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Ecology, Diversity, and Abundance of Macrobenthic Crustaceans in Cochin Estuary, India

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Abstract

Crustaceans that filter plankton or bacteria from the water are common and diversified in estuarine environments. Other crustaceans are active predators or scavenge nutrients from detritus. A few are adapted to high salinity and are parasitic or sessile, hatching young that resemble miniature adults; others go through larval stages. This study examined the diversity and ecology of macrobenthic crustaceans from selected stations in Cochin estuary, Kerala. Field sampling conducted from June 2009 to May 2011 on monthly basis. The major crustaceans were amphipods, tanaids, isopods, insects, decapods, and acarina. Corophium volutator and Cirolana fluviatilis were the dominant amphipod and isopod species, respectively. Tanais philetaerus Stebbing was the dominant tanaid species. The crab species Halicarcinus messor was the dominant decapod and Neumania spp. (water mite) were the major Acaridae. Chironomid larvae were the most abundant insects. The temperature and pH of the sediments and benthic waters varied seasonally, and the dissolved oxygen content of the latter greatly influenced the diversity and abundance. The spatial abundance of the crustaceans varied between the stations, with a low at Station 8 (80 no/m^2) and a high at Station 5 (9733 no/m^2). The seasonal abundance was least (182 no/m^2) during the pre-monsoon season of 2011, and maximum (7935 no/m^2) in the post-monsoon season in 2009–10. The numerical abundance varied between the three zones of the estuary, with the maximum mean abundance found in the middle region (4452 no/m^2), followed by the southern (2582 no/m^2) and northern (1157 no/m^2) regions. The crustacean abundance fell remarkably between the first (3705 no/m^2) and second (1674 no/m^2) years. The numerical abundance was highest in the region of the estuary with high salinity, a moderate pH, and a high percentage of silt and clay.

Keywords: Crustaceans, macrobenthos, amphipod, decapods, Cochin estuary.

Introduction

Crustaceans are the second most abundant and diversified organisms in the estuarine environment. The benthic crustaceans in the estuaries are mainly composed by amphipods followed by isopods, tanaids, juveniles of decapods, acarids and diepterans. Morphological diversity of crustaceans were higher than any other organisms in the earth and especially isopods are most diversified crustacean[1]. They are integral part of estuarine food web and nutrient dynamics in estuaries. Large members are the active predators and some group are filter feeders and medium species are scavengers. Some crustaceans act as biofoulers, borers, parasites or ecologically nuisance species.

India have no single literature that brings together crustacean fauna yet, some of the major works on the crustaceans in India had reported that the taxonomy of Indian Isopods by Stebbing[2] and Indian prawn by George[3]. A checklist of Isopod fauna of India was prepared by Dev Roy[4]. Crustacean isopod from Maharashtra coast was recorded by Dev Roy et al.[5] and overall 38 families, 299 isopod species were recorded from different parts of India[6]. The paper was described the total 2.7 % of the global isopod fauna belonging to 131 genera and 38 families. A review of isopods from Indian Ocean was published by Kensley[7], two sixty eight isopods species was recorded from Indian region. The freshwater crab diversity from five states of India were studied by Dev Roy[8].

Based on the available literature of the study on crustacean fauna in Cochin estuary was less than the other Indian estuaries. Scanty information has been reported on the crustacean taxonomy and diversity in Cochin estuary. Pillai[9] reported four isopod species belonging to genera Cirolana from Indian Ocean; two species belonging to genus Cirolana Leach and five species of genus Eurydice Leach from estuarine water of Kerala. In the upper reaches of the Cochin estuary the amphipod *Eriopisa chilkensis* and *Gammarus sp.* were dominant species[10-14]. Thirty species of crustaceans were recorded from Cochin estuary[15,16]. The crustacean fauna were composed of mainly amphipods, tanaids, isopods, cumaceans and brachyuran crabs and Penaeids in Cochin estuary.

Crustaceans were the second dominant group among macro benthic fauna in the subtratum of Cochin estuary with twenty species were recorded by Sheeba[17] and ten species by Anon[18] and twelve species by Feebarani[19]. Recently one species of amphipod and one species of tanaidacean was recorded from Cochin estuary[20]. Aquatic macrofaunal invertebrates are bioindicators and effective tool for the assessment of

environmental health of marine and coastal waters[21], estuaries [22] and streams[23].

Urbanization and anthropogenic interventions perishes the wetlands and coastal low lying lands globally[24,25]. So many earlier studies reported that the ecological health of Cochin estuarine system has degraded due to various developmental projects and anthropogenic interventions. The pollution load increased due to dredging, waste disposal, industrialization, transportation and metal pollution [26-29]. City area of Cochin was increasing due to unscientific land usage and urbanization[30]. Cochin estuary is a most productive tropical estuary on the west coast of India[31]. But comprehensive information on a time scale changes on the various eco-biological aspects of the Cochin estuary is still lacking. So, the present investigation regarding the diversity of the benthic crustaceans and its relation to environmental parameters in Cochin estuary.

Material and Methods

Study area: Cochin estuary is a shallow brackish water body situated on the south west coast of India. It is a tropical positive estuary extending between 9°40' and 10°12'N and 76°10' and 76° 30' E. Its length varies from 60- 80 Km, width from 500 and 4000 meters and depth range of 2-7 meters. The estuary opening to the Lakshadweep Sea by Cochin bar mouth (450m width) at Cochin and another at Azhikode The map of Cochin estuary is given in Figure-1. As per the Environmental (Protection) Act, 1985 (29 of 1986) the Cochin backwater in the Vembanad Lake is classified under the "ecological sensitive zone".

