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The biology and population dynamics of the spadenose shark *Scoliodon laticaudus* in the coastal waters of Maharashtra State, India

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ABSTRACT

The study of the biology and dynamics of *Scoliodon laticaudus* indicates a fast growth of 21.8 cm, 54.5 cm and 65.5 cm, in the first, second, and third year respectively. The von Bertalanffy growth equation was fitted to the above values for which the parameters calculated (on an annual basis) were : K = 0.6812, L_∞ = 74.023 cm, T_∞ = 12 years and t_o = –0.01 year. The maximum length of this shark in the Mumbai waters is about 66 cm (3.1 years). The weight growth parameters (on an annual basis) for sexes combined by the VBGF are K = 0.5823, W_∞ = 1756.93 g, t_o = 0.0032 year. The length at birth is 14 cm with a gestation period of 4 months. The ovarian and uterine cycles operate concurrently with broods being released once a month. The average fecundity was 11 embryos per female. The L_m/L_∞ was estimated to be 0.47 - 0.54. *Scoliodon laticaudus* is an active carnivore with a mixed diet composing of small sized teleosts, prawns, squilla and molluscs. There is no evidence of cannibalism. The study of the dynamics of *Scoliodon laticaudus* indicates that the stock is exploited at its optimum level. Therefore any increase in effort from the present level may not increase the yield and it is advisable to sustain the effort at the present level. For the sharks (all species combined) and the elasmobranchs there is still some scope for increasing the effort in order to reach the MSY level.

Introduction

The spade nose shark, *Scoliodon laticaudus* locally called *sonmunshi* is one of the smallest carcharhinids inhabiting the shallow waters of the continental shelf of the Indo - Pacific region. This shark is found in the coastal waters of Maharashtra State, India, throughout the year in fair abundance and contributes about 30% to the total sharks landed in the state. The earlier works on this species were mostly confined to its taxonomy and distribution. Literature on the biology of this shark is limited. Those worth mentioning are Mahadevan (1940), Choodamani (1941), Setna and Sarangdhar (1948), Nair

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(1976), Nair *et, al.* (1974), Kulkarni *et al.* (1988) and Devadoss (1979, 1989). However, there has not been any significant attempt to elucidate the dynamics of the exploited stock of this economically important fishery in India. Hence a study was made to bridge the gap and the results are reported in this paper.

Materials and methods

The study was carried out from September 1986 to September, 1988. Random sampling methods were followed in the collection of the length frequency and catch data from three major trawler landing centres, namely the New Ferry Wharf, the Sasoon Docks and the Versova fishing village in the city of Mumbai on a weekly basis. The entire continental shelf of Maharashtra constitutes the fishing grounds for the trawlers landing at these three ports. Samples were also taken from the fishing cruises of M.F.V. *Saraswati* of the Central Institute of Fisheries Education (CIFE) in the entire continental shelf of Maharashtra. The total length in cm from the tip of snout to the tip of caudal fin of 9,200 specimen of *Scoliodon laticaudus* was measured for the purpose of determination of age and growth.

The monthly length – frequency data for all stages including foetii, juveniles and adults, set at 2 cm interval was used for age determination on the basis of the modal progression analysis. The progression of modes was traced free-hand through time in months and extrapolated to the time axis in order to identify the number of broods per year class and to determine the growth of the successive broods (Devaraj, 1983). The modes for the successive months for the period October 1988 to December1990 were repeated, where necessary, through the successive years beyond December 1990 also to be able to trace the growth of the fish through its entire life span that the modes in the scattogram represent. In this exercise each brood was treated separately for determining the length in cm at age in months. As the growth of male and female was found to be almost the same they were combined together and the average taken for fitting the von Bertalanffy growth function (VBGF), (Bertalanffy, 1938).

For the estimation of the growth in weight, the length in cm weight in g relationship for this fish was first fitted on the basis of the data for about 950 fresh specimens of both males and females of different sizes, and then the age-length key converted into age-weight key using the length-weight relationship.

The scattogram technique (Devaraj, 1983) was also used to determine the periodicity of brood release, gestation period and to see whether reproduction was concurrent or consequent. The number of embryos per female was taken as the basis for determining fecundity. The reproductive characteristics as determined from the scattogram were further confirmed by examining the reporductive tracts of about 950 individuals of both sexes. For this purpose, the state of maturity in the male sharks was determined on the basis of the growth of the claspers and the collection of milt in the sperm sacs, while in the case of females after recording the length and weight they were cut open and the condition of the ovaries, the uterii and the embryos was examined following Holden and Raitt (1974), Devadoss (1979) and Ebert (1986). The relative condition factor (K_n) computed from the length-weight rela-

tionship was also taken into account in assessing the breeding season.

The recruitment pattern which indicates the variation in the recruitment strength by months was determined by tracing the length - frequencies for each month to their zero age by means of the age length key (Pauly, 1982).

For the study of the feeding biology, gut analysis of 678 sharks of various size groups was made both qualitatively and quantitatively. As the stomach contents were found to be in various stages of digestion they could be identified upto the generic level only and sometimes upto the species level. The volume (displacement method) and the frequency of occurrence of each item were noted. The index of preponderance (IP) method of Natarajan and Jhingran (1961) was employed for the quantification of the food items. The intensity of feeding was assessed by the degree of distension of the gut in each fish (gorged, full, 3/4 full, 1/2 full, 1/4 full, trace and empty). The nature of predation was established by observing the orientation of the forage in the gut of the shark.

The annual total instantaneous mortality rate (Z) for males and females of *S. laticaudus* was estimated by cumulative catch curve method (Jones and Van Zalinge, 1979). Since there was no length-frequency data for the years 1978 to 1985 - '86 Z values for these years were determined from the values of catchability coefficient (q = F/f) estimated for the years 1986 to 1988, for which the values of both annual instantaneous fishing mortality coefficient F = Z–M and annual fishing effort (f in boat hours bh) were avaliable (Table 2). Z was also estimated following Jackson (1939) and Beverton and Holt (1956) methods. The annual instantaneous natural mortality coefficient (M) was determined according to Cushing (1968) and Pauly (1978).

The annual catch and effort data required for stock assessment were taken from the various published records of the Central Marine Fisheries Research Institute (CMFRI), Cochin and the Department of Fisheries, Maharashtra State, which collect the data on a regular basis following the stratified multistage probability sampling (Kutty *et al.*, 1973).

