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Diversity of zooplankton in Kadalundi-Vallikunnu Community Reserve, North Kerala, India

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ABSTRACT

Zooplankton samples collected from ten stations covering the entire stretch of the Kadalundi-Vallikunnu Community Reserve, Kerala, south India, for a period from July 2018 to June 2019 were studied. Twenty eight groups of zooplankton *viz*. copepods, foraminifera, medusae, chaetognaths, siphonophores, ctenophores, ostracods, cladocera, *Lucifer* sp., amphipods, isopods, appendicularia, *Balanus* nauplii, cyphonautes larvae, polychaete larvae, echinoderm larvae, ephyra larvae, brachiopod larvae, alima larvae of squilla, aquatic insect larvae, prawn larvae, crab zoea, crab megalopa larvae, bivalve larvae, pteropods, gastropod larvae, fish eggs and fish larvae were recorded. Among these, copepods formed the major portion of 43%. An average of 18330 nos. per 100 m^3 was noticed from the study area. The maximum and minimum density of zooplankton was observed at Station 1 and 10 respectively and a decreasing trend in abundance was recorded from barmouth towards upstream stations. Seasonal studies indicated a maximum of 52% during pre-monsoon, followed by 36% during post-monsoon and a minimum of 12% during monsoon. Different indices of diversity, dominance plot, dendrogram and Multi Dimensional Scaling (MDS) plot are presented and discussed.

Keywords: Biodiversity, Estuary, PRIMER, Primary consumers, Seasonality

Introduction

Zooplankton community is a heterogeneous assemblage of animals covering many taxonomic groups and they form the vital intermediary link in the food chain of any aquatic ecosystem both as consumers of the primary producers and as contributors to the higher trophic levels. The distribution and abundance of zooplankton depend on the water movement, ecological characters, depth, season and other prevailing conditions of the environment. Several studies have been carried out on zooplankton in Indian estuaries (Haridas *et al.*, 1973; Wellershaus, 1974; Pillai *et al.*, 1975; Goswami and Selvakumar, 1977; Madhupratap, 1978; Arunachalam *et al.*, 1982; Bhat and Gupta, 1983; Nair *et al*., 1984; Srinivasan and Santhanam, 1991; Nandan and Azis, 1994; Karuppasamy and Perumal, 2000; Patil *et al*., 2002; Santhanam and Perumal, 2003; Qasim, 2005; Jyothibabu *et al*., 2006; Madhu *et al*., 2007; Perumal *et al*., 2009; Jeyaraj *et al*., 2014). However, not much work has been carried out on zooplankton diversity from the estuarine waters of north Kerala. The Kadalundi-Vallikunnu Community Reserve is the first Community Reserve of Kerala and lies partly in Kozhikode and Malappuram districts and is managed jointly by Kadalundi and Vallikunnu Grama Panchayats. The area has been officially declared as a Community Reserve in October, 2007. The faunal diversity of mangrove ecosystem of Kadalundi and Nalallam was studied by Araty (2009). Recently, Ali *et al*. (2018) gave a brief account of zooplankton from three stations along southern side of Kadalundi River estuary. In their studies, they have used a net with a relatively smaller mesh size (158µm) for collecting zooplankton. The mesh size of the net greatly influences the studies on the community structure of zooplankton in any aquatic ecosystem. Hence this study was undertaken to explore the zooplankton in the Kadalundi-Vallikunnu Community Reserve using a larger mesh sized plankton net in order to cover more groups of zooplankton. The study was carried out extensively from ten stations in the estuary covering the entire stretch of the Kadalundi-Vallikunnu Community Reserve. The updated information on zooplankton diversity of the Community Reserve may serve as a good plankton database for the region.

Materials and methods

Zooplankton samples were collected from ten stations in Kadalundi-Vallikunnu estuarine system on monthly intervals during the period from July 2018 to June 2019 (Fig. 1). Apart from sampling stations, different Islands, mangrove area and sand bar formations are indicated in the figure. The geo-locations of the sampling stations are given in Table 1.

