J. mar. biol. Ass. India, 1974, **16** (2) : 491-511

OBSERVATIONS ON THE DEEP-SEA PRAWN FISHERY OFF THE SOUTH-WEST COAST OF INDIA WITH SPECIAL REFERENCE TO PANDALIDS*

C. SUSEELAN

Central Marine Fisheries Research Institute, Cochin, India

ABSTRACT

The recent exploratory trawling operations conducted by some of the larger vessels of the Indo-Norwegian Project have indicated immense potentialities of deep-sea prawns along the upper continental slope off the south-west coast. Although more than a dozen species of prawns often occur in the deep-sea catches, only five of them representing the family *Pandalidae* namely *Heterocarpus woodmasoni*, *H. gibbosus*, *Parapandalus spinipes*, *Plesionika martia* and *P. ensis* constitute the bulk of the catches from 225-400 m depth. The present paper deals with the abundance of these five species in different regions and at different depths between Trivandrum and Cannanore based on the catches of 559 hauls taken during October 1967 to December 1969. Some biological aspects such as size distribution, sex ratio, breeding periods, fecundity and food of the individual species are also reported.

INTRODUCTION

THE occurrence of large varieties of prawns beyond the continental shelf of Indian Coasts is on record from as early as the beginning of this century. Over 55 species of deep-sea prawns chiefly belonging to the Families Penaeidæ, Pasiphaeidæ, Oplophoridæ and Pandalidæ, have been reported from the west-coast, particularly from the southern regions (Alcock, 1901, 1906 ; de Man, 1911, 1920 ; Calman, 1939 ; John and Kurian, 1959 ; Kurian, 1964 ; George, 1966 ; George and Rao, 1966 and Suseelan and Mohamed, 1968). However, the existence of some of these species in commercial concentrations in these deeper waters has been brought to light only very recently. Silas (1969) and Mohamed and Suseelan (1973) have given general accounts of the distribution and relative preponderance of the common species of prawns of the shelf-edge and upper continental slope of the South-west coast. With a view to assess the potentialities of this newly recognised resource, a detailed investigation on the fishery and biology of the deep-sea prawns has been undertaken in 1967 by the Central Marine Fisheries Research Institute. The present paper, which is based on part of this study, deals with the catch distribution and some biological aspects of five species of pandalid prawns that contribute to the major portion of the deep-sea prawn catches from this area.

* Presented at the 'Symposium on Indian Ocean and Adjacent Seas—Their Origin, Science and Resources' held by the Marine Biological Association of India at Cochin from January 12 to 18, 1971.

The author is highly grateful to Dr. E. G. Silas, Director, Central Marine Fisheries Research Institute, for his kind guidance and encouragement. He is also thankful to Mr. K. H. Mohamed and Dr. P. Vedavyasa Rao of this Institute, for critically going through the manuscript and offering valuable suggestions for its improvement. His thanks are also due to Mr. M. Devidas Menon, Director, Indo-Norwegian Project, for providing some of the facilities for carrying out this work.

The material for this study was obtained from the exploratory and survey cruises of three large vessels of the Indo-Norwegian Project, namely *KLAUS SUNNANA* (65', 220 H.P.), *VELAMEEN* (82', 480 H.P.) and *TUNA* (82', 480 H.P.), carried out during the period, October 1967 to December 1969. The trawling operations were conducted mainly between Trivandrum and Cannanore extending from the lower limit of the continental shelf to 400 metres depth. Three types of trawl nets viz. Norwegian deep-sea shrimp trawl, Japanese shrimp trawl and Mexican shrimp trawl were employed during these cruises, the details of which have been given by Joseph and Radhamma (1970). Particulars regarding the areas and depths of operation, duration of actual trawling, total catch of prawns and other items recorded for each haul etc. were taken from the Skipper's Log. In the present study the catches taken beyond 225 m depth were only analysed, since pandalid prawns were not represented in the catches from shallower depths. The catch data were analysed area-wise and depth-wise. The area is demarcated in ten nautical mile squares based on longitude and latitude, similar to those that have been charted out for Government of India vessels (Kagwade, 1967). The depth region between 226 and 400 m of a particular area is sub-divided into the following 7 depth zones at intervals of 25 metres :—

Depth Zone 1	.. 226 - 250 m	Depth Zone 5	.. 326 - 350 m
Depth Zone 2	.. 251 - 275 m	Depth Zone 6	.. 351 - 375 m
Depth Zone 3	.. 276 - 300 m	Depth Zone 7	.. 376 - 400 m
Depth Zone 4	.. 301 - 325 m		

For species composition and biological studies an unsorted prawn sample weighing 2 to 3 Kg was regularly collected as soon as the vessels reached the shore. Haul-wise samples were also collected whenever possible. The samples were then sorted out into species and particulars regarding sex, size, percentage of ovigerous females, developmental stages of eggs on the pleopoda etc. were recorded. Sexes were determined largely based on the shape of endopods of the first pleopod and the presence or absence of appendix masculina on the endopod of the second pleopod. Total length (size) of the specimens was measured from the tip of the rostrum to the tip of the telson.

Fishing Ground and Operations

The areas covered during this exploratory fishing lie between Lat. 08° 32′ N to 11° 58′ N and Long. 74° 21′ E to 76° 09′ E (Fig. 1). The topography, extent and hydrographic features of these trawling grounds have been described by Menon (1968), Silas (1969), and Mohamed and Suseelen (1973). The bottom here is generally soft and covered by a type of black-green sediment composed of foraminiferan shells. Towards the north, however, this softness of the bottom is occasionally interrupted by rocky and coral patches.

