Mangrove vegetation and community structure of brachyuran crabs as ecological indicators of Pondicherry coast, South east coast of India

Satheeshkumar P.*

Received: December 2010 Accepted: April 2011

Abstract

Baseline ecological studies of Pondicherry mangroves are important for monitoring, management and conservation of mangrove ecosystems. A brachyuran crab faunal assemblage at four stations of Pondicherry mangroves is described and monthly samplings were made during September 2008 – August 2009. Totally 22 species of brachyuran crabs belonging to 12 genera and 5 families were recorded; crabs belonging to the family Portunidae and Ocipodidae are most dominant group represented by total of 16 species. Six species considered are as a commercially important and out of which, on three species *Scylla serrata*, *Thalamitta crenata* and *Portunus sanguinolentus* are catch large quantities from stations 1 and 2. *Portunus pelagicus*, *P. sanguinolentus* and *T. crenata* were totally absent in stations 3 and 4. Population densities of brachyuran fauna ranged from 29 -71 ind. m^2, the diversity ranged from 0.96 -2.18 bit. ind $^{-1}$, the richness varied from 0.42 -0.74, and the evenness varied from 0.41 -.072. Maximum diversity values were recorded during post monsoon. The crab community recorded was analyzed by univariate and multivariate statistical techniques. Crab community structure was correlated with vegetation structure, and environmental factors were positively correlated with surface water pH, salinity, tree dominance, tree diversity and tidal inundation and negatively correlated with sulphide, organic matter, senescent leaves and decaying leaves, suggesting that the mangrove vegetation is important to the crab fauna as a habitat and food supply.

Keywords: Brachyura, Crustacea, Decapoda, mangrove, Pondicherry

[DOR: 20.1001.1.15622916.2012.11.1.14.0]

Central Marine Fisheries Research Institute,Kochi, Kerala – 682018, India.
*Corresponding author's email: indianscientsathish@gmail.com

Introduction

Indian mangroves have a rich diversity of soil dwelling organisms which include micro, meio and macro forms. Mangrove ecosystem provides an ideal nursery and breeding ground to most of the marine and brackish water fish and shellfish. Decapoda crustaceans are very common invertebrates inhabiting the marine environment. Brachyuran crabs comprise approximately 6793 species worldwide and due to their great abundance, they may be considered as one of the most relevant groups of the marine benthos, both in terms of biomass and community structure (Ng et al., 2008). Several studies have focused on the seasonal movements of economically viable crab species such as (Raut et al., 2005; Ajmal Khan et al., 2005; Saravanakumar et al., 2007). The association of brachyuran crabs with mangrove flora, behavior, feeding and ecology is of great interest to biologists (Raut et al., 2005). Seasonal movements of brachyuran crabs are related to different life stages such as mating, spawning, maturation, etc. (Stone et al., 1992). Continued examination of spatial and temporal studies on floral and faunal assemblages with the previous works will provide better estimates of recent changes in marine communities and patterns of biodiversity. Many factors control the size of the brachyuran assemblage of a habitat qualitatively and quantitatively, of which habitat complexity is the chief factor that widens the spectrum of the brachyuran diversity of a habitat (Williams et al., 1990; Bortulus et al., 2002). The role of brachyuran crabs in mangroves has been emphasized in recent years, especially in view of commercially valuable species found there and others which affect the overall mangrove ecology (Tan and Ng 1994). Degradation of mangrove leaf litter by crabs, sesarmids in particular, plays a major link between primary and secondary producers (Ajmal Khan et al., 2005). Their burrowing habit assists in oxidizing the sulphide that builds up due to high rate of organic decomposition in mangrove swamps (Diemont and van Wijngaarden 1975. Crabs are good source of food to marine life as well as to man as a good protein source (Siddiqui and Zafar, 2002). They form food for many birds, snakes and predatory fishes and their larvae are also consumed by many carnivores; thus crabs play a significant role in the food chain. In a way, the saying ‘no mangroves, no prawns’ is more applicable to the crabs. Recent investigations have shown that loss of diversity can have a significant effect on ecosystem functioning in experimental systems (Symstad and Tilman, 2001; Ashton et al., 2003). However, current understanding cannot predict how natural ecosystems respond to increasing losses of species. Anthropogenic disturbances to natural ecosystems often result in simplification of the ecosystem and diversity loss, but the consequences on ecosystem functioning are often unrecorded due to a lack of baseline studies and monitoring of natural ecosystems. Environmental parameters also play a role in the biodiversity and ecological function of mangrove ecosystems. Studies conducted on the mangrove macrofauna in South- East Asia (Ashton et al.,, 2003a, b) have described the abundance and distribution of benthic macro fauna in relation to environmental conditions. The objective of this study was to describe and compare the biodiversity and community structure of brachyuran crabs at mangrove forest sites and to use the data sets of the study as a baseline data to monitor the mangrove ecosystem of Pondicherry.

Materials and methods

Study site

In nature the study area lies within the margins of latitudes 11°.90’107” N to 11°.90’703” N and longitudes 79°. 80' 547" E to 79°.81' 851" E. Mangrove exists as fringing vegetation over 168 ha distributed along the sides of Ariankuppam estuary, which empties into the Bay of Bengal at Veerampatinam on the southeast coast of India (Fig. 1). The present investigation was carried out in four well formed stations: 1 Veerampattinam; 2 Thengaithittu; 3 Ariyankuppam; 4 Murungapakkam mangrove areas of Pondicherry and monthly samplings were made during September 2008 – August 2009. The details on GPS coordinates, zone and soil substratum are presented in Table 1.

Mangrove zonation of the study site

Seven true mangrove species belonging to 3 families, 16 mangrove associate plants belonging to 12 families were recorded in this present study area (Saravanan et al., 2008). *Avicennia* zone – It forms very small patch of *Avicennia marina* and *A. officinalis* dense stand to the mouth region of estuary of Veerampattinam (Station1), *Rhizophora* zone - they are four patches of *Rhizophora mucronata* and *R. apiculata* on the southern part of Thengaithittu (Station 2) and four patches of *R. mucronata* and *R. apiculata* near the mouth of river. *Acanthus* zone – *Acanthus ebracteatus* and *A. illicifolius* forms dense stand to the western and northern side of Ariyankuppan (Station 3) and Murungapakkam (Station 4). *Bruguiera cylindrica* spreads from the western end of Murungapakkam up to eastern end of Ashram Islet. *Avicennia* and *Rhizophora* mixed zone spreads near the bridge at station 4.

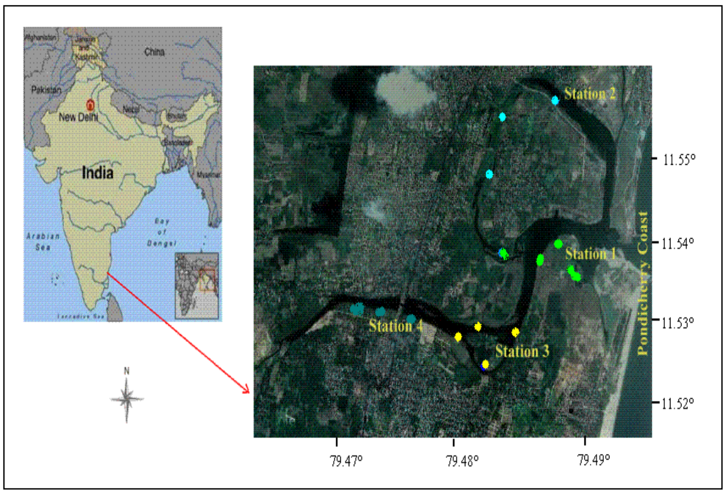


Figure 1: Monitoring stations in Pondicherry mangroves

[DOR: 20.1001.1.15622916.2012.11.1.14.0]

