ESTIMATES OF *COILIA DUSSUMIERI* POPULATION ALONG THE NORTHWEST COAST OF INDIA USING COHORT ANALYSIS

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ABSTRACT

Cohort analysis for the *Coilia dussumieri* stock along the northwest coast (Maharashtra and Gujarat coasts) of India for 1981-1983 indicated annual recruits to be ranging from 5.1×10^9 to 6.8×10^9 (mean = 5.7×10^9) and the spawners from 3.1×10^9 to 4.2×10^9 mean = 3.55×10^9). The annual yield ranged from 16,353 t to 19,610 t (mean = 17,534 t). The fully recruited group of $\frac{1}{2}+$ year (6 to 11 mon. fish), which was the age at first maturity as well as for maximum exploitation, formed the mainstay of the fishery. The present yield per recruit (Y|R = 3.0 g, for the annual exploitation ratio, E = 0.51 and the age at first capture, tc = 0.6 year) is close to the maximum Y|R of 3.04 g at E = 0.6; suggesting that only marginal increase in yield is possible by increasing the effort. At the present level of exploitation (51%), the effective fishing effort is about 1,300 trawlers per day (Maharashtra = 740; Gujarat = 560) and about 2,000 dol netters per day (Maharashtra = 1,200; Gujarat = 800) for about 215 fishing days per year. The fishing effort seems to have remained around this level since 1971 obviously because of near-optimum level of yield from nearly all the inshore stocks including that of *C. dussumieri*.

INTRODUCTION

As fishing intensity increases and mesh size decreases, more and more fish are caught at incompletely recruited ages, leading ultimately to stock depletion through both growth and recruitment overfishing. It is, therefore, necessary to optimise the parameters of critical importance to fisheries such as the fishing intensity and mesh size, in order to sustain the stock at levels yielding maximum catches. Population size in number and weight in relation to catch in number and weight at successive ages would indicate whether the fishery is operating at the optimum level or not. *Coilia dussumieri* which forms one of the most important fisheries along the northwest coast of India comprising Maharashtra and Gujarat has been studied in this perspective. Sequential estimates of population size through successive year classes have been made for this purpose by means of cohort analysis.

Material and Methods

C. dussumieri samples for length-frequency data were collected randomly at weekly intervals from the fishlanding centres in Bombay and Dahanu (90 km north of Bombay), and from the vessels of the Central Institute of Fisheries Education, namely M. V. Saraswati (operating along the entire Maharashtra and Gujarat coasts) and M V Narmada (operating off Bombay) during 1981 to 1983. This species is mainly exploited by dol net (fixed bag net) of 20 mm codend mesh operated near shore and by trawl net of 20 to 40 mm codend mesh operated up to the 40 m depth. Records of the annual catch of *C. dussumieri* were obtained from the Central Marine Fisheries Research Institute (Anon. 1982, 1983).

A total of 9,228 fish, sampled at weekly or fortnightly intervals during 1981-1983, were used for age determination by the scatter-diagram technique of tracing the progression of modes in the length-frequency data (Devaraj 1983) and for the determination of growth parameters. The age-length key in Fernandez (1986) and Fernandez and Devaraj (MS I) was used for grouping the length composition into age composition.

Pope's (1972) cohort analysis has been described by Jones (1974, 1976, 1981) and Jones and van Zalinge (1981). The procedure involves the determination of the numbers in the sea necessary to account for the numbers caught in each length (or age) group (Jones and van Zalinge 1981). The principle followed in this analysis is simple and can be used to estimate the rate of fishing at all ages, given the values of natural mortality (M) and total mortality (Z). While Z was estimated by the method of Jackson (1939) from the age composition data, M was estimated from the empirical relation given by Pauly (1980). The ratio of annual fishing mortality (F) to annual total mortality (Z) indicates the ratio of exploitation, E (= F|Z). Annual age composition and annual catch data form the basic input material for the analysis. The computation starts with the value of fishing mortality (F) considered to be the F_t for the oldest age group (N_t) and works back down to the youngest age group. These two operations constitute steps 1 and 2 of the analysis. Steps 3 and 4 show the estimates of F and the average biomass in the sea respectively for the respective age groups.

Population number at a given age was multiplied by the weight of individual fish at that age to give the weight biomass, which when plotted for successive ages indicate the so-called optimum age of exploitation (t_y) at which the biomass of the given cohort was at its maximum. This value of t_y was compared with that estimated by applying the Krishnan Kutty and Qasim (1968) model to test its reliability.