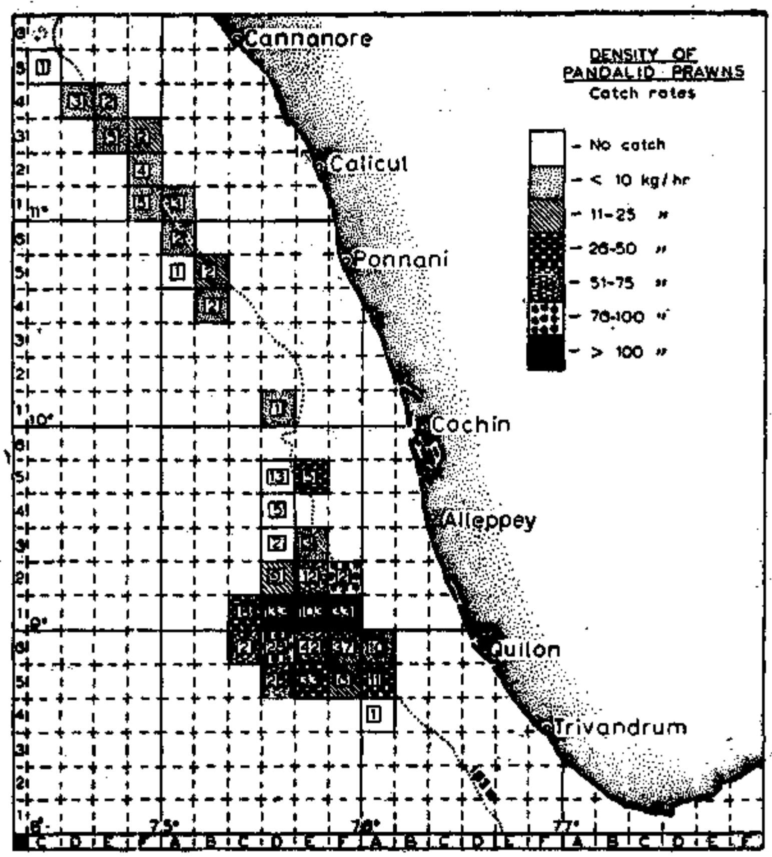

Fig. 1. Areas of operation. Figures inside the squares indicate total number of hauls taken beyond 226 m depth.

Among the three vessels engaged in this survey, intensive operations were carried out by *KLAUS SUNNANA* concentrating mainly on the areas off Quilon and Alleppey at 300 - 375 m depth range. Details of the fishing grounds covered and the total number of hauls taken by the vessels in different months between October 1967 and December 1969 are given in Table 1.

Catch Distribution

During the period of these observations, the three exploratory vessels took 559 hauls from 35 areas and landed a total quantity of 64,865 Kg of deep-sea prawns, spending 688.17 hours of actual trawling. Of this, pandalids alone contributed

TABLE 1. *Details of monthly operations at 226-400 m depth*

Months	Vessels operated	Total number of hauls taken	Trawling grounds
October 1967	Klaus Sunnana, Velameen & Tuna.	17	Off Quilon, Alleppy & Ponnani.
November 1967	Klaus Sunnana	12	Off Quilon and Alleppey.
December 1967	Klaus Sunnana and Tuna	36	do.
January 1968	Klaus Sunnana, Velameen and Tuna.	85	do.
February 1968	Klaus Sunnana and Velameen.	37	Off Quilon, Alleppey and Calicut.
May 1968	Klaus Sunnana	12	Off Quilon.
October 1968	Klaus Sunnana	50	Off Quilon and Alleppey.
November 1968	Klaus Sunnana	47	do.
December 1968	Klaus Sunnana	47	do.
January 1969	Klaus Sunnana	40	do.
February 1969	Klaus Sunnana	2	Off Quilon.
March 1969	Klaus Sunnana	4	Off Quilon and Alleppey.
May 1969	Klaus Sunnana	19	Off Quilon.
June 1969	Velameen	10	Off Quilon and Alleppey.
July 1969	Velameen	20	Off Quilon, Alleppey and Calicut.
August 1969	Velameen	12	Off Quilon and Alleppey.
September 1969	Velameen	7	Off Cochin.
October 1969	Velameen and Tuna	67	Off Quilon, Alleppey, Cochin, Ponnani, Calicut and Cannanore.
November 1969	Velameen	15	Off Trivandrum, Quilon and Alleppey.
December 1969	Velameen	20	Off Quilon and Alleppey.

51,274.18 Kg with an average catch rate of 74.50 Kg/hr., forming 79% of the entire prawn catch. Results of the area-wise and depth-wise analysis of the catch data are summarised in Table 2.

The general composition of pandalid prawns in total prawn catches ranged between 7.8% and 95.0%, with maximum abundance in the higher depth zones 4, 5 and 6 almost throughout the area of survey. Their percentage at lower depth zones was very poor showing sharp improvement with increase in depth.

The catch of these prawns in individual hauls varied from nearly 1 Kg to 840 Kg for approximately one hour trawling. The maximum catch rates were obtained from 9-75 : 1D, 1E and 1F in depth zones 4, 5 and 6, where the average catch per hour of trawling varied between 103 Kg and 201 Kg (Table 2). These three areas were the best explored and over 70% of the entire catch of pandalids was registered from here. 8-75 ; 6D and 9-75 : 2F were the next two important productive grounds, where the average catch rates were respectively 96 and 86 Kg/hr., with very high catch returns from depth zones 5 and 6 particularly of the former area. In 8-76 : 5A, 8-75 : 5D, 5E, 6C, 6E and 9-75 : 1C, 2E and 5E the average catch returns were to the tune of 33 to 64 Kg/hr of trawling, with maximum yields, again, in the depth zones 4, 5 and 6. In all other areas sampled, excepting 8-76 : 4A, 9-75: 3D, 4D, 10-75: 5A and 11-74 : 5C where there was no prawn catch at all, the catch rates were very poor being less than 20 Kg/hr.

TABLE 2. *Catch distribution of pandalid prawns in different areas and depth zones during October 1967 to December 1969*

Areas of operation	Depth zones	Number of hauls taken	Total effort of trawling (Hrs.)	*Catch details of pandalids* Total catch (Kg)	Catch-rate (Kg/Hr.)	% in Total deep-sea prawns
(1)	(2)	(3)	(4)	(5)	(6)	(7)
8-76 : 4A	3	1	0.50	X	X	X
5A	1	1	0.50	3.10	6.20	7.8
	2	4	2.50	26.30	10.52	52.5
	3	1	2.00	17.60	8.80	50.4
	4	2	4.00	144.00	36.00	72.0
	5	2	4.50	308.30	68.51	71.7
	6	1	2.00	90.00	45.00	90.0
	Total ..	11	15.50	589.30	38.02	68.9
6A	1	1	2.00	1.60	0.80	15.5
	2	9	11.32	28.90	2.55	48.2
	Total ..	10	13.32	30.50	2.29	43.5
8-75 : 5D	3	4	6.42	528.20	82.27	70.8
	4	8	9.91	374.40	37.78	80.0
	5	16	19.01	993.20	52.25	79.2
	Total ..	28	35.34	1895.80	53.64	76.8

