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QUANTITATIVE DISTRIBUTION OF PELAGIC SHRIMPS IN THE DEEP SCATTERING LAYERS OF THE INDIAN EEZ

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ABSTRACT

A study of 383 samples of Isaac - Kidd Midwater Trawl collections taken by FORV *Sagar Sampada* during 1985-'86 has shown that the Deep Scattering Layers of the Indian EEZ harbour rich population of pelagic shrimps, with maximum abundance in the west coast. The mean density of shrimps estimated is 311 nos/haul for the west coast including Lakshadweep, 82 nos for the east coast and 107 nos for Andaman-Nicobar region. In most part of Indian coasts the shrimp population is more numerous in the neritic waters than in the oceanic. Season-wise analysis of catch data from the west coast indicates that the abundance of shrimp is higher during premonsoon and monsoon seasons in the oceanic waters and during postmonsoon season in the neritic waters. In general, the shrimp catch is better during night than in day time.

The pelagic shrimp population is multispecies in character and represented chiefly by the genera *Sergestes*, *Acetes*, *Thalassocaris*, *Pasiphaea* and *Leptochela*. Species of *Sergestes* dominate in the oceanic waters. The possible feeding relationship between oceanic tunas and pelagic shrimps is discussed.

INTRODUCTION

Among the various species of prawns and shrimps occurring in the sea, the great majority are benthic in existence throughout their life except for a short pelagic phase during metamorphosis. The commercial shrimp fishery is predominantly supported by the benthic forms. A number of species, however, live permanently in the columnar layers of the ocean where they are fed upon by fishes and other aquatic organisms, besides some of them being caught commercially by man from the inshore waters. According to Omori (1974), out of a total of about two thousand species of prawns recorded from the world oceans, as many as 210 species pass their complete life in the pelagic realm. Though the occurrence of pelagic shrimps in the mid and deep waters of the ocean has been reported as early as the middle of nineteenth century, serious attention to study their role in the productivity of the sea has been paid only in recent years (Pearcy and Forss, 1966; Aizawa, 1969; Foxton, 1970 a, b; Omori *et al.*, 1972; Matthews and Pinnoi, 1973). In Indian waters, the earliest attempt to throw light on pelagic shrimps was the faunistic work of Alcock (1901) who enlisted several species along with the benthic forms from the collections of the marine survey ship *Investigator*. Later, Kemp (1917, 1925), Menon

(1937), Nataraj (1942, 1947), Pillai (1955), George and Rao (1966), Rao (1968) and others have recorded many more species from the west and east coasts of India and studied their taxonomy. The complete larval history of some of the oceanic species was worked out by Menon and Williamson (1971) and George and Paulinose (1973). Most of the species of pelagic shrimps recorded by these authors belong to the families Sergestidae, Benthescymidae, Pasiphaeidae, Oplophoridae and Thalassocarididae. Among sergestid shrimps, species of the genus *Acetes* generally occupy the inshore or neritic waters and contribute to the commercial fishery in many parts of the Indian coasts. In the oceanic realm, this family is mainly represented by the genus *Sergestes*.

Pelagic shrimps form an important forage of oceanic tunas, flying fish etc. (George and George, 1964; George and Paulinose, 1973; James *et al.*, 1987) and a number of fish species inhabiting the shelf waters which support commercial fisheries (Nataraj, 1947; Chacko, 1949; Venkataraman, 1960; Suseelan and Nair, 1969). They link the zooplankton and large animals of the higher trophic levels in the food chains and transport organic matter produced in the upper layers to the lower layers of the sea through vertical migrations. A knowledge

of the distribution and biology of the pelagic shrimp population would, therefore, be of great relevance in the management of fishery resources. Lack of such information from Indian waters has prompted the authors to carry out detailed investigations on the pelagic shrimps based on the collections of FORV *Sagar Sampada*. The present paper, which forms part of these studies, deals with distribution and numerical abundance of pelagic shrimps excluding *Lucifer* in the Deep Scattering Layers (DSL) off the Indian coasts including the Lakshadweep and Andaman seas.