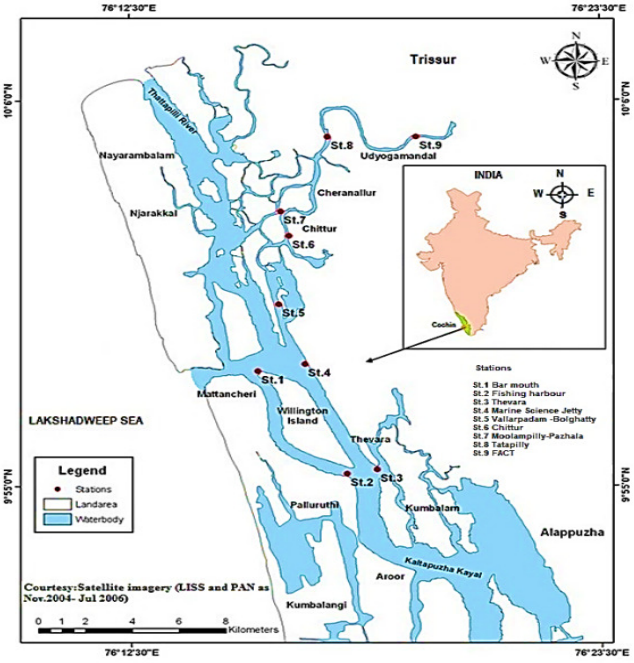

Figure-1
Map of Cochin estuary indicating the study stations

Nine sampling stations were selected for collection of water, sediment and benthos. Stations. 1 to 9 respectively Stations.1 (Barmouth), Station. 2 (Fishing Harbour), Station.3 (Thevara), Station. 4 (Marine Science Jetty), Station.5 (Vallarpadam–Bolgatty), Station. 6 (Chitoor), Station. 7 (Moolampilly-Pazhala), Station. 8 (Tatapilly) and Station. 9 (FACT-Eloor). Stations 2 and 3 were in the southern zone of the estuary. Whereas the Sts. 1, 4 and 5 in the middle zone and Station. 6, 7, 8 and 9 were in the northern zone of the estuary.

Field sampling was invariably made monthly basis in morning hours. The 2L Niskin sampler was used to collect water and standard Van Veen Grab (area -0.04 m^2) for sediment collection[32,33]. The temperature of the bottom water and sediment was determined by a standard degree centigrade thermometer and pH by suitable pH meter (Systronics Model no: 132) in the field[34]. Dissolved oxygen was estimated using the modified Winkler method and salinity by Mohr-Knudsen method [35,36]. Sediment particle size analysis done by particle size analyzer SYMPATEC H70010 Sucell.

The collected samples were preserved in 4% formalin in plastic bottles. These preserved samples were washed through suitable sieves of mesh size 500 µm for macro fauna, those that were retained in the sieve were collected in a wide mouth labeled plastic container. A few drops of Rose Bengal stain added to this bottle for overnight and identified the organisms with the help of standard literature[32,33]. The Rose Bengal dye at strength of 0.1% selectivity colored all the living organisms in the sample[37-39].

Taxonomy of crustaceans: The washed and preserved sediment with benthic invertebrates were poured into a white enamel tray. The organisms were sorted and arranged into different groups and preserved in separate vials and preserved in 5% formalin. The preserved animals were later identified to their lowest taxonomic group under light and stereo dissecting microscope and counted. The dissected portions were analysedusing compound microscope- Laica DM 500. The standard as well as published references were employed for identification of different fauna. Taxonomic and morphological studies were conducted using standard literature, monographs and keys[7,33,40-46].

Statistical analysis: The software PRIMER v 6 was used for univariate and multivariate analysis of data[47]. The diversity indices and similarity indices were determined. Distributions of organisms were linking with the environmental variables by BIO-ENV procedure[48].

Results and Discussion

Environmental parameters: The bottom water temperature varied between 25°C to 33.1°C during the study period. The mean seasonal temperature varied between minimum 27.46°C (pre- monsoon 2011) and maximum 30.83°C (post monsoon

201-11). The mean temperature recorded was 29.4°C for southern zone, 29.3°C for middle zone and 29.2°C for northern zone. pH varied between 4.4 to 8.3 during the study period. The mean seasonal pH varied between minimum of 6.68 during monsoon 2010 and maximum of 7.42 during post monsoon 2009-10. The mean pH recorded was 7.5 in the southern zone, 7.4 in the middle zone and 6.8 in northern zone. Dissolved oxygen (DO) of bottom water varied between 2.4 mg/L to 10.61 mg/L for the study period. Mean seasonal variation of dissolved oxygen observed was minimum of 2 mg/L (monsoon 2010) and maximum of 13.9 mg/L (monsoon 2009). The zone wise mean dissolved oxygen recorded was 6.0 mg/L in the southern zone, 6.3 mg/L in the middle zone and 6.6 mg/L in northern zone. Bottom water salinity varied from 0.01ppt to 34.70ppt in all the stations during the study period. The mean seasonal salinity varied from minimum of 3.05ppt during monsoon 2010 and maximum of 11.4ppt during post monsoon 2009-10. The mean salinity recorded was 11.4ppt in the southern zone, 12.5ppt in the middle zone and 2.4ppt in the northern zone.

The sediment temperature varied between 23°C to 33°C during the study period. The mean seasonal variation of temperature was minimum (27.46°C) during monsoon 2010-11 and maximum (30.4°C) during post monsoon 2010-11. The mean temperature recorded was 28.4°C in the southern zone, 28.1°C in the middle zone and 28.4°C in northern zone of the Cochin estuary. Sediment pH varied between 3.03 to 10.48 during the study period. The mean seasonal pH varied between minimum (6.68) during pre monsoon 2011 and maximum (7.7) during monsoon 2009-10. The mean pH recorded was 7.4 in the southern zone, 7.4 in the middle zone and 6.9 in northern zone of the estuary.

Sediment grain size varied from varied 0.64 to 97.61% for clay, 2.39 to 94% for silt and 0.03 to 96.00% for sand during the study period in Cochin estuary. Spatial distribution of clay, silt and sand highly varied from stations. Mean station wise clay recorded was minimum at 11.81% in Stations.8 in the northern zone and maximum at 81.55% in Stations.4 in the middle zone; silt recorded was minimum of 17.29% in Stations.1 and maximum of 66.08% in Stations.5 in the middle zone; the sand observed was minimum of 0.21% in Stations.3 in the southern zone and maximum of 54.3% in Stations.9 in the northern zone.

The graphical representation of bottom water and sediment characteristics are given in figure-2 to 4.

