

Spatial Zonation of Zooplankton in the Northwestern Arabian Sea: A Multivariate Approach

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ABSTRACT

Latitudinal variation in abundance, diversity, dominance pattern and zonation of the major groups of zooplankton was studied in the coastal waters of northwestern Arabian Sea, between 25°44' N and 10°44' N. Maxwell Boltzmann Statistic and multivariate approach by factor analysis adopting varimax rotation was used for grouping of the plankton.

Maxwell Boltzmann test resulted in significant clustering tendency during day and night with relatively high values during night. The value of the index based on the proportional abundance of all the groups considered together in each quadrat, decreased gradually from Gulf of Aden to off Karachi along the Pakistan Coast with maximum value in the Saudi Arabian Coast. But the index evaluated for each taxon, implied a significant positive correlation with the variation (%) in the spatial distribution, having high value in the Saudi Arabian Coast due to nutrient enrichment of the surface by upwelling and decreases towards north during day. Thus, the zooplankton taxa are not randomly or uniformly distributed but have a patchy distribution with degree of patchiness much more than that given by the theoretical distribution.

Significant inverse relationship was observed between the value of the index and the total variance explained by the significant factor groups of the zooplankton taxa. The zooplankton samples represented single continuously varying plankton population rather than separate and distinct populations thereby ruling out the possibility of any sudden and unpredictable changes in the plankton population during the transitional period, March to June in the coastal regions of the Northwestern Arabian Sea. Day collections are more diverse than the night collections with relatively high equality in the spatial distribution.

Key Words: Diversity, Latitudinal variation, Multivariate analysis, Zonation, Zooplankton

INTRODUCTION

Information on zooplankton population of the Arabian Sea are mainly confined to areas of local interest. The Somali Arabian coasts are highly productive areas of the world's oceans. High zooplankton production was reported by Panikkar and Rao (1973) and Smith (1982) in Somali upwelling regions, mostly during the period of the southwest monsoon. Several reports are available on the zooplankton of the eastern Arabian Sea, but the western Arabian coast remains rather unexplored except for the northern regions (Haq et al. 1973, Paulinose and Aravindhakshan 1977, Tirmizi and Nayeem 1992). A general

picture of major zooplankton constituents for the entire Arabian Sea and Pakistan Coast is given in the results of the International Indian Ocean Expedition (IIOE; Panikkar and Rao 1973). Apart from this, comprehensive attempts are very few from the north-western Arabian Sea.

Zonation of zooplankton taxa along the physical gradient is a well recognised biological phenomenon especially at night than during day. But it is very difficult to measure the zonation pattern particularly when many groups are involved because the clustering tendency can be due to an environmental preference or due to an affinity between groups or may be due to competition for food, etc. Maxwell Boltzmann Statistic (Frederick and Richard 1978) provides almost useful preliminary step to application of more instructive methods such as cluster analysis and factor analysis. If this test results in significantly high value, implying that the taxa are significantly clustered, cluster analysis by multi-linkage averaging (Sanders 1963) and factor analysis by varimax rotation to simple structure are applied to find the statistically significant groups of zooplankton taxa which have relevance to environmental variations (Castro et al. 1991). Maxwell Boltzmann statistics consist of introduction of a random variable as an index of zonation. This index to which confidence limits can be applied assumes relatively large values if taxa are spaced haphazardly along the coast and relatively small values if they are regularly spaced in different quadrants along the coast. This test is very useful to the data because with highly significant values for the index, it is safe to assume that spatial zonation occurs and it enables to find the causative agents such as the affinity to environmental parameters or biological restraints imposed by interspecific competition. Small values of the index suggest that further analysis is not necessary. Without justifying whether clustering tendency occurs or not the cluster analysis if directly applied produces clusters which do not really exist but be only spurious clusters. Factor analysis by varimax rotation to simple structure leads to unique factor groups which helps to study the unique distribution of the zooplankton taxa classified as: (1) separate distinct populations, (2) single homogenous population and (3) single continuously varying populations based on the factor score distribution of taxa/species. This analysis further enables to determine the different groups based on which the complete information about the distribution of zooplankton groups can be gathered (Dagnelie 1981).

This paper deals with the zooplankton population in the coastal waters of north-western Arabian Sea, especially zonation of major groups and their distribution using Maxwell Boltzmann Statistics and factor analysis. Spatial zonation of the zooplankton during day and night was investigated along four transects in (1) the Gulf of Aden, (2) Saudi Arabian Coast, (3) Gulf of Oman, and (4) Off Karachi in the northern Arabian Sea.

MATERIAL AND METHODS

This study is based on zooplankton samples collected under the UNDP/FAO pelagic fisheries project to assess the resources of the coastal waters of India, Arabian coast and Somalia (Anonymous 1975). The zooplankton samples were collected from hydrographic stations onboard the ship *Fridtj of Nansen* during March to June 1976. The details of the stations are given in the Cruise report (Anonymous 1975). The area covered and the station positions are shown in Figure 1.

