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Stock assessment of *Sepiella inermis* (Orbigny, 1848) from Mumbai waters

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Abstract

The catch of *Sepiella inermis* landed at New Ferry Wharf contributed about 6.1% to the cephalopod landings during 2001-2003 and the catch rate of the species decreased from 0.26 kg/hr in 2001 to 0.08 kg/hr in 2003. The fishery was supported mainly by the size-range (dorsal mantle length) 40-50 mm for males and 40-60 mm for females. The K and L_{∞} estimated by Gulland-Holt Plot were 2.63 $year^{-1}$ and 68.0 mm for males, and 2.35 $year^{-1}$ and 97.4 mm for females respectively. Males attain 49.74 mm and 63.10 mm and females attain 67.32 mm and 88.11 mm at the end of 6 and 12 months respectively. The total mortality coefficient (Z), natural mortality (M) and fishing mortality (F) was 7.48, 5.09 and 2.39 for males, and 10.78, 4.28 and 6.50 for females respectively. Length at capture (L_{50}) for males is 41.8 mm at an age 4.4 months and the same for the females is 43.9 mm at an age of 3.1 months. Thompson and Bell estimates suggest that to achieve the MEY level the fishing effort has to be increased two-fold. Increasing the effort would not be economically viable and it is also detrimental to the stock. Thus the present level of fishing effort seems to be appropriate.

Keywords: Cephalopods, fishery, age and growth, stock assessment, cuttlefish

Introduction

There are about 80 species of cephalopods of commercial and scientific interest distributed in the Indian seas (Silas, 1968; Sarvesan, 1974). The world cephalopod catch increased from 0.58 million tones in 1950 to 3.51 million tones in 2003 while the all India cephalopod catch increased from 400 t in 1957 to 89,353 t in 2003 (FISHSTAT, 2004). In recent years, the cephalopods have gained economic importance necessitating fishery management measures for judicial exploitation. Therefore stock assessment of cephalopods is required as a prerequisite in fisheries management.

Spineless cuttlefish *Sepiella inermis* is a demersal shallow-water species, widely distributed along the Indo-Pacific region (Roper *et al*., 1984). Among the maritime states of India, Maharashtra is one of the leading states in cephalopod landings contributing 14.6% to the all India cephalopod production. The landings of *S. inermis* have increased over the years and contributed 12.9% to the cephalopod landings of Maharashtra for the year 2007 (CMFRI, 2007). In the light of targeted exploitation of cephalopods in general and *S. inermis* in particular in recent years, the present investigations on the fishery, age and growth, population dynamics and stock assessment of this species from Mumbai waters, northwest coast of India has been made.

Studies were conducted on the resource characteristics of the species by Unnithan (1982) from Mandapam, Silas *et al.* (1985a, b) from different centers in India such as Waltair, Madras, Proto Novo, Cochin, Kakinada and Visakhapatnam, Kuber (1987) from Mumbai, Kasim (1988) from Saurashtra, Sarvesan (1996) from Madras and Chakraborty *et al.* (2005) from Mumbai waters.

Material and Methods

During January 2001 - December 2003, weekly random samples of *S. inermis* were collected from the commercial catches landed by trawlers operated from New Ferry Wharf. About 1,000 to 1,200 shrimp trawlers are operated from this centre during the

fishing season. These trawlers undertake 6-10 days of fishing per trip, expending trawling hours of 45-60 hrs/trip. The fishing area extends from south of Saurashtra coast to Ratnagiri (17^0 - 21^0 N lat. and 71^0 - 73^0 E long.) covering an area of approximately 25,000 sq.km. The depth of operation extends from 30 to 100 m, but generally they carry out trawling in waters beyond 40 m depth.

The samples from a wide range of sizes were measured separately for males and females. The dorsal mantle lengths (DML) of samples were measured from the landing centre using a divider and measuring board to the nearest millimeter as described by CMFRI (1995). Weights of the samples were taken using a single pan Yamoto balance. A total number of 5,090 and 7,054 specimens of males and females respectively were measured at an average of 155 males and 214 females per month. As mechanised trawling was suspended from 10th June to 15th August every year due to the restrictions imposed by the government of Maharashtra, samples could not be collected for the month of July. The length measurements were grouped into 5 mm class intervals for size frequency analysis. The length frequency so obtained was raised to the total catch of the species for each sampling day. The raised size frequencies for the observation days in a month were pooled and raised to the monthly catch to obtain the monthly numbers (Sekharan, 1965).

