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Stock assessment of *Penaeus* spp. off the east coast of India

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ABSTRACT

Penaeid prawn landings increased from 20 744 tonnes in 1980 to 37 410 tonnes in 1986 and then declined to 31 029 tonnes in 1989 (average 29 642 tonnes). Prawns of the genus *Penaeus* supported good fishery all along the east coast of India forming 40% of the penaeid prawn landings. The three commercially important species, viz. *Penaeus indicus*, *P. semisulcatus* and *P. monodon*, contributed 5 849, 4 387 and 639 tonnes, respectively, to the annual penaeid prawn landings of the east coast. Tamil Nadu with annual landings of 7 880 tonnes was the major contributor to the *Penaeus* landings of the east coast followed by Andhra Pradesh (1 639 tonnes), Orissa (387 tonnes), Pondicherry (119 tonnes) and large trawlers (850 tonnes). Past work on biological aspects such as postlarval immigration, juvenile emigration, food and feeding habits and maturation and spawning has been reviewed. Age and growth parameters of *P.indicus* and *P. semisulcatus* were estimated by employing ELEFAN I method. Population estimates of *P.indicus* and *P. semisulcatus* showed very high fishing mortality and declining yield while those of *P. monodon* indicated scope for increasing the landings. HSY estimates for *P. indicus*, *P. semisulcatus* and *P. monodon* are 5 961 tonnes, 4 681 tonnes and 652 tonnes respectively. Species-wise and state-wise catch quotas have been suggested based on MSY and the present landings.

Prawns of genus *Penaeus* are in great demand in export market. Their intensive exploitation is causing a decline in per unit landings in many areas of the seas around India. Although *Penaeus* spp. are landed along the coasts of India, east coast alone contributes as much as 40% of the penaeid prawn landings. A study was attempted to assess the present status of the fishery for the 3 commercially important species, viz. *Penaeus indicus*, *P. monodon* and *P. semisulcatus*, by analysing the population parameters so as to forecast the future consequences if the harvesting is continued at the present level.

Much of the information available on these species from the east coast of India is mainly on biology (Thomas 1972, 1974, 1975, 1980, Rao 1975, Subramanian 1987, Sriraman *et al.* 1989) and fishery (Rao 1975, 1987, Rao *et al.* 1981, Nandkumar 1980, Sampson Manickam 1973, Sampson Manickam *et al.* 1989, Manisseri 1981, 1982, 1986, Rajamani and Manickaraja 1990) from different localities of the east coast. Very few studies (Rao 1988 a,b, 1992, Lalitha Devi 1986, 1987) have been conducted on the population dynamics of these species. Even these studies are limited to the Kakinada and Visakhapatnam areas and do not provide a comprehensive picture of the population dynamics of the species concerned. In this study, the data collected

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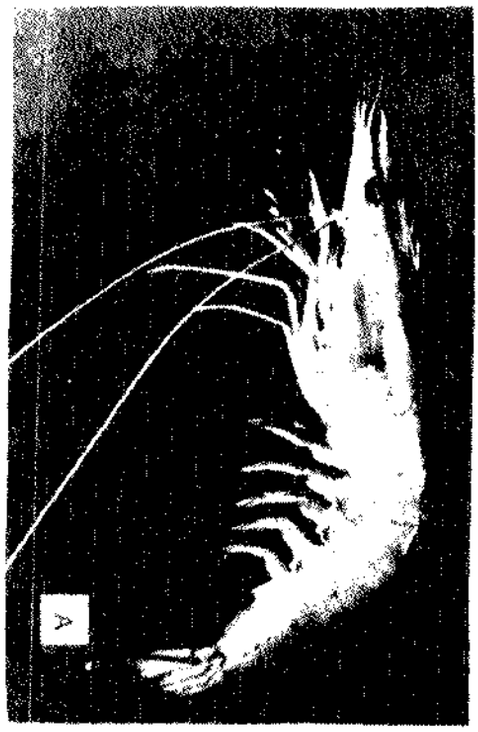

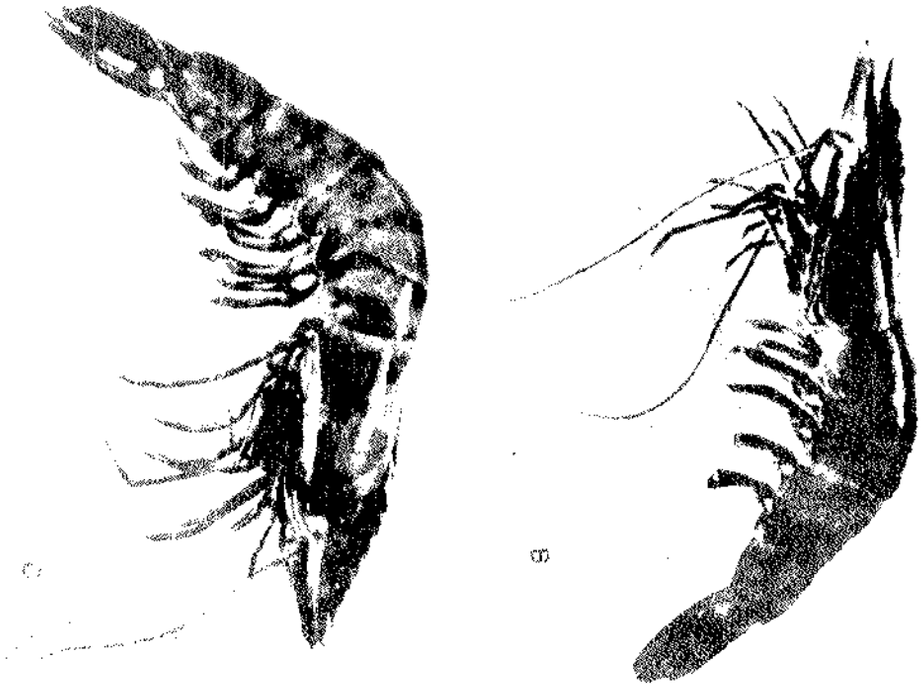

A, Penaeus indicus; B, Penaeus monodon; C, Metapenaeus dobsoni

from the entire east coast are presented to get a true picture of the population dynamics of the entire populations of the 3 species so that management measures could be adopted to derive optimum yields.

