2(ref. 21).

2. Equitability or evenness (J), was calculated (range 0-1) according to the ratio:

$$J = H / H_{max} \quad \ldots (4)$$

Where, H = observed species diversity, H_{max} = maximum number of species and is equal to $\log_2 S$, and S = number of species in each sample.

3. Species richness (S) is the number of species present in the study area and it is the oldest concept of species diversity. Species richness[22] was calculated according to the equation:

$$S = (S-1) \log_2 N \quad \ldots (5)$$

Where, S = number of species.

4. The Simpson index (D) is a measurement that accounts for the percent of each species from a biodiversity sample within a local aquatic community; the index assumes that the proportion of individuals in an area indicates their importance to diversity.

$$D = \text{sum } (Pi)^2 \quad \ldots (6)$$

Where, Pi = the number of given species divided by the total number of shrimps observed.

All Statistical analysis was performed by using the Minitab software (Version 13.1). Cluster analysis (Dendrogram) was made from the statistical interpretation of the environmental parameters of water and distribution of penaeid shrimp species.

Results

The different seasons showed changes in temperature, salinity and pH which seemed to correlate with the distribution of the shrimp population. A typical seasonal pattern of mean temperature was observed, with highest values during the summer (March to June) and lowest during the winter season (November to January). The salinity showed considerable monthly fluctuations (from 34 to 37 ppt) throughout the study period. The highest salinity was observed in winter months (November to January) and the lowest was observed during the summer months (April to June). Average pH values remained very similar throughout the study period (Fig. 1). The fluctuations of seawater salinity and temperature were inversely related, so that when its temperature increased its salinity decreased. This was probably due to the input of fresh water from rainfall and from adjacent rivers.

The abundance and biomass composition of penaeid shrimp species in the Sonmiani Bay lagoon during the present study are shown in Table 1. Twelve penaeid species of three genera were identified, of which *Penaeus indicus*, *P. merguiensis*, *Metapenaeus affinis*, *M. brevicornis* and *M. stebbingi* were the dominant species, together making up the bulk (98.7 %) of the total catch. Other species, which were present in very small numbers (fewer than 10 specimens), were *P. penicillatus*, *P. japonicus*,

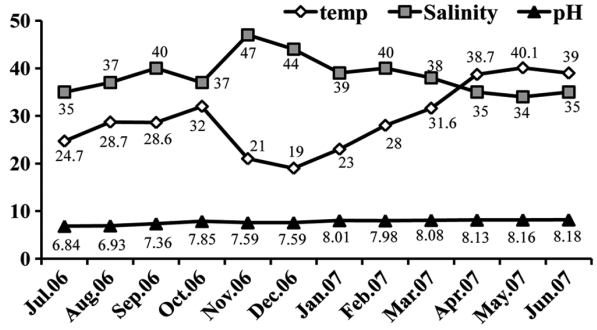

Fig. 1 — Monthly mean values of hydrographic parameters (temperature, salinity, pH) collected from the Sonmiani Bay lagoon

Table 1 — Total abundance, percent abundance, mean total length, range of total length, mean wet weight, range of wet weight, total biomass, and percent biomass of shrimp species collected from the Sonmiani Bay Lagoon in the period July 2006 to June 2007