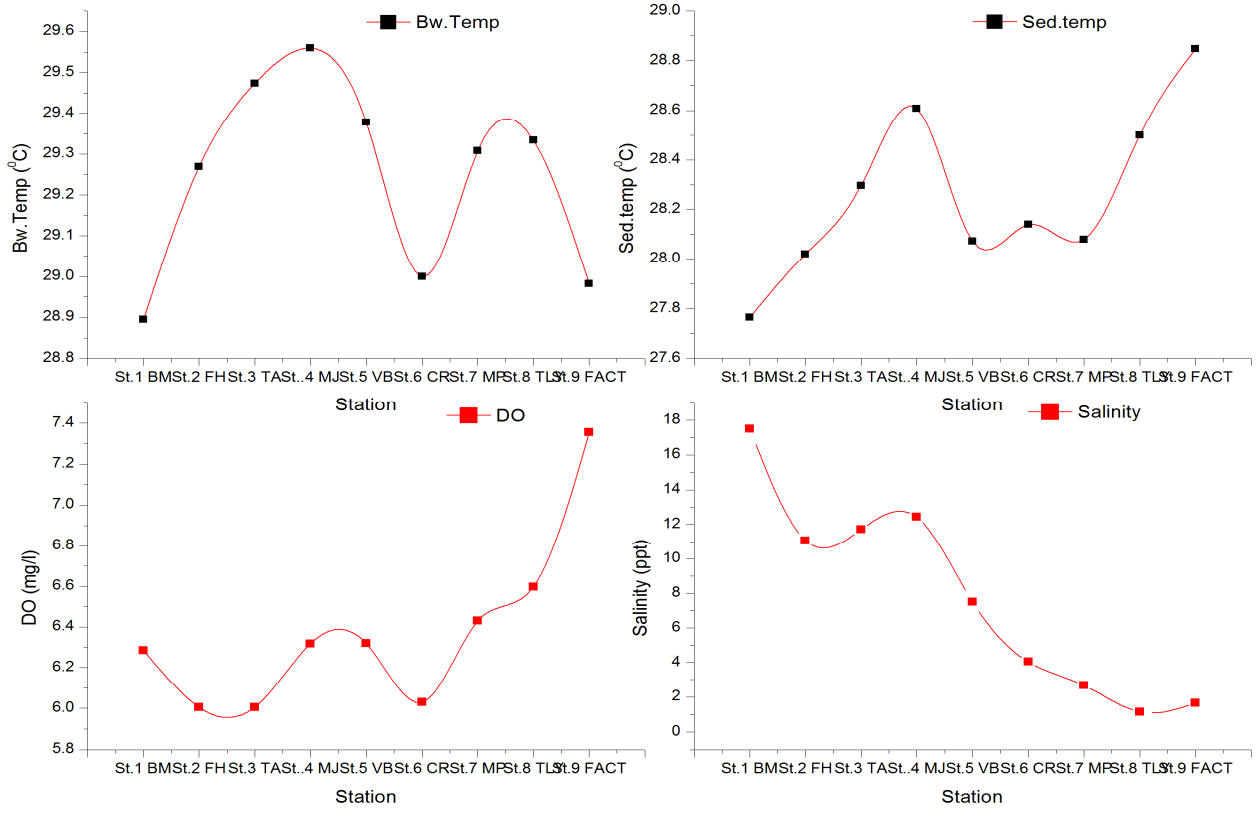

Figure-2
Mean variation of temperature of bottom water and sediment, dissolved oxygen and salinity of bottom water in Cochin estuary during 2009-11 period

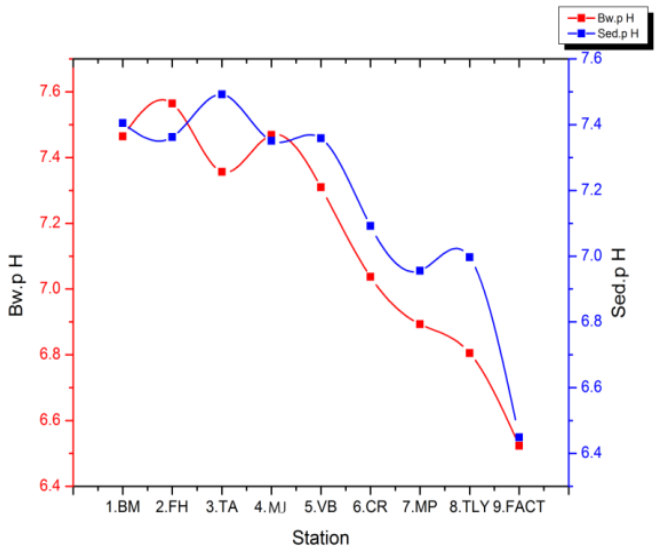

Figure-3
Stationwise mean variation of bottom water pH and sediment pH in Cochin estuary during 2009-11 period

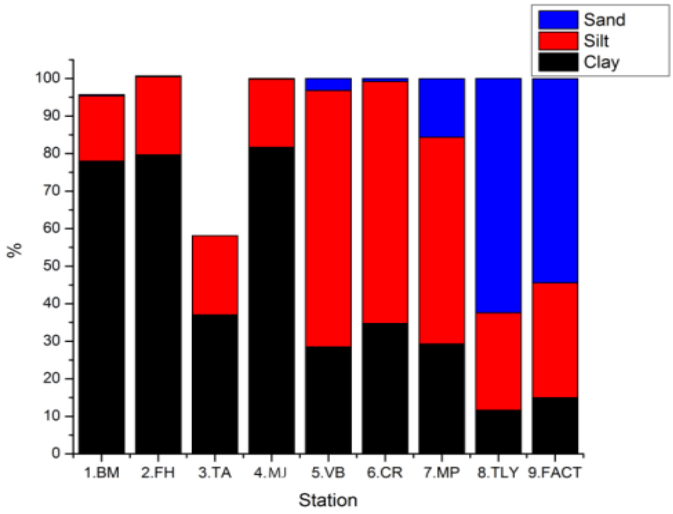

Figure-4
Stationwise mean variation of grain size distribution in Cochin estuary during 2009-11 period

Macrobenthos: The macrobenthos comprised of seven groups in the present study and were nemerteans, sipunculids, oligochaetes, polychaetes, crustaceans, molluscs and pisces. Numerical abundance and distribution of organisms showed a spatio-temporal variation in the estuary. Based on the numerical abundance, the polychaetes (624148 no/m^2) were the dominant group followed by crustaceans (580338 no/m^2), molluscs (28592 no/m^2), oligochaetes (137485no/m^2), sipunculids (35267 no/m^2), nemerteans (9045 no/m^2) and Pisces (3042 no/m^2). Station wise mean abundance of organisms were found to be low (94 no/m^2) in Stations.9 (northern zone) and high (2043 no/m^2) in Stations.5 (middle zone) of the estuary (Figure-5).

