A review of the shrimp fisheries of India: a scientific basis for the management of the resources

E G Silas, M J George and T Jacob

Abstract

Shrimp are caught along most of the 6000 km long coastline of India. Total catches expanded rapidly between 1965 and 1973, but since then catches have fluctuated, and most recent catches have been below the peak of 220 000 tons in 1975. A number of different species are caught, with a variety of gears, including trawlers in the offshore grounds, and several types of traditional gear in the inshore and lagoon areas. Examination of catch and effort statistics from different areas suggest that many stocks are fully exploited. In most fisheries shrimp make up only a small part of the total catch, but except for some large trawlers on the east coast, this by-catch is brought ashore. The geographical and seasonal variations in the by-catch are discussed.

The varying objectives of management – biological, economic and social (including reducing conflicts between user groups) – are discussed. The problems include protection of the nursery areas in brackish waters, and control of fishing on the adult stocks. The various techniques that could be applied – seasonal and area closures, mesh regulation, limitation of fishing effort, and catch restrictions – are discussed.

1 Statement of the problem

The shrimp resources along the 6 100 km long coastline of India are being increasingly exploited both by the artisanal as well as industrial sectors. The pressure of fishing on existing stocks within the 75 m depth zone along the different regions of the coast is increasing with additional inputs of effort brought in by various programmes of mechanisation of the country craft and boats being implemented by the different maritime States as

well as the entry of large business houses into shrimp fishing. These activities have resulted in placing India as the top ranking nation for shrimp production in the world ever since 1973.

However, a study of the trend in total production of shrimp over the past several years would indicate that the steady increase in production was maintained till 1973, the catch almost doubling, by this time. Although showing a decrease in 1974, the maximum of 220 thousand tonnes was recorded in 1975. But thereafter there is a downward trend, showing wide fluctuations below 200 thousand tonnes. These fluctuations in total shrimp production in recent years has resulted in the decline in catches in some areas causing apprehensions of depletion of the resource. This concern is genuine calling for evolving urgent measures for the proper management and conservation of this resource. The problem is of a complex nature on account of the multi-species nature of the fishery in which a wide variety of craft and gear are used.

In order to keep track of the stock position of the resources of different regions, in addition to the data collected on the total shrimp landings by various gears and crafts, regular monitoring of the biological and population characteristics is maintained at important shrimp landing centres in the different maritime States. In order to determine whether there are any indications of biological or economic overfishing in any of the areas under exploitation, macro and micro analysis of shrimp catch and effort data of the areas concerned is necessary. Scientific input applying resource assessment models to the available data pertaining to different regions is required in order to resolve the problems concerning conservation and management of the exploited shrimp stocks and for the continued sustenance of the fishery. The Central Marine Fisheries Research Institute is conducting this analysis to a certain extent. However, further effort on these studies is necessary.

2 Shrimp fisheries

2.1 *The biology of major species*

Shrimp fisheries of the different regions and the biological aspects of economically important species of India are fairly well documented. Full bibliographies and reviews of the main features of shrimp biology are available in species synopsis papers and other publications by George (1970a, 1970b, 1970c, 1970d, 1972, 1978, 1979), Kunju (1970), Mohamed (1970a, 1970b, 1973), Rao (1970, 1973) and Kurien and Sebastian (1975).

About 62 species of prawns and shrimps of the family Penaeidae, of which some are either commercially exploited at present or have great commercial potentialities, occur in the Indian waters. The others belong to families Sergestidae, Palaemonidae, Oplophoridae, Hippolytidae, Pandalidae and Atyidae. Based on the natural habitat of the adults, these species can be broadly grouped under three categories of penaeids and non-penaeids, namely deep-water species, littoral species and fresh water species. Of these, the important species contributing to the fishery are: *Penaeus indicus* H. Milne Edwards, *P. monodon* Fabricius, *P. semisulcatus* de Haan, *P. merguiensis* de Man, *Metapenaeus dobsoni* (Miers), *M. monoceros* (Fabricius), *M. affinis* (H. Milne Edwards), *Parapenaeopsis stylifera* (H. Milne Edwards), *P. sculptilis* (Heller), *P. hardwickii* (Miers), *Solenocera crassicornis* (H. Milne Edwards), *Hippolysmata ensirostris* Kemp, *Exopalaemon styliferus* (H. Milne Edwards), *Nematopalaemon tenuipes* (Henderson), *Acetes indicus* (H. Milne Edwards), *Macrobrachium rosenbergii* (de Man) and *M. malcolmsoni* (H. Milne Edwards). Various aspects like distribution of adults as well as different stages of life history, reproduction, spawning, larval history, adult history, population and exploitation concerning the different species are dealt with in these reviews.

Recently studies on the movement and migration of some of the commercial species of shrimps in the fishery by mark recovery experiments have been initiated and these have given some interesting results. Tagging of different species in CMFRI by using the Petersen disc tagging method commenced in 1972. A total of 3 189 tagged shrimps, mostly *Penaeus indicus*, *Metapenaeus dobsoni*, *M. affinis*, and *M. monoceros* were released from Goa (424 shrimp), Cochin (1 564 shrimp) and Madras (1 201 shrimp) between 1972 and 1974. A recovery of 2·1% was obtained, indicating localised movements, ranging to a maximum of 19 km from the place of release, except a specimen of *M. dobsoni* recovered 60 km away from the release position and another 25 km away after periods of 10 and 8 days from release respectively. In all these places none of the shrimps released in the backwaters were recovered from the sea.

During the years 1976 to 1980 more concentrated efforts were made in tagging of shrimps at Cochin using the loop tag and releasing them in the sea as well as in the backwaters. Out of a total of 15 830 *P. indicus* and *M. dobsoni* released in the sea off Cochin, 1·6% were recovered, all of them within a period of a fortnight after release and up to 10 km from the site of release, indicating only

extremely limited movement. From 38 233 juvenile shrimps released in the backwaters of Cochin during these years only 0·8% was recovered. Among these recoveries only 6 specimens of *P. indicus* were obtained from the sea.

Although these results may probably be taken as pointing to the fact that the emigrant shrimps from the backwaters of Cochin are not the sole support of the shrimp fishery in the sea and that part of the brood produced in the sea remains there itself, only part of it migrating into the inside waters, further confirmatory evidence is necessary. A few recent recoveries of tagged shrimps using the loop tags released on the south west coast and captured from the south east coast may probably have far reaching implications concerning our approach to the assessment of the shrimp stocks of the different areas, their exploitation and management.

2.2 *Description of the fishery*

A section of the shrimp fishery of the country continues with the traditional crafts and gears, while mechanisation is slowly replacing the indigenous sector in several areas. The major development in mechanisation of shrimp fishery took place in the fifties with the introduction of shrimp trawling and at present trawling is being increasingly practised in most of the areas. In addition some of the indigenous gears like the 'dhol nets' of Maharashtra and gill nets of other areas are operated by mechanised boats. *Table 1* indicates the extent of shrimps landed in the country by the mechanised and non-mechanised sectors (average for the past 6 years).

Table 1

STATEWISE AVERAGE CATCHES (1974–79) OF SHRIMPS BY MECHANISED AND NON-MECHANISED SECTORS

State	*Shrimp catch mechanised*	*Shrimp catch non-mechanised*
Orissa	2544	458
Andhra Pradesh	5357	6300
Tamil Nadu	9109	4000
Kerala	26814	2800
Karnataka	4633	2200
Maharashtra	100000	9600
Gujarat	4600	6400
Total	153057	31758

2.2.1 *Fishing crafts* A variety of indigenous crafts is used in shrimp fishing, from the simple catamarans of the east coast to the well-built canoes of Maharashtra on the west coast. Motorised pablo boats and small and large sized trawlers are engaged in shrimp trawling. Ramamurthy and Muthu (1969) gave a detailed review of the fishing crafts and gears employed in the shrimp fishery of the country. Although the process of mechanisation of crafts has been in progress for the past several years, indigenous crafts like catamarans, canoes and plank-built boats are still operating in the small scale sector. According to 1973–77 census there were 106 480 non-mechanised crafts.

2.2.1.1 *Catamarans* The catamarans are primitive type of crafts used on the surf beaten coast, consisting of 3 to 5 logs tied together in a raft fashion. In different areas the size and number of the logs used vary slightly. Usually 2 to 4 men operate the craft.

2.2.1.2 *Canoes* Dug-out canoes are most common along the west coast, made by hollowing out a single log of wood and of varying sizes from 6·10 to 12·5 m length. Boat seines, shore seines, gill nets and cast nets are operated from those canoes often with a crew of 4 to 8 men. Plank-built canoes, out-rigger canoes and flat-bottom canoes are also in use in different areas.

2.2.1.3 *Plank-built boats* These are sturdy boats used in the northern part of both east and west coasts, used for bag net fishing. Manned by 7 to 12 men, these are considered most suited for mechanisation and quite a number of them have been mechanised. The length of the boat ranges from 6·5 to 13·0 m. The various types of plank-built boats have been indigenously evolved on the basis of their suitability for operation in the respective local conditions.

2.2.1.4 *Mechanised crafts* Motorisation of the indigenous crafts was the first step in the mechanisation of shrimp fishing. In due course many designs of small and medium sized mechanised boats to be operated from harbours and sheltered bays were introduced. The number of mechanised crafts currently in operation is 12 000. Shrimp trawling is mostly carried out by the Dan boats (6·6 × 2·2 × 1·0 m), Pablo boats (7·4 × 2·1 × 1·05 m) and shrimp trawlers (9·6 × 3·0 × 1·2 m and above). The horse power of the smaller boats ranged from 10 to 60. The larger of these boats are partly or fully decked and with trawling winches. Larger steel trawlers fitted with 90–300 HP engines and refrigerated fish holds are operated by some of the big firms as well as the Exploratory Fisheries Projects of the Government. The number of larger trawlers amounts to 75–100.

2.2.2 *Fishing gear* As in the case of fishing crafts, a variety of indigenous gears are operated for

capturing shrimps in addition to the trawl nets. Nearly 0·7 million gears of assorted types are operated in the country according to the 1973–77 census. Ramamurthy and Muthu (1969) reviewed the different types of gears in operation in shrimp fishing. According to the mode of operation the gears can be grouped under the following categories.