Shrimp species	Abundance		Total length (cm)		Mean wet weight (g)		Biomass	
	N	%	Mean ± SD	Range	Mean ± SD	Range	g	%
Penaeus indicus	1724	67.50	9.5±3.7	2.3-16.5	6.3±5.5	0.03-25.4	10998.79	65.46
Penaeus merguiensis	307	12.02	13.2±2.7	3.6-32.5	14.0±5.7	0.3-43.9	4323.17	25.73
Penaeus monodon	1	0.03	14.0	-	19.2	-	19.25	0.11
Penaeus japonicus	1	0.03	11.4	-	9.2	-	9.29	0.05
Penaeus penicillatus	16	0.62	7.7±1.8	4.7-10.7	2.0±1.2	1.1-5.0	33.4	0.19
Metapenaeusaffinis	340	13.31	6.7±2.9	3.1-19.6	3.0±4.8	0.1-63.0	1048.51	6.24
Metapenaeus stebbingi	41	1.60	7.4±3.0	3.7-14.1	4.0±4.2	0.3-17.7	164.55	0.97
Metapenaeus monoceros	1	0.03	19.6	-	15.0	-	15	0.08
Metapenaeus brevicornis	109	4.26	4.3±0.9	3.1-12.3	0.7±1.3	0.1-14.0	82.31	0.48
Parapenaeopsis stylifera	8	0.31	8.5±0.7	7.4-10.1	3.8±0.8	2.5-5.2	30.46	0.18
Parapenaeopsis hardwickii	3	0.11	10.0±0.4	9.6-10.5	5.7±0.9	5.0-6.7	17.3	0.10
Parapenaeopsis accilivirostris	3	0.11	13.9±4.3	8.9-16.9	19.6±14.2	3.2-29.2	58.94	0.35
Total	2554						16800.97	

P. monodon, *M. monoceros*, *Parapenaeopsis stylifera*, *P. hardwickii* and *P. accilivirostris*. The *P. indicus* was the most abundant species in the Sonmiani lagoon, which represented 67.50 % tothe total shrimps with respect to numbers and 65.46 % with respect to biomass. The second most abundant species is *M. affinis*, which represented 13.31 % with respect to numbers and 6.24 % with respect to biomass. *P. merguiensis* was the third most abundantly found species, representing 12.02 % with respect to numbers and 25.73 % with respect to biomass. *M. brevicornis* and *M. stebbingi* were the fourth and fifth most abundant species in the lagoon, representing 4.26 % and 1.60 % with respect to numbers and 0.48 % and 0.97 % with respect to biomass, respectively (Table 1).

Monthly measures revealed that the peak of abundance for *P. indicus* was observed in the month of July, whereas the peaks for *M. affinis* and *P. merguiensis* occurred in the months of February and May, respectively (Fig. 2a). In terms of seasonal distribution, *P. indicus* had the highest abundance during the SW monsoonseason, *M. affinis* in the SW and post-monsoon seasons, *P. merguiensis* in the SW monsoon season, *M. brevicornis* in the pre-monsoon season and *M. stebbingi* in the SW monsoon season (Fig. 2b). One way ANOVA showed that there is a significant difference between seasons for *P. indicis* ($F_{3,4}$ = 15.71; $P < 0.005$), *M. affinis* ($F_{3,4}$ = 4.55; $P < 0.005$), *P. merguiensis* ($F_{3,4}$ = 7.82; $P < 0.005$) and *M. stebbingi* ($F_{3,4}$ = 6.25; $P < 0.005$) while for *M. brevicornis* ($F_{3,4}$ = 1.24; $P > 0.005$) there was no significant difference between seasons.

The highest Shannon–Weiner index (H) was found in the post-monsoon season (1.59) and the lowest in the pre-monsoon season (0.66), while the equitability or evenness (J) was highest in the post-monsoon (0.71) and was lowest during pre-monsoon (0.36) seasons. Species richness (S) had its highest value in the SW monsoon season (9.12) and was lowest in pre-monsoon season (4.45) and the Simpson index (D) was highest in the pre-monsoon season (0.76) and lowest in the post-monsoon season (0.41; Fig. 3).

Monthly sex ratios were found consistently, to fluctuate in *P. indicus*, *M. affinis*, *P. merguiensis*, *M. brevicornis* and *M. stebbingi*. The female specimens were collected more abundantly than males during the present study. 1724 specimens of *P. indicus* comprising of 1279 females and 445 males were observed; in *M. affinis* total of 340 specimens was observed comprising of 234 females and 106 males; 307 specimens of *P. merguiensis* were found comprising of 208 females and 99 males; 109 specimens of *M. brevicornis* were found comprising 75 females and 34 males; and 41 specimens of *M. stebbingi* were observed comprising 28 females and 13 males. The chi-square test showed a significant difference between sexes in all months in the *P. indicus* (χ^2 = 148.816; $P < 0.005$) and *M. brevicornis* (χ^2 = 19.913; $P < 0.005$) while showed a significant difference was not observed in *P. merguiensis* (χ^2 = 9.993; $P > 0.005$), *M. affinis* (χ^2 = 21.286; $P > 0.005$) and *M. stebbingi* (χ^2 = 1.029; $P > 0.005$; Table 2).

