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Dynamics of the gold-spotted grenadier anchovy (*Coilia dussumieri*) stock along the northwest coast of India

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ABSTRACT

The *Coilia dussumieri* along the northwest coast of India (18° 38' N to 21° 68' N) was studied using the Beverton and Holt analytical model, Ricker's stock–recruitment relation and the surplus production models of Schaefer and of Fox for 1960–'85. The length growth parameters: L_∞, annual k and t_0 for 1963–'64 were found to be 27.20 cm, 1.10 and 0.001 year respectively while during 1981–'85 L_∞ ranged from 22.20 cm in 1985 to 26.52 cm in 1981, annual k from 1.07 in 1985 to 1.49 in 1984 and t_0 from –0.58 year in 1982 to –0.02 year in 1981. The weight growth parameters: W, annual k and t_0 were estimated to be 18.50 g (1963–'64) and 20.50 g (1981–'85), 0.93 (1963–'64) and 1.23(1981–'85) and 0.01 year (1963–'64) and –0.15 year (1981–'85) respectively. The lengths at first capture (l_c) and recruitment (l_r) were found to be 8.75 cm and 3.50 cm respectively and their corresponding t_c and t_r were estimated to be 0.42 year and 0.08 year respectively. Total mortality (Z) ranged from 3.20 in 1985 to 7.31 in 1982, natural mortality (M) from 2.02 in 1985 to 2.46 in 1984 and fishing mortality (F) from 1.19 in 1985 to 5.20 in 1982. Cohort analysis indicated maximum F at the 1/2+ age (=2.16) in 1981, 1+ age during 1982 (=5.20), 1983 (=1.23) and 1984 (=4.21) and 1 1/2+ age in 1985 (=1.19). In the premechanization period (1960–'70) the MSY for the exploited (by indigenous fishing) portion of the underexploited stock was 5,356 t (analytical model), 6,322 t (Schaefer model) and 6,309 t (Fox model). The MSY for the fully exploited stock in the mechanised period (1971–'84) was 17,237 t (analytical model), 16,805 t (Schaefer model) and 20,489t (Fox model). The MSY estimated by the stock–recruitment model for the 1960–'84 period was found to be 24,451 t. The prediction model indicated an estimated catch of 22,540t in the year 2000 if the effort remained constant.

Introduction

The gold-spotted grenadier anchovy, *Coilia dussumieri*, ranks sixth in the commercial landings along the Maharashtra (18° 38' N) and Gujarat (21° 68' N) coasts of the northwest coast of India. Along this coast (about 500 km) there has been a rapid increase in mechanised fishing since 1971, primarily shrimp trawling, which resulted in

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both qualitative and quantitative changes in fishing effort. *C. dussumieri*, basically a zooplankton feeder, undertakes diurnal vertical migration, emerging to the surface layer in the night for feeding. Owing to this habit, it is much less vulnerable to night trawling, but forms one of the important bycatches in day trawling. The catches of *C. dussumieri* indicated generally an increasing trend ranging from 2.7 x 10^3 t to 9.6 x 10^3 t during 1960-'70 which was followed by considerable fluctuations and a substantial increase (2.6 x 10^3 to 23 x 10^3 t during 1971-'85) due to the general increase in effort and the growth of the trawler fleet.

This fishery has been widely studied for its biology (Bal and Joshi, 1957; Gadgil, 1965; Kapadne, 1986; Fernandez and Devaraj, 1988). The present study uses the length frequency and the catch and effort data for the period 1960 to 1985 for stock dynamics by means of the analytical model (Beverton and Holt, 1957), the stock-recruitment model (Ricker, 1975) and the surplus production models (Schaefer, 1954; Fox, 1970; Roff, 1983).

Materials and Methods

The study includes a total of 15,425 specimens of *C. dussumieri* pertaining to the periods 1963-'85 which included 14,034 from the 3 major landing centers in Bombay, *viz.*, the Sassoon Docks, the New Ferry Wharf and the Versova fishing village and from the catches by the research vessels *Saraswati* and *Narmada* of the Central Institute of Fisheries Education. The catch and effort data were taken from the reports and publications of the Central Marine Fisheries Research Institute, Cochin.

Growth, mortality and selection parameters for the Beverton and Holt (1957) analytical model were estimated from the length frequency data. Bhattacharya's (1967) method was applied to split the monthly length frequency distributions into their modal components which were then plotted against time in the form of a scatter diagram for the purpose of modal progression analysis (Devaraj, 1983). The length at age in months for the broods was determined by connecting the modal points representing the growth of the respective broods by eye-fitted lines. Recruitment pattern was constructed by projecting the length frequency data backwards on to the time axis using the age-length key according to Pauly (1982). Bagenal's (1955) method was applied to estimate the von Bertalanffy growth parameters for 1963-'64 while the growth parameters, L_∞ and k for 1980-'85 were estimated by the Gulland and Holt (1959) method and t_0 by the VBGF method as shown in Sparre (1985). The weight growth parameters of W_∞, k and t_0 of the VBGF were estimated by the Bagenal's (1955) method after converting the length–at age to weight-at-age using the constants in the length in cm (L)-weight in g (W) relation. Total mortality coefficient (Z) was calculated from the age composition data (Jackson, 1939; Ricker, 1958), length composition data (Jones and van Zalinge, 1981) and growth and selection parameters (Beverton and Holt, 1956). Natural mortality coefficient (M) was estimated using the methods of Pauly (1984), Caddy and Csirke (1983) and M/k ratios that of Cushing (1968). The annual fishing mortality (F) for 1960-'64 was calculated for the annual fishing effort in manhours (f) using the following relation,