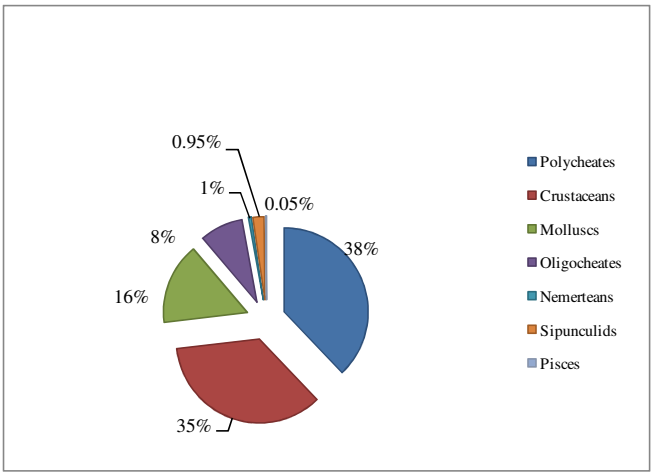

Figure-5
Mean percentage abundance of macrobenthos in Cochin estuary during June 2009-May 2011

Crustacean fauna: The crustacean fauna were the second dominant group with 35% of all the macrobenthic fauna.They were comprised as seven groups represented by amphipods (80%), isopods (7%), tanaids (4%), mysids (2%), decapods (1%), acarids (3%) and dipterans (3%) (figure-6). Thirty four species belonging to twenty seven families and thirty four genus of crustaceans were encountered in the study. Among these, the amphipods were the major group. Six species of amphipods were identified, *Gammarus tigrinus, Corophium volutator, Psammogammarus sp, Eriopisa chilkensis, Microdeutopus sp, Jassa falcata* were the representative species.*Corophium volutator* was the dominant species (317219no/m^2). Sea weeds and algae are major factors controlling the high abundance of gammaridean amphipods in estuarine environment[49].

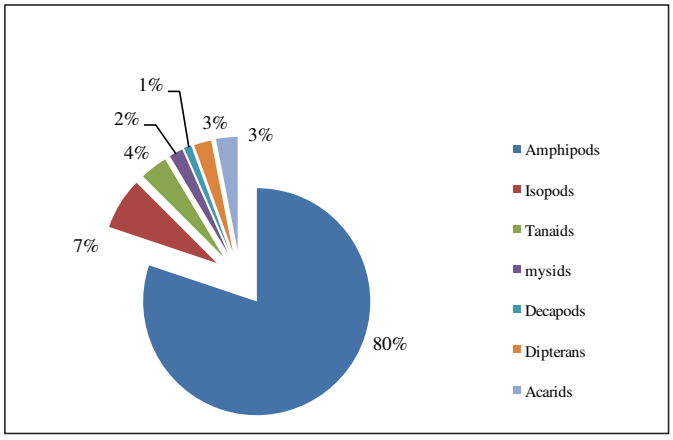

Figure-6
Mean percentage abundance of crustaceans in Cochin estuary during June 2009-May 2011

Seven species of isopods were identified. The dominant species was *Cirolana fluviatilis* Stebbing (23111no/m^2). In the

present study isopod *Sphaeroma annaandei travencorensis* (wood borers) was observed in Stations.2 near the fishing harbor and Stations.4 near to bar mouth area. The maximum activity of borers was noticed in the bar mouth region[50].

Other representative species of tanaids were *Tanais philetaerus* Stebbing, *Apseudes chilkensis* Chilton, *Leptochelia* savignyi. Among the tanaid, *Tanais philetaerus* Stebbing (9444no/m^2) was the dominant species.

Only one species of mysid was identified, *Gastrosuccus dunkeri* Zimmer (1772no/m^2) was represented species in the study. Eight species of decapods were identified and *Halicarcinus messor* was dominant decapod species. The four species of acarids and five species of dipterans (insects) were identified. Among acarids the *Neumania sp* was the dominant species and chironomid larvae were dominant in dipterans. The diversity and distribution pattern of crustacean fauna are given in (table-1 and 2).

Diversity: The diversity indices of crustaceans were lowered in all stations during the study period. Compared to three zones of the estuary the diversity indices were highest in the middle zone. The highest value of d - 3.7833 (Species richness) was observed in Stations.4; J' – 0.985 (Species evenness) was observed in Stations.8. Whereas H' (log e) – 3.039 (Shannon diversity) and 1-Lambda' – 0.946 (species dominance) were observed in Stations.4 during 2009-11 periods in Cochin estuary (figure-7).

The dominance plot of crustaceans used to find out the stress to the biota. The plot was near to 'J' shaped curve suggesting the high dominance of abundant species (opportunistic species) which could be due to the disturbed environment in some situations. In Stations.4 the species abundance were increased (figure-8). It indicates that some stations were moderately stressed. The J' shaped curve become much flatter in some stations indicates that less pollution and less abundance. The abundant species is usually opportunistic species. Such species is increasing in polluted environment. Here in Sts.4 and 5 were more polluted stations due to various human activities such as dredging, oil pollution and transportation. The geometric class plot showed a highly irregular pattern. It indicates that the crustaceans were under medium stressed condition in some stations (figure-9). The drawing and analysis of K' dominance curve used to detect the disturbance in different stations that affected the species diversity of benthic crustaceans. In Stations.4 the curve was near to S' shaped and it showed a highest species abundance in the plot. All other stations showed a steep elevation, that indicates the less diversity in those stations (figure-10). Zonal abundance of crustaceans were varied in three zones. The K'dominans plot showed the highest species abundance of crustaceans in middle zone followed by northern zone and southern zone of the Cochin estuary (Figure-11).

Based on the BIOENV analysis by combinations of 7 variables (temperature and pH of bottom water and sediment, bottom water dissolved oxygen, salinity; silt, clay and sand fraction of sediment) in Cochin estuary resulted that 8 species of crustaceans were the most influential species during the study period. Among these, amphipod species *G. tigrinus*, *C. volutator*, *Psammogammarus sp* and *E.Chilkensis* where the most influential species in the Cochin estuary during 2009-2011 periods giving a correlation coffefficient of 0.806.

