New Zealand Journal of Marine and Freshwater Research, 2005, Vol. 39: 723–732
0028–8330/05/3903–0723

Status of the major lobster fisheries in India

E. V. RADHAKRISHNAN
V. D. DESHMUKH
MARY K. MANISSERI
M. RAJAMANI
JOE K. KIZHAKUDAN
R. THANGARAJA
Central Marine Fisheries Research Institute
Cochin 682 018
Kerala, India
email: mdcmfri@md2.vsnl.net.in

Abstract Commercial exploitation of lobsters from the Indian seas began in the 1950s. Annual landings have been declining from a peak of 4075 t in 1985 to 1364 t in 2002. Major fisheries were located on the north-west, south-west, and south-east coasts. Among the 12 species recorded, only four species of spiny lobsters (three littoral and one deep sea) and one species of slipper lobster are commercially important. At Kayalpattinam and Tharuvaikulam, on the south-east coast, lobster landings sharply declined for the gill-net fishery. Of the two species that contributed to the fishery, *Panulirus ornatus* and *Panulirus homarus*, the latter has been more affected owing to high vulnerability to fishing activities. Catch composition analysis of the trammel-net fishery showed that 35% of the landings consisted of *P. homarus* in the size range of 23–50 mm carapace length. On the north-west coast, the spiny lobster *Panulirus polyphagus* and the slipper lobster *Thenus orientalis* are incidentally caught in trawl nets. However, the fishery for *T. orientalis* in the waters off Mumbai lasted only up to 1994. Large-scale exploitation of spawning females, which formed 60% of the total catch, might have been detrimental to the recruitment process resulting in rapid decline and total collapse of the fishery. Abundance of *P. polyphagus* reached its maximum during September, constituting 23% of the average annual landing during 1988–2002. A high exploitation ratio (>0.7) indicated over-fishing of the stock. Repeated spawning and high annual egg production are probably responsible for sustaining the stock, despite over-exploitation. Major problems confronting the resource management of the multi-gear and multi-species lobster fisheries in India are discussed. An operational project, involving fisher community, has been taken up for creating awareness of the need for sustainable exploitation of the resource. Regulatory measures, such as closure of the fishery during the peak of the breeding season, ban on trammel-net, mandatory release of egg-bearing lobsters, and establishment of lobster sanctuaries are suggested to the State Governments for implementation.

Keywords lobster fishery; stock assessment; over-exploitation; management

INTRODUCTION

Lobsters are one of the most valuable and highly priced crustaceans in India, as well as an important export commodity. Though widely distributed along the entire coast, major fisheries are located on the north-west, south-west, and south-east coasts (Radhakrishnan & Manisseri 2003). The north-west coast is particularly rich in lobster resources, contributing to nearly three quarters of the total lobster landing in India (Kagwade et al. 1991; Radhakrishnan 1995). Two species, the palinurid spiny lobster *Panulirus polyphagus* (Herbst) and scyllarid *Thenus orientalis* (Lund) predominate in the fishery along the north-west coast (Chhapgar & Deshmukh 1971). At Mumbai and Veraval, in the north-west, lobsters are incidentally caught in trawl nets. Extensive information is available on the reproductive biology and growth of *P. polyphagus*

M04014; Online publication date 8 June 2005
Received 8 February 2004; accepted 18 April 2005

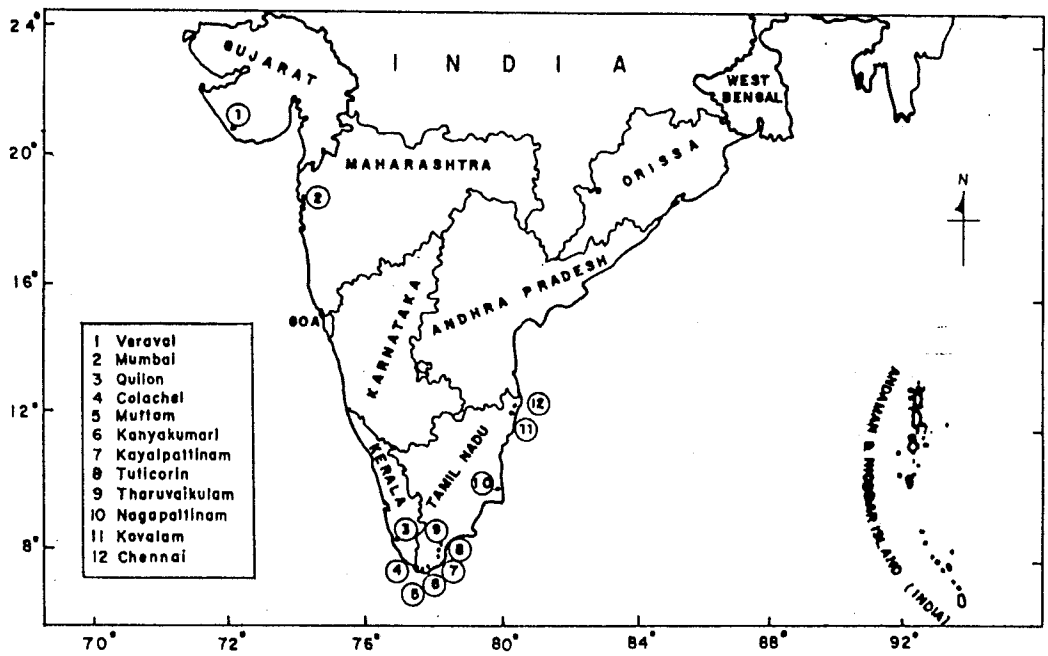

Fig. 1 Major lobster fishing centres along the Indian coast.