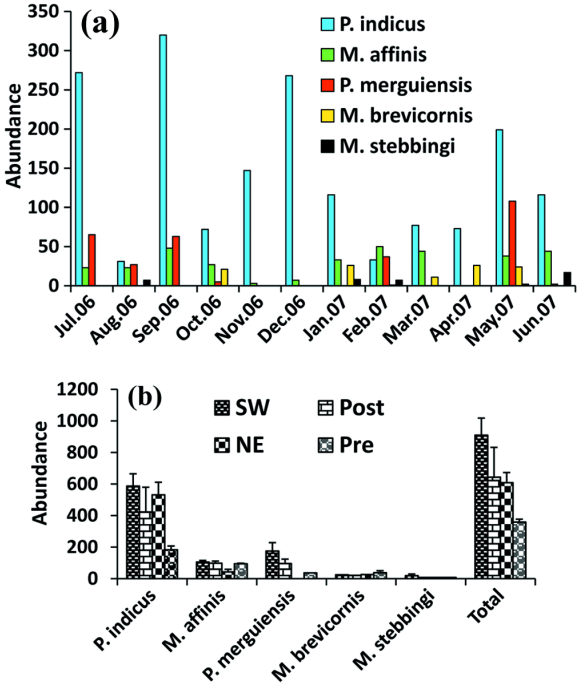

Fig. 2 — (a) Monthly and (b) Seasonal - distribution of the five most abundantly found penaeid shrimp species from the Sonmiani Bay lagoon

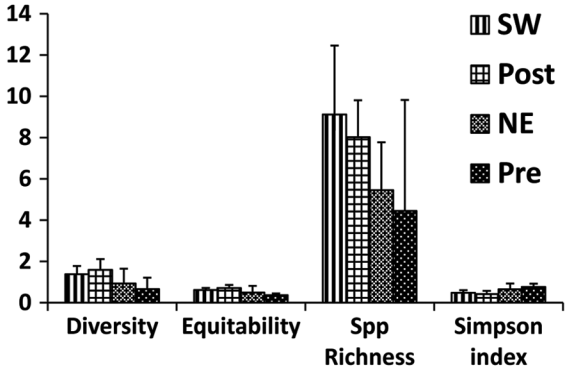

Fig. 3 — Seasonal variation in the diversity indices (Diversity, Equitability, Species Richness and Simpson index) of penaeid shrimps from the Sonmiani Bay lagoon (Mean ± S.E)

Table 2 — Chi-square test for sex ratio and Fulton condition factor of penaeid shrimp species (*Penaeus indicus*, *P. merguiensis*, *Metapenaeus affinis*, *M. brevicornis* and *M. stebbingi*) collected from the Sonmiani Bay lagoon in the period July 2006 to June 2007

S. No.	Species	DF	Chi square	*P*-value	Fulton condition factor (K)
1	*Penaeus indicus*	11	148.816*	< 0.005	0.72
2	*Penaeus merguiensis*	6	9.993	> 0.005	0.59
3	*Metapenaeus affinis*	10	21.286	> 0.005	1.01
4	*Metapenaeus brevicornis*	5	19.913*	< 0.005	0.92
5	*Metapenaeus stebbingi*	4	1.029	> 0.005	0.96

