Indian J. Fish., 60(3) : 1-7, 2013

Growth, mortality and population parameters of three cephalopod species, *Loligo duvauceli* (Orbigny), *Sepia aculeata* (Orbigny) and *Sepiella inermis* (Orbigny) from north-west coast of India

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ABSTRACT

Growth, mortality and population parameters of three commercially important cephalopods *viz*., *Loligo duvauceli, Sepia aculeata* and *Sepiella inermis* are reported based on length measurement of 49,960 specimens collected during the period 2001-'06. The asymptotic length (L_∞) was estimated as 380, 300, 108 and 102 mm for *L. duvauceli, S. aculeata* and *S. inermis* male and *S. inermis* female, respectively. The growth coefficient (K) was estimated as 0.90, 0.67 and 1.81 and 1.74 yr^{-1} for *L. duvauceli, S. aculeata* and *S. inermis* male and female, respectively. Highest value of total mortality was recorded for *S. inermis* female (11.43) and lowest (4.43) for *L. duvauceli.* The optimum length of capture (L_{opt}) has been calculated as 139, 150 and 89 mm, whereas, the length of first capture for the three cephalopod species in the same order has been estimated as 100, 95 and 42 mm. The yield isopleths were generated for all the three species to ascertain the potential yield at different levels of L_c/L_∞ and E. Major percentage of the catch of these resources is below the length at maturity (L_m) and optimum length of capture (L_{opt}). All the three species are of high demand in the export market and therefore, some measures need to be taken in order to reduce exploitation of young ones of these species in order to sustain the fishery in future.

Keywords: Cephalopod, Growth, Isopleths, Mortality, Relative yield

Introduction

The average annual estimated world production of cephalopods between 2001-2010 was 37,41,772 t. while the average annual cephalopod production in India during the same period was 1,27,937 t, contributing 3.41% to the world catch of cephalopods. Investigations related to taxonomy, biology, stock assessment and population dynamics have been carried out by various workers from different parts of India (Goodrich, 1896; Massy, 1916; Adam, 1939; Adam and Rees (1966). Hornell (1917) has given an account of the fishing gear and fishery for cephalopods in Madras Presidency. Biology and fisheries of *Sepioteuthis lessoniana* has been described by Rao (1954). Alagarswami (1967) has described the eggs and early developmental stages of *S. arctipinnis.* Silas (1968) has given an exhaustive account of the cephalopods distributed in the Indian Ocean. Several authors have reported on population dynamics of various species of cephalopods from Indian waters (Silas *et al.,*1985; Kasim, 1988; Rao, 1988; Meiyappan and Srinath, 1989; Vidyasagar and Deshmukh, 1992; Meiyappan, *et al.,* 1993; Rao *et al.,* 1993; Mohammed and Rao, 1997; Chakraborty *et al.,* 1997; Karnik *et al.,* 2003; Mohamed and Sarvesan, 2004; Thomas and Kizhakudan, 2006; Sundaram and Khan, 2009). However, the status of stock and different aspects of biology is expected to be altered due to the advancement in fishing technology and disturbances of surrounding aquatic environment as a result of industrial revolution. Maharashtra and Gujarat states in the north-west coast contribute to the major share of the cephalopod landings in the country.The present study was carried out to assess the status of stocks of *Loligo duvauceli* (Orbigny), *Sepia aculeata* (Orbigny) and *Sepiella inermis* (Orbigny) along the north-west coast of India.