The annual effective fishing effort in terms of actual number of trawlers actively engaged in fishing was estimated through four steps such as: (i) for Maharashtra state as a whole the annual trawler effort in boat trips (bt) recorded as per the above design was known for the years 1978 to 1984-'85 (George *et al.*, 1979; 1979 a, b; 1982 a, b; Mathew *et al.*, 1986) while for the years 1986 - '87 districtwise effort was available (Department of Fisheries, Maharashtra, 1986-'87, 1987-'88). (ii) the total annual effort in boat trips for 1978 to 1985 - '86 was split up into district wise (for coastal districts) effort using the average percentage composition of effort expended from these districts during 1986 - '87 and 1987 - '88 (Department of Fisheries, Maharashtra 1986 - '87, 1987 - '88) (iii) the annual trawler effort (bt) for each district was converted into effort in boat hours (bh) by multplying the effort in bt by the average hours of actual fishing (59 hours for Bombay, 8 hours for Raigadh and 9 hours each for Ratnagiri and Sindhudurg districts. The total districtwise effort in bh gave the effort in bh for the entire Maharashtra state and (iv) the annual trawler effort (bt) for

each district was divided by the observed average number of fishing trips per year (50 trips of 4 days each for Bombay and 200 trips of 1 day each per year for each of the districts of Raigadh, Ratnagiri and Sindhudurg) in order to express the effort in number of trawlers. (Table 1). The annual landing of sharks in Maharashtra for the years 1981 to 1985 - '86 were taken, from George *et al.* (1982 - '83) and Mathew *et al.* (1986 - '89). For the earlier years (1975 to '80) separate shark landings data were not available as they were treated together with skates and rays under the group elasmobranchs (George *et al.*, 1979, 1980, 1981). Therefore the shark landings for the years 1978 to '80 were computed from the percentage of sharks in the elasmobranchs for 1981 to 1985 - '86 period. For the years 1986 - '87 and 1987 - '88 the data for shark landing was obtained from the reports of the Department of Fisheries, Maharashtra (Department of Fisheries, Maharashtra, 1986-'87, 1987-'88).

The *Scoliodon laticaudus* component in the shark landing was estimated on the basis of the author's regular weekly observation at New Ferry Wharf, Sassoon Docks and Versova village during 1986-'88.

Yield in weight per recruit (Y W/R) was determined as a function of annual fishing intensity F (or annual exploitation ratio E = F/Z) for the present age at first capture (t_c) of 0.67 years (the length at first capture l_c = 27 cm) and as a function of age at first capture (t_c) for the average fishing intensity for 1978 to 1987 - '88 (Beverton and Holt, 1957).

The optimum age of exploitation (t_y) and the potential yield per recruit (Y')

TABLE 1. *Districtwise effective effort by trawlers in terms of boathours (bh) and number of trawlers for the years 1978 to 1987-'88 in the state of Maharashtra*

Year	Mumbai		Reigadh		Ratnagiri		Sindhudurg		Maharashtra State	
	Boathours (bh)	No. of trawlers	Boathours (bh)	No. of trawlers	Boathours (bh)	No. of trawlers	Boathours (bh)	No. of trawlers	Boathhours (bh)	No. of trawlers
1978	31,37,148	1,063	76,880	48	6,31,350	351	2,45,043	136	40,90,421	1,598
1979	48,72,456	1,652	1,19,400	75	9,80,568	545	3,80,583	211	63,53,007	2,483
1980	29,53,540	1,001	72,376	45	5,94,387	330	2,30,697	128	38,51,000	1,504
1981	22,52,738	764	55,200	35	4,53,348	252	1,75,959	98	29,37,245	1,149
1982-'83	43,83,464	1,486	1,07,416	67	8,82,153	490	3,42,387	190	57,15,420	2,233
1983-'84	34,76,811	1,179	85,200	53	6,99,687	389	2,71,566	151	45,33,264	1,772
1984-'85	37,61,427	1,275	92,176	58	7,56,963	421	2,93,796	163	49,04,362	1,917
1985-'86	34,27,723	1,162	84,000	53	6,89,814	383	2,67,741	149	44,69,278	1,747
1986-'87	36,26,022	1,229	88,856	56	7,29,720	405	2,83,230	157	47,27,828	1,847
1987-'88	33,81,526	1,146	82,864	52	6,80,517	378	2,64,123	147	44,09,030	1,723

were estimated according to Kutty and Qasim (1968). The absolute annual yield (Y) was calibrated graphically from the Y=W/R curve after plotting the average annual yield in tonnes for the period 1978 to 1987 as the stabilised yield (as there was little annual fluctuations in values) against the corresponding values of F or E (Corten, 1974 ; Devaraj, 1983).

Length cohort analysis (Jones, 1984) was performed to estimate the maximum biomass and yield.

The surplus yield models of Schaefer (1954) and Fox (1970) of the hyperbolic type were fitted to the time series data on annual catch (Y) and annual fishing effort (f) for 1978-'88 in order to estimate the biologically optimum maximum sustainable yield (MSY) and the biologically optimum effort F_{msy}).

Results

Growth and reproduction

The pattern of growth of the successive broods identified in the scattogram of length modes traced from their orgin and to the maximum age indicates no significant difference in growth between broods and between year classes. There was no difference in the growth between the male and female, but the females grew to a larger size and hence to an older age than the males (Figs. 1 & 2). The mean observed growth in length in cm at age in months indicated that *S. laticaudus* attained a length of 21.7, 35.8, 46.4, 54.5, 60.8, and 65.5 cm at the age of 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 years respectively. The growth coefficient (K), the asymptotic length (l_∞) and the arbitrary origin of growth (t_0) were estimated to be 0.05681 monthly or 0.68172 annually, 74.023 cm and –0.13237 month or –0.01 year respectively. The VBGF estimated lengths (21.78, 36.87, 47.60, 55.23, 60.66 and 64.52 cm at age of 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 year) agree closely with the observed length-at-age. The age of *S. laticaudus* (66 cm) observed in this study is 37 months while the infinite age (T_∞) for L_∞ = 74.023 cm, was

