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Fauna associated with the marine macro alga *Chaetomorpha aerea* (Dillwyn) Kutzing, (Chlorophyceae) in Pulicat estuary, Tamil Nadu, India

Azhagu Raj R, J Ganesh, A Prakasam, D Krishnamoorthy, Majesh Tomson and MC John Milton

Abstract
In the present study, an attempt was made to find out the animal associates of the seaweed *Chaetomorpha aerea*, at four sampling stations during the monsoon seasons in Pulicat estuary, India. A total of 5964 specimens were sorted and examined, twenty-one phytal fauna species were associated with the macroalga *Chaetomorpha aerea.* The data analysis showed that the phytal fauna in *C. aerea* mainly occupied by Gastropods followed by Amphipods, Decapods, Isopods and Polychaetes. The faunal composition of *C. aerea* ranged between 1.41 and 36.63%. The quantitative data indicated the dominant occurrence of Neritidae (62.47%) and Potamididae (9.94%), followed by Corophiidae (14.84%), Paguridae (3.31%) and Portunidae (0.97%) Cirolanidae (2.63%), Nereidae (2.26%) and Penaeidae (3.54%). The present study constitutes the first baseline approach to the Phytal fauna diversity of the seaweed *C. aerea* at the Pulicat Tamil Nadu, India.

Keywords: *Chaetomorpha aerea*, Phytal fauna, Pulicat Estuary and Species diversity

1. Introduction
Seaweeds are primary producers and they play a significant role in the benthic food web. Macroalgae are important primary producers along coasts worldwide, serving as habitat or functioning as ecological engineering species [1]. Seaweed and Seagrasses form small patches or larger vegetation beds which support epiphytic algae and animals, as well as a variety of associated mobile animals, including meiofauna, macrofauna and fish [1]. Many macroalgae build biogenic habitats which give refuge and offer an appropriate physical environment for a huge diversity of organisms [2]. Estuarine ecosystems have high ecological and environmental importance. They offer a substantial diversity of habitats, food resources and nursery areas for numerous species [2, 7]. Macroalgal beds are one of the most productive habitats in the marine environment and frequently support high densities of mobile invertebrates including small crustaceans, gastropods, copepods and polychaetes [8]. The fauna associated with seaweed beds offer a significant relationship to fishes [9, 10].
Seaweed beds are one of the most productive habitats in the marine environment and frequently support high densities of mobile invertebrates including small crustaceans, gastropods, copepods and polychaetes [8]. Seaweeds and Seagrasses habitually occur as thick aggregations support feeding and breeding ground for numerous shellfish and finfishes [11, 12]. Animals associated with algae were reported by Lough Rapids and Mukai [13] from Mukaishima Island, Japan; Zaleha [14] *et al*. studied the seaweed assemblage from Pulau Besar, Melaka, Malaysia. There have been a number of studies on macrophytes as habitats, but they mainly focus on fauna associated with single species of small red algae [15]. Seaweeds are among the most productive on the planet [16, 17] and may thus be expected to be important as a food resource to associated fauna [1]. A food chain from macrophytes *via* invertebrates to fish has been identified [18-20].
In India, Sarma and Ganapathy [21, 22], Sarma [23] have studied the phytal fauna from Visakhapatnam coast and Mohan [24, 25] have deliberate the algae associated fauna from Mandapam, Gulf of Manner Tamil Nadu. Yogamoorthi [26] and Selva Ranjitham [29] have reported that the seaweed associated faunas from Vellar estuary, Tamil Nadu. Muralikrishnamurthy [27] have calculated the phytal fauna from Visakhapatnam coast.

James [28] have studied the fauna associated with macroalgae, from Palk Bay and Gulf of Mannar and Jansi and Ramadhas [30] have studied the seaweed associated faunal diversity from Manakkudy estuary, India. Seaweed or macroalgae provides habitat for many organisms. Macrophytes are important primary producers in coastal ecosystems, and potential food resource for the associated animals [31-33]. Hitherto report on seaweed-associated fauna from Pulicat estuary. Hence, the present study is aimed at to study the phytal faunal association in Pulicat Lake Tamil Nadu, India.