TALBE 2. (*Continued*)

Areas of operation	Depth zones	Numbers of hauls taken	Total effort of trawling (Hrs.)	*Catch details of pandalids*		
				Total catch (Kg)	Catch rate (Kg/Hr.)	% in Total deep-sea prawns
(1)	(2)	(3)	(4)	(5)	(6)	(7)
5E	3	3	5.08	171.10	33.68	65.8
	4	11	18.00	17.30	0.96	82.5
	5	9	9.33	621.80	66.65	81.5
	6	8	8.00	589.00	73.62	95.0
	7	2	2.50	22.40	8.96	37.3
	Total ..	33	42.91	1421.60	33.13	82.4
5F	5	2	3.75	69.10	18.43	86.4
	6	2	3.08	47.10	15.29	78.5
	7	2	1.92	41.60	21.67	83.3
	Total ..	6	8.75	157.80	18.03	83.0
6C	5	2	2.00	83.50	41.75	83.5
6D	4	9	16.75	958.40	57.22	80.0
	5	15	24.75	2534.90	102.42	86.4
	6	4	3.75	833.50	222.27	95.0
	Total ..	28	45.25	4326.80	95.62	85.5
6E	2	1	1.50	x	x	x
	4	15	17.49	1103.80	63.11	81.7
	5	18	25.91	1607.40	62.04	85.5
	6	8	7.50	665.30	88.70	79.2
	Total ..	42	52.40	3376.50	64.44	82.9
6F	1	18	29.48	37.90	1.28	15.7
	2	8	6.33	148.30	23.43	64.5
	3	3	5.17	126.70	24.51	65.0
	4	6	8.16	31.20	3.82	78.1
	5	2	0.50	2.60	5.20	86.5
	Total ..	37	49.64	346.70	6.98	48.8

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
9-75 :	1C	4	2	4.58	55.40	12.10	72.0
		5	6	12.50	707.80	56.62	82.3
		Total ..	8	17.08	763.20	44.68	81.5
	1D	4	10	11.39	1185.30	104.06	75.5
		5	100	112.37	12634.30	112.43	83.0
		6	23	26.90	2935.10	109.11	79.2
		Total ..	133	150.66	16754.70	111.21	81.7
	1E	4	33	56.91	6586.90	115.74	76.0
		5	45	62.07	6450.50	103.92	80.2
		6	25	25.22	3151.20	124.95	80.0
		Total ..	103	144.20	16188.60	112.26	78.4
	1F	1	7	9.25	27.60	2.98	13.8
		2	6	6.24	182.20	29.19	40.5
		3	3	2.00	97.50	48.75	65.0
		4	4	4.50	674.20	149.82	72.5
		5	3	5.33	1036.70	194.50	83.2
		6	10	7.83	1576.40	201.33	78.0
		Total ..	33	35.15	3594.60	102.26	71.9
	2D	4	2	1.84	12.70	6.90	70.5
		5	5	2.82	41.50	14.72	83.0
		6	2	1.17	14.90	12.73	74.6
		Total ..	9	5.83	69.10	11.85	78.5
	2E	2	1	0.50	x	x	x
		4	4	8.50	623.90	73.40	72.3
		5	5	7.00	473.20	67.60	84.5
		6	1	3.00	180.00	60.00	90.0
		7	1	1.00	9.40	9.40	94.0
		Total ..	12	20.00	1286.50	64.32	78.8
	2F	3	2	2.00	172.72	86.36	68.0
	3D	2	2	3.00	x	x	x

TABLE 2. (*Continued*)

Areas of operation	Depth zones	Numbers of hauls taken	Total effort of trawling (Hrs.)	Catch details of *pandalids*		
				Total catch (Kg)	Catch-rate (Kg/Hr.)	% in Total deep-sea prawns
(1)	(2)	(3)	(4)	(5)	(6)	(7)
3E	1	1	1.00	x	x	x
	2	1	0.75	x	x	x
	5	1	1.50	12.10	8.06	80.6
	Total ..	3	3.25	12.10	3.72	80.6
4D	1	2	2.75	x	x	x
	2	3	4.00	x	x	x
	Total ..	5	6.75	x	x	x
5D	1	10	14.32	x	x	x
	2	3	5.75	x	x	x
	Total ..	13	20.07	x	x	x
5E	4	2	0.83	93.10	112.17	40.5
	7	3	3.42	64.60	18.89	38.0
	Total ..	5	4.25	157.70	37.10	39.4
10-75 : 1D	2	1	1.00	1.62	1.62	54.0
4B	2	1	0.25	0.57	2.28	56.8
	5	1	0.25	2.40	9.60	80.0
	Total ..	2	0.50	2.97	5.94	74.3
5A	4	1	0.25	x	x	x
5B	2	2	0.50	5.55	11.10	50.5
6A	1	1	0.25	x	x	x
	2	1	0.25	0.76	3.04	76.3
	Total ..	2	0.50	0.76	1.52	76.3

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
11-75 :	1A	2	3	0.83	1.68	2.04	28.0
11-74 :	1F	2	4	1.25	2.90	2.32	32.0
		6	1	0.25	x	x	x
		Total ..	5	1.50	2.90	1.93	32.0
	2F	1	1	0.42	x	x	x
		2	2	0.58	2.80	4.83	31.5
		4	1	0.50	4.50	9.00	75.0
		Total ..	4	1.50	7.30	4.86	48.7
	3E	1	1	0.25	x	x	x
		2	3	0.91	4.50	4.94	45.2
		3	1	0.33	1.20	3.64	60.0
		Total ..	5	1.49	5.70	3.82	47.5
	3F	2	1	0.50	x	x	x
		6	1	0.25	9.48	37.92	15.8
		Total ..	2	0.75	9.48	12.64	15.8
	4D	2	1	0.25	0.50	2.00	17.8
		3	1	0.25	2.80	11.20	46.0
		5	1	0.25	3.10	12.40	78.2
		Total ..	3	0.75	6.40	8.53	49.2
	4E	2	1	0.25	2.10	8.40	21.5
		3	1	0.25	x	x	x
		Total ..	2	0.50	2.10	4.20	21.5
	5C	1	1	0.25	x	x	x

