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V.N. Pillai and N.G. Menon

Central Marine Fisheries Research Institute
(Indian Council of Agricultural Research)
Tatapuram P.O., Cochin-682 014
Kerala, India

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36 A review on cephalopod resources, biology and stock assessment in Indian seas

M.M. Meiyappan, K.S. Mohamed, K. Vidyasagar, K.P. Nair, N. Ramachandran, A.P. Lipton, G.S. Rao, V. Kripa, K.K. Joshi, E.M. Abdussamad, R. Sarvesan and G.P.K. Achary

ABSTRACT

Cephalopods are fished from the seas around India from very early times and at present contribute one of the most important exploited marine fishery resources of the country (between 4 and 5% of the all India production). The production, which remained at very low level up to the early seventies, has shown a remarkable increase crossing the 1,00,000 tonne mark in 1994. The taxonomy, biology and stock assessment of the various exploited species have been studied since the early seventies by the CMFRI. Studies indicate that upto 1994 the exploitation has remained within rational limits in almost all maritime states. The recent rapid increase in production warrants close monitoring of this short-lived resource from the viewpoint of judicious management.

Introduction

Cephalopods are a marine fishery resource of increasing importance and many species are exploited as bycatch by trawlers from throughout the Indian coast. Although they form only 4-5% of the total marine fish landings, cephalopod stocks are under heavy fishing pressure because of their high value as an exportable commodity. So much so, of late, they are even targeted by the trawl fleet in certain seasons of the year along parts of the westcoast of India. The CMFRI has initiated studies on cephalopod stock from Indian waters during the seventies. The initial results of this programme on the taxonomy, biology, fishery and stock assessment of cephalopod stocks pertaining to the seventies were published as a bulletin (Silas, 1985). Subsequently a major

exercise on the stock assessment of Indian cephalopod stock with data of 1979-89 was made by CMFRI. These studies indicated that squids were exploited at optimum level on both coasts (Meiyappan *et al.* 1993) and cuttlefishes were optimally exploited along east coast and under exploited along west coast (Nair *et al.*, 1993 and Rao *et al.*, 1993). Besides, a number of authors (Kasim, 1985; Rao, 1988; Mohamed, 1996; Mohamed and Rao, 1997) have published information on specific aspects of cephalopod stocks. Other contributions from India on cephalopod resources, biology and population dynamics include that of Kore and Joshi (1975) on the food of squids, Oommen (1977) on the food, feeding and fishery of squids, Silas *et al.* (1982) on the resources, Philip and Ali (1989) on cuttlefish population dynamics, Nair *et al.* (1992a and b) on squids caught by jigging along SW coast and the monsoon fishery for cephalopods along west coast and Kripa and Mathew (1994) on the octopus resources of Cochin.

This paper presents a brief review of the investigations on cephalopods carried out in India, besides, the statewise cephalopod catch data for the period 1990-94 has been analysed in detail to bring out the status of the cephalopod fishery during the early nineties in different maritime states.

Exploited cephalopods

Cephalopods exploited from Indian seas can be broadly divided into three, viz., squids (order: Teuthoidea), cuttlefishes (order: Sepioidea) and octopuses (order: Octopoda). A list of neretic species commercially exploited is given in *Table 1*. The dominant species occurring in commercial catches are *Loligo duvauceli*, *Sepia pharaonis*, *S. aculeata* and *Octopus membranaceous*.

Table 1: List of commercially exploited cephalopods from Indian Seas

Species	Common Name	Distribution
Squids		
Loligo duvauceli	Indian squid	All along Indian coast
L. uyii	Little squid	Madras & Visakhapatnam
Doryteuthis sp	Needle squid	SW and SE coast
Loliolus investigatoris		All along Indian coast