$F = qf$

where, q = the catchability (or availability) coefficient for the period 1981-'84 which was assumed to be a constant for 1960-'84. F for various age groups was calculated using Pope's (1972) cohort analysis. Age at first capture (t_c) and at recruitment (t_r) were obtained from the age-length key for the lengths at first capture (l_c) and recruitment (l_r), estimated arbitrarily from the length frequency histograms. The yield in weight per recruit (Y_w/R), yield in number per recruit (Y_n/R), biomass in weight per recruit (P_w/R), biomass in number per recruit (P_n/R) and the total number of fish in the population (P_n) were estimated for the period 1960-'84 for the respective values of M, F, t_r and t_c.

The stock (P_n) and recruits (R_c) in numbers (the two basic inputs for the determination of the stock-recruitment relation) and stock in weight were estimated from the values of annual yield (Y), Y_w/R, P_w/R, F and E (=F/Z). The stock-recruitment relation was determined using Ricker's (1975) stock-recruitment curve which was fitted to the data that showed a general dome-shaped distribution for the observed values of P_n and R_c. The maximum sustainable yield (MSY) and the biologically optimum level of effort (f_{msy}) were estimated using the surplus production models of Schafer (1954) and of Fox (1970). The state of the future stock was predicted using Roff's (1983) simple autoregressive model.

Results and Discussion

Age and growth

A combination of Bhattacharya's (1967) and Devaraj's (1983) methods were applied to the data of the later years (1981-'86). As Bhattacharya's method was basically used to split the monthly length frequency distribution into modal components, it necessiated the actual length frequencies for various length groups which were only available during 1981-'86 unlike the percentage frequencies for the earlier years (1963-'64). These two methods reveal that each year class comprises of 5 broods, released mainly in February, June, August, October and November. The growth pattern has been almost the same for 1963-'64 and 1981-'86 (Fig.1.). Recruitment is more or less continuous with one peak in October-March during 1963 and March to July during 1980-'85 (Fig. 2). The length growth parameters estimated by the Bagenal's (1955) method for 1963-'64 are L_∞ = 27.20 cm, annual k = 1.10 and t_0 =–0.001 year and for 1980-'85; L_∞= 22.20 cm (in 1985) to 26.52 (in 1981), annual k = 1.07 (in 1985) to 1.49 (in 1984) and t_0 = –0.02 year (in 1981) to –0.58 year (in 1982). L_∞ and k for 1980-'85 were estimated by the Gulland and Holt (1959) method and t_0 by the VBGF method as shown in Sparre (1985). The decline of L_∞, is rather difficult to explain in mathematical or statistical terms. Therefore, there could be a biological basis where the growth has been faster due to eutrophication from domestic sewage and thinning of the population due to intensive fishing. The weight growth parameters W_∞, annual k and t_0 were found to be 18.50 g (in 1963-'64) and 20.5g (in 1981-'85), 0.93 (1963-'64) and 1.23 (1981-'85) and 0.01 year (1963-'64) and –0.15 year (1981-'85) respectively (Table 1).

The length at first capture, l_c and the corresponding t_c were found to be 8.75 cm and 0.42 year respectively, while the