Geographic distribution

A knowledge of geographic distribution of a species is a prerequisite to delineate different populations of the species, since population characteristics have to be estimated separately for each population. The genus *Penaeus* is represented by 8 species, viz. *P. monodon*, *P. semisulcatus*, *P. japonicus*, *P. latisulcatus*, *P. canaliculatus*, *P. indicus*, *P. merguiensis* and *P. penicillatus*. In Indian waters each of the species has peculiar latitudinal and longitudinal distribution pattern. Except *P. latisulcatus* which is limited to the southern-most portions of both the coasts all the other 7 species are known to occur all along both the coasts with fishery abundance restricted to certain areas. *P. japonicus* and *P. canaliculatus* do not form any fishery in the Indian coast. *P. merguiensis* is observed in abundance at localized pockets around Kakinada and Puri in the east coast and Goa-Karwar and Gulf of Kutch in the west coast. *P. penicillatus* is restricted to northern latitudes, forming fishery only off West Bengal coast and Saurashtra-north Maharashtra coast.

For the purpose of present analysis the east coast stocks of the 3 species, viz. *P. indicus*, *P. semisulcatus* and *P. monodon*, were assumed as separate from the west coast stocks.

P. monodon occurs in stray numbers in the west coast while it forms a good fishery on the east coast. Even here the abundance gradually increases from south to north. *P. semisulcatus* forms a fishery in the Palk Bay and Gulf of Mannar with its abundance gradually reducing south to north on the east coast. In the west coast it forms a fishery only along the Gujarat coast, that too for a short period during October-November. *P. indicus* forms a good fishery along the east coast from Tuticorin to Chilka Lake and a fishery of lesser magnitude in the west coast between Kanyakumari and Karwar. The east coast and west coast populations maintain their separate status as shown by the size composition and abudance between Tuticorin fishery and Manappad fishery (Manisseri and Manimaran 1981).

MATERIALS AND METHODS

Data required for the present analysis were retrieved from a number of sources. Data of annual penaeid prawn landings during 1980-84 were taken from Dharmaraja *et al.* (1987), Alagaraja *et al.* (1987), Scariah *et al.* (1987) and Philippose *et al.* (1987) for Tamil Nadu, Andhra Pradesh, Orissa and West Bengal respectively. Data on quarter-wise and district-wise penaeid prawn landings during 1985-89 were collected from Fishery Resources Assessment Division of CMFRI. District-wise and quarter-wise composition of *P. monodon*, *P. indicus* and *P. semisulcatus* were estimated based on the data available from the primary data sheets of FRAD staff stationed all along the east coast, since processed information on these aspects was not available from FRAD. Penaeid prawn landings and species composition of large trawler fishery were estimated from the daily fishing log available for sampled number of vessels. Total length measured in millimetres from the tip of rostrum to the tip of telson was taken for the analysis of length composition for all the species. All the specimens in a sample were sexed and measured for total length and sample weight. Whenever it was not possible to get sample

weights, it was calculated from the length-weight relationship available from Rao (1992) for *P. indicus*, from Thomas (1975) for *P. semisulcatus* and from Rao (1967) for *P. monodon*. Length frequency distribution with 5 mm class intervals obtained separately for males and females from the daily samples were raised to the sample days catch. Length frequencies estimated to sample days catches were pooled and estimates for a month derived. The data so obtained for the months formed the basis for the estimation of age and growth. However, it was made up to quarters in the case of *P. semisulcatus*, since monthly data did not give acceptable results. The data thus obtained for *P. indicus* at Visakhapatnam for the years 1984-88 and for *P. semisulcatus* at Mandapam for the years 1986-88 were used for the estimation of age and growth parameters employing ELEFAN I method of Pauly and David (1981).

Since age and growth estimation of *P. monodon* was not possible with the present data, the estimates given by Rao (M S) for the Kakinada region were taken into consideration for mortality rates and estimation of stock of this species. Length-weight relationships given by Thomas (1975) for *P. semisulcatus*, Rao (1967) for *P. monodon* and Rao (1992) for *P. indicus* were employed wherever necessary in the derivation of stock estimates.

The monthly estimates of length frequencies at different sampling stations were raised to the area's/region's catch which in turn were raised to that particular state's catch. These monthly data for different states were pooled to get the length frequency distribution for the entire east coast. Based on these data instantaneous mortality rates and stock estimates were obtained by employing length cohort analysis of Jones (1981). MSY for yield and biomass at different levels of instantaneous fishing mortality rate (F) were estimated following Thompson and Bell (1934) modified by Sparre (1985). Length composition data collected at Visakhapatnam, Cuddalore, Mandapam and Tuticorin from small trawler landings formed the basis for stock assessment. Adequate data on the length composition of the small trawler landings are available. But enough data could not be collected from non-mechanized gear landings as the prawn catches were of lesser magnitude and irregular in occurrence. However, it was found from the examination of samples that the length composition of trawler landings and non-mechanized gear landings was more or less identical. Therefore the data obtained from trawler landings were used for the estimation of length composition of the catches of non-mechanized gear also.

Craft and gear

Ramamurthy and Muthu (1969) described the fishing methods employed in the prawn fishing on the east coast of India. Boat seines and shore seines of various types are widely used since ancient times. However, in recent years the bottom set gill nets are widely used for catching large-sized prawns. This gear, made of synthetic twine, is operated all along the east coast in varying intensities. More recent innovation is the emergence of 'Disco net' (Joel and Ebenezer 1985). The disco net introduced in the Kanyakumari district in 1984 was so efficient in entangling prawn, that it replaced the gill nets all along the east coast.

Trawling with mechanized boats, started in 1950s off the Tamil Nadu coast and has spread to all the areas along the east coast. Trawlers of various dimensions are fishing for prawns along the coast. They

are broadly classified as small trawlers (9.75 m), 'sona' boats (13.1 m), mini trawlers (16 m) and big trawlers (23 m). The small trawlers are distributed all along the coast whereas the bigger ones are more popular in the upper east coast. Mini trawlers and big trawlers, together known as large trawlers, fish in the far off 'Sandheads' grounds off West Bengal and land the catch at Visakhapatnam.

RESULTS AND DISCUSSION

Fishery

During the 10-year period of 1980-89 the penaeid prawn landings along the east coast fluctuated from 20 744 tonnes in 1980 to 37 410 tonnes in 1986 (average 29 642 tonnes). The east coast penaeid landings formed about 23.3% of the all-India penaeid landings. Tamil Nadu contributed 49% to the east coast landings (average 14 464 tonnes). The penaeid landings of Tamil Nadu varied from 9 082 tonnes in 1980 to 18 185 tonnes in 1987 without a perceptable regular trend. With an annual landing of 8 286 tonnes, Andhra Pradesh contributed about 28% followed by Orissa (7%), West Bengal (2%) and Pondicherry (2%). Annual landings of penaeid prawn varied randomly in these states without any regular trend.