(Kagwade 1987a,b, 1988a,b) and *T. orientalis* (Kabli & Kagwade 1996a,b,c). As a result of the absence of regulatory measures for the fishery in the State of Maharashtra, the sand lobster fishery collapsed by 1994 and there is no sign of its recovery (Deshmukh 2001).

In the south-west, *Panulirus homarus* (Linnaeus) and the deep sea lobster, *Puerulus sewelli* (Ramadan), are the top contributors to the fishery. However, *Panulirus versicolor* Latreille and *Panulirus ornatus* (Fabricius), are also landed in small quantities. Colachel and Muttom are the major fishing grounds, where gill-net, trammel-net, and traps are used for catching lobsters. The fishery and biology of *P. homarus* were studied during the 1950s and 1960s (Miyamoto & Sheriff 1961; Balasubramaniam et al. 1960, 1961; George 1965). Mohammed & George (1968) conducted tagging experiments at Muttom to study the movement and growth of *P. homarus*. Major fishing grounds for the deep sea lobster, *P. sewelli* were located off Quilon in the south-west and off Tuticorin in the south-east coasts, at depths ranging from 150 m to 400 m. The commercial importance of the resource was established through exploratory surveys (John & Kurian 1959; Kurian 1964; Silas 1969).

Along the south-east coast, *P. homarus*, *P. ornatus*, and *T. orientalis* were the major species exploited. *Linuparus somniosus* was reported from the Andaman and Nicobar Islands, but has not been commercially exploited. Kayalpattinam and Tharuvaikulam are important gill-net fishing centres, landing mainly *P. ornatus* and *P. homarus* (Nair et al. 1973; Rajamani & Manickaraja 1991, 1995, 1997a,b). Further north, lobsters are mainly caught off Chennai and nearby fishing villages. *T. orientalis* and small quantities of spiny lobsters are landed as bycatch by trawlers at Chennai.

The present work is an attempt to review the general status of the lobster fishery in India. An assessment of the exploited stock of spiny lobster from Mumbai waters during 1998–2002 has also been carried out, which would enable formulation of a management plan for using the lobster resources on a sustainable basis. The "Minimum Legal Size Law" (promulgated in 2003 by the Ministry of Commerce and Industry, Government of India) prohibiting export of lobsters below a certain size, and an educational programme taken up for creating awareness among fishers of the adverse effects of large-scale exploitation of egg-bearing lobsters and juveniles, are also discussed.

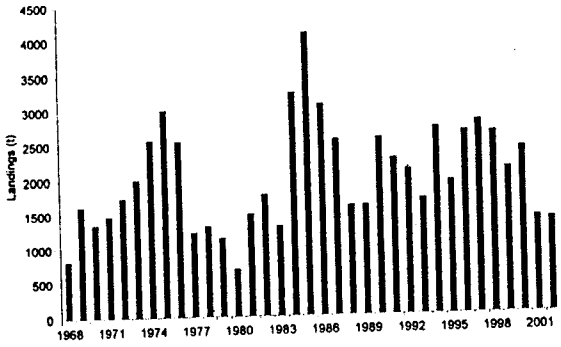

Fig. 2 Total annual lobster landing (t) in India, during 1968–2002.

MATERIALS AND METHODS

Data on the total landing of lobsters by mechanised trawlers were collected based on a multistage stratified random sampling design. Month-wise catch, fishing effort, and species composition of lobsters caught by the artisanal fishery were estimated by collecting data from major landing centres (Fig. 1). At the landing centres, sex-wise total length (Mumbai) and carapace length (CL) (other centres) were measured by examining 100 specimens each from random samples, once a week. The stock parameters and exploitation rates of the lobster fishery from Mumbai waters were studied in detail. During 1998–2002, a total of 12 727 specimens, comprising 4974 males and 7753 females, were examined at the two trawl landing centres (Sassoon dock and New Ferry Wharf, in Mumbai) for size, sex, and ovigerous condition of females. For *T. orientalis* total length (TL) was measured from the notch in front of the carapace to the posterior margin of the telson. In spiny lobster, it was from the transverse ridge between the supraorbital horns to the tip of telson. CL was measured from the transverse ridge between the supraorbital horns in front, to the posterior margin of the carapace. The lengths were grouped into 10 mm size classes and sex-wise size frequencies were obtained from each sample. With the help of sex-wise length-weight relationships (Kagwade 1987a; Kabli & Kagwade 1996c), sample weights were calculated for both sexes in the two species mentioned and a factor was obtained to raise the length-frequencies to the day's catch. The same procedure was followed for raising the length-frequencies to the monthly estimated catch after pooling the data for observation days. The monthly length-frequencies were then pooled on an annual basis.