Growth parameters were estimated using Gulland-Holt Plot (1959) which was further used for the stock assessment. Fishing mortality 'F' and total mortality 'Z' was estimated by Beverton and Holt (1956). The mean sea surface temperature of Mumbai waters was considered 28.2°C as reported by Bapat *et al.* (1982). By substituting these values in the expression given by Pauly's method (1980a), natural mortality (M) was estimated. Exploitation ratio 'E' and exploitation rate 'U' (Gulland, 1971), standing stock 'Y/F' and total stock 'Y/U' (Ricker, 1958) were also estimated.

The size at 50 % maturity for *S. inermis* is 48.06 mm (age: 0.47 year) for males and 55.04 mm (age: 0.36 year) for females (Sundaram, 2007).

Monthwise numbers of males and females in different size classes raised to the catch for three years 2001, 2002 and 2003 were pooled and used for the length structured Virtual Population Analysis (VPA). These numbers represented the numbers caught. The relevant input parameters for the VPA are L_∞, K, M, F, 'a' and 'b'. The estimated 'a' and 'b' values for males were 0.001507 and 2.4474 respectively and for females it was 0.00674 and 2.6808 respectively (Sundaram, 2007).

Probability of capture was estimated by the method described by Beverton and Holt (1957). Maximum Sustainable Yield (MSY) and Maximum Economic Yield (MEY) were estimated by Thompson and Bell analysis (1934).

Results

Fishery: The estimated catch of *S. inermis* by trawlers at New Ferry Wharf showed a declining trend from 358.3 t in 2001 to 313.3 t in 2003 and the catch rate decreased from 0.26 kg/hr (2001) to 0.08 kg/hr (2003). The number of trawlers operated from this centre decreased from 24,395 (2001) to 21,880 (2003). The percentage of *S. inermis* in the cephalopod catch was 6.3% for the year 2001, which decreased to 5.8% for the year 2003. The dorsal mantle length of males ranged from 17 mm to 70 mm and females from 17 mm to 90 mm. Indeterminates ranging from 5 mm to 17 mm were observed to enter into the fishery between April-May with peak in June (Sundaram and Chavan, 2005). It was also observed that the percentage of juveniles by numbers was very high (30 - 40% by weight) during the study period. Larger males ranging from 60 mm to 70 mm and females 70 mm to 90 mm were dominant in the catches during March-May and October-November. Males ranging in size from 40 mm to 50 mm and females 40 mm to 60 mm dominated the fishery at New Ferry Wharf. Though trawling was not carried out during the monsoon months, dol netters were operated in inshore waters (along Mumbai harbor at the depths of 5-10 m) and in this gear *S. inermis* formed about 4% (280 kg) of the cephalopod catch in 2003.

Age and growth: The von Bertlanffy growth parameters obtained by Gulland-Holt plot for the males and females (Fig. 1a and Fig. 1b) were used for calculating age and growth of the species. Males attained 49.74 mm and 63.10 mm at the end of 6

and 12 months respectively and females 67.32 mm and 88.11 mm at the end of the same time intervals. The life-span (t_{max}) of the species was estimated to be 1.141 years for males and 1.277 years for females as derived from the relationship of longevity and growth coefficient *i.e.*, 3/k (Pauly, 1980b). The von Bertalanffy growth function for males is $L_t = 68\ (1-e^{-2.63\ (t\ -\ t0)})$ and for females it is $L_t = 97.4\ (1-e^{-2.35\ (t\ -\ t0)})$.

From the probability of capture curve for trawl type selection it was observed that length at capture (L_{50}) for males is 41.84 mm and for females 43.88 mm.