Table 1: Details on GPS coordinates, Mangrove zone and soil substratum

Study area	Mangrove Zone	Latitude	Longitude	Substratum
Station 1	*Avicennia* zone	11°. 90'450" N	79°. 82' 563" E	Sand
Station 2	*Rhizophora zone*	11°. 90'703" N	79°. 81' 851" E	Sandy and silt
Station 3	*Acanthus + Acicennia* mixed zone	11°. 90'107" N	79°. 80' 547" E	Silt and clay
Station 4	*Rhizophora & Acicennia* zone	11°. 90'154" N	79°. 80' 571" E	Clay

Table 2: Summary of the history, vegetation and environmental characteristics

Site	Planting	Density in 100 m^2	Tree species	Dominance	H	DL (no.m^2)	SL (no.m^2)	TDNC
Veerampattinam	Natural + Man	21	8	0.51	0.64	34	2.4	254
Thengaithittu	Natural + Man	19	6	0.6	0.68	53	3.6	248
Ariayankuppam	Natural + Man	22	7	0.54	0.6	66	4.5	153
Murungapakkam	Natural	18	4	0.58	0.52	47	5.8	129

Planting Source (Kathiresan et a l., 2000; Saravanan et al., 2008).

DL = Decaying Leaves; SL = Senescent Leaves; TDL = Tidal inundation; TDNC= **TDL no. days covered/yr);** H’ = Shannon diversity

[DOR: 20.1001.1.15622916.2012.11.1.14.0]

Field collection

The surface water temperature was measured using a standard thermometer. Salinity by hand held Refractometer (ERMA), water pH (hand held pH meter, pH scan-2), Dissolved oxygen was estimated by Winkler's method and Sulphide by (Strickland and Parsons 1972), and Sediment texture (Krumbein and Pettijohn 1983) was determined by pipette analysis method. Total organic matter of sediment was determined by wet oxidation method (El Wakeel and Riley 1957). A 100 m^2 vegetation quadrate was sampled at each site. Within each quadrate the number of mangrove tree and sapling species and the number of individuals within each species was determined (Tomilson 1986). Replicate measurements (n=3 to 5) of environmental variables were made in each vegetation quadrate. The number of senescent and decaying leaves was recorded from ten 1-m^2 quadrates and tidal inundation regime recorded using the method of English et al., (1994).

Crab were sampled during these periods were collected by hand using a trowel and plastic beaker; burrowing intertidal crabs were collected by digging the substratum. The crabs were sampled at low tide, with the assumption that brachyuran crabs faunas do not change significantly overt this time scale (Ashton et al., 2003a). Brachyuran crabs were preserved using 10% formalin and identified up to species level using the taxonomic keys of (Williams 1984; Sethuramalingam and Ajmal Khan 1991; Ng et al., 2008). For the sake of interpreting the data, a calendar year wise divided into four main seasons, viz pre monsoon (July-September), monsoon (October-December), post monsoon (January-March), and summer (April-June). The data was subjected to univariate analyses for studying the brachyuran community structure using Shannon and Weaver (1949) for species diversity, Pielou (1966) for species dominance and evenness and Gleason (1992) used for species richness.

Data analysis

Statistical analyses were performed using SPSS (statistical Version 13 for Windows XP, SPSS, and Chicago, IL, USA). Simple correlation (r) was made for the statistical interpretation of the physico-chemical parameters of water, sediment characteristics and crab species diversity indices. Relationship of brachyuran crab species to different environmental parameters was determined using multivariate statistical analysis such as Cluster analysis (CA), Principle Component Analysis and Multidimensional Scale plot (MDS) was constructed based on crab abundance after log transformation. Based on the groups obtained cluster analysis, species having the greatest contribution to this division were determined using similarity percentage program PAST (statistical Version 1.93 for Windows XP).

Results

Mangrove Vegetation

Table 2 gives a summary of the forest management and vegetation characteristics at the study sites. In this study sites the number of mangrove tree species was low and dominance of *Rhizophora* spp. and *Avicennia* spp. high. Veerampattinam the mouth of estuary and Thengaithittu lagoon

[DOR: 20.1001.1.15622916.2012.11.1.14.0]

had the highest density (31 and 38) and diversity (0.64 and 0.68). The lowest dominance and diversity was found at Ariyankuppam because the site was *Acanthus* - *Acicennia* spp. mixed zone had the lowest *Acanthus* dominance (25%). The Murungapakkam transect had the lowest *Rhizophora* dominance (21%).

Environmental parameters

Total annual rainfall of the study area 1520.7 mm, with monthly varied from 1.1-808 mm. Surface water temperatures in the study area varied from 20.13 ºC - 37.91 ºC respectively, whereas maximum during summer and minimum during monsoon (Fig. 2).

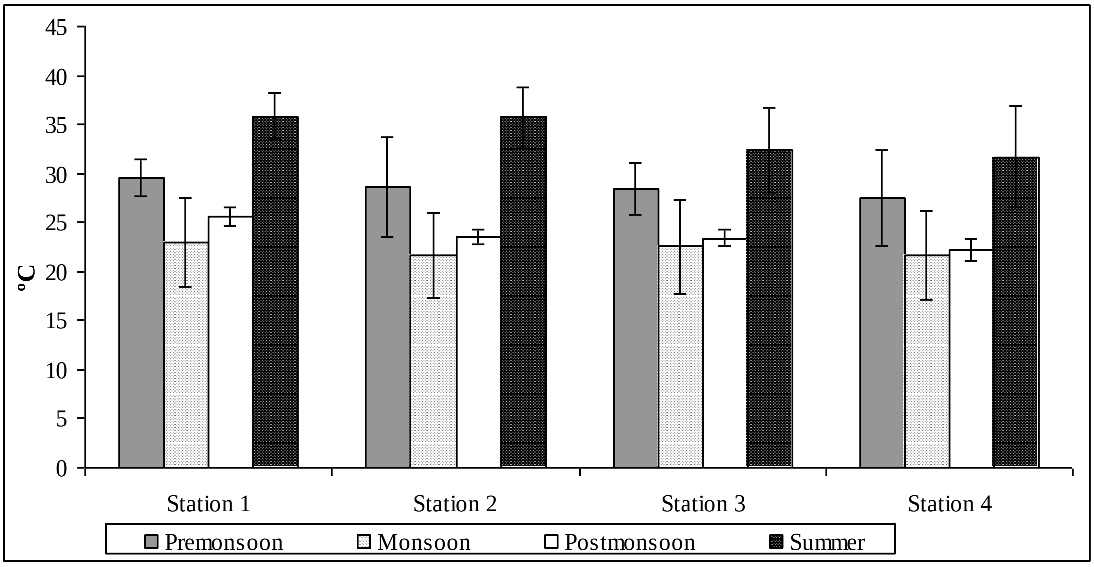


Figure 2: Seasonal variation of temperature at stations 1- 4 Pondicherry mangroves