'x' — denotes no catch of deep-sea prawns, *Species abundance :* The five species that constituted the pandalid catches were *Heterocarpus wood-masoni* Alcock, *Heterocarpus gibbosus* Bate, *Parapandalus spinipes* (Bate), *Plesionika martia* (A. M. Edwards) and *Plesionika ensis* (A. M. Edwards) (Fig. 2). Except for *P. martia*, which is reported to have minor commercial importance (Holthuis and Rosa, 1965 ; Maurin, 1965), no other species is known to

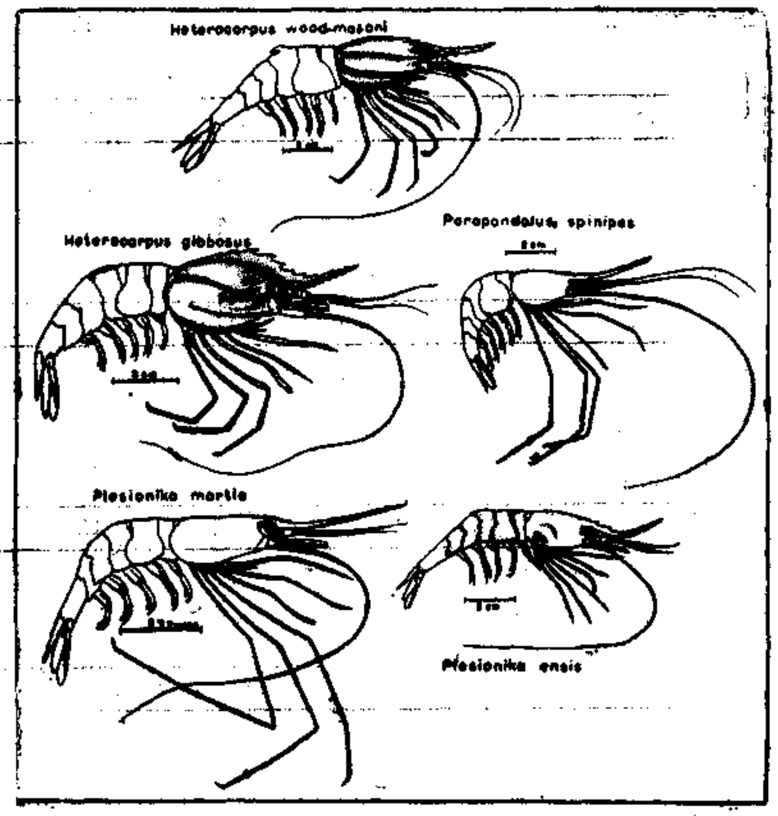

Fig. 2. The pandalid prawns in the deep-sea catches.

occur anywhere in the world in such large quantities as to support any significant fishery. These prawns occurred in varying proportions in the catches from different areas and also in different depth zones of the same area. Their relative abundance in Region I* and Region II* is given in Table 3. *H. wood-masoni* contributed to the bulk of the catch (56.7%) and it was caught exclusively from the southern region. *P. spinipes* was the next abundant species and it formed 27.6% of the total catch landed from both the regions. The percentage composition of *H. gibbosus*, *P. martia* and *P. ensis* were respectively 6.8, 6.1 and 2.8 in the overall catch. The depth-wise percentage contribution of these species for the two regions is shown in Fig. 3.

* Region I comprises all the areas of ten nautical mile squares south of 10° 00' N Lat. and Region II all the areas north of 10° 00' N Lat.

TABLE 3. *Species-wise landings (in Kg) from different depth zones of Region I & II*

Region	Depth zones	*H. wood-masoni*	*H. gibbosus*	*P. spinipes*	*P. martia*	*P. ensis*	Total
	1	..	..	70.20	..	..	70.20
	2	77.90	..	265.40	42.40	..	385.70
	3	554.68	32.30	413.23	100.24	13.37	1113.82
I	4	7140.08	628.61	3083.76	770.94	237.21	11860.60
	5	15636.10	1930.38	7500.93	1654.61	854.88	27576.90
	6	5595.79	877.18	2732.35	554.54	322.64	10082.50
	7	71.21	7.18	46.09	9.66	3.86	138.00
	Total ..	29075.76	3475.65	14111.96	3132.39	1431.96	51227.72
	1	No catch	..	..	..	..	..
	2	..	13.45	7.67	1.86	..	22.98
	3	..	2.40	1.50	0.08	0.02	4.00
II	4	..	2.69	1.10	0.71	..	4.50
	5	.	4.32	..	1.18	..	5.50
	6	.	7.17	..	2.31	..	9.48
	7	No operation	..	..	..	..	..
	Total ..	Nil	30.03	10.27	6.14	0.02	46.46

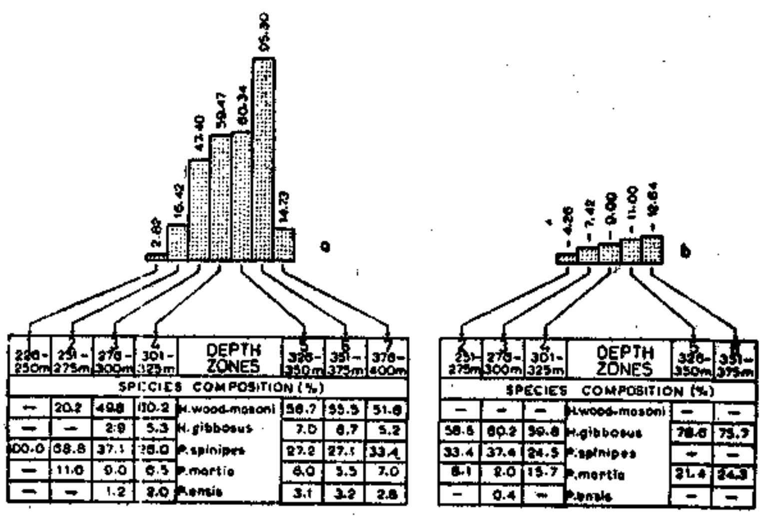

Fig. 3. Catch rates (shown in histograms) and species composition of pandalid prawns in different depth zones. a. Region I; b. Region II.