Growth parameters for spiny lobster (Kagwade 1987b) were used to find the exploitation rates during 1998–2002. The natural mortality coefficient was estimated by using Pauly's empirical formula (Pauly 1980) and total mortality coefficient (Z) by length converted catch curve method (Pauly 1984). The exploitation ratio (E) that gave maximum relative yield per recruit (E_{max}) and the exploitation ($E_{0.50}$) at which the relative biomass per recruit of the stock was reduced to 50% level, were calculated by using FISAT program (Gayanilo et al. 1996).

RESULTS

The annual lobster landing increased from 800 t in 1968 to 3000 t in 1975, and attained a peak of 4075 t in 1985 (Fig. 2). Thereafter, the fishery showed a trend of decline, averaging 2200 t for nearly 15 years. The landings further declined to 1389 and 1364 t in 2001 and 2002, respectively. The north-west region contributed 70%, the south-east 16%, and the south-west 14% of the total landing during 1992–2001.

North-west coast fishery

At Veraval, the annual landing of lobsters decreased from 315 t in 1987 to 102 t in 2000, and then sharply declined to 22 t in 2002 (Fig. 3). During 1987, 189 t of *P. polyphagus* were landed. However, the landing decreased to just 3.9 t during 2002. A similar trend was observed for *T. orientalis* (Fig. 3). The annual mean CL of *P. polyphagus* decreased from 68.5 mm in males and 74.9 mm in females in 1997, to 41.5 mm and 47.9 mm respectively, in 2001. Adults and spawners mainly comprised the trawl catch, whereas gill-net and other traditional gears brought more juveniles. Gill-nets were operated on the shallow reefs, which were inhabited by juveniles and subadults. Peak landing of *P. polyphagus* by trawl nets coincided with the breeding season and the onset of winter in October–December. Maximum landing by gill-nets was during September–October. *T. orientalis* is exploited mostly by multi-day fishing vessels. The mean CL of this species did not show much variation.

Year-wise landing of lobsters at Mumbai during 1978–2002 is shown in Fig. 4. The annual landings increased from 200 t in 1978, reaching a peak of 1040 t in 1986 and thereafter declining to 104 t in 2002. Commercial fishery for *T. orientalis* was initiated in 1978, with a catch of 1.5 t. The landing

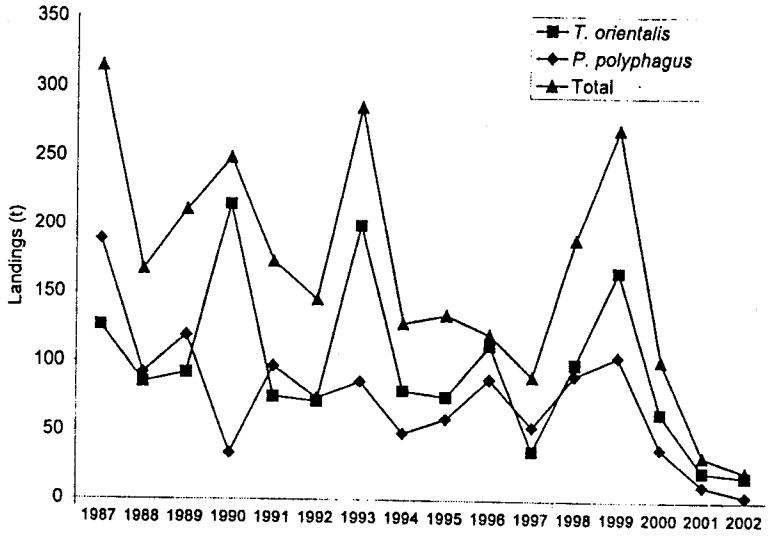

Fig. 3 Annual landing of lobsters (*Panulirus polyphagus* and *Thenus orientalis*) in trawl fishery at Veraval, India.

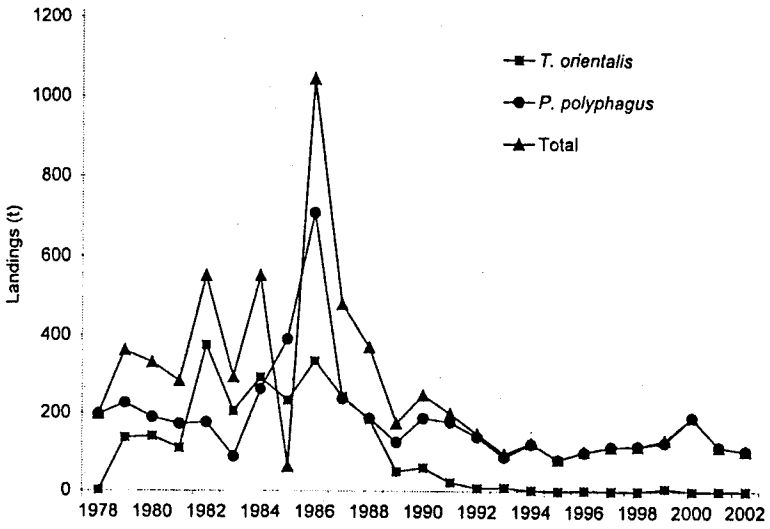

Fig. 4 Annual landing of lobsters (*Panulirus polyphagus* and *Thenus orientalis*) in trawl fishery at Mumbai, India.

reached a maximum of 375 t in 1982. Subsequently the catch declined to 250 t and reached another peak (334 t) in 1986. Thereafter the catch declined rapidly, landing only 2.2 t in 1994. As a consequence, the fishery collapsed, and the species occurred only in small quantities in the following years.

