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Stock assessment of the pharaoh cuttlefish *Sepia pharaonis* Ehrenberg

K PRABHAKARAN NAIR[1], M SRINATH[2], M M MEIYAPPAN[3], K SATYANARAYANA RAO[4], R SARVESAN[5], KUBER VIDYASAGAR[6], K S SUNDARAM[7], G SYDA RAO[8], A P LIPTON[9], P NATARAJAN[10], G RADHAKRISHNAN[11], K SUNILKUMAR, MOHAMED[12], K A NARASIMHAM[13], K BALAN[14], V KRIPA[15] and T V SATHIANANDAN[16]

Central Marine Fisheries Research Institute, Cochin, Kerala 682014

ABSTRACT

The data collected during 1979 to 1989 at different centres on both the coasts of India, indicate that the landings of the cuttlefish *Sepia pharaonis* Ehrenberg, increased by 3 times (11,000 t in 1989). Over 84% was from the west coast, with Maharashtra accounting for 44% and Kerala 33%. About 87% of cuttlefish is obtained in trawl net as by-catch, while a small portion is taken in localized hand-jigging operation. On the east coast over 63% of the total catch is during the second and third quarters of the year (April-September). On the west coast the fourth quarter is the most productive (50%), the second quarter being the least. The natural mortality (M) ranges from 1.08 to 1.8 for males and 1.23 to 2.05 for females on the east coast; on the west coast the corresponding values were 1.41-2.35 and 1.5 - 2.5. On both the coasts the M for females was higher than for males. On the east coast the maximum values of fishing mortality ('F' in the range 1.65-2.9 in male cuttlefish) was observed at a size of 170 mm; for females it is at 190 mm in the range 1.95 - 2.8. On the west coast it is at a uniform size of 190 mm in the range 1.27 - 2.14 in males and 1.33 - 1.66 in females. The standing stock of male cuttlefish is higher than that of females on the east coast, while the reverse is true for the west coast. Using Thompson and Bell long-term forecast analysis the MSY and mean biomass at different M/K levels are also estimated for males and females separately for each coast. The present level of exploitation is considered to be optimal on the east coast, whereas on the west coast there is scope for increase.

Sepia pharaonis Ehrenberg, a coastal Indo-West Pacific species, is the largest cuttlefish in the Indian seas. It grows up to 40 cm or slightly more in dorsal mantle length. It holds a special position in India's marine fisheries because of its economic importance in the export trade. There has been a steady increase in its production in recent years due to the rising demand in the export markets. The great bulk of the landings is obtained as by-catch in trawl fishing all along the coasts, while a small portion comes in targeted fishing (hand-jigging) restricted to

Present address : [1]Scientist (Selection Grade), Vizhinjam Research Centre of CMFRI, Vizhinjam P.O., Trivandrum 695 521.

[2,14]Scientist (Selection Grade), [13]Principal Scientist, [15,16]Scientist.

[3]Scientist (Selection Grade), [4]Principal Scientist, [10]Scientist S-2, Madras Research Centre of CMFRI, 68/I, 4th Floor, Greams Road, Madras 600 006.