2. Materials and Methods

2.1. Study area –Pulicat Estuary

Pulicat estuary, is the second largest brackish water body in India and is located between 13°26'and 13°43' N latitude and 80°03' and 80°18' E longitudes, with an average water spread area of about 461 sq. km on the Coromandel coast. Pulicat estuary has been so rich in biodiversity and fisheries since ancient times. The sampling stations are within the Pulicat estuary, Station I-13°25'57.60N 80°18°40.28"E,StationII-13°26'15.76N 80°19°02.31"E, Station-III-13°26'02.11'N 80°19°17.78"E and Station IV-13°25'41 N 80°18°54.86"E were fixed on the basis of biomass of the marine macroalgae.

2.2. Collection and Identification

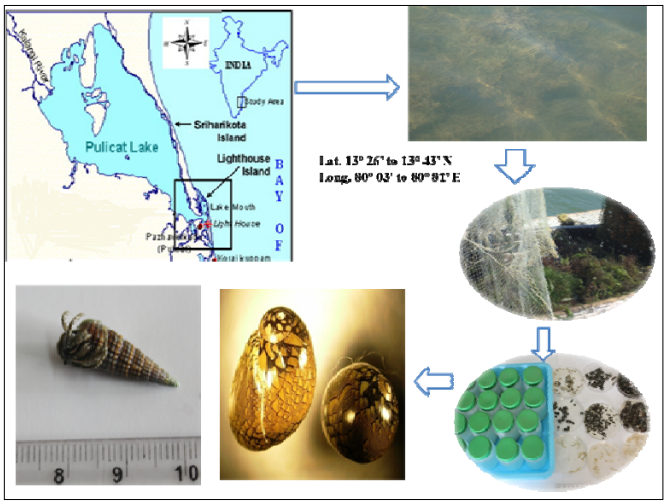
The macroalga *Chaetomorpha aerea* was collected from Pulicat estuary (stations I-IV, Quadrate, 25 X 25 cm2; each10 replicates). The animal groups were sorted, counted and preserved in 4% formalin for specific determination. The collection of fauna associated with the seaweeds was carried out following the procedure advocated by Sharma and Ganapati [21].

2.3. Data analysis

The structure and composition of seaweed -associated faunal data were approached to various statistical methods namely univariate and multivariate methods. The computer program PRIMER-E (ver.6.1.7) (Plymouth Routines in Multivariate Ecological Research), was used for univariate and multivariate analyses of data [34].

2.4. Statistical Analysis

Statistical analysis was performed by the Graph Pad Prism version 5.0. One way Analysis of Variance (ANOVA) was used to access difference in abundance of seaweed associated faunas in Pulicat Estuary. One-Way ANOVA was conducted, assuming there were significant differences among them when the statistical comparison gave $p < 0.05$ followed by, Bonferroni's Multiple Comparison Test (BMCT) are used to compare the all stations and variables.



Graphical abstract: Collection, identification and segregation of seaweed *Chaetomorpha aerea* and associated faunas in Pulicat Estuary.

3. Results and Discussion

3.1. Seaweed *Chaetomorpha aerea* associated fauna

In the present study, seaweed *C. aerea* associated fauna of the following six groups were recorded (Mollusca, Amphipods, Fishes, Prawns, Crab and Polychaetes) Twenty-one species of macrofauna were recorded from four stations of Pulicat estuary. Among the twenty-one species recorded, Crustaceans (Amphipods, Crab and Prawns) were found to be the largest component in the collection with ten species. Mollusca and fishes emerged as next dominant group in the order of abundance with five species. The polychaetes came last in the order with one species (Table1and 2).

Table1: Checklist of the Macroalga *Chaetomorpha aerea* associated fauna at Pulicat estuary

Crustacea			Polychaete
Amphipods	**Crabs**	**Prawns**	
Order: Amphipoda Family: Gammaridae Genus: *Eriopisa* Species: *E. chilkensis*	Order: Decapoda Family: Diogenidae Genus*: Clibanarius* Species : *C.clibanarius*	Order: Decapoda Family: Penaeidae Genus: *Penaeus* Species:*P. monodon*	Order: Phyllodocida Family: Nereidae Genus: *Nereis* Species: *N.chilkaensis*
Order: Amphipoda Family: Talitridae Genus: *Parorchestia* Species: *P. morini*	Order: Decapoda Family: Diogenidae Genus: *Clibanarius* Species: *C. longitarsus*	Order: Decapoda Family: Penaeidae Genus: *Fenneropenaeus* Species: *F. indicus*	
Order: Amphipoda Family: Ampeliscidae Genus: *Ampelisca* Species:*A. scabripes*	Order: Decapoda Family: Portunidae Genus*: Portunus* Species: *P. hastatoides*	Order: Decapoda Family: Penaeidae Genus: *Penaeus* Species: *P. semisulcatus*	
Order: Amphipoda Family: Aoridae Genus: *Grandidierella* Species: *G.gravipes*			

Table 2: Checklist of seaweed *C. aerea* associated molluscs and fishes at Pulicat estuary.