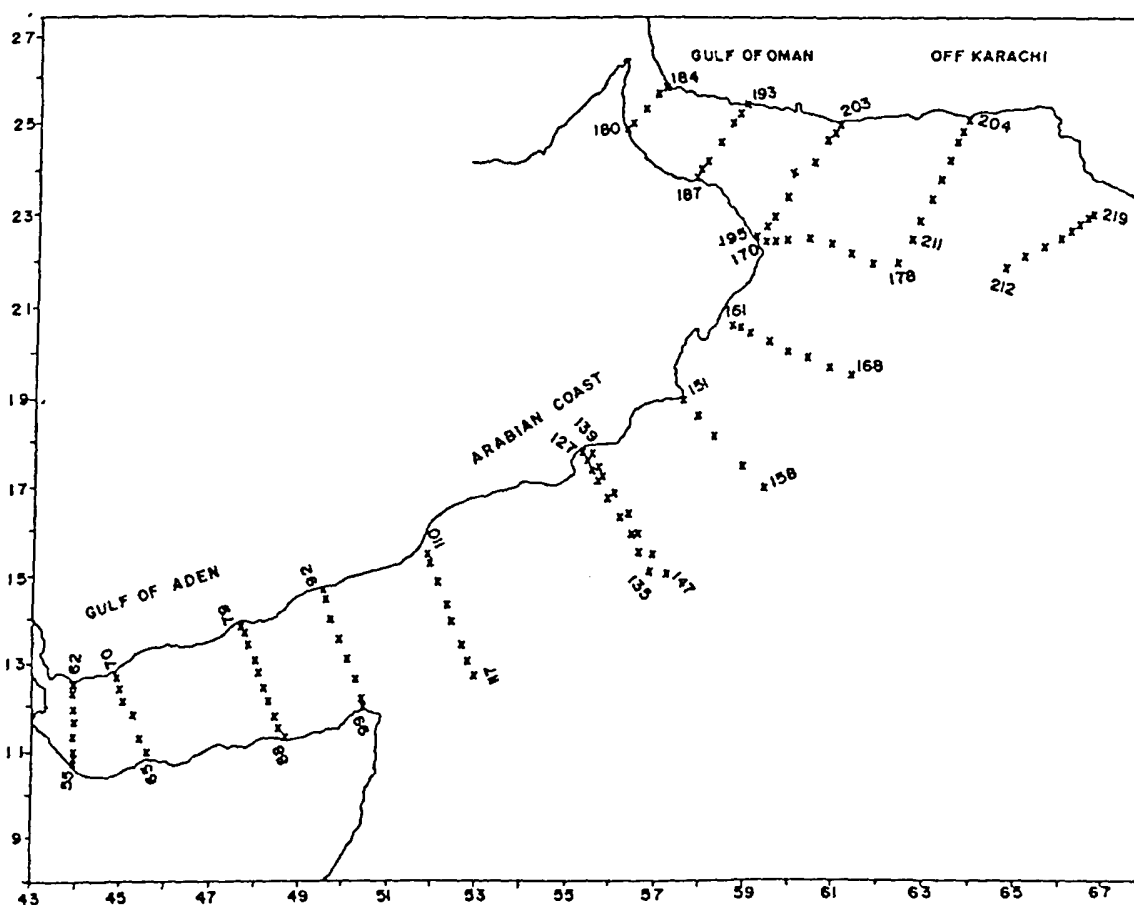


Figure 1. The area covered and the position of stations in the four transects, namely: (1) Gulf of Oman, (2) Arabian Sea, (3) Gulf of Aden and (4) off Karachi.

The region under study was divided into the following areas: (I) Gulf of Aden ($10^{\circ}44' \text{ N} - 14^{\circ}45' \text{ N}$, 31 stations), (2) Saudi Arabian coast ($12^{\circ}45' \text{ N} - 22^{\circ}27' \text{ N}$, 43 stations), (3) Gulf of Oman ($22^{\circ}32' \text{ N} - 25^{\circ}44' \text{ N}$, 18 stations) and (4) Pakistan coast ($22^{\circ}30' \text{ N} - 24^{\circ}55' \text{ N}$, 13 stations). Zooplankton samples were collected during both day and night. The number of samples in the day collections is 16, 18, 9 and 5, and in the night collections 15, 25, 9 and 8 respectively, in the four areas. Oblique hauls were made from 50 m depth with a 60 cm diameter Bongo net (mesh size 0.33 mm). After estimating the biomass (expressed as mL per 100 m^3), each sample was sorted into 10 major taxa and their densities were expressed as number per 100 m^3 . The taxa considered were: (1) Copepoda, (2) Chaetognatha, (3) Decapoda, (4) Amphipoda, (5) Euphysiacea, (6) Ostracoda, (7) fish eggs, (8) fish larvae, (9) Medusae and (10) Mysidacea. The stations over the coastal regions along transects through the four areas stated earlier. In the transects 1-4, 4, 6, 3 and 2 quadrats were considered respectively for the study (Figure 1).

Following notations are used for the analysis,

U_i = number of stations having night collections in the i th quadrat

U_{ik} = number of stations with k th taxon collected from the i th quadrat during night

D_i = number of stations having day collections in the i th quadrat

D_{ik} = number of stations with k th taxon collected from the i th quadrat during day

$k = 1, 2, 3, \dots, 10, i = 1, 2, \dots, n_j, j = 1, 2, 3, 4; n_1 = 4, n_2 = 6, n_3 = 3, n_4 = 2.$

Probability distribution for U_i, U_{ik}, D_i and D_{ik} according to Pielou and Roulledge (1976) has three drawbacks. So Maxwell Boltzmann statistics was applied in which the assignment of a taxon to a quadrat is taken as an event independent of other assignments already made. Following probabilities are calculated for each quadrat in each transect.

$$P_{i(u)} = P(\text{taxa occur in the night collection in the } i\text{th quadrat}) \\ = (\text{Total abundance of the zooplankton taxa in the night collection in the } i\text{th quadrat}) / (\text{Total abundance of the taxa in all the quadrats during night})$$

$$P_{ik(u)} = P(k\text{th taxon occurs in the night collection in the } i\text{th quadrat}) \\ = (\text{Total abundance of the } k\text{th taxon in the night collection in the } i\text{th quadrat}) / (\text{Total abundance of the } k\text{th taxon in all the quadrats during night})$$

Similar expressions are used for $P_{i(d)}$ and $P_{ik(d)}$ of day collections. Random variables V_u and V_d for testing purposes are defined as:

$$V_u = (1 / Q) \left[\sum_{i=1}^Q U_i^2 / P_{i(u)} \right] \text{ and } V_d = (1 / Q) \left[\sum_{i=1}^Q U_i^2 / P_{i(d)} \right].$$

Similarly V_{uk} and V_{dk} are defined. A significantly large value for $V_u(V_{uk})$ and $V_d(V_{dk})$ would indicate a clustering tendency for the zooplankton taxa as a whole (individual taxon) in the various quadrats during night and day respectively beyond the one implied by the theoretical distribution.

The hypotheses to be tested are:

- (1) H_0 :- Night collections are uniformly distributed over the quadrats in each transect.
- (2) H_0 :- Day collections are uniformly distributed over the quadrats in each transect.
- (3) H_0 :- Each zooplankton taxon is uniformly distributed over the quadrats in each transect during night.
- (4) H_0 :- Each zooplankton taxon is uniformly distributed over the quadrats in each transect during day.

The test statistics used for the above hypotheses are:

$$\chi_u^2 = \sum_{i=1}^Q Y_{i(u)}^2 \quad \text{where } Y_{i(u)} = (U_i - P_{i(u)}) / (P_{i(u)})^{0.5}$$

$$\chi_d^2 = \sum_{i=1}^Q Y_{i(d)}^2 \quad \text{where } Y_{i(d)} = (U_i - P_{i(d)}) / (P_{i(d)})^{0.5}$$

$$\chi_{k(u)}^2 = \sum_{i=1}^Q Y_{ik(u)}^2 \quad \text{where } Y_{ik(u)} = (U_{ik} - P_{ik(u)}) / (P_{ik(u)})^{0.5}$$

$$\chi_{k(d)}^2 = \sum_{i=1}^Q Y_{ik(d)}^2 \quad \text{where } Y_{ik(d)} = (U_{ik} - P_{ik(d)}) / (P_{ik(d)})^{0.5} \text{ respectively.}$$

On the basis of significance of the above hypothesis multilinkage cluster analysis was applied for grouping the taxa into similar groups of various similarity levels and factor analysis (Rummel 1975) was applied for unique factor groups on the basis of maximum factor loadings (Cassie 1963) obtained after row (column) standardisation and normalisation (Cassie 1959, Williamson 1961) for Q-mode (taxa) and R-mode (for stations) respectively after varimax rotation to simple structure (Guttman 1954, Kaiser 1958, Harman 1967). Factor score distribution of stations was studied for the average distribution of taxa with maximum abundance in each factor group. Factor score distribution of the taxa was also considered to understand the nature of the distribution of the zooplankton population from which sample was collected (Goodall 1954) based on coefficient of Skewness (γ_1) and the test statistic t for its significance (Snedecor and Cochran 1967). The factor analysis model fitted is tested for its significance (Bartlett 1954).