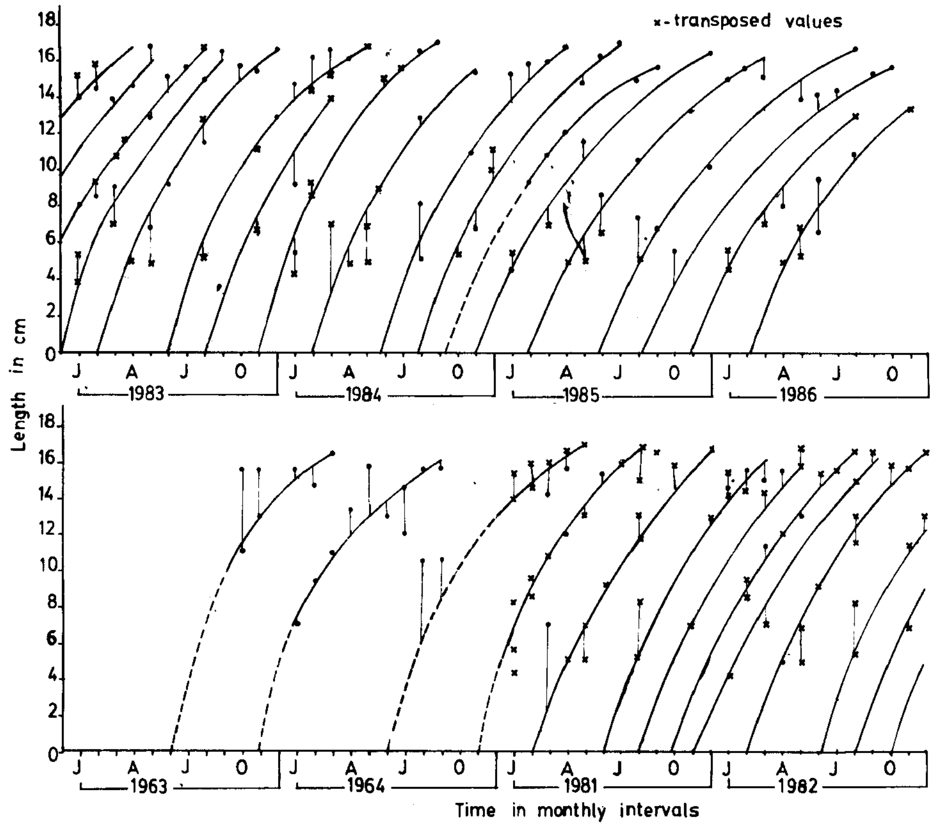

Fig. 1. Modal progression analysis.

TABLE 1. *Estimates of population parameters*

Period	Length growth parameters			Weight growth parameters			Mortality estimates		
	L_∞ (cm)	k (yr)	t_0 (yr)	W_∞ (g)	k (yr)	t_0 (yr)	Z	M	F_∞ (F=Z–M)
1963-'64	27.20	1.10	0.001	18.50	0.93	0.01	4.78	1.68	3.10
1981	26.52	1.16	–0.02				4.19	2.03	2.16
1982	25.61	1.21	–0.58				7.31	2.11	5.20
1983	25.65	1.16	–0.08	20.50	1.23	–0.15	6.28	2.05	4.23
1984	23.85	1.49	–0.06				6.67	2.46	4.21
1985	22.20	1.07	–0.09				3.20	2.02	1.18

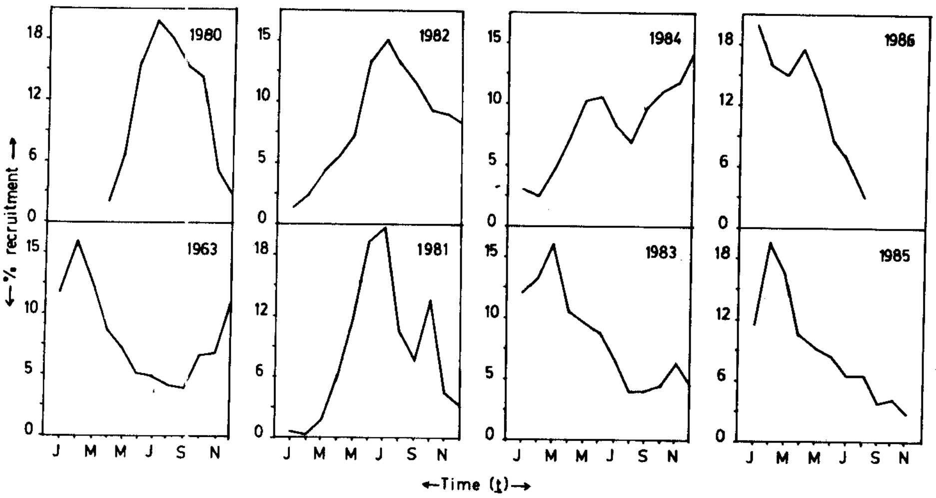

Fig. 2. Recruitment pattern.

l_r and t_r were found to be 3.50 cm and 0.08 year respectively.

Mortality estimates

Various methods were used to evaluate Z so as to be able to select the best method yielding the most realistic values. Owing to the short life span of *C. dissumieri*, the length composition data was divided into quarter year age groups (Table 2) to facilitate calculation of Z using Ricker's (1958) catch curve method. However, half year age groups have been used for the calculation of Z using Jackson's (1939) method. This method yielded annual Z from 1.82 in 1985 to 10.36 in 1982. Jones and van Zalinge's (1981) method yielded annual Z ranging from 4.43 in 1985 to 11.21 in 1981 while in Ricker's (1958) method, the annual Z ranged from 3.20 in 1985 to 7.31 in 1982. Of these, the Ricker (1958) estimates were found to be more realistic than the estimates obtained from the rest of the methods. The choice of Z was guided by the rather short life span and intensive fishing than by statistical consideration.

The actual mortality, M, could not be estimated using the Caddy and Csirke (1983) model as the model proved to be inadequate to track the fluctuations in annual yields (Y) as a function of annual

TABLE 2. *Age (quarter year groups) composition*

Period	Percentage age composition							
	0+ (0-2)	1/4+ (3-5)	1/2+ (6-8)	3/4+ (9-11)	1+ (12-14)	1 1/4+ (15-17)	1 1/2+ (18-20)	1 3/4+ (21-23)
1981	1.28	6.95	46.38	44.68	0.71			
1982	0.07	5.04	37.80	53.96	3.08	0.07		
1983	0.92	16.07	42.81	36.86	3.21	0.13		
1984	10.86	11.25	37.70	38.90	2.09			
1985	1.46	2.03	4.72	11.87	15.45	5.51	1.95	0.69

Z. The fit was very unrealistic as it gave negative values. M based on Cushing's (1968) method was found to be rather unrealistically high at 9.21. M/k ratio, as stated by Beverton and Holt (1959), Banerji (1973) and Devaraj (1983), is usually found to be a constant for closely related species and for smilar taxonomic groups, therefore, M/k = 2.2 for *Sardinella longiceps* (family Clupeidae) was used for the estimation of M for *C.dussumieri* (family Engraulidae), as they belong to closely related families. M was found to be 2.68 using this method. Independent estimates of M using Pauly's (1984) method ranging from 2.02 in 1985 to 2.46 in 1984, are compatible with the Ricker (1958) estimates of Z, and hence, chosen for various applications in this study. The fishing mortality, F, using Eq.1 ranged from 1.19 in 1985 to 5.20 in 1982.