The penaeid landings of large trawlers varied from 2 662 tonnes in 1987 to 4 594 tonnes in 1986. The large trawler prawn fishery, after 1986, could not recover to previous level in spite of considerable increase in the number of trawlers.

The data for 1985-89 were analysed in detail to find out the contribution of *P. monodon*, *P. indicus* and *P. semisulcatus* to the fishery in different states and to understand the status of their fisheries. The landings in West Bengal were meagre and hence a split up of the landings was not necessary in the present context. Quarter-wise landings of these 3 species in different states of east coast in relation to the total prawn landings are presented in Tables 1-5 and the annual landings *P. indicus*, *P.monodon*, and *P. semisulcatus* are presented in Tables 6-8. With the average annual landings estimated at 5 849 tonnes *P. indicus* forms about 20% of the penaeid prawn landings of the east coast of India with Tamil Nadu contributing as much as 59% followed by Andhra Pradesh (25%), large trawlers (10%), Orissa (5%) and Pondicherry (2%). In Tamil Nadu non-mechanized boats contribute 73% to the *P. indicus* landings. The contribution of trawlers to the *P. indicus* fishery in Tamil Nadu is only 27%. In Andhra Pradesh also the situation is more or less similar to that of Tamil Nadu. Most of it is landed by the bottom set gill nets and disco nets. Almost the entire catch of *P. indicus* in Orissa was landed by non-mechanized gear with very little representation in the trawler landings. The seasonal abudance in different states and in different years varied randomly without any sequential trend in different quarters of 1985-89 period. The annual large trawler landings of *P. indicus* amount to 570 tonnes contributing to 10% of the east coast landings of the species. In most of the years better landings of *P. indicus* were observed during October-December as compared to the other months.

Although *P. monodon* with the average annual of 639 tonnes forms only 2.2% of the penaeid prawn landings of the east coast it is economically very important because of its demand in the export market and the price it commands (Table 8). Large trawler landings varied from 177 tonnes in 1988 to 305 tonnes in 1986. They contributed as much as 37% to the annual *P. monodon* landings of the east coast followed by Tamil

Table 1. Quarter-wise penaeid prawn landings (t) in Orissa during 1985-88

Year	Quarters	*P. monodon*		*P. indicus*		*P. semisulcatus*		Other species		Total		Gears combined
		NM	M	NM	M	NM	M	NM	M	NM	M	
1985	1	-	50	-	4	-	24	2	598	2	676	678
	2	-	-	116	-	-	-	1	9	117	9	126
	3	4	6	262	-	2	1	45	169	313	176	489
	4	6	58	40	-	2	20	11	1167	59	1245	1304
	Total	10	114	418	4	4	45	59	1943	491	2106	2597
	%	2.0	5.4	85.1	0.2	0.8	2.1	12.0	92.3	18.9	81.1	100.0
1986	1	-	50	18	-	3	24	58	599	79	673	752
	2	1	-	299	-	1	-	32	1	333	1	334
	3	3	2	124	-	2	-	28	51	157	53	210
	4	6	58	43	-	2	20	10	1450	61	1528	1589
	Total	10	110	484	-	8	44	128	2101	630	2255	2885
	%	1.6	4.9	76.8	-	1.3	2.0	20.3	93.2	21.8	78.2	100.0
1987	1	-	16	5	1	2	2	7	555	14	574	588
	2	69	-	4	-	1	-	30	3	104	3	107
	3	12	6	74	-	1	10	262	168	349	184	533
	4	6	32	29	-	2	17	12	840	49	889	938
	Total	87	54	112	1	6	29	311	1566	516	1650	2166
	%	16.9	3.3	21.7	0.1	1.2	1.8	60.3	94.9	23.8	76.2	100.0
1988	1	-	16	1	4	-	2	2	552	3	574	577
	2	2	-	1	-	-	-	3	60	6	60	66
	3	2	16	10	-	1	20	12	122	25	158	183
	4	10	32	50	1	3	17	21	833	84	883	967
	Total	14	64	62	5	4	39	38	1567	118	1675	1793
	%	11.9	3.8	52.5	0.3	3.4	2.3	32.2	93.6	6.6	93.4	100.0

NM Non-mechanized; M, mechanized.

Nadu (23%), Andhra Pradesh (21%) and Orissa (18%). In Tamil Nadu, Andhra Pradesh and Orissa, trawlers contributed 80, 87 and 74%, respectively, to the *P. monodon* fishery of these states with only a fraction landed by non-mechanized gear. The annual landings of *P. monodon* in all the 3 states showed a declining trend from 1986 till 1988.

With an average annual landing of 4 387 tonnes *P. semisulcatus* forms about 14.8% of the penaeid landings of the east coast (Table 8). The landings in 1987 to 1988 were almost entirely (97.9%) from Tamil Nadu, there too localized in the Palk Bay and Gulf of Mannar regions. The landings north of Nagapatnam were negligible. In Tamil Nadu, almost 89% of the landings in 1988 were by trawlers with only a fraction (11%) landed by non-mechanized boats.

The less common species of *P. merguiensis* and *P. penicillatus* are also landed in commercial quantities in some localized areas of Andhra Pradesh, Orissa, West Bengal and by large trawlers. The landings of these two species was about 330 tonnes each annually. Including these two species the annual landings of *Penaeus* spp, along the east coast are estimated at 11 535 tonnes or 40% of the annual prawn landings of the east coast.

Table 2. Quarter-wise penaeid prawn landings (t) in Andhra Pradesh during 1985-88

Year	Quarters	*P. indicus*		*P. monodon*		*P. semisulcatus*		Other species		Total		Gears combined
		NM	M	NM	M	NM	M	NM	M	NM	M	
1985	1	86	66	4	34	-	2	294	1060	384	1162	1546
	2	130	144	-	25	-	3	580	889	710	1061	1771
	3	595	183	4	43	-	13	685	1579	1284	1818	3102
	4	34	81	3	30	1	14	66	1164	104	1289	1393
	Total	845	474	11	132	1	32	1625	4692	2482	5330	7812
	%	34.1	8.9	0.4	2.5	0.1	0.6	65.4	88.0	31.8	68.2	100.0
1986	1	290	112	9	42	-	7	828	1893	1127	2054	3181
	2	413	127	-	32	-	10	180	1942	593	2111	2704
	3	446	223	2	59	-	17	308	2370	756	2669	3425
	4	151	150	6	41	-	11	108	1655	265	1857	2122
	Total	1300	612	17	174	-	45	1424	7860	2741	8691	11432
	%	47.4	7.0	0.6	2.0	-	0.5	52.0	90.4	24.0	76.0	100.0
1987	1	60	111	25	43	-	14	11	1715	96	1883	1979
	2	173	50	-	16	-	4	56	1077	229	1147	1376
	3	338	94	-	23	-	9	148	1540	486	1666	2152
	4	123	49	-	12	-	8	83	901	206	970	1176
	Total	694	304	25	94	-	35	298	5233	1017	5666	6683
	%	68.2	5.4	2.5	1.7	-	0.6	29.3	92.4	15.2	84.8	100.0
1988	1	55	107	18	25	-	19	428	1745	501	1896	2397
	2	224	62	-	13	-	12	40	55	264	642	906
	3	682	118	-	24	-	11	136	1555	818	1708	2526
	4	318	52	-	16	-	9	105	1356	423	1433	1856
	Total	1279	339	18	78	1	51	708	5211	2006	5679	7685
	%	63.8	6.0	0.9	1.4	0.1	0.9	35.3	91.8	26.1	73.9	100.0

