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Zooplankton Assemblages in Spatial Stretches of a Tropical Estuary

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Abstract: Present study embodies the spatial variations in zooplankton species dispersal and copepod community structure in the near mouth, away from the mouth, mid estuarine and upstream region of the Mandovi estuary. Overall 35 copepod species were identified in the 4 spatial demarcation of the estuary. Cluster analysis revealed the upstream zooplankton community were remarkably different from the near shore and mid estuarine regions. In the similar conext, upstream water represented Diaptomus sp., Acartiella sp., Heliodiaptomus cinctus and Cyclops sp. abundantly while Paracalanus parvus, Paracalanus aculeatus and Oithona similis were characterising near mouth of the estuary. The mid estuarine location revealed higher abundance of Acrocalanus longicornis and Oithona brevicornis. The SIMPER analysis confirmed the influence of environmental factors on the zooplankton community distribution at a spatial distinction, where Salinity was the maximum contributor (93-94%) in differentiating these environmental settings.

Key words: Zooplankton assemblages, Estuarine partition, Environmental influence, Multivariate analysis, PRIMER

I. INTRODUCTION

An ecosystem is multiplexed with the association of biological communities and their respective environment [1]. The number of ecosystems varies with the geographical alternations and their function regulated by the environmental attributes. The multivariate tools have been used for the comparison of biotic community structure in different habitats and their significant association with surrounding physicochemical factors. A huge number of studies has debated the abundance and patterns of zooplankton community composition in ambient estuarine conditions[2, 3, 4]. Zooplankton is an important constituent in the aquatic food web, which plays a key role in the transfer of organic carbon from the autographs to higher trophic levels[5]. It is a measure of secondary productivity, and they respond to change in surrounding physical, chemical and biological parameters due to their short generation times (Anger, 2003; Bornet and Frid, 2004; Queiroga and Blanton, 2004) [6, 7, 8]. It is well known that the environmental factors mediated spatial distinction of estuarine regions influence the biological community variation [9]. Estuarine copepod distribution is governed by the interaction of physicochemical factors concerning their surrounding water masses.

In the current study multivariate methods are used to obtain possible cause, effect and relation among the zooplankton assemblages in four spatial distinctionsof the Mandovi estuary, which split into near mouth (M1), away from the mouth (M2), mid estuarine (M4) and upstream stations (M6). Mandovi is one of the well-known estuaries in Goa on the west coast of India, which is experienced with seasonal as well as spatial variation of physical, chemical and biological factors. Salinity is one of the major criteria for the selection of euryhaline and stenohaline copepod communities associated with this estuarine system [3]. This estuary becomes saline dominated during the premonsoon period (Feb-May), and the well-mixed water column was in the estuarine system. The entry of sea water with the tidal variation regulates the flow of the Mandovi estuarine system. Mandovi River has an extension of 75 km, where the width of the mouth is 3.2 km, and the upstream narrows down to < 0.25 km [3].Numerous studies have already discussed the zooplankton community structure in Mandovi estuary. However,these has not elaborated the association of environmental factors from near mouth to upstream water. During the current study, we have observed the distinguished zooplankton assemblages from near mouth to upstream waters of Mandovi estuary using multi variate analysis.Findings obtained during the investigation are considered vital because of identifying source responsible for changing biological assets in different environmental conditions.

II. MATERIAL METHODS

The sampling was carried out during the spring intermonsoon on 31st march 2015 at a stretch of four stations in Mandovi estuary (FIG. 1).The mechanised trawler was employed for the estuarine sampling. Zooplankton samples were collected from the near mouth (M1), away from the mouth (M2), mid estuarine (M4) and upstream stations (M6) using the Heron-Tranter net (mouth area 0.25 m^2 and mesh size of 200 µm) through horizontal hauls. The average station depth varied in between 5 and 15 m. The samples were preserved in 4% buffered formalin. Depending on the sample concentration splitting(%) was determined through Folsom splitter. Total zooplankton and copepod numerical counts were calculated for the whole sample in the term of ind $100m^{-3}$. Surface water samples were collected for the analysis of important environmental factors such as temperature, salinity, nitrate, nitrite and dissolved oxygen concentration following standard protocols[10].

The statistical analysis includes multivariate analysis as cluster analysis and multidimensional scaling (MDS) through PRIMER v6 [11, 12].