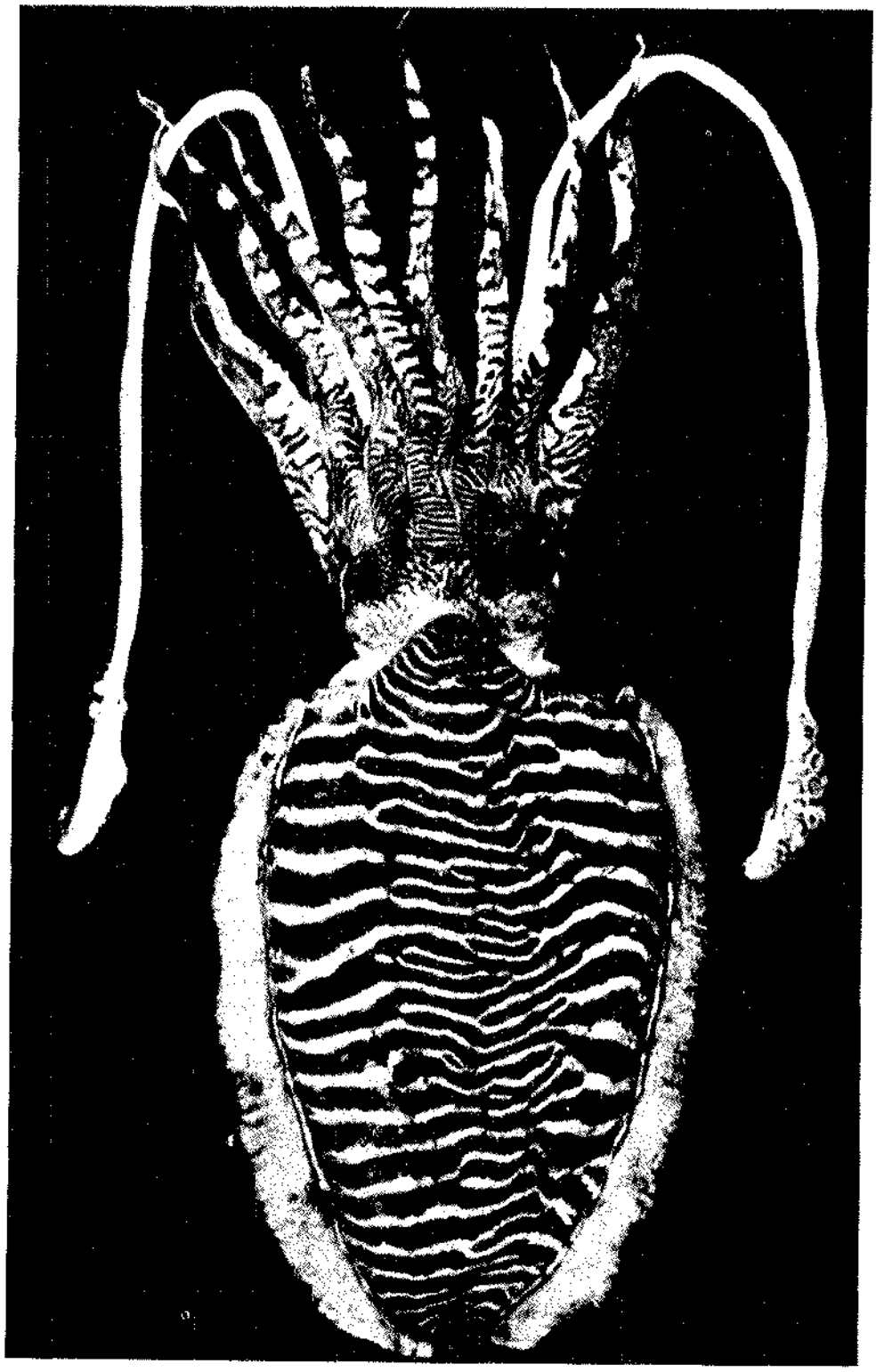
[5]Scientist (Selection Grade), [11]Scientist, Vishakhapatnam Research Centre of CMFRI, Andhra University, P.O., Vishakhapatnam 530 003.

[6]Senior Scientist, [7]Scientist (Selection Grade), Bombay Research Centre of CMFRI, 148, Army & Navy Building, 2nd Floor, M.G. Road, Bombay 400 023.

[8]Senior Scientist, Kakinada Research Centre of CMFRI, Door No. 8-14-38, Red Cross Street, Gandhi Nagar, Kakinada 533 004.

[9]Senior Scientist, Mandapam Regional Centre of CMFRI, Marine Fisheries P.O., Mandapam Camp 623 520.

[12]Scientist, Mangalore Research Centre of CMFRI, P.B. No. 244, Bolar, Mangalore 575 001.



Sepia pharaonis Ehrenberg

Vizhinjam-Colachel area on the southwest coast.