NM, Non-mechanized; M, mechanized.

BIOLOGY

Juvenile phase

Mohammed (1970) reviewed the biological information available on *P.indicus* and *P. monodon*. Both the species spawn in the sea, and their larvae and postlarvae enter into backwaters and estuaries. In these ecosystems they grow into juveniles and support good fisheries all along the east coast (Rao 1967, Subramaniam 1987). *P. semisulcatus* rarely enters backwaters and estuaries but spends its juvenile phase in the shallow inshore waters where seagrass is abudant (Maniserri 1983, Sampson Manickam *et al.* 1989). These species after reaching sub-adult stage migrate into inshore waters and on attaining maturity further migrate to deeper waters for spawning and support fisheries in all these areas.

Panikkar and Aiyar (1939) were the first to state that *P. indicus* enters the backwaters and lagoons as larvae and postlarvae grow there and leave before attaining maturity. These findings were confirmed by Subramanyam (1964, 1965) and Rao (1975) from the Godavari estuary, Subramanyam (1966) and Rao (1967) from the Chilka Lake, Subramanyam (1968) from the Ennore and Adayar estuaries, Subramanyam and Rao (1978) from

Table 3. Quarter-wise penaeid prawn landings (t) in Tamil Nadu during 1985-88

Year	Quarters	*P. indicus*		*P. semisulcatus*		*P. monodon*		Other species		Total		Two gears combined
		NM	M	NM	M	NM	M	NM	M	NM	M	
1985	1	310	148	79	715	12	25	31	711	472	1599	2051
	2	349	400	40	826	13	5	4	1184	406	2415	2821
	3	343	263	26	1158	-	40	-	1539	369	3000	3369
	4	285	88	144	1074	1	5	53	1412	483	2579	3062
	Total	1287	899	289	3773	26	75	88	4846	1730	9593	11303
	%	75.3	9.4	16.9	39.3	2.7	0.8	5.1	50.5	15.1	84.9	
1986	1	445	212	126	696	14	42	69	1296	684	2246	2930
	2	1378	81	56	1244	4	19	46	4171	1644	4515	7159
	3	575	144	40	1446	-	77	-	1634	615	3301	3916
	4	664	199	62	836	6	7	208	1553	940	2595	3535
	Total	3062	636	284	4222	24	145	323	8654	3883	13657	17540
	%	78.9	4.6	7.3	30.9	5.5	1.1	8.3	63.3	22.1	77.9	
1987	1	694	300	131	536	17	60	137	1297	1079	2192	3221
	2	1288	333	77	583	8	43	53	2917	1786	3876	5482
	3	1686	433	44	1379	-	-	-	2311	1810	4203	5933
	4	172	333	162	818	2	25	53	1984	389	3160	3549
	Total	3840	1399	414	3316	27	128	243	8508	4984	15511	18185
	%	80.8	10.4	8.7	24.7	5.4	1.5	5.1	63.3	26.1	73.9	
1988	1	551	559	194	498	16	45	51	1825	892	2927	3779
	2	131	48	50	1227	8	4	3	1945	192	3223	3416
	3	824	135	32	1478	-	60	-	2086	856	3759	4615
	4	256	135	575	822	2	7	74	1717	907	2681	3688
	Total	1762	877	851	4025	26	116	128	7573	2847	12591	15398
	%	62.8	7.0	30.3	32.0	2.4	0.9	4.6	60.1	18.2	81.8	

NM, Non-mechanized; M, mechanized,

Table 4. Annual penaeid prawn landings (t) in Pondicherry for 1985-88

Year	*P. indicus*	*P. semisulcatus*	*P. monodon*	Other species	Total
1985	146	10	8	590	754
1986	105	7	6	429	547
1987	96	6	5	387	494
1988	75	5	4	305	389
Average	106	7	6	427	546

Roopnarayan estuary and Rao (1968) from the Hooghly estuarine system. Although there is disagreement among different workers regarding the age of the migrating juveniles into the sea, most of them have agreed that total length at migration is around 100 mm. The seasonal abudance in the different estuaries varies from year to year without any predicatable trend. Subrahmanyam (1964, 1965, 1967) tried to relate the *P. indicus* landings in the Chilka Lake and Godavari estuary to lunar periodicity but failed to give a convincing relationship.

Table 5. Penaeid prawn landings (t) by large trawlers at Visakhapatnam

Year	*P. monodon*	*P. indicus*	*P. merquiensis*	*P. penicillatus*	*P. semisulcatus*	Other species	Total
1985	279	663	331	332	52	2885	4542
1986	305	713	356	357	57	2806	4594
1987	178	328	164	164	33	1394	2261
1988	177	576	288	288	39	2170	3538
Average	235	570	285	285	45	2314	3734

Table 6. State-wise landings of *P. indicus* along the east coast of India

Year	Orissa	Andhra Pradesh	Tamil Nadu	Pondicherry	Large trawlers	Total
1985	422	1319	2186	146	663	4736
1986	484	1912	3698	105	713	6912
1987	143	998	5239	96	328	6774
1988	67	1618	2639	75	576	4975
Average	271	1461	3441	106	570	5849
%	4.6	25.0	58.8	1.8	9.7	100.0

Table 7. State-wise landings of *P. semisulcatus* along the east coast of India

Year	Orissa	Andhra Pradesh	Tamil Nadu	Pondicherry	Large trawlers	Total
1985	-	33	4062	10	52	4157
1986	-	45	4506	7	57	4615
1987	-	35	3730	6	33	3804
1988	-	52	4876	5	39	4972
Average	-	41	4294	7	45	4387
Percentage	-	0.9	97.9	0.2	1.0	100.0

Table 8. State-wise landings of *P. monodon* along the east coast of India

Year	Orissa	Andhra Pradesh	Tamil Nadu	Pondicherry	Large trawlers	Total
1985	124	143	114	8	279	668
1986	120	191	169	6	305	791
1987	141	119	155	5	178	598
1988	78	96	142	4	177	497
Average	116	137	145	6	235	639
Percentage	18.2	21.4	22.7	0.9	36.8	100.0

Panikkar and Aiyar (1939) reported that the larvae and postlarvae of *P. monodon* enter the Adayar estuary during all the months. Similar observations were made from the Chilka lake (Subramanyam 1964, Rao 1967), the Hooghly estuary (Rao 1968), and the Godavari estuary (Subramanyam 1966, Rao 1975). These studies also indicated that the process of immigration and emigration is continuous with the seasonal peaks of abundance varying from year to year.