Abundance: The numerical abundance of crustaceans varied in nine stations. The mean numerical abundance were low (125no/m^2) in Stations.8 in the northern zone and highest (9616 no/m^2) in Stations.5 in the middle zone. In the middle zone *C. volutator* and *E. Chilkensis* were dominant species. Whereas in the southern zone *C.volutator* was the dominant species. Whereas in the northern zone *C. volutator*, *E. Chilkensis* and *G. tigrinus* were the dominant species. Seasonally the numerical abundance of benthic crustaceans was low in pre monsoon (2011) and high in post monsoon (2009-10) (figure-12). MDS plot drawn for the analysis of stationwise similarity of crustaceans in the estuary. MDS plot showed an overall 20 % similarity between all stations during the study period; a 40% similarity between Sts. 1 to 7 and 40% similarity between Sts. 8 and 9. The stress value (0.03) which was overlying the MDS plot showed good ordination during June 2009- May 2011 period for the macrobenthic crustaceans in the Cochin estuary (figure-13). Mean annual variation of crustaceans showed a higher abundance in the year 2009-10 than 2010-11 period in the estuary.

Table-1
Mean abundance pattern of crustacean groups (no/m^2) in Different zones of the Cochin esuary

Crustaceans (no/m^2)	Southern zone	Middle Zone	Northern zone	
Amphipods	6936	15698	2417	High
Isopods	1373	810	325	
Tanaids	444	691	120	Medium
Mysids	389	222	83	
Decapods	271	116	10	
Acarids	139	213	444	Low
Dipterans	256	89	344	

Table-2
List of macrobenthic Crustaceans, habitat, occurrence and species rank in Cochin estuary during June 2009-May 2011

Order	Family	Genus	Species	Habitat	A	MO	F	RA	O	Species rank
Amphipoda	Gammaridae	Gammarus	*G.tigrinus*	M,E,R	A					III
	Corophidae	Corophium	*C.volutator*	M,E,R	A					I
	Melitidae Bossfield	Psammogammarus	*Psammogammarus sp*	R,E,M		MO				V
		Eriopisa	*E.chilkensis*	M,E,R		MO				II
	Aoridae	Microdeutopus	*Microdeutopus sp*	M				RA		
	Ischyroceridae	Jassa	*J. falcata*	M,E,R			F			
Isopoda	Cirolanidae	Cirolana	*C. fluviatilis* Stebbing	M,E,R	A					IV
			C.concharm	M,E,R			F			
	Spaeromatidae Laterelli	Sphaeroma	*S.annanadei travencorensis*	M,E,R			F			
	Idoteinae	Idotea	*Idotea baltica*	R				RA		
	Anthuridae	Cyathura	*C.carinata*	M,E,R	A					VI
		Caenanthura	*Indanthura carinata*	M,E,R		MO				
	Hyssuridae	Kupellonura	*Kupellonura sp*	M,E,R			F			VIII
Tanidacea	Tanaidae dana	Tanais	*Tanais philetaerus* Stebbing	M,E,R		MO				VII
	Apsudidae	Apseudes Leach	*Apseudes chilkensis Chilton*	R			F			
	Leptocheliidae	Leptochelia	*Leptochelia Savignyi*	M			F			
Mysida Haworth	Mysidae Haworth	Gastrosuccus	*Gastrosuccus dunkeri Zimmer*	M,E,R			F			
Decapoda	Hymenosomatidae	Halicarcinus	*H.messor*	R				RA		
		Ebalia	*E.malefactrix*	M					O	
	Pinnotheridae	Xenophthalmus	*X.pinnotheroids*	M,E,R			F			
	Penaidae	Macrobrachium	*M.rosenbergii*	M,E,R				RA		
		Metapenaeus	*M.monoceros*	M,E,R				RA		
		Penaeus	*P.indicus*	M,E,R			F			
	Luciferidae	Lucifer	*Lucifer hanseni* Nobili	M					O	
	Alphaeidae	Alpheus	*Alpheus sp.*	M,E,R		MO				
	Sergestidae	Acetus	*Acetus indicus H. Milne* Edwards	M,E,R				RA		
Acarina	Hygrobatoidea	Neumania	*Ameronothrus*	M,E,R			F			
	Acaridae	Oribatidae	*Neumania sp*	M,E,R		MO				X
	Halacaridae	Copidognathus	*Copidognathus sp*	M,E,R		MO				
	Thrombidiidae	Thrombidium	*T.holocericium*	M,E,R		MO				
Diptera	Chironomidae	Chironomus	*Chironomid sp larvae*	M,E,R	A					IX
		Chironomus	*Chironomid sp pupae*	M,E,R	A	MO				
		Tendipus	*T.astenus* larvae	R			F			
	Tipulidae	Tipula	*Tipula sp*	R			F			
	Polycentropodidae	Polycentropus	*Polycentropus sp larvae*	M,E,R		MO				

M-Marine, E-Estuarine, R-Riverine, A-Abundant, MO-Moderate, F-Frequent, RA-Rare, O-Occasional

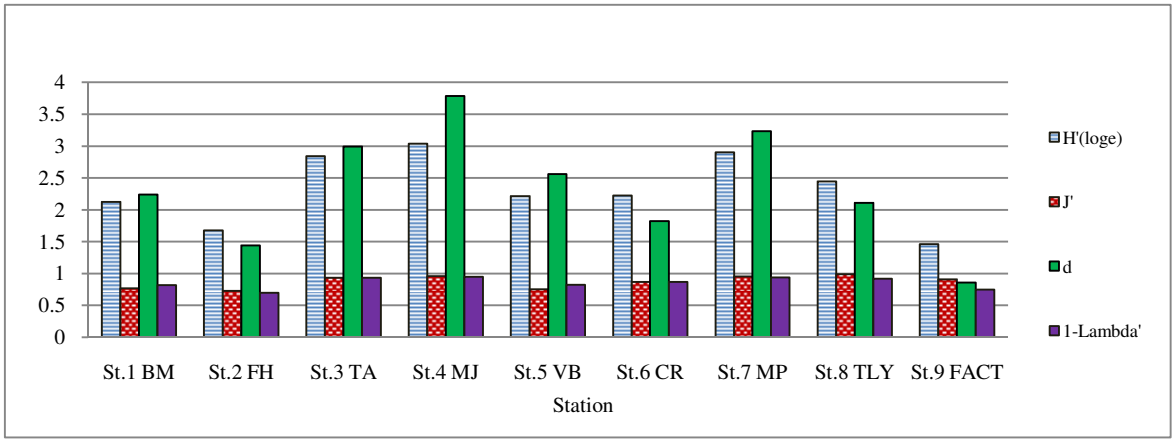

Figure-7
Diversity indices of Crustaceans in Cochin estuary during June 2009-May 2011

