Assessment of the Stock of Threadfin Bream *(Nemipterus japonicus)* in the Northwest Continental Shelf of India.

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Abstract

The threadfin bream *(Nemipterus japonicus)* attains an average length of 150 mm, 250 mm and 280 mm in the 1st, 2nd and 3rd years of its life respectively. The length at recruitment (1_r) is 45 mm while the length at first capture (1_c) for the commercial trawl fishery is 115 mm. The annual exploitation ratio *(E)* for 1983-85 was only 0.2099. The yield per recruit *Y/R)* reaches the maximum of 18.01 g at $F = 1.98$ ($E = 0.060$) while the potential yield per recruit for the so called optimum age of exploitation (1.197 year) at $F_{oo} = 25.08$ ($E = 1$) is 26.9 g.

The annual total stock *(P)* and mean stock *(P)* for 1983-84 in the exploited inshore grounds to a depth of 50 m were estimated to be 38,736 tons and 18,836 tons respectively. The average annual yield of 6,600 tons at $F = 0.3504$ ($E = 0.2099$) for 1983-84 was far less than the maximum sustainable yield (MSY) of 11,887.3 tons attainable at 60% exploitation from the inshore grounds. Direct estimates (trawl swept area method) for 1984 indicate the standing stock of threadfin bream in the northwest (Maharashtra and Gujarat coast) continental shelf to be 484,189 tons comprising 419,634 tons in the Gujarat shelf and 64,555 tons in the Maharastra shelf. The standing stock is distributed in the 0 to 50 m, 50 to 100 m and 100 to 200 m deep grounds in the ratio of 23.7%, 70.7% and 5.9% respectively in the Gujarat shelf and 43.5%, 9.7% and 46.8% in the Maharashtra shelf. The standing stock of threadfin bream represents 15.6% of the standing stock of all demersal species (3.35×10^6 tons) in the northwest continental shelf where 55% of the stocks occur in the Kori Great Bank in 50 – 100 m depths off the Gujarat coast. The maximum sustainable yields of *N. japonicus* and all-demersal fish from the northwest continental shelf are estimated to be 136,975 tons and 1,056,246 tons respectively. The standing stock of *N. japonicus* in the Karnataka shelf is 38,621 tons, which is about 27.7% of the standing stock of all demersal species.

Introduction

The threadfin bream, *Nemipterus japonicus,* is widely distributed in the Indo west Pacific region, where it constitutes one of the most abundant demersal resources, especially in grounds between the depths of about 70 m and 180 m. The occurrence of threadfin bream stocks in the offshore Indian continental shelf in commercial quantities came to light through the exploratory surveys conducted by the Fishery Survey of India since 1948. However, only after the advent of commercial trawling since the late 1960s by small mechanised boats (28′ to 32′), a small scale fishery for groundfish including the threadfin bream commenced in India. The catch taken by the inshore trawlers represents only a small portion of the offshore stock that moves into the less than 50 m deep grounds during the southwest monsoon season (May to September). The offshore stock seems substantial, and could be exploited only by larger vessels. As a result of the introduction of 47′ to 54′ trawlers since 1980 in Gujarat (now about 100), Maharashtra (now about 1,000), Karnataka (now about 100) and Andhra Pradesh (now about 75), the groundfish stocks including the threadfin bream in the grounds between 50 m and 100 m depths are being exploited increasingly. The present study gives an assessment of the stock of threadfin bream in the northwest continental shelf of India according to depth zones and matches the present production with the stock in order to indicate the gaps and prospects.

Material and Methods

Age was determined by tracing the progression of modes in the length (from snout to tip of lower candal lobe) frequency distributions, after plotting them against time in successive months in the form of a scatter diagram (Devaraj, 1983). The length frequency data for this purpose included 7,501 fish sampled during 1983-85 from the bottom trawl (40 mm codend mesh) catches of the fishing vessel M.V. Saraswati (120′ overall length) along the northwest coast of India (Maharashtra and Gujarat coasts) from grounds ranging from 30 to 200 m depths. These data were used in conjunction with that for 3,914 fish sampled during 1977-78 (Acharya, 1979) from market landings in Bombay from trawls (20 to 300 mm codend mesh) operating along the Maharashtra coast.