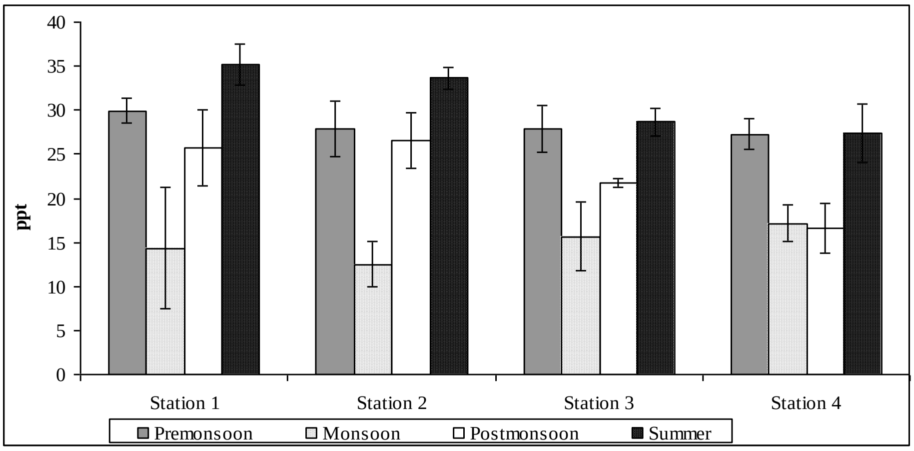


Figure 3: Seasonal variations of salinity at stations 1- 4 Pondicherry mangroves

[DOR: 20.1001.1.15622916.2012.11.1.14.0]

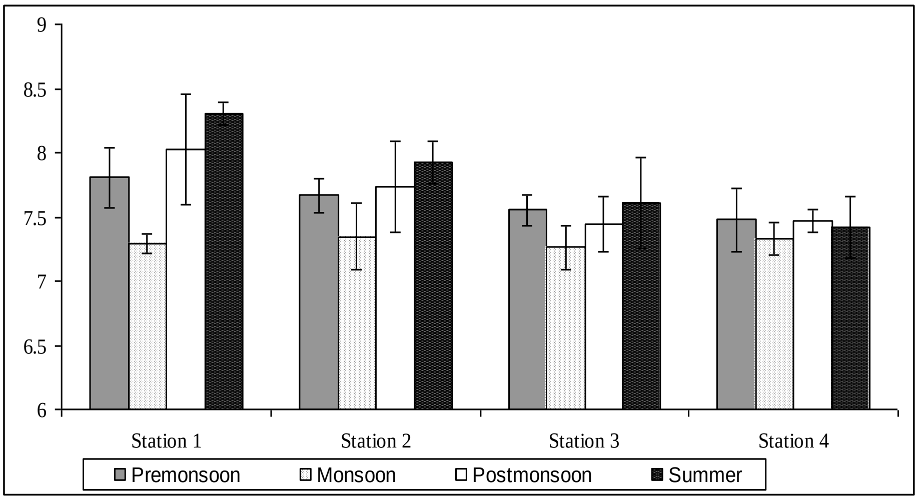


Figure 4: Seasonal variations of pH at station 1- 4 Pondicherry mangroves

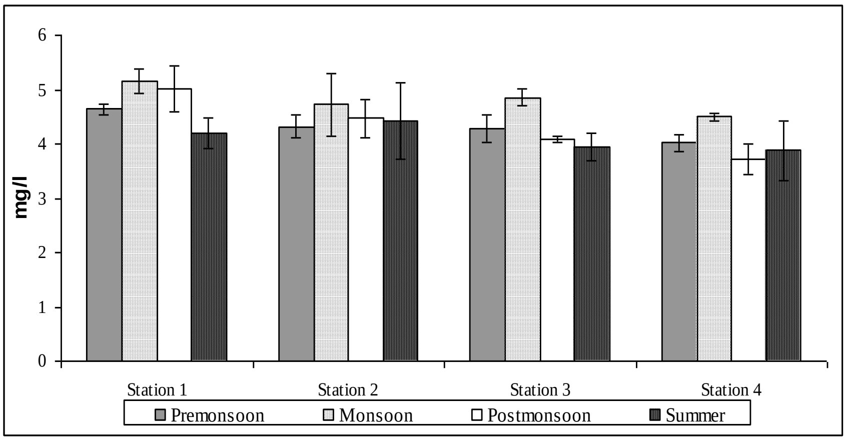


Figure 5: Seasonal variations of dissolved oxygen at station 1- 4 Pondicherry mangroves

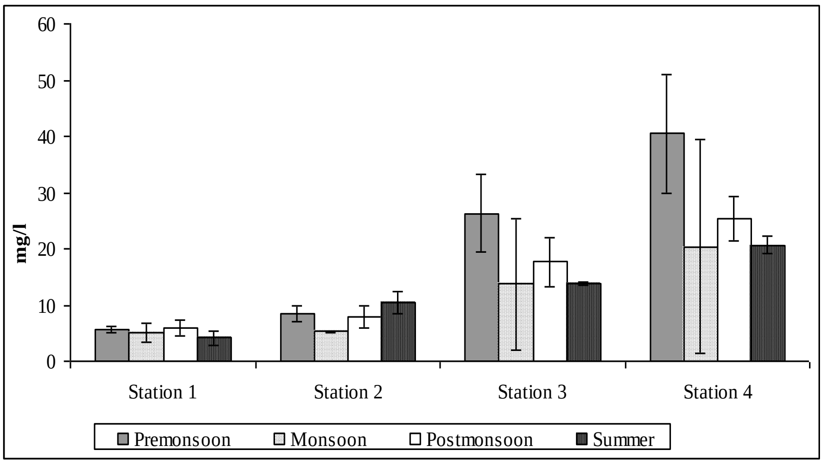


Figure 6: Seasonal variations of sulphide recorded from station 1- 4 Pondicherry mangroves

Salinity indicated wide variations ranged between 6.36-36.77 ppt (Fig. 3), salinity was positively correlated with tidal inundation (r = 0.569; P<0.05). Hydrogen ion concentration (pH) varied from 7.11-8.36, pH in surface waters remained slightly alkaline throughout the study period at all 4 stations with maximum during summer and minimum during monsoon (Fig. 4). Dissolved oxygen recorded high (5.16 mg/l) during monsoon and low (3.45 mg/l) during summer (Fig. 5) and season-wise observation of dissolved oxygen indicated an inverse trend with temperature and salinity. Seasonal mean fluctuations recorded in sulphide concentration varied from 2.76-47.16 mg/l respectively with maximum (47.16 mg/l) were recorded at station 4. Significant negative correlation between sulphide and DO (r = -0.601; P<0.05) at station 4 indicates that DO is largely influenced by sulphide at this station. The highest numbers of senescent leaves were recorded from the stations 4 and 3 and the highest numbers of decaying leaves were recorded at station 3. The numbers of senescent leaves and DO were negatively correlated (r= -0.66; P<0.05) and pH (r= -0.583; P<0.05). Organic matter and decaying leaves were significantly correlated (r= 0.592; P<0.05) and with senescent leaves ((r= 0.890; P<0.01). Tidal inundation was also negatively correlated with senescent leaves (r = -0.923; P<0.01), and with OM ((r= 0.94; P<0.05). Table 3 gives a summary of mangrove sediment characteristics, At all the areas the substratum was predominated by sand followed by silt and clay in comparatively smaller proportions. Sand fraction ranged between 63.69-87.31% followed by silt (9.89-29.35%), clay (3.06-17.98%). Organicmatter varied from (0.94-3.94%) attributing transport of sediments from one place to another associated with tidal currents and relatively high in Pre monsoon. Significant negative correlation between OM and clay (r= -0.537; P<0.05) and sulphide positively correlated with OM (r= 0.84; P<0.01) at stations 3 and 4.

Brachyuran crab abundance and diversity

A total of 22 species of brachyuran crabs belonging to 12 genera and 5 families were recorded from all the four stations (Table 4). The abundance of crabs' value between 29-71/m^2, while the highest number of species was found at stations 1 and 2, the lowest amount was found at stations 3 and 4 in Pondicherry mangroves. Systematic studies on the brachyuran crabs of Pondicherry coast are poorly known till the present authors took up the study. The most dominant species was *Uca annulipes* followed by *Cardisoma carnifex* and *Selatium brockii* were recorded abundantly in all seasons in almost all the study site from intertidal zone where the fringing mangrove distribution is established. Species found in all the four stations include *Scylla serrata*, *S. tranquebarica, Muradium tetragonum* were recorded from all the four stations. *Portunus sanguinolentus, P. pelagicus, Thalamitta crenata, Charybdis lucifera* and *Callappa lophos* were recorded respectively in stations 1 and 2 only; it's totally absent in stations 3 and 4 because of high sulphide content and high pollution which may be the responsible factor for the non availability of this species. The result of various diversity indices are calculated and given in Table 5.