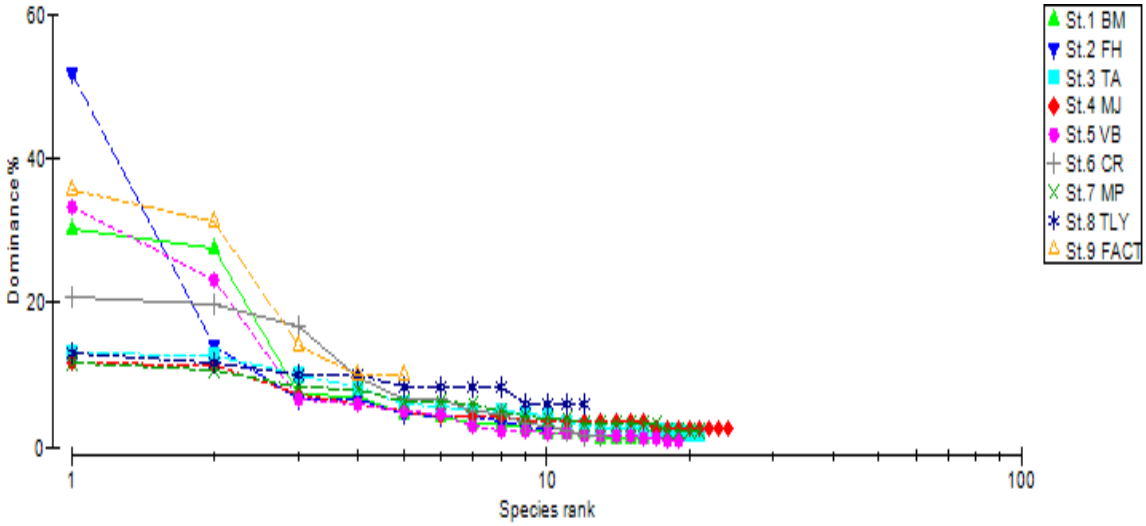

Figure-8
Dominance plot of crustacean species in Cochin estuary during June 2009 - May 2011

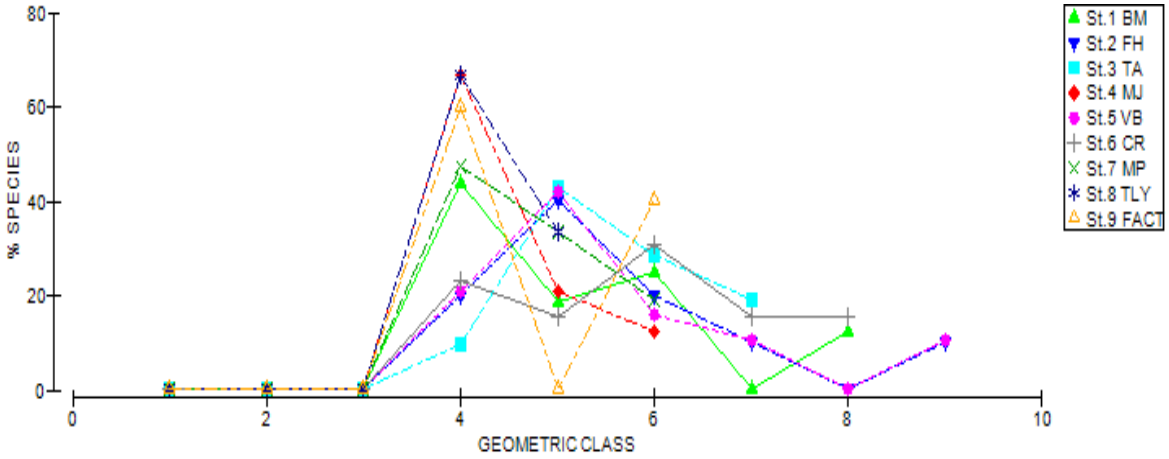

Figure-9
Geometric class plot of mean crustaceans in Cochin estuary during June 2009-May 2011

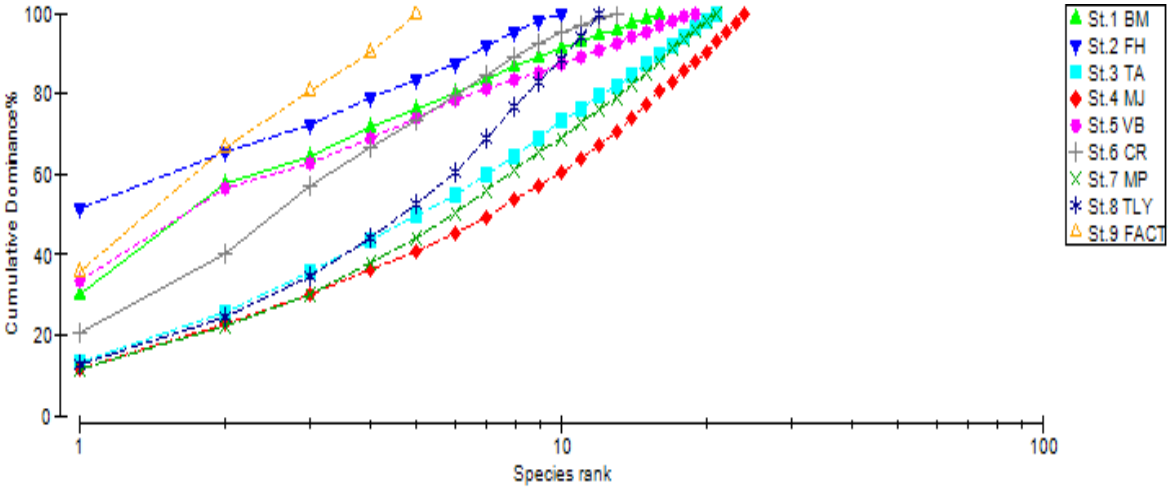

Figure-10

K' dominance plot of mean crustaceans in Cochin estuary during June 2009-May 2011