MATERIAL AND METHODS

The Isaacs-Kidd Midwater Trawl (IKMT) collections taken from the Deep Scattering Layers during the period February, 1985 to May, 1986 by *Sagar Sampada* were used for this study. Details of the IKMT operations have been described by Menon and Prabhadevi in their account on the biomass in the DSL of Indian waters being published elsewhere in this volume. The catches of 383 hauls of IKMT covering almost the entire area of EEZ of India and some contiguous waters have been examined for the pelagic shrimps. Each haul was operated for 30 minutes duration at a towing speed of 3 knots per hour in the sonic scattering layers which occupied depths upto about 600 m from the sea surface. The sampling distribution in each of the half-degree squares demarkated by longitude and latitude lines for the entire area of investigation is shown in Fig. 1.

The numerical data of pelagic shrimps were analysed area-wise and average number per haul worked out for each of the half-degree squares for all practical purposes. The geographical limit of the major regions dealt with in the paper are as follows.

West coast	:	Lat. 7°00'N - 24°00'N and Long. 65°00'E - 77°30'E
East coast	:	Lat. 6°00'N - 15°00'N and Long. 77°30'E - 83°00'E Lat. 15°00'N - 22°00'N and Long. 80°00'E - 92°00'E
Andaman-Nicobar region	:	Lat. 5°00'N - 15°00'N and Long. 88°00'E - 95°30'E

OBSERVATIONS

Spatial distribution and abundance

The pelagic shrimps formed a regular component of the IKMT collections throughout the Indian

EEZ, although their number varied considerably in individual hauls. Out of the total number of 383 hauls operated, 348 hauls indicated the presence of pelagic shrimps in varying degrees of abundance. The distribution pattern and areas of abundance of the shrimps are shown in Fig. 2.

West coast

The IKMT was operated in all the months of the year except in May and June, covering the shelf and oceanic waters between 33 and 4,600 m depth including the seas around Lakshadweep. A total of 244 hauls were taken from this coast, of which 235 (96%) recorded pelagic shrimps and the rest were negative hauls. The number of shrimps per haul ranged from 1 to 10,986, the average number per haul being 311 for the entire coast. Table 1 gives details of shrimp catch for each of the one-degree squares arranged latitude-wise. A comparison of the population density in individual squares would indicate that the maximum abundance of shrimps was recorded in 9-75, 11-75 and 18-72 degree squares where the catch rate exceeded 2,000 nos/haul. The greatest density of over 10,000 nos/haul was observed in the 18-75 degree square lying off Bombay-Ratnagiri coast in Maharashtra during December. As a whole, the southern latitudinal areas including Lakshadweep are found to be more productive than the northwest coast where the shrimp abundance is rather patchy and productive areas are less extensive (Fig. 2).

Analysis of the catch data of pelagic shrimps with reference to inshore-offshore regions has shown that the shrimp population is relatively more numerous in the shelf waters than in the oceanic (Table 4). While the difference in abundance was only moderate between the neritic (393/haul) and oceanic (317/haul) regions along the southwest coast, nearly a three fold increase in abundance was noticed in the neritic waters (632/haul) as compared to the standing stock of shrimps in the oceanic waters (219/haul) along the northwest coast, which was particularly due to the heavy occurrence of shrimps in the near-shore areas of Bombay-Ratnagiri coast.

East coast

Covering almost the northern half of the Bay of Bengal and the entire Coromandel coast and Gulf of Mannar, the IKMT was operated in the months of February, March, May, June, July and November, extending from 14 to 3,639 m depth at bottom. A

