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Stock assessment of the needle cuttlefish *Sepia aculeata* Orbigny

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ABSTRACT

The needle cuttlefish *Sepia aculeata*, along with *Sepia pharaonis*, forms the mainstay of India's cuttlefish resource. A study of the present status of its fishery based on the data collected at different centres on both the coasts of India for 1979-1989 indicates that the production has increased many times in recent years, with Maharashtra alone accounting for about 60% of the total production (10 724 t in 1989) of this cuttlefish. Over 88% of the total production was taken in trawl net as by-catch. The third quarter of the year is the most productive and the first quarter the least on the east coast; on the west coast the fourth quarter is the best season, with the minimum catch during the third quarter (July-September). The natural mortality rates calculated based on different M/K values (1.5,2 and 2.5) range from 1.33 to 2.25 in both males and females on the east coast; on the west coast they are 1.65-2.75 for males and 1.5-2.5 for females. The maximum fishing mortality is at the size of 90 mm for males and 150 mm for females on the east coast, and at 150 mm for males and 170 for females on the west coast. The standing stock estimates at all levels of M/K are higher for females than for males on both the coasts. The MSY and mean biomass estimates indicate that the present catches are optimal on the east coast but on the west coast there is considerable scope for increasing production.

The needle cuttlefish *Sepia aculeata* Orbigny is a neritic species occurring on both the coasts of India where it supports a good fishery. A substantial increase was observed in the catch from 2 900 t in 1979 to 10 724 t in 1989; up to 1988 the highest annual catch was 9 000 t but in 1989 it crossed the 10 000 t mark. Almost the entire catch came as by-catch in trawl fishery The needle cuttlefish grows to a maximum length of 250 mm.

Biology and fishery characteristics of this cuttlefish have been the subject of study of late because of its economic importance in the export market in recent years. Silas *et al.* (1986 a,b,c) studied the identity, biology and stock assessment, and Rahaman (1967) gonad, hepatic indices and

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maturation. They gave some baseline information on certain aspects but largely it remains to be studied in more detail.

There is a need to estimate the resource position and the maximum sustainable yield of this cuttlefish in our water for proper management of its exploitation. An attempt was therefore made to assess the stock, based on the catch, effort and biological data collected at various centres on both the coasts of India over a number of years.

DATA BASE AND METHODOLOGY

The present study was based on: (i) the data on cephalopod landings in the maritime states of India for 1979-1989; (ii) quarterly catch and effort data of trawlers and catch data in respect of all other gears together for the years 1985-1989 obtained from the Fisheries Resources Assessment Division of the Central Marine Fisheries Research Institute; (iii) species-wise cephalopod landings estimated at Veraval, Bombay, Mangalore and Cochin on the west coast, at Tuticorin, Mandapam, Rameswaram, Madras, Kakinada and Visakhapatnam on the east coast; and (iv) the length frequency data collected at Mangalore, Cochin, Mandapam, Rameswaram, Madras and Kakinada on trawl catches. Only the trawl was taken into consideration for stock assessment as it was the most common gear effectively used for catching *Sepia aculeata*.

Monthly catch, fishing effort, species composition and length composition were estimated according to Alagaraja (1984). Date on catch, effort, species composition and length frequency collected on observation days were weighed to arrive at the day's estimates, and these were pooled and weighed to obtain the monthly estimates; these in turn were pooled to get the annual estimates. The monthly length-frequency data for 1984-1988 collected at different centres on either coast were pooled to get the monthly estimates for the respective coast.

As the basic catch data were in the form of total cephalopod landings, the estimates made at different centres in regard to the species composition have been utilized to arrive at the state-wise production of *Sepia aculeata*.

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

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

Length cohort analysis (Jones 1984) with 3 different assumed M/K values (1.5, 2 and 2.5) was carried out to estimate the mortality rates and stock sizes. The maximum sustainable yield (MSY) and mean biomass were estimated with length-converted Thompson and Bell analysis (Sparre 1985).

All the analysis were carried out with the aid of LFSA package of FAO (Sparre 1987).