RESULTS AND DISCUSSION

Arabian and Somali coasts are areas of intense upwelling during the southwest monsoon. The specialities of the plankton distribution during this period is given (Rao 1979). The present account deals with the plankton distribution during March to June, which is the transitional period. Though copepods constituted about 70% of the population, swarming of Ostracoda, Euphasidacea and Decapoda larvae occurred in many stations as observed in northern Arabian Sea (Paulinose and Aravindhakshan 1977, Daniel and Jyothinayagam 1977). The Average number for most of the plankton groups far exceeded that recorded during IIOE. Biomass value of this investigation could be compared with the values obtained during IIOE. The area between 10°N to 25°N and 50°E and 65°E was observed (Prasad 1969a,b) as the richest area in zooplankton biomass (average 57.7 mL 100 m⁻³) for the Southwest monsoon. During the northeast monsoon, values between 25 and 50 mL 100m⁻³ were recorded. Haq et al. (1973) reported biomass of 7.77 mL 100m⁻³ with an average of 38.7 mL 100m⁻³ from the Pakistan coast during March.

The temperature ranged 23.7°C - 26.9°C in transect 1, 24.1 °C - 28.4°C in transect 2, 27.3°C - 31.5°C in transect 3 and 26.4°C - 29.95°C in transect 4. Salinity varied between 35.04 psu (‰) and 36.44 psu in transect 1, between 25.48 psu and 36.63 psu in transect 2, between 36.63 psu and 37.00 psu in transect 3 and between 36.54 psu and 36.87 psu in transect 4. The high salinity observed in the study area can be attributed to the excess of evaporation over precipitation and run off, and to high saline water coming from the Persian Gulf. The values for dissolved oxygen ranged 3.31-4.76 $\mu\text{mol L}^{-1}$ in transect 1, 2.96-7.42 $\mu\text{mol L}^{-1}$ in transect 2, 4.2S-5.10 $\mu\text{mol L}^{-1}$ in transect 3 and 4.28-4.37 $\mu\text{mol L}^{-1}$ in transect 4. The low oxygen values observed in the Gulf of Oman can be as a result of biodegradation of organic matter in the oxygen poor water from the Persian Gulf.

Boltzmann statistics calculated, showed that there is high spatial zonation during day and night but more during night as supported by the observations made by Tirmizi and Nayeem (1992) and is the maximum in the Saudi Arabian Coast and the least along the Gulf of Oman with the changing population rather than distinct and separate populations \ which justified the absence of any sudden and unpredictable changes in plankton

distribution during the study period. Highest biomass ($171 \text{ mL } 100\text{m}^{-3}$) was recorded off Muscat and lowest ($13 \text{ mL } 100\text{m}^{-3}$) was in the Saudi Arabian Coast. The distribution of biomass was patchy in most of the transects, The mean biomass for the whole area was $245 \text{ mL } 100\text{m}^{-3}$. Biomass was quite high in the night samples with an average of $30.4 \text{ mL } 100\text{m}^{-3}$. Average value for the day samples was only $16.67 \text{ mL } 100\text{m}^{-3}$.

Copepods formed the major component of the plankton community. High density of 10^5 per 100m^3 was observed mostly in the northern Arabian Sea and in the Gulf of Aden. No marked diurnal variation was observed. Highest density of 386043 per 100 m^3 was recorded at station 88. Ostracods were observed in swarms at many stations in the Arabian coast and Gulf of Aden. Swarms were noticed during night. The average number for night stations (24788 per 100m^3) far exceeded the average number for the day samples (2602 per 100m^3). Mostly gravid females and mature males were encountered indicating that swarming was associated with mating. Chaetognaths were also represented with an average number of 6829 per 100m^3 . Gulf of Aden and the stations off Pakistan sustained higher density. Euphasiids which were present in majority of the stations resulted in very high biomass. Decapoda were mostly represented by Zoea and Alima larvae. Fish eggs were present mostly in Gulf of Oman region. But were not very frequent in the Arabian coast where as fish larvae were represented in majority of the stations. The four taxa namely Copepods, chaetognaths, decapods and amphipods were uniformly distributed in the four transects. But the total number of organisms showed a decreasing gradient from transect 1 to transect 4 whereas the number of taxa did not vary much between transects. Regarding the richness factor and the diversity in the distribution, higher diversity was observed in transects 2 and 3 with relatively higher equitability in transect 2 (Figures 3a-3d). Similarly, fish larvae, Medusae and mysids were distributed with variation $<20\%$, fish eggs exhibited maximum variation during day at transect 4 and Ostracods at transect 1 during night. Mean distribution of the taxa decreased in abundance in the same pattern in all the transects from Copepods to mysids during day and night with slight variation for Euphasiids, Ostracods and fish eggs during day (Figures 2a-2d). Correlation coefficient of the various taxa with temperature, salinity, dissolved oxygen and the displacement volume when plotted, showed no similarity in the trends which indicated that the four transects were occupied by zooplankton taxa which are of different groups of species or of different abundances due to the variations in the environmental conditions as shown by the relative importance of the parameters. That is, it is due to the high variations in dissolved oxygen distribution at transect 3 (variability explained, v.e. = 23%, $p < 0.05$ in the night collections) and in transect 4 (v.e. $>58\%$, $p < 0.05$) in the day collections and v.e. = 13% for night collections, $p < 0.25$) and the high variations in the distribution of salinity during night collection (v.e. = $>75\%$, $p < 0.05$) and dissolved oxygen during day collections (v.e. = 44%, $p < 0.05$) in the transect 2 as obtained from a 3 parameter linear multiple regression model. Padmavathi and Goswami (1996) had observed that salinity is an important factor influencing the zooplankton distribution in the Mandovi-Zuari estuarine system. Since the variability explained by the regression models is less than 50% in most of the cases, it can also be that the combined variations in the environmental parameters represented by the first order interaction effects may be influencing the secondary production more than the individual effects (Jayalakshmy 1998).