Station 1 was located near the barmouth and other stations towards upstream. A conical plankton net having a mouth diameter of 50 cm and mesh size of 200 µm was used for collection and horizontal surface tows were made for 10 min in each station between 06: 00 and 08: 30 hrs from a canoe powered by oars. The collected samples were preserved in 4% formaldehyde solution and examined under a stereozoom binocular microscope for identification and enumeration. The plankton were identified up to the group level following Newell and Newell (1977), Davis (1955) and Todd *et al*. (2006). They were counted using a modified Bogorov counting tray and computed for 100 m^3 of water (Rani *et al*., 1981). For seasonal studies, June-September was considered as monsoon, October-January as post-monsoon and February-May as pre-monsoon season (Mathew *et al*., 2003). The data was subjected to univariate and multivariate analyses for diversity indices, dominance plot, Bray-Curtis similarity, dendrogram and Multi Dimensional Scaling (MDS) using the PRIMER (v.6) software (Clarke and Gorley, 2006).

Results and discussion

A total of 28 groups of zooplankton *viz*. copepods, foraminifera, medusae, chaetognaths, siphonophores, ctenophores, ostracods, cladocera, *Lucifer* sp., amphipods, isopods, appendicularia, *Balanus* nauplii, cyphonautes larvae, polychaete larvae, echinoderm larvae, ephyra larvae, brachiopod larvae, alima larvae of squilla, aquatic insect larvae, prawn larvae, crab zoea, crab megalopa larvae, bivalve larvae, pteropods, gastropod larvae, fish eggs and fish larvae were recorded. Our results were found to be different from that of a study conducted during 2016-17 in Kadalundi by Ali *et al*. (2018) who recorded only 6 groups namely, Rotifers, Protozoa, Maxillopoda (copepods mainly), Crustacea (ostracods mainly), Rhizopod (foraminifera mainly) and nematodes. The less number of zooplankton groups recorded by them may be due to the smaller mesh size (158 µm) of the net used for the collection and the sites selected for the study. In another study, 22 groups of zooplankton were recorded from estuarine regions of Kasaragod District in northern Kerala (Jeyaraj *et al*., 2014) which is comparable with the results of the present study. The qualitative and quantitative distribution of zooplankton along with diversity profile in the present study is presented here.

Qualitative and quantitative distribution

Station-wise as well as month-wise distribution and abundance of different zooplankton groups were studied

Table 1. Geolocations of sampling stations

Stations	Geo-locations
Station 1	11°07’33.30”N; 75°49’34.26”E
Station 2	11°07’47.70”N; 75°49’41.58”E
Station 3	11°07’30.00”N; 75°49’49.44”E
Station 4	11°07’50.64”N; 75°49’51.24”E
Station 5	11°07’43.74”N; 75°49’54.78”E
Station 6	11°07’49.98”N; 75°50’15.72”E
Station 7	11°07’56.16”N; 75°50’10.14”E
Station 8	11°08’1.08”N; 75°50›04.56”E
Station 9	11°08’3.00”N; 75°49’59.40”E
Station 10	11°08’6.42”N; 75°50’20.88”E