The pattern of recruitment was obtained by tracing the age of fish in the length frequency data to their zero age. The empirial age-length and age-weight (after converting lenght-at-age into weight-at-age by using the length-weight relation) data were fitted by the von Bertalanffy growth function (VBGF). The total mortality coefficient *(Z)* was estimated from the age composition data according to Jackson (1939), while the natural mortality coefficient *(M)* was computed according to Pauly (1980). The yield per recruit *(Y/R)* as functions of fishing mortality coefficient *(F)* was estimated as per the analytical model of Beverton and Holt (1957). The optimum age of exploitation (t_y) and

potential yield per recruit *(Y)* were estimated according to Krishnan Kutty and Qasim (1968). The age at recruitment (t_r) and the age at first capture (t_c) were determined arbitrarily from the annual length frequency polygons for the commercial and exploratory catches.

For the inshore fishery (in the 0 to 50 m deep grounds), operating on the inshore section of the total stock, the annual yield data *(Y)* was used for the estimation of: (1) total stock, *P* (P = *Y/E*, where *E* = *F/Z*)); (2) recruits, (R_c) at t_c ($R_c = Y \div Y/R$); (3) mean number of fish in the exploited phase, P_N ($P_N = R_c \times P_{N/R}$) and (4) yield in number, Y_N ($Y_N = R_c \times Y_{N/R}$) (Beverton and Holt, 1957; Devaraj, 1983). The maximum sustainable yield (MSY) for the inshore ground was computed by calibrating the current catch onto the *Y/R* curve. Length cohort analysis was performed as per Jones (1984).

The standing stock in the continental shelf was estimated from the trawl survey data for MEV Saraswati (120′ overall length) by the swept area method. For areas where the bottom is smooth enough for trawling, the standing stock of demersal fish *(B)* is obtained from the relation, $B = \frac{(\bar{c}/f) \times A}{a \times 1}$ where $\bar{c}/f$ = mean catch/effort for the survey period; *A* = the total survey area; *a* = the area swept by the trawl in one unit of effort (e.g., one hour) and x_1 = the proportion of fish in the path of the trawl actually retained by it. The value $1/x_1$ is called the escapement factor. The value of 0.5 for x_1, commonly used for the southeast Asian waters, has been adopted in this study (Isramkhura, 1971; Seager *et al.*, 1976; SCSP, 1978; Pauly, 1979). The area swept by trawl in one unit of effort (= one hour of trawling) was computed from the relation, a = $tvhx_2$ where *v* = speed (in m) of trawlers while fishing; *h* = length (in m) of the head rope of the trawl; t = time (in hours) spent in trawling; and, x_2 = a fraction equal to the effective width of the net divided by the length of the head rope. In southeast Asian waters, x_2 was found to range from 0.4 (SCSP, 1978) to 0.66 (Shindo, 1973) but 0.5 was considered the best compromise (Pauly, 1980).

Results and Discussion

Analytical model

The scatter diagram of length model progression analysis reveals that each year class is comprised of three broods, the first one released in February – March, the second in June – July and the third in August – September (Fig.1). These broods do not vary from each other in the length at successive age in months. The mean length attained by the fish is 150 mm in the first year, 250 mm in the second year and 280 mm in the third year of life (Fig.2). The maximum length of fish in the catch was found to be 285 mm when its age is 40 months. The length growth parameters have been estimated to be L_{oo} = 298 mm, *k* = 0.8214 (annual) and t_o = –0.0426 year and the weight growth parameters to be W_{oo} = 315.6 g, *k* = 0.8534 (annual) and t_o = –0.0615 year.

Recruitment is continuous, obviously due to protracted spawning, but there are very distinct peaks. In 1983-85 maximum recruitment took place in the months of February and June with almost uniform recruitment during the months of April-May and June to October. In 1977-78 maximum recruitment took place during July-August and September to November unlike in 1983-85 (Fig. 3).