Mollusca	Fishes
Order: Mesogastropoda Family: Cerithidae Genus: *Cerithium* Species: *C. scabridum*	Order: Perciformes Family: Terapontidae Genus: *Terapon* Species*: T. puta*
Order: Mesogastropoda Family: Potamididae Genus: *Cerithidea* Species: *C. cingulata*	Order: Perciformes Family: Ambassidae Genus: *Ambassis* Species: *A. ambassis*
Order: Neogastropoda Family: Nassaridae Genus : *Nassarius* Species: *coronatus*	Order: Perciformes Family: Carangidae Genus: *Atule* Species: *A. mate*
Order: Allogastropoda Family: Pyramidellidae Genus : Odostomia Species: *O. babylonica*	Order: Mugiliformes Family: Mugilidae Genus: *Mugil* Species: *M. cephalus*
Order: Archeogastropoda Family: Neritidae Genus: *Clithon* Species: *oualaniensis*	Order: Perciformes Family: Lutjanidae Genus:*Lutjanus* Species: *johnii*

In stations I to IV, the population density of seaweed-associated macrofauna were 2004 nos/m2; 1304 nos/m2; 1500 nos/m2 and 1156 nos/m2 respectively. Sharma and Ganapthi [21] have observed 13 algae associated fauna in Visakhapatnam coast. Amongst the algae, the fine, bushy, tufted, *Spongomorpha indica* supported the maximum numbers of animals (78807.9/100g and 1134833.0/m2 of rock surface) and *Chaetomorpha antennina* associated fauna showed the minimum number of animals 550.4/100g and 11117.6/m2 of algal coverage. The faunal composition of *C. aerea* ranged between 1.41 and 36.63%. It is well known that the faunal density is also dependent on the morphology of the algae (structure, texture, color and contour) and its sediment retaining capacities.

Penaeid prawns constitute a major fishery in Pulicat estuary. There are about 12 species of penaeid prawns in the Pulicat estuary, of which seven species belong to the genus *Penaeus* and five belong to the genus *Metapenaeus* [35]. Amphipods support the growth, and production of estuarine fishes and prawns [36]. Seaweed, Seagrass, and growing marshes, mangrove substrates may sustain higher densities of amphipods [37, 38]. Hermit crabs occupy empty gastropod shells and these shells act as shelters from biotic factors including predation and abiotic factors such as desiccation and osmotic stress [39-41].

The distribution of polychaetes in Pulicat estuary is determined chiefly by the salinity of water and the nature of substratum. *Nereis chilkensis,* are widespread, in diverse habitats in the Pulicat lake. Polychaetes constitute important links in the food-chains of Pulicat Lake and they are the common food items for several species of top carnivores like fishes and birds in the Lake [14, 21, 25, 26, 28, 30, 42].

The density of macrofauna in *C. aerea* is ranged from 1304 to 2004 and is good agreement with the earlier report by Saravanakumar *et al.* [43]. The lower density of macrofauna might be due to the higher saline nature of the estuary. The assemblage of polychaetes, amphipods, and gastropods in *C. aerea* it may be due to providing more area of the substratum.

The faunal register was showed varies feeding habits such as filter feeders, detritus feeders, scavengers or carnivores and algivorous [29].

The faunal diversity was higher at the station I situated near bar mouth than the interior three stations. Among the regions, the maximum diversity value was found in station I. The species richness, it's generally recognized that the muddy or clay sediments of mangrove forest act as a home for a variety of epifaunal and infaunal invertebrates [44]. True to this, in the present study, the organic carbon and nitrogen percentage was more in the station I which might be the plausible reason for the higher diversity and richness in the station II.

In this study, *C. aerea* associated amphipods mainly depends for their protection. Norderhaug [15] have reordered that kelp-associated amphipods selected habitat (red algal species) according to architectural structure and complexity and not according to food value, indicating that the habitat was mainly important for protection and not as a food source [1, 45].