Material and methods

For length based stock assessment, weekly data on length frequency (dorsal mantle length - DML) of *L. duvauceli*, *S. aculeata* and *S. inermis* were collected for a period of six years (2001-'06) from the landings of commercial vessels at Versova, New Ferry Wharf and Sassoon Docks landing centres in Greater Mumbai. These species were landed as bycatch of shrimp trawlers operating between Ratnagiri (16°59' N) and Veraval (20°54' N) for multiday fishing upto a depth of 100 m. As *S. inermis* exhibits sexual dimorphism, length frequency data on males and females were collected separately. Monthly distribution of length frequency was derived following Sekharan (1962). Growth parameters like asymptotic length (L_∞ in cm) and annual growth coefficient (K) (Bertalanffy, 1938) were computed by ELEFAN method using computer based FiSAT programme developed by Gayanilo *et al.* (1996). Growth performance index (f) was calculated using the empirical formula of Munro and Pauly (1983) The instantaneous rate of total mortality (Z) was estimated by Pauly's (1984) length converted catch curve method, while the natural mortality was estimated by Cushing's (1968) formula. The t_{max} was calculated employing inverse von Bertalanffy's equation. Exploitation rate (E) was calculated from the formula E=F/Z and the exploitation ratio U by the formula $U=F/Z*(1-e^{-Z})$ given by Beverton and Holt (1957). The optimum length of capture was determined using the formula given by Froese and Binohlan (2000) - $\log L_{opt}=1.0421*\log(L_\infty)-0.2742$. Beverton and Holt's (1966) model was used for estimation of relative yield/recruit. Yield isopleth diagram was generated using different values of E on the X-axis and various sizes at capture and L_c50/L_∞ ratios on the Y-axis, with isovalues of relative yield per recruit.

Results

The DML ranged from 20-369 mm in *L. duvauceli*, 20-219 mm in *S. aculeata*, 20-99 mm in *S. inermis* (male) and 10-94 mm in *S. inermis* females. The growth, mortality and population parameters estimated for the three species are presented in Table 1, 2 and 3, with results of earlier studies from other coasts. The annual growth coefficient (K) was highest for *S. inermis*- male (1.81) and lowest for *S. aculeata* (0.67) (Fig. 1). *Sepia aculeata* and *S. inermis* (male and female) face high mortality rate (>9.5), while *L. duvauceli* face relatively less mortality (4.43) (Fig. 2).

Table 1. Growth, mortality and population parameters of *L. duvauceli* from different locations

Location	Sex	L_∞ (mm)	K(y^{-1})	Z	M	F	E	U	Authors
Cochin	M	327	0.61	—	—	—	—	—	Silas *et al.* (1985)
Cochin	F	205	1.19	—	—	—	—	—	Silas *et al.* (1985)
Madras	M	200	0.945	—	—	—	—	—	Silas *et al.* (1985)
Madras	F	200	0.945	—	—	—	—	—	Silas *et al.* (1985)
Veraval	Pooled	300	0.98	3.94	1.74	2.20	0.56	—	Kasim (1988)
Thailand	Pooled	266	0.86		0.90				Supongpan (1988)
Cochin	M	37.9	1.10	9.0	2.2	—	—	—	Meiyappan and Srinath (1989)
Cochin	F	23.8	1.70	10.6	2.2	—	—	—	Meiyappan and Srinath (1989)
Mumbai	Pooled	323	0.448	1.83	1.10	0.73	0.39	—	Vidyasagar and Deshmukh (1992)
East coast	M	220	0.90	—	—	—	—	—	Meiyappan *et al.* (1993)
E ast coast	F	205	1.30	—	—	—	—	—	Meiyappan *et al* (1993)
West. coast	M	360	0.80	—	—	—	—	—	Meiyappan *et al.* (1993)
West coast	F	232	1.10	—	—	—	—	—	Meiyappan *et al.* (1993)
Mumbai	Pooled	343	0.49	2.09	1.10	0.99	0.47	—	Chakraborty *et al.* (1997)
Mangalore	Pooled	231	1.49	—	—	—	—	—	Rao (1997)
Mangalore	Pooled	371	1.40	—	—	—	—	—	Mohammed and Rao (1997)
Mumbai	Pooled	385	0.85	4.29	1.82	2.47	0.57	0.56	Karnik *et al.* (2003)
Veraval	Pooled	303	0.98	3.94	1.94	2.20	0.56		Thomas and Kizhakudan (2006)
Cochin	Pooled	300	0.75	2.61	1.37	1.24	0.48		John (2007)
Mumbai	Pooled	380	0.90	4.43	1.41	3.02	0.68	0.67	Present study

Table 2. The growth, mortality and population parameters of *Sepia aculeata* from different locations