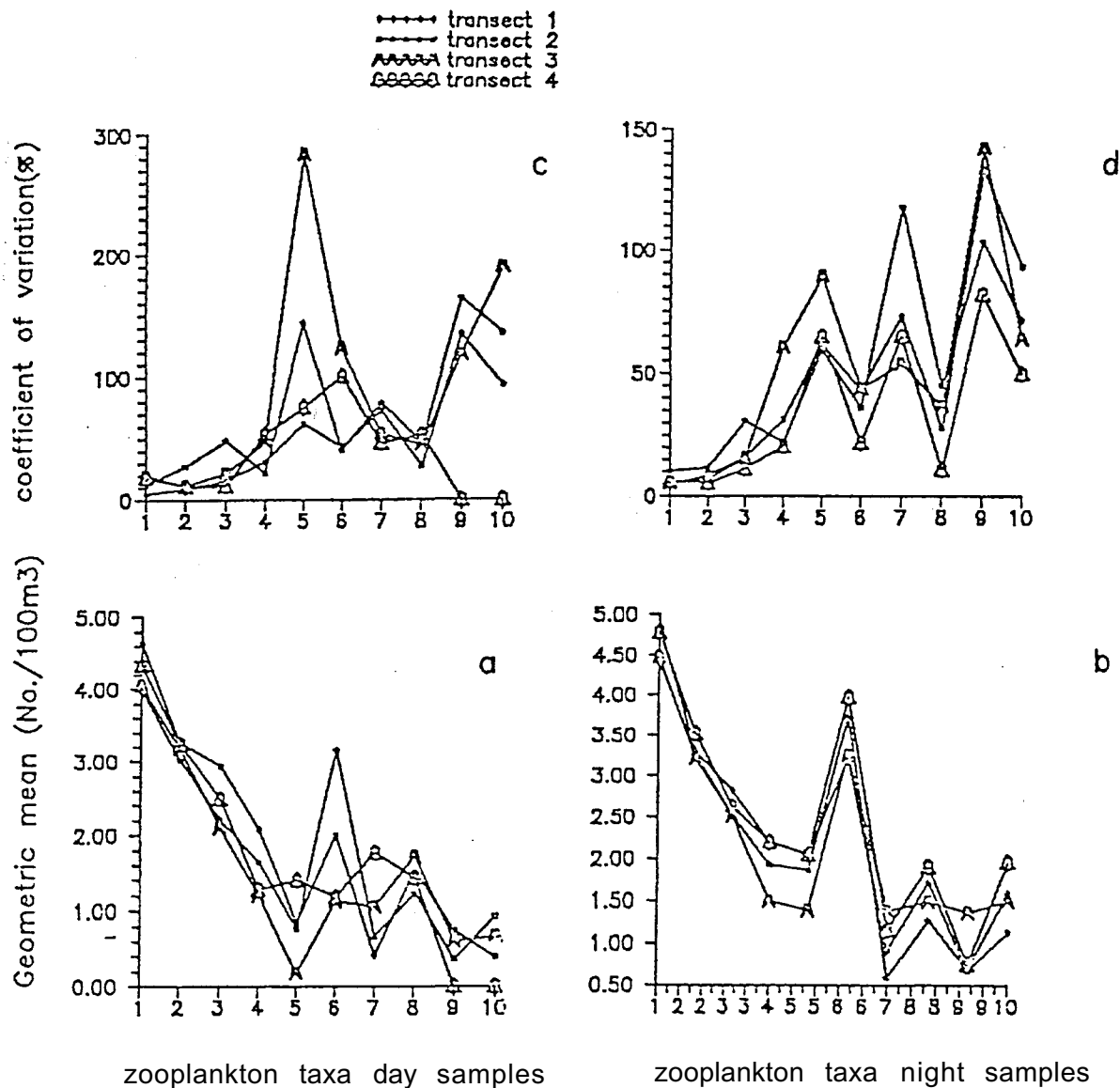


Figure 2a-2d. The mean values (Geometric Mean No per 100 m³) and coefficient of variation (%) for day and night collections in the transects 1 to 4.

Maxwell Boltzmann test for spatial zonation (Tables 1a-1b) resulted in significant clustering tendency during day and night with relatively high values during night. The index decreased gradually from transect 1 to transect 4 with maximum value in transect 2 for zooplankton taxa as a whole. In the case of individual taxon, this index varied in a zig-zag manner during night but varied steadily with a peak value at transect 2 and decreased towards north during day implying highest clustering tendency for Euphasiids, Ostracods and for fish eggs invariably in all the transects with a peak value at transect 2. The clustering tendency showed a decreasing gradient from transect 1 to transect 4. The high value for the index implying high clustering tendency at transect 2 can be attributed to the high level of nutrients brought to the surface by upwelling.

