

Distribution of Oxycephalidae (Hyperiiidea - Amphipoda) in the Indian Ocean - A statistical study

K.K.C. NAIR and K.V. JAYALAKSHMY

National Institute of Oceanography Regional Centre, Kochi - 682 018, India.

Abstract - Out of 1927 samples collected and analysed from the Indian Ocean during the International Indian Ocean Expedition (IIOE), oxycephalids were present in 33.63% of the samples. Statistical analysis on coexistence of the species showed two clusters of high affinity in the Arabian Sea, four in the Bay of Bengal, one in the South East Indian Ocean and three in the south west Indian Ocean. Species occurring in the various clusters were found to tolerate similar environmental conditions. Variability explained by the regression equations in the four regions were 57%, 18%, 66%, and 23% respectively. Salinity was found to be relatively more important in controlling the species total abundance. H(S) and E distribution, indicates that there was high dominance of a few species in the four areas, leading to low species diversity. Significant seasonal variations in species composition was noticed in the SE and SW Indian Ocean during the NE monsoon and during the SW monsoon in the Arabian Sea and SW Indian Ocean. In the Indian Ocean in general, during the NE monsoon, the species abundance varied highly among males, females, juveniles and among species, but during the SW monsoon significant difference in abundance among species alone was noticed.

INTRODUCTION

Oxycephalids are interesting forms of hyperiids and they differ from the other hyperiids in having mostly an elongated head and body and curious transformation in various developmental stages in a few cases. Oxycephalids constitute a group of amphipods that are strictly adapted to the pelagic life of the high seas. Current information on the oxycephalids of the Indian Ocean are mainly based on the work of FAGE(1960) and PILLAI(1966 a). This paper is the first comprehensive statistical account on the ecology and seasonal distribution of Oxycephalidae of the Indian Ocean.

The family Oxycephalidae contains 18 species distributed in 10 genera. They are *Leptocotis tenuirostris*, *Tullbergella cuspidata*, *Simorhynchotus antennarius*, *Oxycephalus piscator*, *Oxycephalus clausi*, *Streetsia challengerii*, *Streetsia procella*, *Streetsia steenstrupi*, *Glossoccephalus milneedwardsi*, *Rhabdosoma whitei*, *Oxycephalus latirostris*, *Streetsia mindanaonis*, *Cranoccephalus scleroticus*, *Calamorrhynchus pellucidus*, *Rhabdosoma brevicaudatum*, *Rhabdosoma minor*, *Metalycaea globosa* and *Rhabdosoma armatum* according to their order of abundance in the Indian Ocean. *Metalycaea globosa* which was only once recorded from the Mediterranean waters by STEPHENSEN (1925) has been recorded from the Indian Ocean during the present study and hence its doubtful existence has been cleared.

MATERIAL AND METHODS

The zooplankton data collected during the International Indian Ocean Expedition (IIOE) are used. The list of stations and the environmental data relating to these stations have been published in the INDIAN OCEAN BIOLOGICAL CENTRE (IOBC) HANDBOOKS (1969, 1973). Out of 1927 samples collected and analysed, oxycephalids were present in 648 samples (Fig. 1). In view of the influence of the monsoons over the Indian Ocean, the period of study is divided into the southwest monsoon (April 16th to October 15th) and the northeast monsoon (October 16th to April 15th) seasons. Day

and night groupings of the stations were done based on the local time. For area-wise assessment and evaluation, samples were further grouped under four regions, the Arabian Sea (area north of 5°N and west of 77°E), the Bay of Bengal (area north of 5°N and from 77°E to 110°E), the South West Indian Ocean (area south of 5°N up to 40°S and west of 77°E) and the South East Indian Ocean (area south of 5°N up to 40°S and from 77°E to 110°E). The number of samples considered for the present study are 164 from the Bay of Bengal, 118 from the Arabian Sea, 200 from the SE Indian Ocean and 179 from the SW Indian Ocean.