[DOR: 20.1001.1.15622916.2012.11.1.14.0]

Table 3: Seasonal variation of Physico-chemical parameters of water and sediment characteristics

Season	Sand (%)	Silt (%)	Clay (%)	OM (%)
Monsoon				
Station 1	85.38±3.64	10.45±7.81	4.17±1.59	0.94±0.31
Station 2	69.92±11.18	23.61±6.48	6.47±4.98	1.94±0.89
Station 3	73.24±17.20	21.60±12.94	5.81±3.18	3.21±0.88
Station 4	75.78±4.02	22.53±2.85	3.49±0.44	3.3±0.79
Postmonsoon				
Station 1	72.40±16.31	16.66±14.41	10.01±0.84	2.58±0.31
Station 2	74.55±21.19	17.39±20.67	8.22±4.47	2.07±1.27
Station 3	67.60±22.37	26.06±24.07	6.23±1.91	3.13±0.86
Station 4	39.54±22.62	29.35±8.03	31.20±22.35	3.53±0.71
Summer				
Station 1	87.31±9.74	9.89±11.46	3.06±1.59	2.74±0.51
Station 2	83.42±11.46	12.23±9.36	4.99±3.021	2.18±0.39
Station 3	75±11.48	15.31±8.64	10.49±10.23	3.64±0.45
Station 4	67.88±29.44	14.72±19.25	17.98±11.24	3.76±0.44
Pre monsoon				
Station 1	71.83±21.02	24.21±20.75	4.04±0.42	1.12±0.30
Station 2	63.69±22.63	25.66±9.06	11.76±12.51	1.20±0.36
Station 3	77.87±10.06	18.02±8.69	4.07±2.05	3.82±0.74
Station 4	68.13±12.28	26.41±12.84	5.54±0.74	3.94±0.68

OM = Organic matter

[DOR: 20.1001.1.15622916.2012.11.1.14.0]

Table 4: Checklist of Brachyuran crabs recorded at Stations 1-4, Pondicherry mangrove

S.No	Species	Station 1	Station 2	Station 3	Station 4
1	*Callappa lophos*	-	+	-	-
2	*Cardisoma carnifex*	+	+	+	+
3	*Charybdis lucifera*	+	+	-	-
4	*C. feriata*	+	+	+	-
5	*C. granulta*	+	-	+	-
6	*Muradium tetragonum*	+	+	+	+
7	*Scylla serrata*	+	+	+	+
8	*S. tranquebarica*	+	+	+	+
9	*Selatium brockii*	+	+	+	+
10	*Portunus sanguinolentus*	+	-	-	-
11	*P. pelagicus*	+	+	-	-
12	*Thalamitta crenata*	+	+	-	-
13	*T. chaptali*	-	+	+	-
14	*Uca anulipes*	+	+	+	+
15	*U. triangularis*	-	+	+	-
16	*U. inversa*	-	-	+	+
17	*Metapograpsus latifrons*	+	-	-	+
18	*M. messor*	-	-	-	+
19	*Ocypode macrocera*	+	+	+	-
20	*O. platytarsis*	+	+	-	-
21	*Macropthalmus depressus*	+	-	-	-
22	*M. erato*	-	+	+	-

(+) Present; (-) absent

The brachyuran fauna in the study area showed great diversity in stations 1 and 2 and less diversity in station 3 and 4. Species dominance was least (0.32) at station 3 and maximum (0.48) at station 1. The diversity values varied from 0.96-2.18, the highest H' value was observed in Post monsoon season at station 1 and least observed in monsoon at station 3. Evenness and richness was least at station 3 during monsoon and maximum at station 1 in Post monsoon.

Fauna Correlation with mangrove vegetation

Fauna correlation of crab and with the plant community (total species, tree density, diversity, senescent leaves, decaying leaves) is shown in Table 6. The results show tree dominance, diversity and total species were positively correlated to crab dominance and diversity indices. Pearson correlations between the brachyuran fauna and the vegetation structure revealed significant ($P<0.05$) positive relationships between crab dominance and tree dominance ($r = 0.64$;

P<0.01), tree diversity (r = 0.57; P<0.05), Crab diversity (H') and total species (r = 0.54; P<0.05) and with tree diversity (r = 0.84; P<0.01), Crab richness and tree diversity (r = 0.76; P<0.01) and total species (r = 0.65; P<0.01). Crab dominance was negatively correlated with senescent leaves (r = -0.60; P<0.01) and the richness ((r = -0.78; P<0.05).

Table 5: Species diversity indices of brachyuran crabs in Pondicherry mangroves

Season	Dominance	Sha. Diversity	Evenness	Richness
Monsoon				
Station 1	0.419	1.47	0.54	0.53
Station 2	0.473	1.26	0.59	0.60
Station 3	0.324	1.08	0.41	0.48
Station 4	0.354	0.96	0.46	0.42
Post monsoon				
Station 1	0.484	2.18	0.72	0.72
Station 2	0.466	2.16	0.67	0.69
Station 3	0.397	1.96	0.63	0.63
Station 4	0.389	1.67	0.71	0.46
Summer				
Station 1	0.431	1.28	0.63	0.65
Station 2	0.415	1.14	0.61	0.65
Station 3	0.348	1.17	0.48	0.52
Station 4	0.406	0.97	0.55	0.54
Premonsoon				
Station 1	0.406	1.56	0.52	0.74
Station 2	0.448	1.31	0.68	0.61
Station 3	0.374	1.20	0.56	0.52
Station 4	0.370	1.0	0.61	0.47

[DOR: 20.1001.1.15622916.2012.11.1.14.0]

Table 6: Correlation relationship between environmental parameters and brachyuran fauna diversity indices and mangrove vegetation structure