2.2.2.1 *Fixed or stationary nets* These include the various types and sizes of bag nets and stake nets operated against the flow of the tide in both inshore waters and brackish water areas. The bag nets constitute the most important gears for shrimp fishing in Bombay and Gunarat coasts, where they are locally known as 'Dol nets'. Depending on the manner in which these nets are operated there are two types, namely *Khunt fishing* and *sus fishing*. The nets are conical in shape, with a wide rectangular mouth. The size varies considerably, from 12 to 200 m in length with cod end mesh size of 10 mm. There are different types of bag nets operated in West Bengal and Andhra Pradesh also, locally known as '*Behundijal*' and '*Thoka vala*' respectively in these two areas. The fixed nets known as stake nets are in operation in the backwaters of west coast as well as east coast.

2.2.2.2 *Seine nets* The seine nets include the seines with or without bags (and wings). They are known as boat-seines or shore seines depending upon whether they are hauled from a boat or from the beach. One of the important gears operated by the indigenous craft along Kerala coast is the boat seine known as *Thangu vala* of various dimensions, usually operated by two dug-out canoes with 6 to 10 men. Boat seines of different types and dimensions are in operation for catching shrimps in other areas also.

Although the shore seines are mostly used for catching inshore pelagic fishes, prawns are also caught in these nets. Shore seines of varying sizes are in use in all the areas of the coastline.

2.2.2.3 *Cast nets or falling nets* These are very common and primitive gears used all along the coast and limited in their efficiency. They are operated by a single person very near the shore in the open sea as well as in the creeks and estuaries. The size of the net varies from 2·5 to 6·0 m in radius with webbing of mesh size 10 to 20 mm. The net is cast fully spread and as it closes traps the fishes and prawns in the water column below the net.

2.2.2.4 *Scoop nets or skimming nets* These are employed exclusively in the creeks and backwaters and comprise of the hand net, push net and lift net. The Chinese dip nets of Kerala backwaters is a type of lift net.

2.2.2.5 *Drift nets* The drift nets, also called gill nets, are passive wall nets of selective nature made of cotton, hemp or synthetic fibre. The gill nets are at present increasingly used in fishing larger sized shrimps from the sea in certain regions.

2.2.2.6 *Trawl nets* With the increase in demand for shrimps for processing and export, and the spread of mechanisation, stern trawling, particularly for shrimps, was attempted even with small mechanised boats and met with unprecedented success. Consequent to the expansion of the shrimp industry in a big way this new fishing method has come to stay, although indigenous crafts and gears are also being operated for catching shrimps to a certain extent.

Otter trawls are the most effective gears operated for shrimp fishing, the sizes of the trawl nets varying with the sizes of the crafts from which they are operated. Generally two or four seam trawl nets, overhang or non-overhang type with headline length of 7 to 27 m between the upper wing ends are used. Depending on the dimensions of the net and the towing power required the size and weight of the otter boats vary. The Indian Standards Institution has brought out requisite standards for the stern trawling gears for the different class of vessels.

Several new designs of trawling gear were introduced during the last few years. Design of a 15·25 m four-seam trawl for operation from a 9·45 m trawler is very popular. In addition to these trawls, bulged belly trawls are also in use. A 15 m bulged belly trawl suitable for 10·97 m trawler is being increasingly used. Some of the larger trawlers are resorting to out-rigger trawling.

2.2.3 *Historical review of catch trends*

2.2.3.1 *Total shrimp production* A look at the trends in the total production (*Table 2* and *Fig. 1*) over the past 20 years shows that from 1962 through 1968 the catch, although increasing, remained below 100 thousand tonnes. Banerji (1969) has indicated this by statistical analysis of the catches. Between 1969 and 1973 there was a steep increase, the catch almost doubling. After 1973 there were fluctuations from year to year, the production decreasing in 1974 to 170 thousand tonnes, reaching the maximum of 220 thousand tonnes in 1975 and again going down to less than 200 thousand tonnes in subsequent years. The shrimp production in 1979 was 177 582 tonnes, that for 1980 170 737 tonnes and 144 969 tonnes in 1981. The trend in triennial average catch shows an overall increase

Table 2
MARINE PRAWN LANDINGS OF INDIA (IN TONNES) FROM 1962 TO 1981

Year	*Penaeid prawns*	*Non-penaeid prawns*	*Total*
1962	48 251	34 984	83 235
1963	41 071	40 522	81 593
1964	63 389	31 506	94 895
1965	38 085	41 415	79 500
1966	56 146	34 768	90 914
1967	63 310	31 112	94 422
1968	69 514	31 922	101 436
1969	72 133	33 965	106 098
1970	89 857	31 834	121 691
1971	72 109	76 734	148 843
1972	78 361	85 488	163 849
1973	136 514	66 955	203 469
1974	114 934	55 244	170 178
1975	141 713	79 038	220 751
1976	114 640	76 787	191 427
1977	96 472	73 992	170 464
1978	129 204	50 652	179 856
1979	113 665	63 917	177 582
1980	112 037	58 700	170 737
1981	83 539	61 430	144 969

of more than 125% in the landings from 1962 to 64 and 1972 to 76, falling to less than 100% in 1977–79 and slightly less in later years.

2.2.3.2 *Shrimp landings from the west and east coasts of India* It is well known that the west coast of India accounts for more than 85% of the total marine prawn landings. As a result, the trend in the catches of this coast determines the trend in the total landings. This is clearly seen in the trend of catches of west coast which remained at a steady level up to 1968, thereafter showing a steep increase up to 1973 and then fluctuating. The percentage of increase in the triennial averages over the years is the same as that of the total landings.

The picture of the trend in catches along the east coast is quite different. Forming less than 15% of the total landings, the catches remained below 12 thousand tonnes up to 1966. In 1967, a sharp increase to above 24 thousand tonnes is noticed and this is kept up in the subsequent year also. Then, there is a steep decline through 1972 to about the landing figures of 1966. Once again, the catches rise and reach the maximum of above 28 thousand tonnes in 1975 with slight reductions in subsequent years. Although there is a sharp decline in the catches during 1970–72 the overall increase in percentage in the triennial average is about 150%.

2.3 *Statewise production of shrimp*

The major contribution of the fishery being from the west coast, the general trend in the total production is set by the landings of this coast, in which Maharashtra and Kerala States account for the bulk of the catch, 48% and 31% respectively. In the northern states of Gujarat, Maharashtra and Goa the maximum catches were in 1976, and were slightly lower in subsequent years (*Table 3*). Along the Kerala and Karnataka coasts the highest catches were recorded in 1973 and 1974 respectively with subsequent decrease. In Kerala slight improvement was noticed from 1976 onwards, but during 1979 there was a decline, reaching very low

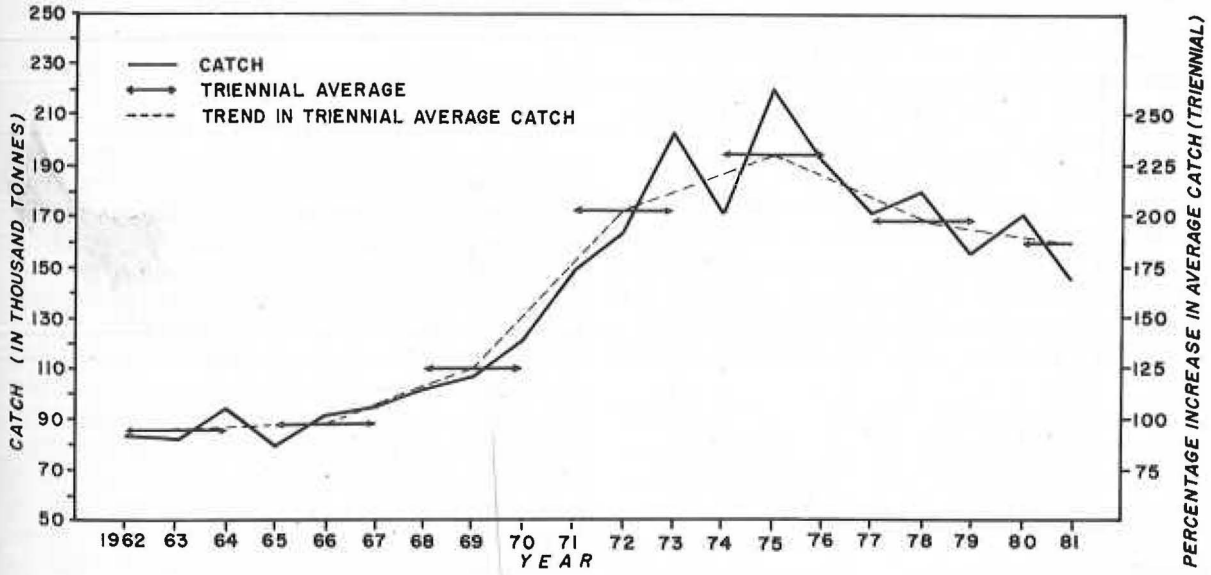

Fig 1 Trend in marine shrimp landings—India (1962–1981)

Table 3
TOTAL PRAWN LANDINGS IN 13 YEARS (1969–1981)

Maritime States	*1969*	*1970*	*1971*	*1972*	*1973*	*1974*	*1975*	*1976*	*1977*	*1978*	*1979*	*1980*	*1981*
West Bengal													1 495
and Orissa	5 638	3 016	1 500	1 471	3 051	3 487	5 707	5 635	1 690	3 879	3 588	1 304	1 383
Andhra Pradesh	6 064	6 890	9 205	5 582	8 839	12 699	10 675	11 108	11 375	9 563	11 814	10 006	8 335
Tamil Nadu	5 814	5 264	3 699	5 033	5 789	8 106	12 033	9 033	8 356	13 912	11 119	10 028	14 252
Pondicherry	614	447	290	182	41	29	64	93	105	316	604	527	389
Kerala	34 368	36 954	32 813	36 577	85 751	60 829	77 962	34 533	40 324	45 428	29 597	54 375	22 428
Karnataka	3 980	7 539	4 420	8 075	8 236	12 696	3 074	2 594	3 335	8 440	4 660	3 226	4 126
Goa	559	627	279	561	785	1 448	1 762	4 643	1 460	1 673	1 594	1 853	2 237
Maharashtra	45 780	57 345	93 611	104 125	80 349	64 737	93 665	104 474	93 653	85 346	101 846	70 742	74 571
Gujarat	3 273	3 599	3 014	2 231	10 620	6 119	15 781	19 275	10 121	11 034	11 953	18 590	15 727
Andamans	8	10	12	12	8	28	28	39	45	265	64	54	26
Larger private trawlers	—	—	—	—	—	—	—	—	—	—	743	32	—
All India total	106 098	121 691	148 843	163 849	203 469	170 178	220 751	191 427	170 464	179 856	177 582	170 737	144 969

production and showing improvement again in 1980. In 1981 an all time low catch is recorded. In Karnataka there was considerable improvement in landings in 1978, but a decrease in 1979 to 1981. On the east coast both Andhra Pradesh and Tamil Nadu show significant improvement in shrimp landings in recent years.