The estimated yield of *S. inermis* for the years 2001-2003 by Thompson and Bell analysis was 219 t and the annual average yield was 73 t. It is observed

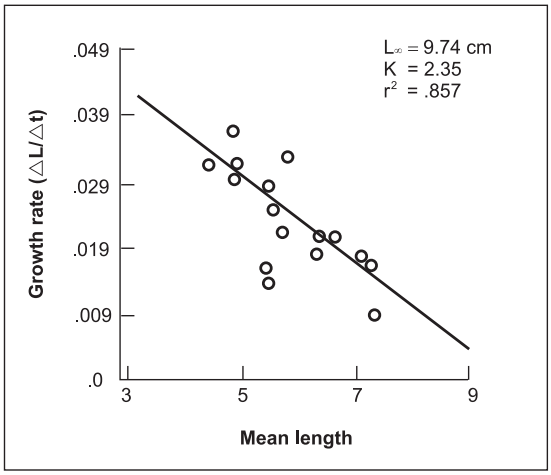

Fig. 1a. Gulland and Holt plot for *Sepiella inermis* (male)

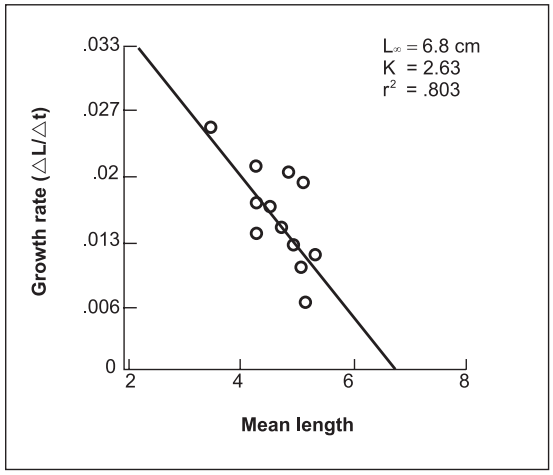

Fig. 1b. Gulland and Holt plot for *Sepiella inermis* (female)

Population dynamics and stock assessment: Using Pauly's method, the natural mortality was estimated as 5.09 for males and 4.28 for females. The estimates of total mortality (Z), natural mortality (N), fishing mortality (F), yield (Y), exploitation ratio (E), exploitation rate (U), total stock (Y/U) and standing stock (Y/F) of *S. inermis* of males and females from Mumbai waters for the period 2001-2003 are given in Table 1.

that the yield was increasing with increase in effort without attaining maxima. However, the MEY was estimated at Rs.0.32 crores at F = 2.2 which is twice the present level of exploitation with the biomass 69 t.

Discussion

Kuber (1987) observed two peaks of abundance for the species, with a major one during April-May

Table 1. Population parameters of *Sepiella inermis* in Mumbai waters for the period 2001-2003

Sex	Total mortality Z	Natural mortality M	Fishing mortality F	Yield Y(t)	Exploitation rate U	Exploitation ratio E	Total stock P (t)	Standing stock Y/F (t)
Male	7.48	5.09	2.39	79.20	0.32	0.32	248.01	33.14
Female	10.78	4.28	6.50	151.30	0.60	0.60	250.93	23.28

The results of Virtual Population Analysis are presented in Tables 2 and 3. The yield was 75.21 t for males and 144.34 t for females and the steady state biomass of males was 58.14 t and for females 34.66 t.

and minor peak in November-December from Mumbai waters, which was also the case in the present study. Sarvesan (1996) noticed peaks during April-May and July-August from Madras waters.

Table 2. Virtual Population Analysis of male *S. inermis* from Mumbai waters

Length class (cm)	Numbers attaining each age (N * 10 ^{2})	Number in the sea	Yield (tonnes)	Fishing mortality	Steady state biomass (t)
1.45 - 1.95	392, 077	1286286	0.01	0.0030	2.02
1.95 - 2.45	326, 567	1172120	0.04	0.0104	3.44
2.45 - 2.95	266, 784	1056449	0.19	0.0371	5.10
2.95 - 3.45	212, 619	935746	1.38	0.2019	6.84
3.45 - 3.95	163, 100	801142	5.51	0.6590	8.35
3.95 - 4.45	117, 035	640386	14.38	1.5807	9.09
4.45 - 4.95	74, 317	460958	19.84	2.3029	8.62
4.95 - 5.45	40, 238	294376	17.19	2.4406	7.05
5.45 - 5.95	18, 070	163526	10.84	2.2138	4.90
5.95 - 6.45	6, 126	74281	4.22	1.5439	2.73
6.45 - 6.95	1, 199	—	1.61	2.2000	0.00
Total	—	6885270	75.21	—	58.14

The estimated K and L_∞ values of *S. inermis* from Mumbai waters were compared with the values estimated by other authors from different centres (Table 4). It was observed that the L_∞ values obtained from Mumbai waters were comparatively less and K values were higher. The marginally higher values of the growth constants can be attributed to the shorter life span of this species. Kasim (1988) estimated the life span of *S. inermis* of Gujarat coast as 2.12 years (male and female). Sarvesan (1996) estimated t_{max} as 1.75 and 2.3 for males and females respectively from Madras waters.