The length at recruitment (1_r) is 45 mm (t^r = 3 months) and the length at first capture (1_c) 115 mm (t_c = 7 months) (Fig. 4). The selection factor *(K)* for trawl codend mesh (*m* = 20 to 30 mm stretched knot to knot in most commercial trawlers) has been estimated to be 5.75 (*K* = 115/20 = 5.75), but there is not much difference in the length composition of catches between the commercial trawls (20 to 30 mm codend mesh) and Saraswati trawl (40 mm codend mesh; Fig.4). The annual total mortality coefficient (*Z*) for the inshore section of the stock exploited by the smaller trawlers during 1977-78 was 1.669. The annual natural mortality coefficient (*M*) of 1.3186 indicates that the annual fishing mortality coefficient (*f*) for 1977-78 was 0.3504. However, for the offshore section of the stock sampled from the 50 m to 200 m deep grounds by M.V. Saraswati during 1983-85, *Z* = 1.282 was nearly the same as *M*, suggesting the absence of any commercial fishing. The optimum age of exploitation and potential yield per recruit were estimated to be 1.197 year end 26.9 g respectively for the inshore fishery (Fig. 5). The yield per recruit *(Y/R)* attains a maximum of 18.01 at F 1.98 for the present T_c of 0.51 year.

For *E* of 0.2019 for 1977-78 and average annual catch (*Y*) of 6,600 tons for 1983-84 (*Y* data were not available for 1977-78), the mean annual stock and annual total stock in the exploited inshore ground along the northwest coast to a depth of about 50 m are estimated to be 18,836 tons and 38,736 tons respectively for the fully recruited groups (>90 cm). For *F* = 0.3504 and t_c = 0.51 year for the inshore grounds, the absolute number of recruits (R_c) at (t_c) was found to be 569 million, *PN* = 247 million and *YN* = 81.8 million. The inshore *MSY* of 11,887 tons is attainable at E 0.60 (Fig.6).

Cohort analysis

The maximum number of fishes exploited from the northwest inshore grounds (Gujarat and Maharashtra) during 1983-85 belonged to the 12.1 – 13.0 cm length group which contributed 26% (2,111 tons) to the annual inshore catch of 8,219 tons. The length of 13.0 cm at first maturity (Acharya, 1978) also belongs to the maximum exploited length group. Length cohort analysis for 1983-85 reveals that the 12.1 – 13.0 cm group (*t* = 0.66 year) suffered the maximum fishing mortality (*F* = 4.49) and maximum

exploitation ratio (F = 0.7798). The biomass of 8,651 tons for the 12.1 – 13.0 cm group formed 7% of the total biomass of 123,325 tons in the inshore grounds.

The mean annual number of 163.8 million fish ranging from 4.1 cm to 29.0 cm caught during 1983-85 along the northwest coast constituted only 3.479% of the survivors (4.7088×10^9) in the size range of 4.1 to 29.0 cm in the inshore grounds. The average annual catch of 8219 tons obtained during this period formed only 6.66% of total annual biomass (stock) of 123,325 tons of fish of 4.1 cm to 29.0 cm size in the inshore sea (Table 1), which is very close to the standing stock estimate of 127,419 tons (Gujarat 99,369 tons + Maharashtra 28,050 tons) by the swept area method (*vide infra*). Thus, the annual stock of 38,736 tons estimated from the expression $P = Y/E$ (6,600/0.2019) for the fully recruited group (> 90 cm) for 1983-84 represents 31.4% of the annual total biomass of 123,325 tons of 4.1 cm to 29.0 cm size fish, derived by summing the biomass of successive length groups.

Swept-area method of stock estimation

Gujarat: The standing stock of *N. japonicus* was estimated to be 419,634 tons (15.4% of all demersal stocks of 2.72 million tons) which included 99,369 tons (23.7%) in the 0 to 50 m deep area, 296,840.7 tons (70.7%) in the 50 to 100 m deep area (the Kori Great Bank) and 23,424.2 tons (5.6%) in the 100 to 200 m deep area. The standing stock of all demersal species was estimated to be 2,720,670 tons which included 815,933 tons (30%) in the 0 to 50 m deep area, 1,756,867 tons (64.6%) in the 50 to 100 m deep area (the Kori Great Bank) and 147,850 tons (4.5%) in the 100 to 200 m deep area. The all species demersal standing stock per ha of sea area was 62.94 kg, 100.99 kg and 59.66 kg for the 0 to 50 m deep, 50 to 100 m deep and 100 to 200 m deep areas. The catch of all demersal fish per hour was 571.4 kg for the entire shelf area, while it was 437.5 kg for the areas in the 0 to 50 m depth, 701.9 kg for the areas in the 50 to 100 m depth and 414.5 kg for the areas in the 100 to 200 m depth (table 2).