	Clay	C.domi	Density	Dl	DO	Even	H'	OM	pH	Rich	S	Sand	Silt	SL	Sul	Td	Tl	TD	TS
Clay	1.00	0.03	-0.33	0.00	-0.53	0.33	0.16	0.29	-0.15	-0.28	0.13	-0.85*	0.33	0.44	0.25	-0.42	-0.35	0.40	0.49
C. domi	0.03	1.00	0.73*	-0.47	0.32	0.39	0.58*	-0.69**	0.46	0.62*	0.83**	0.05	-0.18	-0.60*	-0.58*	0.57*	0.77*	0.64*	0.24
Density	-0.33	0.73**	1.00	-0.18	0.51	0.12	0.35	-0.82**	0.45	0.72*	0.30	0.37	-0.29	-0.78**	-0.78**	0.10	0.93*	0.97*	0.51*
DL	0.00	-0.47	-0.18	1.00	-0.32	-0.15	-0.19	0.59*	-0.42	-0.25	-0.17	-0.11	0.22	0.47	0.32	0.26	-0.49	-0.06	-0.15
DO	-0.53*	0.32	0.51	-0.32	1.00	0.03	0.23	-0.66**	-0.02	0.40	-0.27	0.48	-0.23	-0.66**	-0.60*	0.32	0.61*	0.54*	0.57*
Even	0.33	0.39	0.12	-0.15	0.03	1.00	0.47	-0.12	0.22	0.12	0.12	-0.41	0.31	0.04	0.01	-0.35	0.10	0.03	-0.23
H	0.16	0.58*	0.35	-0.19	0.23	0.47	1.00	-0.40	0.30	0.59	0.30	-0.19	0.09	-0.44	-0.37	0.83	0.40	0.37	0.54*
OM	0.29	-0.69**	-0.82**	0.59*	-0.66	-0.12	-0.40	1.00	-0.42	-0.67**	-0.23	-0.31	0.23	0.89**	0.84**	-0.13	-0.94**	-0.78*	-0.60*
pH	-0.15	0.46	0.45	-0.42	-0.02	0.22	0.30	-0.42	1.00	0.64*	0.83**	0.34	-0.47	-0.58*	-0.41	0.15	0.57*	0.44	0.43
Rich	-0.28	0.62**	0.72**	-0.25	0.40	0.12	0.59	-0.67	0.64**	1.00	0.56	0.29	-0.25	-0.78**	-0.70	0.35	0.76**	0.75	0.65**
S	0.13	0.83**	0.30	-0.17	-0.27	0.12	0.30	-0.23	0.83**	0.56*	1.00	0.16	-0.47	-0.35	-0.37	0.13	0.56*	0.31	0.28
Sand	-0.85*	0.05	0.37	-0.11	0.48	-0.41	-0.19	-0.31	0.34	0.29	0.16	1.00	-0.7*	-0.52*	-0.40	0.41	0.43	0.44	0.54**
Silt	0.33	-0.18	-0.29	0.22	-0.23	0.31	0.09	0.23	-0.47	-0.25	-0.47	-0.77*	1.00	0.45	0.44	-0.27	-0.38	-0.32	-0.42
SL	0.44	-0.60**	-0.78**	0.47	-0.66	0.04	-0.44	0.89**	-0.58*	-0.78*	-0.35	-0.52*	0.45	1.00	0.84	-0.48	-0.92**	-0.83*	-0.87**
Sul	0.25	-0.58	-0.78**	0.32	-0.60	0.01	-0.37	0.84**	-0.41	-0.70**	-0.37	-0.40	0.44	0.84**	1.00	-0.33	-0.84**	-0.80*	-0.68
Td	-0.42	0.57*	0.10	0.26	0.32	-0.35	0.83**	-0.13	0.15	0.35	0.13	0.41	-0.27	-0.48	-0.33	1.00	0.15	0.32	0.86**
Tl	-0.35	0.77**	0.93**	-0.49	0.61*	0.10	0.40	-0.94*	0.57*	0.76**	0.56*	0.43	-0.38	-0.92**	-0.8**	0.15	1.00	0.90**	0.63**
TD	-0.40	0.64**	0.97**	-0.06	0.54*	0.03	0.37	-0.78*	0.44	0.75**	0.31	0.44	-0.32	-0.83**	-0.80	0.32	0.90**	1.00	0.66**
TS	-0.49	0.24	0.51*	-0.15	0.57*	-0.23	0.54*	-0.60	0.43	0.65**	0.28	0.54*	-0.42	-0.87**	-0.68**	0.86**	0.63**	0.66*	1.00

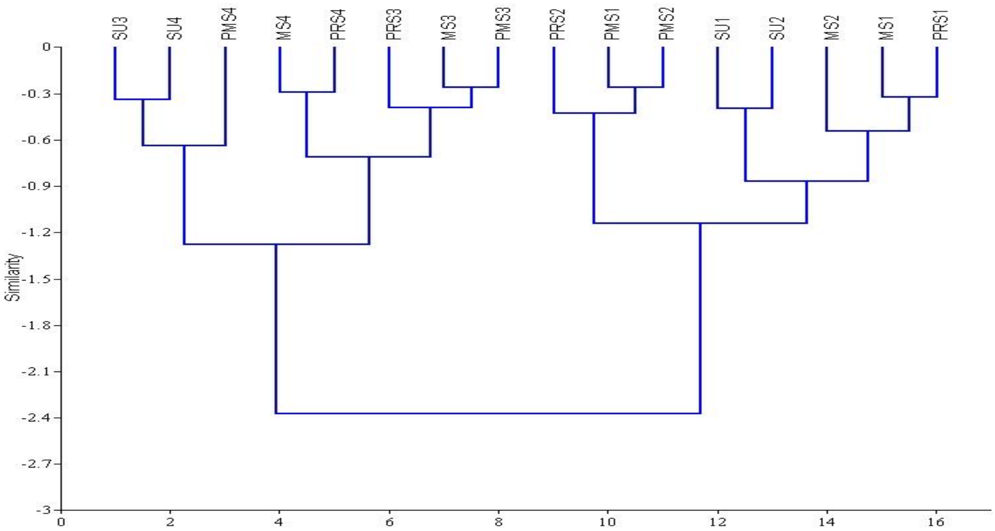
C. domi = Crab dominance; DL =Decaying leaves; DO = Dissolved oxygen; Even = Evenness; H = Shanon Diversity; OM = Organic matter; Rich = Richness; S= Salinity; SL = Senescent leaves; Sul= Sulphide; Td = Tree dominance; Tl = Tidal inundation; TD = Tree diversity; TS = Total species; *Correlation is significant at the 0.05 level; ** Correlation is significant at the 0.01 level

Correlation of species diversity indices with environmental parameters

Correlation analysis showed sufficient relationship between benthic diversity indices and studied a biotic variable (Table 6). Among the independent variables analyzed, salinity indicated significantly a strong correlation with the brachyuran faunal dominance (r = 0.836; P<0.01) and species richness (r = 0.559; P<0.05). pH had a positive correlation with the species richness (r = 0.638; P<0.01). Sulphide show a strong negative correlation between species richness (r = - 0.701; P<0.01) and Organic matter also show a strong negative correlation with the richness (r = - 0.673; P<0.01). This analysis shows that single factor effect alone could not predict the spatial variability in the distribution of brachyuran crabs and from the results it is evident that a minimum of two environmental factors influence significantly.

Multivariate analysis

Bray – Curtis similarities were calculated on (root transformed) species abundance, diversity indices, in relation to the environmental parameters and vegetation structure for the two groups and the resulting dendrogram is shown in (Figure7).