Location	Sex	L_∞ (mm)	K	Z	M	F	E	U	Authors
Madras	M	205	1.13	—	—	—	—	—	Silas *et al.* (1985)
Madras	F	205	1.13	—	—	—	—	—	Silas *et al.* (1985)
E. coast	M	203	0.90	—	—	—	—	—	Rao *et al.* (1993)
E. coast	F	203	0.90	—	—	—	—	—	Rao *et al.* (1993)
W. coast	M	206	1.10	—	—	—	—	—	Rao *et al.* (1993)
W. coast	F	205	1.00	—	—	—	—	—	Rao *et al.* (1993)
Mangalore	Pooled	231	1.49	—	—	—	—	—	Rao (1997)
Kakinada	Pooled	319.9	0.92	4.56	2.22	2.32	0.52		Abusammad *et al,* (2004)
Mumbai	Pooled	300	0.67	10.56	1.33	9.23	0.87	0.87	Present study

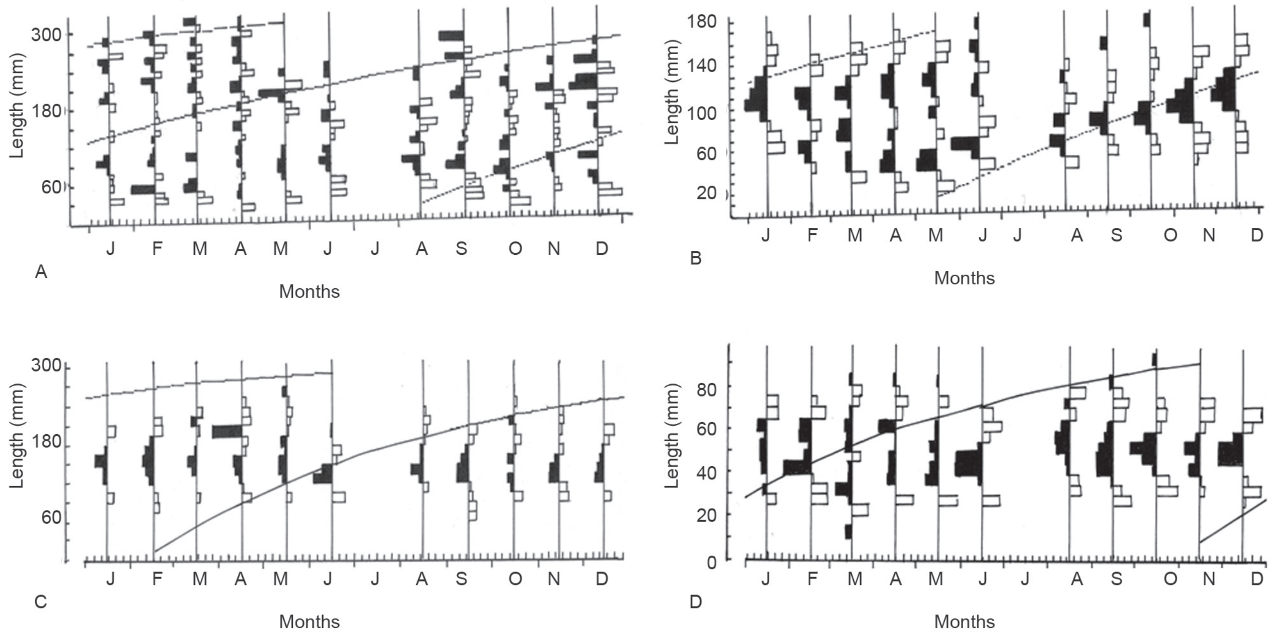

Fig. 1. Growth curve of (A) *L. duvauceli*, (B) *S. aculeata,* (C) *S. inermis* (M) and (D) *S. inermis* (F) as obtained by ELEFAN