Maharashtra: The standing stock of *N. japonicus* was estimated to be 64,555.4 tons (13.3% of all demersal stocks of 0.486 million tons) which included 28,050 tons (43.5%) in the 0 to 50 m deep area, 6,251.4 tons (9.68%) in the 50 to 100 m deep area and 30,254 tons (46.86%) in the 100 to 200 m deep area. The standing stock of all demersal species was estimated to be 486,094 tons distributed in the depth zones of 0 to 50 m, 50 to 100 m and 100 to 200 m in the proportion of 201,995 tons (41.6%), 205,713 tons (42.3%) and 78,386 tons (16.1%) respectively. The all demersal standing stock per ha of sea area was 62.94 kg, 100.99 kg and 59.69 kg for the 0 to 50 m deep, 50 to 100 m deep and 100 to 200 m deep grounds. The catch of all demersal fish per hour for the entire continental shelf was 269 kg while it was 275.16 kg for the 0 to 50 m depth zone, 284.65 kg for the 50 to 100 m depth zone and 34.2 kg for the 100 to 200 m depth zone (Table 2).

Entire northwest coast: Thus, the standing stock of *N. japonicus* in the northwest continental shelf off the coasts of Maharashtra and Gujarat is 484,189 tons forming 14.5% of the standing stock of 3,396,084 tons of all demersal species. The distribution of the standing stock of *N. japonicus* in the 0-50 m, 50-100 m and 100-200 m depth zones is in the proportion of 127,419 tons, 303,092 tons and 53,678 tons respectively.

The stock in the 0-50 m deep grounds is being partially exploited at present (E = 0.20) unlike the >50 m deep grounds which remain in a virgin state. Therefore, the *MSY* from the partially exploited inshore stock would be between 25% and 50% of the stock, i.e., about 37.5% [(25 + 50)/2] of 127,419 tons or 47,782 tons of fish ranging from 4 cm to 29 cm in length represented in the swept area method. However, the *MSY* from the fully recruited section of the stock exploited by the commercial fishery (i.e., > 9 cm long fish) is only 11,887 tons. The *MSY* from the portions of the stock in the virgin state in the 50-100 m deep grounds (303,092 tons) and 100-200 m deep grounds (53,678 tons) considered to be 25% of the virgin stock, is 75,773 tons and 13,420 tons respectively. Thus, the total *MSY* is found to be 136,975 tons comprised in the 0-50 m, 50-100 m and 100-200 m deep grounds in the proportion of 47,782 tons, 75,773 tons and 13,420 tons respectively. The present annual yield being only about 6,600 tons, a production gap of 130,375 tons is indicated.

The all demersal standing stock of 3,207,040 tons in the northwest continental shelf comprises of 1,017,948 tons in the 0-50 m deep grounds, 1,962,850 tons in the 50-100 m deep grounds and 226,242 tons in the 100-200 m deep grounds. Since the inshore fish stocks in general are being exploited at about the optimum level, the *MSY* from the demersal standing stock of 1,017,948 tons could be taken as 508,974 tons (i.e., 50% of the near optimally exploited stock) while the *MSY* from the virgin stocks in the 50-100 m and 100-200 m deep grounds could be considered as 490,712 tons and 56,560 tons respectively (i.e., 25% of the virgin standing stock). Thus the total *MSY* of demersal fish is found to be 1,056,246 tons comprised in the 0-50 m, 50-100 m and 100-200 m deep gounds in the proportion of 508,974 tons, 490,712 tons and 56,560 tons resepctively.

The average annual demersal catch of 285,765 tons (52% of the total 548,718 tons) from the 0-50 m deep grounds for 1983-85 represents 56% of the *MSY* of 508,974 tons from the inshore demersal standing stock of 1,017,948 tons. It indicates a production gap of 223,209 tons for the inshore grounds and 770,481 tons for the continental shelf as a whole. The production gaps could be bridged only with the progressive growth of deepsea fleets of trawlers. The introduction of the second generations of trawlers of 48′ to 54′ overall length in the 50 to 80 m deep grounds since the

early 1980s is a first step in this direction.