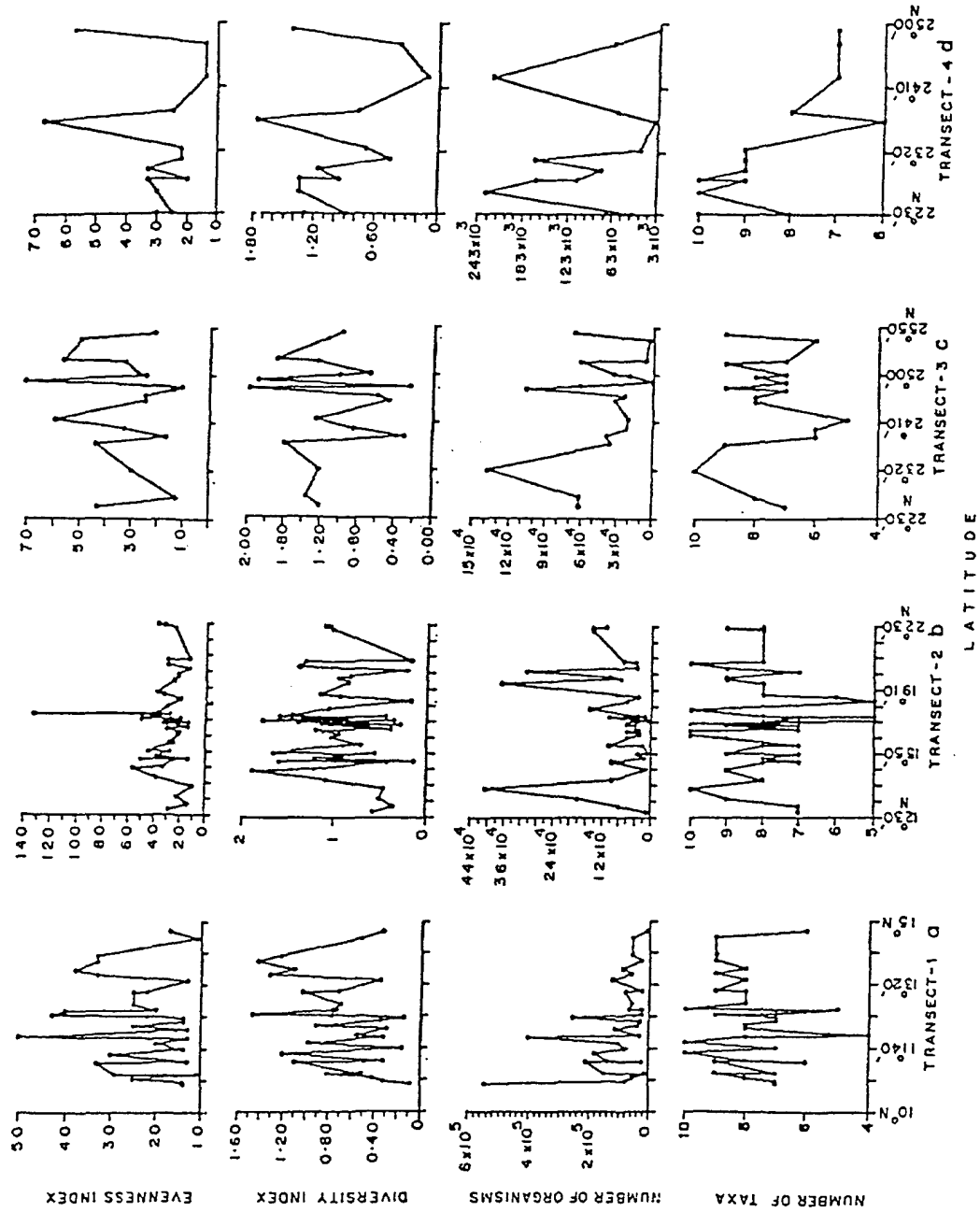


Figure 3a-3d. The number of taxa, number of organisms, diversity index and evenness index in the transects 1 to 4.

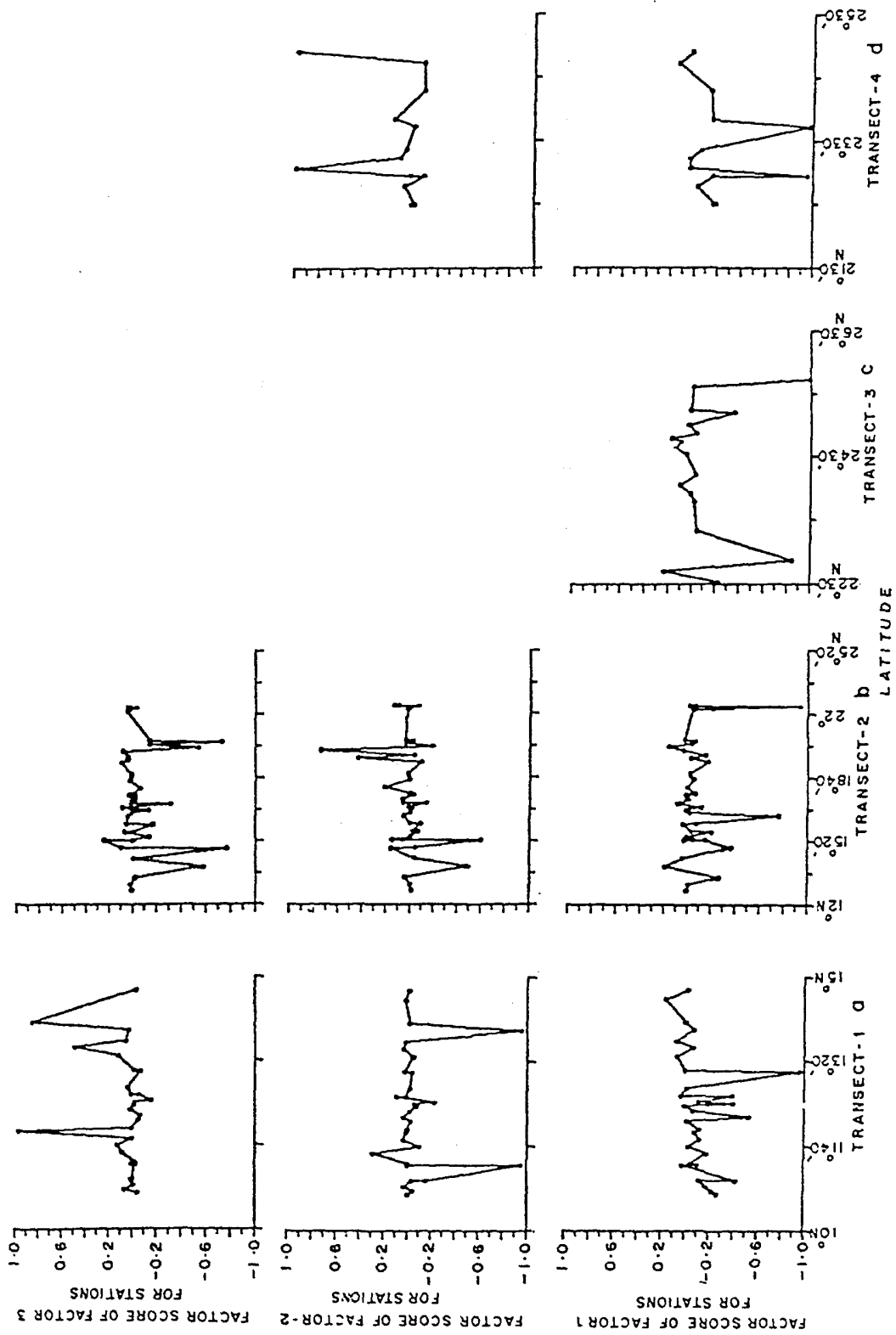
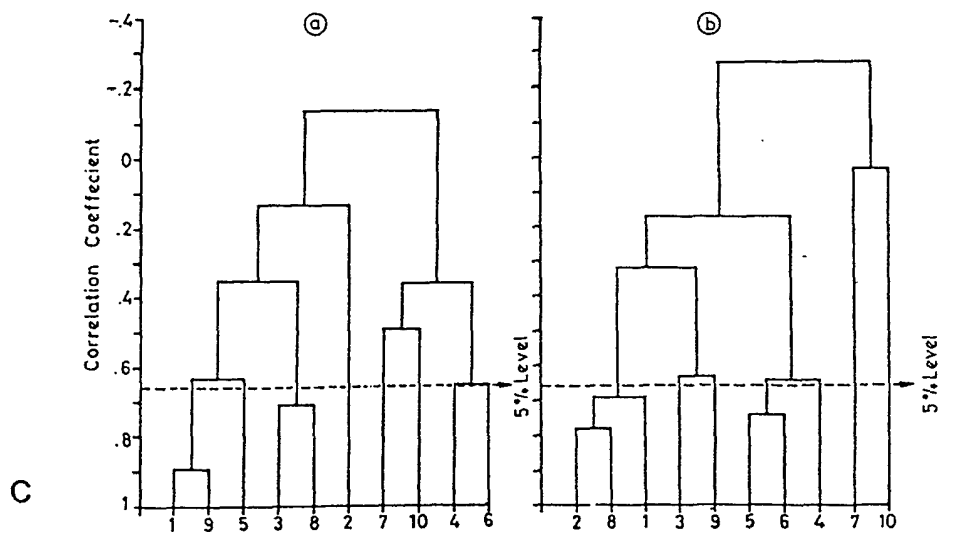
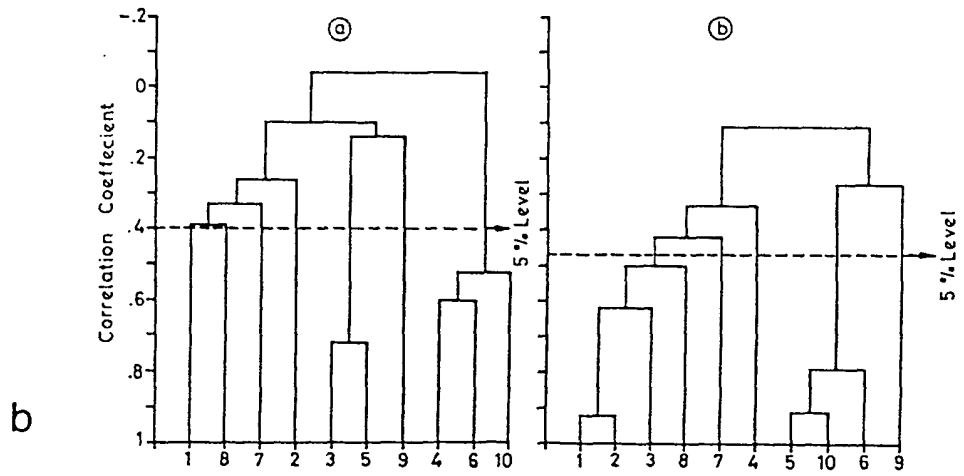
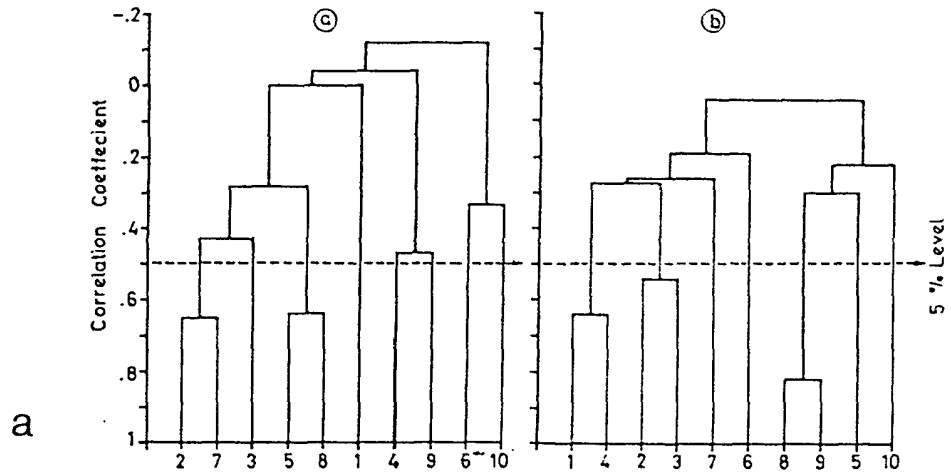