Noteworthy among the recent studies on cuttlefish are those by Silas *et al.* (1982, 1986 a,b,c,d) on the resource and exploitation, identity, biology, stock assessment, utilization and export, Nair (1986) on specialized fishery, Nair *et al.* (1986) on the hatching and post-hatching behaviour, and Philip and Ali (1986) on its population dynamics and stock assessment in the Wadge Bank. Other important investigations were by Dayaratne (1978) on the cuttlefish fishery by trawling in Wadge Bank, Sanders (1979, 1981) on the stock assessment of *Sepia pharaonis* off PDR Yemen, and Sanders and Bouhlel (1981, 1983) on the mesh selection studies.

In view of the urgent need to estimate the resource position and the maximum sustainable yield of this cuttlefish in our waters for proper management of exploitation and conservation of the resource, an attempt is made here to assess the stock, based on the catch, effort and biological data collected at various centres on both the coasts over a number of years.

DATA BASE AND METHODOLOGY

The state-wise cephalopod catch data for 1979-1989 and the gear-wise data for 1985-1989 were obtained from the Fisheries Resources Assessment Division of the Central Marine Fisheries Research Institute. These data were given as cephalopods and not species-wise. The species-wise data collected at various centres (Veraval, Bombay, Mangalore, Cochin, Vizhinjam, Tuticorin, Mandapam, Rameswaram, Madras, Kakinada and Visakhapatnam) have been utilized to obtain the statewise catch of *Sepia pharaonis*. The length-frequency data of this cuttlefish collected from trawl fishery at Cochin and Madras during 1984-1988 were used. Only the catch data from trawl were considered here for the stock assessment as the great bulk of the cuttlefish catch was taken by this gear.

The monthly estimates of catch, effort, species composition and length composition were obtained using the methods of Alagaraja (1984). The monthly estimates were pooled to get annual estimates. The average monthly length frequency data for 1984-1988 collected at different centres on either coast were pooled and raised to get the estimates for the respective coast.

The length was measured along mid-dorsal line from the anterior tip of the mantle to the posterior tip up to the base of spine of the cuttlebone. The length frequency was classified into 10 mm groups and the average monthly length frequency for 1984-1988 was used for the estimation of growth parameters. Males and females were treated separately.

The growth parameters L_∞ and K were estimated using ELEFAN I method of Pauly and David (1981), assuming that the growth in length follows von Bertalanffy growth formula (VBGF).

Jones' (1984) length cohort analysis was applied to estimate the mortality rates and stock sizes by assuming 3 different values for M/K, viz. 1.5, 2 and 2.5. The yield and biomass were estimated with length-converted Thompson and Bell analysis (Sparre 1985).

LFSA package of FAO (Sparre 1987) was utilized for all the anlyses of the data.

RESULTS AND DISCUSSION

Fishery

All-India production: The country's annual production of *Sepia pharaonis* for 1979-1989 showed an increasing trend (Table 1).

Table 1. State-wise production (tonnes) of *Sepia pharaonis* during 1979-1989

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
West Bengal	0	1	0	1	3	6	1	1	4	1	6
Orissa	2	15	9	30	18	9	14	18	15	6	12
Andhra Pradesh	80	72	78	91	79	69	85	105	120	82	76
Tamil Nadu	388	300	344	661	791	754	905	797	828	859	1 129
Pondicherry	10	8	9	17	25	7	9	9	14	5	22
Kerala	628	895	501	746	364	1 144	1 748	3 163	1 590	3 198	4 956
Karnataka	1	3	6	3	22	7	5	47	63	43	54
Goa	4	5	2	4	9	9	6	31	11	9	10
Maharashtra	1 136	342	504	1 372	1 898	2 196	3 752	3 570	3 324	3 832	4 158
Gujarat	337	219	173	190	250	146	288	433	430	181	466
Total	2 586	1 860	1 626	3 115	3 459	4 347	6 813	8 174	6 399	8 216	10 889

State-wise production: Over 84% of the all-India landings of *Sepia pharaonis* were taken on the west coast (Table 1). Maharashtra alone accounted for 44%, followed by Kerala (33%) and Gujarat (5%), while the contribution by Karnataka and Goa was negligible. In Maharashtra except in 2 years, the annual catch was always more than 1 000 t ranging up to a maximum of about 4 200 t in 1989. In the same year the landings in Kerala were still higher 4 956 t. On the east coast the only state which contributed moderate catches of this cuttlefish was Tamil Nadu (14%). The share of all other states combined was only 2%.