Food and feeding

Panikkar (1952) stated that the food of young penaeids consists of organic detritus,

algal matter and other small organisms contained in the mud. Gopalkrishnan (1952) found vegetable matter and crustanceans as the major items of food of *P. indicus* along the Madras coast. Hall (1962) classified it as a carnivore, since more animal matter in different stages of digestion was found in the stomachs. Kuttyamma (1974) and Suseelan (1975) from the west coast also confirmed the findings of the earlier workers on the food of the species.

P. monodon had large crustanceans, vegetable matter, polychaetes, molluscs and fish as its food, and is classified as an omnivore (Hall 1962). Rao (1967) confirmed these findings but Mohanty (1975) contradicted them. However, Rao (1988 c) opined that what was referred to as detritus in the stomach contents of many penaeids was only semidigested matter of the animals.

Hall (1962) observed large and small crustaceans, polychaetes, fishes and vegetable matter in order of abundance in the guts of *P. semisulcatus.* Based on this he classified it as a 'general carnivore'. Thomas (1980) found crustaceans, polychaetes, algae and diatoms as major food items in the stomach contents in all size groups and in different seasons. However, he observed that the feeding intensity was more in night.

Maturation and spawning

All the species of the genus *Penaeus* are heterosexual. Sexes can be distinguished by external characters such as petasma and appendix masculina in males and thelycum in females. George and Rao (1968) traced the development of external genitalia of *P. indicus* from juveniles to adults and found that the males mature at a length of 102 mm. Rao (1969) observed 5 stages in the maturation process based on the ova diameter measurements. He estimated the size at first maturity as 130.2 mm and fecundity as 68 000 in a female of 140 mm to 731 000 eggs in female of 200 mm. The relationship for total length (L) to number of eggs (F) is

$$\log F = -8.1277 + 6.0808 \log L$$

He observed that *P. indicus* spawns 5 times during a life time and that interval between two successive spawnings is about 2 months. He observed a prolonged breeding season from October-April off Cochin. Subramanyam (1963) studied the gonad index of the species from Madras waters and observed pronounced breeding activity in May, July, August and September. Subramaniam (1987) confirmed the findings of Rao (1969) by his studies at Parangipettai. The data collected during 1984-88 at Visakhapatnam and Cuddalore showed that the females attain first maturity at about 120 mm. In other respects the present data confirm the findings of the earlier workers.

Thomas (1974) studied reproduction of *P. semisulcatus* from Mandapam waters. Spawning was observed throughout the year with peaks during June-September and January-February. Size at first maturity was of 23 mm carapace length. The fecundity of the species ranged from 51 605 to 660 904.

Age and growth

Age and growth of *P. indicus* and *P. semisulcatus* were calculated based on the data collected at Visakhapatnam during 1984-88 and at Mandapam during 1986-88 respectively. Monthly samples of length frequencies estimated to monthly catch was used in the case of *P.indicus.* As the monthly data were inadequate, they were pooled to quarters to estimate growth parameters of *P. semisulcatus.* The results of ELEFAN I analysis for the two species are given in Figs 1-4. The results