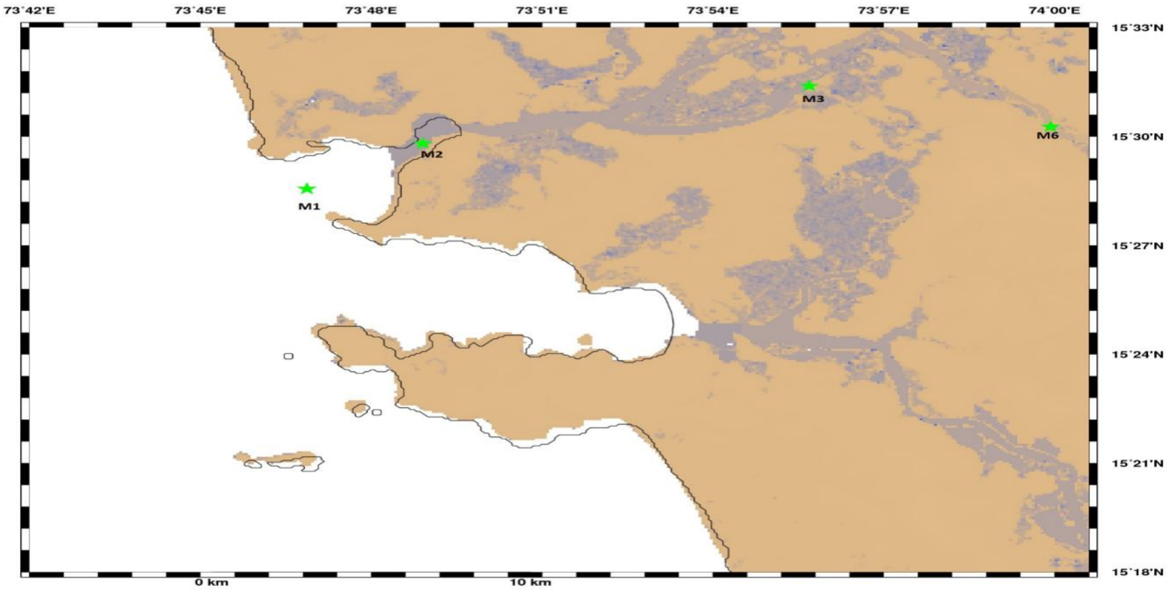

Fig. 1. Sampling locations represented the spatial distinction (near mouth: M1, away from the mouth: M2; mid estuarine: M3; upstream: M6) of the Mandovi estuary.

Zooplankton diversity values were also measured on the species abundance data using the same software. SIMPER analysis was used to identify the species discrimination. Moreover, Redundancy analysis (RDA) was performed by using CANACO 4.5 software to link zooplankton abundance with environmental attributes [13].

III. RESULTS

A. *Environmental attributes*

The detail measures of environmental variables in four different estuarine stations are given in a Table 1. The surface water temperature ranges from 30.5°C to 32.3°C at M1and M6. The highest temperature (32.4°C) was observed at M6, whereas lowest (30.48°C) was recorded at M2. Spatial variability of salinity in the Mandovi estuary appeals the explanation of freshwater discharge into the aquatic system. Measured salinity at M1 was highest (34.18 psu), whereas least salinity (16.42 psu) was recorded at M6.There were no much variation of dissolved oxygen concentration observed in between estuarine stations. The range of dissolved oxygen concentration from 3.8-4.1 µM was observed at all the sampling sites, where the upstream station revealed maximum (4.1 µM) and the minimum value (3.65 µM) was displayed at mid estuarine station M3. Among nutrients, high Nitrate concentration (1.21µM) was noticed at M3 and low nitrite concentration (0.12µM) was recorded at M6.

Table 1: Station-wise details of environmental factors in the Mandovi estuary.

Stations	Temperature (°C)	Salinity (psu)	DO (µM)	Nitrate (µM)	Nitrite (µM)
M1	30.5721	34.1888	3.84	0.83	0.345
M2	30.4842	34.1163	3.85	0.92	0.37
M3	31.0823	31.7251	3.65	1.215	0.53
M6	32.3669	16.4222	4.11	0.89	0.12

B. *Zooplankton Species composition and abundance*

Altogether 15 major groups were encountered in a stretch of estuarine stations from M1 to M6. Copepods were the most dominant group in the term of species richness and numerical abundance. Overall 35 species represented by four diverse groups of copepods were identified. Moreover, these copepods represent fourteen families along the spatial gradient of estuarine stations.Among all the familiesParacalanidae copepods revealed the highest contribution such as 48% at M1, 58% at M2 and M3, and 29% at M6. Details on family wise copepod abundance(ind 100m^{-3}) and other major zooplankton groups are given in the Table 2. Moreover, species-wise copepod information waselaborated the copepod community distribution in four sampling points of the estuary (Table 3).The station M1 the total zooplankton abundance (ind 100m^{-3}) was recorded

The total zooplankton abundance(ind 100m^{-3}) was recordedat M1 was 340677 and 623766 was at the station M2. While the station M3 revealed 274618 ind 100m^{-3} and M4 showed 60098 ind 100m^{-3}. At each station, copepod dominance was contributed by 94% at M1, 80%at M2, 76% at M3 and 65% at M6 (Table 4).

Table 2: Total zooplankton abundance (ind 100m^{-3}) observed in the spatial distinction of Mandovi estuary, including copepods (family) and other zooplankton groups.

Zooplankton (ind 100m^{-3})	M1	%	M2	%	M3	%	M6	%
Calanoida	179200	53	441444	71	167564	61	26693	44
Cyclopoida	45292	13	43707	7	26764	10	6400	11
Harpacticoida	11815	3	6244	1	4073	1	2341	4
Poecilostomatoida	68923	20	8741	1	5818	2	2498	4
Copepod Juveniles	14769	4	-	-	4655	2	1093	2
Other Major Groups	20677	6	123629	20	65745	24	21073	35
Total zooplankton	340677	100	623766	100	274618	100	60098	100

Table 3: Copepod species abundance (ind 100m^{-3}) recorded in spatial reaches of the estuary.

