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Population dynamics of siboga squid *Doryteuthis sibogae* (Cephalopoda/Teuthoidea) in Thoothukkudi (Tuticorin) coast, southeast coast of India

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Study on the population dynamics of siboga squid *Doryteuthis sibogae* in Thoothukkudi coast revealed that the seasonal change has definite impact on the growth of this species. The growth parameters viz. L_∞, K, t_0, C, and φ were 39.5 cm, 0.4, -0.02, 0.5 and 2.9 respectively. Mortality parameters Z, M and F were estimated as 2.27 / year, 0.91 / year and 1.36 / year. Weight was more or less square function of length rather than in cubic function. This squid was found to have two recruitment seasons, one major season during December and a minor season during April. The length structured virtual population analysis revealed heavy fishing pressure on the length group 17 - 20 cm and hence the fishery of *D. sibogae* was not found to suffer due to recruitment overfishing in Thoothukkudi waters. Estimated total stock, average annual stock and maximum sustainable yield(MSY) were 529.47, 209.14 and 217.33 tonnes respectively. Present level of exploitation rate (U) and exploitation ratio (F/Z) was estimated to be 0.5372 and 0.6 respectively. The study infers that the cod end mesh size of the trawls of Thoothukkudi has to be increased from 10 to 25 mm to increase the yield per recruit. Further, the effort should be reduced and maintained at the exploitation ratio of 0.45 to get maximum yield per recruit. The study suggests reducing the present level of effort by 10 percent to sustain the stock of *D.sibogae* in Thoothukkudi waters.

[**Keywords**: *Doryteuthis sibogae*, seasonal oscillation in growth, mortality parameters, recruitment overfishing, MSY-exploitation rate, yield per recruit]

Siboga squid *Doryteuthis sibogae* Adam, 1954 (Class: Cephalopoda ; Order Teuthoidea) is a neritic species, forming a notable fishery along Thoothukkudi coast throughout the year with a peak from June to November. The occurrence of this species on commercial quantities was first reported[1] along southwest coast of India in the year 1982. Attempts were made to study the breeding biology of this squid in Indian waters [2,3]. As far as studies on the population dynamics of squids in Indian waters are concerned, few attempts have been made on the commercially most important species of squid of Indian waters, the Indian white squid, *Loligo duvauceli* [4-8]. So far no studies have been undertaken in Indian waters on the population dynamics of *D. sibogae*, hence an attempt is made to study the population dynamics of *D sibogae* and to assess the stock of this species in Thoothukkudi coast considering its significant contribution to commercial squid catch in this region.

Materials and Methods

Collections were made from the trawl catches of Thoothukkudi fishing harbour (lat. 8° 47' N and long. 78° 9' E) for two years from June 1996 to May 1998. Length frequency data were recorded weekly covering all length groups, which represented the fishery. During each sampling, 500 specimens were collected and the dorsal, mantle length and weight were recorded in centimeter and gram respectively. To assess the standing stock, annual stock, maximum sustainable yield and to have an idea about the present level of effort and its impact over the stock, catch effort data were collected for two years. To work out length-weight relationship, individual weight of 50 specimens covering all length groups was also taken during each sampling. The average catch per boat was worked out based on the catches from 10% of the boats engaged in fishing on the sampling day and was multiplied by the number of boats to obtain the daily estimate of catch. The effort was expressed in boat days. The catch and effort data for the observation days were pooled and multiplied by the number of

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fishing days for the month to obtain monthly catch and effort estimates respectively. The length frequency data of the monthly samples was raised to the monthly total catch by multiplying the corresponding raising factors and corrected for trawl selection using selection factors (L_{25} and L_{50}) derived by analysing the raw data. The data were smoothened by 5 point moving average and subjected to further analysis.