Age at first maturity was used to group the population number into the recruits (R) and the parents or spawners (S). Given the annual yield (Y), the yield per recruit (Y|R) was computed and compared with that estimated according to Beverton and Holt (1957), again to test the values, for the latter model estimates Y|R from growth (W_∞, k and t_o) selection (tr and tc) and mortality (F and M) parameters. A comparison of the current Y|R value (from the direct yield-recruit ratio or the Beverton-Holt method) for the current values of F and tc (age at first capture) with the maximum yield per recruit (Ymax|R) estimate (from the Beverton-Holt method) and with the potential yield per recruit (Y'|R) estimate (from the Krishnankutty and Oasim method or the recruit-yield method) indicated the present status of the fishery, and could therefore form the basis for its better management. The basic parameters used in the various computations are listed in Table 1.

TABLE 1. *Basic parameters used in the study for the period* 1981-1983

1.	Length growth:	
		Length infinity, L_∞ = 28.5 cm
		Annual growth coefficient, k = 0.07
		Arbitary origin of growth, t_o = —0.83 year
2.	Weight growth:	
		Weight infinity, W_∞ = 30.1 g
		Annual growth coefficient, k = 0.10
		Arbitary origin of growth, t_o = —1.81 year
3.	Mortality and exploitation ratio (Mean for 1981-1983)	
		Annual total mortality coefficient, Z = 2.68
		Annual natural mortality coefficient, M = 1.30
		Annual fishing mortality coefficient, F = 1.37
		Annual exploitation ratio, F|Z = 0.51
4.	Selection:	
		Length (lr) and age (tr) at recruitment:
		lr = 3.5 cm; tr = 0.08 yr
		Length (lc) and age (tc) at first capture:
		lc = 8.8 cm; tc = 0.4 yr
5.	Length (L in cm) - Weight (W in g) relation:	
		$W = aL^b$; W = 0.07 g; L = 1.87 cm
6.	Ambient temperature, I for Pauly (1980)	27.9°C.

RESULTS AND DISCUSSION

The analyses have been made for 1981, 1982 and 1983 and the results are presented in Table 2. The age composition of *C. dussumieri*, constructed in half year age groups, included the 0 + age group consisting of 0 to 5 months old fish; the ½+ of 6 to 11 months old fish; the 1+ of 12 to 17 months old fish; and the 1½+ of 18 to 23 months old fish. The annual M was estimated to be 1.30, while the annual Z ranged from 2.31 in 1982 to 2.74 in 1983 (Table 2). The 0+ age group was considered to be the recruits (R) and the ½+, 1+ and 1½+ age groups together treated as the parent or spawner stock (S) since the age at first maturity was to be 6 months (Fernandez 1986, Fernandez and Devaraj, MS 2). The ½+ group formed the fully recruited group. During 1981 there were 6,760.8 x 10^6 recruits (result of spawning of the parent stock of 1980) and 4,212.9 x 10^6 parents, which have given rise to 5,139.3 x 10^6 recruits in 1982. The parent stock of 3,300.7 x 10^6 fish in 1982 (resulting from 5,139.3 x 10^6 recruits) has given rise to 5,252.4 x 10^6 recruits in 1983 (when there were 3,153.6 x 10^6 spawners). Thus while the annual number of recruits ranged narrowly from 5.1 x 10^9 to 6.8 x 10^9 (mean = 5.72 x 10^9), the annual number of spawners ranged from 3.1 x 10^9 to 4.2 x 10^6 (mean = 3.55 x 10^9) (Table 3).

TABLE 2. *Age composition and Z estimates*

Year (Catch in tons)	Age groups (Half year groups)	No. attaining each half year group	% of No. attaining each half year group	½ year Z	Annual Z
1981	0+	40	5.67		
(19,610	½+	523	74.19	1.30	2.60
tons)	1½+	142	20.14		
1982	0+	74	2.49		
(16,639	½+	1985	66.77	1.15	2.30
tons)	1+	912	30.68		
	1½+	2	0.07		
1983	0+	563	10.14		
(16,353	½+	3727	67.15	1.37	2.74
tons)	1+	1253	22.58		
	1½+	7	0.13		

TABLE 3. *Results of Cohort analysis in respect of* Coilia dussumieri *stock for 1981, 1982 and 1983.*

Year	Catch in tonnes	Half year age groups (t)	No. caught C_t	No. attaining each half year age group N_t	St	Z_t	F_t	Average Nos. in the sea $\bar{N}_t$
		0+	108,396,290	6,760,817,475	0.51	0.67	0.02	4,952,365,603
1981	19,610	½+	1,417,281,497	3,442,732,521	0.22	1.50	0.84	1,781,724,850
		1+	384,806,831	770,145,245	0.27	(1.30)	0.65	
		0+	37,742,823	5,139,291,818	0.52	0.66	0.01	3,772,793,938
1982	16,639	½+	1,012,425,724	2,649,247,819	0.24	1.41	0.75	1,418,562,753
		1+	465,154,791	649,074,337	0.004	5.62	4.97	115,075,787
		1½+	1,020,076	2,348,415	0.32	(1.15)	0.50	
		0+	171,994,224	5,252,448,909	0.50	0.70	0.05	3,773,076,580
1983	16,353	½+	1,138,583,431	2,611,295,303	0.21	1.58	0.93	1,312,043,539
		1+	382,786,434	538,266,512	0.008	4.88	4.23	109,463,907
		1½+	2,138,472	4,082,645	0.25	(1.37)	0.72	