	M1		M2		M3		M6	
Copepods (species)	(ind 100m^{-3})	%	(ind 100m^{-3})	%	(ind 100m^{-3})	%	(ind 100m^{-3})	%
Acrocalanus sp.	11815	3	21854	4	13964	5	4683	8
Acrocalanus gibber	71877	21	162341	26	32000	12	4995	8
Acrocalanus monachus	2954	1	-	-	4655	2	-	-
Acrocalanus gracilis	36431	11	43707	7	8727	3	1561	3
Acrocalanus longicornis	9846	3	-	-	78545	29	-	-
Paracalanus sp.	8862	3	18732	3	12218	4	5932	10
Paracalanus aculeatus	-	-	37463	6	2909	1	-	-
Paracalanus parvus	21662	6	74927	12	6982	3	-	-
Pseudodiaptomus bowmini	-	-	1873	-	-	-	-	-
Pseudodiaptomus jonesii	985	-	-	-	-	-	-	-
Pseudodiaptomus serricaudatus	5908	2	3746	1	582	-	-	-
Acartia sp.	985	-	11239	2	1164	-	468	1
Acartia danae	-	-	1873	-	-	-	-	-
Acartia erythraea	-	-	-	-	582	-	-	-
Acartia pacifica	-	-	24976	4	582	-	-	-
Acartia tropica	-	-	-	-	582	-	-	-
Acartiella sp.	-	-	-	-	-	-	468	1
Totanus gracilis	-	-	624	-	-	-	-	-
Centropages sp.	985	-	624	-	-	-	-	-
Centropages furcatus	985	-	-	-	582	-	-	-
Centropages tenuiremis	-	-	-	-	582	-	-	-
Eucalanus sp.	4923	1	10615	2	-	-	-	-

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Temora turbinata	985	-	624	-	-	-	-	-
Temora sp.	-	-	-	-	582	-	-	-
Lebidocera Pavo	-	-	624	-	-	-	-	-
Lebidocera pectinata	-	-	624	-	-	-	-	-
Clausocalanus arcuicornis	-	-	24976	4	582	-	-	-
Clausocalanus sp.	-	-	-	-	1745	1	-	-
Heliodiaptomus cinctus	-	-	-	-	-	-	3122	5
Diaptomus sp.	-	-	-	-	-	-	5463	9
Oithona sp.	985	-	12488	2	7564	3	5620	9
Oithona brevicornis	44308	13	-	-	19200	7	-	-
Oithona similis	-	-	31220	5	-	-	-	-
Cyclops sp.	-	-	-	-	-	-	780	1
Euterpina acutifrons	11815	3	6244	1	4073	1	2341	4
Corycaeus spp.	66954	20	8117	1	5818	2	1873	3
Farranula spp.	1969	1	624	-	-	-	624	1
	M1		M2		M3		M6	
Copepods (species)	(ind 100m^{-3})	%	(ind 100m^{-3})	%	(ind 100m^{-3})	%	(ind 100m^{-3})	%
Acrocalanus sp.	11815	3	21854	4	13964	5	4683	8
Acrocalanus gibber	71877	21	162341	26	32000	12	4995	8
Acrocalanus monachus	2954	1	-	-	4655	2	-	-
Acrocalanus gracilis	36431	11	43707	7	8727	3	1561	3
Acrocalanus longicornis	9846	3	-	-	78545	29	-	-
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Paracalanus aculeatus	-	-	37463	6	2909	1	-	-
Paracalanus parvus	21662	6	74927	12	6982	3	-	-
Pseudodiaptomus bowmini	-	-	1873	-	-	-	-	-
Pseudodiaptomus jonesii	985	-	-	-	-	-	-	-
Pseudodiaptomus serricaudatus	5908	2	3746	1	582	-	-	-
Acartia sp.	985	-	11239	2	1164	-	468	1
Acartia danae	-	-	1873	-	-	-	-	-
Acartia erythraea	-	-	-	-	582	-	-	-
Acartia pacifica	-	-	24976	4	582	-	-	-
Acartia tropica	-	-	-	-	582	-	-	-
Acartiella sp.	-	-	-	-	-	-	468	1
Totanus gracilis	-	-	624	-	-	-	-	-
Centropages sp.	985	-	624	-	-	-	-	-
Centropages furcatus	985	-	-	-	582	-	-	-
Centropages tenuiremis	-	-	-	-	582	-	-	-
Eucalanus sp.	4923	1	10615	2	-	-	-	-
Temora turbinata	985	-	624	-	-	-	-	-
Temora sp.	-	-	-	-	582	-	-	-
Lebidocera Pavo	-	-	624	-	-	-	-	-
Lebidocera pectinata	-	-	624	-	-	-	-	-

Clausocalanus arcuicornis	-	-	24976	4	582	-	-	-
Clausocalanus sp.	-	-	-	-	1745	1	-	-
Heliodiaptomus cinctus	-	-	-	-	-	-	3122	5
Diaptomus sp.	-	-	-	-	-	-	5463	9
Oithona sp.	985	-	12488	2	7564	3	5620	9
Oithona brevicornis	44308	13	-	-	19200	7	-	-
Oithona similis	-	-	31220	5	-	-	-	-
Cyclops sp.	-	-	-	-	-	-	780	1
Euterpina acutifrons	11815	3	6244	1	4073	1	2341	4
Corycaeus spp.	66954	20	8117	1	5818	2	1873	3
Farranula spp.	1969	1	624	-	-	-	624	1

Table 4: Order-wise copepod distribution in the spatial distinction of the estuary.

