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STOCK ASSESSMENT OF THE INDIAN OIL-SARDINELLA (Sardinella longiceps) OFF THE WEST COAST OF INDIA

by

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ABSTRACT

Pooled length-frequency data of Sardinella longiceps raised to the total catch on the West coast of India for the years 1979-83, are used to determine growth parameters by the Bhattacharya and ELEFAN I methods. The estimates of L_∞ = 197.2 mm and K = 1.006 per year, are compared with earlier estimates and used for VPA and catch curve analyses to obtain estimates of the total fishing mortality Z, ranging from 1.33 to 1.62, and total biomass (around 550,000 tonnes). The results are still very preliminary and in particular the estimates of Z may be biased because of migration. Further data collection, pooling and analysis is recommended.

1 INTRODUCTION

The Indian oil-sardinella (Sardinella longiceps Val.) has traditionally played a critical role in the marine fishery economics of India, and in particular in the State of Kerala. It's production on the west coast of India exhibits large fluctuations over the years, though it continues to be commercially the most important and abundant pelagic resource (Table 1). These fluctuations have attracted the attention of many research workers. As early as 1910 Hornell attributed them to changes in diatom production or food availability to the fry and the prevalence of favourable hydrological conditions. Kesteven (1967) was of the view that the fluctuations are related to shifts in the migratory path of the fish, causing variations in the accessibility of the stocks to fishing due to the limited range of the fishing operations.

Sekharan and Dhulkhed (1967) thought that the annual catch fluctuations are related to variations in the newly recruited year classes. Devanesan (1943) attributed the fluctuations to overfishing of the immature fish, while Nair (1952) and Nair and Subrahmanyan (1955) pointed at the changes in the availability of the diatom Fragilaria oceanica in the inshore waters.

Murty and Edelman (1970) stated that the intensity of the monsoon on the west coast of India above a critical value would be favourable for enrichment of the sea not only with nutrients, but also with dissolved oxygen. Bennet (1973) expressed the view that the total number of fish in the population cannot exceed the limits determined by food resources and the rate of its reproduction. If the numerical strength of a generation is large enough to almost completely utilize the food resources, successive generations will be weak in numbers till the dominant generation is much reduced in strength.

On the basis of the available data it can be inferred that the resource potential of oil-sardinella off the west coast of India is quite high despite its inherent fluctuations. Stock assessments have been made by Banerji (1973), Sekharan (1974) and Balan et al. (1979).

Table 1 Annual production of Indian oil-sardinella in India (West and East west) from 1956 to 1985

year	tonnes	year	tonnes
1956	7 412	1971	209 261
1957	191 469	1972	127 568
1958	123 731	1973	144 395
1959	69 234	1974	126 676
1960	189 016	1975	159 240
1961	167 884	1976	169 262
1962	110 299	1977	150 130
1963	63 647	1978	168 078
1964	274 333	1979	153 971
1965	261 863	1980	115 744
1966	247 214	1981	221 026
1967	256 324	1982	205 294
1968	301 446	1983	183 706
1969	174 249	1984	188 832
1970	226 997	1985	120 587