Cohort analysis

Pope's (1972) cohort analysis was initiated with F obtained from Eq.1 for 1981-'85 with M values of 2.03, 2.11, 2.05, 2.46 and 2.02 respectively for the successive years. The numbers attaining age (N_t); 0+ (0 to 5 months) ranged from 19.3 x 10^9 in 1985 to 57.7 x 10^9 in 1984, 1/2+ (6 to 11 months) ranged from 3.23 x 10^9 in 1981 to 25.6 x 10^9 in 1985, 1+ (12 to 17 months) ranged from 0.06 x 10^9 in 1984 to 10.6 x 10^9 in 1982 and 1 1/2 + (18 to 23 months), present only in 1985, was found to be 0.12 x 10^9. F was maximum at 1/2+ (=2.16) in 1981, at 1+ during 1982 (=5.20), 1983 (=1.23) and 1984 (=4.21) and at 1 1/2+ in 1985 (=1.19).

Analytical model

The Beverton and Holt (1957) analytical model was fitted for all the individual years for which independent estimates of M and F were available (Table 3). The exploitation ratio (E=F/Z) based on F obtained from Eq.1 ranged from 0.35 in 1965 to 0.71 in 1983 with the mean at 0.50, while the biologically optimum E (E_{msy}) remained constantly at 0.55 during 1981-'84 and 0.60 for 1960- '80. A comparison of E with E_{msy} suggests overexploitation only during 1963, 1964, 1982 and 1984. The yield in weight per recruit, Y_w/R, ranged from 0.77 g in 1965 to 2.51 g in 1963 and 1964 with the mean at 1.05 g; the yield in number per recruit (Y_n/R) ranged from 0.61 in 1983 to 0.28 in 1963 and 1964 with the mean at 0.20; the MSY per recruit (MSY/R) ranged from 0.92 g during 1960-1962 and 1965-'80 to 1.44 during 1963 and 1964 with the mean at 1.04 g, while the absolute MSY ranged from 2.52 x 10^3 in 1974 to 33.37 x 10^3 t in 1985 with the mean at 12.2 x 10^3 t. The population weight (biomass) per recruit (P_w/R) ranged from 0.17 g in 1982 to 0.81 g in 1963 and 1964 with the mean at 0.52 g; the population number per recruit (P_n/R) ranged from 0.04 in 1982 to 0.14 in 1985 with the mean at 0.10 (Table 3). The mean Y_w/R for 1960-'85 (1.05 g) in relation to the mean (MSY/R) (1.04 g) indicates the fishery to be rather stable.

The standing stock (B or P = Y/F) ranged from 1.26 x 10^3 t in 1974 to 18.67 x 10^3 t in 1985 with the mean at 5.64 x 10^3 t while the total annual stock (P=Y/E) ranged from 5.23 x 10^3 t in 1974 to 59.92 x 10^3 t in 1985 with the mean at 22.45 x 10^3 t. The stock in number (P_n) ranged from 0.04 x 10^9 in 1960 to 3.15 x 10^9 in 1985 with the mean at 1.12 x 10^9 while the recruits (R_c) ranged from 2.73 x 10^9 in 1974 to 24.7 x 10^9 in 1983 with the mean at 11.50 x 10^9.