	M1		M2		M3		M6	
Copepods (family)	(ind 100m^{-3})	%	(ind 100m^{-3})	%	(ind 100m^{-3})	%	(ind 100m^{-3})	%
Paracalanidae	163446	48	359024	58	160000	58	17171	29
Pseudodiaptomidae	6892	2	5620	1	582	0.2	-	-
Acartiidae	985	-	38088	6	2909	1	937	2
Centropagidae	1969	1	624	0.1	1164	0.4	-	-
Tortanidae	-	-	624	0.1	-	-	-	-
Temoridae	985	-	624	0.1	582	0.2	-	-
Eucalanidae	4923	1	10615	2	-	-	-	-
Pontellidae	-	-	1249	0.2	-	-	-	-
Clausocalanidae	-	-	24976	4	2327	1	-	-
Diaptomidae	-	-	-	-	-	-	8585	14
Oithonidae	45292	13	43707	7	26764	10	5620	9
Cyclopidae	-	-	-	-	-	-	780	1
Tachidiidae	11815	3	6244	1	4073	1	2341	4
Corycaeidae	68923	20	8741	1	5818	2	2498	4
Copepod Juveniles	14769	4	-	-	4655	2	1093	2
Other major groups								
Chaetognaths	-	-	4995	1	-	-	-	-
Appendicularians	4923	1	1873	-	582	0.2	-	-
Cladocerans	-	-	1249	-	-	-	-	-
Pelecypoda larvae	3938	1	4371	1	21527	8	468	1
Polychaete larvae	-	-	81171	13	6400	2	-	-
Decapods and Larvae	4923	1	24976	4	10473	4	7024	12
Gastropod larvae	-	-	624	0.1	15127	6	1717	3
Fish eggs and larvae	985	-	-	-	-	-	-	-
Cirripede larvae	985	-	3122	1	11636	4	11863	20
Copepod nauplii	4923	1	1249	0.2	-	-	-	-
Total Zooplankton	340677	100	623766	100	274618	100	60098	100

The surface water at M1 station revealed the dominance of Calanoida copepods (53%), followed by Poecilostomatoida (20%), Cyclopoida (13%), Harpacticoida (3 %)and other major zooplankton groups (6%) (Table 4). These groups were distributed such as Appendicularians (1%), Pelecypoda larva (1%), Decapods (1%), Fish larvae (985 ind 100m^{-3}< 1%), Cirripede larvae (985 ind 100m^{-3}< 1%) and Copepod nauplii (1%) (Table 2).Calanoida copepodswere dispersed in the form of six families, and the dominant contributors were such as Paracalanidae (48%), Pseudodiaptomidae (2%), Centropagidae 1% and Eucalanidae 1%. The Cyclopoida copepods only revealed oithonidae (13%), whereas Harpacticoida copepods were found in the form of Tachidiidae (3%) and

Poecilostomatoida were found in the form of Corycaeidae (20%) (Table 2).Total zooplankton abundance(ind $100m^{-3}$) at M2 was 623766, which revealed the highest counts among other estuarine stations. Calanoid copepods revealed the highest contribution of 71 % followed by 7%Cyclopoida, 1%Harpacticoida and 1% Poecilostomatoida (Table 4).There were 9 families contributed to the order calanoida were paracalanidae (58%), Acartidae (6%), Clausocalanidae (4%), Eucalanidae (2%), pseudodiaptomidae (1%), pontellidae (0.2%), Temoridae (0.1%), Tortanidae (0.1%), centropagidae 0.1%.Cyclopoida contains only Oithonidae (7%) and Harpacticoida were distributed in Tachidiidae (1%) and Poecilostomatoida were found in the form of Corycaeidae (1%).Other major groups of zooplankton contribute 20% of the whole population, of which Chaetognaths were 4995ind $100m^{-3}$-1%, Pelecypodalarvae 4371ind $100m^{-3}$-1%, Polychaete larvae 81171ind $100m^{-3}$-13%, Decapod larva 24976 ind $100m^{-3}$- 4%, Gastropod larva 624ind $100m^{-3}$-0.1%,Cirripede larvae 3122ind $100m^{-3}$-1%, copepod nauplii 1249ind $100m^{-3}$-0.2% (Table 2).