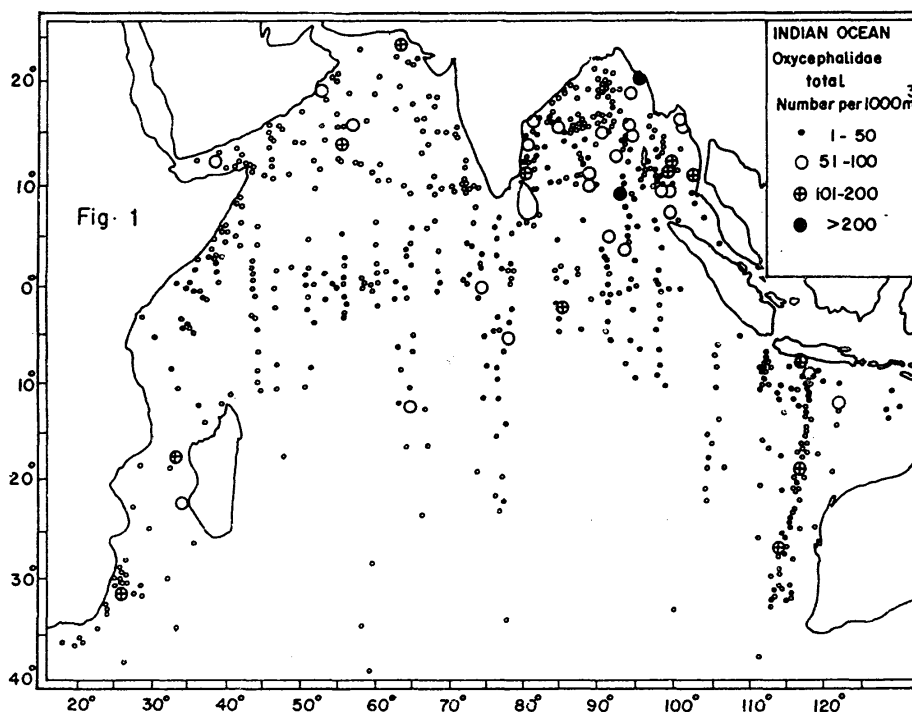


Fig. 1. The distribution of Oxycephalidae in the Indian Ocean.

The data was subjected to statistical analysis after logarithmic transformation (COLEBROOK, 1960). The following mathematical procedures were applied, 1. species affinity to hydrographic parameters such as temperature, salinity and dissolved oxygen, 2. regression analysis (linear multiple regression) to determine the relative importance of the parameters (SNEDECOR and COCHRAN, 1963 and SOKAL and ROHLF, 1981), 3. Shannon Weavers diversity function $H(S)$ (LLOYD and GHELARDI, 1964) and Heip's evenness index E for stations with $S > 1$ and Sheldons evenness index, $E = e^{H/S}$ has been applied for stations with $S = 1$ (to facilitate the distribution pattern of E for each region), (HEIP, 1974), 4. distribution pattern of $H(S)$ and E (FEDERER, 1967) and 5. parametric ANOVA technique based on species abundance for comparison between regions, seasons, day and night.

RESULTS AND DISCUSSION

(a) Species distribution and coexistence

It was found that the stations with larger number of species were mostly located in oceanic province particularly in the Bay of Bengal. In the Arabian Sea, *S. antennarius* was the most abundant species, whereas in the Bay of Bengal, SE Indian Ocean and SW Indian Ocean, *L. tenuirostris* was dominant. *R. armatum* occurred in low numbers in the Arabian Sea, SE and SW Indian Ocean whereas in the Bay of Bengal, *C. pellucidus* was the least represented. Distribution of *S. steenstrupi* in the Arabian Sea, *C. pellucidus* in the Bay of Bengal, *L. tenuirostris* in the SE Indian Ocean and *S. challengerii* in the SW Indian Ocean were found to be most consistent. The distribution of *R. brevicaudatum* in the Arabian Sea, *T. cuspidata* in the Bay of Bengal and SE Indian Ocean and *R. armatum*, *M. globosa* and *G. milneedwardsi* in the SW Indian Ocean were found to be highly heterogeneous, they were very rare and irregularly distributed (Table 1). This appears to be due to their preference to certain environmental conditions such as high suspended sediment load associated with zones of upwelling. Further, latitudinally oxycephalids were found to have an extended range of distribution either to the north or south, but the maximum number of species and their abundance was mostly found to the north of the sub-tropical convergence. They were extremely sparse between 20° and 40° South.

Table 1. The abundant species along with their geometric mean (G.M)* and coefficient of variation C.V (%) (a), the most rare species, their G.M and C.V (%) in the four geographic areas (b).