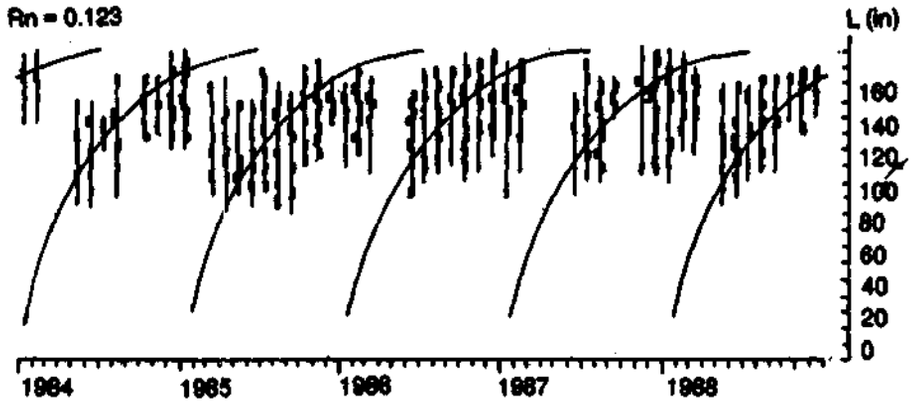

Fig.1. Growth curve of *P. indicus* male by ELEFAN I

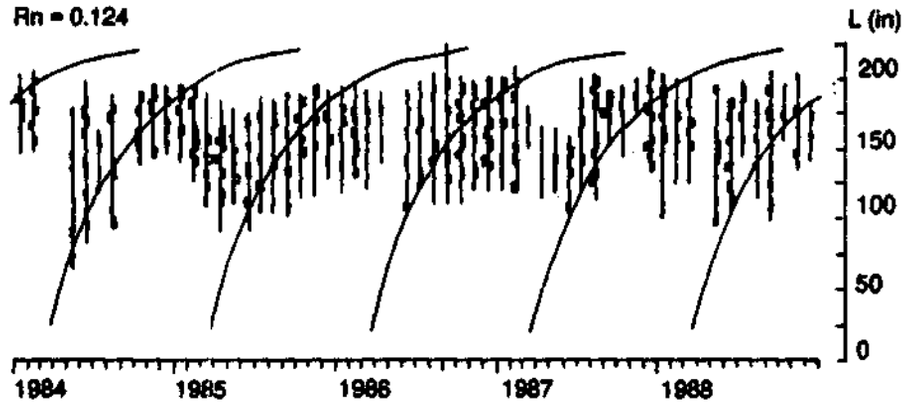

Fig.2. Growth curve of *P. indicus* female by ELEFAN I

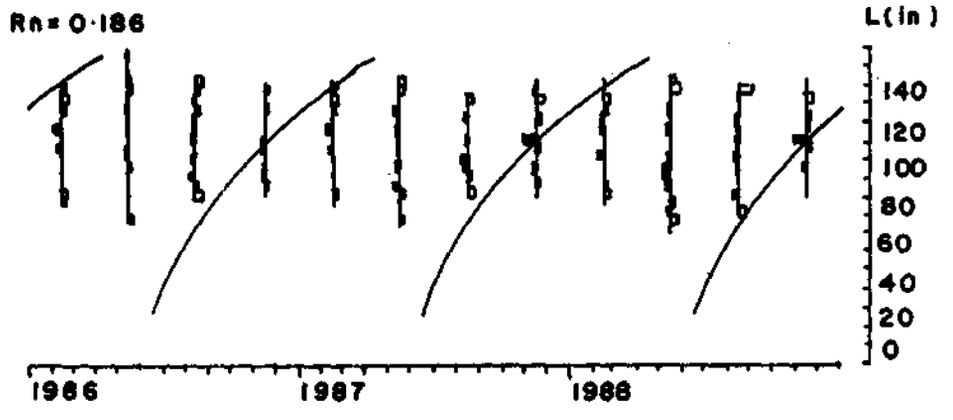

Fig.3. Growth curve of *P. semisulcatus* male by ELEFAN I

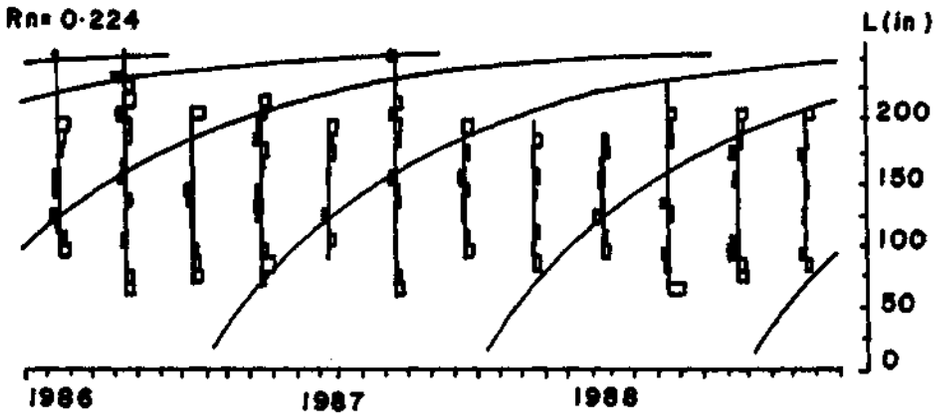

Fig.4. Growth curve of *P. semisulcatus* female by ELEFAN I

are as given below.

Species	Sex	L_∞ (mm)	K	Length at 6 months (mm)	Length at 12 months (mm)
P. indicus	Male	200	2.00	120	180
	Female	230	2.00	135	200
P. semisulcatus	Male	210	1.70	120	170
	Female	261	1.30	135	195

Since the present data are inadequate for the estimation of growth parameters the estimates of Rao (MS2) were used for the estimation of instantaneous mortality rates and stock size. He studied the growth of *P. monodon* by following the modal progression in monthly length frequencies. The growth parameters L_∞ and K (Ford-Walford 1946) and t_o (Gulland 1969) were estimated. Age at length was calculated by von Bertalanffy growth equation. The estimates are given below.

Sex	L_∞ (mm)	K	t_o	Length at 6 months (mm)	Length at 12 months (mm)
Male	285	1.511	0.055	140	217
Female	331	1.591	0.057	167	257

The present estimates of age and growth of *P. indicus* are far higher than those reported by Rao (1967) from the Chilka lake, George *et al.* (1968) from Cochin, Kurup and Rao (1974) from Ambalapuzha and Lalitha Devi (1988) from Kakinada. Similarly the estimates for *P. semisulcatus* are also higher than those reported by Thomas (1975) from Mandapam. Although there is no agreement among the workers regarding the rate of growth, they all agree in that there is differential growth in sexes and that females grow faster than males in both the species. Variations in the growth rates may be due to different methods followed by different workers and non-representation of the entire length range in the samples in some cases.

Length-weight relationship

Since no length-weight data were collected during 1984-88, the relationships derived by different workers in the past are taken into consideration. Relationships derived by Rao (1967) for *P. monodon* from the Chilka lake, Thomas (1975) for *P. semisulcatus* from Mandapam and Rao (1992) for *P. indicus* from Visakhapatnam were used in the stock estimations. The

relationships representing weight in grams and length in millimetres are given below.

P. monodon	
Males	log W = -5.3399 + 3.1032 log L
Females	log W = -4.8953 + 2.9022 log L
P. indicus	
Combined	log W = -6.3299 + 3.5543 log L
P. semisulcatus	
Males	log W = -4.3403 + 2.8953 log L
Females	log W = -4.0088 + 2.6536 log L

Stock assessment

Mortality rates and stock estimates were based on the data for the years 1985-88 for *P. indicus*, 1986-88 for *P. semisulcatus* and 1986-88 for *P. monodon*. Length composition data for *P. indicus* and *P. semisulcatus* were grouped at 10 mm intervals while they were grouped in 20 mm intervals in the case of *P. monodon* to facilitate reasonable estimates by cohort analysis. In the case of *P. indicus* and *P. semisulcatus* instantaneous natural mortality rate (M) was considered as equal to K while in the case of *P. monodon* it was calculated from the maximum length (1 max) observed in the landings and following the method of Cushing (1968). The parameter values taken for the purpose of cohort analysis are given below.

Species	Sex	L_∞ (mm)	K	M	Terminal exploitation rates	Plus group (mm)
P. indicus	Males	200	2.00	2.00	0.732	190
	Females	230	2.00	2.00	0.801	200
P. semisulcatus	Males	210	1.70	1.70	0.845	170
	Females	261	1.30	1.30	0.792	200
P. monodon	Males	285	1.51	2.05	0.669	240
	Females	331	1.59	1.84	0.695	300

The mortality rates, instantaneous fishing mortality rate (F), total mortality rate (Z) and exploitation rate (F/Z) gradually increased from 90-100 to 170-180 mm in males and 90-100 to 180-190 mm in females of *P. indicus*, from 70-80 to 130-140 mm in males and 60-70 to 170-180 mm in females of *P. semisulcatus*, and from 140-160 to 200-220 mm in males and 160-180 to 260-280 mm in females of *P. monodon* indicating an increase in fishing mortality with increasing size. However, in very old fishes the mortality was lesser than in the relatively smaller size groups in all the 3 species. Standing stock in weight gradually increased from 90-100 to 130-140 mm in males and 90-100 to 140-150 mm in females of *P. indicus;* from 70-80 to 110-120 mm in males and 60-70 to 130-140 mm in females of *P. semisulcatus* and from 140-160 to 200-220 mm in males and 150-180 to 260-280 mm in females of *P. monodon*. It then declined gradually with increase in size in all the 3 species.