At mid estuarine station M3, zooplankton density covers 76% of copepods and 24 % other zooplankton groups. Out of 76% copepods Calanoida contributed 61%, Cyclopoida 10%, Harpacticoida 1%, and Poecilostomatoida 2% (Table 4). Calanoida copepods were found in the form of paracalanidae 50 %, Pseudodiaptomidae 0.2 %, Acartiidae 1%, Centropagidae 0.4%, Temoridae 0.2%, Clausocalanidae 1%. 10% Oithonidae represented cyclopaedia, 1% of Tachidiidae represented Harpacticoida, and 2% corycaeidae represented poecilostomatoida.Among other Zooplankton groups, Pelecypoda larvae formed 8% followed by Gastropod larvae 6%, while both decapod and Cirripede larvae contributed 4%. Moreover, Polychaete larvae (2%) and appendicularians (0.2%) were associated with the total zooplankton population (Table2).

The total zooplankton density(ind $100m^{-3}$) in upstream water (M6)consists of 65% of copepods and 35% of other zooplankton groups. Among copepods, Calanoida contributed up to 44%, followed by Cyclopaedia (11%), Harpacticoida (4%), and Poecilostomatoida (4%) (Table 4).Calanoida copepods were distributed by Paracalanidae (29%), Acartiidae (2%), Diaptomidae 14%, whereas Cyclopaedia represented Oithonidae (9%) and Cyclopaedia (1%). The contribution of 4% Tachidiida erepresented Harpacticoida and also 4% Corycaeidae represented Poecilostomatoida (Table 4).Major contributors to other zooplankton groups wereCirripede larvae(20%), Pelecypoda larvae (1%), Decapod larvae (12%), and Gastropod larvae (3%) (Table 2).

C. Diversity and community structure

The diversity index values (Margalef richness, d; Shannon-Wiener, H'; Pielou's evenness, J') for total zooplankton community indicated less diversity variation in between near mouth and upstream stations.Comparatively away from the mouth station revealed the higher diversity and the least diversity was noticed in upstream region (Table 5).The station M1 revealed 90% of total zooplankton contributed by 19 copepod species and M2 represented 80% contributed by 23 species. While 22 species made up of 74% of total zooplankton abundance at M3 and 13 species represented 63% at M6 respectively (Table 3).It is observed that the universal pattern of zooplankton diversity was comparatively less at the upstream station than the near mouth and mid estuarine stations. In a surprise note, higher diversity was observed at M2 than M1.

The total zooplankton (copepods and other zooplankton groups) community structure was spatially changed with the influence of surrounding environmental factors. The results of hierarchical clustering displayed the grouping of sampling sites by linking in zooplankton abundance data for four sampling sites, representing near the mouth, away from near mouth, mid- estuary and upstream regions.

Table 5: Spatial observation of Zooplankton diversity (Maragalef richness d; Shannon-Wiener, H´; Pielou's evenness, J´) in the stretch of the estuary are presented.

Sample	S	N	d	J'	H'(loge)	1-Lambda'
M1	16	29	4.444	0.8782	2.435	0.9142
M2	21	30	5.86	0.8533	2.598	0.9218
M3	16	29	4.437	0.8866	2.458	0.9154
M6	12	30	3.223	0.9412	2.339	0.9219

Datawere square root transformed and then Bray-Curtis similarity was calculated to obtain dendrograms, which define the locations into 2 groups determined at 60% similarity. One group consists of near mouth (M1), away from the mouth (M2) and mid estuarine (M3) stations, while the second one represented upstream station (M6) as a distinct site (Fig. 2). The dendrogram revealing cluster analysis provided the convincing groupism of stations in relation to spatial distinction of the estuary and the same was displayed by MDS analysis (Fig. 3).The segregation of sampling sites was confirmed due to the differences in zooplankton community composition and their abundance in relation to change in environmental factors (salinity, temperature, dissolved oxygen and nutrients).The SIMPER analysis described the contribution of these environmental factors towards the dissimilarity pattern of sampling sites (Table 6a).The highest euclidian distance was observed in between the Upstream and other 3 stations (Near mouth, away from mouth and mid estuarine).Salinity was the highest contributor (93-94%) in differentiating these environmental settings. Moreover, the SIMPER analysis discriminated the copepod species with a particular biotic assemblage. The results described the dissimilarity of sampling sites determined by the contribution of zooplankton groups and copepod species (Table 6b). These are placed orderly by their average contribution to the average dissimilarity. The copepod species which are well discriminator of near mouth, mid estuarine and upstream stations are highlighted (Table 6b). Additionally, Redundancy analysis (RDA) was used to determine the association of different environmental factors with the zooplankton community distribution at different sampling sites. The results of RDA analysis clearly described the influence of environmental factors on the community distribution. It clearly indicates that salinity and temperature and highly influencing thedistribution of zooplankton groups in the Mandovi estuary (Fig. 4).

Table 6a: SIMPER analysis of environmental factors in the different sites of Mandovi estuary.