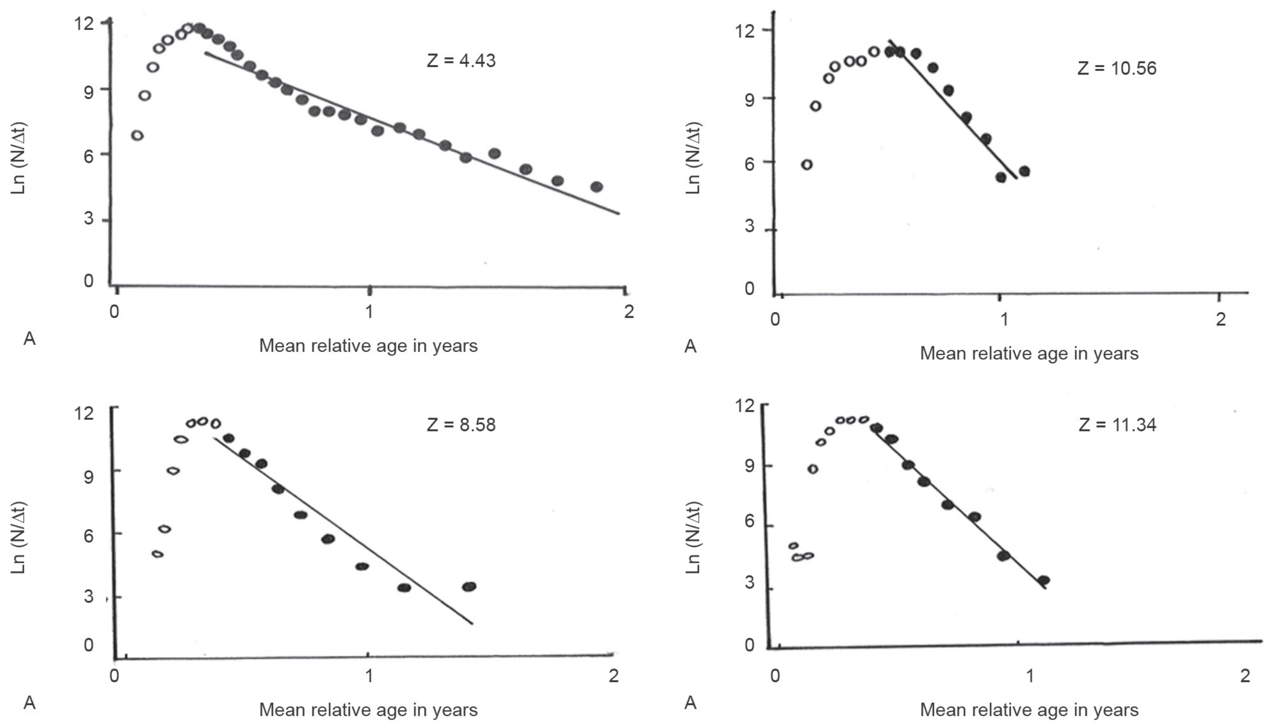

Fig. 2. Length converted catch curve for estimation of Z for (A) *L. duvauceli*, (B) *S. aculeata,* (C) *S. inermis* (Male) and (D) *S. inermis* (Female)

The exploitation rate (E) for all the three species was more than optimum (0.6) as suggested by Gulland (1971). It was 0.68, 0.86, 0.67 and 0.76 for *L. duvauceli*, *S. aculeata* and *S. inermis* (male) and female, respectively. The optimum length of capture (L_{opt}) was estimated as 139, 150 and 89 mm for *L. duvauceli, S. aculeata* and *S. inermis,* respectively, and the length at which 50% of these species become vulnerable to the fishing gears was estimated to be

100, 95 and 42 mm respectively. Silas (1985) estimated length at first maturity for *L. duvauceli, S. aculeata* and *S. inermis* as 107, 132 and 82 mm, respectively. Results of the present study indicate that a high percentage of the exploited catch from the north-west coast were below the length at first maturity, and the length frequency data collected include 87% of *L. duvauceli*, 99.66% of *S. aculeata* and 100% of *S. inermis* below the size of optimum length of capture (L_{opt}). The selection ogive method revealed E_{max} of 0.45 for *L. duvauceli*, and the E as 0.68. For *S. aculeata* the E_{max} based on selection ogive was estimated as 0.55 and the E as 0.86 (Fig. 3).