RESULTS AND DISCUSSION

Fishery

Annual production: There was almost a steady increase in the landings of *Sepia aculeata* from 1979 to 1989 except for small decreases in 1980, 1981 and 1987 (Table 1). A 270% increase was noted in the landings in 11 years. Up to 1988 the highest annual production was 9 000 t but in 1989

Table 1. State-wise production (tonnes) of *Sepia aculeata* during 1979-'89

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
West Bengal	0	1	0	2	5	12	2	2	8	2	11
Orissa	4	27	16	54	33	16	25	34	27	11	22
Andhra Pradesh	145	130	141	164	143	124	150	195	223	152	133
Tamil Nadu	792	612	702	1347	1613	1537	1850	1625	1685	1751	2303
Pondicherry	21	17	18	35	50	15	18	18	28	11	47
Kerala	196	280	157	233	114	358	547	989	497	1001	1551
Karnataka	10	17	38	22	141	48	35	310	413	281	353
Goa	25	30	14	24	57	59	44	203	69	56	69
Maharashtra	1707	513	756	2061	2850	3297	5632	5359	4987	5752	6235
Gujarat	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Total	2900	1627	1842	3942	5006	5466	8303	8735	7937	9017	10724
Average	5954										

this crossed the 10 000 t mark. During the first 6 years (1979-1984) the catches were moderate; afterwards (1985-1989) they increased.

State-wise production : About 27% of this cuttlefish during the 11 year period was taken on the east coast and the remaining bulk on the west coast. On the west coast Maharashtra accounted for almost 60% of the all-India production, followed by Kerala (9%). The contribution by Karnataka and Goa was very small. There was no catch in Gujarat in any of the years. On the east coast the major contributor was Tamil Nadu (24% of the all-India production). There was no catch in West Bengal. Orissa, Andhra Pradesh and Pondicherry together contributed 3%.

Gear-wise production: *Sepia aculeata* is currently taken as by-catch mostly in trawl; a small position comes in a variety of artisanal gears. Over 88% of the total all-India catch of *Sepia aculeata* was taken in trawl net (Table 2). No cuttlefish was obtained in trawl net in West Bengal. The catches by artisanal gears in Tamil Nadu and Kerala were comparatively much higher than the catches by other gears in other

Table 2. State-wise production (tonnes) of *Sepia aculeata* 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	-	2	2	-	2	2	-	8	8	-	2	2	-	11	11
Orissa	14	11	25	14	20	34	20	7	27	9	2	11	22	-	22
Andhra Pradesh	125	25	150	180	15	195	190	33	223	140	12	152	125	8	133
Tamil Nadu	610	1240	1850	880	745	1625	1323	362	1685	1365	386	1751	1248	1055	303
Pondicherry	18	-	18	18	-	18	24	4	28	11	-	11	47	-	47
Kerala	326	221	547	436	553	989	460	37	497	924	77	1001	1415	136	1551
Karnataka	33	2	35	243	67	310	410	3	413	280	1	281	239	114	353
Goa	34	10	44	171	32	203	66	3	69	56	-	56	58	11	69
Maharashtra	5607	25	5632	5332	27	5359	4982	5	4987	5735	17	5752	6208	27	6235
Gujarat	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	6767	1536	8303	7274	1461	8735	7475	462	7937	8520	497	9017	9362	1362	10724

states. In Gujarat both the categories of gears did not take *Sepia aculeata*.

Seasonal production trends: The season-wise relative abundance showed marginal to wide variation from year to year in all the states where there were cephalopod landings. In Orissa the fourth and first quarters were more productive, and the third quarter was the least; there were no landings in the second quarter. In Andhra Pradesh the 4 quarters were almost equally productive. In Tamil Nadu the third and second quarters were better. In Pondicherry most of the catch was taken in the third quarter. On the east coast as a whole, the third quarter accounted for the highest catches, with the minimum landings during the first quarter (Table 3).

On the west coast the first quarter landings were the highest in Karnataka and Goa. In Kerala the cactches during the third and fourth quarters were much higher than in the other two quarters. In Maharashtra the maximum catch was taken during the fourth quarter in all the years. The trend in this state more or less reflected the seasonal trend on the west coast as a whole, in that 66% came during the fourth quarter, 22% in the first quarter and 7% in the second quarter; the least productive was the third quarter comprising the monsoon months of July-September (Table 3).

Biology

Size range: This cuttelfish was larger in size on the west coast than on the east coast. On the west coast the maximum size of male was 245 mm and of female 200 mm; on the east coast the corresponding sizes were 190 and 200 mm. The fishery was supported by cuttlefish of 50-190 mm size on the east coast of 70-190 mm size on the southeast coast and of 90-200 mm size on the west coast (Silas *et al.* 1986b). During the present investigations the maximum sizes observed at different centres on the east coast were 180-210 mm for both the sexes, and on the west coast 190-245 mm for males and 200-245 for females.