Figure 4a-4d. The factor score distribution of the locations in transects 1 to 4.



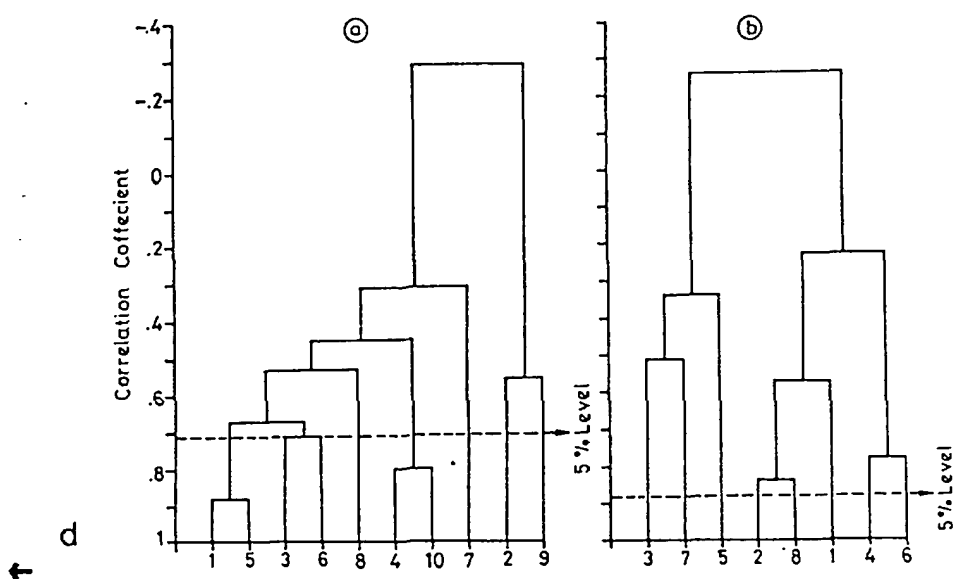


Figure 5a-5d. Dendrograms based on cluster analysis using correlation coefficient as the measure of association for zooplankton taxa after log transformation in the transects 1 to 4. The numbers on the X-axis refer to the zooplankton groups: 1. Copepoda, 2. Chaetognatha, 3. Decapoda, 4. Amphipoda, 5. Euphasiacea, 6. Ostracoda, 7. Fish eggs, 8. Fish larvae, 9. Medusae, and 10. Mysidae.

Taxonomic groups with high values for V_{uk} and V_{dk} indicated high taxa-quadrat interaction which was further verified by analysis of variance ($F_{(27,27,5\%)} = 4.9877$, $p < 0.05$) after $\log(X+1)$ transformation for normality of data. This indicated that different transects are predominated by different species groups or with varied abundances of the groups in the different quadrats as shown by the average distribution of the abundant taxa with high factor loadings in the different factor groups and by the factor score distribution for stations (Figures 4a-4d). Also the factor score distribution of the zooplankton taxa were all unimodal and significantly skewed ($p < 0.05$). This justifies that zooplankton taxa are not randomly or uniformly distributed in the various quadrats of the 4 transects but have a patchy or clustered distribution with degree of patchiness more than that given by the theoretical distribution as indicated by the Maxwell Boltzmann statistic.

Table. 1a. V_d , V_u , χ^2_d and χ^2_u values in each transect during day and night for all zooplankton taxa.

Statistic	Transect 1	Transect 2	Transect 3	Transect 4
V_u	106.6206	170.2128	33.2222	43.7976
V_d	82.829	137.0127	28.4207	12.6459
χ^2_u	102.6206	164.2128	30.2222	41.7976
χ^2_d	78.829	131.0129	25.421	10.65
Degree of Freedom	3	5	2	1

Table. 1b. $\chi^2_{k(d)}$, $\chi^2_{k(u)}$ values in each transect during day and night for all zooplankton taxa.