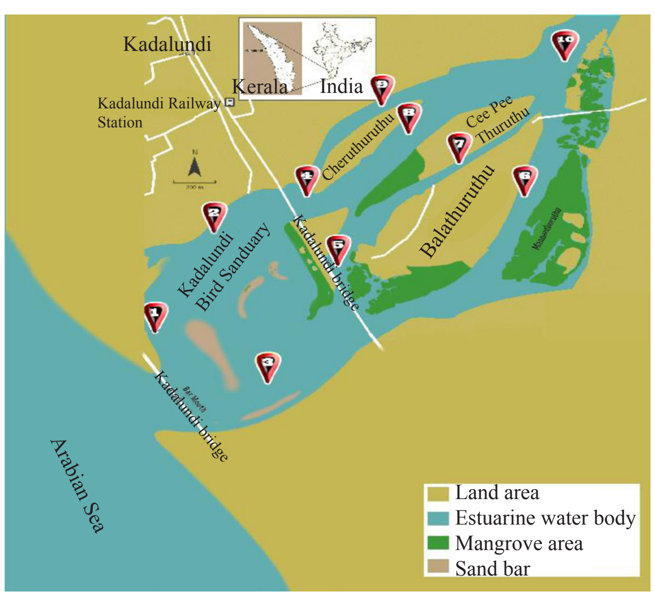

Fig. 1. Map showing sampling sites

and an average concentration of 18330 nos. per 100 m^3 was recorded from the study area. Station-wise abundance (Fig. 2) indicated a maximum of 45362 nos. per 100 m^3 at station 1 followed by station 2 (38926 nos. per 100 m^3), station 4 (29046 nos. per 100 m^3) and a minimum of 6095 nos.per 100 m^3 was noticed at station 10.

A decreasing trend in abundance of zooplankton from station 1 to 10 was observed. The density of zooplankton was found to be more in stations nearer to the barmouth than in other stations located upstream. Station 1 is located very near to the barmouth and the first four stations contributed 68% of the total and the rest of six stations together formed only 32%. This was mainly due to the abundance of copepods, medusae, chaetognaths, ostracods, cladocera, *Lucifer* sp., appendicularia, *Balanus* nauplii, prawn larvae, bivalve larvae, fish eggs and fish larvae in stations 1-4. At station 3, there was a decline which may be due to less water flow as this station was located on the other side of the main channel where the flow was partly hindered by the formation of a sand bar in the region. A higher population density of zooplankton at the mouth of the estuary was also reported by Perumal *et al*. (2009) from Kaduviyar Estuary in south-east coast of India.

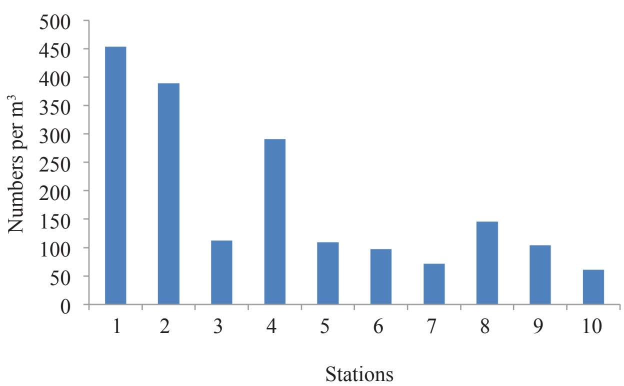

Fig. 2. Station-wise distribution of zooplankton during the study period

Month-wise studies showed the maximum contribution of zooplankton (18%) during November, followed by 16% each during April and February, 13% during March, 10% during January, 8% during September, 7% each during May and December, 2% each during June and August, 1% during October and the contribution of zooplankton was the minimum during July (0.09%). The minimum occurrence of zooplankton during July was also reported by Madhupratap and Haridas (1975) from backwaters from Cochin to Alleppey. They have reported 1.1 nos. m^{-3} during July, which is comparable with the density of 1.99 nos. m^{-3} recorded in the present study. The month-wise distribution of different zooplankton groups in the study area is depicted in Fig. 3.

Copepods formed the major share of 43% in the study area, followed by *Balanus* nauplii (18%) and other zooplankton groups contributed less than 10% each during the study period. The distribution of copepods among different months indicated a maximum of 22% in April, 19% in February, 14% in November, 11% in March, 10% in May and in other months, the contribution was less than 10% each. The dominance of copepods in the zooplankton has been reported by Jeyaraj *et al*. (2014) from estuarine regions of northern Kerala, Nair *et al*. (1984) from Kadinamkulam backwaters, Sarkar *et al*. (1984) from Hooghly Estuary, Nagarajaiah and Gupta (1985) from Netravati Estuary, Nair and Azis (1987) from Ashtamudi Estuary, Padmavati and Goswami (1996) from west coast of India, Mishra and Panigrahy (1999) from Bahuda Estuary, Karuppasamy and Perumal (2000) from Pichavaram mangrove ecosystems, Perumal *et al*. (2009) from Kaduviyar Estuary, Madhu *et al*. (2007)