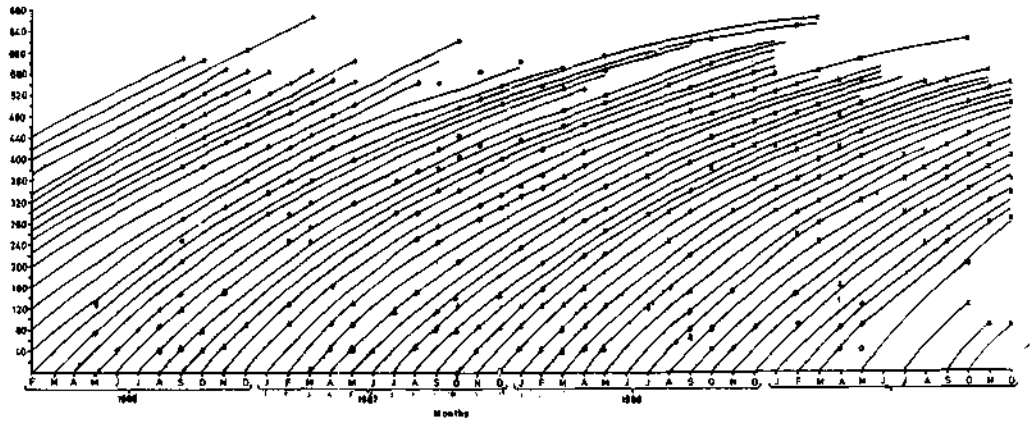

Fig. 1. The growth lines fitted through the scatter diagram of length modes plotted against time indicating the broods of *S. laticaudus* (females) in the waters off Maharashtra State for 1986-'88.

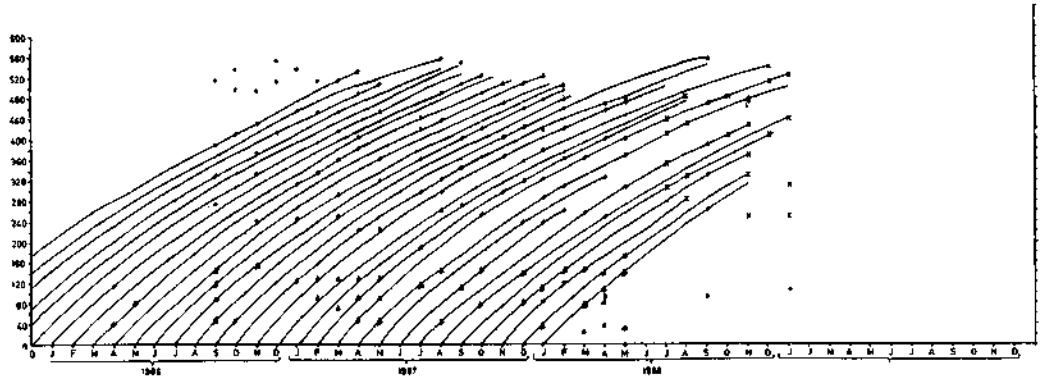

Fig. 2. The growth lines fitted through the scatter diagram of length modes plotted against time indicating the broods of *S. laticaudus* (males) in the waters off Maharashtra state for 1986-'88.

computed to be 12 years. The total length (L in cm) total weight (W in g) relation for the male (r^2 = 0.98), female (r^2 = 0.98) and the sexes combined r^2 = 0.98) is given below:

Male : $W = 0.001519\ L^{3.1914}$

Female : $W = 0.001698\ L^{3.1799}$

Sexes combined : $W = 0.001607\ L^{3.1904}$

The weight-growth parameters for sexes combined estimated by the VBGF are : K = 0.04853 monthly or 0.5823 annually, W_∞ = 1756.93 g and t_o = 0.0385 or 0.0032 year.

The largest foetus measured during the study had a length of 13.5 cm while the smallest free living shark obtained in the catches had a length of 16 cm. These observations indicate that the length at birth might be somewhere in between these values. Setna and Sarangdhar (1948) stated that *S. laticaudus* measured 13 to 15 cm at birth while Nair (1976) calculated the average length of the foetii at birth from the data of Setna and Sarangdhar (1948) to be 14 cm. The observations in the present stduy also suggest that the length at birth could be slightly less than 15 cm and hence, assumed to be 14.5 cm. The von Bertalanffy growth equation fitted to the length-at-age data indicated the age of 14.5 cm long *S. laticaudus* to be 4 months (0.33 year) which was therefore considered as the gestation period.

From the scattogram (Figs. 1 & 2), it is evident that the broods are regularly released once a month. Obviously the ovarian and uterine cycles seem to be operating concurrently (ovarian eggs development taking place at the same time as the pups grow in the uterus with one pregnancy immediately succeeding the other). The size group of 35-40 cm (17 months old) was taken to be the size at first maturity for both the males and females. At this size the claspers in the male were stiff and sturdy, and the milt oozed out from the sperm sacs on applying pressure. In the case of female the ovaries were found to be well developed for the first time and the wall of the uterus was thick at this size.

Although there was only one peak in

the K_n value for the males at 25 cm and females at 29 cm, after the attainment of first maturity at 35 to 40 cm, the K_n values remained almost uniform at the same level throughout the life. The K_n values ranged only very narrowly between the successive months : 0.93 in February (males) to 1.15 in April (females) (Fig. 3). The lengthwise condition factor also showed very little fluctuation between male and female after they attained maturity at 35 to 40 cm. This could be taken as concrete evidence of uniform conditions of maturity throughout the year without any seasonal peak, suggesting thereby continuous maturation and breeding throughout the year (Fig. 3), as was also evident from release of brood at monthly intervals (Figs. 1 & 2).

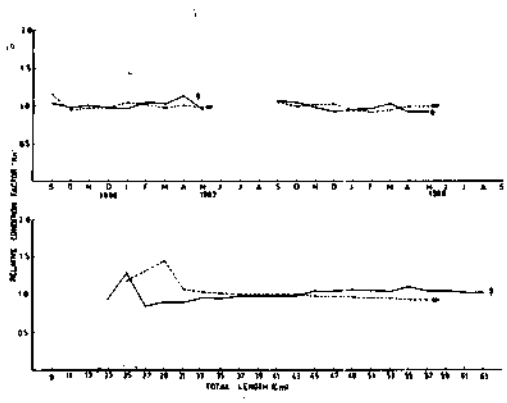

Fig. 3. Monthwise and lengthwise relative condition factor K_n.