Note: * indicates significance at $P < 0.005$

Table 3 — Summary statistics of the morphometric parameters weight (Wt), total length (TL), carapace length (CL), rostral length (RL) and telson length (Ts.L) in females and males of *Penaeus indicus*, *P. merguiensis*, *Metapenaeus affinis*, *M. brevicornis* and *M. stebbingi* collected from Sonmiani Bay Lagoon in the period July 2006 to June 2007 (M = Mean, SD = standard deviation)

S. No.	Species	Wet weight		Total length		Carapace length		Rostrum length		Telson length	
		M ± SD	Range	M ± SD	Range	M ± SD	Range	M ± SD	Range	M ± SD	Range
	P. indicus										
1	Female	5.7±5.6	0.03-25.4	9.0±3.8	2.3-16.5	3.3±1.5	0.4-6.4	2.2±0.9	0.3-4.7	1.0±0.4	0.1-2.0
	Male	8.1±4.9	0.04-19.8	11.0±3. 2	2.9-15.7	4.2±1.2	0.6-6.1	2.6±0.7	0.5-4.2	1.2±0.3	0.2-1.9
	P. merguiensis						.				
2	Female	14.3±5.6	0.6-43.9	13.3±2.3	5.0-26.0	4.7±0.8	1.5-6.8	2.9±0.5	0.6-6.2	1.5±0.2	0.4-2.2
	Male	13.4±5.8	0.3-28.9	13.2±3.3	3.6-32.5	4.5±0.8	1.1-6.1	2.8±0.4	0.4-4.0	1.5±0.2	0.6-2.2
	M. affinnis										
3	Female	2.7±3.5	0.1-22.9	6.5±2.8	3.1-16.6	2.2±1.1	0.7-5.4	1.2±0.6	0.3-2.8	0.8-0.4	0.3-2.2
	Male	3.7±6.9	0.3-63.0	7.0±3.1	3.2-19.6	2.4±1.2	0.8-6.1	1.2±0.7	0.3-3.1	0.9±0.4	0.3-2.1
	M. brevicornis										
4	Female	0.7±1.5	0.1-14.0	4.2±1.0	3.1-12.3	1.3±0.4	0.6-3.5	0.7±0.3	0.3-2.0	0.5±0.1	0.3-1.6
	Male	0.7±0.2	0.3-1.1	4.4±0.5	3.1-5.4	1.4±0.3	0.7-2.2	0.6±0.2	0.3-1.6	0.5±0.09	0.4-0.7
	M. stebbingi										
5	Female	4.3±3.6	0.3-15.8	7.9±2.7	3.7-14.1	2.6±1.4	0.5-5.2	1.6±0.6	0.7-3.0	1.1±0.2	0.5-1.6
	Male	3.3±5.4	0.4-17.7	6.4±3.4	4.0-14.0	1.7±1.6	0.5-4.8	1.7±0.7	0.6-3.0	1.4±0.5	1.0-2.1

In the five most abundantly found penaeid shrimp species thesmallestFulton condition factor was found in *P. merguiensis* (0.59) and the largest in *M. affinis* (1.01). The mean condition factor for all penaeid shrimps was 0.84 (Table 2).

In the five penaeid shrimps species, size variations in the different body parts *viz*. total length (TL), carapace length (CL), rostrum length (RL), telson length (Ts.L) (Table 3) and body wet weight (Wt) were observed between the sexes. Males were heavier than females in *P. indicus* (8.1±4.9 g and 5.7±5.6 g, respectively) and *M. affinis* (3.7±6.9 g and 2.7±3.5 g, respectively) while females were heavier than males in *P. merguiensis* (14.3±5.6 g and 13.4±5.8 g, respectively) and in *M. stebbingi* (4.3±3.6 g and 3.3±5.4 g, respectively), whereas in *M. brevicornis* there was no significant difference in the mean weight between the sexes (females = 0.7±1.5 g; males = 0.7± 0.2 g; Table 3). The *t*-test showed that total length was significantly different between sexes in *P. indicus* ($T = -10.39$; $P < 0.001$) and there was no significant difference in *M. affinis*, *P. merguiensis*, *M. brevicornis* and *M. stebbingi* ($T = -1.27$, $P > 0.005$; $T = 0.32$, $P > 0.005$; $T = -0.71$, $P > 0.005$; $T = 1.43$, $P > 0.005$, respectively).