2.3.1 *Data base* The Central Marine Fisheries Research Institute (CMFRI) is the nodal organisation in India for the collection of marine fish catch statistics and data on biological and related oceanographic and ecological characteristics on a nation-wide basis. The data are collected on a sample system throughout the year.

The Institute has played a pioneering role in developing a suitable sampling design for the collection for catch data from a large number of landing centres spread over the entire coastline. The procedures have been undergoing modifications to accommodate the innovations introduced in the fishing industry from time to time.

At present the Institute is following a stratified multistage probability sampling design for estimation of marine fish landings in the country. The design involves a space-time stratification. Each maritime state is divided into zones based on criteria such as intensity of fishing, type of fishing and geographical conditions. A zone consists of about 20 to 30 landing centres. A ten-day period in a month forms the time-stratum. From the first five days of the month a day is selected randomly which together with the next 5 consecutive days form the first cluster. The next 6 days from the other two groups of ten days are so selected that a ten-day gap falls between the starting day of two consecutive clusters. Three centres are randomly selected for observations over 6 days and each selected centre is observed for two days, first day in the afternoon and second day in the morning for a six-hour duration each day. On the day of observation, based on the landing of a sample number of boats (units) selected in a systematic way, detailed recordings are made on items such as species-wise composition of catch, type of crafts and gears used and effort. The total number of boats landed during the observation period is also recorded. A sub-sample of commercially important fishes is collected for biological observation. Landings at night which are generally of a much smaller magnitude are recorded through careful enquiry.

In zones where considerable variation is observed in the landing pattern, sub-stratification is made based mostly on the intensity of landings and sampling is done from within the substratum.

In fact the stratification procedure often undergoes continuous change depending on the intensity of landings. Work programmes are prepared according to the random procedure every month afresh for implementation at the field level.

From the landings of selected boats (units) the landings for all the boats (units) landed during the observation period are estimated first. By adding the estimated quantities landed during the two six-hour periods and during the night (12 hours) the quantity landed for one day (24 hrs) at a centre is calculated. By using appropriate raising factors the monthly zonal landings are estimated. By pooling the zonal estimates for all the months the figures of annual landing are obtained. The standard errors of the estimates are also computed for the annual estimates of catch.

The Institute maintains a well-trained field staff in 42 research/field centres located along the coastline to monitor the catch. They are specially trained to identify the various species and to collect the needed biological statistics. The scientific and senior technical personnel posted at headquarters and different research centres to implement the research programmes of the Institute carry out supervision of the work of the collection of statistics at the field level.

The data collected for a month are sent within the first ten days of the succeeding month to the Data Centre maintained at the headquarters of the Institute. Scrutiny and processing of data are done by a team of qualified computing staff using partly calculators and partly programmable computers. The processed results are examined and interpreted and the information is disseminated periodically through the Institute's publications.

Some of the states like Maharashtra, Gujarat and Tamil Nadu are also collecting catch statistics from the landing centres in these states employing random sampling procedures. Frequent dialogues are arranged between the scientists of the Institute and the officials of the State Fisheries Departments to examine the figures obtained by the two agencies. Following the recommendation of the National Commission on Agriculture, an integrated methodology is being evolved so that the CMFRI and the State Departments may be able to combine their efforts to arrive at more precise estimates. In case of states where no system of collection of catch statistics exists, the CMFRI is giving the necessary technical support.

The Institute publishes state-wise and species-wise estimates of fish catch and supplies the details to national and international agencies. The species are combined to form 27 groups among which shrimps are categorised as penaeid and non-penaeid prawns.

The types of crafts used, both mechanised and non-mechanised, with further details are recorded during the observation period. Information on total manhours of fishing is also collected. However, gearwise estimates of effort for any particular species poses a major problem as the fishery is one of multiple species operated by multigears. Standardisation of the effort for selected commercially important species with reference to the most important gear prevalent in an area is being attempted.

2.4 *Assessment of shrimp stocks*

2.4.1 *Models for stock assessment* The study of the effect of different levels of fishing on the fish stock is essential for arriving at suitable management policies. The analytical method usually employed aims at estimating the yield per recruit under a particular set of fishing conditions. The Beverton and Holt model is commonly used for the purpose and is expressed as

$$Y/R = f(F, M, K, W, T_0, t_r)$$

where F, M are fishing and natural mortalities, K, W and t_0 are parameters of growth and t_r the age of recruitment to the fishery. For changes in the parametric values, it is possible to predict the corresponding yield per recruit. Reliable estimates of the various parameters are, however, required for the application of the model. Mortality estimates for shrimps have been studied by several workers (Banerji and George, 1967; George *et al*, 1968; Kurup and Rao, 1974; and others).

Another model which is based on the law of diminishing returns can be derived under equilibrium conditions, as

$$Y/f = a - bf$$

where Y is the catch and f is the effort. In a heavily exploited stock the catch per unit effort (CPUE) generally decreases as the effort is increased. Using data on Y/f and f for several years the constants a and b can be estimated by least square procedure. The corresponding yield curve is given by

$$Y = af - bf^2$$

The equation shows that the catch increases with initial stages of increase in effort, reaches a maximum at a particular level of effort and then decreases with further increase in effort. The curve has a maximum at $f = a/2b$ and the maximum sustainable yield (MSY) will be $a^2/4b$.

2.4.2 *Yield curve at particular centres* Using the data on CPUE and effort in respect of shrimp fishery for about ten years in nine important centres in the Indian coast, the MSY and the corresponding optimum effort have been worked out. The results are summarised in *Table 4*.

Table 4

ESTIMATED MSY AND CORRESPONDING EFFORT AT MAJOR PRAWN LANDING AREAS IN INDIA. VALUES FOR 1980 ARE SHOWN FOR COMPARISON

	Values at MSY		*1980 values*	
Centre	*Catch (tons)*	*Effort ('000 boat days)*	*Catch*	*Effort*
Sasson Dock (Bombay)	2 980	39·8	3914	18·0
Karwar	538	10·7	557	5·2
Mangalore	1 715	30·5	980	31·5
Calicut	760	18·7	355	8·7
Cochin	4 426	48·7	3516	44·0
Neendakara	53 487	465·9	36 568	150·0
Mandapam	363	23·8	(b)	
Madras	920	94·0	(b)	
Kakinada	(a)	(a)	2580	40·0

(a) c.p.u.e. increases with effort; so no fit to production model possible
(b) not available.

Figures 2–10 show the graphs of catch plotted against effort and the fitted equation relating the two. The relationship between CPUE and effort is also shown in the same graph as a dotted line. As seen from *Table 4*, for the fisheries around Sasson dock, Karwar, Mangalore, Calicut, Cochin, Neendakara, Mandapam and Madras the indication is that increasing the effort beyond the optimum value is not likely to increase the yield. In Kakinada on the other hand, the slope of the regression line of CPUE on effort was positive indicating that the fishing effort does not have any detectable effect on the CPUE.

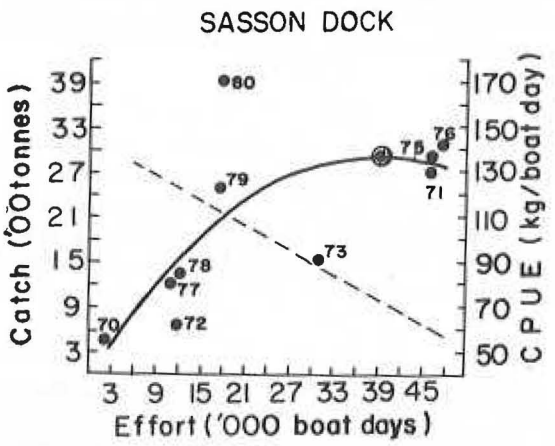

Fig 2 Catch and catch per unit effort related to effort in shrimp catches at Sasson Dock, Bombay (Maharashtra) (1979–80). ◉ Indicates level of maximum sustainable yield (MSY) in figures 4–12

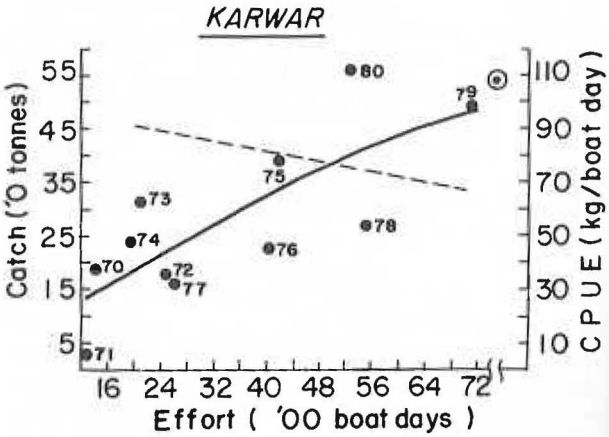

Fig 3 Catch and catch per unit effort related to effort in shrimp catches at Karwar (Karnataka) (1970–80)

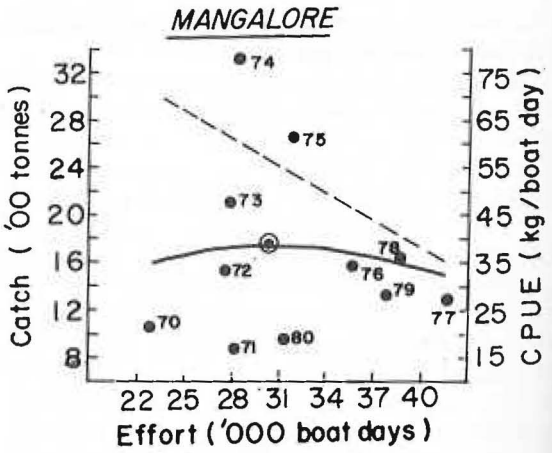

Fig 4 Catch and catch per unit effort related to effort in shrimp catches at Mangalore (Karnataka) (1970–80)

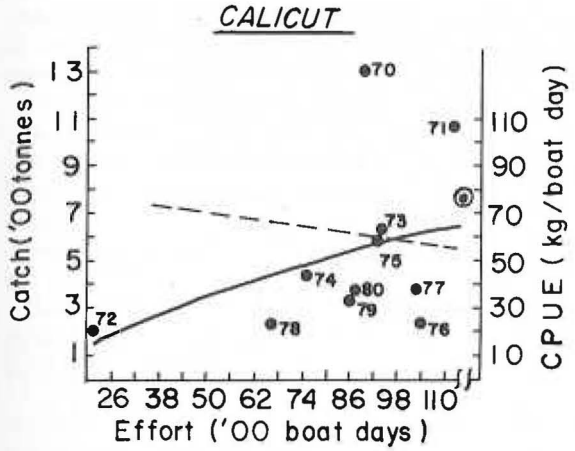

Fig 5 Catch and catch per unit effort related to effort in shrimp catches at Calicut (Kerala) (1970–80)