TABLE 3. *Yield and stock estimates according to the analytical model*

Period Y (t)	F	M	Z	E	L_∞ (cm)	t_c (year)	l_c (cm)	E_{msy}	State of stock	Y_w/R	MSY/R (g)	R_c(*10) (nos)	P_n(*10) (nos)	$\bar{B}$(=Y/F) (t)	P(=Y/E) (t)	Y_n(*10) (nos)	MSY (t)	Pmsy (MSY/E_{msy}) (t)
19603,683	1.82	2.08	3.90	0.47	25.46	0.50	10.00	0.60	UE	0.92	0.92	3,999	43	2,025	7,895	783	3,695	6,158
19617,354	1.89	2.08	3.97	0.48	25.46	0.50	10.00	0.60	UE	0.93	0.92	7,891	835	3,893	15,453	1,577	7,290	1,250
19626,072	1.73	2.08	3.81	0.45	25.46	0.50	10.00	0.60	UE	0.91	0.92	6,686	737	3.511	13.377	1,274	6,177	10,295
19636,938	3.10	1.68	4.78	0.65	27.20	0.50	11.05	0.60	OE	2.51	1.44	2,763	253	2,238	10,698	784	3,992	6,654
19649,617	3.10	1.68	4.78	0.65	27.20	0.50	11.05	0.60	OE	2.51	1.44	3,830	57	3,102	14,830	1,087	5,534	9,223
19652,677	1.13	2.08	3.21	0.35	25.46	0.50	10.00	0.60	UE	0.77	0.92	3,476	434	2,360	7,588	515	3,211	5,351
19668,275	1.22	2.08	3.30	0.37	25.46	0.50	10.00	0.60	UE	0.80	0.92	10,404	1,322	6,771	22,365	1,617	9,611	16,018
19675,165	1.79	2.08	3.87	0.46	25.46	0.50	10.00	0.60	UE	0.92	0.92	5,637	612	2,887	11,172	1,094	5,208	8,680
19684,335	1.68	2.08	3.76	0.45	25.46	0.50	10.00	0.60	UE	0.90	0.92	4,321	539	2,582	9,707	905	4,454	7,423
19695,062	1.60	2.08	3.68	0.43	25.46	0.50	10.00	0.60	UE	0.88	0.92	5,729	654	3,167	11,650	1,046	5,292	8,821
19708,767	1.39	2.08	3.47	0.40	25.46	0.50	10.00	0.60	UE	0.84	0.92	10,446	1,262	6,285	21,847	1760	4,454	7,423
197116,594	1.98	2.08	4.06	0.49	25.46	0.50	10.00	0.60	UE	0.94	0.92	17,590	1,817	8,373	34,018	3,602	16,249	27,082
19729,351	1.74	2.08	3.82	0.46	25.46	0.50	10.00	0.60	UE	0.91	0.92	10,301	1,133	5,382	20,552	1,968	9,516	15,860
197322,994	1.87	2.08	3.95	0.47	25.46	0.50	10.00	0.60	UE	0.93	0.92	24,711	2,624	12,275	48,531	4,915	22,828	38,047
19742,610	2.07	2.08	4.15	0.50	25.46	0.50	10.00	0.60	UE	0.96	0.92	2,728	276	1,259	5,228	572	2520	4200
19759,622	2.35	2.08	4.43	0.53	25.46	0.50	10.00	0.60	UE	0.98	0.92	9,785	929	4,102	13,158	2,177	9,040	15,066
19769,312	2.26	2.08	4.34	0.52	25.46	0.50	10.00	0.60	UE	0.97	0.92	10,068	975	4,351	18,866	2,199	9,301	15,501
197712,523	2.75	2.08	4.83	0.57	25.46	0.50	10.00	0.60	UE	1.01	0.92	12,354	1,069	4,551	21,993	2,940	11,412	19,021
197814,582	2.50	2.08	4.58	0.55	25.46	0.50	10.00	0.60	UE	1.00	0.92	14,610	1,338	5,823	26,697	3,350	13,497	22,494
197921,381	2.77	2.08	4.85	0.57	25.46	0.50	10.00	0.60	UE	1.02	0.92	21,032	1,819	7,713	37,432	5,046	19,429	32,382
19809,852	2.16	2.08	4.24	0.51	25.46	0.50	10.00	0.60	UE	0.97	0.92	10,209	1,012	4,570	19,363	2,181	9,431	15,719
198119,610	2.16	2.02	4.18	0.52	26.52	0.42	8.75	0.55	UE	0.85	1.28	23,161	1,749	9,079	37,952	3,777	29,699	53,998
198215,639	5.20	2.11	7.31	0.71	25.61	0.42	8.75	0.55	OE	0.88	1.40	17,733	727	3,008	21,983	3,779	24,853	45,188
198316,353	1.23	2.05	3.28	0.38	25.65	0.42	8.75	0.55	UE	0.94	1.37	17,347	2,272	13,295	43,608	2,795	23,788	43,251
198418,218	4.21	2.46	6.67	0.63	23.85	0.42	8.75	0.55	OE	0.97	1.26	18,700	1,017	4,327	28,826	4,282	23,630	42,963
198522,212	1.19	2.02	3.21	0.37	22.20	0.42	8.75	0.60	UE	0.96	1.43	23,254	3,151	18,666	59,919	3,751	33,367	55,611
Mean11,126.92.19		2.06	4.25	0.50	25.46	0.48	9.84	0.59		1.05	1.04	11,491	1,118	5,638	22,450	22,99	12,211	20,945

Stock-recruitment relation

The estimates of stock and recruits obtained from the yield per recruit and absolute yield data for the observed values of fishing mortality were plotted as a scatter diagram where the stock-recruitment relation was found to conform more to the dome shaped curve of Ricker (1975). The expression,

$$\log R - \log P = a\text{–}a(P\text{–}P/P_r)$$

was fitted from the regression of $\log_{10}$ (R/P) on P with a slope of –0.0006 and the y-axis intercept of 1.82, as shown below:

$$y = 1.82 - (-°0.6 \times 10^{-3}) \times (R^2 = 0.50)$$

The replacement abundance, P, at which R = P was found to be 3,217 x 10^6. Variance from the regression line was obtained at s = 0.09 from,

$$\log_{10} (AM/GM) = 1.15 \times 0.09 \times N\text{–}1/N$$

The multiplier, 1.25, was obtained to convert the GM line to the AM line as shown in Fig. 4. The optimum number of 738.30 x 10^6 spawners and 23,114.20 x 10^6 recruits generated an MSY of 23,375 x 10^6 recruits (=24,451.19 t) that