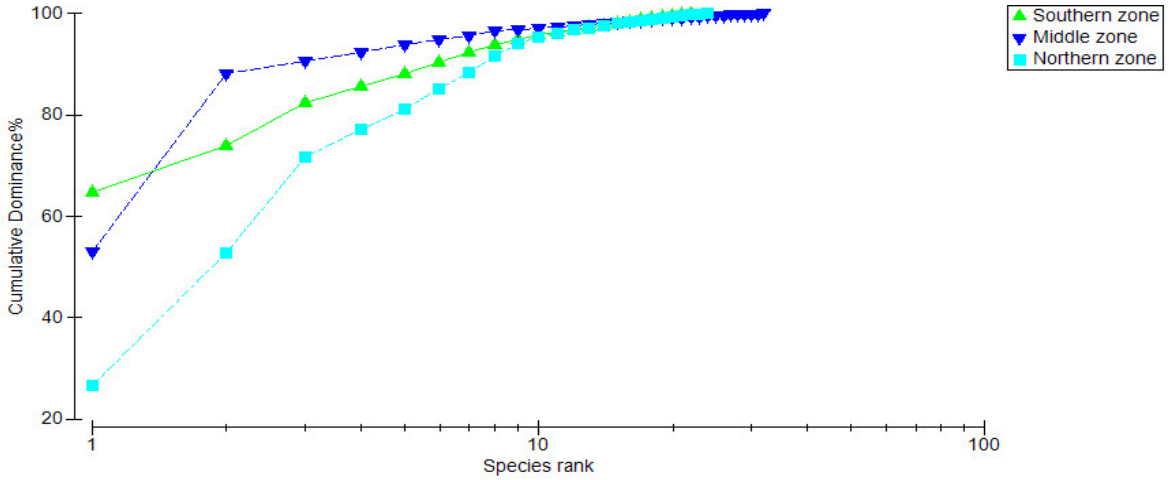

Figure-11

K' dominance plot of mean crustaceans in three zones of Cochin estuary during June 2009-May 2011

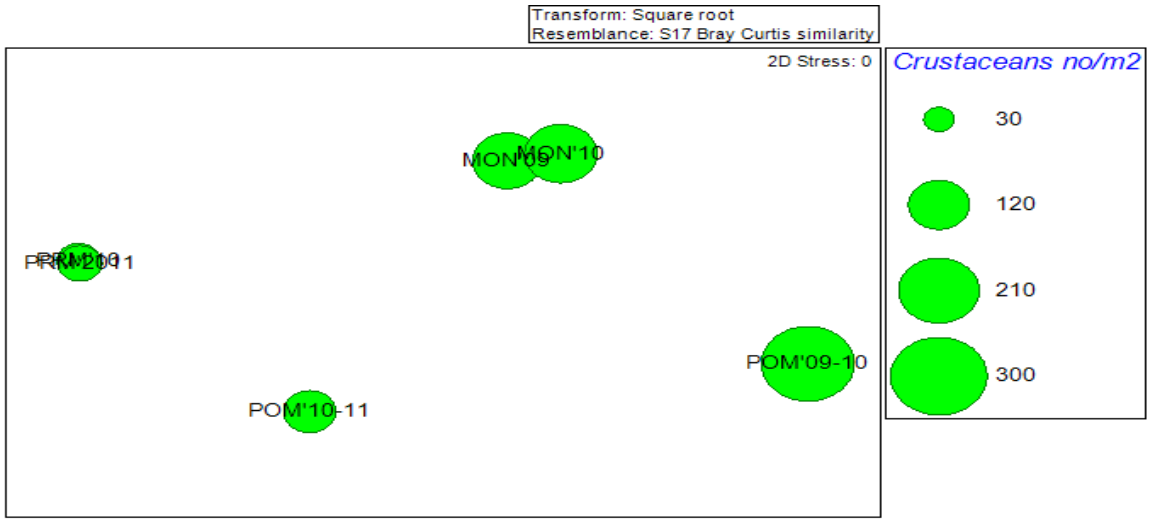

Figure-12

Bubble plot showing the seasonal difference of crustaceans in Cochin estuary during 2009-2011

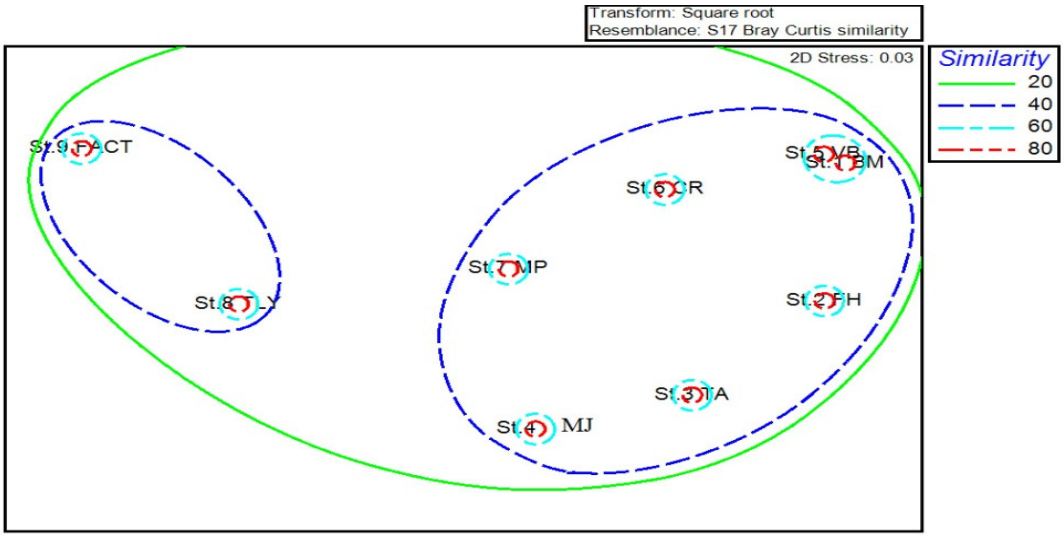

Figure-13
MDS plot showing the stationwise similarity of crustaceans in Cochin estuary during 2009-2011

Discussion: Physicochemical parameters: Temperature, salinity and dissolved oxygen were the most influential factors that control the distribution and abundance of crustaceans in estuarine environment. In the present study the salinity and temperature of sediment were increased in the upper regions of the estuary; salinity was increased in middle regions of the estuary; dissolved oxygen increased in the middle zone and northern zones. Some earlier studies reported that the temperature and dissolved oxygen (DO) link with the extensive human activities in Cochin estuary[51]. The water quality of Cochin estuary degraded by various human activities such as domestic waste disposal[52], increase the content of fertilizers and insecticides[53]. The distribution and abundance of benthic crustaceans in Cochin estuary was mainly depend on the variability of various physicochemical parameters. In northern zone of the estuary the temperature was higher than other zones. The organisms were decreased in the northern zone due to increase of temperature and pH of bottom water and sediment. The high temperature affect the respiration of crustaceans, because the respiration of crustaceans increased by increase of temperature[54].