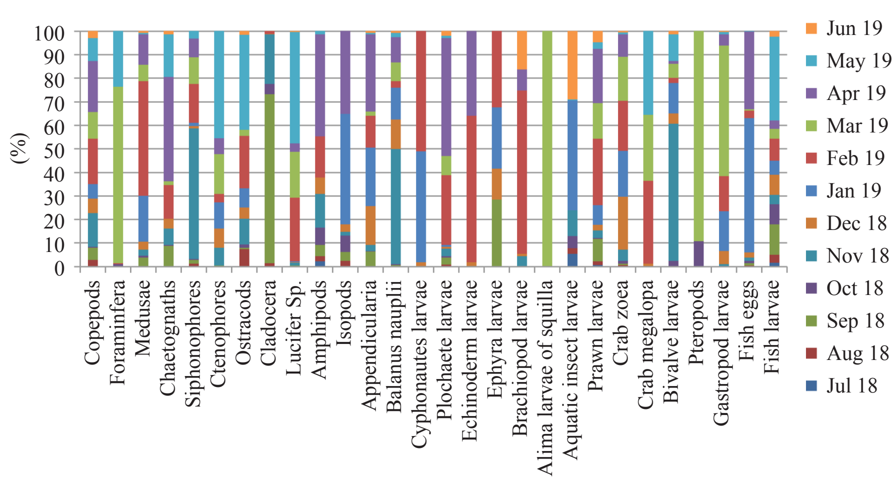

Fig. 3. Month-wise distribution of zooplankton groups in the study area

from Cochin Estuary, Subbaraju and Krishnamurthy (1972) from Vellar Estuary and Goswami (1982) from Mandovi-Zuari estuarine system. Qasim (2005) stated that "in the zooplankton community, copepods constitute the dominant group in all the Indian estuaries".

Season-wise studies indicated the highest abundance of zooplankton during pre-monsoon (52%), followed by post-monsoon (36%) and monsoon (12%). During pre-monsoon months, almost all the groups of zooplankton recorded maximum numbers in this area except siphonophores, isopods, *Balanus* nauplii, crab zoea, bivalve larvae and fish eggs, but these groups showed secondary peak during pre-monsoon. In the case of cladocera, the major peak was during September (72%) and minor peak during November (21%) and swarming of this group was noticed during these months. The high production during pre-monsoon period was also reported earlier by Banarjee and Choudhury (1966), Haridas *et al*. (1973), Pillai *et al*. (1975), Prasad (2003), Nair and Azis (1987), Araty (2009) and Ali *et al*. (2018). The least contribution of zooplankton recorded in the present study during monsoon season was in conformity with the studies made by Goswami and Selvakumar (1977), Arunachalam *et al*. (1982), Bhat and Gupta (1983), Nair *et al*. (1984) and Sasi *et al*. (1999). The freshwater flood from upstream might have caused depletion of zooplankton population density during monsoon season (Perumal *et al*., 2009).

Diversity

The diversity indices of zooplankton community in different stations as well as in different months were calculated. Between stations the variations of different indices are negligible but, between months some variations are noticed and are given in Table 2.