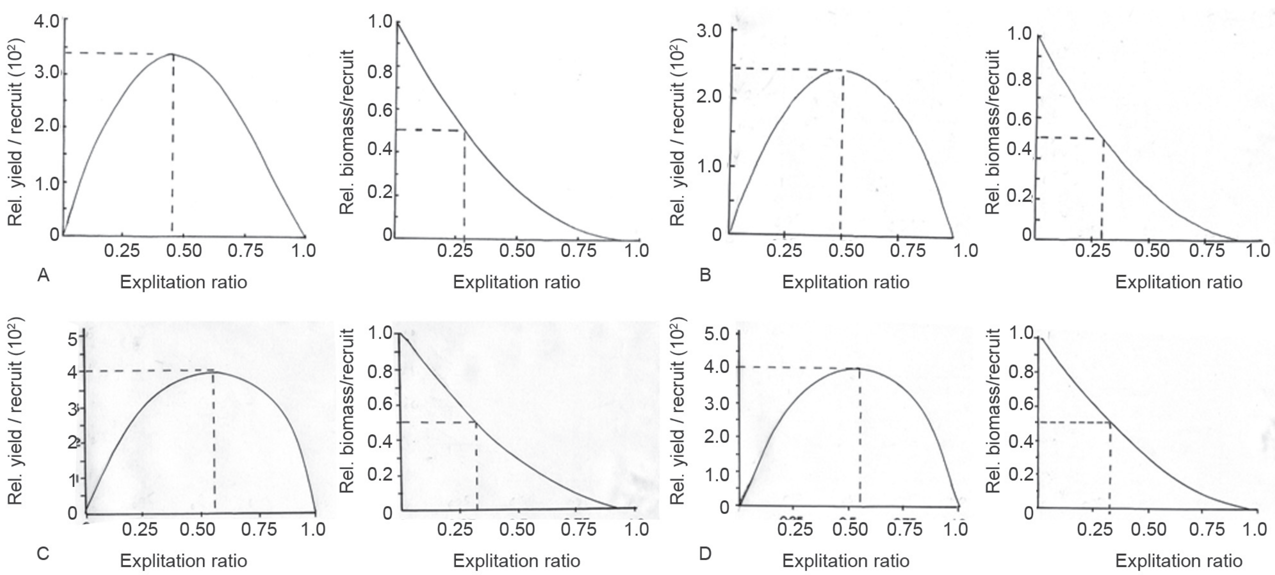

Fig. 3. Relative yield per recruit and relative biomass per recruit from selection ogive of (A) *L. duvauceli*, (B) *S. aculeata,* (C) *S. inermis* (M) and (D) *S. inermis* (F).

For both, males and females of *S. inermis,* the E was estimated as 0.67 and 0.71, respectively. For *S. inermis,* the E_{max} was estimated as 0.55. For all the three species, at E_{max}, the percentage of virgin biomass reduced to about less than 35% of the initial virgin biomass. The yield isopleths indicated potential yield at E of 0.53 and L_c/L_∞ of 0.15 for L. *duvauceli,* at E of 0.55 and L_c/L_∞ of 0.48 for *S. aculeata*, at E of 0.6 and L_c/L_∞ of 0.5 for *S. inermis* male and at E of 0.55 and L_c/L_∞ of 0.45 for female (Fig. 4).

Discussion

The growth parameters estimated for *L. duvauceli* in the present study (L_∞ = 380 mm and K = 0.90 yr^{-1}) are within these ranges reported by earlier researchers *i.e.*, L_∞ in the range of 200-385 mm and K, 0.448 to 1.7yr^{-1} (Table 1). However, the parameters estimated for *S. aculeata* and *S. inermis* in the present study, indicated deviation from values reported earlier from other coasts (Tables 2 and 3).