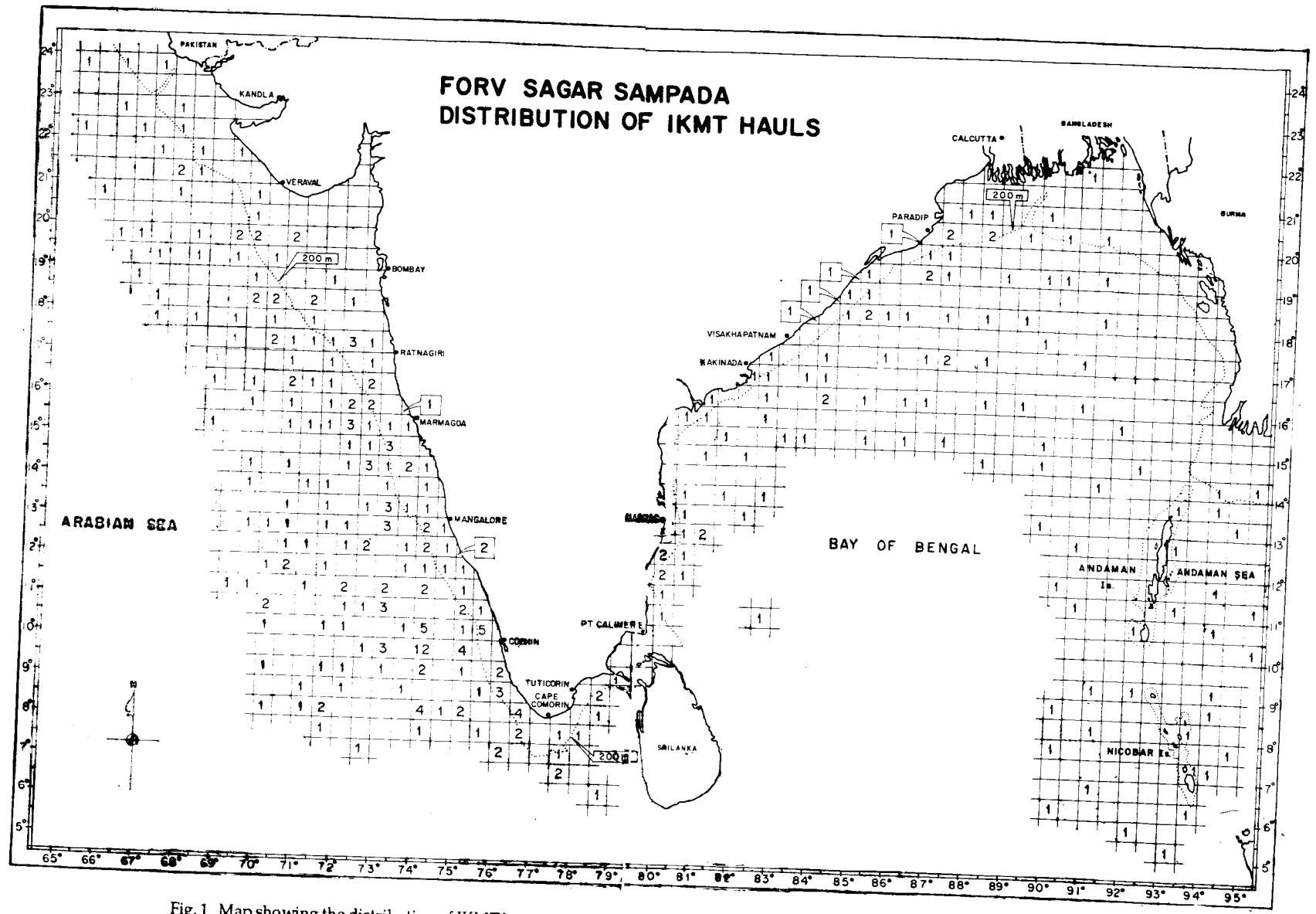


Fig. 1. Map showing the distribution of IKMT hauls in Indian EEZ and contiguous seas. Number in squares indicates total number of hauls taken in each of the half-degree squares.