(a) Region	Abundant species	G.M.	C.V (%)
Arabian Sea	<i>S.a</i>	0.8501	254.71
Bay of Bengal	<i>L.t</i>	0.2744	120.45
SE Indian Ocean	<i>L.t</i>	0.1174	193.61
SW Indian Ocean	<i>L.t</i>	0.1919	519.51
(b) Region	Rare species	G.M.	C.V (%)
Arabian Sea	<i>R. a</i>	0.0252	807.50
	<i>R. b</i>	0.0333	1096.40
Bay of Bengal	<i>R. m</i>	0.0067	745.43
	<i>T. c</i>	0.0054	1179.63
SE Indian Ocean	<i>R. a</i>	0.0030	996.67
	<i>R. b</i>	0.0080	912.54
	<i>R. a</i>	0.0017	1335.41
SW Indian Ocean	<i>G. m</i>	0.0026	1334.40
	<i>M. g</i>	0.0027	1334.40

* G.M. = No. of animals M⁻³/haul

S.a - *Simorhynchotus antennarius*, *L.t* - *Leptocotis tenuirostris*,
R.a - *Rhabdosoma armatum*, *R.b* - *R. brevicaudatum*, *R.m* - *R. minor*,
T.c - *Tullbergella cuspidata*, *G.m* - *Glossoccephalus milneedwardsi*,
M.g - *Metalycaea globosa*

Leptocotis tenuirostris, a widely distributed surface / subsurface species of the tropical and sub-tropical areas of the world oceans, was the most abundant (25.16%) and successful species among the oxycephalids of the Indian Ocean. Among the second dominant group - *T. cuspidata*, *S. antennarius*, *O. piscator*, *O. clausi*, *S. challengerii* were widely distributed in the neritic and oceanic waters of the tropical and sub-tropical areas (except *T. cuspidata* which is mostly a neritic inhabitant of the northern Indian Ocean). The third abundant group (*S. porcella*) was absent all along the tropical and sub-tropical convergence and in the central Indian Ocean waters. Members of the fourth group (*S. steenstrupi*, *G. milneedwardsi*, *R. whitei*, *O. latirostris* and *S. mindanaonis*) barring *R. whitei*

and *S. steenstrupi*, which have a circum global, tropical and sub-tropical distribution were some what confined to the less saline eastern areas of the Indian Ocean, north of equator. Among the least abundant group, *C. scleroticus* and *C. pellucidus* were mostly restricted to the equatorial waters. *R. brevicaudatum* was found to be mostly a neritic inhabitant of the euphotic zone whereas *R. minor* was found to be scattered in the tropical and sub-tropical zones. Distribution of *M. globosa* and *R. armatum*, the least abundant, extended from the tropical to the sub-tropical areas on either side of equator (Table-2).

Table 2. Numerical abundance (%), percentage occurrence, number of males (M), Females (F) and Juveniles (J) in the four geographical areas.

	OC (%)	NA (%)	AS			BB			SWIO			SEIO		
			M	F	J	M	F	J	M	F	J	M	F	J
Lt	30.9	25.2	23	7	50	92	50	88	49	89	77	29	70	24
Tc	1.4	11.3	2	1	18	121	143	4	-	-	-	-	4	2
Sa	11.4	10.9	42	57	25	44	17	22	7	28	6	5	23	5
Op	13.6	10.4	3	34	12	15	34	31	3	18	19	14	40	45
Oc	13.9	9.8	15	40	16	21	32	22	13	16	18	7	26	26
Sc	15.4	8.9	2	26	-	11	25	13	6	51	42	15	25	14
Sp	7.3	5.6	-	11	20	8	27	52	6	10	19	12	13	2
Ss	5.9	2.9	2	-	1	5	7	6	1	8	10	10	17	9
Gm	2.5	2.6	5	6	26	-	12	16	-	2	-	-	-	-
Rw	6.5	2.3	3	6	13	4	10	6	3	3	5	1	3	2
Ol	2.8	2.2	5	4	-	2	6	-	12	5	1	6	3	14
Sm	3.1	2.1	5	-	4	14	5	3	1	5	2	14	1	-
Cs	2.6	1.9	-	2	6	4	2	3	2	2	17	2	8	-
Cp	2.8	1.4	-	6	-	-	2	-	-	8	4	3	8	6
Rb	1.7	1.2	-	4	-	-	-	-	-	8	13	-	5	2
Rm	1.9	1.1	-	-	-	-	1	3	-	10	3	-	2	10
Mg	0.6	0.4	4	-	-	-	-	-	-	-	2	-	-	4
Ra	0.8	0.2	-	3	-	-	-	-	-	1	-	-	1	1

OC = occurrence, NA = Numerical abundance, AS = Arabian Sea, BB = Bay of Bengal, SWIO = South West Indian Ocean, SEIO = South East Indian Ocean.