	Group Near mouth	Group Away from the mouth			
Variable	Av.Value	Av.Value	Av.Sq.Dist	Contribution%	Cum.%
Nitrate	1.56	1.64	7.06E-03	82.5	82.5
Nitrite	1	1.04	1.36E-03	15.87	98.37
	Group Near mouth	Group Mid estuarine	Av.Sq.Dist	Contribution %	Cum.%
Temperature	9.46	9.9	0.195	44.49	44.49
Nitrate	1.56	1.96	0.159	36.25	80.74
Nitrite	1	1.29	8.29E-02	18.9	99.63
	Group Away from the mouth	Group Mid estuarine	Av.Sq.Dist	Contribution %	Cum.%
Temperature	9.45	9.9	0.198	54.9	54.9
Nitrate	1.64	1.96	9.91E-02	27.42	82.32
Nitrite	1.04	1.29	6.31E-02	17.45	99.77
	Group Near mouth	Group Upstream	Av.Sq.Dist	Contribution %	Cum.%
Salinity	10	7.12	8.28	94.21	94.21
	Group Away from the mouth	Group Upstream	Av.Sq.Dist	Contribution %	Cum.%
Salinity	10	7.12	8.28	94	94
	Group Mid estuarine	Group Upstream	Av.Sq.Dist	Contribution %	Cum.%
Salinity	10	7.12	8.28	93.27	93.27

Table 6b:The SIMPER analysis discriminated the copepod species with a particular biotic assemblage in different sampling sites of the estuary.

	Group Near mouth	Group Away from near mouth			
Species	Av.Abund	Av.Abund	Av.Diss	Contribution %	Cum.%
Oithona brevicornis	7.85	0	5.72	13.82	13.82
Corycaeus spp.	9.65	2.24	5.4	13.05	26.87
Paracalanus aculeatus	0	4.8	3.5	8.46	35.33
	Group Near mouth	Group Mid estuarine			
Species	Av.Abund	Av.Abund	Av.Diss	Contribution %	Cum.%
Corycaeus spp.	9.65	2.72	5.35	14	14
Acrocalanus longicornis	3.7	10	4.86	12.73	26.73
Acrocalanus gracilis	7.12	3.33	2.92	7.65	34.38
Acrocalanus gibber	10	6.38	2.79	7.31	41.69
	Group Away from near mouth	Group Mid estuarine			
Species	Av.Abund	Av.Abund	Av.Diss	Contribution %	Cum.%
Acrocalanus longicornis	0	10	8.1	17.07	17.07
Oithona brevicornis	0	4.94	4	8.44	25.52
Oithona similis	4.39	0	3.55	7.49	33
Paracalanus parvus	6.79	2.98	3.09	6.51	39.51
	Group Near mouth	Group Upstream			
Species	Av.Abund	Av.Abund	Av.Diss	Contribution %	Cum.%
Diaptomus sp.	0	9.6	6.16	11.33	11.33
Oithona sp.	1.17	9.73	5.5	10.11	21.44
Oithona brevicornis	7.85	0	5.04	9.27	30.71
Heliodiaptomus cinctus	0	7.25	4.66	8.56	39.27
Paracalanus sp.	3.51	10	4.17	7.66	46.93
	Group Away from near mouth	Group Upstream			
Species	Av.Abund	Av.Abund	Av.Diss	Contribution %	Cum.%
Diaptomus sp.	0	9.6	6.41	11.08	11.08
Heliodiaptomus cinctus	0	7.25	4.84	8.38	19.46
Oithona sp.	2.77	9.73	4.65	8.04	27.49
Paracalanus parvus	6.79	0	4.54	7.84	35.34
	Group Mid estuarine	Group Upstream			
Species	Av.Abund	Av.Abund	Av.Diss	Contribution %	Cum.%
Acrocalanus longicornis	10	0	7.04	11.41	11.41
Diaptomus sp.	0	9.6	6.76	10.95	22.36
Heliodiaptomus cinctus	0	7.25	5.11	8.28	30.64
Oithona sp.	3.1	9.73	4.67	7.57	38.21

In a brief note, salinity is a favourable environmental factor for most of the zooplankton groups at near mouth station M1, whereas high temperature and low salinity are the important environmental factor at the upstream station (M4).

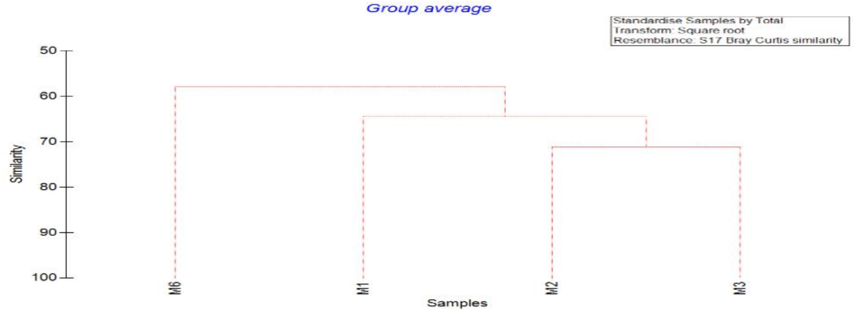

FiG. 2: Dendrogram of hierarchical clusters using group-average linkage of Bray-Curtis similarities based on transformed zooplankton datasets in 4 sampling sites (M1, M2, M3 and M4) of the Mandovi estuary.