ON PELAGIC SHRIMPS IN THE DSL OF INDIAN EEZ

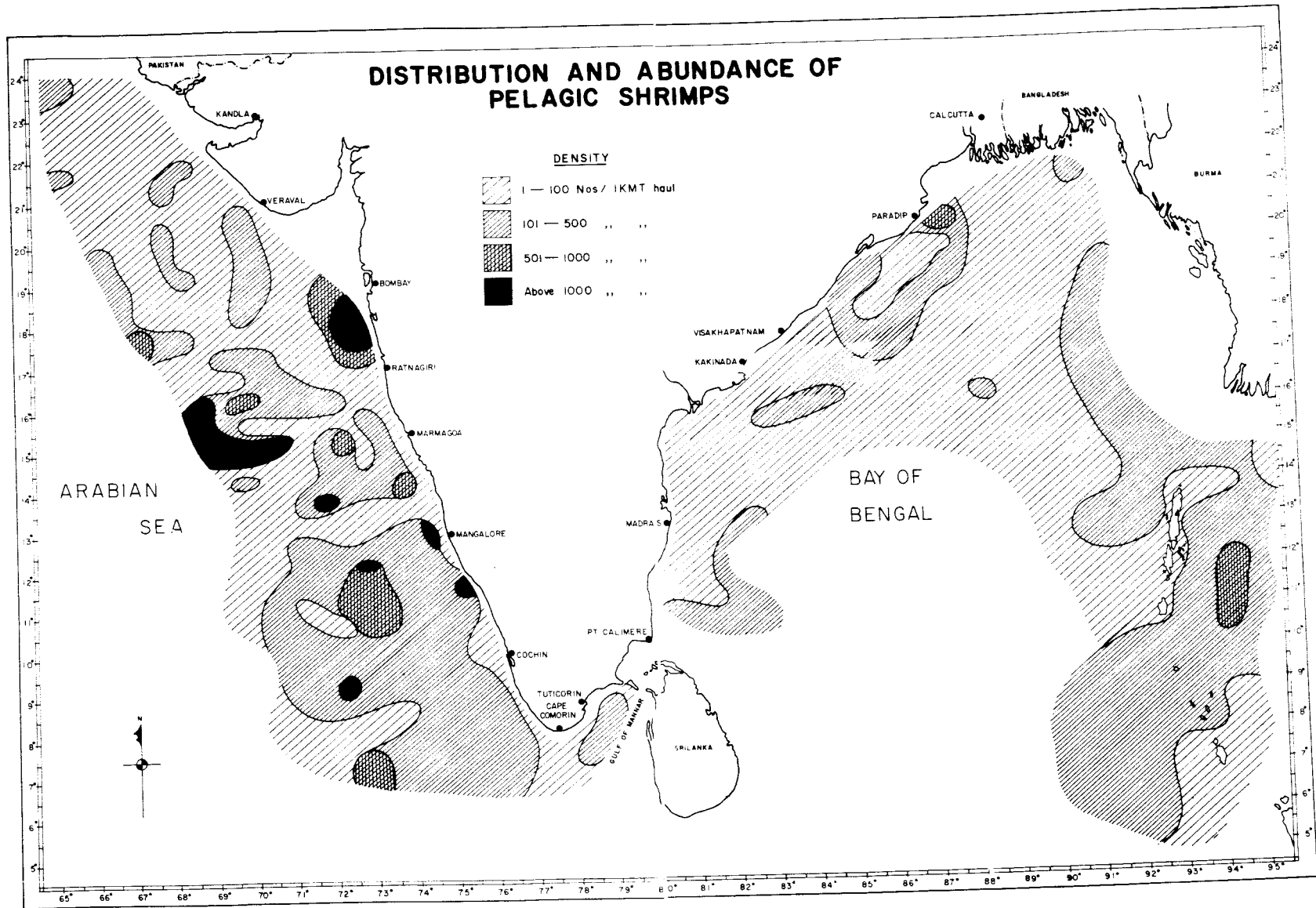


Fig. 2. Spatial distribution and abundance of pelagic shrimps.