O.p - *Oxycephalus piscator*, *O.l* - *Oxycephalus latirostris*, *C.p* - *Calamorrhynchus pellucidus*, *G.m* - *Glossocephalus milneedwardsi*, *O.c* - *Oxycephalus clausi*, *R.w* - *Rhabdosoma whitei*, *M.g* - *Metalycaea globosa*, *R.b* - *Rhabdosoma brevicaudatum*, *S.m* - *Streetsia mindanaonis*, *T.c* - *Tullbergella cuspidata*, *R.a* - *Rhabdosoma armatum*, *S.s* - *Streetsia steenstrupi*, *S.c* - *Streetsia challengerii*, *R.m* - *Rhabdosoma minor*, *C.s* - *Craniocephalus scleroticus*, *S.a* - *Simorhynchotus antennarius*, *S.p* - *Streetsia porcella*, *L.t* - *Leptocotis tenuirostris*

Table 3. Clusters of species with significant affinity formed in the four geographical regions.

Clusters	Arabian Sea	Bay of Bengal	SEIO	SWIO
1	(Sc, Sm)	(Cs, Sa, Rw)	(Rm, Cs)	(Rw, Ra)
2	(Cs, Lt)	(Sp, Rm)		(Mg, Op)
3		(Oc, Ol)		(Cp, Sm)
4		(Cp, Op)		

SEIO = South East Indian Ocean, SWIO = South West Indian Ocean.
O.p - *Oxycephalus piscator*, *O.l* - *Oxycephalus latirostris*, *C.p* - *Calamorrhynchus pellucidus*, *O.c* - *Oxycephalus clausi*, *R.w* - *Rhabdosoma whitei*, *M.g* - *Metalycaea globosa*, *S.m* - *Streetsia mindanaonis*, *R.a* - *Rhabdosoma armatum*, *S.c* - *Streetsia challengerii*, *R.m* - *Rhabdosoma minor*, *C.s* - *Craniocephalus scleroticus*, *S.a* - *Simorhynchotus antennarius*, *S.p* - *Streetsia porcella*, *L.t* - *Leptocotis tenuirostris*,

Table 4. Correlation coefficient (10^{-2}) of species with parameters in the four geographical areas.

Species	Temperature				Salinity				Dissolved oxygen			
	AS	BB	SWIO	SEIO	AS	BB	SWIO	SEIO	AS	BB	SWIO	SEIO
S.a	11	01	02	03	26	01	50	-01	17	01	71	-85
R.w	15	00	01	-12	11	-01	00	07	-05	00	-07	10
R.a	01	00	-04	-02	01	00	-01	12	00	00	01	-07
R.b	-01	00	01	-01	01	00	01	07	-05	00	-02	01
O.c	-01	01	12	60	03	01	23	02	-22	-01	22	82
O.l	03	-01	02	01	01	01	-01	07	01	01	-01	-10
O.p	02	01	03	32	19	01	04	56	06	-01	-02	-06
T.c	01	-01	-	-02	01	01	-	-27	05	01	-	-02
C.p	-74	-01	15	-21	-44	01	17	12	-59	01	23	49
L.t	11	-03	10	-44	11	-01	01	-97	19	-01	-01	-11
G.m	-06	01	-01	04	14	01	01	-01	21	01	02	-02
C.s	-01	-04	02	-49	01	01	-01	-21	04	-01	06	-50
S.c	-09	-02	17	03	-09	01	-01	-01	-13	01	29	-52
S.m	-02	01	02	-06	26	01	-03	-02	03	01	01	-05
S.s	02	01	-19	-06	01	01	01	06	01	-01	06	11
S.p	42	-01	-11	-41	27	01	08	52	25	01	-11	-51
M.g	02	-	26	-03	01	-	01	-04	-01	-	-01	-07
R.m	-	-	-01	-85	-	-01	01	05	-	-01	67	-48