Gear-wise production: Sepia pharaonis was mainly obtained as by-catch in trawl fishing. A small portion of the catch came from hand-jigging operations in Vizhinjam area where the gear is exclusively targeted at this species. On an all-India basis, about 87% of the total catch was taken by trawl alone. The state-wise cuttlefish catches by trawl and by other gears together for 1985-1989 are given in Table 2. In West Bengal no catches of this species were obtained in trawl. In other states the catches in traditional gear were very small when compared to trawl catches. Only in Tamil Nadu and Kerala the traditional gear

Table 2. State-wise production (tonnes) of *Sepia pharaonis* by trawl net and by other gears during 1985-89 (TN: trawl net; OG: other gears; T: total)

	1985			1986			1987			1988			1989		
	TN	OG	T	TN	OG	T	TN	OG	T	TN	OG	T	TN	OG	T
West Bengal	-	1	1	-	1	1	-	4	4	-	1	1	-	6	6
Orissa	8	6	14	7	11	18	11	4	15	5	1	6	12	-	12
Andhra Pradesh	70	15	85	97	8	105	102	18	120	76	6	82	71	5	76
Tamil Nadu	298	607	905	432	365	797	651	177	828	670	189	859	612	517	1 129
Pondicherry	9	-	9	9	-	9	12	2	14	5	-	5	22	-	22
Kerala	1041	707	1 748	1 394	1 769	3 163	1 471	119	1 590	2 953	245	3198	4 523	433	4 956
Karnataka	5	-	5	37	10	47	63	-	63	43	-	43	37	17	54
Goa	5	1	6	26	5	31	11	-	11	9	-	9	8	2	10
Maharashtra	3 735	17	3 752	3 552	18	3 570	3 320	4	3 324	3 820	12	3 832	4 140	18	4 158
Gujarat	282	6	288	420	13	433	429	1	430	181	-	181	463	3	466
Total (All India)	5 453	1 360	6 813	5 974	2 200	8 174	6 070	329	6 399	7 762	454	8 216	9 888	1 001	10 889

contributed to the cuttlefish catch to some extent.

Seasonal production trends in Orissa: The seasonal abundance varied greatly from year to year but as a whole the catches were better in the fourth quarter, with no catch in the second quarter. In Andhra Pradesh the production was almost equal in all the quarters, while in Tamil Nadu the third quarter production was the highest. In Pondicherry the landings were irregular showing much variation from year to year, though on the average the third quarter was more productive. On the east coast as a whole, the third quarter accounted for the highest catch (37%), followed by the second quarter (26%) (Table 3). In 1986 half of the annual catch of this cuttlefish was taken in the third quarter; in other years the catches in this quarter varied from 28% to 39%.

In Kerala on the west coast, the landings in the third and fourth quarters were the best in almost equal proportions but in Karnataka and Goa the first quarter was more productive than other quarters. In Maharashtra the fourth quarter accounted for as much as 61-72% during different years. On the contrary in Gujarat, the first quarter yielded an average of 57% of the total production in the state. On the west coast as a whole, the fourth quarter accounted for 39-63% during different years at an average of 51%, the second quarter being the least productive (12%) (Table 3).