The length frequency data with 1 cm class interval was subjected to modal progression analysis by splitting the modes by Bhattacharya's method[9] followed by linking of means sizes using the computer software, FiSAT[10]. The seasonality in growth, if any was checked using Gulland and Holt plot by analyzing the growth increment data generated through Battacharya's analysis followed by linking of means. As existence of significant growth oscillation was evident through the Gulland and Holt plot, the following seasonally oscillation version of von Bertalanffy's equation[11] was employed to fit the growth curve,

$$L_t = L_\infty (1 - e^{-k(t-t_0) - (ck/2\Pi)[\sin 2\Pi (t-ts) - \sin 2\Pi (t_0 - t_s)]})$$

where L_t, L_∞, K and t_0 are the same parameters as in the normal von Bertalanffy's equation, 'c' is a constant, expressing the amplitude of growth oscillations. The 't_s' is called the 'summer point' and takes values between 0 and 1. It refers to the time when the fraction of a year has elapsed during which growth rate was the highest. At the time of 'winter point', ($t_w = t_s + 0.5$) the growth rate would be the lowest. The φ', an index of growth performance was estimated from length frequency data using FiSAT[10].

The total instantaneous mortality co-efficient 'Z' was estimated by length converted catch curve method available with FiSAT and the natural mortality co-efficient 'M' was estimated using Pauly's natural mortality equation[12] with the mean annual habitat temperature of 28° C. The fishing mortality co-efficient 'F' was obtained by subtracting 'M' from 'Z'.

The length-structured Virtual Population Analysis of FiSAT was employed to assess the natural mortality and the fishing pressure on various length groups. The recruitment pulses of *S. sibogae* were depicted by analysing the length frequency data by FiSAT[10].The total stock (Y/U) and the average annual stock (Y/F) were estimated from the average annual catch (Y). The exploitation rate (U) was estimated from the relation $U = F/Z\ (1 - e^{-z})$[13] and MSY was estimated using the equation $MSY = Z\ (Y/F) \times 0.5$, described by Gulland [14]. The optimum relative yield per recruit and yield isopleth of *S. sibogae*, were derived using FiSAT[10] with the M/K value of 2.28.

Results and Discussion

Length weight relationship—The parabolic equations derived for *D. sibogae* are given below.

Male W = $0.0062153\ L^{1.9986}$
Female W = $0.0092153\ L^{2.1968}$
Combined = $0.008210\ L^{2.0471}$

The 'b' value was estimated for male and female separately and on combining the sexes, the slope was closer to 2 indicating that the weight was more or less square function of length rather than cubic function as reported by Supongpan for *L. duvauceli* [8]. The relatively higher 'b' value for female observed in the present study may be attributed to the higher weight of ovary in female.

Growth parameters—Multiple modes could be seen in the monthly length frequency data and the modes were traceable atleast for 3 consecutive months to assess the growth of a cohort (Fig. 1). The growth parameters of *D. sibogae* viz. L_∞, K, t_0, C and φ' were estimated as 39.5 cm, 0.4, 0.02, 0.5 and 2.9 respectively. The seasonalised version of von Bertalanffy's equation estimated for *S. sibogae* was

$$L_t = 39.5\ (1 - e^{-0.4(t + 0.02) - (0.2/2\Pi)[\sin 2\Pi (t - 0.25) - \sin 2\Pi (-0.27)]})$$

The growth curve, derived using FiSAT, is presented in Fig. 2. The winter point 't_w' was 0.75 which coincided with the winter period (August-November) of Thoothukkudi coast during which the growth rate of *D. sibogae* was found to be notably suppressed. The slight decline in growth during winter period could be observed from the slight suppression in the growth curve (Fig. 2). Squids have a general feature of aquatic poikilotherms that are exposed to seasonal temperature oscillations[15]. The suppression of growth during August - November reveals definite impact of seasons on the growth of *D. sibogae* in Thoothukkudi waters. The value of amplitude of growth oscillations 'C' was found to be 0.5 which revealed significant oscillation in the growth due to temperature and other factors. The L_∞ was estimated for the species (39.5 cm) is higher than that of *Loligo duvauceli* reported off Karnataka coast[7] (37.1 cm) revealing the fact that *D. sibogae* might grow larger than the Indian white squid *L. duvauceli* though its increment in weight in relation to length is much lower than that of *L.duvuaceli* due to its slender body. This could be understood by the relatively low slope value of *D. sibogae* in the length-weight equation (b = 2.0471)