The spiny lobster *P. polyphagus*, also showed a gradual decline in landing at Mumbai. The average annual landing during 1978–85 was 217.5 t. However, the catch declined from 390 t in 1985 to 104 t in 2002 (Fig. 4). Month-wise percentage of catches during 1998–2002 showed that the maximum abundance of *P. polyphagus* was in September and the minimum in July. The size of both males and females ranged from 75 mm to 385 mm TL, the size between 160 mm and 230 mm forming the mainstay of the fishery. The sex ratio showed dominance of females in all years (1:1.16). Ovigerous females occurred throughout the year (23.8%) with the peak occurrence (56.1%) in September. Recruitment of juveniles, ranging from 70 mm to 120 mm TL, was generally observed during December–February, in shallow nearshore waters. From the length composition of the two sexes of *P. polyphagus*, the total mortality coefficient (Z), natural mortality coefficient (M), exploitation rate (U), and the E_{max} were estimated (Table 1). The Z for the entire 5-year period for males was 1.9 which varied from 2.57 in 1998 to 1.57 in 2001. For females, Z was 1.63 which varied from 1.57 in 1998 to 2.01 in 2000. With the

mean seawater temperature at 28°C, M for males and females were 0.53 and 0.60, respectively. The relative yield per recruit (Y/R) analysis indicated that the yield can be maximised when the exploitation ratios are 0.46 and 0.53 for males and females, respectively. However, the present exploitation ratios are 0.65 for males and 0.63 for females, which are much higher. At such exploitation ratios the biomass is reduced to 0.30, which may not sustain future stock.

South-west coast fishery

On the south-west coast, spiny lobster fishing began at subsistence level and gradually transformed into a commercially important fishery. Colachel and Muttom were the two important landing centres where traditional traps made of palmyrah frond were used. Fishers used to dive in the evening and place the baited traps near the mouth of large crevices. Traps were lifted the next morning. Later, gill-nets and trammel-nets were introduced and now traps are used at a few centres. Annual landings gradually decreased from a peak of 301 t in 1966 to 7.6 t in 1996, with only 4 t recorded in 2002. About 92% of the catch comprised *P. homarus*, the remainder being *P. ornatus* and *Panulirus versicolor*. The fishery was seasonal, extending from October to May with maximum landing during November–January. The fishing season coincided with the peak breeding season and 40% of the females caught during this period were egg-bearing. The size of *P. homarus* in the catches ranged from 91 mm to 280 mm TL.

In 1999, fishers ventured into deeper waters (150–400 m) off Quilon ("Quilon Bank") along the south-west coast. The deep-sea lobster *P. sewelli* was landed by trawlers as a bycatch along with deep-sea shrimps. The average annual landing of the species from the Quilon Bank during 1999–2002 was 340 t. The fishery was seasonal, commencing by September–October and extending until February–March. The total landing of *P. sewelli* during 1999–2000 was 574 t, with a peak monthly landing of 180 t in December. The landing decreased to 297 t and 236 t during the years 2000–01 and 2001–02, respectively. Maximum monthly landing was recorded in December (110 t) during 2000–01 and March (49 t) during 2001–02. The size (TL) of *P. sewelli* ranged from 76–80 mm to 186–190 mm in males and from 71–75 mm to 201–205 mm in females. Occurrence of smaller size classes during December–January indicated entry of young ones into the fishery during these months. Maximum numbers of immature lobsters were recorded in January. Sexes were more-or-less equally distributed, with females comprising 47% of the catch during 2000–01 and 56% during 2001–02.

South-east coast fishery

The south-east coast lobster fishery region encompasses Kanyakumari in the south to Chennai in the north. Gill-net is the major gear operated in the southern region as against the trawl nets used widely in the northern region with *T. orientalis* dominating the trawl fishery. In the gill-net fishery at Kayalpattinam, lobster catches increased from 42.2 t (with a catch rate of 6.5 kg/unit) in 1993, to the peak catch of 50.6 t (with a catch rate of 5.5 kg/unit) in 1994 (Fig. 5). However, the fishery declined to 4.4 t (with a catch rate of 1.1 kg/unit) in 2002. A change in the relative abundance of *P. ornatus* and *P. homarus* was also observed. *P. homarus* formed 72.3% of the total catch during 1978–89 whereas *P. ornatus* dominated the fishery (60.6%) during 1993–2002. The modal length of male *P. homarus* occurring in the fishery decreased from 245 mm TL during 1978 to 145 mm TL during 2002. The modal length of females also decreased from 195 mm TL to 165 mm TL during this period. Meanwhile, the modal length of both

Table 1 Stock parameters of males and females of *Panulirus polyphagus* in Mumbai, India. (Z, total mortality coefficient; F, Fishing mortality; E, exploitation ratio.)