Statistic	Transect 1		Transect 2		Transect 3		Transect 4	
	day	night	day	night	day	night	day	night
Copepoda	8.995	6.883	34.362	20.254	26.346	0.497	17.868	0.059
Chaetognatha	2.443	0.141	25.517	20.932	4.810	-	0.519	0.134
Decapoda	10.934	3.826	27.518	6.803	242.825	1.973	3.091	0.515
Amphipoda	3.629	9.259	13.670	13.478	2.672	5.568	0.227	2.458
Euphasiacea	118.014	63.379	473.492	7.122	4.796	-	5.002	5.538
Ostracoda	70.169	20.631	27.656	958.887	110.282	142.048	0.876	13.040
Fish eggs	21.343	15.008	653.954	8.810	21.025	27.111	6.918	114.911
Fish larvae	5.601	195.322	34.765	9.733	4.756	1.101	3.024	1.173
Medusae	18.009	5.121	0.779	4.921	8.668	3.061	3.608	-
Mysidae	28.130	25.485	794.445	582.782	560.546	-	4.579	-
Degree of Freedom	3	3	5	5	2	2	1	1

Multilinkage cluster analysis applied after $\log_e(X+1)$ transformation produced the clusters (Figures 5a-5d) which are either included in the same factor groups or in different significant factor groups. Factor analysis by Q-mode grouped the taxa into three major factor groups (Table 2) in all transects during day and night except at transect four during day, where only two groups could be obtained, it may be due to less number of groups considered in this transect. All the factor models fitted are highly significant ($7.392 < \chi^2 < 16.345$ for 18 degrees of freedom, $p < 0.05$) except in transects 3 and 4. In all the transects either the first factor group (in the day samples collected from transect 1) or the factor group 2 (in all other cases) constituted the differential factor groups. The two methods of groupings although were not identical, significant clusters ($p < 0.05$) obtained under former technique (multilinkage) cluster analysis) are either present in the same factor groups or in different significant (eigen value, $\lambda > 1$) factor groups obtained under latter (factor analysis) method. The difference in the grouping pattern may be due to the different transformations adopted. However the factor analysis is preferred because unlike cluster analysis, it does not impose a hierarchical structure on the data for which there is no prior evidence. A significant relation has been observed between the clustering tendency (Table 1) and the variance explained by the significant factors. Greater the tendency for clustering, less is the information collected from the factor groups (Tables 1a, 1b and 2). In transect 2 during day and night high clustering tendency beyond that explained by the theoretical distribution has been observed and total variance explained by the three factor groups is 72% during day collection and only 62.84% during night collections. This high tendency for clustering could be attributed to the high variation in temperature and dissolved oxygen, tolerable to the dominating species of the significant factor groups when compared to the other transects. Similarly, salinity variation was the highest during day and night in transects 1 and 2 where relatively high values for the zonation index was observed. In transect 4 where the least variation for the three parameters was observed, less tendency for patchy or non uniform distribution was also observed. Therefore the clustering tendency is highly related to the distribution of the environmental parameters.

Table.2. Significant factor groups of zooplankton taxa , maximum factor loading, communality (%) , eigen values , closeness ratio and average abundance.

Factor	Taxon	Maximum factor load	Communality (%)	Eigen value	Closeness ratio	Average abundance
Transect 1 day samples						
i	Chaetognaths	-0.8089	86.76	5.26	52.69	31293
	Decapods	-0.9342	92.39			18746
	Fish larvae	-0.8885	90.78			770
2	Ostracods	-0.929	90.78	1.68	69.48	12289
	Medusae	-0.8109	95.42			157
	Mysids	-0.7804	62.29			94
3	Copepods	0.8287	86.98	1.36	83.07	1111352
	Euphasiids	0.9735	95.5			
Transect 1 night samples						
1	Amphipods	-0.927	88.35	4.397	43.97	5191
	Medusae	0.9726	94.79			761
2	Ostracods	0.9493	91.89	1.831	62.28	256784
	Mysids	0.9678	93.69			2219
3	Euphasiids	0.9774	96.01	1.524	77.52	20021
	Fish larvae	0.6768	47.84			1875
Transect 2 day samples						
1	Copepods	-0.6326	43.68	4.328	43.28	1008235
	Chaetognaths	-0.8891	82.46			42084
	Fish eggs	-0.8334	90.59			29836
2	Euphasiids	-0.8634	78.18	1.953	62.81	9009
	Ostracods	-0.7856	84.56			660273
3	Mysids	-0.9192	96.04	1.005	72.87	5416
Transect 2 night samples						
1	Copepods	-0.8567	74.35	3.575	35.75	998738
	Decapods	-0.636	40.96			20882
	Euphasiids	-0.9303	86.91			68135
2	Ostracods	0.8871	78.73	1.661	52.36	783957
3	Fish eggs	-0.6841	81.29	1.048	62.84	503
	Medusae	-0.8539	74.57			387
Transect 3 day samples						
1	Amphipods	-0.9327	58.46	4.598	45.98	88313
	Euphasiids	-0.9891	97.86			37
	Ostracods	-0.9866	97.35			11842
2	Decapods	-0.9368	89.66	2.215	67.24	1951
	Fish eggs	-0.974	94.91			340
3	Mysids	0.9743	95.24	1.26	79.84	2946

continued

Table 2. (continued)

Factor	Taxon	Maximum factor load	Commonality (%)	Eigen value	Closeness ratio	Average abundance
Transect 3 night samples						
1	Amphipods	-0.8608	82.41	6.107	61.07	1064
	Ostracods	-0.9311	89.61			146936
2	Euphasiids	0.7655	74.75	1.761	78.68	1690
	Fish eggs	0.9487	96.22			863
	Mysids	0.9525	95.8			1569
3	Copepods	0.5598	53.6	1.023	88.91	318109
	Decapods	0.793	78.06			4093
	Fish larvae	0.8403	82.19			395
Transect 4 day samples						
1	Chaetognaths	-0.6764	62.28	4.478	55.99	10776
	Fish eggs	-0.9787	95.79			1057
2	Amphipods	0.744	55.87	1.568	75.59	191
	Ostracods	0.9934	98.69			1043
	Fish larvae	0.9378	85.07			318
Transect 4 night samples						
1	Chaetognaths	-0.7405	63.15	6.253	62.53	29469
	Medusae	-0.9778	99.49			89
2	Fish eggs	0.9793	99.82	1.419	76.72	359
	Fish larvae	0.7415	84.08			726
	Mysids	0.758	57.74			3121
3	Decapods	0.691	67.75	1.131	88.02	4229
	Euphasiids	0.9798	97.92			4006
	Ostracods	0.7392	67.69			230664

In all the transects temperature, salinity and dissolved oxygen were grouped into a single group with high negative loadings contributing about 90.32% of the information about the spatial distribution of environmental parameters implying that addition of more parameters other than the interaction effects may not increase the information about the distribution of zooplankton groups substantially. In no transect factor score distribution of the taxa was multimodal during day and night collections. All were either unimodal and skewed negatively or positively, but not highly significant or unimodal symmetric distributions. This analysis reveals that the samples represented single continuously varying zooplankton populations, variations being due to the variations in the environmental parameters as stated earlier, but relatively high Skewness in the transect 2 can be associated with the variations in the plankton population which is highly linked with the varied nutrient distribution in this transect, this being an upwelling area.