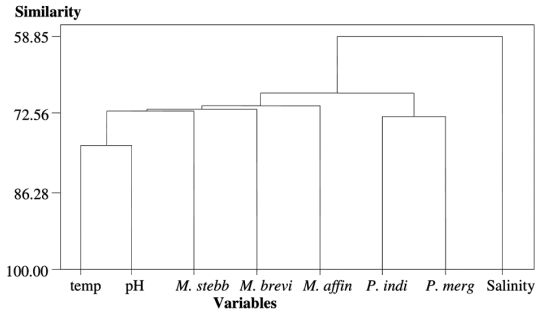

Fig. 4 — Cluster analysis (Dendrogram) showing the relationship between the environmental parameters of temperature, salinity and pH and the abundance of penaeid shrimps (*P. indi = Penaeus indicus*, *P. merg = P. merguiensis*, *M. affin = Metapenaeus affinis*, *M. brevi = M. brevicornis* and *M. stebb = M. stebbingi*)

The dendrograms resulting from cluster analysis of penaeid shrimp species with environmental parameters (temperature, salinity and pH) for Sonmiani Bay lagoon show similarities to each other (Fig. 4).

Discussion

A total of twelve shrimp species were collected during the present study from the Sonmiani Bay lagoon namely, *Penaeus indicus*, *P. merguiensis*, *P. japonicas*, *P. monodon*, *Panulirus penicillatus*, *Metapenaeu saffinis*, *M. brevicornis*, *M. stebbingi*, *M. monoceros*, *Parapenaeopsis stylifera*, *P. accilivirostris* and *P. hardwickii. P. indicus* was found to be the most dominant shrimp species of Sonmiani Bay lagoon (67.50 %), which indicates that its coastal waters provide a suitable environment for this species, followed by *M. affinis* (13.31 %), *P. merguiensis* (12.02 %), *M. brevicornis* (4.26 %) and *M. stebbingi* (1.60 %). Luchmann *et al*.[23] observed that two penaeid shrimp species that were present throughout the year showed seasonal differences, with *Farfantepenaeus paulensis* being more abundant in summer and *F. brasiliensis* in autumn. This suggests that there can be a temporal ontogenic partitioning, with different timing of off-shore migration of shrimp species and inshore recruitment patterns. Seasonal distribution of shrimp species indicates a reduction strategy for possible interspecific interactions. In the present study, seasonal differences were also observed with *P. indicus* being highly abundant during the SW monsoon, *M. affinis* in the SW and post-monsoon, *P. merguiensis* in the SW monsoon, *M. brevicornis* in the pre-monsoon and *M. stebbingi* in the SW monsoon seasons. Seasonal distribution of penaeid shrimp species shows that *P. inducs* are abundantly found in the SW monsoon. The seasonal peaks are dependent on environmental conditions and suitable habitats and have different strengths[24]. Another reason for peaks in penaeid shrimp numbers in the SW monsoon is that the period from May to July is a closed season for fisheries of Pakistan, and so no penaeid shrimps are removed from the lagoon by fisherman during this time. Environmental parameters such as temperature, salinity, light and pH affects the reproduction and abundance of marine penaeid shrimps. The present study showed that the abundance of penaeid shrimps was associated with increasing temperature and decreasing salinity of the lagoon. Increasing temperature is one of the factors known to influence migration of penaeid shrimps[25]. Indeed, their emigration from the lagoon is known to be influenced throughout the year by different environmental factors such as lunar phase, salinity and temperature[26]. Many studies have been reported on the abundance and distribution of penaeid shrimp in estuaries with respect to temperature and salinity gradients, substratum, type and the areal extent of estuarine vegetation, food resources and interspecific interactions[8-9,27-34]. In *P. indicus*, emigration has been related to decreasing water temperatures[35], and the current study has found that *P. indicus* which is the most abundant species on the coast of the Sonmiani Bay, showed similar results associated with decreasing temperatures.