Parameter	Sex	1998	1999	2000	2001	2002
Z	Males	2.57	1.96	2.01	1.57	2.71
	Females	1.57	1.87	2.04	1.66	1.76
F	Males	2.02	1.43	1.48	1.04	2.18
	Females	0.97	1.27	1.44	1.06	1.16
E	Males	0.79	0.73	0.74	0.66	0.80
	Females	0.62	0.68	0.71	0.64	0.66

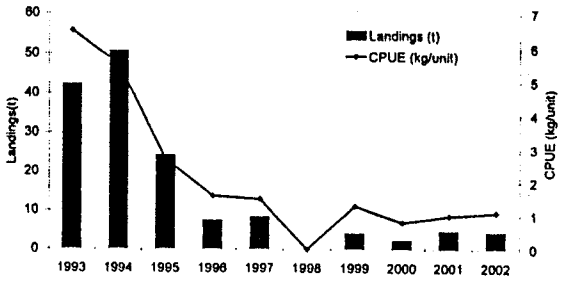

Fig. 5 Annual landing and catch per unit effort (CPUE) of spiny lobsters (*Panulirus homarus* and *P. ornatus*) in the gill-net fishery at Kayalpattinam, India.

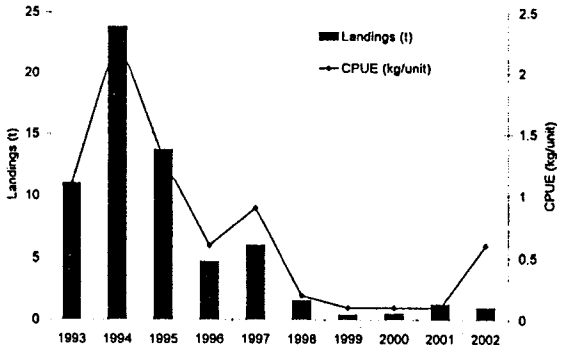

Fig. 6 Annual landing and catch per unit effort (CPUE) of spiny lobsters (*Panulirus homarus* and *P. ornatus*) in the gill-net fishery at Tharuvaikulam, India.

males and females of *P. ornatus* showed an increase from 175 mm to 195 mm TL. At Tharuvaikulam, another gill-net landing centre, the landings decreased gradually from 11 t (with a catch rate of 1.1 kg/unit) in 1993, to 1.1 t (with a catch rate of 0.6 kg/unit) in 2002 (Fig. 6). Though lobsters were landed throughout the year, the peak seasons were October–December and April–May. During the entire period of study, ovigerous females of *P. ornatus* were not encountered in the inshore gill-net fishery. However, large males and berried females of *P. ornatus* were landed in small quantities at Nagapattinam by gill-nets operated in deeper waters.

In a previous study conducted at Kovalam, near Chennai, during 1986–88, the catch composition of lobsters from the gill-net fishery and trammel-net fishery was examined. The size of *P. homarus* in the trammel-net fishery ranged from 23 mm to 100 mm CL with nearly 35% in the range of 23–50 mm CL. In comparison, size of lobsters caught in gill-nets

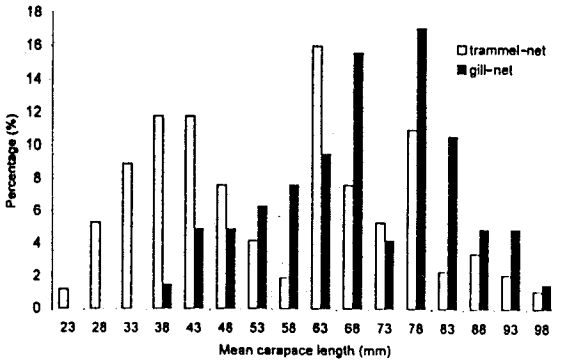

Fig. 7 Length-frequency distribution of *Panulirus homarus* in the trammel-net and gill-net fishery at Kovalam, India.

ranged from 38 mm to 100 mm CL with a majority in the range of 55–80 mm CL. Studies showed that 50% of *P. homarus* caught in trammel-nets were below 55 mm CL, the size at first maturity, whereas only 25% were below the size at first maturity in the gill-net catches (Fig. 7).

Awareness programme for lobster conservation

A project on community participation in lobster resource management was initiated in the fishing village of Kadiyapattinam (near Kanyakumari) (Fig. 1), in November 2002. It is increasingly understood that lobster management is not possible just through an isolated promulgation of a law. Involvement of fishers in the management of the resources, on which they depend for their livelihood, could be an alternative strategy. Five meetings, involving fishers, traders, exporters, and fisheries officials were held to discuss the need for development of strategies for sustainable exploitation of the lobster resources. Fisher meetings were organised at Kadiyapattinam near Kanyakumari, Veraval in Gujarat, and Mumbai in Maharashtra to convey the message of responsible fishing to the community. Lobster conservation leaflets, stickers, and wall posters were distributed in lobster fishing villages. Two hundred egg-bearing lobsters purchased from fishers were "V" marked on the uropods and released, to educate the fishers on the need for protection of lobsters carrying eggs. On two occasions, fishers released the marked lobsters voluntarily. They were shown the advantage of using wire traps with escape vents and are slowly being convinced that, in the long term, such responsible fishing methods will benefit them economically. Rallies were also held at three fishing villages in Gujarat to convey the message of conservation.