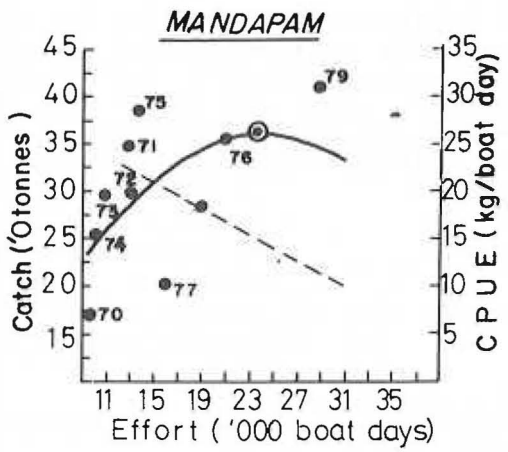

Fig 8 Catch and catch per unit effort related to effort in shrimp catches at Mandapam (Tamil Nadu) (1970–79)

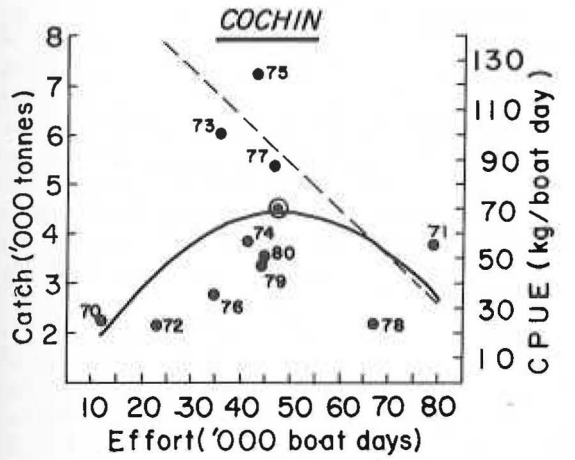

Fig. 6 Catch and catch per unit effort related to effort in shrimp catches at Cochin (Kerala) (1970–80)

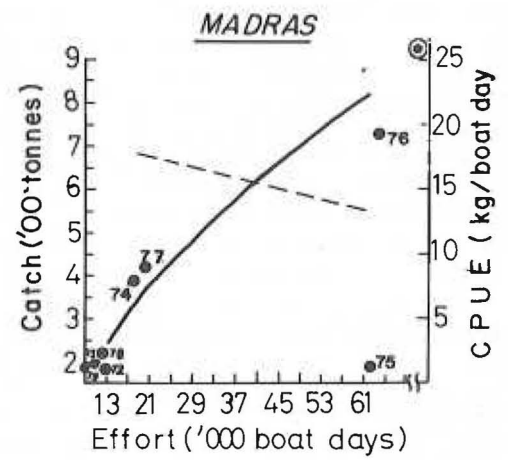

Fig 9 Catch and catch per unit effort related to effort in shrimp catches at Madras (Tamil Nadu) (1972–79)

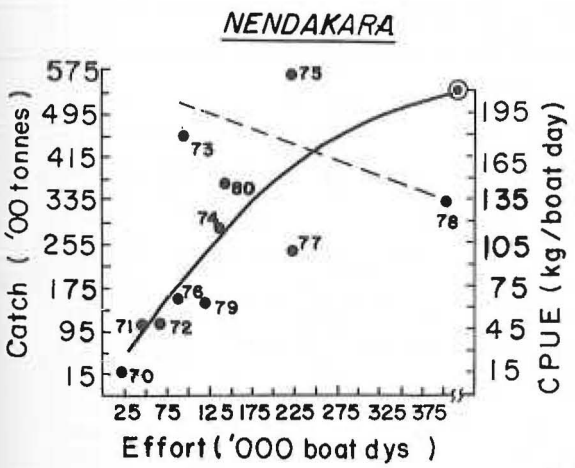

Fig 7 Catch and catch per unit effort related to effort in shrimp catches at Neendakara (Kerala) (1970–80)

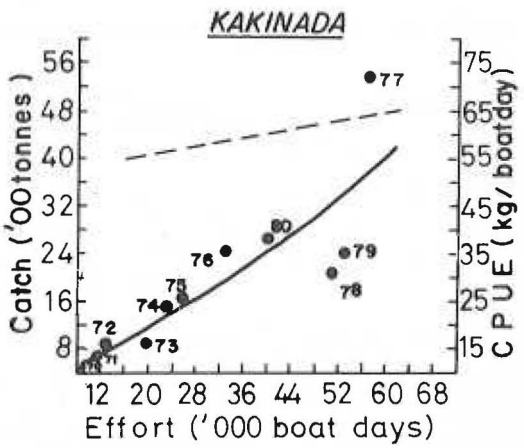

Fig 10 Catch and catch per unit effort related to effort in shrimp catches at Kakinada (Andhra Pradesh) (1970–80)

2.4.3. *Estimation of growth parameters* There are conventional methods for estimation of growth and mortality parameters. However, these need to be critically examined, especially when we consider their application to tropical fisheries with their special features like multiple spawning in one year and short life span. The Institute is examining these problems both from the theoretical and applied aspects. The results of a case study for estimation of growth parameter of one of the species of commercial shrimp are included here. Monthwise length frequency data (total length in cm) for 1980 pertaining to *Metapenaeus dobsoni* from Cochin area of Kerala State have been analysed following the procedure given by Pauly and David (1981) for extraction of growth parameters from length frequency data which involves tracing through a series of length frequency samples sequentially arranged in time, using a range of alternative growth curves and selecting the single curve that passes through a maximum number of peaks. Using a suitable computer programme the best fitting curve was selected from the series of combinations generated. The estimates of asymptotic length and the growth coefficient that best explains the peaks were L_∞ = 12·5 cm and K = 0·13 respectively. These are very close to the estimates of these parameters for the same species in the fishery of Cochin in earlier years by Banerji and George (1967).

3 Other species in shrimp fishery

3.1 *Estimates of catches*

A considerable quantity of fishes by way of by-catch from shrimp trawling as well as indigenous shrimp fishery, consisting of both trash fishes of cheaper varieties and quality table fishes is landed in India. Thus a bottom fishery or demersal fishery of very high magnitude exists in the country. These landings are estimated in the same way as the catches as described elsewhere in this review. In a total marine landing of 1 388 380 tonnes in 1979, 640 027 tonnes were contributed by demersal catches, inclusive of indigenous fishery. The statewise details are given in *Table 5*. In the total landings of 398 945 tonnes in 1979 by smaller shrimp trawlers the fish and other miscellaneous by-catches apart from shrimp amounted to 315 902 tonnes forming 79·18% of the total (*Table 6*).

The details of landings (provisional) of commercial shrimp trawlers at some selected centres in the different maritime states during 1980 is given in *Table 7*. It is seen that among all the centres Sakthikulangara (Neendakara) in Kerala State shows the maximum number of units operated as well as the greatest landings of both fish by-catches and shrimps. It is interesting to note that the percentage of by-catch during the year is also at the minimum of 54·98 in this Centre. At Cochin, the other centre of observation in Kerala, the percentage of by-catch is also comparatively low. Sassoon Dock in Bombay comes next in the quantity of by-catch and shrimps landed by the trawlers, as can be seen in the table.

From the total by-catch including various groups of fishes and miscellaneous items consisting of crustaceans other than shrimps, cephalopods *etc* only a negligible quantity is discarded. In addition to the landed by-catch of 315 902 tonnes in 1979, only an insignificant quantity consisting of Squilla and miscellaneous items such as young ones of

Table 5
STATEWISE DISTRIBUTION OF BOTTOM FISHERY DURING 1979 (IN TONNES)

State	*Trawler catch*		*Total demersal catch including indigenous*	*Total marine catch*
	Shrimps	*Fish*		
West Bengal	—	—	4 325	10 744
Orissa	2 160	7 275	28 675	51 808
Andhra Pradesh	5 373	23 312	49 377	91 426
Tamil Nadu	8 216	83 496	122 085	235 008
Pondicherry	492	3 158	4 273	10 068
Kerala	24 512	54 952	102 237	330 509
Karnataka	3 857	18 157	28 495	126 384
Goa	1 559	6 493	9 558	25 388
Maharashtra	31 242	48 788	186 102	293 326
Gujarat	5 632	70 271	86 836	191 312
Andamans	—	—	576	1 721
Lakshadwip	—	—	648	3 846
Private trawlers (Large)	743	16 097	16 840	16 840
Total	83 786	331 999	640 027	1 388 380

Table 6

LANDINGS OF SHRIMPS AND BY-CATCHES OF COMMERCIAL TRAWLERS IN DIFFERENT MARITIME STATES DURING 1979 TO 1981 (IN TONNES)

States	1979				1980				1981			
	Shrimp	By-catch	Total	% of by-catch	Shrimp	By-catch	Total	% of by-catch	Shrimp	By-catch	Total	% of by-catch
Gujarat	5632	70271	75903	92·6	10315	73718	84033	87·7	8805	89994	98799	91·1
Maharashtra	31242	48788	80030	60·9	15107	41394	56501	73·3	14908	35858	50766	70·6
Goa	1559	6493	8052	80·6	1707	10095	11802	85·5	2025	12051	14076	85·6
Karnataka	3857	18157	22014	82·5	2445	17034	19479	87·4	3235	29235	32470	90·1
Kerala	24512	54952	79464	69·2	46161	59900	106061	56·5	16305	33008	49313	67·0
Tamil Nadu	8216	83496	91712	91·1	6114	76333	82447	92·6	11684	92761	104445	88·8
Pondicherry	492	3158	3650	86·5	443	2556	2999	85·2	300	3227	3527	91·5
Andhra Pradesh	5373	23312	28685	81·3	3891	15768	19659	80·2	5045	21128	26173	80·7
Orissa	2160	7275	9435	77·1	843	7678	8521	90·1	1241	4781	6022	79·4
All India	83043	315902	398945	79·2	87026	304476	391502	77·8	63548	322043	385591	83·5

Table 7

LANDINGS OF SHRIMP AND BY-CATCHES (IN TONNES) OF COMMERCIAL SHRIMP TRAWLERS AT SELECTED CENTRES DURING 1980 (PROVISIONAL)

Centres	Number of units operated	Total landings	Prawn catch	Other Crustaceans	By-catch			Percentage of by-catch in total landings
					Fish	Miscellaneous items	Total	
Bombay (Sassoon Dock)	21469	18144	5138	4	12924	78	13006	71·68
Mangalore (Tadri)	7922	2417	353	1	1779	284	2064	85·39
Cochin	46096	7912	3514	704	3416	278	4398	55·58
Sakthikulangara (Neendakara)	172732	81213	36559	4167	36607	3880	44654	54·98
Tuticorin	31517	6417	534	12	5871	—	5883	91·67
Mandapam	25143	2533	217	151	2047	118	2316	91·43
Rameswaram	78758	14378	1367	602	11692	717	13011	90·49
Nagapatnam	9307	2007	125	26	1729	127	1882	93·77
Cuddalore	16012	1969	121	31	1642	175	1848	93·85
Pudumanikuppam	13154	1416	165	62	919	270	1251	88·34
Kakinada	41174	9025	2698	352	5557	418	6327	70·10
Visakhapatnam	35406	8051	784	400	6325	542	7267	90·26

fishes and shrimps and crabs were normally discarded. In addition in the case of the smaller trawlers when the shrimp catches are unusually heavy occasionally the fish by-catches are discarded over board due to lack of space for storage and the quantity thus thrown out is not known. From the larger trawlers operated, most of the smaller fish by-catch is discarded at sea, about which data is not available.