By-catches: In the deep-sea catches a wide variety of bathypelagic fishes (Tholasilingam *et al.*, 1964; Silas, 1969), Penaeid prawns, crabs, lobsters and other decapod crustaceans (Mohamed & Suseelan, 1973) were found associated with pandalids. Among prawns, the smaller penaeids such as *Penaeopsis rectacuta*, *Metapenaeopsis andamanensis*, etc. were the chief items from the shallower grounds, while bigger species such as *Aristeus semidentatus*, *Aristaeomorpha wood-masoni* and *Solenocera hextii* occurred in good quantities along with pandalid prawns from the deeper grounds. *Puerulus sewelli*—the Indian deep-sea spiny lobster—was trawled in plenty from depth zone 1 of the southern region together with *P. spinipes*.

Biological Observations

Size distribution: The size range of *H. wood-masoni* was 72 mm to 130 mm in male and 75 mm to 135 mm in female. Invariably all the catches were predominated by different model size groups within 100-125 mm in both sexes (Fig. 4). In most of the months, the predominant model sizes of the male were at 111-115 mm and 116-120 mm length. Smaller size groups within 96 and 110 mm length also occurred in considerable numbers in the catches from deeper grounds during October to December. The model sizes of the female were generally higher than that of the male and they were at 116-120 mm and 121-125 mm in the months of October, November and December. Smaller size groups 106-110 mm and 111-115 mm either dominated the catches or formed a significant part of them in January and also some times in December.

H. gibbosus was by far the largest of the five species and in the overall catch its size varied from 76 mm to138 mm in male and from 67 mm to 140 mm in female. In the samples from 300-375 m depth this species was chiefly represented by 111-125 mm size group in male and by slightly larger size class of 116-130 mm length in female (Fig. 5). Those from shallower grounds, however, were mainly constituted by smaller size groups of 86-105 mm male and 81-105 mm female.

The total length of *P. spinipes* recorded during the present investigations ranged between 63 mm and 115 mm in male and 75 mm and 125 mm in female. The model sizes between 96 mm and 110 mm often dominated the catches in both sexes. Larger individuals measuring 111-115 mm also contributed a significant part of the catches obtained in certain months especially from lower depths (Fig. 7).

The size range of *P. martia* was from 71 mm to 120 mm in male and from 76 mm to 130 mm in female. All the catches were predominated by 90-110 mm sized individuals in both sexes. In the overall size distribution of this species (Fig. 6 a) the model lengths for males and females were at 90-95 mm and 96-100 mm respectively.

The size range of *P. ensis* in the catches varied from 56 mm to 118 mm in male and from 70 mm to 120 mm in female. The bulk of the catch was supported by individuals within 96-110 mm size range in both sexes (Fig. 6 b).

Sex composition: In all the species, the sexes are separate at all stages of growth represented in the catches and no evidence of protandric hermaphroditism as exhibited by many commercial pandalids of North Atlantic and North Pacific

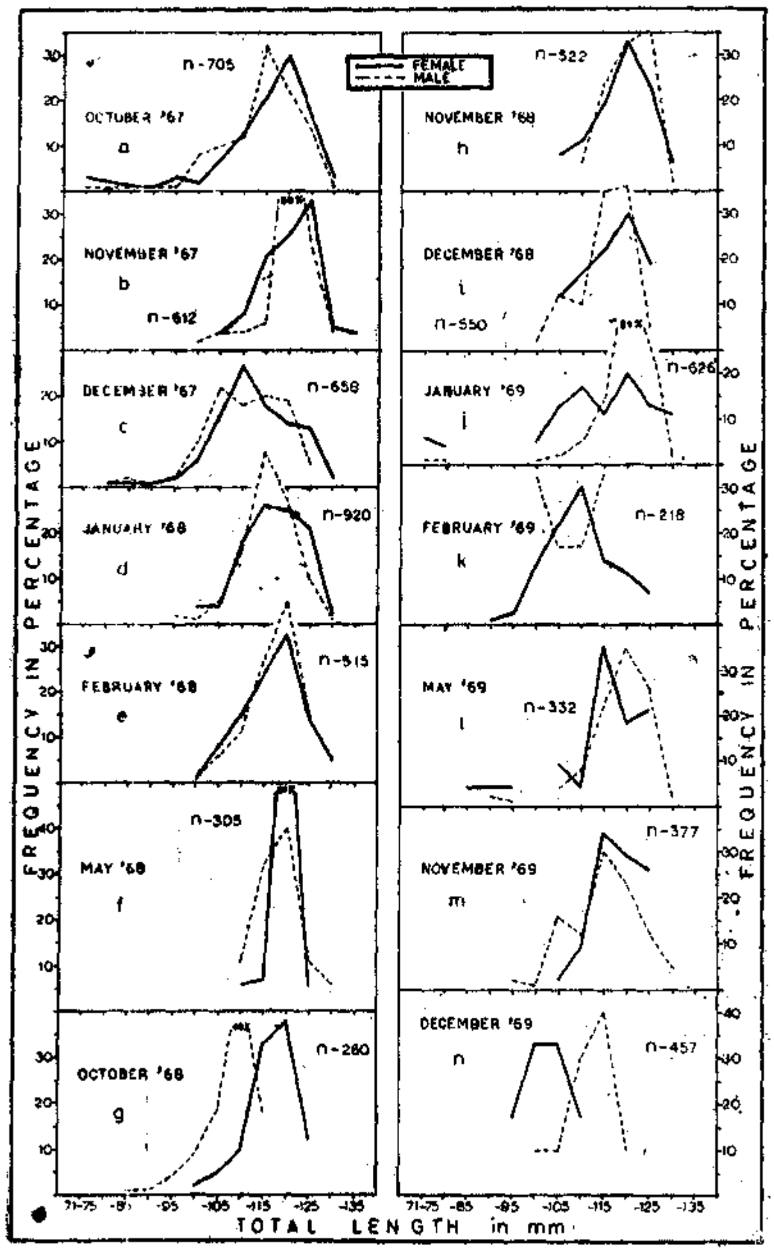

Fig. 4. Size frequency distribution of *Heterocarpus wood-masoni*. a - j & l - n. at 300-375 m depth; k, at less than 300 m depth.