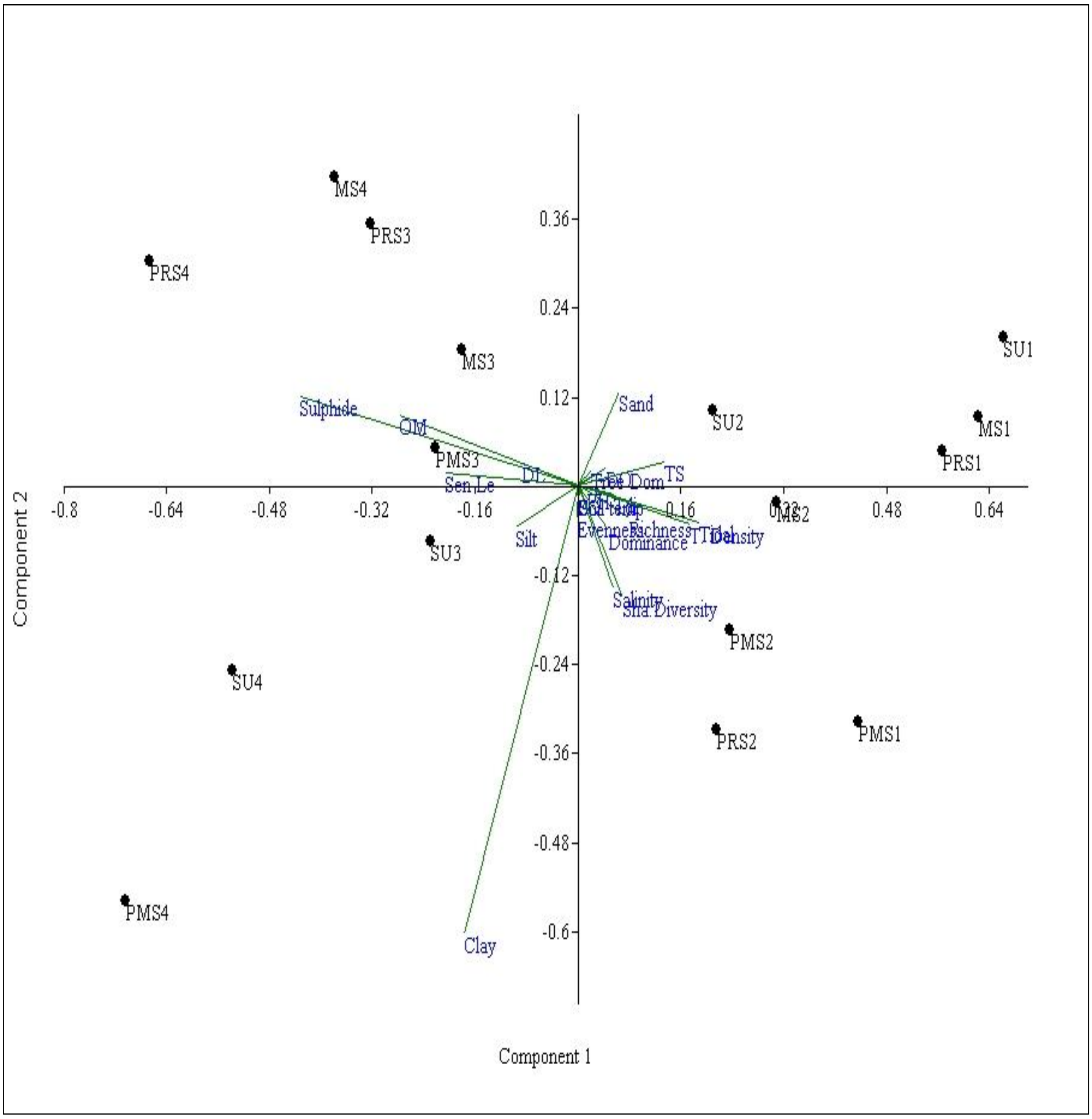
MS1monsoon station 1, MS2 monsoon station 2, MS3 monsoon station 3, MS4 monsoon station 4, PMS1 post-monsoon station1, PMS2 post-monsoon station 2, PMS3 post-monsoon station 3, PMS4 post-monsoon station 4, SU1 Summer station 1, SU2 Summer station 2, SU3 Summer station 3, SU4 Summer station 4, PRS1 pre-monsoon station 1, PRS2 pre-monsoon station 2, PRS3 pre-monsoon station 3, PRS4 pre-monsoon station 4

Figure 7: Dendrogram based on ward's method clustering for four stations in different seasons in Pondicherry mangroves

They consisted Group 1 (*Avicennia* and *Rhizophora* zone) MS1-MS2, PMS1-PMS2, SU1 –SU2, PRS1-PRS2 and Group 2 (Sites 3 and 4) MS3-MS4, PMS3-PMS4, SU3 –SU4, PRS3-PRS4. Group I consisted of increased diversity, richness and abundance of organisms observed in stations 1 and 2, could be due to the increase proportion of coarser sediment with high amount of DO observed in these stations. Group 2 (*Acanthus* and *Acicennia* mixed and *Rhizophora* and *Acicennia* zone) was differentiated in to fine sediment texture with high OM content, however low amount of DO and high sulphide with high OM content observed in these stations. In this case, low species abundance and diversity at stations 3 and 4, where the high OM and sulphide adversely affect the benthic fauna. This could also be evidenced from the negative correlation of faunal groups obtained from the correlation analysis. Figure (8) Shows the Principle Component Analysis was calculated on species abundance, diversity indices, in relation to the environmental parameters and vegetation structure for the two groups and distinct groups at 56.46% similarity in the study area. Group 1 was restricted to the station 1 and 2 to all the seasons and was characterised by diversity indices, salinity, sand and vegetation structure such as decaying leaves, total species, senescent leaves and Tidal inundation. Group 2 stations 3 and 4 remained separate as it did not cluster with any of the season with stations 1 and 2, which confirm the dendrogram. Figure 9 shows the MDS ordination of crab abundance and in relation with environmental parameters and diversity indices data. The high stress values show that the community structure is well represented, it was found that stations 3

[DOR: 20.1001.1.15622916.2012.11.1.14.0]

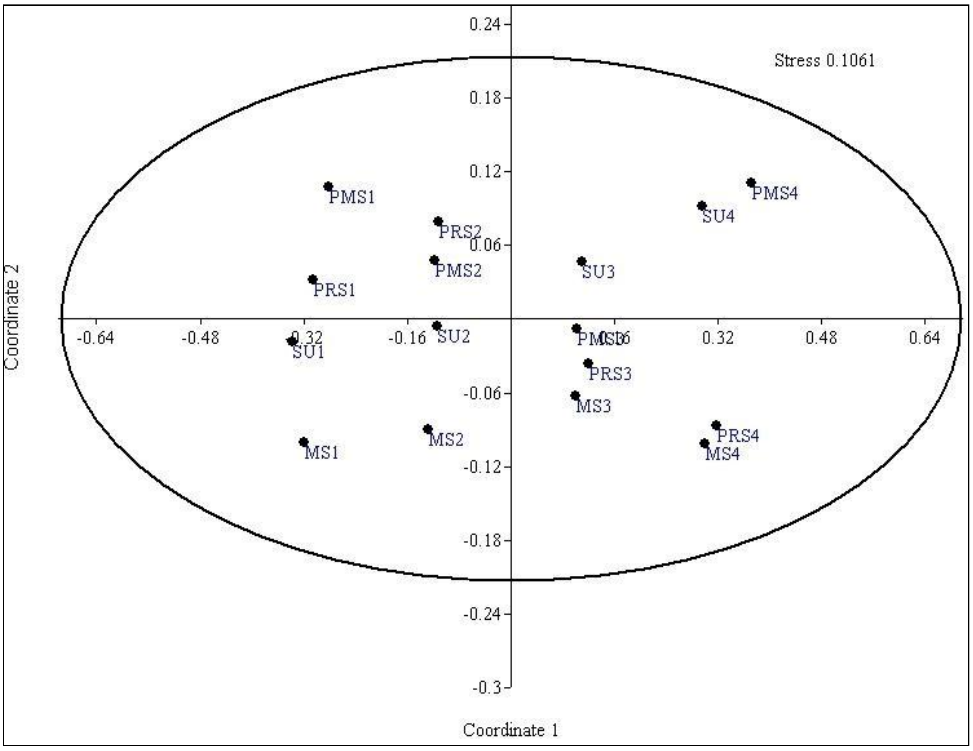
and 4 samples were ordinated separately from all other samples which confirm the dendrogram.