S. a - *Simorhynchotus antennarius*, R. w - *Rhabdosoma whitei*, R. a - *Rhabdosoma armatum*, R. b - *Rhabdosoma brevicaudatum*, O. c - *Oxycephalus clausi*, O. l - *Oxycephalus latirostris*, O. p - *Oxycephalus piscator*, T. c - *Tullbergella cuspidata*, C. p - *Calamorhynchus pellucidus*, L. t - *Leptocotis tenuirostris*, G. m - *Glossoccephalus milneedwardsi*, C. s - *Cranoccephalus scleroticus*, S. c - *Streetsia challengerii*, S. m - *Streetsia mindanaonis*, S. s - *Streetsia steenstrupi*, S. p - *Streetsia porcella*, M. g - *Metalycaea globosa*, R. m - *Rhabdosoma minor*

Table 3 shows the degree of affinity between species and the significant clusters having high affinity formed in the four regions. In all areas each highly coexisting clusters has a minimum correlation of 0.22. Species of each cluster have the same affinity to temperature, salinity and dissolved oxygen.

(b) Species affinity to hydrographic factors

Table 4 shows the extent of affinity of the species to temperature, salinity and dissolved oxygen respectively in the four geographical areas. In the SE Indian Ocean species were generally negatively correlated with these parameters whereas in the SW it was mostly positive. In the Bay of Bengal none of the species showed any significant correlation with the parameters. In the Arabian Sea, significant positive correlations with salinity and dissolved oxygen were observed. The species relation with various parameters was further examined through the prediction equation for predicting the

total abundance of the oxycephalids from the values of temperature, salinity and dissolved oxygen. In all the four regions the model was found to be significant ($P < .01$)

Table 5. Results of the linear multiple regression model fitted for predicting the total abundance of oxycephalidae species in the four geographical areas.

	ArabianSea	Bay of Bengal	SE Indian Ocean	SW IndianOcean
RI	1.1145	0.1638	0.5888	0.0945
Temp.				
PRC	1.7072	-0.4502	5.5163	0.1024
RI	0.7105	0.4489	0.7950	0.4518
Sal.				
PRC	-0.6170	0.4531	46.1914	0.5955
RI	0.2602	0.3098	0.8982	0.0035
D.O				
PRC	0.6680	0.6845	18.3321	-0.0067
F R	52.9828	12.6564	130.7300	18.6743
V E	57(%)	18(%)	66(%)	23(%)
D F	(3,114)	(3,160)	(3,194)	(3,175)

R I = Relative Importance, Temp. = Temperature, PRC = Partial Regression Coefficient, Sal. = Salinity, D.O = Dissolved Oxygen, F R = Calculated F Ratio, V E = Variability Explained and D F = Degrees of Freedom.

Table 5 shows the regression coefficients and the corresponding F values for the regression equations fitted. The relative importance as measured by standard partial regression coefficient for the parameters are given (Table 5) below.

- (1) Temperature > salinity > dissolved oxygen for the Arabian sea.
- (2) Salinity > dissolved oxygen > temperature for the Bay of Bengal
- (3) dissolved oxygen > salinity > temperature for the SE Indian Ocean
- (4) salinity > temperature > dissolved oxygen for the SW Indian Ocean.

Both temperature and salinity were found to influence the distribution of oxycephalids. Temperature is often one of the significant parameters which determines the faunistic barriers in an oceanic environment and generally it is also evidenced from the latitudinal distribution (KINNE,1970).