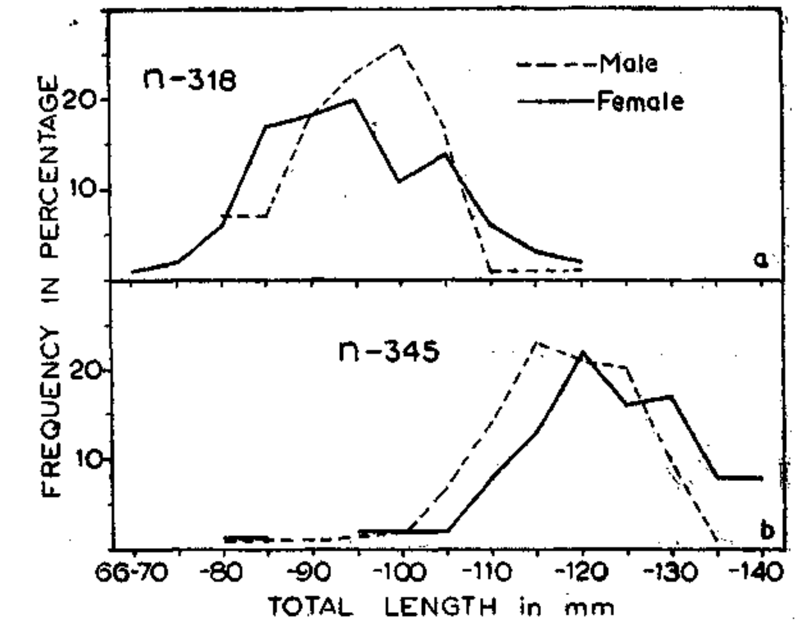

Fig. 5. Size frequency distribution of *Heterocarpus gibbosus* : a. at 275 m depth (off Ponnani) ; b. at 300-375 m depth (off Quilon).

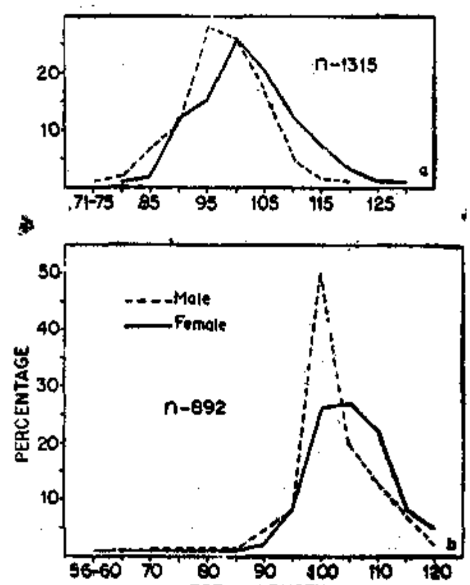

Fig. 6. Size distribution of — a. *Plesionika martia* and b. *Plesionika ensis.*

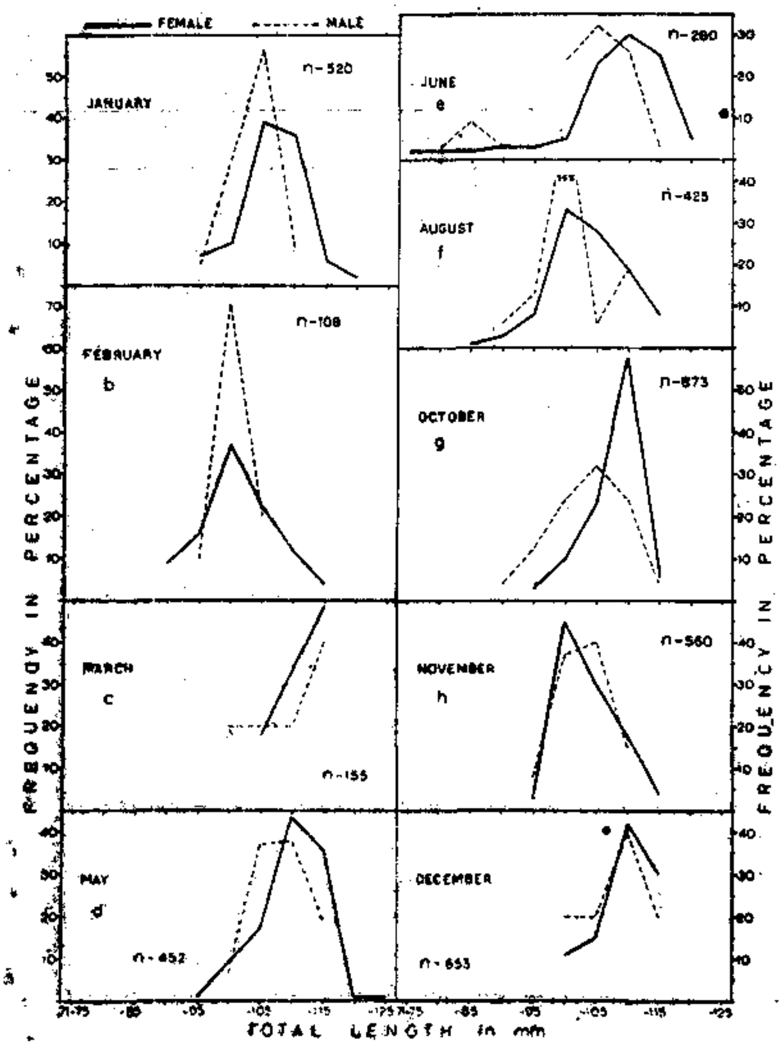

Fig. 7. Size frequency distribution of *Parapandulus spinipes* during the year 1969. a, b, d, h and i—at 300-375 m depth ; c, e, f and g—at less than 300 m depth.

waters (Rasmussen, 1953 ; Horsted and Smidt, 1956 ; Butler, 1964) was observed. The overall sex ratio (expressed in percentage) of three species is shown in Table 4.

TABLE 4. *Sex composition by percentage of three species in the exploratory catches*

Month		*Heterocarpus wood-masoni*		*Parapandalus spinipes*		*Plesionika martia*	
		Male	Female	Male	Female	Male	Female
October 1967	..	65	35	33	67	32	68
November 1967	..	70	30	36	64	66	34
December 1967	..	61	39	21	79	45	55
January 1968	..	63	37	35	65	33	67
February 1968	..	64	36	45	55	46	54
May 1968	..	76	24	39	61	40	60
October 1968	..	68	32	15	85	39	61
November 1968	..	62	38	3	97	68	32
December 1968	..	73	27	28	72	47	53
January 1969	..	69	31	21	79	52	48
February 1969	..	14	86	24	76	x	x
March 1969	..	x	x	10	90	x	x
May 1969	..	79	21	21	79	x	x
June 1969	..	x	x	44	56	x	x
August 1969	..	x	x	10	90	40	60
October 1969	..	x	x	45	55	x	x
November 1969	..	63	37	52	48	50	50
December 1969	..	50	50	49	51	x	x

'x' — material not sufficiently represented in the samples.