MS1monsoon station 1, MS2 monsoon station 2, MS3 monsoon station 3, MS4 monsoon station 4, PMS1 post-monsoon station1, PMS2 post-monsoon station 2, PMS3 post-monsoon station 3, PMS4 post-monsoon station 4, SU1 Summer station 1, SU2 Summer station 2, SU3 Summer station 3, SU4 Summer station 4, PRS1 pre-monsoon station 1, PRS2 pre-monsoon station 2, PRS3 pre-monsoon station 3, PRS4 pre-monsoon station 4

Figure 8: Principle component analysis method for four stations in different seasons in Pondicherry mangroves

[DOR: 20.1001.1.15622916.2012.11.1.14.0]



MS1monsoon station 1, MS2 monsoon station 2, MS3 monsoon station 3, MS4 monsoon station 4, PMS1 post-monsoon station1, PMS2 post-monsoon station 2, PMS3 post-monsoon station 3, PMS4 post-monsoon station 4, SU1 Summer station 1, SU2 Summer station 2, SU3 Summer station 3, SU4 Summer station 4, PRS1 pre-monsoon station 1, PRS2 pre-monsoon station 2, PRS3 pre-monsoon station 3, PRS4 pre-monsoon station 4

Figure 9: Non-multidimensional scale plot analysis for four stations in different seasons in Pondicherry mangroves

Discussion

This study gave a reference state of the structural benthic composition of the mangrove communities along the Pondicherry coast. The salinity acts as a limiting factor in the distribution of living organisms, and its variation caused by dilution and evaporation influences the fauna most likely in the intertidal zone (Gibson 1982). In this present study, salinity at all the stations was high during summer and low during the monsoon season. Higher values in summer could be attributed to faster evaporation in the study area. Thus, the variation of salinity at study sites is probably due to freshwater runoff and rain. Schrijvers et al., (1998) stated that temperature; salinity and bottom deposits were major factors influencing the distribution of bottom fauna. In the present investigation, dissolved oxygen was high during the monsoon season at all sites, which might be due to the cumulative effect of higher wind velocity coupled with heavy rainfall and the resultant freshwater mixing. Satheeshkumar and Khan (2011) have attributed seasonal variations in dissolved oxygen mainly to the freshwater influx and ferriginous impact of sediments. It is well known that the temperature and salinity affect the dissolution of oxygen. Hydrogen ion concentration (pH) in surface waters

[DOR: 20.1001.1.15622916.2012.11.1.14.0]

remained alkaline at all sites throughout the study period, with the maximum value during premonsoon season and the minimum during monsoon. Generally, fluctuations in pH values during different seasons of the year are attributed to factors like removal of CO_2 by photosynthesis through bicorbonate degradation, dilution of seawater by freshwater influx, reduction of salinity and temperature, and decomposition of organic matter (Kundu et al., 2010; Satheeshkumar and Khan, 2011).

In the present study 22 species (1 callappid, 1 gecarcinid, 9 portunid, 7 ocypodid, and 4 grapsids) of brachyuran crabs were recorded at Pondicherry mangroves which have an area of 168 ha only. There is seasonal fluctuation in the population density of crabs and *U. annulipes, U. inversa* and *U. triangularis* are largely caught during monsoon. *S. serrata* and *T. crenata* are mostly caught during post monsoon. *P. sanguinolentus* and *C. lophos were* observed mostly near the mouth region. In the earlier records from the same study area 9 brachyuran crabs were reported (Saravanan et al., 2008). 13 species of brachyuran crab (4 species of grapsids and 10 species of ocypodids) in the arid zone mangroves of Gulf Kachchh recorded (Sravanakumar et al., 2007). 38 species of brachyuran crabs in both natural Pichavaram and artificially developed mangroves of Vellar estuary which has an area of 1200 ha (18 species of graposids and 7 species of ocypodoids at Pichavaram mangroves; while 8 species of grapsoids and 3 species of ocypodids at Vellar mangroves) reported by (Ajmal Khan et al., 2005).

Tree dominance, diversity, Total species were correlated with the brachyuran crab diversity. High abundance of Portunid crabs dominates in stations 1 and 2 (*Avicennia* and *Rhizophora* zone), whereas large number of ocypodid and grapsid crabs dominate mature forest station 2 (*Rhizophora* zone) and station 3 and less abundance in lower stream (station 4). Similar patterns have been found elsewhere in India (Raut et al., 2005; Saravanakumar et al., 2007) concluded that tree abundance, diversity, tree felling and regeneration were responsible for much of the observed disturbance and variation in the faunal composition. It is probable that the textural qualities of the soil change rapidly once mangrove vegetation becomes established, and that burrowing crustaceans are an important element in the process that leads to the soil becoming suitable for other species to colonize (Berry, 1972). Relatively few mangrove species have been used in restoration projects; species of the genus *Rhizophora* spp. are the most commonly used (Kathiresan et al., 2000) and commented on an apparent decline in production at Pondicherry mangroves and considered that there may be an ecological price to pay for the present form of management because of the dominance of *Rhizophora* spp. Increased habitat heterogeneity and mangrove species diversity may support a more diverse crab fauna.

Species diversity is a simple and useful measure of a biological system. Sanders (1968) found a high level of agreement between species diversity and the nature of the environment and, hence, regarded the measure of species diversity as an ecologically powerful tool. Sanders (1968) postulated that the species diversity is mainly controlled by the fluctuations in the environment that lead to less diversity. In the present study H' values from 0.96 – 2.18 was observed. Evenness and richness was least at station 3 during monsoon and maximum at station 1 in Post monsoon. Moreover Ajmal Khan et al., (2005) recorded H' values in the diverse nature of the Pichavaram mangroves (2.70- 3.38) and (1.66- 2.26) in the Vellar mangroves. The low richness and diversity recorded in this study during monsoon might be due to the freshwater inflow which induced low saline conditions, which in turn affected the distribution of crabs (Sandilian et al., 2010). Maximum diversity and richness recorded in postmonsoon at the study sites might be due to stable environmental factors, such as salinity, DO, which play a most important role in crab distribution. The pattern of lower species diversity in monsoon and higher diversity in postmonsoon recorded at different mangrove sites is in conformity with earlier observations of Pichavaram and Vellar mangroves, Tamil Nadu (Ajmal Khan et al., 2005), Godavari mangroves, Andhra Pradesh (Raut et al., 2005) and Gulf of Kachchh mangroves, Gujarat (Saravanakumar et al.,, 2007).

Cluster analysis has delineated two major clusters, which were mainly segregated based on mangrove ecosystem. Clustered stations 1 and 2 were densely populated than its station 3 and 4 mangrove sites. The increased abundance, diversity and richness of brachyuran crab was observed in the *Avicennia* zone and *Rhizophora zone* (stations 1 and 2) could be due to the increased surface area and increased habitat complexity in mangrove regions and abundance of food from decaying leaves and organic sedimentary material support these large diverse populations of benthic invertebrates in such ecosystem (Ansari, 1984). Generally species richness and density increased with increasing plant biomass at the collection site (Orth, 1973). The results of the present study corroborate these findings. The low frequency of tidal inundation at stations 3 and 4 may be a reason for the absence of some crab species from this location. Mangrove crabs are well known to show a zonation of species with shore level (Jones, 1984). Tan and Ng (1994) suggest the maintenance of high crab species diversity is integral to the health of the mangroves. Natural and human- induced disturbances pose serious threats to the functioning of mangrove ecosystems (Osborn and Polesenberg, 1996). The brachyuran community composition at a site may give an indication of the habitat a stressful environment, Ghost crabs have been used a tool for rapid assessment of human impacts on exposed sandy beaches (Barros, 2001). Conversion of mangroves to shrimp farm and discharged effluent from the shrimp farm, industrialization and pollution load are major threat to brachyuran crab diversity in this study site.

An effective conservation strategy for mangrove needs to be supported by a better understanding of the processes operating within mangrove ecosystems. Pondicherry mangrove sites are valuable for research and present findings have identified number potentially important correlations between mangrove environment, the vegetation structure and major components of brachyuran crab fauna. In addition, the maintenance of the undisturbed areas should be a primary objective for the management, since it represents a more constant brachyuran crab diversity and highest abundance and sustains the production of commercial important species such as *Scylla serrata, Portunus sanguinolentus, P. pelagicus* and *Thalamitta crenata.* Juveniles and undersized crabs should not be caught and fishing of crabs should be strictly banned during their peak-breeding season. Past and present management practices play an important role in moderating crab abundance, composition, diversity and further research is required to understand the ecological effects of disturbance to mangrove forest and whether changes in crab community structure with management are consistent in other locations.