Zupanovic[36] studied the distribution and abundance of penaeid shrimps along the coast of Pakistan *i.e*. Balochistan and Sindh coast with Pasni, the Sonmiani Bay and the coast of Karachi as the principal areas. He found *P. merguiensis* to be the dominant species in the months of January, February and April from these areas, while *P. penicillatus* was found in a high concentration near Karachi coast. Gololobov & Grobov[37] found that the species, *P. merguiensis* was caught from Sonmiani Bay and Karachi in the months of July and August, while fewer numbers of *P. penicillatus* were caught towards the southeast of Karachi, which is in partial agreement with the findings of this study.

In the present study, females exhibited a greater weight than males in two species, *P. merguiensis* and *M. stebbingi*, whereas males had a greater weight than females in *P. indicus* and *M. affinis*; in *M. brevicornis* there was no significant difference in weight between the two sexes. Differences in body size may be due to a greater weight increase per moult cycle, leading to a faster growth rate[38]. Sex-based size dimorphism in penaeid shrimps, with larger sizes and faster growth rates in females were observed as compared to males, in *P. aztecus*[39], *P. indicus*[40], *P. longistylus*[41], *Litopenaeus vannamei*[42] and *M. endeavouri*[43]. In contrast, in the present study the mean sizes of different body parts (*i.e.* carapace length, rostrum length and telson length) showed that in most cases males were larger in size compared to females.

No previous work has been done on the seasonal abundance, species diversity and growth parameters of the two sexes of penaeid shrimps in the Sonmiani Bay region. This study therefore adds more information on the family Penaeidae to complement the existing data available to manage the culturing of penaeid shrimps species in the Sonmiani Bay lagoon. This information will play a crucial role in origination of a sustainable development strategy for the fishing industry in this lagoon.

Acknowledgements

This work was accomplished under the project "The Status of Shrimp Fisheries in Sonmiani Bay Lagoon" funded to Naureen Aziz Qureshi from Pakistan Agricultural Research Council (PARC) and is thankfully acknowledged.

Conflict of Interest

No previous work has been done on the seasonal abundance, species diversity and growth parameters of the two sexes of penaeid shrimps in the Sonmiani Bay region. The Authors declare no conflicting interests.

Author Contributions

ZA: Conceptualization; formal analysis; investigation; software; original draft; and writing – review & editing. NUS: Supported to resend the manuscript to the Journal IJMS and NAQ: Funding acquisition; conceptualization; and supervision.

References

1 Trayer G W, Bjorndal K A, Ogden J C, Williams S L & Zieman J C, Role of larger herbivores in seagrass communities, *Estuaries*, 7 (1984) 63-76.

2 Huh S H & An Y R, Seasonal variation of shrimp (Crustacea: Decapoda) community in the eelgrass (*Zostera marina*) bed in Kwanyang Bay, Korea, *J Kor Fish Soc*, 30 (1997) 532-542.

3 FAO, *Fisheries Department, Fisheries Information, Data and Statistics Unit, FISHSTAT Plus database*, (FAO, Rome) 2008.

4 Garcia S, Reproduction, stock assessment models and population parameters in exploited penaeid shrimp populations, In: *Second Australian National Prawn Seminar*, edited by P C Rothlisberg & H P Staples, (NPS2 Cleveland, Australia), 1985, pp. 139-158.

5 Qureshi N A, The status of shrimp's fisheries in Sonmiani Bay Lagoon, Balochistan, Pakistan, (Pakistan Agricultural Research Council, Agricultural Linkage Programme (ALP)), 2007, pp. 1-127.

6 Aamir S A, *Fishing gears in operation along the coast of Pakistan: Their selectivity and effectiveness*, M. Phil. Thesis, University of Karachi, Pakistan, 2004.

7 Macnae W, Mangrove Forest and Fisheries, (FAO/UNDP Indian Ocean Fishery Programme and Indian Ocean Fishery Commission, IOFC/Dev/74/34, FAO, Rome), 1974, pp. 35.