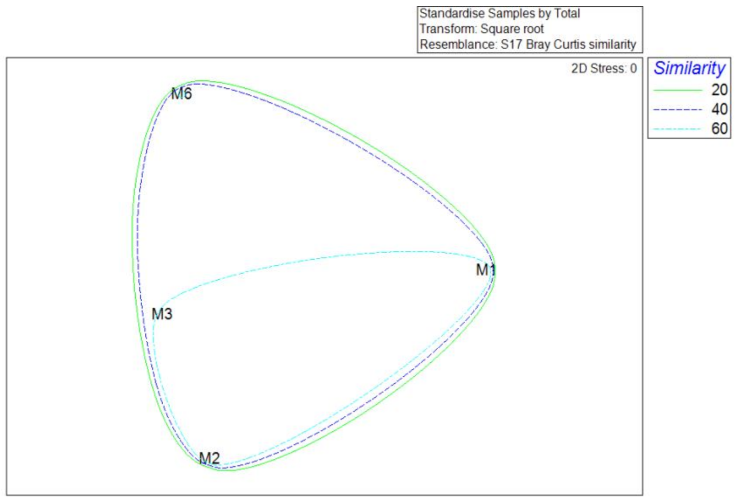

Fig. 3: Spatial separations in the estuary represented zooplankton assemblages based on the MDS (2D stress: 0) analysis.

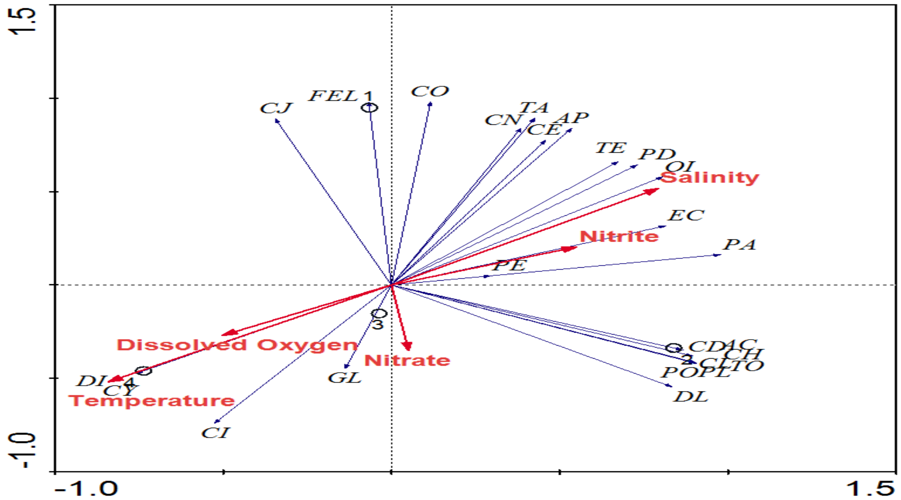

Fig.4: Redundancy analysis of Zooplankton communities at 4 sampling sites of the estuary. Zooplankton communities were represented as copepod families and other major groups of zooplankton, which are Paracalanidae: PA, Pseudodiaptomidae: PD, Acartiidae: AC, Centropages: CE, Euchaetidae: EU, Temoridae: TE, Eucalanidae: EC, Pontellidae: PO, Calanidae: CA, Clausocalanidae: CL, Diaptomidae: DI, Oithonidae: OI, Cyclopidae: CY, Tachidiidae: TA, Oncedae: ON, Corycaeidae: CO, Copepod Juveniles: CJ, Chaetognaths: CH, Appendicularians: AP, Cladocerans: CD, Pelecypoda larvae: PE, Polychaete larvae: PL,

Decapods and larvae: DL, Gastropod larvae: GL, Fish eggs and larvae: FEL, Cirripede larvae: CI and Copepod nauplii: CN; Stations are represented as 1: near mouth of the estuary, 2: away from the mouth, 3: mid estuarine station, M6: upstream station.

IV. DISCUSSION

Zooplankton Assemblages are an important aspect of ecological research, which are quantified through statistical multivariate approaches (clustering and ordination approach) proves the association of biotic and abiotic factors in a particular ecosystem and their changes concerning space and time [14]. It is important to find the community pattern and their relation to surrounding environmental attributes, which defines the specific community structure in the array of aquatic ecosystems such as estuaries, the coastal and open ocean. In this study, we focused the variation of zooplankton community structure observed in different parts of the estuary and the reasonable explanation for their association in the ecosystem. In the same scenario, some earlier studies for zooplankton assemblages through the multivariate methods were well described in some estuarine waters [15, 16]. With reference to zooplankton abundance data and species assemblages, it is further discussed the varying pattern of most dominant copepod communities in different environmental settings of Mandovi estuary. In this context,upstream water represented Diaptomus sp., Acartiella sp., Heliodiaptomus cinctus and Cyclops sp. abundantly while *Paracalanus parvus*, *Paracalanusaculeatus* and *Oithona similis*werecharacterising near mouth of the estuary. The mid estuarine location revealed higher abundance of *Acrocalanus longicornis* and *Oithona brevicornis.*