Acknowledgements

Author thanks the University Grants Commission, Government of India for the financial support and Pondicherry University administration for providing infrastructural facilities.

References

Ajmal Khan, S., Raffi, S. M., and Lyla, P.S., 2005. Brachyuran crab diversity in natural Pichavaram and artificially developed mangroves Vellar estuary. *Current Science,* 88, 1316-1324.

Ansari, Z.A., 1984. Benthic macro and meio fauna of Seagrass (*Thalassia hemprichii*) bed at Minicoy, Lakshadweep. *Indian Journal of Marine Science,* (**3**), 126-127.

Ashton, E.C., Hogarth, P. J., and Macintosh, D. J., 2003a. A comparison of brachyuran community structure at four mangrove locations under different management systems along the Melaka Straits- Andaman Sea Coast of Malaysia and Thailand. *Estuaries and Coast*, 26(**6**), 1461-1471.

Ashton, E. C., Macintosh, D. J., and Hogarth, P. J., 2003b. A baseline study of the diversity and community ecology of crab and molluscan macrofauna in the Sematan mangrove forest, Sarawak, Malaysia. *Tropical Ecology*, 9, 127–142.

Barros, F., 2001. Ghost crabs as a tool for rapid assessment of human impacts on exposed sandy beaches. *Biological Conservation,* 97, 399–404.

Berry, A. J., 1972. The natural history of West Malaysian mangrove faunas. *Malaysian Natural History Journal*, 25, 135–162.

Bortolus, A. E., Schwindx, E., and Iribane, D., 2002. Positive plant – animal interactions in the high marsh of an Argentnean coastal lagoon, *Ecology*, 83,733-742.

Diemont, W. H., and van Wijngaarden, W., 1975. Nature conservation of mangrove in West Malaysia. Nature conservation Department Report, Agricultural University Wageningen.

El Wakeel, S. K., and Riley, J. P., 1957. The determination of organic carbon in marine muds. *Cons Perm Int Exp Mer J* 22,180-183.

English, S., Wilkinson, C., and Baker, V., 1994. Survey Manual for Tropical Marine Resources. Australian Institute of Marine Science, Townsville, Australia.

Gibson, R. N. 1982. Recent studies on the biology of intertidal fishes. *Oceanography and Marine Biology Annual Review,* 20, 363–414.

Gleason, H. A., 1992. On the relation between species and area. Ecology, 3,156-162.

Jones, D.A., 1984. Crabs of the mangal ecosystem, *In* F. D. Por and I. Dor (eds.), Hydrobiology of the Mangal.,m W. Junk Publishers, The Hague, The Netherlands, 89–109 p.

Kathiresan, K., Rajendran, N., and Palaniselvam, V. 2000. Growth of *Rhizophora apiculata* in degraded areas of Ariyankuppam estuary along Pondicherry coastline, southeast coast of India. *Indian Journal of Marine Science*, 29, 86-88.

Krumbein, W.C., and Petttijohn, F.J. 1983. Manual of sedimentary Petrography Appleton Century- Crafts Inc, New York, 549 p.

Kundu, S., Mondal, N., Lyla, P. S., and Ajmal Khan, S., 2010. Biodiversity and seasonal variation of macro-benthic infaunal community in the inshore waters of Parangipettai Coast. *Environmental Monitoring and Assessment*, 163, 67–79.

Ng, P. K. L., Guinot, D., and Davie, P. J. F., 2008. Systema Brachyurorum: Part I. An annotated checklist of extant brachyuran crabs of the world. *Raffles Bulletin of Zoology,* 17, 1-286.

Orth, R. J. 1973. Benthic infauna of eelgrass, *Zostera marina*, beds. *Chemosphere Science,* 14, 258.

Osborn, J. G., and Polsenberg, J. F., 1996. Meeting of the mangrovellers: The interface of biodiversity and ecosystem function. *Trends in Ecology and Evolution*, 11, 354–356.

Pielou, E. C., 1966. The measurement of diversity in different types of biological collection. *Theoretical Biology*, 13, 131-144.

Raut, D., Ganesh, T., Murty, N. V. S. S., and Raman, A. V. 2005. Macrobenthos of Kakinada Bay in the Godavari delta, East coast of India: comparing decadal changes. *Estuarine and Coastal Shelf Science*, 62, 609-620.

Sanders, H. L., 1968. Marine Benthic diversity: a comparative study. *American Naturalist*, 102, 243-282.

Sandilyan, S., Thiyagesan, K., Nagarajan, R., and Vencatesan, J., 2010. Salinity raises in Indian mangroves a looming danger for coastal biodiversity. *Current Science*, 98(**6**), 754-756.

Saravanakumar, A., Sesh Serebiah, J., Thivakaran, G. A., and Rajkumar, M., 2007. Benthic Macrofaunal Assemblage in the Arid Zone Mangroves of Gulf of Kachchh-Gujarat. *Journal of Ocean University of China*, 6, 303-309.

Saravanan, K. R., Ilangovan, K., Khan, A. B., 2008. Floristic and macro faunal diversity of Pondicherry mangroves, South India. *Tropical Ecology*, 49(**1**), 91-94.

[DOR: 20.1001.1.15622916.2012.11.1.14.0]

Satheeshkumar, P., Khan, A. B., 2011. Identification of mangrove water quality by multivariate statistical analysis methods in Pondicherry coast, India. *Environmental Monitoring and Assessment*, DOI 10.1007/s10661-011-2222-4.

Schrijvers, J., Camargo, M.G., Pratiwi, R., Vincx, M., 1998. The infaunal macrobenthos under East African *Ceriops tagal* mangroves impacted by epibenthos. (IZWO) Institute for marine scientific research: *Collected Reprints*, 28, 245-263.

Sethuramalingam, S., and Ajmal Khan, S., 1991. Brachyuran crabs of Parangipettai coast. Annamalai University, India, 193 p.

Shannon, C. E., and Weaver, W., 1949. The mathematical Theory of communication, University of Illinois Press, Urbana, 117 p.

Siddiqui, M. Z. H., and Zafar., 2002. Crabs in the Chakaria Sunderban area of Bangladesh. *Journal of Noami*, 19, 61-77.

Stone, R. P., Clair, C. E., and Shirley, T. C., 1992. Seasonal migration and distribution of female red king crabs in a southeast Alaskan estuary. *Crustacean Biology*, 12(**4**), 546-560.

Strickland, J. D. H., and Parsons, T. R., 1972. A practical handbook of seawater analysis. *Bulletin Fisheries Research Board of Canada*, 167, 311.

Symstad, A. J., and Tilman, D., 2001. Diversity loss, recruitment limitation, and ecosystem functioning: lessons learned from a removal experiment. *Oikos*, 92, 424-435.

Tan, C. G. S., and Ng, P. K. L., 1994. An annotated checklist of mangrove brachyuran crabs from Malaysia and Singapore. *Hydrobilogia*, 285, 75-84.

Tomlinson, P. B., 1986. The Botany of Mangroves. Cambridge University Press, Cambridge, UK.

Williams, A. B., 1984. Shrimps, Lobsters and crabs of the Atlantic Coast, Eastern United Stated, Main Florida, Smithsonian Institution Press, Washington, 550 p.

Williams, A. H., Coen, L. D., and Stoelting, M. S., 1990. Seasonal abundance, distribution and habitat selection of juvenile *Callinectes sapidus* (Rathbun) in the Northern Gulf of Mexico. *Journal of Experimental Marine Biology,* 137 (**3**), 165-183.