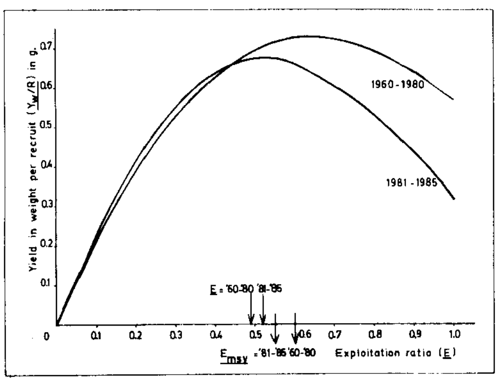

Fig. 3. Yield curves.

could be taken at a constant rate of exploitation of 96.8%. The density rate of reproduction was 6.17 which meant that if the stock were to be reduced to a low ebb, then each spawner would produce on the average a little more than 6 recruits. Recruitment mortality in this stock is density independent as the value of β is much less compared to α which is equal to 1.82. As long as the stock is less than the replacement stock ($P < P_r$), the recruits will always be greater than the stock (R > P). In this case, since the average P_n (=1.10 x 10^9) is less than P_r (=3.22 x 10^9) recruitment would exceed the stock size, and provide considerable quantities of forage to the intermediate predators.

Surplus production models

The catch per unit effort as a function of effort for 1960-'70 (premechanization period) was dealt separately from that for 1971-'84 (mechanization period). The MSY for the limited portion of the resource exploited by the indigenous nonmechanised fleet for the premechanization period (1960-'70) estimated according to the Schaefer (1954) model was 6,322.40 t for the annual effort of 38.5 x 10^6 manhours and 6,038.83 t for 50.3 x 10^6 manhours according to the Fox (1970) model. According to the analytical model the MSY estimated for the former period (1960-'70) was 5,356 t, which was fairly close to that estimated by the surplus production models. Schaefer (1954) and Fox (1970) models indicated the MSY for the premechanization period (1971-'84) to be 16,805.21 t and 20,488.49 t for the annual effort of 85.1 x 10^6 manhours and 156.6 x 10^6 manhours respectively. The MSY obtained by the analytical model for this period was found to be 17,237.31 t, which was close to that