DISCUSSION

Though not big in volume, lobster is an important crustacean resource from the Indian seas. Commercial exploitation of the lobster fishery in India began in the early 1950s. However, reliable data on the landings are available only from 1968. The fishery experienced rapid growth in 10 years, landing 3000 t in 1975. Though the fishery suffered a setback for nearly 5 years afterwards, it attained the peak landing of 4075 t in 1985. The sharp fall in the landings in 2001 and 2002, however, was an indication of the growing instability of most of the lobster stocks on both the east and west coasts of India.

In the north-west, lobsters are incidentally caught in trawl nets, except for a small quantity landed by gill-nets at Veraval. In Mumbai, the slipper lobster *T. orientalis* disappeared from the fishery by 1994 (Deshmukh 2001). Heavy reduction in the biomass of the species from overexploitation resulted in the collapse of the fishery. Unlike most of the tropical species, *T. orientalis* showed a single well-defined breeding period from October to January. The sex ratio was disproportionate with females outnumbering males, particularly during the breeding period. It is also a slow-growing species with relatively low fecundity (Kabli & Kagwade 1996a). Exploitation of the spawning females which formed 60% of the total landing might have been detrimental to the recruitment process, resulting in rapid decline of the fishery in the waters off Mumbai. This is a classic example of recruitment overfishing which is not precluded by the growth overfishing.

The ovigerous females of *P. polyphagus* occurred throughout the year, the month-wise abundance showing peaks in August–September. Thus, unlike *T. orientalis*, the species breeds throughout the year. However, Kagwade (1988a) reported two major spawning peaks, in January and September. In the present study, no such peak was observed in January. The size at 50% maturity of females is 205 mm TL weighing 218 g (Kagwade 1988a), and the annual production of eggs is as high as 143 000 and 4.72 million in specimens of 180 mm and 353 mm TL, respectively (Kagwade 1988b). With the assumption that natural mortality remained constant during the period, the maximum yield of *P. polyphagus* could have been obtained at the exploitation ratio (E_{max}) of only 0.46 for males and 0.53 for females. However, it was as high as 0.66–0.80 for males and 0.62–0.71 for females. It is important to note that at such exploitation ratios, the biomass of the stock is reduced to less than 50%, which clearly indicates overfishing of the stock. This situation, therefore, calls for immediate management action to save the stock from collapse. Action should be taken to conserve the spawning stock during September–October and the juveniles during December–January when they abound in the shallow coastal waters.

In Kanyakumari district, on the south-west coast, the fishery for *P. homarus* flourished during 1964–73. Increase in effort, introduction of gill-nets for fishing, and exploitation of egg-bearing lobsters during the peak breeding season have been the major factors responsible for reduction in landings. George (1965, 1973) observed that the peak breeding season for *P. homarus* coincided with the active fishing season and suggested a minimum legal size of 130 mm or 140 mm TL for the species exploited from the south-west coast. *P. homarus* is an inshore species with restricted movements (Mohamed & George 1968) and is therefore highly vulnerable to fishing. Trammel nets bring in large quantities of juveniles and subadults, which otherwise would sustain the fishery. Based on the current landing data and biological information on the mean size of *P. homarus*, it could be deduced that the stock has been overexploited. A similar situation prevails in the gill-net fishery at Kayalpattinam and Tharuvaikulam. Reduction in the landing and modal size of *P. homarus* is indicative of growth overfishing and requires immediate remedial measures to protect the juvenile population and breeding females. *P. ornatus* landed by gill-nets from the inshore fishing grounds along the south-east coast comprise juveniles and subadults. Adults are caught incidentally in trawl nets. Exploitation of the juvenile population from the inshore nursery areas may have an adverse impact on the fishery in the long term. Kagwade et al. (1991) did not notice a single berried specimen of the species either in the gill-net or in the trawl fishery. The possibility of *P. ornatus* migrating through the Palk Strait to a deeper breeding ground near the northern Sri Lankan coast cannot be ruled out. Similiar migratory behaviour of spawning females of *P. ornatus* through the Torres Strait in northern Australia has been reported (Skewes 1994). Migration to deeper areas keeps the breeding population away, probably giving a natural protection from large-scale exploitation. Fishers from Nagapattinam, who fish in deeper waters, land adult lobsters and berried females from this ground, though in small quantities. Subramanian (2004) studied the fishery for *T. orientalis* in the trawl fishery along the Chennai coast during 1982–99. The average annual catch of 10 t during 1982–85

increased to 60 t (0.14 kg/h) in 1993 and 115 t (0.23 kg/h) in 1994. However, a declining trend was recorded in the following years with only 8 t (0.01 kg/h) in 1999. Maximum landing was in October. The mean sizes of *T. orientalis* landed were 153.6 mm and 156.9 mm TL for males and females respectively. The females attained maturity at 105.5 mm TL. Maximum spawning activity was observed during January–March and June–July with peak recruitment around October and January.