Biology

Size range: Cuttlefish, both male and female, on the west coast were of maximum size. Silas *et al.* (1986b) recorded that the largest male was 265 mm at Visakhapatnam and 334 mm at Vizhinjam on the west coast. In females the largest size on the east coast was 245 mm and 320 mm on the west coast. More or less the same size pattern was observed by us. The fishery on the east coast was generally supported by males in the

Table 3. Trawl fishing effort and *Sepia pharaonis* catch (tonnes) by season (quarter of the year) on the east and west coasts during 1985-89

	I quarter		II quarter		III quarter		IV quarter		Annual	
Year	Effort	Catch	Effort	Catch	Effort	Catch	Effort	Catch	Effort	Catch
East Coast										
1985	131 939	66	127 494	102	170 644	132	155 270	85	585 347	385
1986	143 398	76	133 044	90	183 831	272	152 897	107	613 170	545
1987	160 420	140	126 051	226	190 474	277	178 867	132	655 812	775
1988	171 446	133	146 754	261	177 542	215	150 203	147	645 945	756
1989	131 304	86	134 048	166	177 781	278	181 016	187	624 149	717
Average	147 700	101	133 478	169	180 054	235	163 650	132	624 882	637
West Coast										
1985	278 396	1 011	214 575	473	81 535	385	284 355	3 199	858 861	5 068
1986	359 312	1 057	256 058	480	76 670	527	283 579	3 365	975 619	5 429
1987	436 814	1 686	336 371	572	113 671	458	438 303	2 577	1 325 159	5 293
1988	470 588	1 561	362 046	880	133 694	905	502 831	3 660	1 469 159	7 006
1989	446 142	1 723	331 957	1 281	131 204	2 597	266 307	3 570	1 175 510	9 171
Average	398 250	1 409	300 201	736	107 355	974	355 055	3 275	1 160 861	6 394

size range of 90-150 mm and females in the range of 90-170 mm. On the west coast the fishery was supported by larger cuttlefishes: males in the range of 130-210 mm and females 150-230 mm.

Sex-ratio: There was great numerical difference in sex on most occasions and the expected equal distribution of sexes was very rarely observed. According to Silas *et al.* (1986), the sex ratio was highly variable from centre to centre during different months. On the east coast as a whole the male-female ratio varied from 48:52 to 10:90; on the west coast also it went up to 23:77. During the course of the present study similar conditions were observed. At Visakhapatnam on the east coast there were only males in some months; in other months the male-female ratio was 32:68 and 74:26. At Vizhinjam on the west coast, in most months the males outnumbered females in the ratios 55:45 to 74:26, while in a very few months the females were slightly more in number than the males.

Food and feeding: In cephalopods the stomach contents are often macerated and are in semi-digested state and therefore the identification of food items to the species or even genus level is difficult. What is generally possible is to segregate them into groups like fish, crustaceans or cephalopods based on undigested pieces of hard parts like bones, scales and eyeballs of fishes, exoskeleton of crustaceans and eyeballs and beaks of cephalopods. *Sepia pharaonis* is an active predator feeding on a variety of fish and crustaceans, and sometimes on other cephalopods (Silas *et al.* 1986b). Because of their benthic nature, they mostly feed on small fish and crustaceans like prawns and crabs that dwell near the bottom.

Maturity: Silas *et al.* (1986b) have given the maturity sizes of male and female cuttlefish at different centres. There were variations in the minimum size at which the cuttlefish of either sex become mature, as well as in the size at first maturity (the size at which 50% of the individuals are mature). At different centres on the east coast the size at first maturity was in the range of 119-121 mm for males and 120-138 mm for females. On the west coast both the sexes attained maturity at slightly larger sizes than on the east coast. For females this was 157-160 mm. These indicated that males attain maturity at slightly smaller size than females on both the coasts, and that the sizes at first maturity of both sexes are larger on the west coast.

Spawning: Cuttlefishes of both sexes with mature gonads were observed in several months at many centres on both coasts indicating that spawning is not restricted to any season but extended over a period of time, as in many cephalopods in Indian waters. According to Silas *et al.* (1986b), spawning occurs from October to April in general on both the coasts, sometimes extending up to August. In contrast to this, spawning in *Sepia pharaonis* is restricted to March-May period in Hong Kong waters (Voss and Williamson 1971), and to August-October in the Red Sea (Sanders 1981).