In *H. wood-masoni* the males always dominated in the catches and the females formed only 1/3 or less in most of the months. In February 1969, however, the females of this species were observed far in excess of males in the catches taken from relatively shallow depths (below 300 m). *P. spinipes* showed just the opposite pattern in the nature of sex ratio, with very high preponderance of the females in many months. Although not so pronounced as in *P. spinipes*, *P. martia* was also represented by more of females in the catches in most of the months. In *H. gibbosus*, the two sexes were more or less equally represented in the catches, while the composition in *P. ensis* was almost in the same manner as observed for *P. martia*.

Eggs and fecundity : Fertilized eggs are attached to the ovigerous setae found on the inner edge of the protopods of the pleopods 1 - 4. The endopods and exopods do not carry eggs and they project freely from the egg mass. The colour of the egg mass of the berried females of *H. wood-masoni* and *H. gibbosus* is light orange in the very early stages, but becomes greyish afterwards. The freshly acquired berry of *P. spinipes* is greenish-blue, while in *P. martia* and *P. ensis* it is deep blue. These colours gradually fade away and become dull white when the eye spots of the embryos become clearly visible to naked eye as the development advances.

The shape and size range of eggs on the pleopods of the five species are given in Table 5.

TABLE 5. *Shape and size range of eggs*

Species	Shape	Size range in mm	
		Length/diameter	Width
H. wood-masoni ..	Elliptical or oval	0.80-0.90	0.62-0.67
H. gibbosus ..	oval	0.64-0.78	0.59-0.64
P. spinipes ..	oval	0.75-0.96	0.59-0.74
P. martia ..	Spherical	0.50-0.75	..
P. ensis ..	oval	0.64-0.90	0.56-0.70

The fecundity of the individual species was estimated by total count of fertilised eggs attached to the pleopods. The average number of eggs carried by the berried females varied from 2625 to 14539, depending on the species (Table 6).

TABLE 6. *Fecundity of the species*

Species	Number of specimens investigated (different sizes)	Smallest berried female (mm)	Range of total number of eggs	Average number of eggs
H. wood-masoni ..	12	88	7387-11092	8864
H. gibbosus ..	10	105	10732-17095	14539
P. spinipes ..	15	84	1818-7469	3972
P. martia ..	8	80	1152-5230	2733
P. ensis ..	10	85	1542-3927	2625

H. gibbosus had the highest average number of eggs among all the species.

Breeding : All the species appear to be continuous breeders as ovigerous females were observed in the catches throughout the year. The percentage occurrence of berried individuals, however, showed marked fluctuations in the different months. Table 7, shows the percentage frequencies of berried females of *H. wood-masoni*, *P. spinipes* and *P. martia* recorded in different months. The breeding intensity of *H. gibbosus* and *P. ensis* was almost in the same pattern as observed in *H. wood-masoni* and *P. martia* respectively. In May and June the percentage of ovigerous females was seen to be very low. Majority of the females without ' berry ' during these months possessed ' head roe ' and fast developing oostegites on the pleopods.

TABLE 7. *Percentage of ovigerous females in total females*

Month		*Heterocarpus wood-masoni*	*Parapandalus spinipes*	*Plesionika martia*
October 1967	..	77.5	77.2	86.0
November 1967	..	83.3	92.3	91·8
December 1967	..	75.0	95.0	100.0
January 1968	..	87.8	92.9	83.3
February 1968	..	82.8	77.5	100.0
May 1968	..	40.0	36.7	80.0
October 1968	..	78.2	94.0	100.0
November 1968	..	76.5	100.0	100.0
December 1968	..	83.7	100.0	90.0
January 1969	..	75.9	98.9	87.5
February 1969	..	71.0	87.5	x
March 1969	..	x	81.8	x
May 1969	..	55.0	54.6	x
June 1969	..	x	46.5	x
August 1969	..	x	89.0	80.0
October 1969	..	x	93·5	x
November 1969	..	80.1	97.3	100.0
December 1969	..	87.0	98.0	x

'x' — material not sufficiently represented in the samples.

Food of the prawns : Remains of pandalid prawns (body scales and fragments of appendages) and foraminiferan shells were the only items noticed in the stomach of many prawns examined and they were found in almost equal proportions. The prawns thus seem to be strictly bottom feeders. All the species appear to have almost a similar type of food since no marked difference was observed in the items consumed. The feeding intensity of berried females, particularly during the peak breeding period of October to January, was always very low as evidenced by high percentage of empty stomachs and stomachs containing very little food. Kurian (1965) observed foraminifera, crustacean appendages, decapod larvae and isopods as the predominant elements of food from the stomach of *Penaeopsis philippi* and *P. rectacutus*, two species of panaeid prawns he collected from these areas.

General Considerations

The trawling operations conducted in the areas studied here are only initial exploratory surveys for fishery resources of the upper continental slope and therefore the operations were not uniformly distributed throughout. Nevertheless, the results obtained indicate that the density of pandalids in general and the pattern of distribution of the different species in particular vary quite conspicuously in the southern and northern regions (Fig. 1, 3). In the southern region, the catch rates of these prawns are relatively very high and the resource is chiefly concentrated at 300-375 m depth. The relative abundance of these prawns in different depth zones of the two regions also exhibit considerable variations. In depth zone 1 of the southern region this group is represented by only *P. spinipes* and it continues to be the main constituent in the catches of depth zone 2. Other species gradually begin to appear in the catches from depth zone 2 onwards. *H. wood-masoni* replaces *P. spinipes* in the catches from depth zone 3 and in still deeper depth zones it forms the principal item of the catches. The maximum percentages of *H. gibbosus* and *P. ensis* were obtained from depth zones 5 and 6, while that of *P. martia* was recorded from the lower depth zones 2 and 3 of this region.