Though considered as a nonconventional source of food, over the years demand for cephalopods has increased substantially because of their low fat content. Therefore, fishery managers and researchers agree that cephalopods are potential future marine living resources for large scale exploitation (Silas, 1985). Cephalopod landings from most of the coastal ecosystems have increased from 1960-70 to 1990-2004 period (Hunsicker *et al.,* 2010). However, they also play a vital role, as food for a wide variety of predators like large perches, tunas, sword fishes, dolphin, toothed whales, sharks and sea birds, in the marine food webs. Fecundity of the group is medium and growth rate is fast.

Table 3. The growth, mortality and population parameters of *Sepiella inermis* from different locations

Location	Sex	L_∞ (mm)	K	Z	M	F	E	U	Authors
Madras	M	89.3	2.01	—	—	—	—	—	Sarvesan (1996)
Madras	F	107.2	1.16	—	—	—	—	—	Sarvesan (1996)
Saurashtra	Pooled	128.8	1.37	6.25	2.09	4.16	0.66	0.66	Kasim (1998)
Mumbai	Pooled	106.0	1.81	—	—	—	—	—	Chakraborty *et al.* (2005)
Mumbai	Pooled	68.0	2.63	7.48	5.09	2.39	—	—	Sundaram and Khan (2009)
Mumbai	M	106	1.81	8.58	3.07	5.51	0.64	0.63	Present study
Mumbai	F	108	1.75	11.34	3.94	7.40	0.65	0.64	Present study