Septoteuthis lessoniana	Palkbay squid	Palk bay & Gulf of Mannar
Symplectoteuthis oualaniensis	Oceanic squid	Oceanic Indian EEZ
Thysanoteuthis rhombus	Diamond squid	Oceanic Indian EEZ
Cuttlefishes		
Sepia pharaonis	Pharaoh cuttlefish	All along Indian coast
S. aculeata	Needle cuttlefish	All along Indian coast
S. elliptica		Veraval & Cochin
S. prashadi	Hooded cuttlefish	SW & SE coast
S. brevimana	Shortclub cuttlefish	Madras & Visakhapatnam
Sepiella inermis	Spineless cuttlefish	All along Indian coast
Octopuses		
Octopus membranaceous	Webfoot octopus	SW & SE coast and islands
O. dolifusi	Marbled Octopus	SW & SE coast and islands
O. lobensis	Lobed octopus	SW & SE coast and islands
O. vulgaris	Common octopus	SW & SE coast and islands
Cistopus indicus	Old woman octopus	SW & SE coast and islands

Methods of exploitation

Although about 40% of the world's cephalopod catches are taken by squid jigging and 25% by trawling (Rathjen, 1991), in India, cephalopods are principally caught by bottom trawlers operating upto 100m depth zones. While most of the catch is brought in as bycatch from the shrimp and fish trawls employed by the trawlers, of late, there is a targeted fishery for cuttlefishes during the post monsoon period (Sep-Dec) using off bottom high opening trawls along the SW and NW coast. Prior to the seventies traditional gears like shore seines, boat seines, hooks and lines and spearing were the principal gear employed to capture cephalopods. These traditional gears continue to be used especially for cuttlefishes at Vizhinjam. Experimental squid jigging has been tried with Japanese expertise along the westcoast by GOI vessels with consid-

erable success (Nair *et al.*, 1992a). However, commercial squid jigging is not practised in India.

Cephalopod Production

Cephalopod production, which remained at very low level upto the early seventies, has shown a remarkable increase crossing the 1,00,000 tonne mark in 1994 (Fig.1). From 1973 onwards the commencement of export of frozen cephalopod products to several countries saw the transition of the resource from a discard to a quality resource fetching high foreign exchange (Silas, 1985). Thereafter its production showed a steep increase. The mean cephalopod production in different maritime state during 1990-94 is shown in Fig.1. The westcoast maritime states, Gujarat (GUJ), Maharashtra (MAH), Goa (GOA), Karnataka (KAR) and Kerala (KER) contribute to the bulk (86%) of the production. While the production from the east coast amounts to only 14% of 84551 t, of which, Tamil Nadu (TN) contributes the maximum followed by Andhra Pradesh (AP). The states of West Bengal (WB), Orissa (OR) and Pondicherry (PON) contribute only a small percentage. Overall, KER ranks first contributing a third of the all India production followed by MAH, GUJ and KAR. The cephalopod production (t/km^2) in different maritime states in

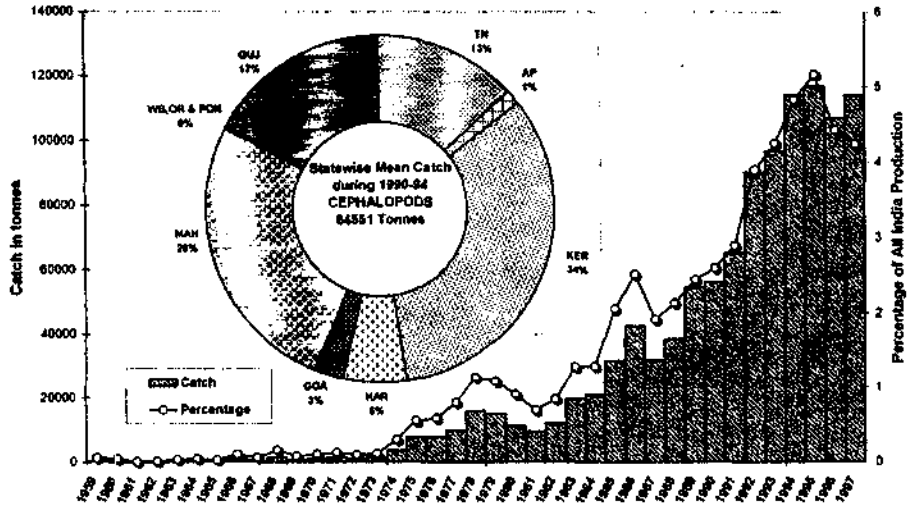

Fig.1. All India cephalopod production (1959-1997) and its percentage. The piediagram gives mean statewise percentage production (1990-94).

the continental shelf is shown in Fig.2. Indirectly this indicates the relative abundance and level of exploitation of cephalopods in the different maritime states.