As a general rule the number of intrauterine embryos was 14, distributed equally (7:7) in each uterus, but in one case a maximum of 12 foetii were observed in a single uterus, while the maximum number of foetii for a single female was found to be 22. The average number of foetii per female was 11. The sex of the foetii was distinguishable when the embryos were 3 to 4 cm long.

The lm/L_∞ for *S. laticaudus* estimated in the study was 0.47 to 0.54 which was much less than the average value of 0.77 given by Holden (1974) for 20 species of elasmobranchs but agrees well with the average of 0.51 for six species of Indian elasmobranchs (Devaraj, 1983). Thus the comparatively low lm/L_∞ values for *S. laticaudus* indicated low reproductive stress. The lower the reproductive stress the greater the longivity (94.4 years for L_{max} and 12 years for L_∞), which ensures higher reproductive rates. The recruitment pattern for *S. laticaudus* also suggests protracted spawning and uniform recruitment throughout the year.

Feeding

Fish, prawn, molluscs and squilla formed major part of the diet. Fish belonging to six species could be identified, viz; *Coilia dussumieri, Trypauchen vagina, Otolithes cuvieri, Harpodon nehereus, Polynemus* sp. and *Gazza* sp. while the others could only be identified upto the family level, viz; Sciaenidae, Apogonidae, Cynoglossidae, Clupeidae, Muraenesocidae, Tetradontidae and Trichiuridae. Among crustaceans, both penaeid and non - penaeid prawns belonging to five species could be identified, viz; *Acetes indicus, Nematopalaeomon tenuipes, Metapenaeus monoceros, Metapenaeopsis stridulens* and *Parapenaeopsis stylifera,* while the others could only be identified upto the family level, viz; Solenoceridae and Hippolytidae. Squilla formed a good portion of the diet while crabs were of some significance. The molluscs were represented by species of *Sepia* and *Loligo* in good numbers and occasionally by a few molluscan shells (Fig. 4).

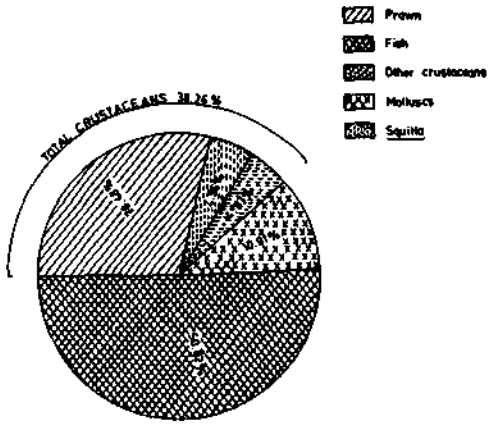

Fig. 4 Average percentage composition of food of *Scoliodon laticaudus*.

Population characteristics

The annual M was found to be 1.35 based on the method of Cushing (1968); the L_{max} of 70.32 cm used in his method was 95% of the L_{∞} (74.023 cm). Pauly's (1978) method resulted in M of 0.9690; the average annual ambient temperature (T) used in this method was 27.86°C. Besides these estimates of M, certain assumed values of M were also used in the study (Smita and Devaraj, 1989).

By using the Beverton and Holt (1956) method Z for 1986-'87 and 1987-'88 was estimated to be 1.32 and 1.30 respectively while the l for these two years was estimated to be 43.04 and 43.19 cm respectively. By Jackson's (1939) method Z for 1986-'87 and 1987-'88 was estimated to be 1.19 and 1.23 respectively. Z estimated by the cumulative catch curve method was 4.38 and 3.91 for 1986-'87 and 1987-'88 respectively (Table 2, Fig. 5). The length groups belonging to the age 1.9 to 3 years exhibited linearity in the regression of cumulative frequency on length during 1986-'87 and 1.8 to 3.1 years during 1987-'88, (Fig. 5). For the known values of Z and f (*vide infra*) for the years 1986 to '88 the annual catchability coefficient (q = F/f ; F = Z-M) was estimated for M = 1.95 (assumed value).

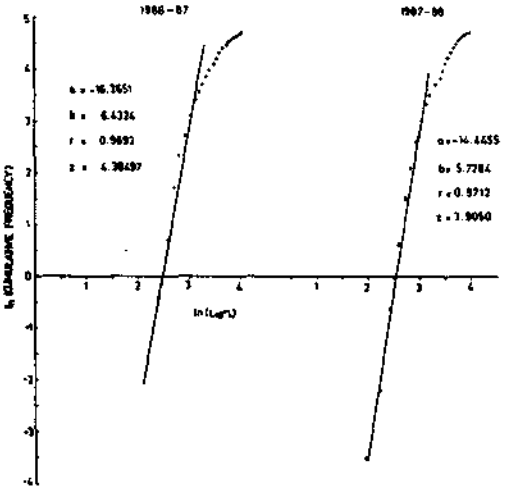

Fig. 5. Cumulative catch curve of *Scoliodon laticaudus* for 1986-87 and 1987-'88 for Maharashtra.

TABLE 2. *Estimation of catchability coefficient for 3 M values for 1986-'88*

Year	F in boat hours x 10^5	Z'	Pauly's method M = 0.9690		Cushing's method M = 1.35		Assumed value M = 1.95	
			F	q	F	q	F	q
1986-'87	47.28	4.38	3.41	7.21×10^{-7}	3.03	6.41×10^{-7}	2.43	5.14×10^{-7}
1987-'88	44.09	3.91	2.94	6.67×10^{-7}	2.56	5.81×10^{-7}	1.96	4.45×10^{-7}
Average	45.69	4.15	3.18	6.94×10^{-7}	2.80	6.11×10^{-7}	2.20	4.80×10^{-7}

' From cumulative catch curve.
q = F/f where F = Z-M and f = observed number of boathours.