The number of groups of zooplankton (S) varied from 12 during July 2018 to 24 each during February, 2019 and December 2018. The minimum number of groups recorded during July 2018 can be due to the onset of heavy rainfall and subsequent flow of turbid freshwater from upstream of the river which might have resulted in rapid decline in salinity and increase in turbidity. The Margalef's index (d) which incorporates the number of individuals and groups (S) showed the highest during December 2018 (5.2734) and minimum during July 2018 (3.6549). The Pielou's evenness index (J') which expresses the evenness of distribution of individuals among the different groups ranged from 0.9349 during September 2018 to 0.9736 during July 2018. The Simpson index (1-Lambda') provided information on dominance of groups and it was found to be high during October 2018 (0.9622) and low during September 2018 (0.9406). Shannon-Wiener's diversity index (H') which is the most commonly used diversity measure varied between 2.4193 in July 2018 and 3.0499 in February 2019, which indicates that the groupwise composition between months did not vary to a large extent. Also, there was no particular changing pattern in diversity index (H') and the values fluctuated between months. Ali *et al*. (2018) also noticed minimum diversity of Shannon-Wiener's index during July in Kadalundi but maximum was observed by them during January instead of February as observed in the present study, which may be due to the year-wise variations of hydrobiological characteristics of the ecosystem.

In the dominance plot (Fig. 4), the curve for February 2019 lies on the lower side and extends further due to the presence of more number of zooplankton groups when compared to other months. As the percentage contribution of each group is added, the curve extends horizontally along with species numbers in the X- axis, before reaching the cumulative 100%. The number of groups was the lowest during July and the curve for July lies on the upper side. This plot also made it clear that

Table 2. Diversity indices of zooplankton during different months

Month/Year	S	d	J'	1-Lambda'	H'
18-Jul	12	3.6549	0.9736	0.9521	2.4193
18-Aug	18	4.5609	0.9378	0.9432	2.7106
18-Sep	20	4.5066	0.9349	0.9406	2.8008
18-Oct	21	5.1161	0.9691	0.9622	2.9506
18-Nov	22	4.6754	0.9383	0.9445	2.9003
18-Dec	24	5.2734	0.9370	0.9519	2.9778
19-Jan	20	4.2709	0.9505	0.9461	2.8473
19-Feb	24	4.9192	0.9597	0.9557	3.0499
19-Mar	20	4.2313	0.9530	0.9458	2.8549
19-Apr	19	3.9852	0.9589	0.9438	2.8233
19-May	20	4.4072	0.9451	0.9457	2.8311
19-Jun	16	3.8855	0.9667	0.9436	2.6804

S=Number of groups, d= Margalef's index, J'= Pielou's evenness index, 1-Lambda'= Simpson index, H'= Shannon-Wiener's diversity index

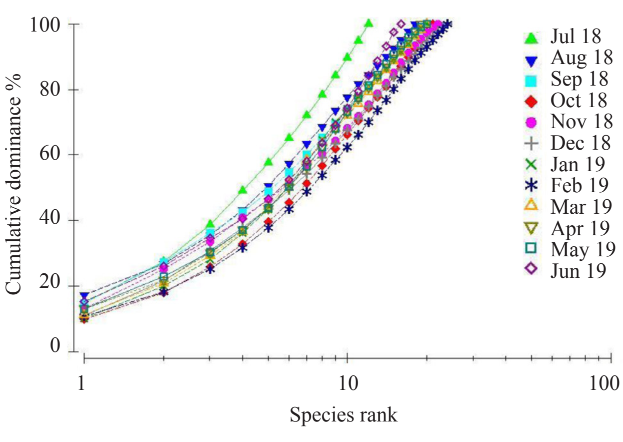

Fig. 4. Dominance plot of zooplankton during the study period

in addition to July; June, August and September also lie on the upper side indicating lesser number of zooplankton groups during monsoon when compared to other seasons. The lower number of groups during monsoon season can be attributed to strong downstream currents and turbidity apart from salinity, rendering the environment severe for many organisms during the monsoon (Madhupratap, 1978).

The similarity in composition and abundance of zooplankton groups among different stations was derived from Bray-Curtis similarity matrix and based on that a dendrogram (Fig. 5) was constructed to understand the hierarchical clusters by using the group average linking between stations during the study period. Cluster analysis is a technique in which entities are sequentially linked together according to their similarity producing a two dimensional hierarchical structure.