Pope's (1972) cohort analysis enables estimation of both the number of parents and the recruits in the stock. These estimates for a large number of years could be used as the basic data for fitting the relation between the parent stock and subsequent recruitment using any of the appropriate stock-recruitment models.

The cohort attains maximum biomass at ½+age (i.e., 6 to 11 months) at which the catch is also at the maximum. The optimum age of exploitation (11 months) at which the cohort attains maximum biomass, estimated by the method given by Krishnankutty and Qasim (1969) agrees very well with that (i.e., ½+group of 6 to 11 months old fish) computed graphically in Fig. 2. The difference between the population in number or weight and catch in number or weight through the successive half year groups narrows down progressively from the maximum at the 0+year group to the minimum at the 1½ +year group (Figs. 1 & 2; Tables 3 & 4) indicating thereby a progressive increase in the vulnerability of the stock to the fishery with the increasing age of the cohort.

TABLE 4. Coilia dussumieri *catch in relation to its biomass*

Year	Age group (t)	Catch in tons	Biomass in tons	% of catch to biomass
	0+	307.3360	19,168.9458	1.6030
1981	½+	14,015.9219	34,046.2147	41.1673
	1+	5,286.7456	10,580.7945	49.9655
	Total	19,610.0035	63,795.9550	30.7386
	0+	143.2944	19,511.8353	0.7344
	½+	9,938.1734	26,005.5464	38.2156
1982	1+	6,536.6342	9,121.1820	71.6643
	1½+	20.9116	48.1425	43.4369
	Total	16,639.0136	54,868.7062	30.4261
	0+	538.9611	16,459.0739	3.2746
	½+	10,330.1398	23,691.7600	43.6022
1983	1+	5,440.0077	7,649.6284	71.1147
	1½+	43.8387	83.6942	52.3796
	Total	16,352.9472	47,884.1565	34.1511

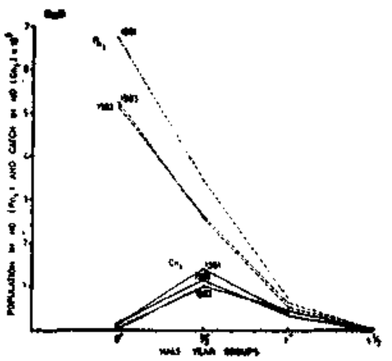

FIG. 1. Relation between population in number (Pnt) and catch in number (Cnt) (in billions) for the half year groups during the 3 periods: 1981, 1982 and 1983.

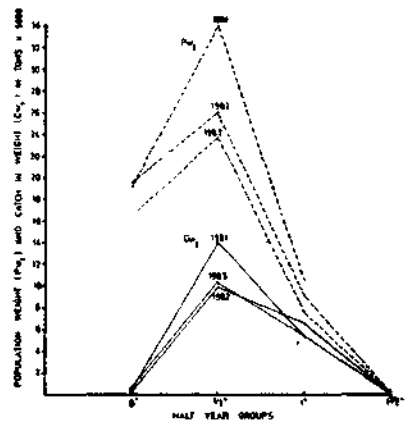

FIG. 2. Relation between population in weight (Pwt) and catch in weight (Cwt) (in thousand tons) for the half year groups during the 3 periods: 1981, 1982 and 1983.

For the northwest coast, the annual yield (Y) of 19,610 tons from 6,760.8 x 10^6 recruits in 1981, 16,639 tons from 5,139.3 x 10^6 recruits in 1982 and 16,353 tons from 5,252 x 10^6 recruits in 1983 indicates the yield in weight per recruit to be 2.90 g, 3.24 g and 3.11 g respectively in 1981, 1982 and 1983 (mean Y|R 3.08 g) which agrees very well with the value of 3.0 g estimated by the Beverton and Holt (1957) analytical model for the present E = 0.51 and tc = 0.6 year corresponding to lc = 12.0 cm (Fig. 3 & 4) for the most predominant trawl codend mesh of 27 mm (the trawl codend selection factor = 4.4; see Fernandez 1986).