The percentage composition of *C. aerea* associated fauna was recorded in four stations as detailed in (Fig 1, 2, 3and 4). The assessment of phytal fauna in Vellar estuary showing the presence of a diversity of nematodes, harpacticoids, and amphipods, were made by Selvaranjitham *et al.* [29]. In addition, a number of polychaetes, ostracods, and gastropods were also present. In the present study, in stations, I-IV, the population density of seaweed-associated macrofauna were 2004 nos/m^2; 1304 nos/m^2; 1500 nos/m^2 and 1156 nos/m^2 respectively. In the present study, the station I showed the high population density compared to other three stations because the total organic carbon was more in sediment as reported by Kumar [44]. This study corroborates the results of the present study.

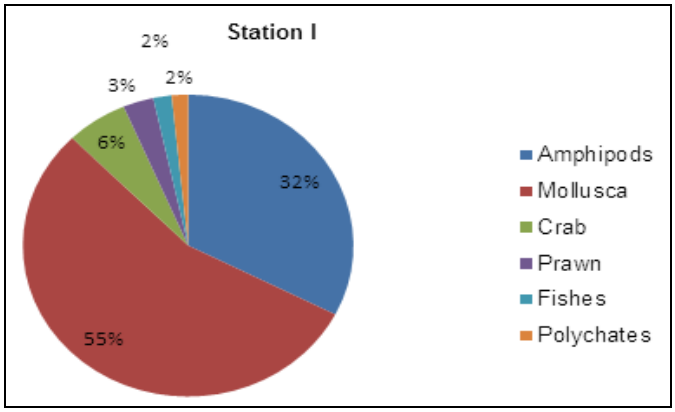


Fig 1: Percentage composition of Macroalga *Chaetomorpha aerea* associated fauna in Pulicat Lake (station I)

In one-way ANOVA confirms that, differences in the stations between variables were found not significant (NS) ($P < 0.05$), P-value (0.6899); R-squared value is (0.01806) and F value (0.4905). Bonferroni's Multiple Comparison Test (BMCT) results show that the mean differences between stations were also found no significant (NS) at ($P < 0.05$), P value (0.2065). These results indicate that *C. aerea* associated fauna in Pulicat estuary, prefers selective habitat in the estuary.

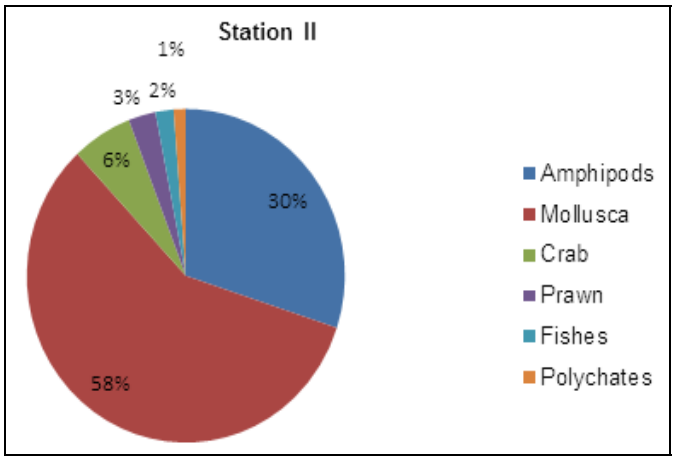


Fig 2: Percentage composition of Macroalga *Chaetomorpha aerea* associated fauna in Pulicat Lake (station II)

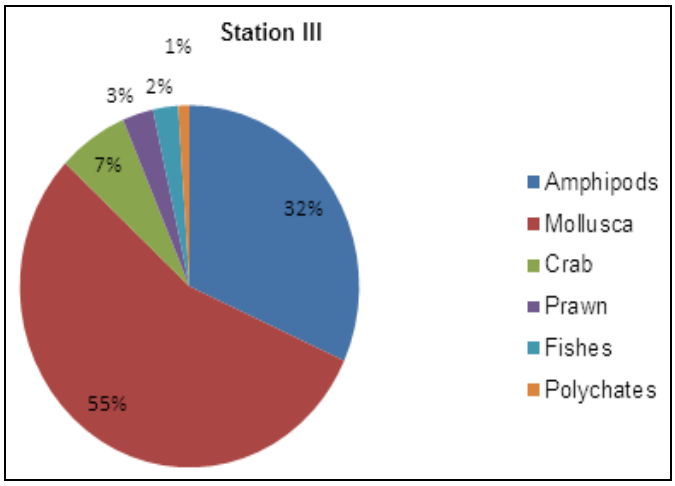


Fig 3: Percentage composition of Macroalga Chaetomorpha aerea associated fauna in Pulicat Lake (station III)