3.1.1 *Species composition of fish in by-catch* The by-catches landed by shrimp trawlers include a wide variety of demersal fishes and a few species of cephalopods and crustaceans other than prawns. Among fishes, the most common items represented in the landings of the different maritime states are: Elasmobranchs, eels, catfishes, dorabs, lizard fish, perches, polynemids, sciaenids, ribbonfishes, carangids, silver bellies, white fish, barracudas and soles.

Elasmobranchs: This group, represented by sharks, skates and rays, is one of the common items of fish caught in shrimp trawls all along the west and east coasts and constitute nearly 5% of the annual landings of by-catches in the country. Out of 15336 tonnes of elasmobranchs landed during 1979 more than 68% was recorded from Maharashtra and Tamil Nadu alone, forming 10·3% and 6·6% of the by-catches of these states. They occur in the trawl nets almost throughout the year, with peak landings during November–March along the coasts of Gujarat, Maharashtra and Kerala and during August–November in Tamil Nadu and Andhra Pradesh. The sharks caught are generally smaller in size than the huge fish captured very often in hooks and lines and other indigenous gears. Rays of all sizes up to about 2 m across the disc are encountered and they form the major component of the elasmobranch catch.

Eels: Although not so very abundant as other groups, two species *Muraenesox talabonoides* and *M. cinereus* are met with very often in the trawl catches of northwest coast and to a limited extent in the east coast. The highest catches are recorded in Maharashtra where they accounted for 5·4% of the total by-catches during 1979. *M. talabonoides* (wam) is the more common and measures a maximum of about 2 m in total length.

Catfishes: The catfishes form one of the common elements of the by-catches all along the Indian coasts and contribute to about 3% of the total landings. Maximum catches are recorded from Maharashtra and Kerala where they are caught throughout the year with peak abundance during the summer period (March–May). The catfishes obtained in shrimp trawls include a large number of species mostly of the genus *Tachysurus* and are generally in the size range 15–75 cm.

Dorabs: The dorabs or wolf herrings (*Chirocentrus dorab* and *C. nudus*) occur rarely in the trawl catches. In Gujarat they are encountered almost regularly from November onwards till the onset of monsoon.

Lizard fish: Contributing to about 3% of the total by-catches the lizard fish *Saurida tumbil* and allied forms constitute an important item of the catch landed in Kerala with peak abundance during the monsoon period. In other states like Maharashtra, Tamil Nadu and Andhra Pradesh also fair quantities are recorded occasionally during the non monsoon periods. The common size range is about 15–40 cm.

Perches: The occurrence of several varieties of small and medium sized perches in shrimp trawls is a regular feature throughout the west and east coasts. *Nemipterus japonicus* (Kilimeen in Malayalam) is the most common species caught in Kerala where this group forms the largest component of the by-catches (31·1%) landed. Its peak abundance is observed during the southwest monsoon period. Other common perches are species of *Pomadasys*, *Lutjanus*, *Gerres*, *Kurtus*, *Sillago*, *Drepane* and *Therapon*. *P. hasta* locally known as 'Karkara' is a highly sought-after species occurring more frequently in Bombay–Saurashtra waters.

Polynemids: The thread fins contribute to the by-catches in minor quantities in Maharashtra, Tamil Nadu, Andhra Pradesh and Orissa. In Bombay waters they form a sizeable portion of the catch and are chiefly represented by two species namely *Polynemus heptadactylus* (Shende) and *P. indicus* (Dara), the former growing up to about 30 cm and the latter to 140 cm in total length.

Sciaenids: Of all the by-catch categories sciaenids, popularly known as 'Jewfishes', are the most common and are represented by various sizes up to about 120 cm. In 1979 they accounted for nearly 21% of the total by-catches of the country ranking first among the categories. The bulk of the landings was contributed by Gujarat and Maharashtra where the catch consists of two large growing species namely *Pseudosciaena diacanthus* (Ghol) and *Otolithoides brunneus* (Koth) and a number of smaller species collectively known as 'Dhoma' belonging to the genera *Johnius*, *Otolithus* and *Sciaena*. Substantial quantities of sciaenids are also landed in Tamil Nadu and other neighbouring areas of the east coast.

Ribbon fishes: They occur in moderate quan-

tities all along the Indian coast contributing to nearly 5% of the total by-catches. Maximum landings are recorded in Gujarat and Maharashtra.

Carangids: Several species of *Caranx* and allied forms are often encountered in shrimp trawls as minor catches all along the west and east coast. The carangids thus caught are generally smaller in size rarely exceeding 30 cm. They are relatively more common on the east coast where peak landings are recorded during the first quarter of the year.

Silver bellies: This is the second dominant item of the by-catches and contributes to about 14% of the annual landings. Out of 43 728 tonnes landed during 1979 nearly 90% was caught from Tamil Nadu coast alone. A number of species of the genus *Leiognathus* and a single species of *Gazza* (*G. minuta*) comprise the silver bellies catch, the former group being dominant. In Tamil Nadu the silver-bellies are caught in trawl nets throughout the year, the maximum catches being recorded from February to May.

White fish: The white fish *Lactarius lactarius* is one of the quality fishes caught in trawls occasionally. It is more common in the northwest coast and Tamil Nadu where the catch is generally represented by small and medium sized fish measuring 5 to 15 cm length.

Pomfrets: Like the white fish, pomfrets are also quality fishes occurring all along the Indian coasts but generally as stray numbers in the by-catches. In Bombay–Saurashtra coast, however, they are caught quite often in fair quantities and are represented by three types of which the brown-pomfret (*Parastromateus niger*) and silver-pomfret (*Pampus argenteus*) are dominant. The former species grows to fairly large size, with the sizes ranging from 10 to 30 cm.

Barracudas: One of the less common groups of by-catches, the barracudas are represented by a few species of *Sphyraena*.

Soles: The soles and other flat fishes form a regular component of the trawler landings throughout the Indian coasts and contribute to about 3% of the annual by-catch production. Maximum quantity is landed in Kerala. Except for a few large growing species like the Indian halibut *Psettodes erumei* (Aayirampalli in Malayalam) and the large 'tongue soles' *Cynoglossus dubius* and others caught occasionally the bulk of the catch is constituted by the smaller species *C. semifaciatus* popularly known as Malabar sole. The usual size is about 8–15 cm. At Neendakara in Kerala they are caught almost throughout the year with peak landings during the monsoon period.

Other crustaceans: Besides shrimps, the trawlers land considerable quantities of other crustaceans as by-catches, amounting to about 5%. Crabs and stomatopods are the most common and they occur in more or less equal proportions in the total catch. In 1979 nearly 50% of these items were landed in Kerala, followed by substantial quantities in Karnataka and Tamil Nadu. The crabs are predominantly represented by *Portunus pelagicus* and *P. sanguinolentus* and the stomatopods by a single species namely *Oratosquilla nepa*. Peak landings are observed during November–February along the west coast and May–October on the east coast. The spiny lobster *Panulirus polyphagus* is another important crustacean by-catch landed on Maharashtra and Gujarat coasts. Similarly, the deep-sea spiny lobster *Puerulus sewelli* has been trawled in considerable quantities along with shrimps from 250–400 m depth off Kerala coast.

Cephalopods: Squids and cuttlefishes contribute nearly 4% of the total by-catches of the country. Out of 10 229 tonnes landed in 1979 over 73% was obtained in Maharashtra and Gujarat. November–May is the period when the maximum catch is landed. In Kerala also substantial quantities are landed particularly during August to November. *Loligo duvaucelli*, *Sepia pharaonis*, *S. aculeata* and *Sepiella inermis* are the common species, the former three being mostly represented by the size group 10–25 cm and the other by 5–10 cm in mantle length.

Miscellaneous: In addition, several species of trash fishes, both demersal and mid-water forms, are landed regularly at all centres of the coast. In the overall by-catch landings they collectively account for about 25%.

The distribution and occurrence of these varieties of fishes vary considerably in the different shrimp fishing grounds along the coast. Their exploitation, distribution and resources in general have been studied by Rao (1973) and Silas *et al* (1976) and different varieties in particular by others. However, no assessment of the direct effect of the fish stocks and their fisheries on shrimp fishing has been made.

3.2 *Biological interaction between fish and shrimp*

The relative abundance of different fishes in the trawl grounds in relation to shrimp catches in various regions along the north west coast was studied by Rao *et al* (1966). Similar studies in other areas along the coast of India were undertaken by Rao (1973) and others. The catch rates were given and these are reliable measures for determining the difference in abundance between regions.

George *et al* (1968) studying the fishery in the trawl grounds off Cochin from 1956–57 to 1962–63 recorded considerable variation in the percentage of fish in the shrimp grounds. The variations in the composition of fishes in these trawling grounds could be seen in *Table 8*. The wide monthly variations in the percentage composition of the shrimps and fishes may be brought about by the biological interaction between these organisms in these grounds. Such variations in percentage composition of shrimps and fishes in the catches from trawling grounds have been noticed in other areas also (George *et al*, 1980),

3.3 *Shrimp catch in non-shrimp fishery*

A few shrimp are taken in the mechanised fisheries using gears other than trawls, but the quantities are very small (see *Table 9*).