Two major clusters were noticed, the first cluster formed with stations 1, 2 and 4 and the second one with stations 3, 5, 6, 7, 8, 9 and 10. Station 1 is near barmouth and the stations nearer to that formed a cluster where the tidal effects are more than other stations. There are smaller clusters depending upon the similarity. The maximum similarity of 92.14% was observed between stations 6 and 8 while the similarity was found to be the minimum (75.55%) between stations 1 and 10 which is very clearly depicted in the MDS plot (Fig. 6).

As station 1 is located near barmouth and station 10 at the farthermost in upstream of this ecosystem, these two stations can have dissimilar tidal influence, freshwater influx, salinity, phytoplankton abundance and other physico-chemical characteristics; which might be the reason for minimum similarity in zooplankton assemblages between these two stations. The abundance and variations in zooplankton of estuaries are mainly related with salinity regime (Perumal *et al*., 2009) and in the present study, maximum and minimum salinities were recorded at station 1 and station 10 respectively.

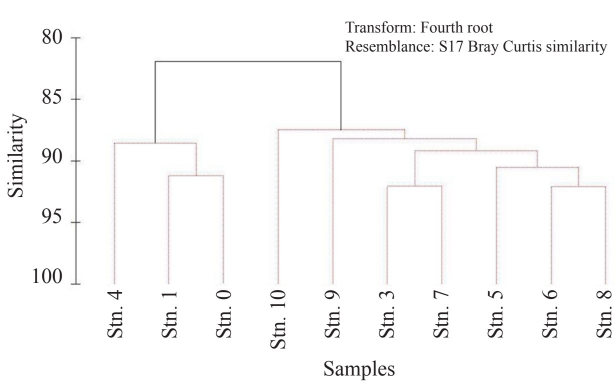

Fig. 5. Dendrogram of zooplankton in different stations

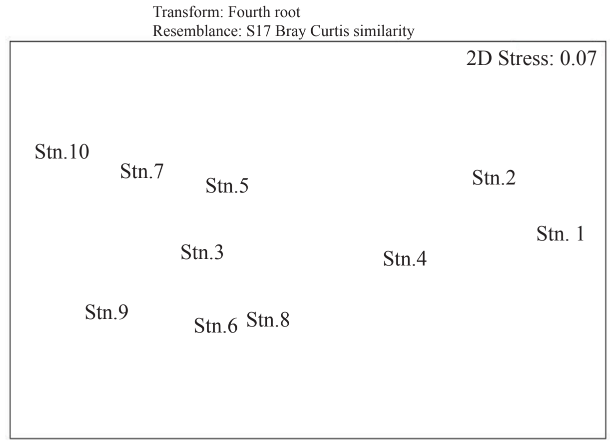

Fig. 6. MDS plot of zooplankton between stations

Even though most zooplankton species survive under a wide range of environmental conditions, their density depend on various physical, chemical and biological factors (Nair *et al*., 1984). Hence, the diversity of zooplankton can be well explained in terms of the ecological characteristics prevailing in the study areas. Thus, a detailed study on zooplankton in relation to hydrobiological variables in Kadalundi Estuary on a long term basis is necessary for better understanding of this ecosystem. As zooplankton forms a major link in the food chain and can influence the fishery of this estuary, the proper understanding of these organisms will be of help in preparing guidelines for the conservation and management of Kadalundi-Vallikunnu Community Reserve.

The present study indicated the availability of 28 groups of zooplankton in Kadalundi-Vallikunnu estuarine system. An average concentration of 18330 nos. per 100 m^3 was observed in this ecosystem with a maximum at Station 1 and minimum at Station 10 and a decreasing trend in abundance of zooplankton was noticed from bar mouth towards upstream. This indicates that the abundance of zooplankton in this estuary is mainly influenced by salinity which in turn is controlled by the tidal influx from the sea. But now, the sand bar formation at the bar mouth considerably restricts the water exchange (Vinod *et al*., 2020). Hence, it is necessary to remove the sand accumulated at the bar mouth to revive the water exchange and to maintain the overall health of this estuarine system.

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