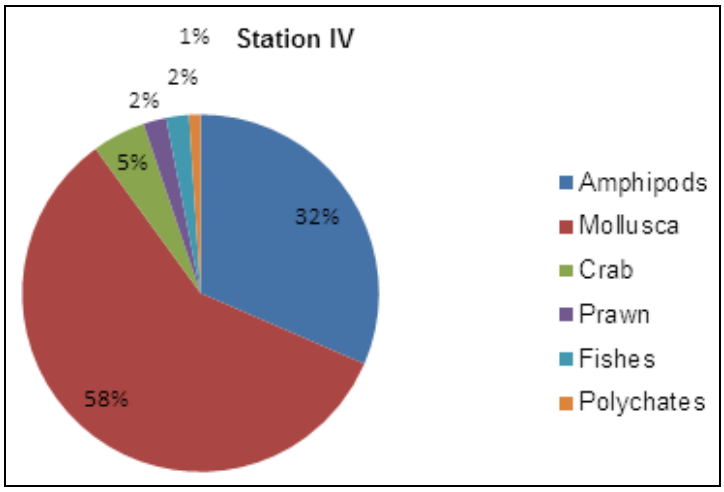


Fig 4: Percentage composition of Macroalga *Chaetomorpha aerea* associated fauna in Pulicat Lake (station IV)

The macroalga *C. aerea* associated faunal densities were low compared to other algal beds in Vellar estuary. Christie, *et al*. [1] have reported that the lowest faunal densities were found in ephemeral turf algae of small size and low habitat complexity. Low densities of animals in these turf samples may also be due to high grazing pressures by small fish [20]. Faunal densities were also lower in intertidal algae *Fucus vesiculosus* than in structurally similar submerged species. This is expected since the littoral zone is a physically harsher environment than the sublittoral zone [1, 33].

In the present study, a marked variation in diversity indices was observed between the stations. In station I-IV, the species diversity (Shannon Weinner index) varied from 2.254 to 2.091. The species richness between the stations I-IV ranged from 2.598 to 3.217. The species evenness, varied from the stations I-IV 0.7235 to 0.7789 (Table 3). The present values observed in all the stations are comparable with the results of an earlier study made by Sunilkumar, [46] who studied the macro benthos in the mangrove ecosystems of Cochin backwaters and reported that the faunal diversity was higher at the station I situated near bar mouth than the interior three stations. Among the regions, the maximum diversity value was found in the station I.

Table 3: Species diversity indices for seaweed *Chaetomorpha aerea* associated fauna in the Pulicat estuary

Stations	Species richness (d)	Pielou's evenness(J)	Brillouin index	Fisher -α	Shannon-Weiner index H'($\log_e$)
Station I	3.217	0.7405	2.177	4.434	2.254
Station II	2.598	0.7789	2.066	3.538	2.16
Station III	2.877	0.7542	2.091	3.963	2.18
Station IV	3.009	0.7235	1.988	4.274	2.091

3.2 Graphical technique (K- dominance plot)

The K- dominance plot is drawn clearly demonstrated the diversity pattern in the four stations. Conforming to the trend observed in diversity indices, curves of stations I and III which lies on the lower side extends further and rises slowly due to the presence of more number of species. As the percentage contribution of each species is added, the curve extends horizontally (species number is evident in the X-axis) before reaching the cumulative 100%. As the curve for the station IV had to accommodate less number of species, it rises quickly. This plot also amply proved the rich diversity in the stations I and III compared to station II and IV (Fig 5).

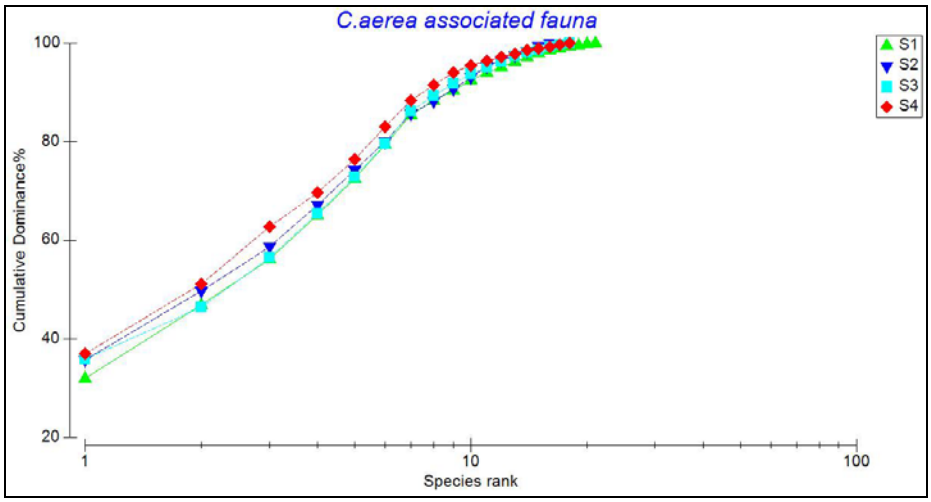


Fig 5: K- Dominance curve for *Chaetomorpha aerea* associated macrofauna in all stations of Pulicat Lake