8 Turner R E, Intertidal vegetation and commercial yields of penaeid shrimps, *Trans Am Fish Soc*, 106 (1977) 411-416.

9 Minello T J & Zimmerman R J, The role of estuarine habitats in regulating growth and survival of juvenile penaeid shrimp, In: *Frontiers of shrimp research*, edited by P F Deloach, W J Dougherty & M A Davidson, (Elsevier), 1991, pp. 1-16.

10 Ayub Z & Ahmed M, Distribution and abundance of penaeid shrimps juvenile in the backwaters and creeks along the coast of Sindh, Pakistan, *Pak J Zool*, 34 (2002) 19-28.

11 Amanat Z & Qureshi N A, Ovarian maturation stages and size at sexual maturity of *Penaeus indicus* (H. Milne Edwards, 1937) in the lagoon water of Sonmiani Bay, Balochistan, *Pak J Zool*, 43 (2011) 447-259.

12 Snead R E, Pakistan, In: *The world's coastline*, edited by E C Bird & M L Schwartz, (Von Nostrand Reinhold Company, New York), 1985, pp. 735-740.

13 Saifullah S M & Rasool F, *A preliminary survey of mangroves of Balochistan*, (WWF Pakistan Project Report), 1995.

14 Rasool F, Tunio S, Hasnian S A & Ahmad E, Mangrove conservation along the coast of Sonmiani, Balochistan, Pakistan, 16 (2002) 213-217.

15 Tirmizi N M & Bashir Q, Shore and off-shore penaeid prawns of northern Arabian Sea, (University Karachi Department Publication), 1973, pp. 71.

16 Bianchi G, Field guide to the commercial marine and brackish-water species of Tanzania, (Prepared and published with the support of TCP/URT/4406 and FAO (FIRM) Regular program, FAO, Rome), 1985.

17 Morrison J M, Codispoti L A, Gaurin S, Jones B, Manghnani V, *et al*., Seasonal variation of hydrographic and nutrient fields during the US JGOFS Arabian Sea process study, *Deep-Sea Res II*, 45 (1998) 2053-2101.

18 Stuerm de L M, Aspects of the biology of Scombemorus maculates (Mitchill) in Trinidad, *J Fish Biol*, 13 (1976) 155-172.

19 Emmanuel B E, Chukwu L O & Azeez L O, Cast net design characteristics, catch composition and selectivity in tropical open lagoon, *Afr J Biotech*, 7 (2008) 2081-2089.

20 Abowei J F N, The abundance, condition factor and Length-weight relationship of *Cynoglossus senegalensis* (Kaup, 1858) from Nkoro River Niger Delta, Nigeria, *Adv J Food Sci Tech*, 1 (2009) 57-62.

21 Pielou E C, *Mathematical ecology*, (John Wiley and Sons New York), 1977, pp. 1-385.

22 Odum E P, *Fundamental of ecology*, (W. B. Saunders Company, Philadelphia), 1971, pp. 574.

23 Luchmann K H, Freire A S, Ferreira N C, Daura-Jorge F G & Marques M R F, Spatial and temporal variations in abundance and biomass of penaeid shrimps in the subtropical Conceicao Lagoon, Southern Brazil, *J Mar Biol Assoc, UK*, 88 (2008) 293-299.

24 Sparre P, Ursin E & Venema S C, Introduction to tropical fish stock assessment, (Part 1: manual. FAO Fish. Tech. Paper no. 306.1. Rome), Italy, 1989.

25 Joubert L S & Davies D H, The penaeid prawns of the St. Lucia Lake System. Investigation report, Vol. 13, Oceanography Research Institute of South Africa, *Assoc Mar Biol Res*, 88 (1966) 293-299.

26 Subramaniam S P, Chwaka Bay (Zanzibar, East Africa) as nursery ground for penaeid prawns, *Hydrobiology*, 208 (1990) 111-122.