Based on these stock estimates the variation in the yield and biomass were estimated at different levels of F by employing Thompson and Bell (1934) method improvised by Sparre (1987). The present F is taken as to determine whether the effort has to be decreased or increased to attain maximum sustainable yield (MSY). The yield curves are represented in Figs 5-7 and the estimates are given below.

Species	Sex	MSY yield in t	MSY biomass in t	Respective F
P. indicus	Male	2646.0	928.5	0.988
	Female	3315.0	1232.9	0.563
P. semisulcatus	Male	1903.0	661.1	0.400
	Female	2778.0	1273.0	0.563
P. monodon	Male	251.2	80.4	3.016
	Female	401.3	164.2	1.663

MSY for males of *P. indicus* was 2 646 t and the average catch for 1985-88 was 2 662 t, a little more than the MSY estimate

(Fig.5). However, the landings of females during the period was 3 127 t where the MSY estimate was 3 315 t. As per the analysis the catch could have been realized at almost half the present effort. This was due to heavy exploitation of the species in 1986 and 1987, wherein 3 766 and 3 691 t of females were exploited instead of 3 315 t which resulted in very poor landings of the species as a whole in 1988 (4 975 t) for lower than the MSY estimate.

In *P. semisulcatus* in both males and females the landings were lower than the MSY estimates although MSY should be realized at a far lower F (0.4 and 0.563) than the present F of 1 (Fig.6). An analysis of the data on landings of *P. semisulcatus* indicates that landings exceeded MSY in