3.3. Geometric Class Plots

Geometric class plots are essentially frequency polygons, plotted for all stations, the number of species that fall into a set of geometric (x^2) abundance classes. It has been suggested that impact on assemblages tends to change the form of this distribution, lengthening the right tail. The geometric class, (0-2, 2-4, 4-6 and 6-8) for all stations were (percentage species 0-28, 10-22, 5-32 and 0-20) respectively (Fig. 6).

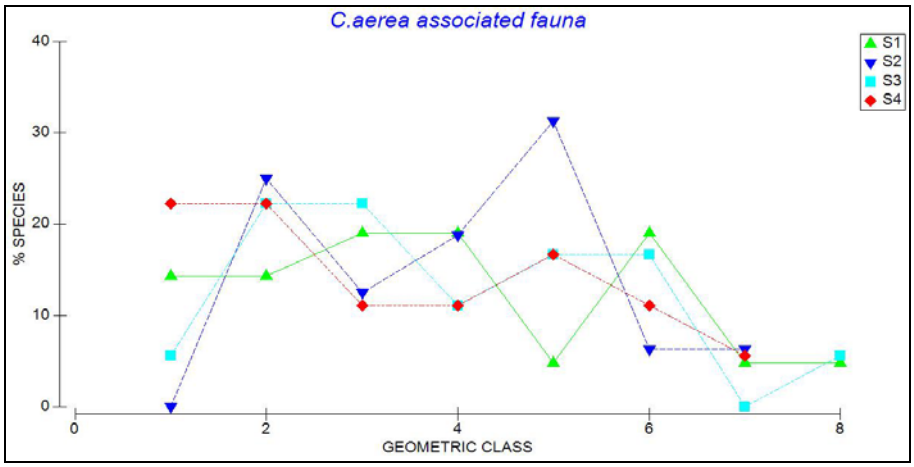


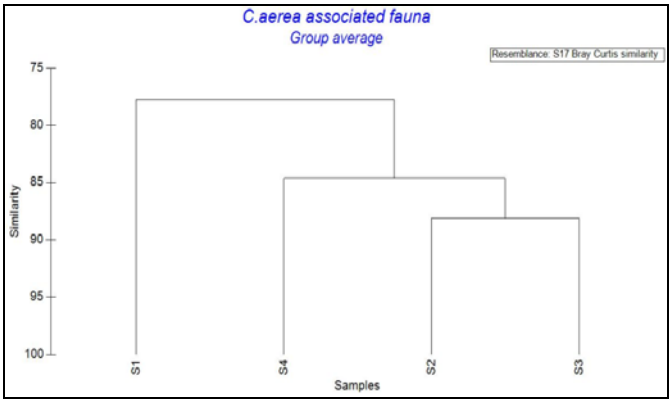
Fig 6: Geometric class plot for *Chaetomorpha aerea* associated macrofauna in all stations of Pulicat Lake

3.4. Multi-Dimensional Scaling (MDS)

Besides this, to study the similarity/dissimilarity, (Bray-Curtis Similarity) the data (Square root) of four stations were also subjected to cluster analysis and MDS ordination. Among the stations, samples of station II & III got grouped at the highest level of similarity (88% & 84%) followed by samples of stations I & III (84%); stations I &II (77%), stations I & IV (71%) stations II & IV (85 %) and stations III&IV (83%). Further, a cluster of stations II & III formed a single cluster at the next level of similarity (88 % & 84 %) and a cluster of stations IV & I grouped successively to this at the next level similarity (71%) (Table 4, Fig.7).