27 Rulifson R A, Substrate preferences of juvenile penaeid shrimps in estuarine habitats, *Cont Mar Sci*, 24 (1981) 35-52.

28 Mayer M A, Ecology of juvenile white shrimp, *Penaeus setiferus* Linnaeus, in the salt marsh habitat, Ms Thesis, Georgia Institute of Technology, Atlanta, GA, 1985.

29 Dall W, Hill B J, Rothlisberg P C & Sharples D J, *Advance in Marine Biology - The biology of Penaeidae*, Vol 27, (London: Academic press), 1990, pp. 489.

30 Vance D J, Haywood M D E & Staples D J, Use of a mangrove estuary as a nursery area by postlarval and juvenile banana prawns. *Penaeus merguiensis* de Man, in northern Australia, *Estuar Coast Shelf Sci*, 31 (1990) 689-701.

31 Vance D J, Haywood M D, Heales D S, Kenyon R A, Lomeragan N R, *et al*., How far do prawns and fish move into mangroves? Distribution of juvenile banana prawns *Penaeus merguiensis* and fish in a tropical mangrove forest in Northern Australia, *Mar Ecol Prog Ser*, 131 (1996) 115-124.

32 Wenner E L & Beatty H R, Utilization of shallow estuarine habitats in South Carolina, U.S.A., by postlarval and juvenile stages of *Penaeus* spp. (Decapoda: Penaeidae), *J Crust Biol*, 13 (1993) 280-295.

33 Haywood M D E, Vance D J & Loneragan N R, Sea grass and algal beds as nursery habitats for tiger prawns (*Penaeus semisulcatus* and *P. esculentus*) in a tropical Australian estuary, *Mar Biol*, 122 (1995) 213-223.

34 McTigue T A & Zimmerman R J, The use of infauna by juvenile *Penaeus aztecus* Ives and *Penaeus setiferus* (Linnaeus), *Estuaries*, 21 (1998) 160-175.

35 Benfield M C, Bosschieter J R & Forbes A T, Growth and emigration of *Penaeus indicus* H. M. Edwards (Crustacea: Decapoda: Penaeidae) in the St. Lucia Estuary, Southern Africa, *Fish Bull*, 88 (1990) 21-28.

36 Zupanovic S, *Shrimp exploitations off the coast of the West Pakistan*, (Report of FAO/Marine Fisheries Department), Pakistan, 1971.

37 Gololobov J A & Grobov A G, The fishery investigation of Azcherniro in the northern part of the Arabian Sea, (Summary account on the scientific research work done of the expedition in the waters adjacent to the Islamic Republic of Pakistan from January to December, 1969). Part I and II, 1969, pp. 252.

38 Hansford S W & Hewitt D R, Growth and nutrient digestibility by male and female *Penaeus monodon*: Evidence of sexual dimorphism, *Aquaculture*, 125 (1994) 147-154.

39 Parrack M L, Aspects of brown shrimp, *Penaeus aztecus*, growth in the northern Gulf of Mexico, *Fish Bull*, 76 (1979) 827-836.

40 Devi S L, Growth and population dynamics of the Indian white prawn, *Penaeus indicus* H. M. Edwards, from Kakinada, *Proc Ind Acad Sci*, 95 (1986) 629-639.

41 Dredge M C L, Movement, growth and natural mortality rate of the red spot king prawn, *Penaeus longistylus* Kubo, from the Great Barrier Reef lagoon, *Aust J Mar Fresh Res*, 41 (1990) 399-410.

42 Chow S & Sandifer P A, Differences in growth, morphometric traits, and mail sexual maturity among pacific white shrimp, *Penaeus vannamei*, from different commercial hatcheries, *Aquaculture*, (1991) 165-179.

43 Buckworth R C, Movements and growth of tagged blue endeavour prawns, *Metapenaeus endeavouri* (Schmii, 1926), in the western Gulf of Carpentaria Australia, *Aust J Mar Fresh Res*, 43 (1992) 1283-1299.