Management

Unlike many other countries, the trawl fishery for lobsters in India does not constitute an exclusively targeted fishery. Therefore, optimising the trawlers for lobsters alone is not an option. Neither is observing a closed season for *P. polyphagus* along the Maharashtra coast during the peak breeding season (September–October) as fishing by mechanised boats in the State is already banned during the monsoon (10 June–15 August). Therefore, one of the management options left is to return egg-bearing females back to sea, at least during August–October so that the spawning stock is protected. Recruitment of juvenile lobsters (40–160 g) generally takes place during December–February. These undersized lobsters do not fetch good prices and therefore could also be returned to sea. *P. polyphagus* is a hardy species which remains alive for 1–2 h after it is brought on board by trawl net. Hence, releasing back the undersized and berried lobsters would ensure future recruitment process. As *T. orientalis* occurs only in small numbers along the coast of Maharashtra, total conservation of the remaining residual population by returning the lobsters caught and a legal ban on landing of the species are the only options which can be followed in future.

Table 2 Minimum legal size for export of lobsters from India (Notification No. 16 (RE 2003)/2002–07 dated 17 July 2003, Ministry of Commerce and Industry, Government of India).

Species	Live/chilled/ frozen (g)	Whole cooked (g)	Tail (g)
Panulirus polyphagus	300	250	90
P. homarus	200	170	50
P. ornatus	500	425	150
Thenus orientalis	150	–	45

The drastic decline of the fishery along the coast of Gujarat is also of serious concern and demands similar management measures. Intensive exploitation of juvenile *P. polyphagus* from the inshore reef area by gill-net at Veraval in Gujarat should be banned, if the fishery is to be sustained.

On the south-west coast, closure of the fishery for *P. homarus* during the peak breeding month of November may protect the spawning stock. A ban on operation of trammel-nets on the entire south-west and south-east coasts may prevent exploitation of juveniles which comprise nearly 35% of the catch. Although the spawning stock of *P. ornatus* in deeper waters may not be in danger of being overfished along the south-east coast, the gill-net fishery for juveniles may be detrimental to the stock, as indicated by the decline in the catch and catch rate during the last decade.

The spiny lobster fishery in India is an open-access one and any restriction imposed is likely to be resisted by fishers. Co-operation among fishers, scientists, and government agencies is important for implementing sustainable management programmes. Apart from legal implementation of fishing regulations, education and creation of awareness among fishers on the negative impact of fishing and marketing egg-bearing lobsters and juveniles, may bring a subtle change in their mindset. The educational programme initiated in 2002 is making slow progress in inculcating a sense of responsible fishing and trade. However, fishers are realising that the lobster fishery on which they depend for their livelihood is gradually becoming depleted, and implementation of regulatory measures would benefit them in the long run. Village-level meetings, distribution of educative posters, stickers and pamphlets, video film shows, V notching and releasing of egg-bearing lobsters, and distribution of lobster traps as a less destructive fishing method, are some of the activities implemented under this programme. Enforcement of the minimum legal size, for export of four commercially important species of lobsters in the country (Table 2), is a positive step from the Ministry of Commerce and Industry, Government of India. Implementation of the minimum legal size for fishing, closure of spiny lobster fishery during the peak spawning season in the southern region, and a ban on trammel-nets are the regulatory measures recommended for implementation by the State Governments. As lobster fishing is a socio-economic activity involving fishers and traders, any regulatory measure implemented should also consider socio-economic aspects.

ACKNOWLEDGMENTS

We thank Dr Mohan Joseph Modayil, Director of the Central Marine Fisheries Research Institute, for the facilities provided and encouragement. We also gratefully acknowledge receipt of the data on total landing of lobsters by trawlers, from the Fishery Resources Assessment Division of the Institute. The first author thanks Marine Products Export Development Authority, India and Dr Stuart Frusher, Convenor of the 7th International Conference on Lobster Biology and Management, for providing the financial support to present the paper at the Conference. The support from Dr Josileen Jose, Ms Jeena, and Mrs K. V. Sajitha is also gratefully acknowledged.

REFERENCES

Balasubramanyam, R.; Satyanarayana, A. V. V.; Sadanandan, K. A. 1960: A preliminary account of the experimental rock-lobster fishing conducted along the south-west coast of India, with bottom set gill-nets. *Indian Journal of Fisheries 7*: 405–422.

Balasubramanyam, R.; Satyanarayana, A. V. V.; Sadanandan, K. A. 1961: A further account of the rock-lobster fishing experiments with the bottom-set gill-nets. *Indian Journal of Fisheries 8*: 269–290.

Chhapgar, B. F.; Deshmukh, S. K. 1971: Lobster fishery of Maharashtra. *Journal of the Indian Fisheries Association 1(1)*: 74–86.

Deshmukh, V. D. 2001: Collapse of sand lobster fishery in Bombay waters. *Indian Journal of Fisheries 48(1)*: 71–76.

Gayanilo, F. C.; Sparre, P.; Pauly, D. 1996: The FAO-ICLARM Fish Stock assessment tools (FiSAT). *FAO Computerized Information Series (Fisheries) No. 8*. Rome, Italy, Food and Agriculture Organisation. 124 p. and 3 diskettes.

George, M. J. 1965: Observations on the biology and fishery of the spiny lobster *Panulirus homarus* (Linnaeus). Proceedings Symposium on Crustacea, Part IV. Marine Biological Association of India, Cochin. Pp. 1308–1316.

George, M. J. 1973: The lobster fishery resources of India. *In*: Proceedings Symposium on the living resources of the seas around India, Cochin, December 1968. Special Publication, Central Marine Fisheries Research Institute. Pp. 570–580.