Table 4: Non-metric multi-dimensional scaling (MDS) studies of seaweed *Chaetomorpha aerea* associated fauna

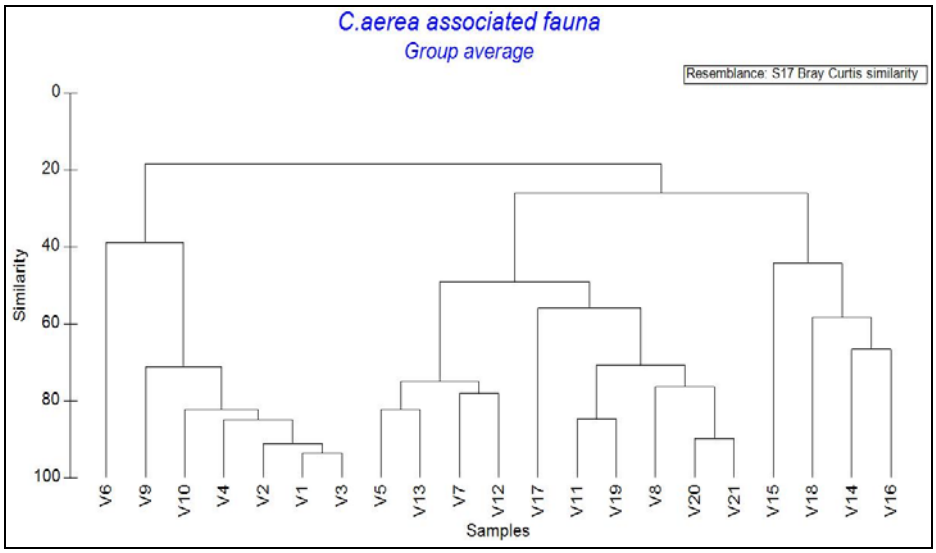
Seaweed *Chaetomorpha aerea* associated fauna				
	Station I	**Station II**	**Station III**	**Station IV**
Station I	0	0	0	0
Station II	77.76428	0	0	0
Station III	84.4649	88.11594	0	0
Station IV	71.0828	85.80858	83.43558	0



(S1-Station I; S2- Station II; S3- Station III; S4- Station IV)

Fig 7: Dendrogram for hierarchical clustering (group average) of stations in Pulicat Lake

To confirm this pattern of grouping, the data were also given as input to MDS (non-metric Multi-Dimensional Scaling). The plot revealed that the groupings recognized in the cluster were quite evident here also. The stress value, which overlies on the top right corner of the plot, showed that the value is minimum (0.0) signaling the excellent ordination pattern of samples collected (Fig.8).

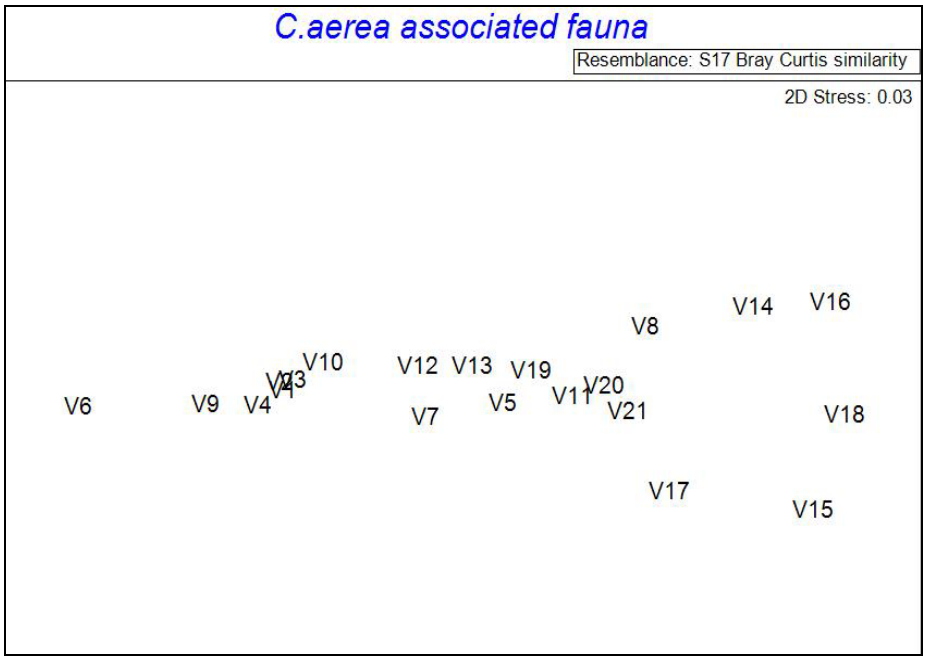


(V1- *C. oualaniensis,* V2- *E.chilkensis,* V3- *P. morini;* V4- *C. cingulata;* V5- *A. scabripes;* V6- *C. scabridum;* V7- *N. coronatus;* V8- *O. babylonica;* V9-*N.chilkaensis;* V10-*C. clibanarius;* V11- *C. longitarsus;* V12- *P. hastatoides;* V13-*P. monodon;* V14- *F. indicus;* V15- *P. semisulcatus;* V17- *T. puta;* V18-*A. ambassis;* V19 *A. mate;* V20-*M. cephalus* and V21- *L. johnii).*