Sex ratio: There was no clear trend in

Table 3. Quarter-wise trawl net fishing effort (in trawler days) and *Sepia aculeata* catch (in tonnes) in 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	131939	131	127494	203	170644	265	155270	168	585347	767
1986	143398	148	133044	180	183831	553	152897	211	613170	1092
1987	160420	277	126051	454	190474	560	178867	266	655812	1557
1988	171446	265	146754	530	177542	434	150203	296	645945	1525
1989	131304	171	134048	337	177781	564	181016	10	624149	1442
Average	147700	199	133478	340	180054	476	163650	262	624882	1277
West Coast										
1985	278396	1213	214575	410	81535	194	284355	4183	858861	6000
1986	359312	1200	256058	535	76670	563	283579	3884	975619	6182
1987	436814	1650	336371	653	113671	275	438303	3340	1325159	5918
1988	470588	1676	362046	606	133694	414	502831	4299	1469159	6995
1989	446142	1755	331957	914	131204	1153	266207	4098	1175510	7920
Average	398250	1499	300201	624	107355	519	355055	3961	1160861	6603

sex ratio of *Sepia aculeata* but it varied from centre to centre and from month to month. While the expected equal ratio of sexes was extremely rare, marked dominance of one sex over the other was also rare. Variation in sex ratio was noticed in different months at the same centre. This confirmed the observation of Silas *et al.* (1986 b). In Madras the male-female ratio varied form 33:67 to 70:30. At Cochin the variation was within a small range, from 45-55 to 53-47. At Mangalore the dominance of males in the ratio 80:20 was reversed in one month by the 100% domination of females but in most of the months it was within a small range.

Maturity: According to Silas *et al.* (1986b) the male cuttlefish on the east coast matured from a size of 70 mm onwards, with the size at first maturity (the size at which 50% of the individuals are mature), being 77 mm at Visakhapatnam, 100 mm at Madras, and 83 mm at Mandapam. In females the size at first maturity was 102 mm at Visakhapatnam, 118 mm at Madras and 110 mm at Mandapam. During subsequent observations at Kakinada in 1986-1988 period the length at first maturity for both the sexes was 80-90 mm. On the west coast the size at first maturity for both the sexes was higher than on the east coast. At Cochin it was 124 mm for males, and 130 mm for females. In Bombay also the size of females was the same as in Cochin. There were no data for males. The size at first maturity observed for both the sexes at Mangalore during 1982-1986 was smaller, about 80-90 mm.

The factors responsible for the difference in the size at first maturity of this and other cuttlefishes on the east and west coasts, as well as at different centres on the same coast, are not known. This aspect needs further study. Silas *et al.* (1986 b) quoted Durchon and Richard (1967) who observed that a secretion of the optic gland of *Sepia officinalis* controls maturation of reproductive organs. Durchon and Richard (1967) reported that optic gland of cuttlefish is controlled by photoperiod: active when day light is short and inhibited during longer day time.

Spawning: Spawning in *Sepia aculeata* is extended and takes place almost throughout the year. Silas *et al.* (1986 b) observed mature and spawning cuttlefish in most of the months at Visakhapatnam, Kakinada, Madras, Porto Novo, Mandapam on the east coast, and at Cochin and Bombay on the west coast. Subsequent observations at Mangalore during 1982-1986 and at Kakinada during 1986-1988 also showed that fully mature cuttlefish occurred in most parts of the year.

Length-weight relationship: A study of the length-weight relationship of this species off Madras coast indicated that the rate of increase in weight in relation to the length differed in males and females (Silas *et al.* 1986b). In the present study (1985-1989) the dorsal mantle length measured to the nearest 1 mm and the weight to the nearest 0.5 g for the full length range of the cuttlefish available to the fishery were used in arriving at the length-weight relationship $W = a L^b$. The estimated values of a and b are given below:

East coast	Males	a = 0.00045
		b = 2.6671
	Females	a = 0.000346
		b = 2.7427
West coast	Males	a = 0.00069536
		b = 2.5974
	Females	a = 0.00087389
		b = 2.5562

Age and growth: Silas *et al.* (1986b) observed that the rate of growth was almost similar in both the sexes. The estimated

size (mm) at age (months) obtained for both the sexes combined is given below:

Centres	Age (months)			
	6	12	18	24
Visakhapatnam	59	103	135	158
Kakinada	61	96	124	-
Madras	89	139	168	184
Mandapam	74	123	155	-
Bombay	67	122	164	202

Growth rate and size in *Sepia aculeata* at different ages varied from place to place. These variations are only expected in tropical species with short life span and protracted spawning. According to Caddy (1983) there are cephalopod species in which different cohorts show different growth rates: some have linear growth while some others show asymptotic growth.