4 Environmental aspects

4.1 *Natural variations*

In a detailed study of the various aspects of the shrimp fishery of Cochin area based on the catches of the trawling vessels of the Exploratory Fisheries Project and the Integrated Fisheries Project through the seasons 1956–57 to 1962–63, George *et al* (1968) explained the decrease in the total catch and the catch rate by natural fluctuations in the fishery. George *et al* (1968) also indicated that the fluctuations in the fishery are due to natural causes. Banerji (1969) studying the shrimp production in India through the years 1959 to 1968 found a rising trend with minor fluctuations and according to him these fluctuations round the trend were random brought about by natural causes. Mohamed (1973) analysing the trend in fishery of penaeid shrimps of the country also found only natural fluctuations. Natural variations in recruitment of different species into the fishery South of Cochin were studied by Kurup and Rao (1974).

Table 9

DETAILS OF SHRIMP CATCH (IN TONNES) IN OTHER FISHERIES DURING 1979

Maritime States	*Drift/Gill net (mechanised)*		*Purse seine*	
	Shrimp	*Total catch*	*Shrimp*	*Total catch*
Gujarat	6	20929	—	—
Goa	1	2199	1	8196
Karnataka	—	—	1	66198
Tamil Nadu	3	262	—	—
All India total	10	23390	2	75104

4.1.1 *Relation to environmental factors* Changes brought about by the physico-chemical disturbances in the environment are known to influence shrimp landings in the areas of 'mud bank' formations during the south west monsoon period along the south west coast of India (Banse, 1959; George, 1961; and George *et al*, 1968). In the 'mud bank' area George (1961) recorded in the monsoon months of active fishery higher shrimp landings along with decreased oxygen and temperature and higher salinity and pH in comparison with areas of lesser fishery, indicating an apparent influence of these environmental factors on the fishery.

Factors influencing shrimp catches in the backwater fishery of Cochin were studied by Menon and Raman (1961). They particularly observed the influence of rainfall on the catches, as there is a regular belief among fishermen and others connected with shrimp fishing that rainfall exerts a direct influence on the fishery. Their study indicates that there was direct relationship between

Table 8

PERCENTAGE COMPOSITION OF BY-CATCH OF FISHES IN THE FISHERY OFF COCHIN DURING 1956–57 TO 1962–63

Months	*1956–7*	*1957–8*	*1958–9*	*1959–60*	*1960–1*	*1961–2*	*1962–3*
August	—	54·6	—	—	—	—	—
September	—	—	99·7	—	—	96·3	78·5
October	—	94·0	99·8	98·2	98·7	82·4	68·8
November	—	83·7	72·8	52·6	96·5	77·3	71·9
December	—	39·5	63·8	84·3	63·6	47·6	55·3
January	88·1	41·6	48·2	74·5	80·8	53·8	69·3
February	46·8	78·6	64·7	67·3	85·2	54·8	51·0
March	58·3	78·7	47·0	86·8	79·1	64·0	78·2
April	57·6	49·6	23·9	84·5	69·1	53·4	88·5
May	35·0	44·7	38·3	72·8	81·0	47·6	76·6
June	26·0	18·8	—	18·0	69·9	40·0	29·7
Average	46·5	52·9	52·8	87·3	80·9	57·8	70·6

the catches and the annual rainfall. They also indicated the possibility of the monthly catches being directly affected by rainfall in one year, probably the stock abundance or recruitment being influenced by rainfall.

Relationship of the backwater shrimp catches with the phases of the moon also was investigated by Menon and Raman (1961). During the two year period of their study the highest catches were recorded on the day of new or full moon or a day or two later, indicating a relationship between the availability of shrimps and lunar periodicity. They were of opinion that the stronger tidal currents on these days forcing a larger volume of water through the nets as well as the lunar phase causing active movements of these shrimps, together resulted in improved catches. The effect of lunar periodicity on the catches of shrimps and their movement in and out of the Godavari estuarine system was studied by Subramanyam (1965).

4.1.2 *Possibilities of prediction* The possibility of using postlarval abundance as an index of fishing success in shrimps was indicated by George (1963). He tried to correlate the recruitment of the postlarvae into the backwaters of Cochin and the subsequent population contributing to both the backwater and marine shrimp fishery and expressed the opinion that this factor could possibly be used for forecasting the magnitude of the fishery.

4.2 *Impact of other human activities on the fishery* Man's activities involving steady incursion into the brackish-water areas such as large scale reclamation for agricultural purposes, destruction of mangroves, diversions of water flows in and out for industrial and agricultural needs, usage of waters for disposal of industrial wastes, exploitation for extraction of underlying mineral deposits *etc* pose an ever-increasing threat to the fishery resources dependent on these areas. George (1973) discussed the influence of backwaters and estuaries on shrimp resources of the country and established that in view of the inseparable link between shrimps and brackishwater environments, the least possible disturbance of the brackishwater habitat is essential for continued high productivity of their resources.

The changes brought about by the activities of man are those caused by (1) changes in total area of brackishwater habitat resulting from large-scale reclamation for agricultural purposes as is happening in the southern half of the Vembanad Lake, (2) protective works such as stream diversion spillways, salt-water barriers like the Thanneermukkom bund being constructed in Vembanad Lake, and tide control structures, (3) pollution of the waters by domestic, industrial and agricultural wastes such as dumping of solid wastes from mining operation of iron ore, industrial sludge from steel mills *etc* and (4) development of mineral resources by dredging of fossil shell deposits. These changes in the environments affect the estuarine phase of the life of the commercial shrimp in any one or more of the following ways, namely, general reduction in acreage of the habitat, change in circulation and thus affecting distribution of salinity, temperature, *etc*, lessening of average depth, impeded exchange of fresh and salt-water, loss of tidal exchange benefits, restricted influx of salt-water, change in water chemistry due to presence of toxic compounds, increased silt load, *etc*. In general the estuarine habitats are affected in two major ways, either by a net loss of total acreage available or by a change in mean salt content and chemical composition. Among others Menon (1967) expressed grave concern about the possible detrimental effects of environmental changes in Cochin backwaters to the prawn resources of the area.

As a result of the rapidly advancing civilisation deterioration in the estuarine habitat is undoubtedly taking place in several areas. The question is what steps could be taken to prevent serious damages to the important biological resources of the estuaries and consequently on the dependent marine resources. Supposing, for instance, that the erection of a particular spill-way or salt water barrier would create a situation of chronically high or low salinity in an area and that over the years this condition in turn would result in decline in production from the coastal fisheries, the amount of projected monetary loss and the benefit-cost ratio will have to be taken into consideration before finalising the project. The Thanneermukkam barrier constructed across the southern half of the Vembanad lake in Kerala State is a salt water extrusion project and its effect on the fishery resources of the area has been under investigation. George and Suseelan (1980) reported that the distribution of the juveniles of penaeid shrimps into the upper reaches of the lake has been affected by the construction of the bund.

5 Management

In view of the fast tempo of development in increasing exploitation and its effect on total and regional shrimp production from the coastal fishery, there is great need for increased research into the resources and devising of proper approach

to management by determining several factors like the permissible yield, suitable gear which will not destroy the resource or damage the habitat and restrictions to be effected in the fishery, if any, in order to get the maximum economic return. There are several factors which make the problem of proper management of the coastal shrimp resources, as in the case of any other resource, highly complex. The facts are very often difficult to ascertain with certainty or quite often when some management measure is indicated based on proven facts the implementation poses problems.

The penaeid shrimp resources of the country which constitutes the coastal shrimp fishery occupy different eco-systems such as estuaries, inshore and offshore waters and in most of the areas along the coastline commercial fishing is well established in these different environments. The constituent species and fishery in each of these environments being the same and interdependent, any approach to coastal shrimp fishery management would involve proper study of the various biological and other aspects of the fishery of all these environments.

Secondly the coastal prawn fishery is a multi-species fishery, with each of the species having individual distribution patterns, growing to different sizes and different in breeding activities. This situation calls for monitoring of the population characteristics of each species separately in a continuing programme in order to keep track of the effects of exploitation on the stocks, which is necessary for proper management.

Thirdly various types of gears with different meshes are in use in the exploitation of the resource. In the traditional indigenous sector different kinds of seine nets, filtering type fixed bag-nets, gill nets and various other gears are in use. In the rapid mechanisation taking place at various centres the trawl nets are being increasingly introduced into the mechanised sector. Standardised effort data is, therefore, essential for working out the different population parameters and also to study the trend of catches in relation to effort.

With the introduction of increasing number of mechanised fishing vessels a certain clash of interest between the traditional sector operating in the near shore areas and the mechanised sector is natural and this has been showing up in several areas in recent years. This has even resulted in violence leading to the closure of fishing operations in some places. For management of the fishery free of such conflicts it may become necessary to delineate areas of operation of inshore and offshore fishermen. For a proper delineation, detailed data on the seasonal, geographic and bathymetric distribution of the main species of prawns are essential and this has to be made available on a continuing basis.

All these inherent problems render the management of the coastal shrimp fishery difficult. Continuous monitoring of the catch and effort data both regionwise and gearwise and biological as well as population characteristics of the constituent species are the essential prerequisites for attempting this management.

5.1 *Management objectives*

Taking into consideration all these inherent problems of the shrimp fishery, management objectives have to be defined, based on which suitable management techniques have to be adopted. There could be different views about the specific objectives in management. One view is that it is difficult to manage shrimp fisheries in the biological sense but purely economic measures should motivate management so that the fishery could be based on orderly exploitation for maximum economic return. Another viewpoint is that the aim should be maximum development of the resources and increase of production. Yet another management motive is concerned with socio-economic aspect in which management aim should be to create maximum employment potential in the fishing sector. Shrimps are annual stocks with high natural mortality and because of this fact it would be advisable to fish hard except for giving protection to the nursery areas, partly to safeguard the young prawns and partly to protect their habitat. This would also indicate that the socio-economic factors were of far more importance than biological factors.

A close look at all these viewpoints might only lead to the conclusion that a combination of all these should be the ideal objective in proper management approach in shrimp fishery. But it has to be admitted that it would be extremely difficult to evolve suitable management techniques with all these objectives put together. The management objectives with which the problems are approached in this country has been oriented towards higher production and maximum development of the resources.