Fig 8: Dendrogram for hierarchical clustering of the *C. aerea* associated macrofauna in stations I-IV in Pulicat Lake

In Bray-Curtis Similarity the data (Square root) pertaining to *C. aerea* associated fauna were subjected to cluster analysis and MDS ordination. Among the samples collected Mollusca and amphipods got grouped at the highest level of similarity (90%), followed by samples of Polychaetes, Crab, Prawn and fishes (78%, 76%, 82% & 65%) respectively. Further, Molluscan and Amphipods cluster exhibited the next level of similarity at 90 % followed by Polychaetes, Crab and Prawn grouped successively the next level at 78%, 76% & 82% respectively, Cluster of fish's base the level of similarity at 65%. Presently, the dendrogram and MDS drew revealed clearly the grouping of samples collected in all stations (Fig.9). The stress value recorded in the present study is comparable with the studies made by Ajmalkhan *et al*. [39] and Tolhurst and Chapman [47].

To confirm this pattern of grouping, the data (Bray-Curtis Similarity) were also given as input to MDS (non-metric Multi-Dimensional Scaling). The plot revealed that the groupings recognized in the cluster were quite evident here also. The stress value, which overlies on the top right corner of the plot showed, minimum (0.03) signaling the good ordination pattern of samples collected. Similarity profiles of *C. aerea* associated fauna station I-IV were calculated. The sample statistic (Pi) value was 2.726 (Fig.9).



(V1- *C. oualaniensis,* V2- *E.chilkensis,* V3- *P. morini;* V4- *C. cingulata;* V5- *A. scabripes;* V6- *C. scabridum;* V7- *N. coronatus;* V8- *O. babylonica;* V9-*N.chilkaensis;* V10-*C. clibanarius;* V11- *C. longitarsus;* V12- *P. hastatoides;* V13-*P. monodon;* V14- *F. indicus;* V15- *P. semisulcatus;* V17- *T. puta;* V18-*A. ambassis;* V19 *A. mate;* V20-*M. cephalus* and V21- *L. johnii).*

Fig 9: MDS ordination generated for the *C. aerea* associated macrofauna in all stations in Pulicat Lake

The filamentous alga *C. aerea* due to its densely growing habit providing more area of the substratum, it supported a high number of organisms, compared to other seaweeds. Many species inhabiting marine algae depend on them for food. The most common are polychaetes, amphipods, and gastropods. The feeding relationships of this algal fauna also vary. Many are filter feeders, detritus feeders, scavengers or carnivores; algivorous ranging from minute crustaceans to large sized gastropods [7, 29]. The observations of the present study are in general agreement with the earlier observation made by Sharma and Ganapthi [21], Selvaranjitham [29] *et al.* [29] Jansi and Ramadhas [30] and Zaleha [14]. It is well documented that the seaweed-associated faunal density is also dependent on the structure, texture, color and its sediment retaining capacity of the algae [21].

4. Conclusion

This is the first study comparing species diversity, composition and richness of faunal assemblages in *C. aerea* at Pulicat estuary. The filamentous alga *C. aerea* due to its densely growing habit providing more area of the substratum, it supported an elevated number of organisms. The number of animals in *C. aerea* was found to attain a minimum in station IV and a maximum in station-I The faunal diversity was higher at the station I situated near bar mouth than the interior three stations. Twenty-one species of seaweed-associated macrofaunal were recorded from the four stations of Pulicat estuary. Among them, Crustaceans were found to be the largest component in the collection with ten species. The molluscs were found to dominate in stations I-IV; Amphipods were next in abundance in stations I-IV. The present study constitutes the first baseline approach to the alga associated faunal diversity in Pulicat estuary. However, knowledge of seasonal fluctuations of seaweeds associated macrofauna is necessary for forthcoming monitoring, administration and for making consistent management decisions, especially in protected areas such as Pulicat estuary, Tamil Nadu, India.

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