At the national level, Jan-Mar and Oct-Dec were the most productive period. Along the upper east and westcoast, the above months were the most productive, while in KAR, KER, TN and AP Jul-Sep was also equally productive.

Specieswise production

The neretic squid *L. duvauceli* contributed more than a third of the cephalopod production during 1990-94. Followed by the pharaoh cuttlefish *S. pharaonis* and the needle cuttlefish *S. aculeata*. These three species together contribute to 84% of the total cephalopod production from India. Along the westcoast, *L. duvauceli* contributes to more than 50% of the landings (Fig.4), followed closely by *S. pharaonis* and *S. aculeata* (47%). Among squids,

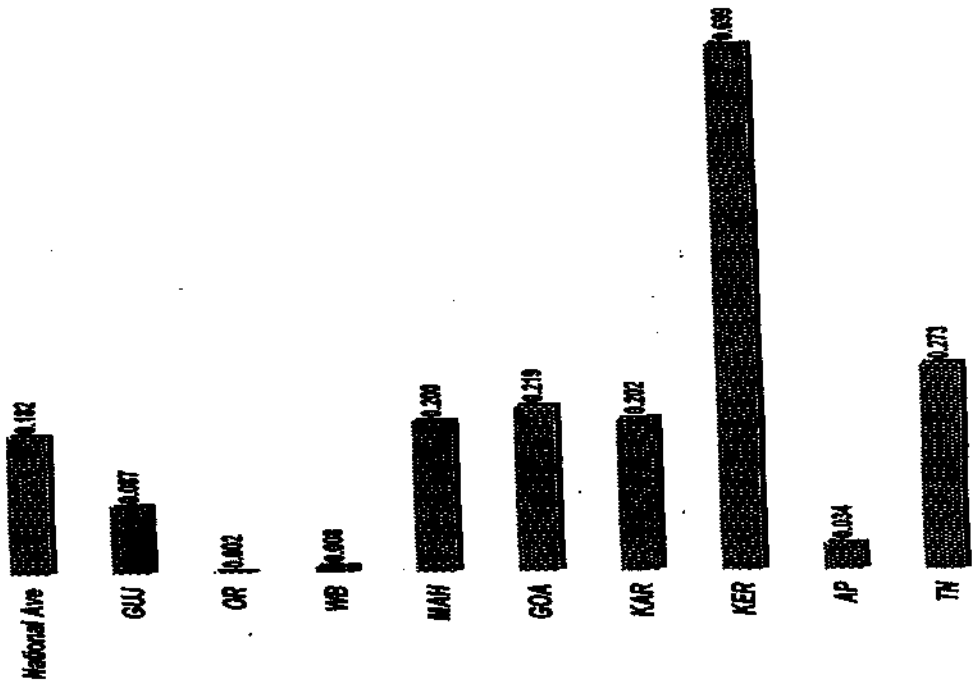

Fig.2. Cephalopod production (t)/km² shelf area in different maritime states of India.