Beverton and Holt (1956) pointed out that the natural mortality coefficient (M) of a fish is directly related to the growth coefficient K and inversely related to the asymptotic length (L_∞) and the life span (t_{max}). In other words, fishes with higher growth coefficient have higher natural mortality and those with longer life span have lower natural mortality coefficient. The same appears to be true for *S. inermis* investigated in the present study from Mumbai waters. Kasim (1988) reported Z as 6.25 and F as 4.16 and Chakraborty *et al*. (2005) estimated Z as 9.57 for males and 9.50 for females and F as 6.78 for males and 6.83 for females.

The length at capture (L_{50}) for males is 41.84 mm and for the females is 43.88 mm. The age of males at this size is 4.4 months and of females 3.1 months. Males ranging in size from 40-50 mm and females ranging in size from 40-60 mm dominated the fishery at New Ferry Wharf. According to Sundaram (2007) the size at 50% maturity for males

Table 3. Virtual Population Analysis of female *S. inermis* from Mumbai waters

Length class (cm)	Numbers attaining each age (N * 10 ^{2})	Number in the sea	Yield (tonnes)	Fishing mortality	Steady state biomass (t)
1.45 - 1.95	180, 479	453827	0	0.0000	0.62
1.95 - 2.45	161, 056	430250	0.03	0.0246	1.16
2.45 - 2.95	142, 535	406040	0.11	0.0600	1.89
2.95 - 3.45	124, 913	379469	1.02	0.3679	2.79
3.45 - 3.95	107, 275	343974	5.69	1.5276	3.72
3.95 - 4.45	87, 298	295729	12.46	2.7746	4.49
4.45 - 4.95	66, 436	235814	22.04	4.5530	4.84
4.95 - 5.45	45, 606	164270	34.64	7.8379	4.42
5.45 - 5.95	24, 700	102581	25.16	7.1284	3.53
5.95 - 6.45	13, 997	61288	19.07	7.2224	2.64
6.45 - 6.95	6, 948	35826	10.06	5.2946	1.90
6.95 - 7.45	3, 517	20947	6.39	4.7396	1.35
7.45 - 7.95	1, 628	10912	4.43	5.2674	0.84
7.95 - 8.45	586	4295	2.52	6.4303	0.39
8.45 - 8.95	126	1364	0.73	5.0000	0.16
Total	—	2946587	144.34	—	34.66

Table 4. Growth parameters of *S. inermis* estimated by different authors from Indian waters

Author/s	Area	Method	Male		Female	
			L_∞ (mm)	K	L_∞ (mm)	K
Sarvesan (1996)	Madras	Ford-Walford method	89.3	2.01	107.2	1.16
Kasim (1998)	Saurashtra	Straight line (Alagaraja, 1984)	128.8*	1.37*		
Chakraborty *et al.* (2005)	Mumbai	von Bertalanffy (1938)	106.0	1.81	102.0	1.74
Present study (2001-03)	Mumbai	Gulland and Holt (1959) plot	68.0	2.63	97.4	2.35

**both sexes combined*

was 48.06 mm and for females it was 55.04 mm. From the above it could be inferred that the mainstay of the *S. inermis* fishery in Mumbai region belongs to the size group which is at the initial stages of their maturity and therefore it is advisable to increase the mesh size so as to catch *S. inermis* at a size larger than length at first maturity.

According to Thompson and Bell analysis the resource has not yet reached it's 'MSY' and the 'MEY'. To achieve the 'MEY' level, which is just 6.6% more than the present 'E' value, the fishing effort has to be increased two fold compared to the present level. Increasing the effort would also increase the operational cost which is not economically viable; moreover it would reduce 26.6% of total biomass which is detrimental to the stock. Thus the present level of fishing effort seems to be appropriate.

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