Our research findings have shown a wide characterstics of zooplankton (copepod) assemblages in different parts of the estuary. This phenomenon of species difference leading to the diversity patterns of zooplanktons in the estuarine ecosystem. Heterogeneity of environmental conditions in the contrasting waters of the Mandovi estuary [17]. Riverine water flow, salinity fluctuation in between the station, temperature and nutrient variability impinging on the photosynthetic productivity, which mediates the secondary production in the different parts of the estuary. These variations may be the controlling factors for the difference in zooplankton abundance and dominant copepod species assemblages [18]. The Arabian Sea is a dynamic ecosystem, where the Mandovi river flows towards the sea that establishes one of the well-marked estuaries on the west coast of India.In this study, the multivariate analysis explained the community alternation in the different parts of the estuary is to relate environmental attributes the zooplankton community. These analyses examine the influence of environmental variables on the community structure of the biota [19]. These statistical analysis showed the extent to which the environmental parameters related to their distribution and the possible reason of the biological association to their surrounding environment. From our study, it is fair to note that changes in salinity and temperature have a major effect on the biota. In this connection, we can assume that nMDS analysis clustered the community structure in three different groups where the near mouth, mid estuarine and upstream station showed different zooplankton assemblages.

V. CONCLUSION

We conclude that the total zooplankton abundance and copepod abundance could be affected by the variation of environmental attributes such as salinity, temperature and their spatial variability influence the species –specific associations (near mouth, away from the mouth, Mid estuarine and upstream) in the array of ecological environment. This is clearly reflect the association of environmental factors including spatial difference of riverine influx, coastal perturbance and circulation etc. are determined by the prevailing spatial regimes.

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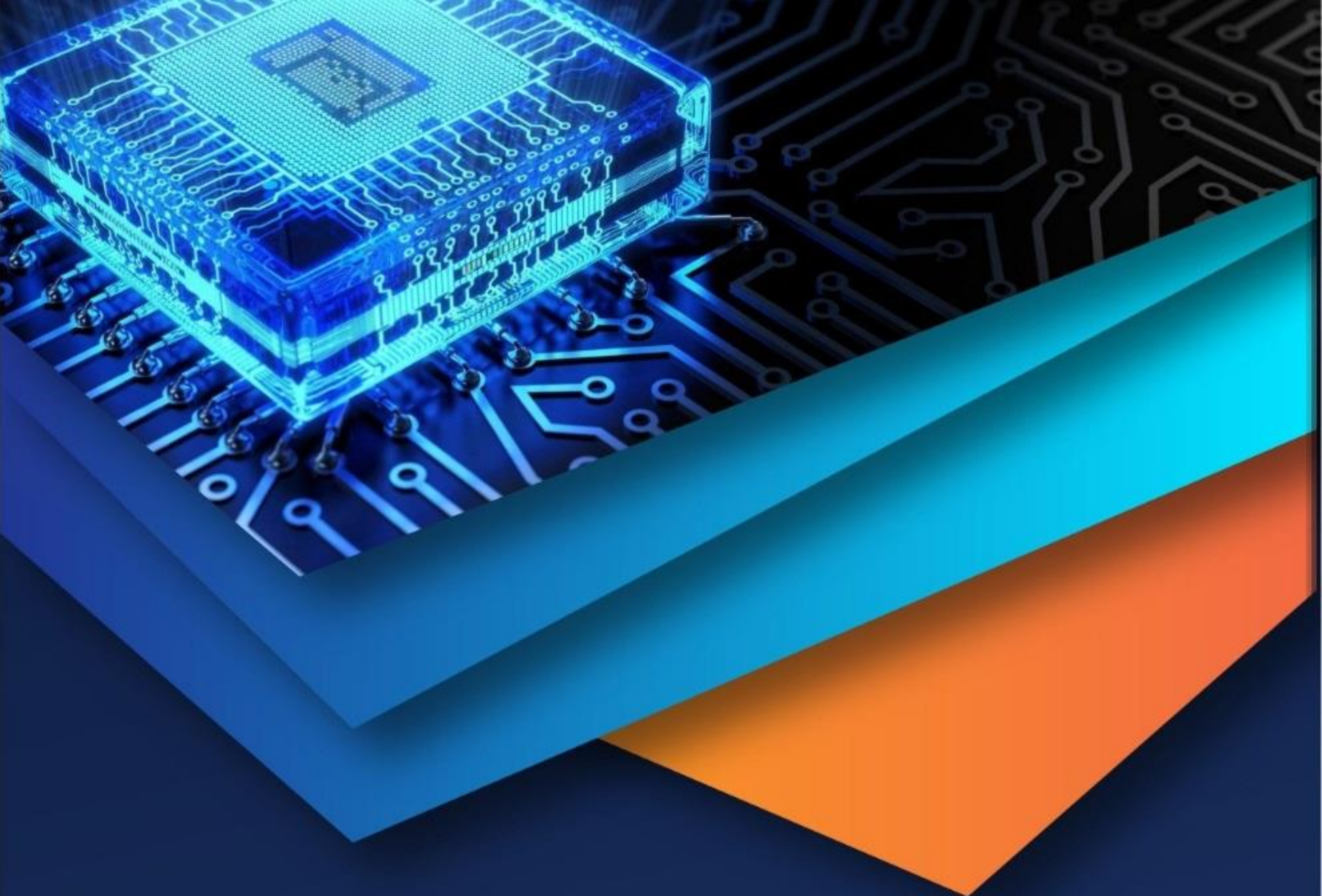

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