The three average values of q for the years 1986-'87 and 1987-'88 estimated for the three values of M were 6.94 x 10^{-7} for M = 0.9690, 6.11 x 10^{-7} for M = 1.35 and 4.80 x 10^{-7} for M = 1.95. Assuming these average values of q to be true for the years 1978 to 1985-'86 for which f values were available, Z = (F+M) was estimated to range from 3.00 in 1981 to 5.38 in 1979 for M = 0.9690 from 3.14 in 1981 to 5.23 in 1979 for M = 1.35 and from 3.36 in 1981 to 5.0 in 1979 for M = 1.95 (Table 2). F values for the years 1978 to 1985 - '86 for which there was no length frequency data for the estimation of Z, was estimated using q = 0.00000048. F thus ranged from 1.41 (f = 29.37 x 10^5 bh or 1,149 trawlers) in 1981 to 3.05 (f = 63.53 x 10^5 bh or 2,483 trawlers) in 1979 (Table 3). F for the years 1986-'87 and 1987-'88 for M = 0.9690, M = 1.35 and M = 1.95 was computed to be 3.41 and 2.94, 3.03 and 2.56, and 2.43 and 1.96 respectively (Table 2). F for the years 1978 to 1985 - '86 varied between 2.04 in 1981 and 4.41 in 1979 for M = 0.9690, between 1.79 in 1981 and 3.88 in 1979 for M = 1.35 and between 1.41 in 1981 and 3.05 in 1979 for M = 1.95.

The yield per recruit, Y/R was estimated for M = 0.9690 (estimated by Pauly's 1978 method), M = 1.35 (estimated by Cushing's 1968 method) and M = 1.95 (assumed value), as function of E for the observed t_c of 0.67 years (l_c = 27 cm for 1986 to 1988 and t_r of 0.33 year (l_r = 17 cm) (Fig. 6).

The Y/R curves for the three values of M were used to compute and fit absolute yield curves through calibration after plotting the values of average annual yield of 2,154 tonnes and average E values of 0.77, 0.66 and 0.53 for M = 0.9690, M = 1.35 and M = 1.95 respectively. The distribution pattern of

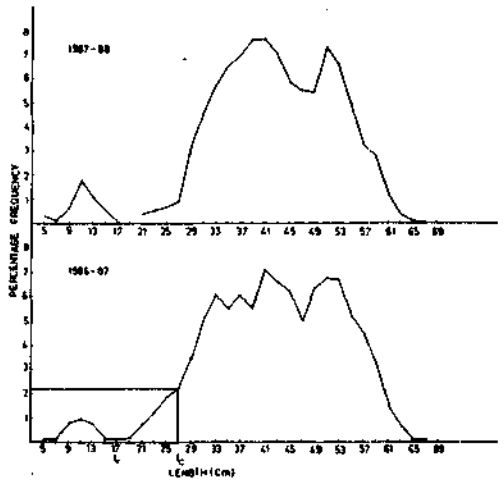

Fig. 6. Annual length-frequency polygons for *Scoliodon laticaudus* (sexes together) from Mumbai for the period 1986-'88, indicating l_r to be 17 cm and l_c to be 27 cm.

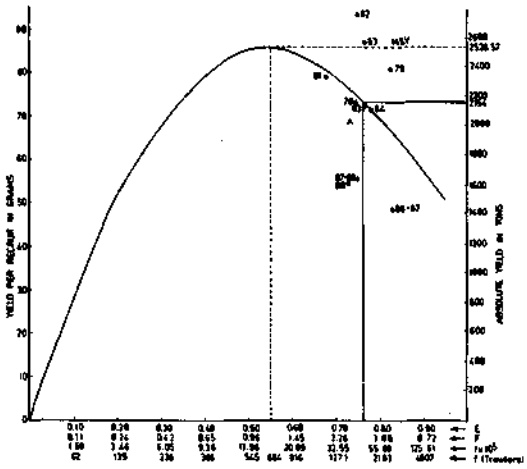

Fig. 7. Yield per recruit curve as a function of E for M = 0.9690 (Pauly's method), t_c = 0.67 years, conversion of Y/R into absolute yield is also shown. The superimposed annual yield values indicate over exploitation in all the years from 1978 to 1988. (A indicates average annual Y, E, F and f for the period 1978 to '88.

the annual yield values for 1978-'88 superimposed on the Y/R curves for the three different values of M was different from each other. On the Y/R curve for M = 0.9690 the observed annual yield values cluster between E = 0.65 in 1981 and E = 0.83 in 1986-'87 suggesting that the stocks were overexploited during all the years from 1978 to 1987-'88 (Fig. 7). On the Y/R curve for M = 1.35 the observed Y values for 1978 to 1987 - '88 cluster between E = 0.57 in 1981 and E = 0.74 in 1979, with poor compatibility with the Y/R curve and suggesting overexploitation for all the years except 1981 and 1987-'88 (Fig. 8). On the Y/R curve for M = 1.95 the annual Y values scattered between E = 0.42 in 1981 and E = 0.56 in 1979, following the course of the Y/R curve very well except for the year 1986-'87 (the annual recruitment during 1986-'87 was low about 39.80 million). Thus, M = 1.95 appears to be the true value of M for *S. laticaudus*. At M = 1.95, Y/R increases quite rapidly to the maximum sustainable Y/R (MSY/R) of 36 g at E_{msy} = 0.65 (F = 3.62, f = 75.495 x 10^5 bh or 2,949 trawlers) and gradually decreases to 31 g at E = 0.95 (Fig. 9). The average annual yield for the years 1978 to 1987-'88 (2,154 t) was near the optimum (2,225 t) inspite of the slightly suboptimum effort (45.99 x 10^5 bh or 1,796 trawlers).

The yield isopleth diagram (Fig. 10) indicates the potential yield per recruit (Y') to be 41 g at E = 0.1 (= $F_{0.1}$). The age (t_y) corresponding to Y' is 1.025 year for l_y = 35.8 cm. The values of Y' and t_y estimated by the method of Kutty and Qasim (1968) were 43.78 g and 1.08 year respectively. Based on the t_y obtained from Jones (1984) length cohort analysis, (Figs. 11 & 12) was 1.00 year

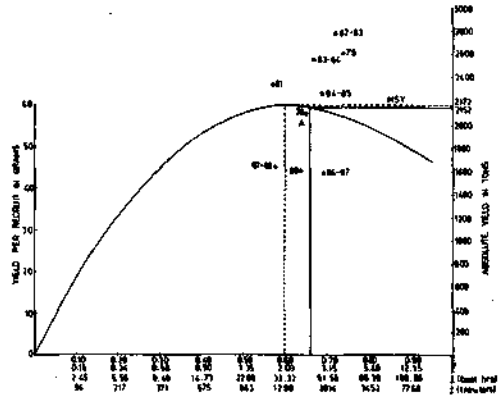

Fig. 8. Yield per recruit as a function of E for M = 1.35 (Cushing's method), t_c = 0.67 years; conversion of Y/R into absolute yield is shown. The superimposed annual yield indicates overexploitation in all years from 1978 to 1988. (A indicates average annual Y, E, F and f for the period 1978 to '88).