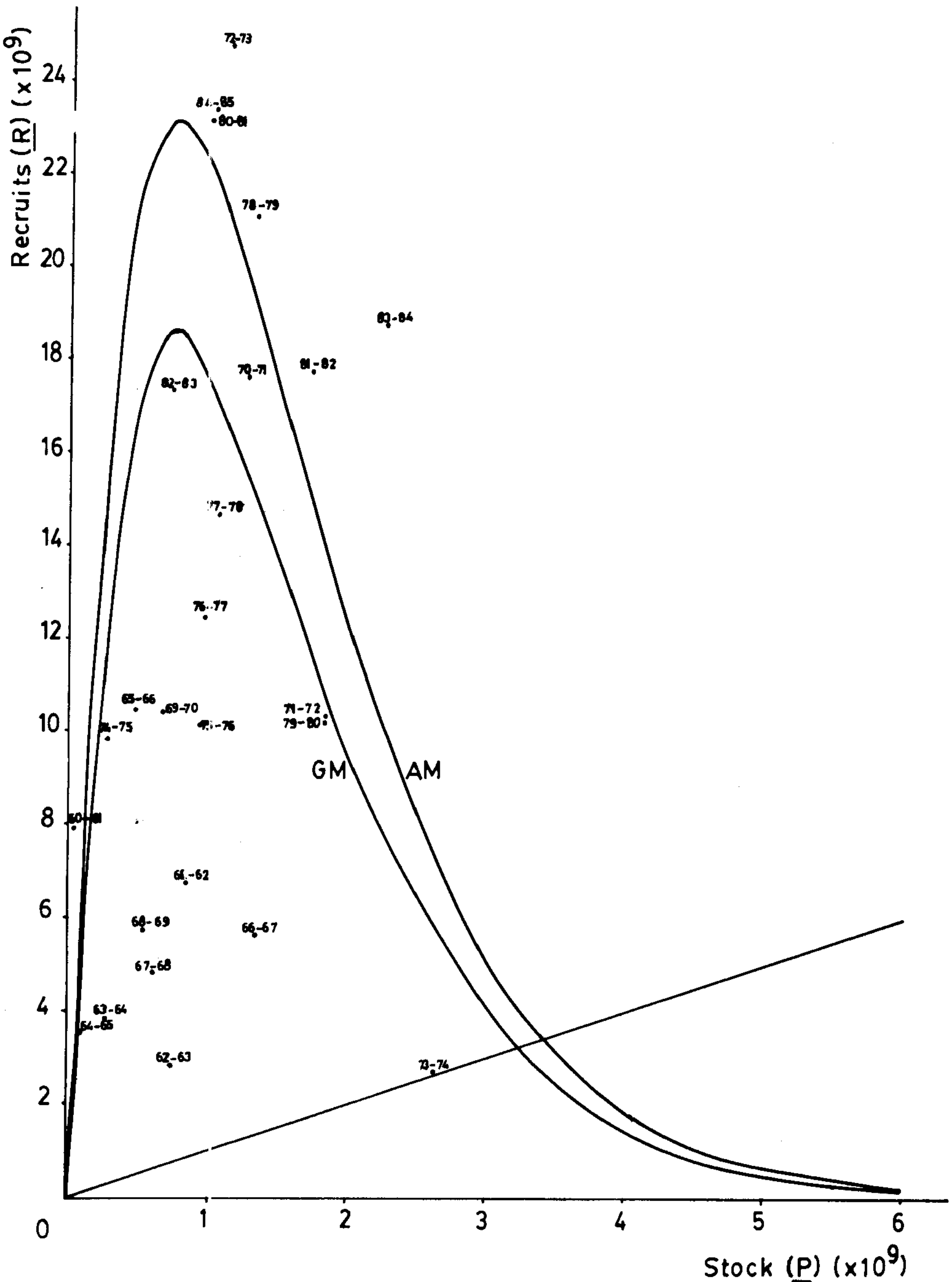

Fig. 4. Stock-recruitment relation.

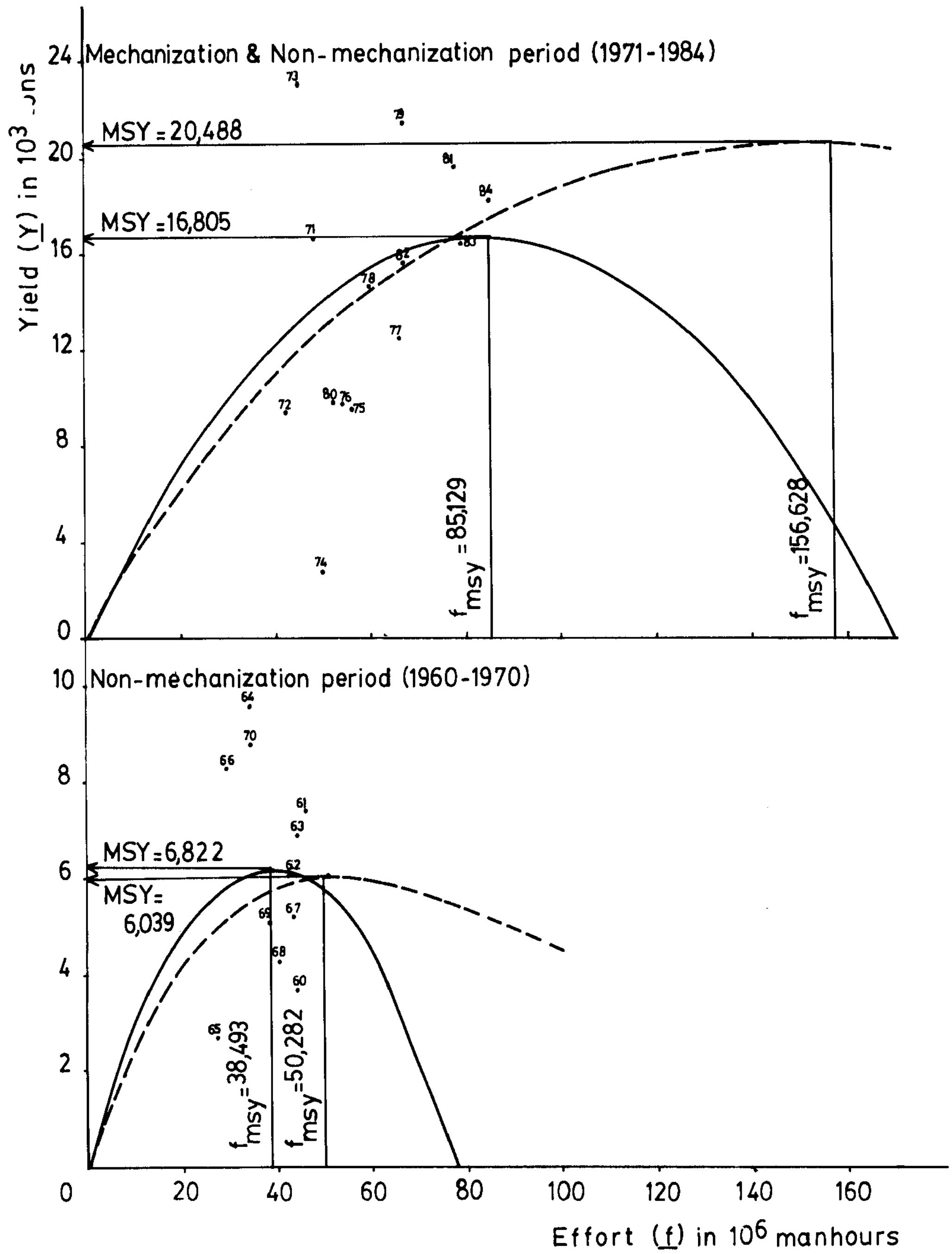

Fig. 5. Surplus production models.

obtained by the surplus production models.

The plot of catch (C(T)) against E(T)C(T-1)/E(T-1) for Roff's simple autoregressive model is fitted by,

$$y = 4,113.25 - 0.72x$$

This relation was used to predict catches for the coming years. Assuming effort to be constant for the periods 1989 to 2000, the catch in 2000 is estimated to be 22,540 t (Fig. 6).