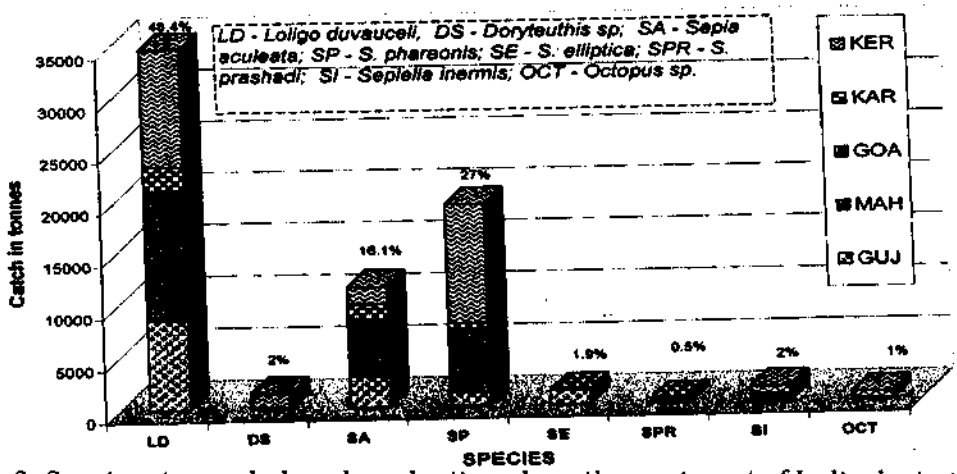

Fig.3. Specieswise cephalopod production along the westcoast of India during 1990-94.

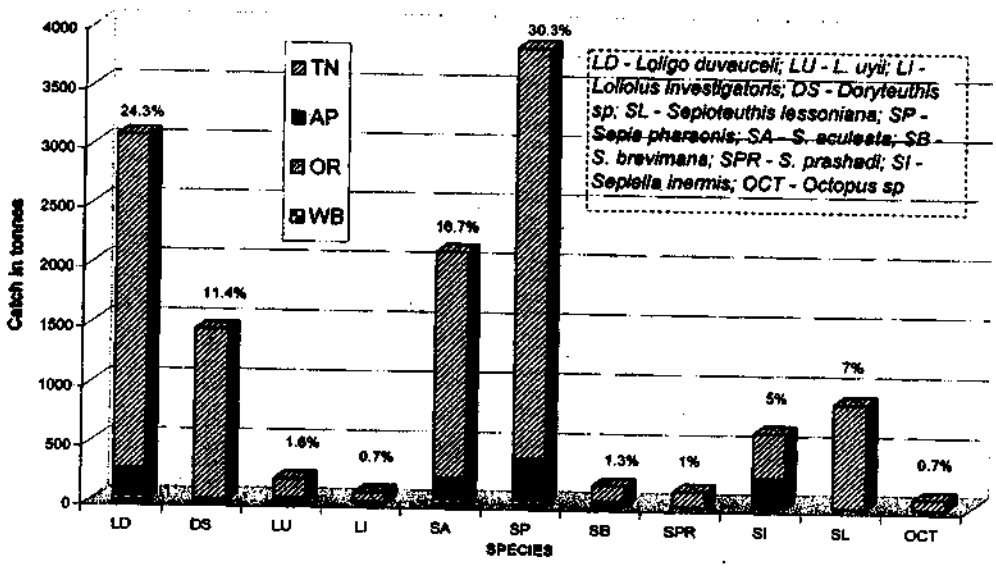

Fig.4. Species wise Cephalopod production along the eastcoast of India during 1990-94.

Doryteuthis sp. and among cuttlefishes, *S. elliptica* form significant part of the catch from Kerala and Gujarat respectively. A number of octopus species, chiefly, *O. membranaceous* forms 1% of the catch mainly from Kerala. The statewise contributions of different species are also shown in Fig.3.

The dominant species in landings from the eastcoast is *S. pharaonis* (Fig.4), followed by *L. duvaucelli and S. aculeata.* The diversity of squid and cuttlefish species exploited in commercial quantities is more along eastcoast as compared to westcoast. *Doryteuthis* sp. and *S. lessoniana* are also caught in considerable quantities from TN and AP. Octopus species, which were formerly discarded, has gained importance in recent years. The major production is from Kerala State (Kripa and Mathew, 1994). Their proportion in the landings from both the coasts are increasing considering the export value of the same.