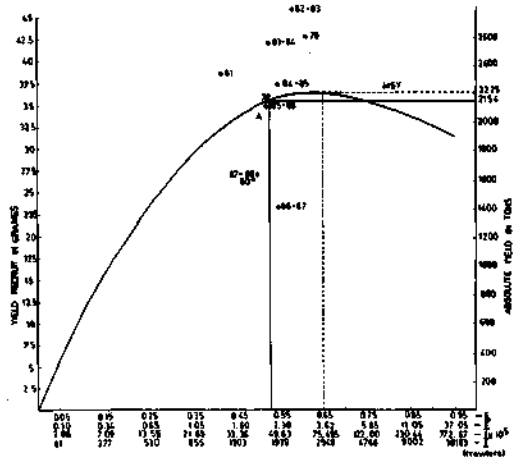

Fig.9. Yield per recruit curve as a function of E for M = 1.95 (assumed value), t_c = 0.67 years; conversion of Y/R into absolute yield is shown. The superimposed annual yield closely follow the Y/R curve. (A indicates average annual Y, E, F and f for the period 1978 to '88.

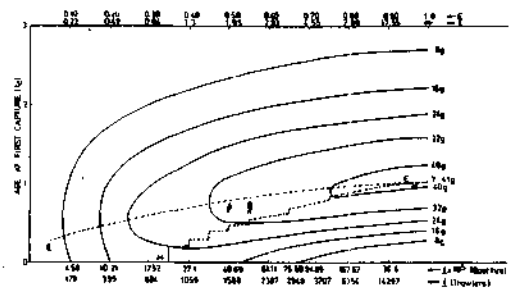

Fig. 10. Isopleth diagram for yield (g) per recruit as a function of effort (f) (also F and E) and t_c for *S. laticaudus* (sexes together), (E E' = curve tracing the enmetric yield, MM' = curve tracing the MSY, A and B = annual Y/R for the years 1986-'87 and 1987-'88 respectively.

which agrees with the above two estimates. The total stock (P) varied from 2,635 t in 1986-'87 to 5,717 t in 1981 and the standing stock (P) varied from 586 t in 1986-'87 to 1,662 t in 1981.

On the basis of Jones (1984) length cohort analysis, the maximum biomass of 2,687.5 t (average annual for 1986-'88) occurs when the cohort reaches the age of 1.00 year (l=35 cm) while the maximum yield of 1,137.5 t (average annual for 1986-'88) occurs when the cohort reaches the age of 1.9 year (l= 58 cm) (Figs. 11 & 12).

The results of the linear (Schaefer, 1954) and exponential relations (Fox, 1970) fitted to the data on catch and effort for : (1) *S. laticaudus* (eqs. 1 & 2), (2) total sharks (eqs. 3 & 4) and (3) total elasmobranchs (eqs. 5 & 6) for 1978 to 1987-'88 are given below:

1. For *S. laticaudus*

$Y/f = 0.838245 - 0.00000007748\ f$
$(r^2 = 0.2991)$ ..... (1)

$Y/f = \exp(-0.154943 - 0.0000001319f)$
$(r^2 = 0.2331)$ ..... (2)

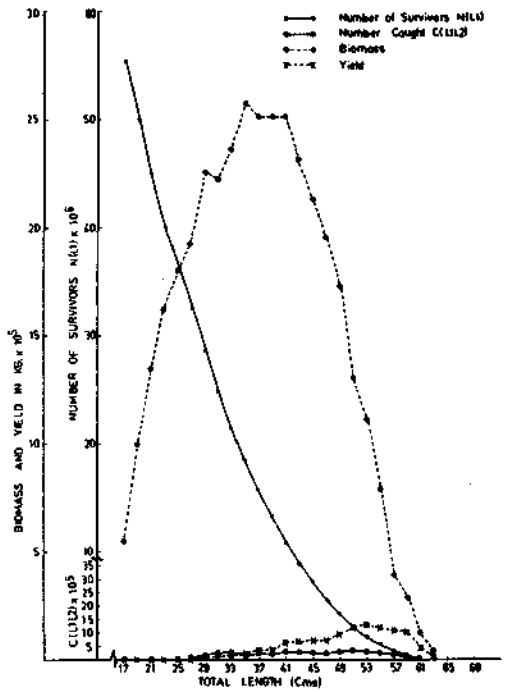

Fig. 11. Jones length cohort analysis for *Scoliodon laticaudus* during 1986 - '87.

Eq. (1) indicates the optimum catch (MSY) and the optimum effort (f_{msy} to be 2,267.2 t and 54.09 x 10^5 bh or (2,113 trawlers) respectively (Fig. 13). Eq. (2) indicates the MSY to be 2,389.06 t for the f_{msy} of 75.795 x 10^5 bh (2,961 trawlers) (Fig. 13). Since eq. (1) gives a slightly better fit, the estimates of MSY = 2,267.2 t and f_{msy} = 54.079 x 10^5 bh (2112 trawlers) may be considered to be the basis for the management of the fishery in the Maharashtra state.

2. For sharks combined

$Y/f = 2.6718 - 0.000000247\ f$
$(r^2 = 0.2993)$ ..... (3)

$Y/f = \exp(1.00429 - 0.0000001319\ f)$
$(r^2 = 0.2312)$..... (4)

Eq. 3 indicates the estimates of MSY

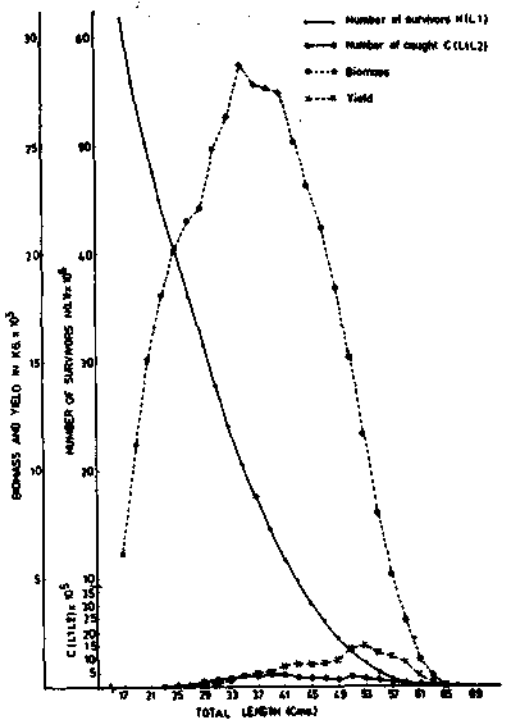

Fig. 12. Jones length cohort analysis of *Scoliodon laticaudus* for 1987 - '88.