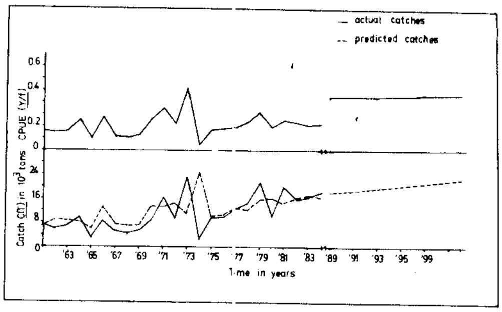

Fig. 6. Simple autoregressive model.

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Reference

Bagenal, T.B. 1955. The growth rate of the long rough dab, *Hippoglosoides platessoides* (Fabr.). *J.mar. biol. Ass. U.K.*, **34** : 297-311.

Bal, D.V. and M.S. Joshi 1957. Studies on the biology of *Coilia dussumieri* (Cuv. & Val.) *Indian J. Fish.*, **3**(1) : 91-100.

Banerji, S.K. 1973. An assessment of exploited pelagic fisheries of the Indian seas. *Proc. Symp.* living resources of the seas around India. *Special Publication, Central Marine Fisheries Research Institute, Cochin*, p. 114-136.

Beverton, R.J.H. and S.J. Holt. 1957. On the dynamics of exploited fish populations. *Fish. Invest. Ser. II*, **19** : 533.

Beverton, R.J.H. and S.J. Holt. 1959. A review of the life spans and mortality rates of fish in nature, and their relation to growth and other physical characteristics. *In* : Wolstenholme. G.E.W. and M.O'Connor (eds.), *The Life Span of Animals. Ciba Found. Colloq. on Ageing*, **5** : 142- 177.

Bhattacharya, C.C. 1967. A simple method of resolution of distribution into Gaussian components. *Biometrics*, **23** : 115-135.

Caddy, J.F. and J. Csirke 1983. Approximations to sustainable yield for exploited and unexploited stocks. *Oceanogr. Trop.*, **18** (1) : 3-15.

Cushing, D.H. 1968. *Fisheries Biology. A Study in Population Dynamics*. Univ. Wisconsin Press, Madison, Wis., 200 pp.

Devaraj, M. 1983. Fish population dynamics. Course manual. *CIFE Bulletin*, No. 3 (10) 83, Central Institute of Fisheries Education, Bombay, India, 98pp.

Fernandez, I. and M. Devaraj 1988. Stock assessment and dynamics of the *Coilia dussumieri* (Engraulidae) resource in the Indian Exclusive Economic Zone along the northwestern coast of India. *Asian Fish. Sci.*, **1** : 157-164.

Fox, W.W. 1970. An exponential yeld for optimizing exploited fish populations. *Trans. Am. Fish. Soc.*, **99** : 80-88.

Gadgil, M.D. 1965. On some aspects of the biology of *Coilia dussumieri* (Cuv. & Val.). *M.Sc. dissertation*. University of Bombay, Bombay, India.

Gulland, J.A. and S.J. Holt 1959. Estimation of growth parameters for data at unequal time intervals. *J. Cons. CIEM.*, **25**(1) : 47-49.

Jackson, C.H.N. 1939. The analysis of an animal population. *J. Anim. Ecol.*, **8** : 238-246.

Jones, R. and N.P. van Zalinge. 1981. Estimates of mortality rate and population size for shrimp in Kuwait waters. *Kuwait Bull. Mar. Sci.*, **2** : 273-288.

Kapadne, S.S. 1986. Stock assessment, dynamics and biology of *Coilia dussumieri* (Cuvier and Valenciennes) along the Bombay coast with special reference to the Versova coast. *M.Sc. dissertation*, University of Bombay, Bombay, India.

Pauly, D. 1982. Studying single species dynamics in a tropical multispecies context. *In* : D. Pauly and G.I. Murphy (eds.) *Theory and Management of Tropical Fisheries*. ICLARM Conference proceedings 9, p. 33-70. International Centre for Living Aquatic Resources Management, Manila, Philippines and Division of Fisheries Research, Commonwealth Scientific and Industrial Research Organization, Cronulla, Australia, 360 pp.

Pauly, D. 1984. Fish population dynamics in tropical waters : A manual for use with programmable calculators. *ICLARM Studies and Reviews*, **8** : 325 pp. International Centre for Living Aquatic Resources Management, Manila, Philippines.

Pope, J.G. 1972. An investigation of the accuracy of virtual population analysis using cohort analysis. *ICNAF Research Bulletin*, **9** : 65-74.

Ricker, W.E. 1958. Handbook of computers for biological statistics of fish populations. *Bull. Fish. Res. Bd. Canada*, 119-300.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. *Bull. Fish. Res. Bd. Canada*, 192-382.

Roff, D.A. 1983. Analysis of catch/effort data: a comparison of three methods. *Can. J. Fish. Aquat. Sci.*, **40** : 1496- 1506.

Schaefer, M. 1954. Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. *Bull. I-ATTC.*, **1**(12) : 27-55.

Sparre, P. 1985. Introduction to tropical fish stock assessment. FAO/DANIDA project. Training in fish stock assessment. GCP/INT/392/DEN, 338 pp.