Length-weight relationship: Dorsal mantle length measured to the nearest 1 mm and weight to the accuracy of 0.5 g, covering the full length range of the cuttlefish caught in the fishery, were used to arrive at the length-weight relationship, which is in the form $W = aL^b$. The estimated values for the east coast are given below:

Males : $W = 0.0006097\ L^{2.5997}$

Females : $W = 0.0005606\ L^{2.6286}$

For the west coast, Silas *et al.* (1986b) have given the relationship as follows:

Males : $W = 0.000988\ L^{2.5058}$
Females : $W = 0.000726\ L^{2.5478}$

The rate of increase in weight in relation to the rate of increase in length is different in males and females of this cuttlefish.

Age and growth: The results of the study based on length frequency data collected at Vizhinjam and Cochin shows the sizes (mm) attained by male and female cuttlefish at ages (months) as given below:

Centre	Sex	Age in months					
		6	12	18	24	30	36
Vizhinjam	Male	104	180	234	274	302	323
	Female	115	192	242	275	297	312
Cochin	Male	101	165	204	229	244	254
	Female	90	145	179	199	211	219

The lengths at ages obtained at Vizhinjam closely agree with those estimated by Silas *et al.* (1986b). The lengths for both the sexes at Cochin were smaller than at Vizhinjam throughout the period. The above Table also shows that the females at Vizhinjam were larger than the males at ages up to 2 years but thereafter their growth was slower than in males. In Cochin the males were always slightly larger than the females at all ages. Sanders (1981) observed that in *Sepia pharaonis* off the coast of PDR Yemen the rate of growth is faster in females but the ultimate size reached is higher in males and they survive longer due to high level of post-spawning mortality of females. In our waters, while disparity in rate of growth within the sex and between the sexes of this species at different centres has been noticed, no evidence has been observed with regard to post-spawning mortality of female cuttlefish.

Stock assessment

Growth parameters: The estimates of growth parameters L_∞ and K, separately for male and female cuttlefishes, are given below:

East coast	Males :	L_∞	= 270 mm
		K	= 0.94/year
	Females :	L_∞	= 230 mm
		K	= 1.0/year
West coast	Males :	L_∞	= 320 mm
		K	= 0.72/year
	Females :	L_∞	= 296 mm
		K	= 0.82/year

Mortality rates and stock estimates: The total mortality rates, fishing mortality rates and stock sizes were estimated using John's (1984) length cohort analysis with terminal exploitation rate (F/Z) given by 0.5 on the assumption that the stock is being exploited for so many years with heavy fishing pressure. The results of the analysis are as follows:

	M/K = 1.5		M/K = 2		M/K = 2.5	
	M	F	M	F	M	F
East Coast						
Catch (t)	588	451				
Natural mortality 'M'	1.08	1.23	1.44	1.64	1.8	2.05
Standing stock (t)	323	232	407	279	551	347
Mean 'F' (L > = 40)	1.13	0.97	0.9	0.77	0.66	0.59
West Coast						
Catch (t)	3,981	3,155				
Natural mortality 'M'	1.41	1.5	1.88	2.0	2.35	2.5
Standing stock (t)	3,065	3,407	4,053	4,654	5,666	6,709
Mean 'F' (L > = 40)	0.60	0.36	0.42	0.23	0.27	0.14

M, Male; F, female.

The above results based on 3 different M/K values (1.5, 2 and 2.5) give the natural mortality rates ranging from 1.08 to 1.8 for males, and from 1.23 to 2.05 for females on the east coast. The same for the cuttlefishes caught along west coast varies from 1.41 to 2.35 and from 1.5 to 2.5 for males and females respectively. On both the coasts the 'M' values for females are higher than those for males. The average fishing mortality (L> = 40) for the cuttlefishes of both sexes are higher on the east coast sector than on the west coast. The maximum fishing mortality ('F') ranging from 1.65 to 2.9 has been noticed in males of the size 170 mm along east coast and from 1.95 to 2.8 in females of the same size as that of males of the same coast, while along the west coast it ranges from 1.27 to 2.14 in males of the size 190 mm, and from 1.33 to 1.66 in females of the same size under the 3 M/K levels. The standing stock estimates are higher for males on the east coast, while the females had higher stock estimates on the west coast.