The distribution of *M. globosa*, *T. cuspidata*, *R. armatum* and *R. brevicaudatum* showed some affinity to areas of upwelling and associated increase of nutrient's concentration. *T. cuspidata* and *G. milneedwardsi* were mainly confined to the north of 10°N and they appeared to be associated with waters of high productivity and low oxygen content. *R. brevicaudatum* was restricted to the south of 10°N. More or less similar trend in the distribution was noted in *R. minor* except two isolated occurrence towards the eastern areas of the Bay of Bengal. The hydro-chemical front at 10°S (WYRTKI,1973) was found to be the southern most extension of the species viz. *O. latirostris*, *C. pellucidus*, *S. streenstrupi*, *S. mindanaonis*, *S. porcella*, *C. scleroticus* and *R. whitei* in the south central Indian Ocean. The zoogeography of both the eastern and western Indian Ocean showed extensive north-south ranges of coastal species. Thus *M. globosa*, *T. cuspidata* and *G. milneedwardsi*, ranged from 25°N to 30°S. *R. armatum* from 15°N to 10°S and *R. brevicaudatum* from 10°N to 38°S. Neritic species like *T. cuspidata* extended from the head of the Arabian Sea and the Bay of Bengal to the waters of the west coast of Australia. *G. milneedwardsi* was confined to the Bay of Bengal and the Arabian Sea.

In the western boundary coasts, the Somali current and the Agulhas current appeared to transport oxycephalids far to the north (20°N) and south (38°S). Distribution

of the species in *Leptocotis* and *Streetsia* along an east west salinity gradient from the high salinities of the Red Sea and Gulf of Aden to the lower salinities of the eastern Bay of Bengal and East Indies is an evidence of allopatric speciation to avoid competition among morphologically similar species, identical in size as noted for Candaciidae by LAWSON (1977), Hyperiididae by BOWMAN and McGUINNESS (1982) and Scolecithricidae by GOPALAKRISHNAN (1982). Oxycephalids showed an extended distribution along meridian beyond zonal boundaries as a result of boundary currents, similar to euphausiids (BRINTON and GOPALAKRISHNAN, 1973), Candaciidae (LAWSON, 1977) and Hyperiididae (BOWMAN and McGUINNESS, 1982). South of 20°S, all the species of Oxycephalidae were found decreasing in abundance and occurrence. The zonal characteristics in oxycephalids were not as explicit as they were found for copepods (LAWSON, 1977) and euphausiids (BRINTON and GOPALAKRISHNAN, 1973). But in general the distribution of oxycephalids revealed zonal characteristics in oceanic regions and meridional characteristics in boundary regions. Primarily zonal characteristics were related to the parallels of latitudes 10°N, equator, 10°S, 20°S, 30°S, 40°S.

Table 6. Numerical abundance of oxycephalid species in two seasons, during day night in the four geographical areas.

	SWM		NEM		DAY		NIGHT	
	Total	N C	Total	N C	Total	N C	Total	N C
<i>It</i>	400	110	248	90	261	87	387	113
<i>Tc</i>	4	3	286	6	5	2	285	7
<i>Sa</i>	93	33	188	40	121	36	160	37
<i>Op</i>	146	47	122	41	130	48	138	40
<i>Oc</i>	150	50	102	40	91	44	161	46
<i>Sc</i>	111	50	119	50	97	42	133	58
<i>Sp</i>	97	27	48	20	72	23	73	24
<i>Ss</i>	49	23	27	15	45	22	31	16
<i>Gm</i>	25	6	42	10	40	7	27	9
<i>Rw</i>	35	22	24	20	26	15	33	27
<i>OI</i>	42	13	16	5	35	11	23	7
<i>Sm</i>	20	8	34	12	15	8	39	12
<i>Cs</i>	25	8	23	9	19	8	29	9
<i>Cp</i>	27	12	10	6	21	10	16	8
<i>Rb</i>	4	1	28	10	8	3	24	8
<i>Rm</i>	24	9	5	3	15	5	14	7
<i>Mg</i>	2	1	8	3	6	2	4	2
<i>Ra</i>	3	2	3	3	2	2	4	3

SWM = South West Monsoon, NEM = North East Monsoon,
NC = Number of Collections. .pa

O.p - *Oxycephalus piscator*, *O.l* - *Oxycephalus latirostris*,
C.p - *Calamorrhynchus pellucidus*, *G.m* - *Glossocephalus*
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armatum, *S.s* - *Streetsia steenstrupi*, *S.c* - *Streetsia challengerii*, *R.m* -
Rhabdosoma minor, *C.s* - *Cranoecephalus scleroticus*, *S.a* - *Simor-*
hynchotus antennarius, *S.p* - *Streetsia porcella*, *L.t* - *Leptocotis*
tenuirostris,