Karnataka: The standing stock of *N. japonicus* was found to be 38,621 tons (28% of all demersal stocks) distributed in the grounds in the depth range of 0 to 50 m, 50 to 100 m and 100 to 200 m in the ratio of 587.2 tons (1.5%). 22,187.4 tons (57.4%) and 15,846.6 tons (41.0%) respectively. The standing stock of all demersal species in the entire continental shelf (0 to 200 m depth) was found to be 139,320 tons comprised in the 0 to 50 m deep, 50 to 100 m deep and 100 to 200 m deep grounds in the ratio of 60,065 tons (43.1%), 52,839 tons (37.6%) and 26,866 tons (19.2%) respectively. The all demersal standing stock per ha of sea was found to be 37.8 kg, 15.84 kg and 15.02 kg for the 0 to 50 m deep, 50 to 100 m deep and 100 to 200 m deep ground respectively. The catch of all demersal species per hour was 262.88 kg. 110.15 kg and 104.4 kg for the 0 to 50 m deep, 50 to 100 to 200 m deep grounds resepctively (Table 2).

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Table 1. Length cohort analysis for the inshores (0 to 50 m depth) *N. japonicus* section of population for the period 1983-85.

Length group (mm) $L_1 - L_2$	Number caught $(L_1, L_2 \times 10^6)$	$\exp\frac{(M\Delta T)}{2}$ (L_1, L_2)	Number of survivors $N(L) \times 10^8$	Exploitation ratio (F/Z)	Fishing motality (F)	Total mortality (Z)	Age in year	C_W $(C_N \times W_L)$ (tons)	P_W $(P_N \times W_L)$ (tons)
41- 50	0.04	1.0290	5.22	0.002	0.002	1.32	0.14	0.05	623.79
51- 60	0.09	1.0302	4.93	0.003	0.004	1.32	0.19	0.19	1074.25
61- 70	0.28	1.0316	4.64	0.019	0.01	1.33	0.24	1.03	1710.72
71- 80	0.28	1.0330	4.35	0.01	0.01	1.33	0.29	1.54	2390.33
81- 90	0.81	1.0346	4.08	0.17	0.27	1.58	0.34	6.24	3147.50
91-100	1.96	1.0363	3.60	0.25	0.44	1.75	0.46	28.63	5267.52
101-110	4.24	1.0382	3.53	0.15	0.24	1.56	0.53	83.30	6929.48
111-120	17.94	1.0404	3.23	0.44	1.02	2.34	0.59	439.26	7910.59
121-130	68.88	1.0428	2.82	0.77	4.49	5.76	0.66	2110.60	8650.90
131-140	17.78	1.0454	1.93	0.52	1.45	2.76	0.74	682.44	7407.70
141-150	12.55	1.0485	1.59	0.50	1.33	2.65	0.82	582.84	7383.97
151-160	5.96	1.0520	1.34	0.31	0.59	1.92	0.90	332.62	7479.88
161-170	4.62	1.0561	1.15	0.27	0.49	1.81	0.99	306.32	7618.21
171-180	4.96	1.0608	0.98	0.33	0.65	1.97	1.09	386.93	7647.33
181-190	4.00	1.0663	0.83	0.29	0.53	1.85	1.21	364.80	7565.70
191-200	5.00	1.0731	0.69	0.37	0.78	2.09	1.33	530.14	7312.21
201-210	3.77	1.0813	0.56	0.33	0.64	1.96	1.45	452.50	6668.11
211-220	2.25	1.0916	0.44	0.24	0.43	1.75	1.60	310.21	6063.28
221-230	1.97	1.1049	0.35	0.25	0.43	1.75	1.61	272.82	4807.20
231-240	1.29	1.1228	0.27	0.32	0.61	1.92	1.78	203.24	4206.84
241-250	1.00	1.1479	0.23	0.16	0.25	1.57	1.97	176.28	3947.68
251-260	1.46	1.1860	0.16	0.24	0.43	1.75	2.21	288.46	3237.82
261-270	1.46	1.2507	0.10	0.29	0.54	1.86	2.50	321.54	2297.48
271-280	0.85	1.3846	0.05	0.27	0.49	1.81	2.89	209.32	1324.50
281-290	0.47	1.8313	0.02	0.21	0.35	1.67	3.45	127.43	606.27

Table 2. Estimation of standing stocks of *N. japonicus* and all demersal species in the continental shelves of Gujarat, Maharashtra and Karnataka.