Biology of exploited species

All investigations on cephalopod biology centre around the commercially exploited species such as the Palk Bay squid, *Sepioteuthis lessoniana* (Rao, 1954), *L. duvaucelli* (Kore and Joshi, 1975; Oommen, 1977; Silas *et al.*, 1985; Rao, 1988; Mohamed, 1993), *Sepia pharaonis, S. aculeata, Sepiella inermis* (Oommen, 1977; Unnithan, 1982; Silas *et al.*, 1985) and *Octopus dollfusi* (Sarvesan, 1969). The aspects of biology of cephalopods detailed here pertain mainly to *L. duvauceli, S. pharaonis* and *S. aculeata.*

Food and feeding: Adult cephalopods are voracious and active carnivores feeding mainly on fishes and crustaceans. Fish always occurs in the diet of *L. duvauceli* of all sizes. The preference to crustacean meal declines with increase in size and there is evidence of cannibalism above 80 mm DML (Kore and Joshi, 1975; Oommen, 1977). Cephalopods are preyed upon by a variety of marine fishes (including tunas and billfishes) and cetaceans (Silas *et al.*, 1985). Many workers have noticed the predominance of empty stomachs in samples and slackness in feeding during spawning period (Oommen, 1977). This may be due to the partial ingestion; fragmentation and rapid digestion of prey (Pierce *et al.*, 1994).

Age and growth: The relationship between length and weight of Indian cephalopods has been reported to be allometric with the 'b' value of the regression near to 2 than 3 (Meiyappan *et al.*, 1993; Nair *et al.*, 1993; Rao *et*

al, 1993). This relationship is also significantly different for males and females (Mohamed, 1996).

Growth in cephalopods has been perceived to be linear, exponential, asymptotic and/or oscillating and Pauly (1985) advocated the use of VBGF model with seasonal oscillation as a means of standardising growth estimates of different cephalopods allowing comparative studies to be made. Studies on the growth of Indian cephalopods have been made by using the asymptotic (VBGF) model (Kasim, 1985; Philip and Ali, 1989; Meiyappan and Srinath, 1989; Meiyappan *et al.*, 1993; Nair *et al.*, 1993; Rao *et al*, 1993; Mohamed, 1996) and the seasonally oscillating version of VBGF (Mohamed and Rao, 1997). Clear sexwise difference in growth rate has been reported from Indian waters. In the case of *L. duvaucelt* and *S. pharaonis* females grow faster than males, while in the case of *S. aculeata* males grow faster than females. A comparison of the results of various studies carried out in India is given in *Table 2*.

Table: 2. Estimates of growth parameters (L_∞ and K), natural mortality rates (M) and level of exploitation of cephalopod stocks exploited from the seas around India.

Species	Sex	Area	Period of	L_∞	(cm)	K yr^{-1}	M	Level of exploitation	Reference
Lotigo duvaucelt	Male	Madras	1979-80	20.0	0.94	1.42		Optimum	Silas *et al* (1985)
	Female	Madras	1979-80	20.0	0.94	1.42		Optimum	Silas *et al* (1985)
	Male	Cochin	1979-80	32.7	0.61	0.91		Optimum	Silas *et al* (1985)
Female	Cochin	1979-80	20.5	1.19	1.78			Optimum	Silas *et al* (1985)
L. duvaucelt	Comb	Veraval	1979-83	33.4	0.5	1.5-2.2		Under	Kasim (1985)
L. duvaucelt	Male	Cochin	1981-84	37.2	1.1	2.2		NA	Meiyappan & Srinath (1989)
	Female	Cochin	1981-84	23.8	1.7	2.2		NA	Meiyappan & Srinath (1989)
L. duvaucelt	Male	E Coast	1984-88	22.0	0.9	1.3-2.7		Optimum	Meiyappan *et al* (1993)
	Female	E Coast	1984-88	20.5	1.3	1.9-3.9		Optimum	Meiyappan *et al* (1993)