Between the values of: (1) Y|R = 3.08 g estimated by directly dividing the actual Y by R; (2) Y|R = 3.0 g for the present E = 0.51 and tc = 0.6 year; (3) Ymax|R = 3.04 g at E = 0.6 year (2 and 3 = 0.60 for tc = estimated by the analytical model); and (4) the Y'|R of 3.8 g at ty = 0.94 year for E = 1 (i.e., for F = ∞) estimated by the method of Krishnankutty and Qasim (1968), there is little difference. Therefore, the present exploitation rate of 51% and the present yield of about 16,000 to 20,000 tons (mean = 17,500 tons) should be considered biologically optimum (i.e., the maximum biological yield, MSY) for the *C. dussumieri* fishery along the northwest coast. It should not, therefore, be economically or biologically prudent to increase the exploitation from the present 51% to any further level. The potential yield per recruit (Y'|R) = 3.8 g for E = 1 at F_∞ is only of theoretical interest and a mere reference point to compare the present Y|R with, for measuring the rela-

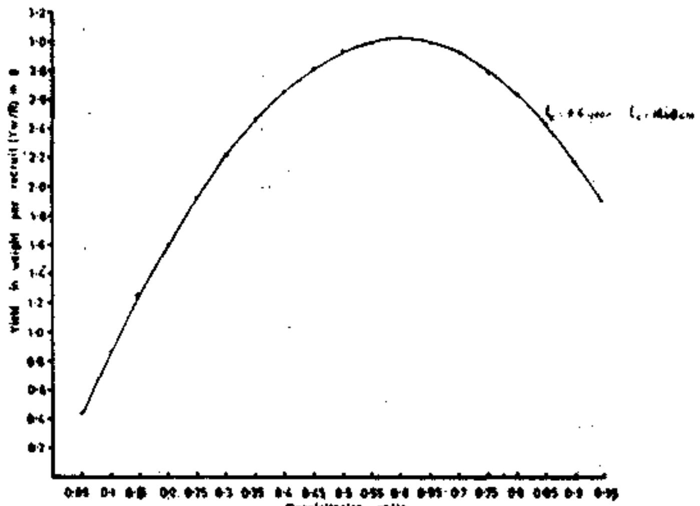

FIG. 3. Yield in weight (g) per recruit (Yw|R) as a function of exploitation ratio (E) as estimated from the analytical model.

tive efficiency of the fishery. However, even on this score also, the *C. dussumieri* fishery would appear to have been carried out at the best possible level of efficiency.

Along the northwest coast of India, *C. dussumieri* forms 2.05% of the trawl catches and 7.5% of the dolnet catches. It contributes 2.3% of the total annual fish catch along the northwest coast. The fish ascend to the surface in the night and they become less vulnerable to the bottom trawl, which operates for shrimps in the nights. But dolnet fishing

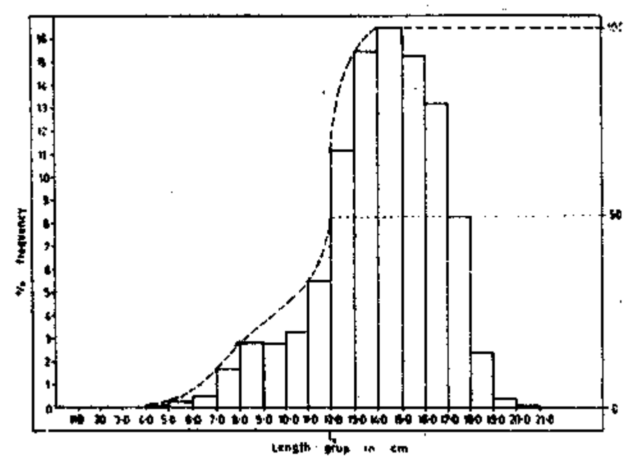

FIG. 4. Trawl codend selection from the length frequency data for the commercial fishery (50% selection length, lc = 120 mm).

compensates for whatever *C. dussumieri* catch that would have been taken by day trawling. As a result, the fishery seems to have reached and stabilized at its biologically optimum level. The functional number of trawlers and dol netters (in terms of effective effort) along the northwest coast have stabilised at about 1300 (Maharashtra = 740; Gujarat = 650) and 2000 (Maharashtra = 1200; Gujarat = 800) vessels respectively since 1971. The nearly stable level of fishing effort indicates that all the inshore species stocks (whether target species or by catch species) are being exploited at the level yielding the best biological returns. It appears that the best biological returns are closer to the best economic returns because of the existing and rapidly growing demand for fish in the urban markets like Bombay. Production considerations arising from high demands, while forecing the fishery to stabilise at the biologically optimum level, help stabilise the fishery at the ecologically optimum level as well, since the sustained levels of the forage biomass such as of *C. dussumieri* at the MSY levels can benefit considerably the predator stocks and thereby their fisheries also.

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