Maximum sustainable yield (MSY) and mean biomass : The length-based Thompson and Bell long-term forecast analysis has given the following estimates of the maximum sustainable yields and mean biomass for the 3 M/K values:

M/K	MSY (t)		'F' Factor at MSY		Biomass at MSY level of exploitation	
	Male	Female	Male	Female		
East coast						
1.5	603	455	0.69	0.71	494	306
2.0	582	448	1.09	1.2	369	238
2.5	636	484	1.86	2.05	317	212
West coast						
1.5	4,054	3,606	1.49	3.02	2,272	1,841
2.0	4,707	4,710	3.02	7.20	2,103	2,026
2.5	6,183	6,847	6.36	19.33	2,390	2,569

The MSY estimates of male cuttlefishes on the east coast at different M/K values varied from 582 to 636 t and that of females from 448 to 484 t. At M/K = 1.5 level, the present catch has already gone beyond the MSY level in both the sexes. At M/K = 2 level, the effort has to be increased by 10% and 20% for males and females, respectively, to obtain MSY. At M/K = 2.5 level, the effort has to be increased further by 80% and 100% to reach MSY. But in any case the increase in effort will bring in only a small increase in catches.

Along the west coast the MSY for males at the 3 M/K levels have been estimated at 4 054, 4 707 and 6 183 t, respectively, and for females 3 606, 4 710 and 6 847 t respectively. In males, the effort has to be increased by 50%, 200% and 530%, respectively, in the 3 M/K levels to obtain the MSY. In the females the effort has to be increased by 200, 720 and 1 800% to reach the MSY level. But in all the 3 levels the difference between MSY level, and the present catch is 73 t, 726 t and 2 202 t, respectively, in males, and 51, 1 555 and 3 692 t in females.

Sepia pharaonis constitutes one of the most important cephalopod resources caught all along the Indian coasts in trawl nets (87%) and also in other gears, the chief among them being hooks and lines. Its occurrence in trawl net increases with increasing depth. This cuttlefish is caught mostly from depths beyond 30 m. Its size shows increasing trends with increasing depth. Whenever the trawls are operated beyond 40 m depths, they often catch very good quantities of this cuttlefish. As the gear is aimed at shrimps, the operation of it in various depths depends upon the availability of shrimps and this may result in the fluctuations of cuttlefish catches. However, gear is effective for cuttlefishes.

The estimation of growth parameters poses great problems. The only available study on the growth of this species is by Silas *et al.* (1986b) who have estimated the growth based on catch data from hooks-and-line fishery at Vizhinjam. This gave a higher L_∞ values of 365 mm for males and 342 mm for females than the present estimated values of 320 mm for males and 296 mm for females, made from trawl data at Cochin (west coast). Again, trawl-based data from Madras (east coast) gave still smaller values of L_∞, 270 mm for males and 230 mm for females. This disparity is because the cuttlefish obtained in hooks-and-line, which is highly selective, are always larger in size; even within the trawl catches the east coast cuttlefish are smaller than those of the west coast.

The estimation of natural mortality has also been difficult. As reliable estimates of natural mortality ('M') could not be arrived at, a range of 3 M/K values were assumed for the estimation of mortality rates and stock sizes. The use of range of M/K values gives freedom of analysis amounting to fixing 'confidence limits' to natural mortality parameter. This also provides a range of management options (Ref: J. Gulland's letter to the editor of Fishbyte, Vol.6, No.1, April 1988).

The estimate of MSY and F-factor analysis for the 3 values of M/K indicate that on the east coast the catches are at optimal levels and any increase in effort will result only in small increases in yield, while on the west coast there is scope for increased exploitation. But any recommendation to increase the effort in a multi-species gear, such as the trawl net, should consider all the components of the fishery by the gear while arriving at meaningful management options.

This study is only an attempt with limited data to estimate the stocks of this important cuttlefish. However, it gives a clear picture of the present exploitation of the cuttlefish and the gross estimates of its stock. A sound data base covering all the gears that take this cuttlefish and operate at different depth ranges may help in solving most problems faced in the study of the stock of this species.

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