John, C. C.; Kurian, C. V. 1959: A preliminary note on the occurrence of deep-water prawn and spiny lobster off the Kerala Coast. *Bulletin Central Research Institute, Trivandrum, Ser. C. 7(1)*: 155–162.

Kabli, L. M.; Kagwade, P. V. 1996a: Reproductive biology of the sand lobster *Thenus orientalis* (Lund) from Bombay waters. *Indian Journal of Fisheries 43(1)*: 13–25.

Kabli, L. M.; Kagwade, P. V. 1996b: Age and growth of the sand lobster *Thenus orientalis* (Lund) from Bombay waters. *Indian Journal of Fisheries 43(3)*: 241–247.

Kabli, L. M.; Kagwade, P. V. 1996c: Morphometry and conversion factors in the sand lobster *Thenus orientalis* (Lund) from Bombay waters. *Indian Journal of Fisheries 43(3)*: 249–254.

Kagwade, P. V. 1987a: Morphological relationships and conversion factors in spiny lobster *Panulirus polyphagus* (Herbst). *Indian Journal of Fisheries 34(3)*: 348–352.

Kagwade, P. V. 1987b: Age and growth of the spiny lobster *Panulirus polyphagus* (Herbst). *Indian Journal of Fisheries 34(4)*: 389–398.

Kagwade, P. V. 1988a: Reproduction in the spiny lobster *Panulirus polyphagus* (Herbst). *Journal of Marine Biological Association of India 30(1&2)*: 37–46.

Kagwade, P. V. 1988b: Fecundity in the spiny lobster *Panulirus polyphagus* (Herbst). *Journal of Marine Biological Association of India 30(1&2)*: 114–120.

Kagwade, P. V.; Manickaraja, M.; Deshmukh, V. D.; Rajamani, M.; Radhakrishnan, E. V.; Suresh, V.; Kathirvel, M.; Rao, G. S. 1991: Magnitude of lobster resources of India. *Journal of Marine Biological Association of India 33(1&2)*: 150–158.

Kurian, C. V. 1964: Deepwater prawns and lobsters off the Kerala coast. Fishery Technology: symposium on prawn fisheries in India, Cochin, October 3–4, 1964. Pp. 51–53.

Miyamoto, H.; Shariff, A. T. 1961: Lobster fishery off the south-west coast of India—anchor hook and trap fisheries. *Indian Journal of Fisheries 8*: 252–268.

Mohamed, K. H.; George, M. J. 1968: Results of the tagging experiments on the Indian spiny lobster, *Panulirus homarus* (Linnaeus)—movement and growth. *Indian Journal of Fisheries 15*: 15–26.

Nair, R. V.; Soundararajan, R.; Dorairaj, K. 1973: On the occurrence of *Panulirus longipes longipes*, *Panulirus penicillatus* and *Panulirus polyphagus* in the Gulf of Mannar with notes on the lobster fishery around Mandapam. *Indian Journal of Fisheries 20(2)*: 333–350.

Pauly, D. 1980: On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. *Journal du Conseil international pour l' Exploration de la Mar 39(2)*: 175–192.

Pauly, D. 1984: Length converted catch curve. A powerful tool for fisheries research in the tropics. *ICLARM Fishbyte 2(3)*: 9–10.

Radhakrishnan, E. V. 1995: Lobster fisheries of India. *The Lobster Newsletter 8(2)*: 1, 12–13.

Radhakrishnan, E. V.; Manisseri, M. K. 2003: Lobsters. *In*: Mohan Joseph, M.; Jayaprakash, A. A. *ed.* Status of exploited marine fishery resources of India. Central Marine Fisheries Research Institute, Kochi–682014, India. Pp.195–202.

Rajamani, M.; Manickaraja, M. 1991: On the collection of spiny lobsters by skin divers in the Gulf of Mannar off Tuticorin. *Marine Fisheries Information Service, Technical & Extension Series No. 113*: 17–18.

Rajamani, M.; Manickaraja, M. 1995: Fishery of the painted cray fish *Panulirus versicolor* in the Gulf of Mannar. *Marine Fisheries Information Service, Technical & Extension Series No. 140*: 6–7.

Rajamani, M.; Manickaraja, M. 1997a: On the fishery of the spiny lobster off Tharuvaikulam, Gulf of Mannar. *Marine Fisheries Information Service, Technical & Extension Series No. 146*: 7–8.

Rajamani, M.; Manickaraja, M. 1997b: The spiny lobster resources in the trawling grounds off Tuticorin. *Marine Fisheries Information Service, Technical & Extension Series No. 148*: 7–9.

Silas, E. G. 1969: New findings on trawling grounds on the continental slope bordering the Wadge Bank and extending to the Gulf of Mannar. *Bulletin, Central Marine Fisheries Research Institute No. 12*: 34–37.

Skewes, T. D. 1994: Changes in the composition and moult frequency of the ornate rock lobster *Panulirus ornatus* population in Torres Strait associated with an annual breeding migration. *Bulletin Marine Science 54(1)*: 38–48.

Subramanian, V. T. 2004: Fishery of sand lobster *Thenus orientalis* (Lund) along Chennai coast. *Indian Journal of Fisheries 51(1)*: 111–115.