The zooplankton taxa collected, represented a single and continuously changing population rather than distinct and separate populations which justified the absence of any sudden and unpredictable changes in plankton distribution during the study period.

CONCLUSION

Maxwell Bohzmann test resulted in significant clustering tendency during day and night catch relatively high values during night. The value of the index based on the proportional abundance of all the groups considered together in each quadrat decreased gradually from Gulf of Aden to off Karachi along the Pakistan coast with maximum value in the Saudi Arabian coast. But the index evaluated for each taxon, implied a significant positive correlation with the coefficient of variation (%) in the spatial distribution having high value the Saudi Arabian coast due to nutrient enrichment of the surface by upwelling and creases towards north during day. This test thus justifies that zooplankton taxa are not randomly or uniformly distributed but had a patchy distribution with degree of patchiness much more than that given by the theoretical distribution.

Significant inverse relationship was observed between the value of the index and the total variance explained by the significant factor groups. The zooplankton samples represented single continuously varying plankton population rather than separate and distinct populations thereby ruling out the possibility of any sudden and unpredictable changes in the population during the transitional period in the coastal regions of the North-western Arabian Sea. Day collections were more diverse than the night collections with datively high equality in the spatial distribution.

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REFERENCES

- Anonymous. 1975. Reports on cruises Nos. 1 and 2 of R.V. "Dr. Fridtjof Nansen". Indian Ocean Fishery- and Development Programme, Pelagic Fish Assessment Survey, North Arabian Sea, F.A.O., Rome, 15 pages (Mimeo).
- Cassie, R.M. 1959. An experimental study of factors inducing aggregation in marine plankton New Zealand Journal of Science 2: 339-365.
- Castro, L.A., Bernal, P.A. and Gonzalez, H.E. 1991. Vertical distribution of Copepods and the utilisation of chlorophyll, a rich layer within Conception Bay, Clute. Estuarine Coastal and Shelf Science 32: 243-256.
- Daniel, A. and Jyothinayagam, J.T. 1977. Neuston biomass and variations in abundance of its major zooconstituents in the Northern Arabian Sea during the oceanographic expeditions on the I.N.S. Darshak (December 1975, May. 1974). Pages 273-283, In: Symposium on Warm Water Zooplankton, Special Publication. National Institute of Oceanography, Dona Paula, Goa, India.
- Fernandes, A.A. and Mahadevan, R. 1982. Factor Analysis of Multivariate Data, Technical Report, National Institute of Oceanography, Dona Paula, Goa, India. 182 pages.
- Frederick, P.G. and Haedrich, Richard L. 1978. Zonation in the deep benthic megafauna, Application of a general test. Woods Hole Oceanographic Institution. 1978, collected reprints No. 4724, part 2, Published in December 1979.

- Goodall, D.W. 1954. Objective methods for the classification of vegetation, 111, An essay in the use of factor analysis, Australian Journal of Botany 2: 304-324.
- Gunman, I. 1954. Some necessary conditions for factor analysis, Psychometrika 19: 146-161.
- Haq, S.M., Alikhan, J. and Chutgal, S. 1973. The distribution and abundance of zooplankton along the coast of Pakistan during post monsoon and premonsoon periods. The biology of the Indian Ocean Ecological Studies. Edited by B. Zeitzschel Springer-verlag, Berlin-Heidelberg. New York, pages 257-272.
- Harman, H.H. 1967. Modern Factor Analysis, Chicago, University of Chicago Press. 479 pages.
- Jayalakshmy, K.V. 1998. The biometric studies of trophic level relations in the Indian Ocean. Ph.D. Thesis. Cochin University of Science and Technology. 464 pages.
- Kaiser, H.F. 1958. The varimax criterion for analytic rotation in factor analysis, Psychometrika 23: 187-200.
- Padmavathi, G. and Goswami, S.C. 1996. Zooplankton ecology in the Mandovi and Zuari estuarine system off Goa, West Coast of India. Indian Journal of Marine Sciences 25(3): 26S-273.
- Panikkar, N.K. and Rao, T.S.S. 1973. Zooplankton investigations in Indian waters and the role of the Indian Ocean Biological Centre. Handbook to the International zooplankton collections 5: 111-162.
- Paulinose, V.T. and Aravindhakshan, P.N. 1977. Zooplankton biomass, abundance and distribution in the north and northeastern Arabian Sea. Proceedings of the Symposium on warm water zooplankton special publication. N.I.O, pages 132-136.
- Pielou, E.C. and Roulledge, R.D. 1976. Salt marsh vegetation, latitudinal gradients in the zonation patterns. Oceanologica (Berl.) 24: 311-321.
- Prasad, R.R. 1969a. A recent advance in the study of production in the Indian Ocean, Morning Review Lecture of the Second International Oceanographic Congress, Moscow, 1966, Paris, UNESCO, pages 239-248.
- Prasad, R.R. 1969b. Zooplankton biomass in the Arabian Sea and the Bay of Bengal with a discussion on the Fisheries of the region, Proceedings of the National Institute of Science, India 35(5): 399-347 .
- Rao, T.S.S. 1979. Zoogeography of the Indian Ocean. Pages 254-292, In: Vander Spoel, S. and Rierrot-Bults, (Editors). Zoogeography and Diversity in Plankton. Bunge Scientific Publishers, Utrecht.
- Rummel, R.J. 1975. Applied Factor Analysis, John Wiley, New York. 792 pages.
- Shannon, C.E. and Weaver, G. 1949. The Mathematical Theory of Communication. University of Illinois Press, Urbana, Chicago. 125 pages.
- Smith, S.I. 1982. The Northwestern Indian Ocean during the monsoon of 1979. Distribution, abundance and of zooplankton, Deep Sea Research 29: 1331-1353.
- Snedecor, G.W. and Cochran, W.G. 1967. Statistical Methods, Oxford and IBH Publishing, Calcutta. 593 pages.
- Tirmizi, N.M. and Nayeem, I. 1992. Zooplankton in the Northern Arabian sea. Pakistan Journal of Zoology 24(3): 267-268.
- Williamson, M.H. 1961. A method for studying the relation of plankton variations to hydrography. Bulletin of Marine Ecology 5: 224-229.