The problems connected with shrimp resource management revolves around (1) management of the resource at the earlier phases of each species in relation to its recruitment in and out of the brackish water systems and (2) proper management of the adult population in the fishing grounds in order to limit the exploitation at the optimum level of sus-

tainable yield. As far as the earlier phase of the shrimp is concerned, a proper understanding of the breeding season, the migratory pattern particularly bathymetrical, recruitment to the brackish water region and growth pattern of juveniles are necessary. As regards the resources in the offshore fishing grounds, a close monitoring of the total catch, catch per unit effort, sizes of the component species and their recruitment and mortality rates will be necessary. Depletion in shrimp stocks are probably indicated by (1) catches decreasing regularly over the years, (2) reduction in the average sizes, (3) imbalances in the sex ratios, and so on. In a capital intensive fishery the fall in catch rate may result in economic over-fishing. At the same time the resources may be still biologically viable capable of speedy recovery or even attaining stability of production over a number of years. In the case of shrimp resources in certain areas of the coastline of India there has been records of such decreasing trends in catch rate in the '60s and '70s and subsequent revival of the fishery. In other words conservation in the biological sense was of minor importance, but exploitation for maximum economic return should be the consideration, so much so the problem of management is a socio-economic one.

5.1.1 *Fishery economics in relation to management* Studies on economics of fishing operations, the socio-economic impact of mechanisation on traditional fisheries and the behaviour of market mechanisms are important prerequisites for the formulation of suitable management policies. Such studies will also help in identifying bottlenecks and in arriving at modifications in the management strategies to suit changing conditions. Similar studies dealing with the mechanised sector are in progress. The year 1980–81 also witnessed a revolution in the mechanisation of canoes both with outboard motor and inboard diesel engines in the Quilon–Cochin sector of Kerala coast was well as other areas. The impact of this in production as well as socio-economic conditions is under study.

Investigations on the economics of production of shrimps at least in some representative areas indicate a considerable increase in costs for the effort expended for catching shrimps in recent years, brought about by various factors like the rise in fuel prices. According to the Mechanised Boat Owner's Association the break even point for operation of a small mechanised boat taking into account all expenses including fuel cost, maintenance, depreciation *etc* at Neendakara in Kerala State towards the close of 1979 worked out to Rs 990/- per day of operation and this was expected to cross Rs 1000/- in 1980. This break even point had more than doubled in the course of the previous four years. According to the same source the average return from a day's catch amounted to only Rs 750/-, resulting in a net loss to the boat operator. Although this may be a little biased, the management objective in the fishery here would be to increase the economic return per boat so as to enable the small boat operator to get a reasonable profit and the management technique has to be evolved in order to achieve this goal. This type of economic analysis is needed from other areas too.

With the large scale introduction of trawlers and purse-seiners in the inshore waters, total shrimp and fish production no doubt has increased. However, the process of modernisation often affects the socio-economic conditions of the fisherfolk engaged in traditional fisheries. There is a need to undertake socio-economic surveys to study the impact, if any, and to arrive at timely remedial measures. The CMFRI has undertaken for instance, an intensive study of the impact of introduction of commercial purse-seining on the traditional rampan fishery for pelagic fish in the Karnataka coast in India. Several measures such as delimiting the area of operation of purse-seiners and preference for employment for rampani operators in purse-seine boats were suggested and are being implemented. Similar impact studies involving trawlers have been taken up.

Neendakara area in Kerala has been the biggest single centre for fishing where over 15 000 tonnes of shrimps are landed every year by mechanised boats. However, the economic condition of the large number of fishermen engaged in fishing and allied operations continues to be poor and many are in debt. The CMFRI conducted an investigation there to study the extent of rural indebtedness of fishermen families and it was observed that majority of the community is in debt to private money lenders. Steps such as liberalisation of the conditions for credit facilities by nationalised banks and promoting saving habits have been suggested to gradually bring them into a more organised form of social life.

Another important aspect which needs attention is the techno-economics of fishing operations involving input–output analysis. A case study on the various factors of expenditure and the profitability of operations in small scale fisheries has been undertaken and the results have been published.

5.2 *Management techniques*

The techniques for the management of a fishery

would largely depend on the objective. Thus there are several methods which could be adopted for proper management of the shrimp fishery.

5.2.1 *Closure of fishery* Enforcement of a temporary closure of the fishery is a method adopted in conservation. This can be either by closed seasons or closed areas. Off the south west coast of India the south-west monsoon season used to act almost as a closed season for the mechanised fishery, so that another closed season was not necessary. The stoppage of the fishery due to the south west monsoon takes place at a time when the mean sizes of all the species in the fishery are at their lowest. The absence of fishing operations for two or three months at that time acted as a natural conservation measure. But in recent years fishing operations are being carried out during these monsoon months in several centres. For example at Neendakara the maximum fishing operations and peak landings now occur during the south-west monsoon period. In such places a closed season to conserve the resources could be thought of. In locational closures the approach is to close one particular locality or fishing ground for a certain period based on the data available.

5.2.2 *Mesh regulation* Regulation of mesh sizes of the gears used in the fishery is another important method. However, in the case of the shrimp fishery, being a multispecies fishery constituted by species growing to different sizes, catches of small or medium sized shrimps include adult specimens of the species growing to smaller sizes as well as the juveniles of species growing to medium or larger sizes. Hence enforcement of a larger mesh size with a view to catch only the larger sizes would prevent the capturing of adults of the smaller species which would thus be lost to the fishery. Thus mesh regulation at larger sizes will not be helpful in Indian shrimp fishery of the inshore regions. But in the estuarine fishery involving smaller sizes of shrimps only, limiting the mesh size at larger dimensions may help in sparing the very small shrimps being subjected to the fishery.

5.2.3 *Limitation of fishing effort* When the available shrimp resources in the fishing grounds is subjected to increasing exploitation by introduction of more and more effort, a stage would be reached when further input of effort results in uneconomic returns. In such cases it would be helpful if some limitation is enforced on additional input of effort, which may be achieved by licence limitation or any other governmental control, aiming at optimum efficiency for individual fishing unit. Its implementation would require biological, sociological, economic and political value judgements.

5.2.4 *Catch restrictions* Limiting the catch per boat from a particular area or enforcing a quota system for catch per boat may also be used as a conservation measure. Enforcing catch quota or restricted hours of fishing for the boats in operation aims at restricting the total catch to an optimum level.

5.2.5 *Diversification* Where the existing fishery is predominantly trawling for shrimp, diversified fishery during certain seasons may be suggested for tapping other resources. In such cases adequate incentives and subsidies may be provided to help the diversification process.

5.2.6 *Protection of brackishwater nursery grounds* In view of the inseparable link between the marine shrimp of commercial importance and brackish water nursery grounds, in any conservation measure concerning the marine shrimp resources the protection of these nursery areas would have to be considered. Complete prohibition of shrimp fishing in these environments as practised in some countries of the world would be ideal. This being almost impracticable under the present circumstances, alternative methods of protection of the young ones in these environments have to be thought of. Closing the areas for shrimp fishing during certain seasons, mesh size regulation of the various gears in use in the fishery, limiting the unrestricted operation of fixed gears and such other small mesh nets or even phasing out the operation of these gears, total ban of export of count sizes of shrimps below a fixed minimum level *etc* are some of the methods for consideration in the protection of the nursery.

5.3 *Management advice and implementation*

In most of the resources, implementation is the primary problem to be faced on account of the social angle. However, with the objective to have a constructive management and conservation programme, a Committee appointed by the Government of India to study the shrimp resources and its conservation, has suggested the following draft recommendations.

5.3.1 *Inshore fishery*

5.3.1.1 *Reliable estimates of mechanised boats*

It is estimated that over 12 000 mechanised boats operate in the coastal fishery. Under the Plan

Programmes each of the maritime State/Union Territory is introducing additional boats to the existing fleet, while several of the boats are decommissioned, rendering it difficult to know the reliable number of boats in effective operation. The Committee therefore recommends that:

> Each of the maritime state/Union Territory may arrange for obtaining statistics of the mechanised boats in operation.

5.3.1.2 *Monitoring of inshore fisheries* The inshore fishery both at the national and regional levels shows wide seasonal and annual fluctuations. In certain centres along the coast, fishing pressure, due to the concentration of mechanised boats and the infrastructure facilities available, has considerably increased in recent years causing apprehension about the over-exploitation of resources. For a pragmatic appraisal of the situation and for framing suitable management policies to obtain maximum sustainable yield it is essential that the production and effort trends and biological and environmental characteristics of the exploited populations are clearly understood. Keeping this in view the Committee recommends that:

> Intensive monitoring of the inshore fisheries on both fisheries independent and dependent factors be undertaken.

5.3.1.3 *Fisheries Commission to monitor north-east coast shrimp fishery* Following the location of lucrative fishing grounds for shrimps off the Orissa and West Bengal coasts the fishing vessels based in these states as well as from neighbouring states, have stepped up their operation in this region. Consequent on this there are indications that the shrimp resources in these grounds are heavily exploited. Taking note of these developments and the imperative need to safeguard the resource the Committee recommends that:

> Appropriate Fisheries Commission comprising of the representatives of the government and the industry in these states be constituted to make periodic review of the situation and to prescribe the total allowable catch and adequate arrangements be made to implement the recommendations made by the Commission and to prohibit illicit catching, with the assistance of coast guards.

5.3.1.4 *Conflicts and delimitation of fishing zones* Several maritime state governments have stipulated fishing zones for the operation of non-mechanised fishing vessels, small mechanised fishing vessels and larger vessels. However, conflicts between the non-mechanised fishing vessels and mechanised vessels are being reported. Viewing this with profound anxiousness the committee recommends that:

> The operation of different types and categories of vessels in the prescribed fishing zones be strictly adhered to and implemented for the benefit of all.

5.3.2 *Brackishwater and estuarine areas*

5.3.2.1 *Nursery grounds as reserve areas* It is well-known that estuaries and mangrove swamp areas serve as nursery grounds for several species of fin fishes and shell fishes of both marine and fresh water origin. Besides, these ecosystems also play a vital role in maintaining the balance of nature. In view of this the Committee strongly recommends that:

> Certain areas of such ecosystems be demarcated as reserved areas and for this purpose necessary provision be included in the Wildlife Act and Indian Fisheries Act.

5.3.2.2 *Regulation of fixed gears* Large number of fixed gears (stake nets) are operated in several of the estuaries of the country. Unrestricted operation of these nets and the smaller mesh sizes bring in appreciable quantities of small sized juveniles of commercial species. The Committee discussed in depth the destructive nature of fishing by these gears, its effect on the fisheries of the adjoining marine and fresh water regions, the pros and cons of total banning of these gears and the consequent effect on the socio-economic conditions of the fishermen of the area. Observing the social, economical, political and ethnological problems involved in total banning of these gears the Committee recommends that:

> Those gears having cod end mesh size of less than 20 mm be phased out and that such of the fishermen affected by the implementation of this proposal be provided with alternate vocation through aquaculture programme.