ON PELAGIC SHRIMPS IN THE DSL OF INDIAN EEZ

TABLE 1. Area-wise catch and abundance of pelagic shrimps on the west coast

Area (1° square)		Total No. of hauls	No. of positive hauls	Total No. of shrimps	Mean No. per haul
Lat. (°N)	Long. (°E)				
7	76	4	4	587	147
	75	1	1	178	178
	74	1	1	165	165
	73	-	-	-	-
	72	1	1	548	548
	71	1	1	93	93
8	76	7	7	1,739	248
	75	3	3	264	88
	74	5	5	1,034	207
	73	1	1	47	47
	72	1	1	127	127
	71	4	2	437	109
9	76	2	1	232	116
	75	5	5	891	178
	74	14	13	2,627	188
	73	4	4	356	89
	72	2	2	4,882	2,441
	71	1	1	183	183
10	76	1	0	0	0
	75	9	8	1,083	120
	74	5	5	2,238	448
	73	4	4	1,456	364
	72	3	3	1,269	423
	71	1	1	313	313
11	76	3	2	257	86
	75	2	2	5,122	2,561
	74	4	3	429	107
	73	3	3	1,009	336
	72	2	2	1,005	503
	71	2	1	276	138
12	76	3	3	416	139
	75	2	2	96	48
	74	2	2	142	71
	73	6	5	1,155	193
	72	4	4	410	103
	71	4	4	3,259	815
13	76	2	2	601	301
	75	3	3	976	325
	74	1	1	54	54
	73	5	4	331	66
	72	1	0	0	0
	71	3	3	3,246	1,082
14	76	1	1	17	17
	75	1	1	62	62
	74	1	1	30	30
	73	6	6	1,837	306
	72	6	6	1,376	229
	71	-	-	-	-
15	76	1	1	29	29
	75	1	1	275	275
	74	3	3	234	78
	73	8	8	2,469	309
	72	3	3	215	72
	71	2	2	1,267	634
16	76	1	1	2	2
	75	1	1	1,598	1,598
	74	3	3	251	84
	73	3	3	243	81
	72	3	3	712	237
	71	3	3	758	253
17	76	3	3	1,033	344
	75	4	4	2,100	525
	74	3	3	174	58
	73	4	3	318	80
	72	2	2	280	140
	71	1	1	100	100
18	76	1	1	630	630
	75	1	1	10,986	10,986
	74	3	3	1,098	366
	73	2	2	140	70
	72	3	3	392	131
	71	-	-	-	-
19	76	1	1	45	45
	75	1	1	301	301
	74	3	2	171	57
	73	5	4	435	87
	72	2	1	107	54
	71	1	1	96	96
20	76	2	2	270	135
	75	2	2	279	140
	74	-	-	-	-
	73	2	2	190	95
	72	-	-	-	-
	71	1	1	13	13
21	76	1	1	11	11
	75	2	2	330	165
	74	3	3	417	139
	73	-	-	-	-
	72	1	1	189	189
	71	1	1	134	67
22	76	2	2	48	24
	75	1	1	4	4
	74	1	1	14	14
	73	1	1	6	6
	72	1	1	312	312
	71	1	1	312	312

total of 103 hauls were attempted along this coast, of which 80 hauls (78%) were positive and 23 hauls negative for the occurrence of pelagic shrimps. The number of shrimps per haul ranged from 2 to 948, the average abundance worked out for the entire

coast being 82/haul. Details of the shrimp catch from different squares are given in Table 2. In general, the density of pelagic shrimps in this coast was considerably less as compared to the same in the west coast. The maximum catch rate of 458 nos/haul was recorded in the 20-87 degree square off Paradip in Orissa coast from where the largest haul (948 nos) was taken (Fig. 2) in the month of March. The areas of abundance were relatively less and more widely spaced than in the northwest coast.

A comparison of the numerical abundance of shrimps in the neritic and oceanic waters (Table 4) would reveal that a denser population exists in the

TABLE 2. Area-wise catch and abundance of pelagic shrimps on the east coast

Area (1° square)		Total No. of hauls	No. of positive hauls	Total No. of shrimps	Mean No. per haul	
Lat. (°N)	Long. (°E)					
6	77	2	2	17	9	
	78	1	0	0	0	
7	77	2	2	72	36	
	78	1	1	300	300	
8	78	3	3	687	229	
9	79	1	1	67	67	
10	80	1	0	0	0	
	82	1	1	197	197	
11	80	4	4	273	68	
	12	80	4	4	229	57
		81	2	2	142	71
13	80	3	3	14	5	
	81	1	1	75	75	
	82	2	2	247	124	
14	80	2	2	39	20	
	81	1	1	6	6	
	82	1	1	11	11	
15	80	2	2	21	11	
	81	2	1	10	5	
	82	1	1	183	183	
	83	2	1	72	36	
	84	-	-	-	-	
	85	1	1	16	16	
	86	1	1	7	7	
	87	1	1	98	98	
	88	-	-	-	-	
	89	1	0	0	0	
	90	-	-	-	-	
91	1	1	10	10		