Vertical migration and monsoonal effects

Oxycephalids are mostly surface / subsurface species. However, their distribution offer certain clues regarding their vertical distribution at least in the euphotic zone. *M. globosa*, *O. latirostris*, *C. pellucidus* *S. steenstrupi* and *G. milneedwardsi* did not show any preference for the surface layers during night and they were more abundant during day. But most of the remaining species were more in the night hauls than in day

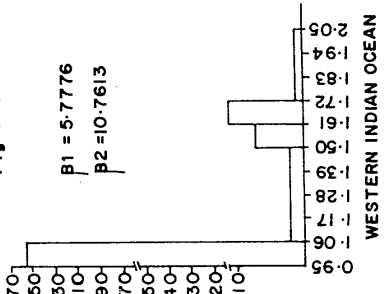
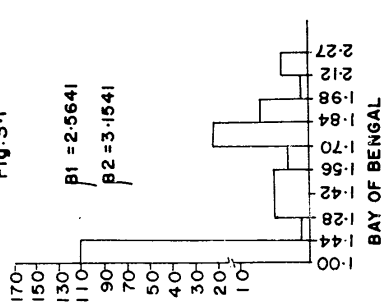
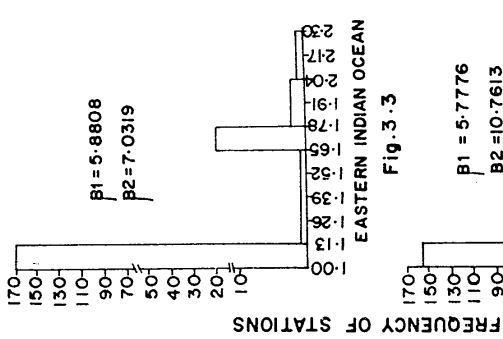
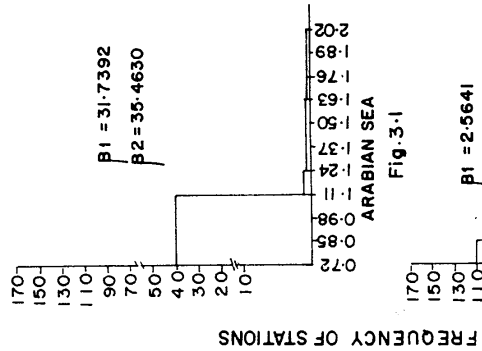
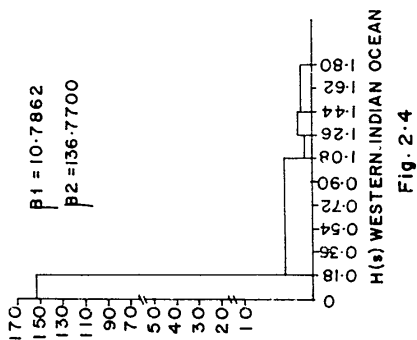
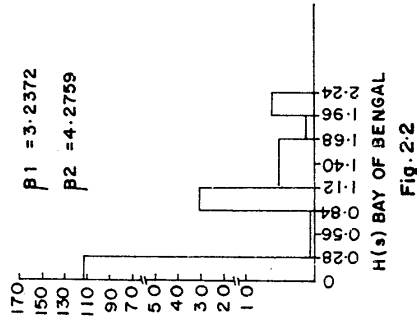
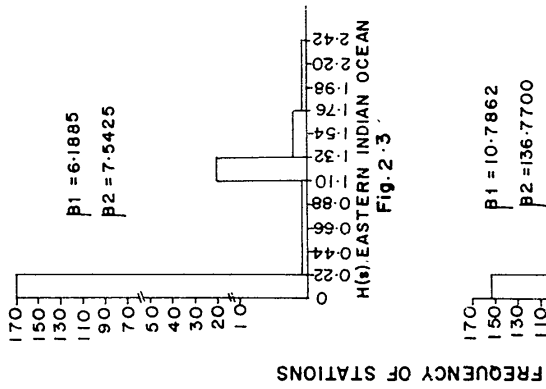
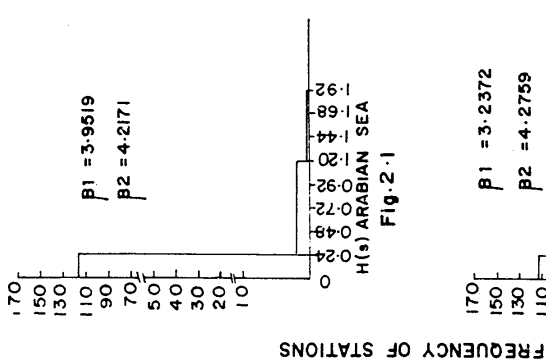


Fig. 2.1 to 2.4 Distribution of diversity function, $H(s)$ in the Arabian Sea, Bay of Bengal, SE Indian Ocean and SW Indian Ocean.