5.3.2.3 *Implementation of regulatory orders* Several states have enacted legislation and regulatory orders under the Fisheries Act in respect of closed seasons or mesh regulation for the conservation of the fisheries resources in the inland as well as territorial waters. However, the Committee notes that they are not fully implemented and hence recommends that:

The maritime States/Union Territories should take necessary steps for effective implementation of these regulations.

5.3.2.4 *Prevention of pollution* With the advancement of industrialisation several agro-industrial complexes have been established in the vicinities of the estuaries. Large-scale domestic and industrial discharges into the estuaries cause considerable damage to the living resources often resulting in heavy fish mortalities. Noting the grave hazards of this pollution the Committee strongly recommends that:

Adequate precautionary measures be taken to prevent the effluents reaching the estuaries.

5.4 *Implementation*

Based on these recommendations and earlier studies and consultations, the enactment of a Marine Fishing Regulation Bill is under active consideration of the Government of India in consultation with the different states. This would in turn be fully utilised by the States for formulating appropriate State Fisheries Acts. Some of the States, like for instance Kerala State have already passed Acts delimiting the fishing zones for the operation of indigenous fishing vessels and mechanised fishing vessels and also banning of operation of mechanised fishing vessel activities in certain areas along the coast during certain seasons and these are being implemented.

6 Future work

6.1 *Constraints in data collection and change necessary*

In order to formulate suitable policies for efficient management of the shrimp fishery, data acquisition, processing and dissemination need strengthening. A number of fishing harbours are being constructed in different parts of the country. Many of these would require exclusive coverage for the estimation of landings at these places. This combined with the changing patterns of fishing necessitates more intensive monitoring. The sampling fraction is at present about 2% and it is desirable to increase this fraction in order to improve the precision of the estimate. Programmes involving increase of frequency of collection of data from landing centres, round the clock collection of data from fishing harbours and other centres of concentration of boats and evolution of special designs for collection of data from operation of gears such as purse-seines are necessary. Retrieval of data from the operation of the larger type of boats belonging to the big firms needs streamlining.

Another area which requires immediate and urgent attention is the data collection from the estuarine and brackishwater systems. Development of a proper catch monitoring system involving a suitable statistical design is quite essential.

6.2 *Biological studies needing priority attention*

For a proper understanding of certain phenomena in shrimp fishery, like for instance the heavy landings at Neendakara in Kerala State during the monsoon season and the shrimp fishery related to the mud bank formation in adjacent region, each having its own species composition, it would be desirable to collect intensive data on oceanographic, both biological and physico-chemical, parameters from in and around the fishing grounds on a continuous monitoring basis along with the data on production. Each prawn fishing ground has its own particular problems which need to be considered individually. Detailed studies on biological parameters for the determination of various population characteristics and delineation of stocks are necessary.

6.3 *Technological, economic and other research needs*

Fishery economic studies at micro and macro levels play an important role in the formulation of management policies. The input of fishing effort is very much linked not only with the resources but also with the state as well as national economic activities. Studies on topics such as cost economics of production, input–output relationship, variation in price structure dependent on various factors, demand supply and other market mechanisms, impact of mechanisation on the socio-economic conditions and repercussions of legislative measures on fishing activities are quite essential in order to have a proper insight into the problems facing the industry. The creation of the new Economic Division in CMFRI would go a long way in initiation of such studies. The process of modernisation of the traditional fisheries has its own impact on the socio-economic conditions of the fisher-folk. Therefore, there is a need for making socio-economic surveys at a number of centres so as to assess any adverse impact and arrive at timely remedial measures. Studies are also required to be undertaken to get an insight into the economic structure governing various activities directly or indirectly related to fisheries.

There is also need for strengthening of research

basis on all aspects including handling, preservation and utilization of products.

6.4 *Need for new models and methods of analysis*

Factors such as recruitment, growth and mortality, both natural and fishing, are all interlinked within a population and between populations. Most of the models now used treat a population by itself without taking into consideration the interacting factors. Analytical models for the interacting situations can be built up; but explicit solutions may be quite difficult to obtain. A step-by-step procedure will have to be followed to study the effort of one factor over the other and consequently the overall picture. Considering the inherent complexities of the fisheries and the lack of suitable data, an alternative procedure is to resort to simulation techniques involving use of mathematical and statistical models. Such studies could be initiated, especially now that electronic computing facilities are becoming increasingly available.

References

BANERJI, S K. Crustacean production in India. In Prawn Fisheries of India. *CMFRI Bulletin No. 14:* 259–272. 1969

BANERJI, S K and GEORGE, M J. Size distribution and growth of *Metapenaeus dobsoni* (Miers) and their effect on the trawler catches off Kerala. *Proc. Symp. Crustacea. Mar. biol. Ass. India*, Part II, 634–648. 1967

BANSE, K. On the upwelling and bottom trawling off the southwest coast of India. *J. Mar. biol. Ass. India*, (1): 33–49. 1959

GEORGE, M J. Studies on the prawn fishery of Cochin and Alleppy coast. *Indian J. Fish.*, 8(1): 75–95. 1961

GEORGE, M J. Post larval abundance as a possible index of fishing success in the prawn *Metapenaeus dobsoni* (Miers). *Indian J. Fish.*, 10A(1): 135–39. 1963

GEORGE, M J. Synopsis of biological data on penaeid prawn *Metapenaeus dobsoni* (Miers), 1878. *FAO Fish. Rep.*, (57), Vol. 4, 1335–1357. 1970a

GEORGE, M J. Synopsis of biological data on penaeid prawn *Metapenaeus affinis* (H. Milne Edwards) 1837. *FAO Fish Rep.*, (57), Vol. 4: 1359–1375. 1970b

GEORGE, M J. Synopsis of biological data on penaeid prawn *Metapenaeus monoceros* (Fabricius) 1798. *FAO Fish. Rep.*, (57), Vol. 4, 1539–1557. 1970c

GEORGE, M J. Synopsis of biological data on penaeid prawns *Metapenaeus brevicornis* (H. Milne Edwards) 1837. *FAO Fish Rep.*, (57), Vol. 4, 1559–1573. 1970d

GEORGE, M J. On the zoogeographic distribution of Indian Penaeidae. *Indian J. Mar. Sci.*, 1(1): 89–92. 1972

GEORGE, M J. The influence of backwaters and estuaries on marine prawn resources. *Proc. Symp. Living Resources of the Seas around India. Spl. Publ. CMFRI:* 563–569. 1973

GEORGE, M J. Trends in marine prawn production in India. *Indian Seafoods*, 13(4) and 14(1): 19–24. 1978

GEORGE, M J, RAMAN, K and NAIR, P K. Observations on the off shore prawn fishery of Cochin. *Indian J. Fish.*, 10(2): 460–499. 1968

GEORGE, M J, BANERJI, S K and MOHAMED, K H. Size distribution and movement of the commercial prawns of the south west coast of India. *FAO Fish. Rep.*, (57), Vol. 2: 265–284. 1968

GEORGE, M J and SUSEELAN, C. Distribution of species of prawns in the back-waters and estuaries of India with reference to coastal aquaculture. *Symp. Coastal Aquaculture Mar. biol. Ass. India*, January 1980. 1980

GEORGE, M J, SUSEELAN, C, THOMAS, M M and KURUP, N S. A case of overfishing: Depletion of shrimp resources along Neendakara coast, Kerala. *Mar. Fish. Infor. Serv. T and E Ser.*, 18: 1–8. 1980

KUNJU, M M. Synopsis of biological data on the penaeid prawn *Solenocera indica* Nataraj (1945). *FAO Fish Rep.*, (57), Vol. 4, 1317–33. 1970

KURIAN, C V and SEBASTIAN, V O. Prawns and prawn fisheries of India. Hindustan Publishing Corporation (India): 1–280. 1975

KURUP, N S and RAO, P V. Population characteristics and exploitation of important marine prawns of Ambalapuzha, Kerala. *Indian J. Fish.*, 21(1): 183–210. 1974

MENON, M K and RAMAN, K. Observations on the prawn fishery of the Cochin backwaters with special reference to the stake-net catches. *Indian J. Fish.*, 8(1): 1–23. 1961

MENON, M D. 'Carpe Diem' *Seafood Trade Journal*, 2(1): 99–106. 1967

MOHAMED, K H. Synopsis of biological data on the jumbo tiger prawn *Penaeus monodon* Fabricius, 1798. *FAO Fish. Rep.*, (57): Vol. 4: 1251–1256. 1970a

MOHAMED, K H. Synopsis of biological data on the Indian prawn *Penaeus indicus* H. Milne Edwards, 1837. *FAO Fish Rep.*, (57): Vol. 4: 1267–1288. 1970b

MOHAMED, K H. Penaeid prawn resources of India. *Proc. Symp. Living Resources of the Seas around India. Spl. Publ. CMFRI:* 548–556. 1973

PAULY, D and DAVID, N. ELEFAN I, a BASIC program for the objective extraction of growth parameters from length frequency data. *Meeresforsch*, 28, 205–211. 1981

RAMAMURTHY, S and MUTHU, M S. Prawn fishing methods. In prawn fisheries of India. *CMFRI Bulletin 18:* 235–257. 1969

RAO, P VEDAVYASA. A synopsis of biological data on penaeid prawn *Parapenaeopsis stylifera* (H. Milne Edwards) 1837. *FAO Fish Rep.*, (57), Vol. 4, 1575–1606. 1970

RAO, K VIRABHADRA. Distribution pattern of the major exploited marine fishery resources of India. *Proc. Symp. Living Resources of the Seas around India. Spl. Publ. CMFRI:* 18–101. 1973

RAO, K VIRABHADRA, MEENAKSHISUNDARAM, P T and DORAIRAJ, K. Relative abundance of trawl fishes in the Bombay and Saurashtra waters. *J. Mar. biol. Ass. India*, 8: 205–212. 1966

SILAS, E G, DHARMARAJA, S K and RENGARAJAN, K. Exploited marine fishery resources of India—A synoptic survey with comments on potential resources. *CMFRI Bulletin 27:* 1–25. 1976

SUBRAMANYAM, C B. A note on the annual reproductive cycle of the prawns *Penaeus indicus* (M. Edwards) of Madras coast. *Curr. Sci. 32*(4): 165–166. 1963

SUBRAMANYAM, M. Lunar, diurnal and tidal periodicity in relation to the prawn abundance and migration in the Godavari estuarine systems. *Fish. Tech. 2*(1): 26–33. 1965