Stock assessment

Growth parameters: The estimated growth parameters L_∞ and K for male and female *Sepia aculeata*, based on length-frequency data collected at different centres and pooled for each coast, are presented below:

East coast Males : L_∞ = 203
K = 0.9/year
Females : L_∞ = 203
K = 0.9/year
West coast Males : L_∞ = 206
K = 1.1/year
Females : L_∞ = 205
K = 1.0/year

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

Particulars	M/K = 1.5		M/K = 2		M/K = 2.5	
	M	F	M	F	M	F
East coast						
Catch (t)	700	1410				
Natural mortality 'M'	1.35	1.35	1.8	1.8	2.25	2.25
Standing stock (t)	441	917	565	1158	761	1530
Mean 'F' (L > = 40)	1.22	0.92	0.92	0.69	0.65	0.49
West coast						
Catch (t)	3152	3801	-	-	-	-
Natural mortality 'M'	1.65	1.5	2.2	2.0	2.75	2.5
Standing stock (t)	3457	5514	4824	7961	7197	12303
Mean 'F' (L > = 40)	0.47	0.37	0.29	0.22	0.17	0.12

M, Male; F, female.

Under the 3 different M/K regimes the natural mortality rates (M) are the same in both the sexes on the east coast (range 1.35 to 2.25). On the west coast these ranged from 1.65 to 2.75 in males and from 1.5 to 2.5 in females. The average fishing mortality (L> = 40) for the male population is higher than for females on both the coasts. The maximum fishing mortality (F) is seen at M/K = 1.5 level in both the sexes on both the coasts. The maximum 'F' value is at the size 90 and 150 mm in males and females, respectively, on the east coast, and at 150 and 170 mm on the west coast. The standing stock estimates at all levels of M/K are higher for females than for males on both the coasts and much higher for both the sexes on west coast than on east coast.

Maximum sustainable yield (MSY) and mean biomass: The results of the length-based Thompson and Bell long-term forecast analysis for estimating the MSY

and the mean biomass are summarized below:

M/K	MSY (t)		'F' factor at MSY		Biomass at MSY level of exploitation (t)	
	Male	Female	Male	Female	Male	Female
East coast						
1.5	685	1381	0.91	1.01	461	868
2.0	718	1470	1.61	1.79	363	750
2.5	859	1750	3.02	3.33	338	740
West coast						
1.5	3687	4735	3.02	4.02	1627	2177
2.0	4996	6922	6.36	9.02	1882	2627
2.5	7652	11424	16.02	23.02	2438	3689

The maximum sustainable yields for males on the east coast varied from 685 t to 859 t under the 3 M/K levels, and for females from 1 381 t to 1 750 t. The exploitation at M/K=1.5 level is almost at the optimum level for both the sexes. In the other two levels the effort has to be increased by about 60% and 200%, respectively, to obtain the MSY of both sexes.

On the west coast the MSY of males varied from 3 687 t to 7 652 t and that of females from 4 735 t to 11 424 t. The analysis indicates that at all the 3 levels of M/K, the effort has to be increased by many times to reach the MSY levels.

Sepia aculeata is caught all along the Indian coasts. Bulk of the catch comes from the operation of trawl nets aimed at shrimps. This cuttlefish is caught in good numbers from depths beyond 30 m.

Details regarding its spawning and post-spawning behaviour, spawning grounds and areas of distribution of juveniles are yet to be investigated. Mature specimens of this cuttlefish are observed throughout the year.

Silas *et al.* (1986b) studied the growth of this cuttlefish from Indian waters for the first time. The study was based on the assumption that the growth in length follows VBGF. Based on trawl fishing along Madras coast these authors estimated that L_∞ at 205 mm in both the sexes was almost similar to the present estimates but the K values were higher.

As reliable estimates of natural mortality could not be made, a range of M/K values were assumed. The use of a range of M/K values gives the freedom of analysis amounting to fixing 'confidence limits' to 'M' resulting in a range of management options (Ref: J. Gulland's communication to the editor of Fishbyte, Vol. 6, No.1, April 1988).

The MSY estimates and F-factor analysis indicate that along the east coast catches are almost at optimal level and any increase in effort will result only in small increases in the catches. But along the west coast there is considerable scope for increasing the production as shown by the yield and biomass observations.

Recommendations

Since the trawl net is targeted towards a group of multi-species assemblage, any recommendation to increase the effort to obtain the MSY of a particular target fish (here *Sepia aculeata*) will not hold good unless the gear is studied in its totality. The management measures taken for a single species, which is one of the components of a mixed fishery, may conflict with those taken for the other components (Murty 1989). What is to be attempted, therefore, is to make mixed fishery assessments with due consideration to all individual components occurring in the fishery. With all limitations, the present study is important as far as it gives a picture of the present exploitation of this species of cuttlefish and a gross estimate of its stock.

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