and f_{msy} to be 7,224.45 t and 54.08 x 10^5 bh or 2,112 trawlers respectively (Fig. 14) while eq. (4) gives an MSY estimate of 7,612.1 t for f_{msy} of 75.795 x 10^5 bh or 2,961 trawlers (Fig. 14). Since the

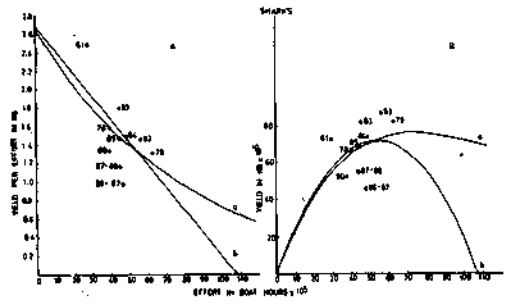

Fig. 14. Relative (A) and absolute (B) yields as function of effort in boat hours for 1986-'88 [a=linear relation of Schaefer (1954); b = exponential relation of Fox (1970)] for sharks in the coastal waters off Maharashtra.

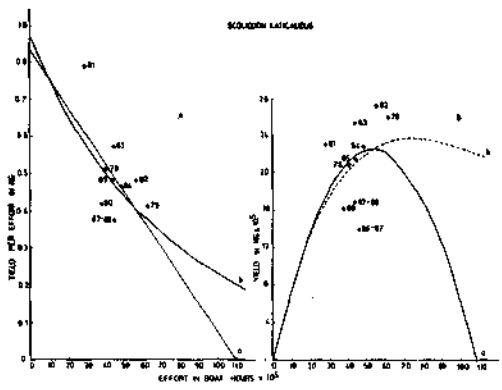

Fig. 13. Relative(A) and absolute (B) yields as function of effort in boathours for 1986-88 [a = linear relation of Schaefer (1954); b = exponential relation of for (1970] for *S. laticaudus* in the coastal waters off Maharashtra.

Schaefer model gives a slightly better fit it may be considered as the basis for managing the fishery.

3. For *elasmobranchs combined* (Fig. 15)

$$Y/f = 3.60248 - 0.0000002862\ f \quad (r^2 = 0.2498) \quad \ldots\ldots (5)$$

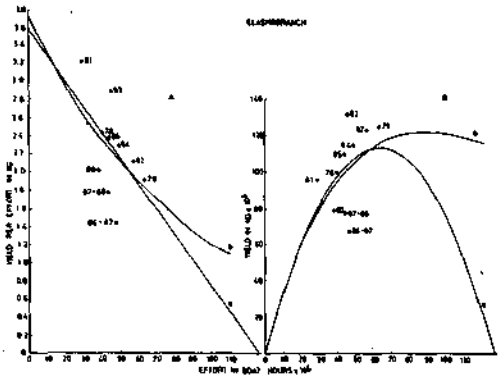

Fig 15. Relative (A) and absolute (B) yields as function of effort in boat hours for 1986-'88 (a = linear relation of Schaefer (1954); b= exponential relation of Fox (1970)] for elasmobranchs in the coastal water off Maharashtra.

$Y/f = \exp (1.31521 - 0.0000001117\ f)$
$(r^2 = 0.1954)$ ..... (6)

Eq. (5) gives an MSY estimate of 11,337.3 t for f_{msy} of 62.94 x 10^5 bh or 2,459 trawlers (Fig. 16) while eq. (6) indicates the MSY to be 12,269.7 t for the f_{msy} of 89.52 x 10^5 bh (3,497 trawlers) (Fig. 15). Since the Schaefer (1954) model gives a slightly better fit the estimates of MSY = 11,337.3 t and f_{msy} = 62.94 x 10^5 bh or 2,459 trawlers may be considered as the basis for managing the elasmobranch fishery in Maharashtra.

Fishery

The catch of elasmobranchs increased from 6,811 t in 1986-'87 to 13,265 t. in 1993 (Fig. 16).

The catch of sharks varied from 4,536 t in 1986-'87 to the peak of 8,887t in 1982 (Fig. 16).

The spade nose shark which formed about 31% of the total shark landings

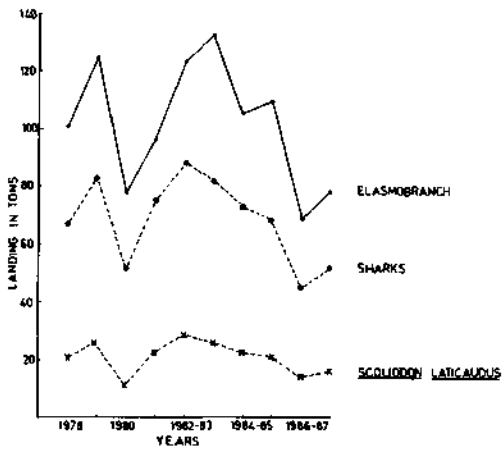

Fig. 16. Landings of Elasmobranchs, Sharks and *Scoliodon laticaudus* in Maharashtra during the period 1978-'88.

varied from 1,423 t in 1986-'87 to 2,789 t in 1982. The total effort for the trawl fishery as a whole ranged from 2.94 million boat hours or 1,149 trawlers in 1981 to the peak value of 6.35 million boat hours or 2,483 trawlers in 1979 (Table 1).

Discussion

In the present study the growth of the foetii (inutero), juveniles and sub-adults of *Scolidon laticaudus* was found to be rapid. After the gestation period of 4 months, the length at birth of *S. laticaudus* was about 14 cm. In the first year after birth it grew to 21.9 cm, while in the second year it attained a length of 54.5 cm at the rate of 32.7 cm from the first to the second year. In the third year it reached a length of 65.5 cm, gaining 11 cm over the second year of growth.