	Male	W Coast	1984-88	36.0	0.8	1.2-2.4	Optimum	Meiyappan *et al* (1993)
	Female	W Coast	1984-88	23.2	1.1	1.6-3.3	Optimum	Meiyappan *et al* (1993)
L. duvauceli	Male	Mangalore	1987-91	41.5	0.9	1.8	Over	Mohamed (1996)
	Female	Mangalore	1987-91	24.5	1.1	2.1	Over	Mohamed (1996)
L. duvauceli	Comb	Karnataka	1983-95	37.1	1.4	2.1	Over	Mohamed & Rao (1997)
Sepia pharaonis	Male	Vizhinjam	1978-80	36.5	0.7	1.07	Under	Silas *et al* (1985)
	Female	Vizhinjam	1978-80	34.2	0.86	1.29	Under	Silas *et al* (1985)
S. pharaonis	Male	E Coast	1984-88	27.0	0.9	1.08-1.8	Optimum	Nair *et al* (1993)
	Female	E Coast	1984-88	23.0	1.0	1.23-2.05		Optimum Nair *et al* (1993)
	Male	W Coast	1984-88	32.0	0.7	1.41-2.35		Under Nair *et al* (1993)
	Female	W coast	1984-88	29.6	0.8	1.5-2.5	Under	Nair *et al* (1993)
Sepia aculeata	Male	Madras	1979-80	20.5	1.13	1.69	Optimum	Silas *et al* (1985)
	Female	Madras	1979-80	20.5	1.13	1.69	Optimum	Silas *et al* (1985)
S. aculeata	Male	E Coast	1984-88	20.3	0.9	1.33-2.25		Optimum Rao *et al* (1993)
	Female	E Coast	1984-88	20.3	0.9	1.33-2.25		Optimum Rao *et al* (1993)
	Male	W Coast	1984-88	20.6	1.1	1.65-2.75		Under Rao *et al* (1993)
	Female	W Coast	1984-88	20.5	1.0	1.5-2.5	Under	Rao *et al* (1993)

Size at first maturity: Pioneering work on the reproductive biology of the Palk bay squid *Septoteuthis lessoniana* has been made by Rao (1954). Later, Silas *et al.* (1985) reported on the maturity of three species of squids and six species of cuttlefishes. They reported that in *L. duvauceli* males attained sexual maturity earlier than females and in all species spawning is prolonged. The size at first maturity of male and female squids and cuttle-

fishes along west and eastcoast of India is shown in *Table 3*.

Maturity stage and spawning: Silas (1985) described and standardised the maturity stages for biological studies of squids and cuttlefishes. He described a simple 4 point (Immature, Maturing, Mature and Spent) maturity scale, which has since been used by all workers on Indian cephalopods. Rao (1988) gave detailed descriptions, of *L. duvauceli* maturity stages on the above line.

Table 3. Size at first maturity (in mm DML) of various exploited cephalopods along the Indian coast (from Silas *et al.*, 1985)

Species	East coast		West coast	
	Male	Female	Male	Female
L. duvauceli	85	96	122	128
S. lessoniana	122	98	-	-
Doryteuthis spp.	-	-	97	84
S. pharaonis	121	138	154	157
S. aculeata	100	118	124	130
S. brevimana	56	63	-	-
S. elliptica	-	-	93	96
Septella inermis	53	61	81	83

Similar to other tropical marine resources, cephalopods along the Indian coast are reported to spawn almost throughout the year. Information on this aspect is scanty, but the peak spawning period of some of the studied species is given in *Table 4*.