than that reported for *L. duvauceli* by Mohamed & Rao[7]. In the present study 'K' value was 0.4 for *D.sibogae* which is lesser than that reported already for *L.duvauceli* in Indian waters. Earlier workers have reported the 'K' of *L. duvauceli* as 0.5/year[4], 0.448/year[5], 0.92/year[6], 1.4/year[7] and 0.8/year[8]. The relatively low 'k' value reveals comparatively lower growth rate of *D. sibogae* than that of *L. duvauceli.* In the present study the φ' was 2.9 which falls in the range (2.5 to 3.2) reported for *L.duvauceli* [6] which shows a closer resemblance between the growth performance of the two neritic squids in Indian waters. Further, it could be inferred from the growth curve (Fig. 2), that this species has a maximum life span of about 2 years, which is slightly lesser than that reported and for *L. duvaucel*[6], (3.2 ± 0.4 years for male and 2.6 ± 0.2 years for female).

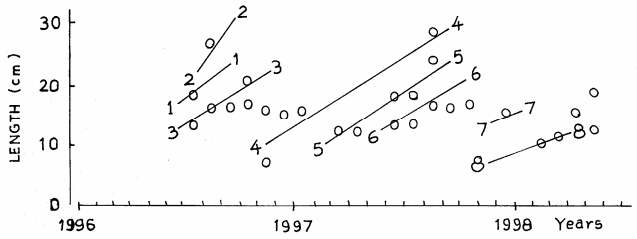

Fig. 1—Growth progression of various broods of *Doryteuthis sibogae*

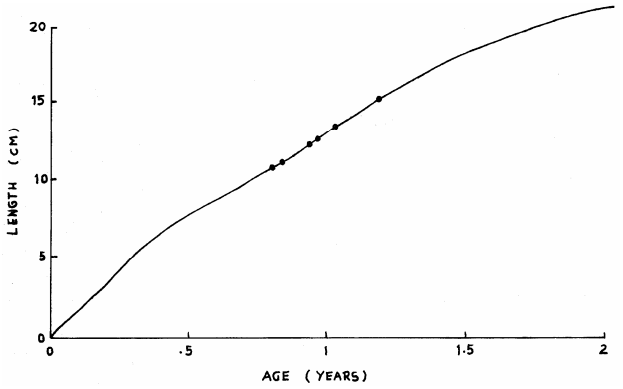

Fig. 2—Growth curve of *Doryteuthis sibogae*

The growth of *D. sibogae* could be deduced as 7.5 cm in 6 months, 13 cm in 12 months, 18 cm in 18 months, 19 cm in 21 months. Regarding the mortality rates, the natural mortality coefficient 'M', derived for *D. sibogae* in the present study (0.91 / year) is comparatively lower than that of *L. duvauceli* reported by various authors[4-8] i.e. 0.5 – 2.2. The 'Z' and 'F' were estimated as 2.27 and 1.36 respectively. The present level of exploitation rate of *D.sibogae* was estimated to be 0.5372 and the exploitation ratio (F/Z) was 0.6.

Virtual population analysis—The results of the length structured virtual population analysis of *D. sibogae* are presented in Fig. 3. It could be understood from this figure that the length group 17-20 cm are subjected to heavy fishing pressure which reveals that *D. sibogae* do not suffer due to recruitment over fishing as the length at first maturity of this species is estimated as 13 cm for male and 11.8 cm for female[3] and hence the animals with the length group 17-20 cm might have spawned once. Natural mortality was found to be higher in the smaller length group and it decreased gradually as the animal grows up to 18.5 cm. Afterwards, the mortality has been mainly due to fishing. Increasing the codend mesh size of the trawls can minimize the growth overfishing of *D. sibogae*. Square