The growth rates of *S. laticaudus* are found to be higher than that reported by Prabhakaran Nair (1976) for this species, (1st year 26 cm, 2nd year 38 cm, 3rd year 47 cm, 4th year 53 cm and 5th year 59 cm), on the basis of length frequency analysis pertaining to the same Mumbai waters. This is obviously because of the faulty technique used by him in his analyses. He has not only pooled the length frequencies on a quarterly basis but also treated them within successive periods of unequal heights, as a result, accurate identification of the modes representing specific broods was not possible. The maximum length of this shark in the present study was 66 cm for the female and 60 cm for the male as also observed by Prabhakaran Nair (1976).

Among the juveniles and adults of *S. laticaudus* no difference in growth could be detected between the sexes, but

the presence of slightly larger females suggests that they might live slightly longer. Casey *et al.* (1985) reported such a difference for the sandbar shark (*C. plumbeus*) from the NW Atlantic and Branstetter and Stiles (1987) reported it for *C. leucas* from Northern Gulf and Mexico.

In the case of *S. laticaudus* recruitment into the fishery takes places almost immediately after the birth, as the length of 14 to 15 cm at birth is close to the length of 17 cm at recruitment (l_r); the age at recruitment (t_r) being 0.33 year. At 17 cm (0.33 year), they encounter the trawl of 2 cm codend mesh, while at the length of 27 cm (0.67 year) they become fully vulnerable to the trawl, and therefore the length at first capture l_c has been taken to be 27 cm (= 0.67 year) (Fig. 6).

The yield at the biologically optimum level of exploitation E_{msy} = 0.65 (at F = 3.62, f = 75.495 x 10^5 bh or 2,949 trawlers per day for 320 fishing days a year at the rate of 8 bh per day) was 2,225 t (MSY/R was 36 g). The average annual yield for the years 1978 to 1987-'88 (2,154 t, Y/R 35.08 g) is close to the optimum (2,225 t, MSY/R 36 g) inspite of less than optimum effort (45.99 x 10^5 bh or 1,796 trawlers per day for 320 fishing days an year). Therefore any increase in the effort from the present level may not increase the yield from the stock and it is advisable to sustain the effort at the present level of E = 0.55, F = 2.28, f = 45.66 x 10^5 bh or 1,796 trawlers.

The optimum catch and effort estimated for *S. laticaudus* by the Schaefer model are 2,267.2 t and 54.094 x 10^5 bh (2,113 trawlers) respectively. The Fox model estimates of optimum yield and effort are 2,389.06 t and 75.82 x 10^5 bh (2,962 trawlers) respectively. The average annual yield and effort for *S. laticaudus* in Maharashtra during the period 1,978 to 1987-'88 were 2,153.8 t and 45.989 x 10^5 bh (1,796 trawlers) respectively. The estimates obtained from the above models suggest that the present average annual yield is nearer to the optimum (MSY) level at an average annual effort which is somewhat below the f_{msy}. However, it is possible that any further increase in effort may not effect any tangible increase in yield.

The optimum catch and effort for sharks (all species combined) are 7,224.5 t and 54.079 x 10^5 bh or 2,112 trawlers estimated by the Schaefer model while the Fox model estimates of optimum catch and effort are 7,612.1 t and 75.795 x 10^5 bh or 2,961 trawlers. The average annual shark catch in Maharashtra state during the period 1978 to 1987-'88 was 6,863.5 t for an average annual effort of 45.989 x 10^5 bh or 1,796 trawlers. This difference between the observed and estimated values suggests some room for increasing the effort in order to reach the MSY level.

The optimum catch and effort for all elasmobranchs combined according to the Schaefer model are 11,337.3 t and 62.942 x 10^5 bh or 2,459 trawlers respectively. The Fox model estimates the optimum catch and effort to be 12,269.7 t and 89.525 x 10^5 bh or 3,497 trawlers respectively. The average annual catch and effort in Maharashtra state during the period 1978 to 1987-'88 was 10,248.1 t for an average annual effort of 45.989 x 10^5 bh or 1,796 trawlers. Thus for the elasmobranchs fishery there seems to be some scope for increasing the effort in order to reach the MSY level.

During 1978 to 1988 period the

landings of the elasmobranchs in Maharashtra ranged from 13,265 t for an effort of 45.333 x 10^5 bh or 1,772 trawlers in 1983 to 6,811 t for an effort of 47.278 x 10^5 bh or 1,847 trawlers in 1986-'87 while for total sharks and *S. laticaudus* the landing in Maharashtra State ranged from 8,887 to 2,789 t for an effort of 57.154 x 10^5 bh or 2,233 trawlers in 1982 and from 4,536 to 1,423 t for an effort of 47.278 x 10^5 bh or 1,847 trawlers respectively.

The average catch of sharks and *S. laticaudus* in Mumbai during the study period 1986 to 1988 was 2,757.41 and 865.32 t respectively. The females formed 52.48% while the males 47.52% of the catches. Age group 1/2 to 2+ in the length groups of 21.7 to 59.8 cm formed the mainstay of the fishery for *S. laticaudus* during this period.

Scoliodon laticaudus is an active carnivore with a mixed diet composing of small sized teleosts, prawns, squilla, and molluscs. *S. laticaudus* develops feeding inhibition as it approaches maturity. It was observed that in the juveniles (15 to 20 cm) and adolescent sharks (25 to 30 cm), 50 and 35% respectively were well fed. As they grew to maturity the number of well fed sharks dropped to about 30%. Once they reached maturity (35 to 40 cm) there was a further decrease in the percentage of well fed sharks to about 26%. This feature was also observed by Springer (1960) in the female sandbar shark, (*C. plumbeus*) from the northwest Atlantic region and Devadoss (1989) in *S. laticaudus* off Calicut, India. *S. laticaudus* exhibits preferance for a particular diet during different phases of its life history. In their early growing years after birth when they are unable to move fast, they seek bottom living fishes like soles, sciaenids and crustaceans like prawns, squilla and small crabs. When they grow up and have gained enough strength, they migrate to the pelagic zone and start actively preying on pelagic fishes like *Coilia*, Bombay duck and fast moving molluscs like squids and cuttlefish. Cannibalism was not encountered during the study.

S. laticaudus is a macrophague. It occupies a high position in the marine foodweb, far from the primary producers and this has its significance in the low productivity of its fishery unlike *Coilia*, sardines or mackerel.

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