Table 4: Areawise peak spawning season of Indian cephalopods

Species	Geographic Area	Peak Season	Reference
Loligo duvauceli	East Coast	Throughout the year	Silas *et al.*, 1985
	West Coat	Throughout the year	Silas *et al.*, 1985
	Bombay	Sep	Silas *et al.*, 1985

	Ratnagiri	Oct-Nov	Kore and Joshi, 1975
	Mangalore	Dec-May	Rao, 1988
	Mangalore-Malpe	Sep-Oct	Mohamed, 1993
Doryteuthis sibogae	Vizhinjam	Dec-Feb	Silas *et al.*, 1985
Sepioteuthis lessoniana	East Coast	Jan-Oct	Silas *et al.*, 1985
	Mandapam	Jan-Jun	Rao, 1954
Sepia pharaonis	East Coast	Oct-Apr	Silas *et al.*, 1985
	West Coast	Oct-Apr	Silas *et al.*, 1985
Sepia aculeata	E.coast (Waltair)	Jan-Apr; Jul-Dec	Silas *et al.*, 1985
	E.coast (Mandapam)	Feb-Apr; Jul-Aug	Rahaman, 1967
	W.coast (Cochin)	Apr, Jul, Dec	Silas *et al.*, 1985
	W.coast (Bombay)	Feb-Mar, Sep-Nov	Silas *et al.*, 1985
Septella inermis	E.coast (Mandapam)	Oct-Dec	Unnithan, 1982
	W.coast	Sep-Dec	Silas *et al.*, 1985

The squid *L. duvauceli* spawns throughout the year along both the coast, but along the westcoast, peak spawning has been observed during post monsoon i.e., Sep-Nov (Kore and Joshi, 1975; Silas *et al.*, 1985; Mohamed, 1993). This species forms large schools (consisting of fully mature animals, 80% males) during this season, and becomes vulnerable to the purse seine fleet operating along Karnataka coast (Mohamed, 1993) and also to cast netters along coastal knee deep water of Alleppey (Meiyappan and Srinath, 1989). Based on this observation, Mohamed (1993) opined that the squids congregate for spawning (copulation) in near shore areas after which the females migrate to the shallow subtidal regions with hard substratum for laying the fertilized eggs. Asokan and Kakati (1991) have collected such eggs from the subtidal areas of Karwar for rearing. From the sex ratio (M 80: F 20) of such squid schools it would be easy to conclude that female die after spawning (semelparity is common among cephalopods worldwide). However, based on the relatively low GSI levels and the occurrence of mature females over a wide range of size classes, Mohamed (1993) concluded that this species is a multiple spawner and not a semelparous species. More evidence needs to be

gathered to reach a final conclusion. Similar studies on other commercial cephalopods are lacking.

Fecundity: Estimates on the fecundity of Indian cephalopods are few. Unnithan (1982) reported that in the spineless cuttlefish *S. inermis* the total number of ripe eggs of individuals between 69-71 mm DML was from 470 to 850 (average 14.9 eggs/g body weight). In the squid *L. duvauceli* Rao (1988) reported that on an average an individual produced 5300 eggs and that there was good correlation between length, ovary weight and fecundity. Mohamed and Nagaraja (1997) estimated the fecundity of the same species varied between 2000 to 14000 eggs (average 65 eggs/g body weight). In general, fecundity is low in cephalopods because of the absence of a larval stage and the hatchlings are virtually miniature adults.

Stock assessment and management

Ever since the CMFRI initiated a major research project on the biology and stock assessment of cephalopod resources of India, a number of research papers have been published on the subject (see Table 2 for complete list). Mostly F based models have been applied to study cephalopod stocks. In the first study on Indian cephalopod stocks, Silas *et al* (1985), used length cohort analysis to estimate stock sizes. Later studies (Meiyappan *et al.*, 1993; Nair *et al.*, 1993 and Rao *et al.*, 1993) also used cohort analysis to estimate mortality and stock and the yield and biomass estimates were obtained with length based Thomson and Bell analysis. Mohamed (1996) used the yield per recruit model to estimate MSY for Mangalore populations of *L. duvauceli*. Later Mohamed and Rao (1997) assessed the squid yield along Karnataka coast using the TB model to derive MSY and MSE. They also studied the relationship between spawning stock and recruitment of squids to assess the productivity of the population in terms of recruitment. They found that Ricker's stock recruitment curve could adequately explain the variation in recruitment with respect to spawning stock biomass (SSB).