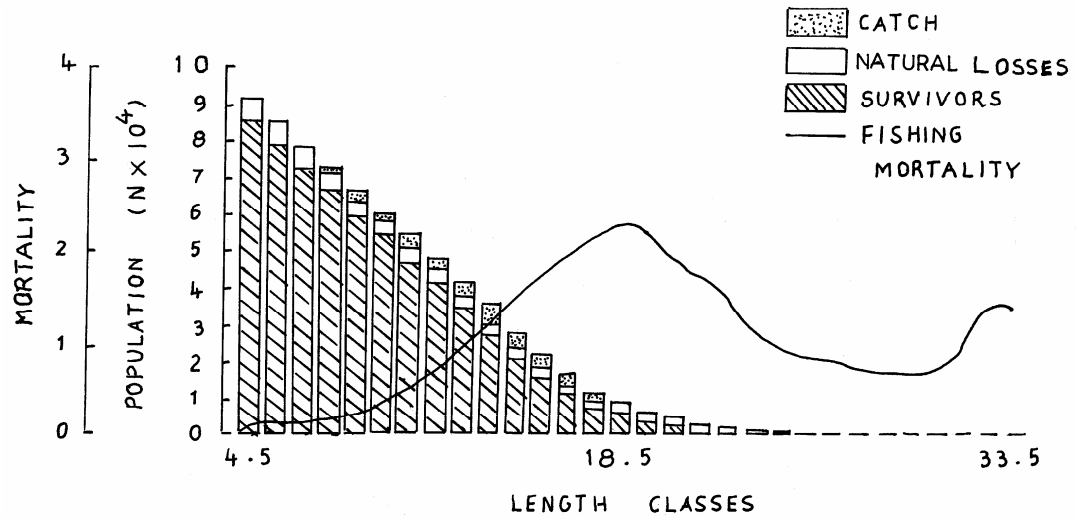

Fig. 3—Length structured virtual population analysis of *Doryteuthis sibogae*

Table 1—Average catch, effort and landings of *Doryteuthis sibogae* in different months during the period June 1996-May 1998

Month	Average no. of boats operated	Boat days	Average no. of squids landed / boat	Average squids landed / boat (kg) (CPUE)	Estimated total landings in number	Estimated total landings in weight(kg)
June	118	3,055	25	4.33	76,375	13,228.15
July	128	3,315	75	14.62	2,48,625	48,465.90
August	105	2,730	60	30.50	1,63,800	83,265.00
September	110	2,860	50	17.50	1,43,000	50,050.00
October	80	2,080	47	16.00	97,760	33,280.00
November	74	1,911	40	15.00	76,440	28,665.00
December	58	1,495	5	1.90	7,475	2,840.50
January	30	780	4	0.43	3,120	335.40
February	30	845	2	0.11	1,690	92.95
March	30	780	2	0.09	1,560	70.20
April	33	845	2	0.04	1,690	33.80
May	35	910	2	0.09	1,820	81.90
Total	831	21,606			8,23,355	2,60,408.80

mesh panel of appropriate dimension in the codend may be fitted to reduce the juvenile fishing of *D. sibogae*.

Recruitment pattern—*Doryteuthis sibogae* was found to have two recruitment pulses, one major one during September and October followed by a minor pulse during May and June (Fig. 4) although continuos recruitment could be ascertained by the occurrence of many micro cohorts in the length frequency data. Occurrence of continuous breeding has already been reported in the closely related neritic species, *L. duvauceli*[3]

Stock estimates—The average catch per boat, month wise average landings and average effort in terms of boat days are given in Table 1. Both the catch per unit effort (CPUE) and total catch were maximum during the peak fishing season i.e. from June to November. The average annual catch, annual stock and total stock of *D.sibogae*, were estimated to be 260, 209 and 529 tonnes respectively. The maximum sustainable yield (MSY) was estimated as 217 tonnes. The difference between MSY and the present level of catch was found to be 43 tonnes in excess, which corresponds to the excess F_{MSY} of 5,141 boats days per year.

Yield isopleth—The yield isopleth of *D. sibogae* is presented in Fig. 5. It could be understood from the yield isopleth that the maximum yield per recruit of 142 g is obtainable at various combinations of exploitation ratio ranging from 0.26 to 0.65 and L_{50}/L_{∞} from 0.08 to 0.53. The present value of L_{50}/L_{∞} was found