The present study also confirmed that the temperature of bottom water and sediment showed a significant difference in stations. pH showed a variation in different zones of the estuay. Whereas the salinity showed an interesting seasonal variation in different zones; during post monsoon it was increased and during monsoon it was decreased in the estuary. The major groups of crustaceans such as amphipods were abundant in the high saline regions in the estuary in all seasons. During monsoon the salinity decreased due to the dilution of estuarine water by the effect of freshwater intrusion by river runoff and rainfall. Comparatively in the middle zone the salinity were higher in all seasons than other zones due to the seawater intrusion into the estuary through the barmouth. So that the high salinity in the middle estuary favours the survival of organisms than southern zone and northern zone of the Cochin estuary.

Dissolved oxygen and temperature of bottom water always showed an opposite trend in the distribution pattern. The dissolution of dissolved oxygen in the estuaries mainly occurred by the variation of temperature and also the salinity have a role in this process. Similar observation was reported in two estuaries in south east coast of India[55]. These changes affect the diversity and abundance of crustaceans in the estuary. Because, in the present study during post monsoon season the faunal abundance were maximum and during premonsoon it was minimum. pH were neutral at middle stations during almost all seasons. The decline of salinity, temperature and increase of decay of organic matter by the effect of river runoff may induce the reproduction of crustacean fauna in Cochin estuary during post monsoon season 2009-10 period.

Generally, pH of bottom water and sediment showed an acidic trend in almost all season in northern zones. Whereas, in the southern zone the pH showed an alkaline trend and in the middle zone it was neutral.

The northern zone of the estury were polluted with the industrial discharges from nearby factories. So that tne substratum were disturbed with the pollutants. Sediment pH observed was acidic in the northern zone. This may affect the faunal distribution in the northern zone. The nature of the substratum was another factor that controlling the crustacean fauna in Cochin estuary. The pollution tolerant species Chiranomid were inreased in the northern zone of the estuay. The abundance and diversity of organisms were decreased in the northern zone. The northern zone was riverine region and the bottom water salinity were lower than other zones.

This study revealed that the macrobenthic crustaceans were maximum in middle estuary; it may be due to high salinity and clayey silt substratum. Amphipods were observed high in middle zone. Each orders of crustaceans showed a different distribution pattern in three zone of the estuary. Because the high salinity and the low pH in the seaward side promote the seaweed and algal diversity and it favours the amphipods to flourish in these regions of the estuary.

Salinity was low and pH were nalkaline in the southern zone; sediment was clayey nature. The numerical abundance and diversity were low in the southern zone. It may be due to the nature of the substratum and salinity gradient. Decapod were the dominant group in the southern zone. The interaction of bottom water and sediment chracteristics influence the faunal distribution and diversity of crustaceans in the estuarine environment. The temperature, salinity and pH also contribute a major role in distribution of organisms. Therefore, it is obvious that the combination of different physicochemical parameters of estuarine water and soil controlling the distribution of benthic crustaceans in Cochin estuary. The macrobenthic composition, diversity and abundance were response to the pollution, domestic sewage and other contaminations by various human interventions[56,57].

Diversity, distribution and ecology: The above results indicate that the maximum abundance of benthic crustacean was observed in the middle zone and minimum in the north zone of Cochin estuary. Amphipods were the dominant group among benthic crustacean in three zone of the estuary. They were mainly live associated with seaweeds and algae in optimum salinity and temperature. *Corophium volutator* and *E. chilkensis* were dominant in the middle zone, *C. volutator* in southern zone and *G.tigrinus, C.volutator and E.chilkensis* in the northern zone.

The abundance of isopods were highest in the southern zone. They were mainly, wood borers and parasites on fishes. In the southern zone of the temperature and were lower than other two zones. But they were observed minimum in northern zone of the estuary. Tanaids are euryhaline and raptorial feeders, they collect the detritus matters and microorganisms from surrounding medium. The availability of food and high salinity in the middle zone of the estuary favours the survival of tanaids in that environment. Mysids and decapods were abundant in the southern zone of the estuary. The juveniles of crabs and prawns were the representatives. The southern zone were subjected to various fishing activities in the estuary. In this zone the salinity were dynamic due to freshwater inflow from rivers and increased distance from bar mouth. The decapods were observed minimum in northern zone. Whereas the dipterans were maximum observed in the northern zone. They were adapted to the high temperature and pH of water and sediment in low salinity.

The different groups of crustaceans showed some preference in selection of substratum. Because the tube building tanaids and amphipods were highest in the clayey silt substratum. Whereas the isopods and decapods were selected more clayey susbstratum than others. They were abundant in the southern zone. The dipterans and water mites were live in sandy substratum in northern zone of the estuary.

Conclusion

In the present study the macrobenthic crustacean fauna showed a zone wise variation in the diversity, abundance and their relationship to environmental variables in the cochin estuary. Amphipods were highest in the middle zone. Tanaids were highest in the middle zone and isopods, mysids and decapods in the southern zone. Acarids and dipterans were dominant in the northern zone. The diversity and species richness was highest in the middle estuary. Whereas, evenness was higher in the northern zone of the estuary. It may be due to the effect of increased pH of water and sediment in the industrial discharge area. In total, thirty four benthic crustacean species were encountered in the present investigation. The diversity and occurrence of crustaceans mainly depend on the physicochemical parameters of bottom water and sediment in Cochin estuary. In conclusion, variation in zonal distribution of crustaceans indicates that the nature of the substratum and dynamic nature of environmental variables in the Cochin estuary due to natural and anthropogenic impact.

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