Most of these studies indicated that cephalopods were either under exploited (e.g. *S. pharaonis* and *S. aculeata* along eastcoast) or optimally exploited (Table 2). While Mohamed (1996) and Mohamed and Rao (1997) found squid stock along Karnataka coast to be marginally over exploited.

Cephalopods are not a targeted fishery along the Indian coast (except-

ing seasonally along the SW coast) and therefore, it is difficult to set management targets and many of the models applied would have little relevance. Yet, Rosenberg *et al.* (1990) suggests that the most effective means of managing cephalopod fisheries is by regulating fishing effort, which will reduce the risk of recruitment overfishing. The present ban on trawl fishing during the monsoon as variously practised by different maritime states along the westcoast is in effect a means of regulation of fishing effort and should be continued.

Utilization and marketing

There is very little internal market demand for cephalopods and consequently almost all the catch is exported. Export of cephalopods from India during 1991 to 1996 is shown in Fig 5. While the quantity peaked in 1995, when cephalopods formed about the 45% of the total quantity exported, the annual average is about 25%. However, the value of cephalopods in total marine exports has remained at 15% from 1992 onwards without much variation. In 1996 the value of cephalopods exported amounted to more than Rs. 8500 million. Categorywise, squid products are the maximum in all years followed by cuttlefish products. The products include dried, frozen whole, filleted, tentacles, rings, roe, wings, IQF and bones and ink. Octopus products exported are meagre, but from 1994 onwards there is rising trend in its

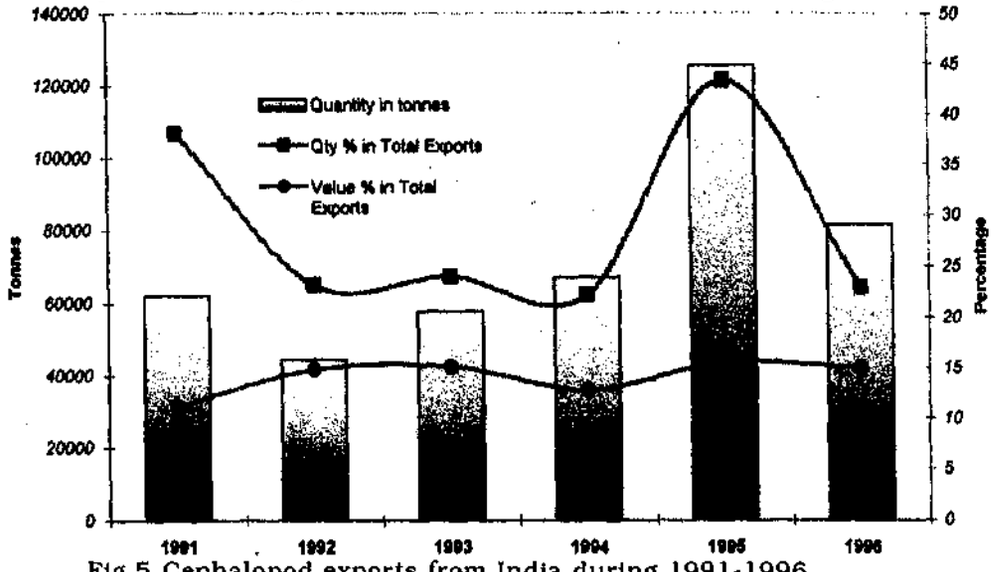

Fig.5. Cephalopod exports from India during 1991-1996 (source MPEDA, Kochi)

exports. The main markets for export of Indian cephalopods are Europe, Japan and China.

Future research

The emergence of cephalopods as an important marine fishery resource of the country with almost cent percent export potential warrants careful monitoring and appropriate management. Several gaps exist in our knowledge of these valuable resources, especially on the life histories of our species. For example, we still have not resolved the question of semelparity of most of our species. At present we know that most of the species lay their eggs in the shallow inshore waters. These grounds are subjected to sedimentation due to man-made causes such as dumping of sludge. This might degrade the benthic conditions with a negative impact on cephalopod egg laying and consequently on the recruitment.

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