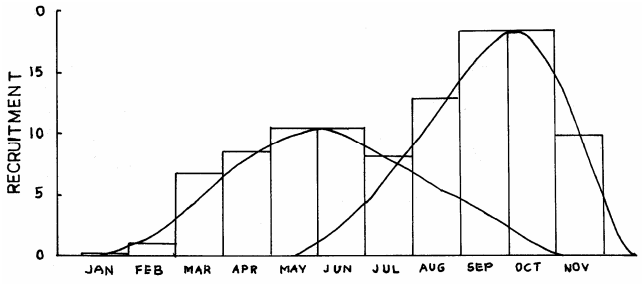

Fig. 4—Recruitment pattern of *Doryteuthis sibogae*

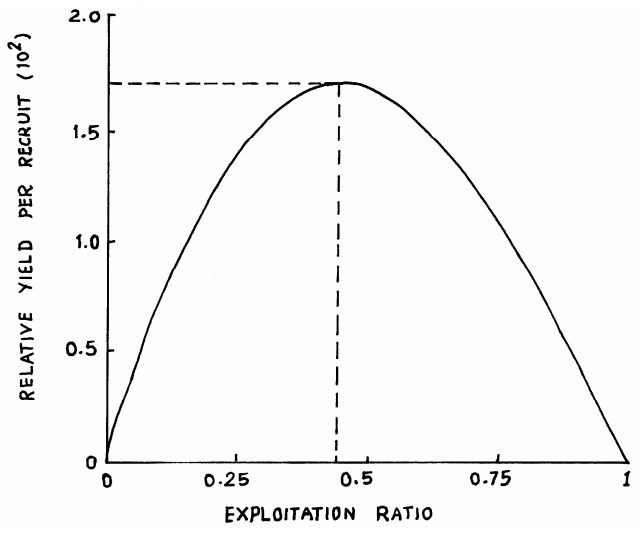

Fig. 5—Relationship between yield per recruit and exploitation ratio in *Doryteuthis sibogae*

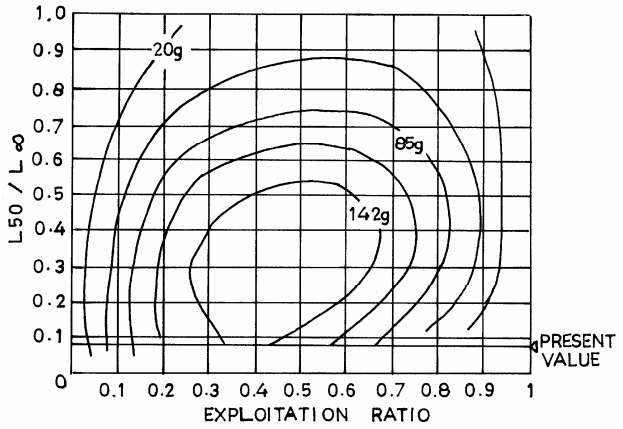

Fig. 6—Yield isopleth of *Doryteuthis sibogae*

to be 0.28. The exploitation ratio (F/Z) was 0.6 and the exploitation rate (U) was 0.537. The present level of exploitation ratio has exceeded the exploitation ratio corresponding to the maximum yield per recruit (0.45) (Fig. 6). Further, it is also evident from the stock estimates, that the present level of average catch (260 tonnes/year) exceeded both the average annual stock (209 tonnes) and the MSY (217 tonnes/year). Therefore conservation measures have to be taken to reduce the effort at least by 10 percent and to increase the codend mesh size of trawl from the existing size of 10 mm to 25 mm to sustain the stock of *D. sibogae* in Thoothukkudi waters.

The study reveals the existence of seasonal oscillations in the growth of *D. sibogae* in Thoothukkudi coastal waters. Unlike finfishes, weight was more or less square function of length rather than cubic function. *Doryteuthis sibogae* was found to have two recruitment seasons, one major season during December and a minor season during April. The length structured virtual population analysis revealed heavy fishing pressure on the length group 17 - 20 cm and hence the fishery of *D. sibogae* was not found to suffer due to recruitment overfishing in Thoothukkudi waters. The study infers that the cod end mesh size of the trawls of Thoothukkudi has to be increased from 10 to 25 mm so as to increase the yield per recruit. Further, the effort should be reduced to maintain the exploitation ratio at 0.45 to get maximum yield per recruit. The study suggests 10 percent reduction in the present level of effort besides recommending the fitting of square mesh panels in the codend of trawls.

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