Area (1° square)		Total No. of hauls	No. of positive hauls	Total No. of shrimps	Mean No. per haul
Lat. (°N)	Long. (°E)				
16	81	1	0	0	0
	82	3	2	79	26
	83	1	0	0	0
	84	3	2	267	89
	85	1	1	43	43
	86	2	0	0	0
	87	-	-	-	-
	88	1	1	160	160
	89	1	0	0	0
	90	1	1	125	125
17	82	1	0	0	0
	83	-	-	-	-
	84	1	0	0	0
	85	1	1	144	144
	86	1	1	30	30
	87	2	2	8	4
	88	1	0	0	0
	89	1	1	79	79
	90	1	1	129	129
	18	83	1	0	0
84		3	3	361	120
85		4	4	249	62
86		1	1	163	163
87		1	1	3	3
88		1	0	0	0
89		1	0	0	0
90		-	-	-	-
91		1	0	0	0
19		84	1	1	172
	85	1	1	195	195
	86	3	2	150	50
	87	2	2	496	248
	88	1	1	10	10
	89	1	1	70	70
	90	1	0	0	0
20	86	1	1	16	16
	87	3	2	1,374	458
	88	3	3	135	45
	89	2	1	32	16
	90	1	0	0	0
21	90	1	1	125	125

oceanic areas of the southeastern region, whereas in the northeastern region the neritic zone is more productive.

Andaman-Nicobar Region

The study from this region is restricted to 36 IKMT hauls taken during April, 1986 from the oceanic waters between 635 and 4,101 m depth at

bottom. As many as 33 hauls (91%) were positive and the rest negative. The number of shrimps present in individual hauls ranged from 2 to 717, with an average catch rate of 107/haul for the whole region. The square-wise catch details are given in Table 3. When compared with the east coast region, it is observed that the seas around Andaman-Nicobar Islands are more populated with pelagic shrimps. The greater part of the region is characterised by moderate abundance of shrimps ranging from 101 to 1,000 nos/haul, with the maximum density off Middle and Little Andaman islands in the Andaman Sea (Fig. 2).

Seasonal variations

As the west coast provided almost an year-round coverage of IKMT sampling, an attempt was made to analyse the catch data of this region to study the seasonal pattern in the occurrence of pelagic shrimps. For this purpose the period of an year was divided into three seasons, namely pre-monsoon (February-May), monsoon (June-September) and postmonsoon (October-January), and the average number of shrimps per haul was worked out for each of the seasons separately for the neritic and oceanic waters (Table 5).

It is evident from the analysis that the pelagic shrimp population occurs throughout the year in the neritic as well as oceanic areas. During the pre-monsoon and monsoon seasons, the shrimp abundance is considerably higher in the oceanic waters than in the neritic zone. The post-monsoon period, however, exhibit an opposite trend, the shelf region being highly productive than the oceanic. The increase in shrimp population in the neritic waters during this season was due to the heavy occurrence of the same in the near-shore areas of regions like the Bombay-Ratnagiri coast during December.

Day and night variations

Changes in abundance of shrimps in the IKMT during day and night could throw light on the nature of vertical migration of these crustaceans (Foxton, 1970 a, 1970 b) as the DSL is characterised by cyclic changes in position in the upper columnar region of the sea with change of day and night (Menon and Prabhadevi, MS; Mathew and Natara-jan, MS). According to the latter authors, the deep scattering layers ascend to surface or epipelagic realm during night and descend to deeper waters during day. In order to understand the diurnal

TABLE 3 . Area-wise catch and abundance of pelagic shrimps on the Andaman - Nicobar region