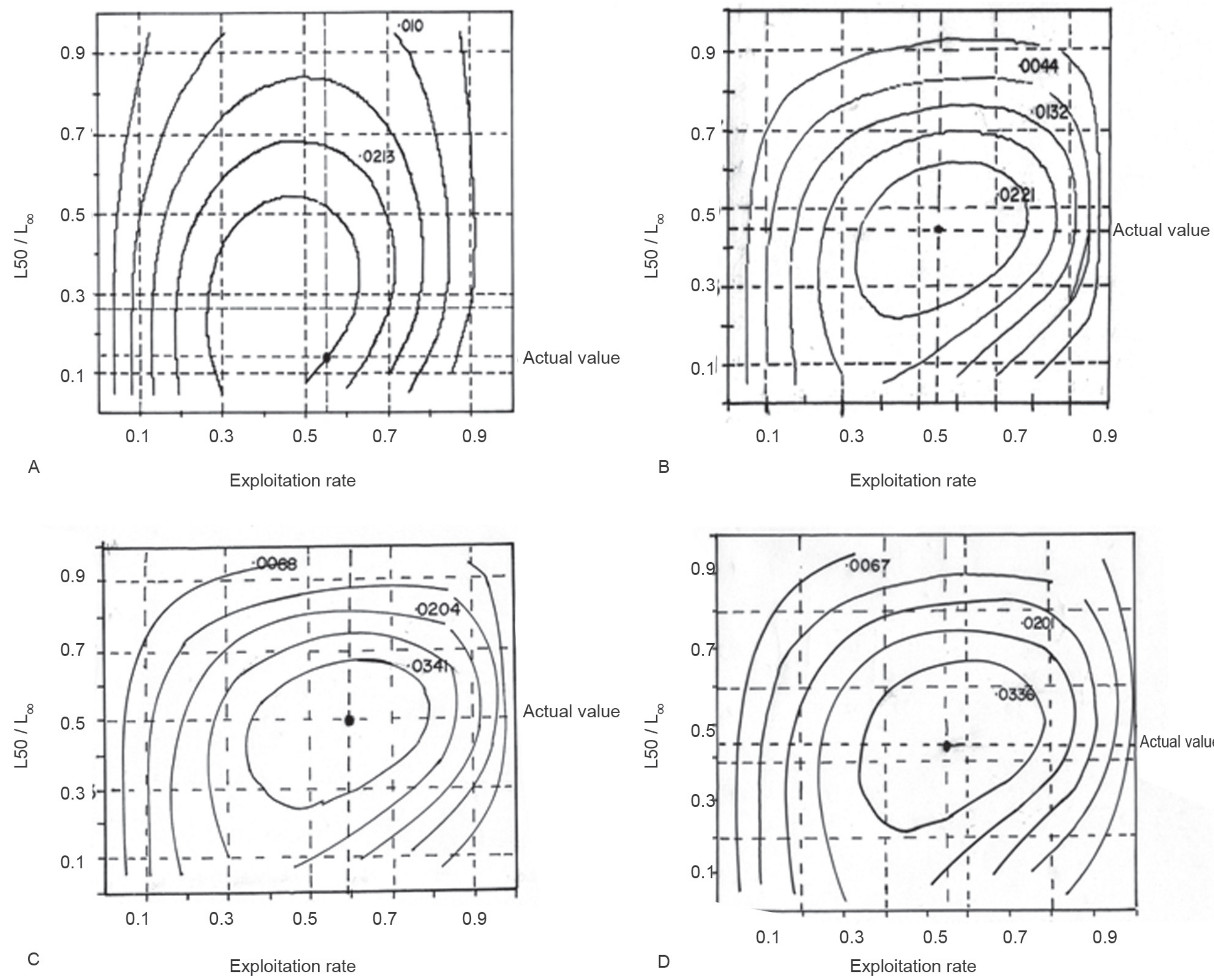

Fig. 4. Yield isopleths diagram of (A) *L. duvauceli*, (B) *S. aculeata,* (C) *S. inermis* (M) and (D) *S. inermis* (F)

Therefore, proper evaluation of the cephalopods as forage has to be carried out to determine whether the large predators, would in any way, reduce the recruits/spawners, with the added pressure from the fishing sector. Sustainability may be doubtful on account of the high rate of natural mortality coupled with semelparity in the females of these species.

The estimation of length at maturity (L_m), the maximum age (t_{max}) and the optimum size of exploitation (L_{opt}) are important parameters for the conservation and management of resources. In the present investigation, 87% of *L. duvauceli*, 99.66% of *S. aculeata* and 100% of *S. inermis* were found to be below the optimum length and a large percentage of their population below the length of first maturity and this is a matter of serious concern.

As a thumb rule, if Z/K=1, then the stock is mortality dominant, and if it is less than 1, it is growth dominated. In a mortality dominated population if Z/K=>2, it is said to be highly exploited (Pauly and Soriaro, 1986). Therefore, high values of Z/K found for the three species indicate highly exploited status which must also be a concern for the fishery managers.

The ratio between the L_m and L_∞, known as the reproductive load (Cushing, 1981), normally falls between 0.4–0.9, and is relatively constant within taxa of fish of approximately similar dimensions (Pauly, 1984). But in the present investigation the Lm/L_∞ ratio was found to be 0.37, 0.50 and 0.83 for *L. duvauceli, S. aculeata* and *S. inermis,* respectively, indicating that in the case of *L. duvauceli*, it does not fall in the normal range as suggested by Cushing (1981) which is slightly below the L_m/L_∞ ratio of 0.40.

The study also highlights the increase in the exploitation of cephalopod resources over the years, perhaps ever since squids and cuttlefish gained importance as an export commodity. Consequently, mortality rates, especially the fishing mortality, have almost doubled as compared to a decade ago. If the natural mortality and fishing mortality are equal, then the stock is supposed to be in a healthy state (Devaraj and Vivekanandan, 1999). But, in all the three species of cephalopods, the fishing mortality was more than twice the natural mortality. This has also led to decline in the mean length, and major portion of catch is composed of individuals below the L_m and L_{opt}. Therefore, their survival and sustainable contribution to the fishery is doubtful. In addition, there are no specialised fishing gears like jigging for catching cephalopods and the catch is landed mostly as bycatch of shrimp trawl. Though suggesting management measures for a nontargeted fishery is very difficult, some control mechanisms have to be implemented to protect and reduce juveniles of these resources from being captured so that further damage to the stocks can be checked.

Acknowledgements

The authors are grateful to the former Directors of CIFE. Dr. S. C. Mukherjee and Dr. Dilip Kumar for providing all the facilities. They offer their sincere thanks to Dr. W. S. Lakra, Director of CIFE for all the facilities and encouragement.

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Date of Receipt : 03.12.2012
Date of Acceptance : 17.04.2013