Depth (M)	Fishing effort (hr)	Total area swept (ha)	Total area (ha)	*N. japonicus* catch/hr (kg)	*N. japonicus* Standing stock (tons	All demersal species Catch/hr (kg)	All demersal species Standing stock (tons)	State
0-50	12.67	88.06	6,481,000	53.28	99,369	437.5	815,953.3	
50-100	21.50	149.43	8,967,485	118.6	296,840.7	701.9	1,756,867.0	Gujarat
100-200	7.08	49.21	1,239,515	65.67	23,424.2	414.5	147,850.0	
0-50	87.25	606.39	2,551,000	38.21	28,050.0	275.16	201,995.0	
50-100	54.17	376.48	2,511,342	8.65	6,251.3	284.65	205,713.0	Maharashtra
100-200	6.00	41.70	7,964,658	13.2	30,254.2	34.2	78,386.0	
0-50	18.52	128.71	794,000	2.57	587.2	262.88	60,065.4	
50-100	14.92	103.69	1,652,764	46.65	22,187.4	110.15	52,389.0	Karnataka
100-200	7.58	52.68	894,235	61.58	15,846.6	104.4	26,865.6	

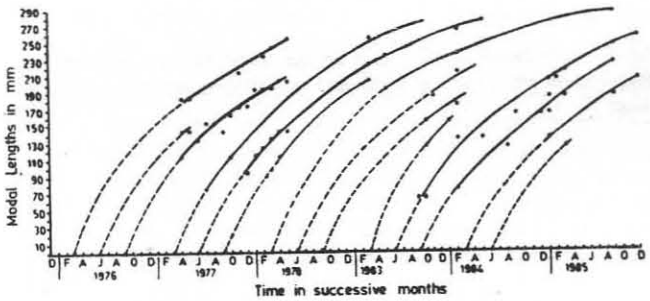

Fig. 1. Growth of individual broods on the basis of the modes in the length frequency distribution for successive months.

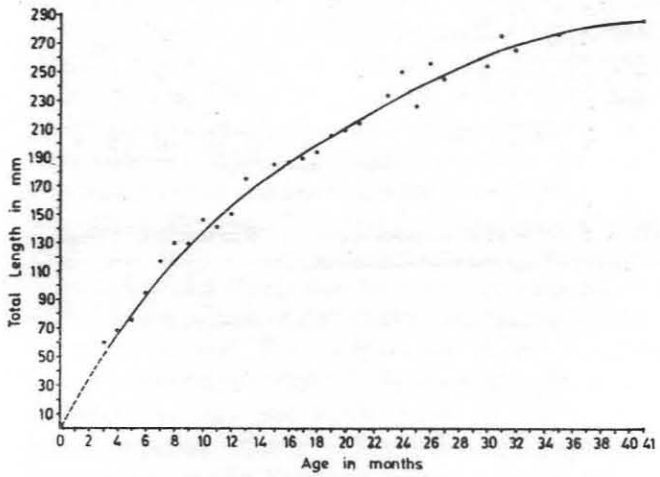

Fig. 2. Growth curve indicating the mean length at successive age in months.

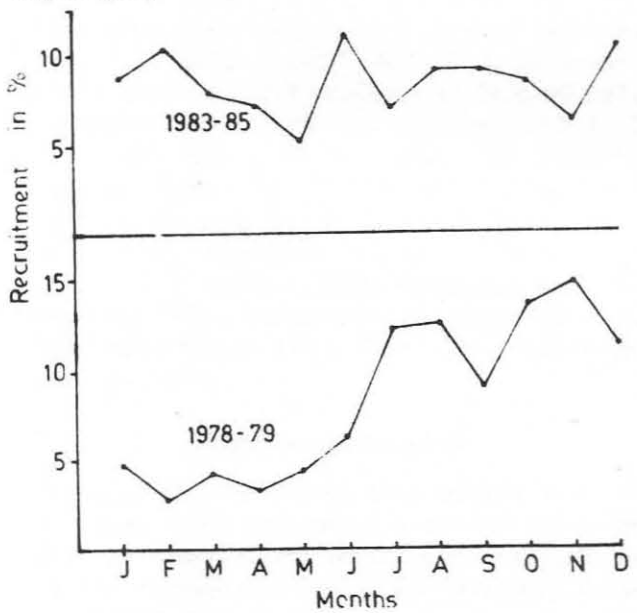

Fig. 3. Percentage recruitment pattern for 1978-79 and 1983-85.