The catch per hour of trawling realised from Northern Region was considerably poor. The species distribution in this region also shows quite a different pattern. There was no catch of pandalid prawns from depth zone 1 of this region. *H. wood-masoni*, the most common species of the southern region, is never encountered here and instead, *H. gibbosus* forms the major item in the catches even from comparatively shallower depth zones. The percentage of this species increases with increase in depth. *P. spinipes* is the next important species in depth zones 2 to 4. *P. martia* is the only species associated with *H. gibbosus* in depth zones 5 and 6 (there was no operation in depth zone 7). *P. ensis* was represented in the catches by only stray specimens and they were caught from off Ponnani.

The differential distribution and abundance of the prawns noticed in these two regions can be attributed largely to the difference in the bottom conditions. Off Quilon and Alleppey, the upper continental slope region at 300-375 m depth, where the maximum catch rates have been recorded, is considerably expanded, even and soft and it provides a very ideal habitat for these species to abound. The corresponding region towards north is a very narrow belt, with slightly different bottom conditions, as already mentioned, and it does not seem to afford a suitable environment for them to flourish and propagate. Hydrographic parameters like temperature, salinity etc. can also be expected to play an important role in limiting their distribution. In the case of the deep-sea prawn, *Pandalus borealis*, of the arctic waters, the prawn stock is known to be greatly influenced by the temperature of the trawling grounds (Rasmussen, 1953 ; Smidt, 1965).

The trawling experiments conducted in the northern areas are, no doubt, not adequately exhaustive to give a very clear and reliable picture for their actual potentialities in respect of these prawns. It can, therefore, be hoped that further intensive survey of these areas will certainly uncover many similar problems which at present remain imperfectly understood.

References

ALCOCK, A. 1901. *A descriptive catalogue of the Indian deep-sea Crustacea, Decapoda, Macrura and Anomala in the Indian Museum, being a Revised Account of the Deep-sea Species collected by the Royal Marine Survey Ship 'Investigator'*, Calcutta, India, 286 pp.

——— 1906. *Catalogue of the Indian Decapod Crustacea in the Collections of the Indian Museum*. Part III. Macrura (*Penaeus*). Indian Museum, Calcutta, 55 pp.

BUTLER, T. H. 1964. Growth, reproduction and distribution of Pandalid shrimps in British Columbia. *J. Fish. Res. Bd. Canada*, **21** (6) : 1403-1452.

CALMAN, W. T. 1939. Crustacea : Caridea. *John Murray Exped.*, 1933-34, *Scientific Reports*, **6** (4) : 183-224.

DE MAN, J. G. 1911. The Decapoda of the Siboga Expedition—Part I. Family Penaeidae. *Siboga Exped. Monogr.*, **39a** : 1-131.

——— 1920. Decapoda. Part IV. *Siboga Exped. Monogr.*, **39a** : 1-318.

GEORGE, M. J. 1966. On a collection of the penaeid prawns from the off shore waters off the south-west coast of India. *Proc. Symp. Crustacea, mar. biol. Ass. India*, Part I : 337-346.

——— AND P. VEDAVYASA RAO 1966. On some decapod crustaceans from the south-west coast of India. *Ibid.*, Part I : 327-336.

HOLTHUIS, L. B. AND ROSA, Jr. 1965. List of species of shrimps and prawns of economic value. *FAO Fish. Tech.* Pap., **52** : 21 pp.

HORSTED, S. A. AND E. SMIDT 1956. The deep-sea prawn (*Pandalus borselis* Kr.) in Greenland waters. *Medd. Denmarks Fish.—og. Havunders.*, N. S., **1** (11) : 1-118.

JOHN, C. C. AND C. V. KURIAN 1959. A preliminary note on the occurrence of deep-water prawn and spiny lobster off the Kerala Coast. *Bull. Cent. Res. Inst. Trivandrum*, Ser. C., **7** (1) : 155-162.

JOSEPH, K. M. AND K. RADHAMMA 1970. A study of the deep-sea prawn resource off the southwest coast of India. *Seafood Export J.*, **2** (8) : 17-32.

KAGWADE, P. V. 1967. Prawn catches by mechanised vessels in the trawling grounds of Bombay and Saurashtra. *Proc. Symp. Crustacea, Mar. biol. Ass. India*, Part IV : 1348-81.

KURIAN, C. V. 1964. On the occurrence of the deep-water prawn *Penaeopsis rectacutus* (Spence Bate) off the Kerala Coast. *Curr. Sci.*, **33** (7) : 216-217.

——— 1965. Deep-water prawns and lobsters off the Kerala Coast. *Fish. Tech.*, **2** (1) : 51-53.

MAURIN, Cl. 1965. Les Crevettes Profondes de la Région Atlantique Ibéro-Marocains : Repartition bathymétrique et geographique, importance économique. *Con., Intern. pour L'explor. de la Mar : Rapports et Proces—Verbaux*, **156** : 116-119.

MENON, M. D. 1968. The pink tide. *Seafood Trade J.*, **3** (1) : 73-79.

MOHAMED, K. H. AND C. SUSEELAN 1973. Deep-sea prawn resources off the South-West Coast of India. *Proc. Symp. Living Resources of the Seas around India*, CMFRI., India, pp. 614-633.

RASMUSSEN, B. 1953. On the Geographical variation in growth and sexual development of the deep-sea prawn (*Pandalus borealis* Kr.). *Rept. Norwegian Fish. Mar. Invest.*, **10** (3) : 160 pp.

SILAS, E. G. 1969. Exploratory fishing by R. V. Varuna. *Bull. cent. mar. Fish. Res. Inst.*, No. **12** : 1-86.

SMIDT, E. 1965. Deep-sea prawns and the prawn fishery in Greenland waters. *Cons. Intern. pour L'explor. de la Mer : Rapports et Proces—Verbaux*, **156** : 100-104.

SUSEELAN, C. AND K. H. MOHAMED 1968. On the occurrence of *Plesionike ensis* (A. M. Edw.) (Pandalidae, Crustacea) in the Arabian Sea, with notes on its biology and fishery potentialities. *J. mar. biol. Ass. India,* **10** (1) : 88-94.

THOLASILINGAM, T. G., VENKATARAMAN AND K. N. KRISHNAKARTHA 1964. On some bathypelagic fishes taken from the continental slope off the south-west coast of India. *Ibid.*, **6** (2) : 268-284.