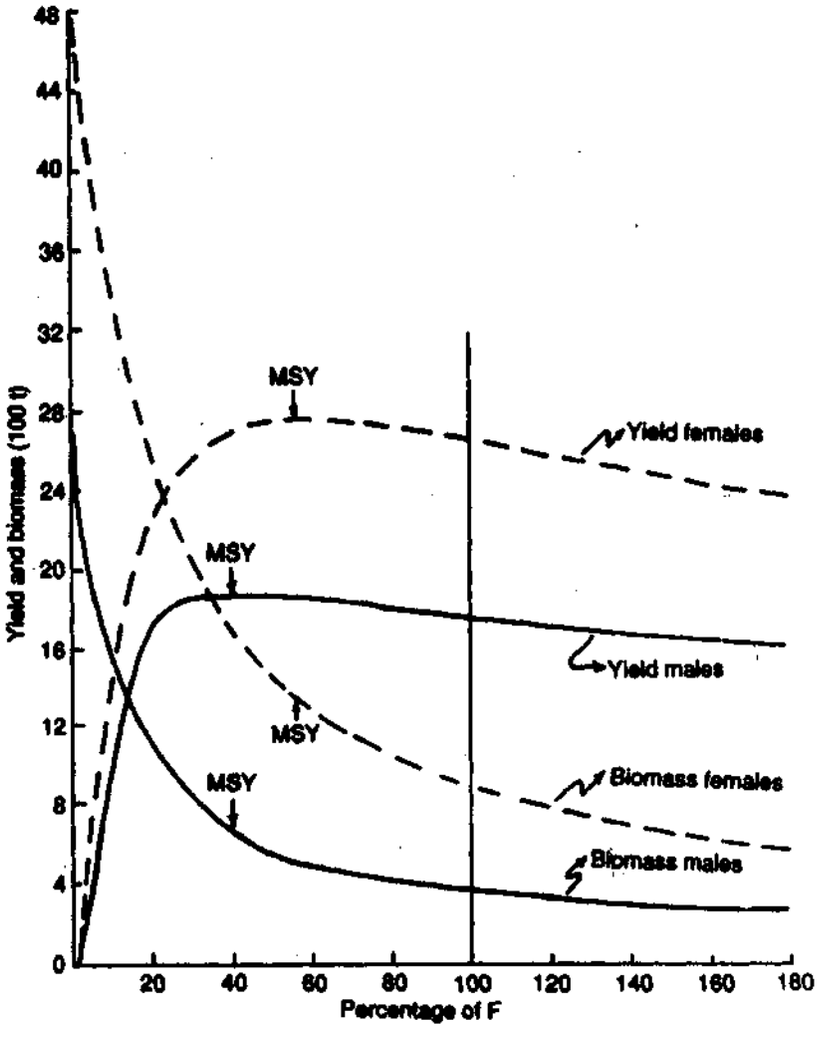

Fig.5. Yield curves of *P. indicus* by the method of Thompson and Bell

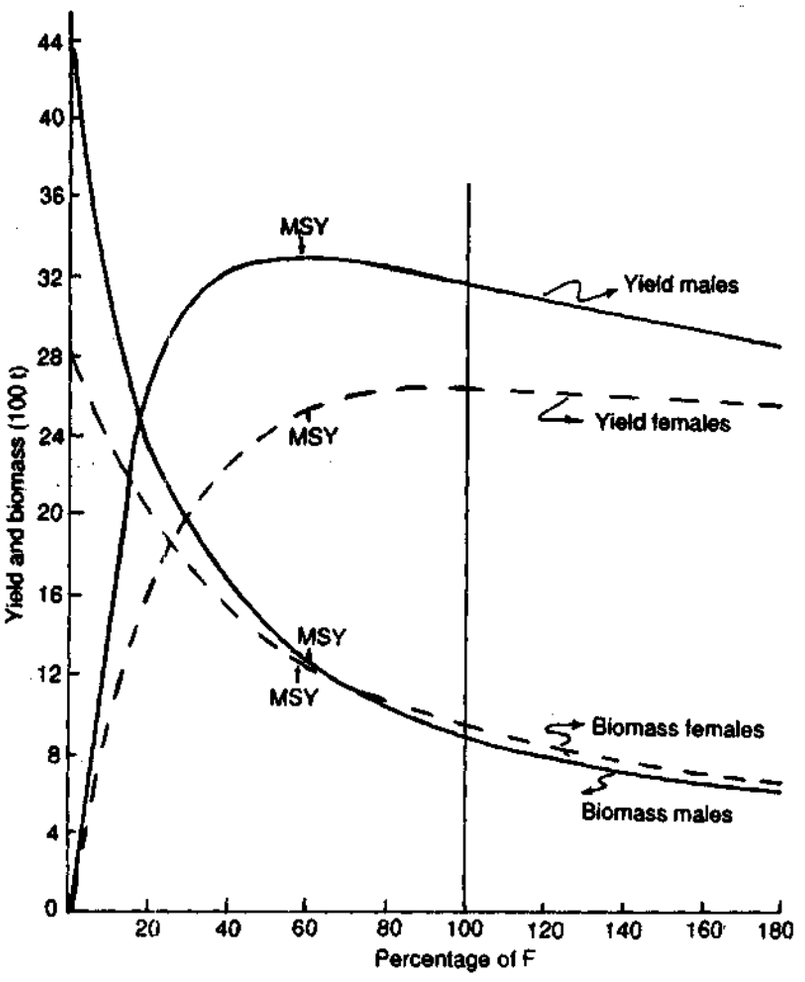

Fig.6. Yield curves of *P. semisulcatus* by the method of Thompson and Bell.

some years as in 1988 creating such a situation. It is not necessary to increase the effort to reach the MSY level. Fig.6 clearly indicates this aspect. Hence it is necessary to reduce the effort to maximize landings.

The estimates for *P.monodon* are lesser than the present level of landings. To attain MSY in both the sexes F has to be increased enormously (Fig.7). It may not be economical to increase the present F 3.016 times to get an increased catch of 6 t of males and 1.665 times to catch an additional 7 t of females. The annual landings of males and females are 245 and 393 t, respectively, whereas the MSY estimates are 251 and 401 t respectively. Hence it is better to harvest the species at the present level of effort. However, it should be noted that even if the present effort level is doubled there is no danger of overfishing of the stock.

Exploitation strategies

The foregoing analysis clearly shows that both *P.indicus* and *P. semisulcatus* are

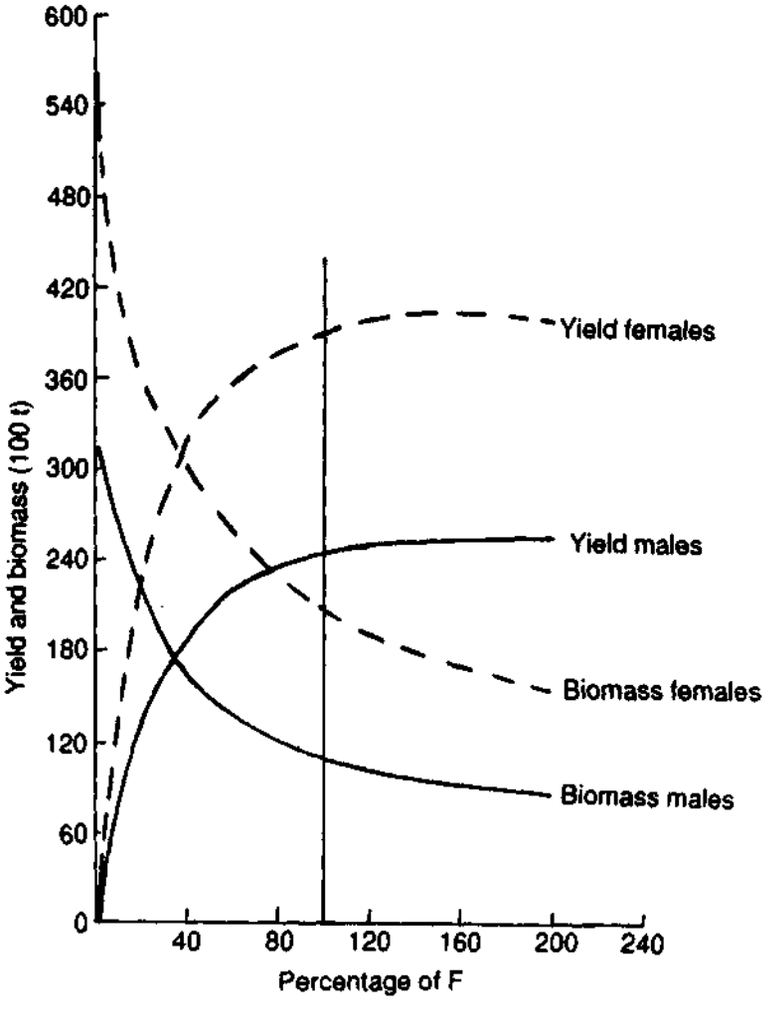

Fig.7. Yield curves of *P. monodon* by the method of Thompson and Bell.

heavily exploited, and hence require to be properly managed. This has led to dwindling per unit landings and consequent conflicts among different groups of fishermen. To avoid all such conflicts it is better to apportion the catch among different states and among different gears within each state. These species are harvested by a variety of gears all along the coasts of the 3 states of east coast of India. An attempt is made in the table on the next page to apportion the MSY based on the present landings of different states.

Realizing these problems associated with different species each state should formulate its own measures to regulate the fisheries. Andhra Pradesh can harvest 1 489 t of *P. indicus*, 140 t of *P. monodon* and 44 t of *P. semisulcatus* annually without any adverse effect on the stocks. This can be

State	Orissa	Andhra Pradesh	Tamil Nadu	Pondicherry	Large trawlers	East Coast
			P. indicus			
Present landing (t)	271	1461	3441	106	570	5849
Catch quota (t)	276	1489	3507	108	581	5961
			P. monodon			
Present landings (t)	116	137	145	6	235	639
Catch quota (t)	118	140	148	6	240	652
			P. semisulcatus			
Present landings (t)	-	41	4294	7	45	4387
Catch quota (t)	-	44	4581	8	48	4681

apportioned between mechanized gear and non-mechanized gear as follows based on the present landings of these gears.

Species	Mechanized	Non-mechanized	Total
P. indicus	1049	440	1489
P. monodon	122	18	140
P. semisulcatus	1	43	44

For Orissa the catch can be aportioned as follows:

Species	Mechanized	Non-mechanized	Total
P. indicus	1	275	276
P. monodon	87	31	118

In Orissa much of *P. indicus* catch is landed along with *P. merguiensis* and *P. penicillatus.*

The catch quota for Tamil Nadu is given below.

Species	Mechanized	Non-mechanized	Total
P. indicus	2535	972	3507
P. monodon	121	27	148
P. semisulcatus	4090	491	4581

If all the states concerned limit their landing as aportioned above there should not be any danger of overfishing of these species and the economy of different sectors also could be maintained at a higher level. This objective can be achieved by limiting the number of units and mesh size at optimum levels based on the present effort and MSY, and effort relationship described in this report.

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