Fig. 3.1 to 3.4 Distribution of evenness index E in the Arabian Sea, Bay of Bengal, SE Indian Ocean and SW Indian Ocean.

collections indicating a pronounced vertical migration towards the surface layers during night. *O. piscator*, *S. porcella* and *R. minor* did not show any noticeable difference in their concentration between day and night samples. However the vertical migration exhibited by some of the species was not statistically significant ($P > .05$) because the most dominant species did not show much appreciable difference between day and night collections. Hence instances of interaction of species abundance with time of collection or with males, females or juveniles were never noticed ($P > .05$) indicating the possible dominance of neutral species (Tables - 2 and 6).

In the Arabian Sea and Bay of Bengal, during the NE monsoon, abundance of the oxycephalid species did not vary significantly among males, females and juveniles or among species during day and night. In the SW ($F(17, 54) = 2.10$) and SE ($F(17,54) = 3.06$) Indian Ocean, the species abundance varied significantly among species irrespective of the time of collection, sex or stage of the specimens ($P < .05$).

During the SW monsoon the abundance varied highly ($P < .05$) among species in the Arabian sea ($F(17,54) = 2.41$) and in the SW Indian Ocean ($F(17,54) = 2.23$). Difference in abundance among males, females and juveniles was significant in the Bay of Bengal ($F(2,54) = 13.18$). In general the total distribution of hyperiid amphipods in the Indian Ocean showed their dominance during the SW monsoon period compared to the NE monsoon (NAIR *et.al.*, 1973 a,b).

Data were averaged over time in each region and the four regions were compared with respect to seasonal variations. During the NE monsoon there was no significant difference between regions with respect to species total abundance even though some species showed zonal preferences ($P > .05$). But sex or stage wise $F(12, 24) = 3.80$, $P < .05$ as well as species wise difference ($F(17,124) = 4.01$, $P < .05$) were high between regions. Hence species - sex or stage wise interaction ($F(53,124) = 3.33$, $P < .05$) remained very high. But during the SW monsoon only species wise difference ($F(17,124) = 5.15$), $P < .05$) was highly pronounced.

(d) Species diversity and evenness in the species distribution

In majority of the samples (84.26%) only one species each was present. The rest of the collections numbering 72, 21, 6, 2 and 1 had 2, 3, 4, 5 and 6 species respectively. A detailed analysis of the number of species present at various stations revealed that stations with larger number of species were mostly located in the oceanic province more so in the Bay of Bengal. Shannon Weaver information function $H(S)$ and Heips and Sheldon's evenness indices E computed showed that $H(S)$ and E distributions were significantly positively skewed ($P < .05$) and leptokurtic indicating the high abundance of few species dominating the four areas, leading to low species diversity (Figs. 2.1 to 2.4 and figs. 3.1 to 3.4).

Generally a decrease in species diversity occurred in oxycephalids from east to west. About 13 species were observed in the Indo- West Pacific areas which got reduced to 7 in the Gulf of Aden (*S. antennarius*, *O. clausi*, *L. tenuirostris*, *S. challengerii*, *S. porcella*, *G. milneedwardsi* and *R. whitei*).

The number of species of oxycephalids was found to decrease from 18 in the northern equatorial latitudes to 15 in the sub- tropical convergence. Species diversity was more during the months of March and september in the Bay of Bengal, while it was uniformly low in the Arabian Sea. Diversity in the SW Indian Ocean was found to be more during March-May and August- December, whereas in the SE Indian Ocean it was more during April-May and August- September. The fairly good representation of most of the species to the south of Java and off the north- western Australian coast may be as a result of exchange of the Pacific waters with the Indian Ocean through

Malacca Strait and the Timor Sea. Less diversity in the Bay of Bengal can be attributed to the high variations in the salinity (31 to 35 x 10⁻³) and temperature (24 to 30°C) of the area (WYRTKI, 1971).

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