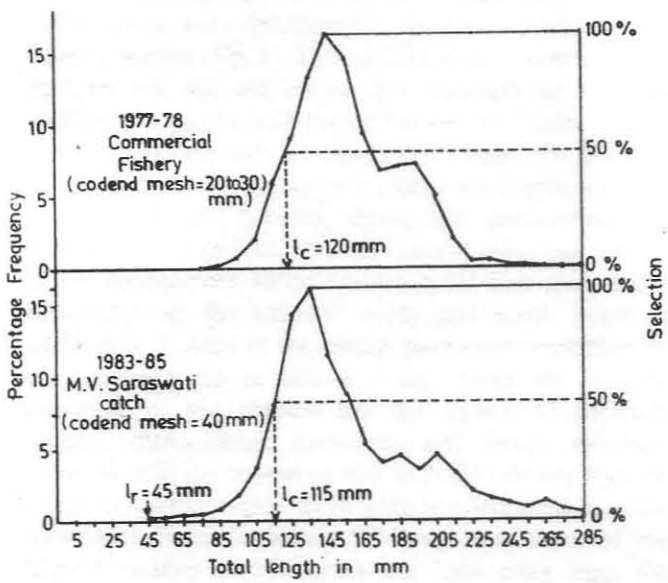

Fig. 4. Arbitrary determination of the length at recruitment (l_r) and the length at first capture (l_c) from the length frequency distribution.

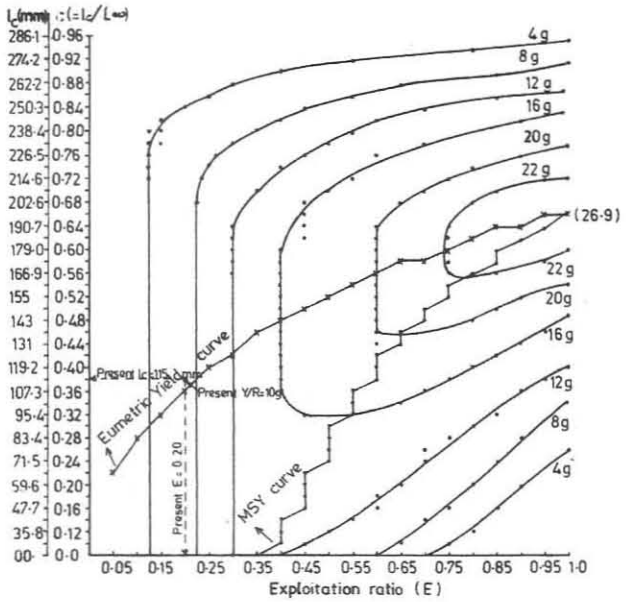

Fig. 5. Yield isopleth diagram depicting *Y/R* as function of length at first capture (l_c) and exploitation ratio (*E*).

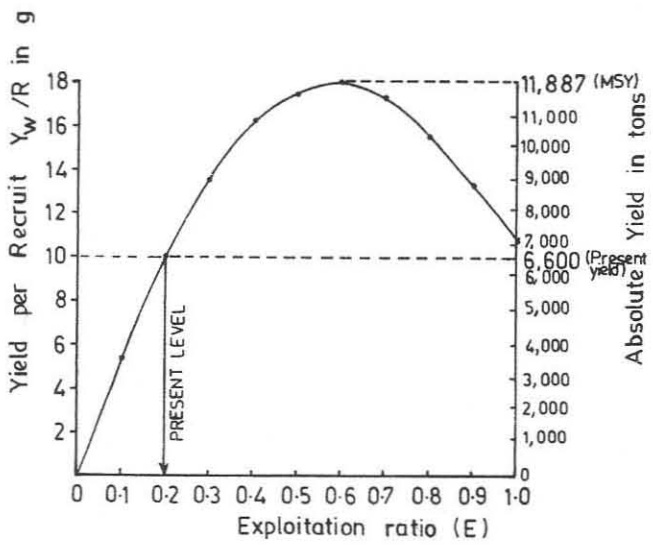

Fig. 6. Estimation of MSY and annual yield for various levels of exploitation from current yield and exploitation for the northwest coast.