Area (1° square)		Total No. of hauls	No. of positive hauls	Total No. of shrimps	Mean No. per haul
Lat. (°N)	Long. (°E)				
5	92	1	1	228	228
	93	1	1	24	24
6	90	1	1	137	137
	91	1	1	378	378
	92	-	-	-	-
	93	1	1	18	18
7	90	1	1	200	200
	91	-	-	-	-
	92	-	-	-	-
	93	1	1	90	90
	94	2	2	172	86
8	90	1	1	380	380
	91	1	1	101	101
	92	-	-	-	-
	93	1	1	168	168
	94	1	1	64	64
9	91	1	1	435	435
	92	1	1	148	148
	93	-	-	-	-
	94	1	1	198	198
10	92	1	1	2	2
	93	-	-	-	-
	94	1	1	717	717
	95	1	0	0	0
	-	-	-	-	-
11	90	2	2	61	31
	91	-	-	-	-
	92	-	-	-	-
	93	1	1	257	257
	94	1	1	505	505
	95	1	1	124	124
12	90	1	1	113	113
	91	-	-	-	-
	92	-	-	-	-
	93	1	1	150	150
13	89	1	1	13	13
	90	-	-	-	-
	91	-	-	-	-
	92	-	-	-	-
	93	1	1	51	51
	94	2	2	309	155
14	88	1	1	14	14
	89	1	0	0	0
	90	-	-	-	-
	91	1	0	0	0
	92	1	1	127	127
	93	-	-	-	-
	94	1	1	105	105
	95	1	1	26	26

TABLE 4. Relative abundance (Av. No. /haul) of pelagic shrimps in the neritic and oceanic waters of different regions of Indian coasts

Regions	Neritic waters	Oceanic waters
South-western region including Lakshadweep (Lat. 7° N to 15° N)	393	317
North-western region (Lat. 16° N to 24°N)	632	219
South-eastern region (Lat.6°N to 22°N)	114	87
Andaman and Nicobar islands	-	107

TABLE 5. Seasonal abundance of pelagic shrimps along the west coast of India

Particulars	Neritic waters	Oceanic waters
<i>Premonsoon</i>		
Total number of hauls	7	50
Total number of shrimps	1,275	11,214
Average number of shrimps/haul	182	280
<i>Monsoon</i>		
Total number of hauls	20	44
Total number of shrimps	5,938	16,230
Average number of shrimps/haul	297	369
<i>Postmonsoon</i>		
Total number of hauls	43	80
Total number of shrimps	21,491	16,978
Average number of shrimps/haul	500	212

variations in shrimp distribution, the catch data of day and night hauls were analysed separately and the results are presented in Table 6. It can be seen that the pelagic shrimps occur in greater abundance during night in all the regions of investigation. On

TABLE 6. Day and night variations in abundance of pelagic shrimps in different regions of Indian EEZ

Latitudinal areas	Average number of pelagic shrimps per haul					
	West coast		East coast		Andaman & Nicobar region	
	Day	Night	Day	Night	Day	Night
5°N	-	-	-	-	228	24
6°N	-	-	6	-	18	256
7°N	113	246	-	124	137	98
8°N	164	200	283	122	83	380
9°N	121	499	67	-	148	317
10°N	178	322	-	99	-	360
11°N	59	971	75	66	236	3
12°N	151	479	72	51	150	113
13°N	38	596	41	64	25	162
14°N	144	342	14	-	44	64
15°N	137	506	9	53	-	-
16°N	329	212	15	92	-	-
17°N	194	293	28	72	-	-
18°N	80	2,094	29	96	-	-
19°N	141	15	77	135	-	-
20°N	95	97	170	16	-	-
21°N	156	10	125	-	-	-
22°N	37	38	-	-	-	-
23°N	163	6	-	-	-	-
Total No. of hauls	128	116	57	46	19	17
Av. No. of shrimps/haul	141	473	64	89	112	188

the west coast, out of the 17 latitudinal areas as many as 13 have recorded higher catch rates for the night collection. The average density of shrimps during night (473 nos/haul) was over three times greater than the same during day time. For the other regions, the increase in overall abundance of shrimps during night was to the extent of 39% on the east coast and 67% in the Andaman Nicobar region.

Composition of pelagic shrimps

The pelagic shrimp collections were invariably multispecies in nature and represented by the penaeidean as well as caridean groups. A gross examination of representative samples from the different regions of Indian coasts has shown that the shrimp population is predominantly constituted by species of the genera *Sergestes* and *Acetes* (*Sergestidae*) *Thalassocaris* (*Thalassocarididae*) and *Pasiphaea* and *Leptocheila* (*Pasiphaeidae*). In the oceanic waters around Lakshadweep and off the south-west coasts, species of *Sergestes* were observed in large swarms. In some of the hauls they formed as much as 72-100% of the shrimp catch by number. Voracious feeding on species of this genus by tunas

(albacore) has been reported from the Pacific waters, besides the same being eaten in large quantities by fin and sei whales (Omori et al., 1972; Omori, 1974). Among caridean shrimps recorded during the present study, a species that deserves special mention is *Leptochela robusta* which was caught in fair quantities throughout the west coast. This species is reported to form an important forage of tunas and other pelagic fishes in the Lakshadweep and neighbouring seas (George and Paulinose, 1973; James et al., 1987).

The shrimp catch near the coast was characterised by dominance of *Acetes*. Off Bombay-Ratnagiri coast where the maximum density of pelagic shrimps was observed, species of *Acetes* accounted over 80% of the catch. *A. johni* predominated in the population followed by *A. indicus* and other species.

DISCUSSION

The present study of the IKMT collections taken by FORV *Sagar Sampada* reveals that the Deep Scattering Layers harbour rich population of pelagic shrimps throughout the Indian EEZ. Among the larger pelagic crustaceans occurring in the sea, shrimps appear to occupy a position next to euphausiids in numerical abundance. Looking at their distribution pattern in different regions of Indian coasts (Fig. 2, Tables 1 to 4) it becomes apparent that the southwest coast including Lakshadweep and the seas around Andaman-Nicobar region are the most productive. As tunas are the important predators of pelagic shrimps, as already pointed out, a positive relationship between the abundance of these two groups could be expected. According to George et al. (1977) the maximum density of tunas and allied fishes in Indian EEZ is in the southwest coast and the oceanic islands. It is therefore reasonable to presume that the high productivity of pelagic shrimps could be one of the influencing factors for the abundance of tunas and allied fishes in these regions. The observation of James et al. (1987) that oceanic tunas in Lakshadweep feed heavily on *Leptochela robusta* is indicative of selective feeding of tunas on such species of pelagic shrimps. Perhaps a detailed study of the inter-relationship between the forage species of shrimps and tunas may reveal that the former could serve as indicator for tuna shoals. Use of selected species of pelagic shrimps as live bait for tuna fishing is also worth attempting in view of the increasing shortage

of live-bait fishes in the traditional fishing grounds around Lakshadweep.

The occurrence of *Acetes* in large quantities in the coastal stations off Bombay-Ratnagiri coast in Maharashtra shows that potentially exploitable stocks of these shrimps exist outside the present fishing areas covered by the indigenous gears like 'dol' nets. Commercial mid-water trawling for the exploitation of *Acetes* in the offshore waters along the northwest coast could be an alternative for augmenting production of non-penaeid prawns in the country.

According to Omori (1974), pelagic shrimps are distributed at various depths ranging from surface to at least 4,000-6,000 m in the sea. Distinct diurnal migration of pelagic shrimps in Indian seas is evident from the day and night variations in the catch of the IKMT hauls. Foxton (1970 a, 1970 b), in his exhaustive work on vertical distribution of pelagic decapods in the eastern North Atlantic, has observed that several species of shrimps exhibit active vertical migrations between surface and deeper waters upto about 1,000 m depth. Species living in the depth range 800-1,500 m, however, perform only limited upward migration (Omori, 1974). As the data on hand is limited to only the epi- and mesopelagic realms, no conclusion is possible as to the lower limit of the distribution of pelagic shrimps in Indian waters. Systematic survey of the deeper strata of the columnar sea is needed for proper understanding of the ecology and biological characteristics of this interesting group.

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