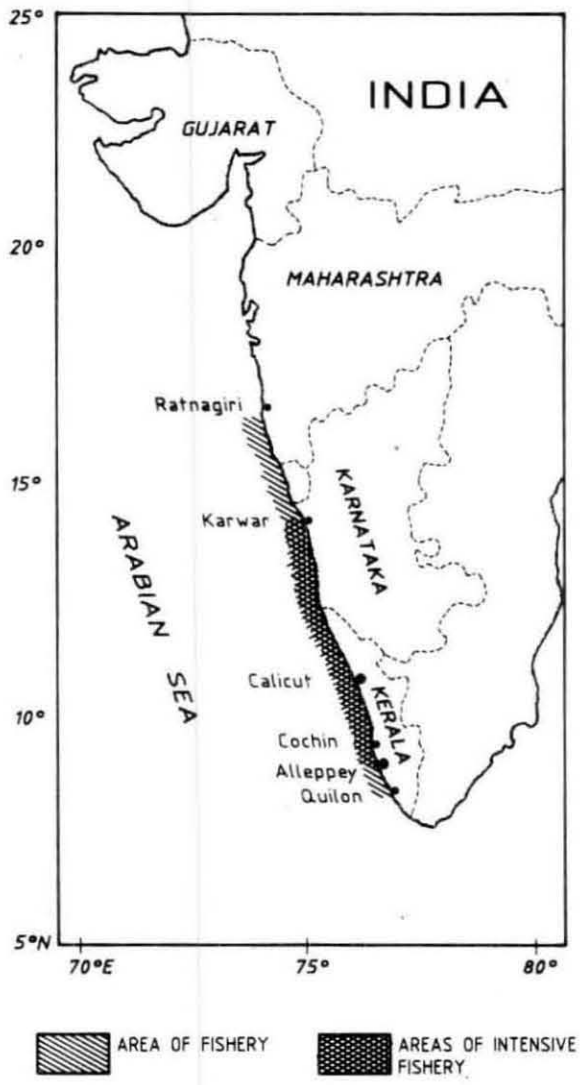

Fig. 1 Distribution of fisheries for Indian oil-sardinella (S. longiceps) at the West coast of India

2 THE FISHERY AND BIOLOGY

2.1 The fishery

S. longiceps sustains the most important pelagic fishery of the south-west coast of India, off the States Kerala and Karnataka, where it is commercially landed from Quilon in the south to Karwar in the north (Fig. 1). The fishery generally starts in June-July and continues till March-April. Adult fish appear in the fishery in the beginning of the season and a couple of months later juveniles follow.

Usually the fishery starts first in the south and progresses to the north, probably in sequence with the early upwelling in the southern areas. The above cycle of events is repeated each year.

Traditionally the fishery was restricted to about 20 km from the shore, the main fishing units being non-mechanized indigenous canoes with boat seines (bag nets and encircling nets) as well as gill nets. Rampani and other shore seines were widely prevalent in Karnataka and Goa as gears for encircling oil-sardinella shoals.

In the late seventies the introduction of commercial purse-seining with small mechanized boats started in Karnataka to be followed in Kerala and Goa. The artisanal sector also underwent changes especially in Kerala by way of motorisation with outboard engines (Jacob et al., 1987; Kurup et al., 1987).

The bulk of the catches is used fresh, while canning and production of fishmeal and oil is done when the market is glutted with it. The oil is used in paint and leather industries, and for coating wooden boats, while fishmeal is used as cattle and poultry feed.

2.2 Biology

Various aspects of the general biology of S. longiceps have been studied (Antony Raja, 1967, 1969, 1971 and 1972; Balan, 1968). Since it feeds on phyto- and zooplankton, its entire life cycle is aligned to the seasonal production cycle on the west coast starting with the peak breeding season around the south-west monsoon (June-August) when upwelling induced primary production caters to the food need of the larvae and young recruits. In August-September the recruits move to the inshore waters, organized in surface schools, where they sustain a fishery for several months till around March-April (Antony Raja, 1967).

Very rapid growth is reported during the first 12 months, when they can reach a length of 14 cm. This is also the age and length of first maturity. The fecundity has been estimated at around 48,000 eggs per female. Spawning may take place over an extended period and larvae have been noticed in some quantity during many months of the year.

Due to the early migration to shallow waters the traditional fishery was largely sustained by 0 and 1 + class fish, ranging in size from 9 to 18 cm (Hornell and Nayudu, 1924; Antony Raja, 1967).

3 DATA BASE

The estimates of the landings of oil sardinella were obtained at two prominent landing centres in Kerala, Cochin and Calicut, through a sample survey of a stratified multistage random sampling design (Jacob, Alagaraja and Kurup, 1983). Coinciding with the sample survey length frequency samples were collected from all interviewed fishing units. In 1979 the data from Cochin still pertain to two types of gear viz. boatseines and

Table 2 **Landings of oil-sardinella in Cochin, Calicut, the whole of Kerala and West coast as used to raise length-frequency samples in Table 3**

Area gear	Cochin purse seines	Cochin boat seines	Calicut boat seines	Kerala total	West coast total
1979	2449	63562	50312	116323	152960
1980	9436		60231	69667	115424
1981	12165	3398	134018	146982	220831
1982	8082		135125	143205	204210
1983	8505		145827	154332	182245

purse seines, but from 1980 onwards the data refer only to purseseines, which by then had become the most prominent gear. For Calicut only data from boatseines were used, as landings from other gears were comparatively insignificant.

The total length was measured to the millimeter. The length-frequencies were grouped into 5 mm classes and raised to the total of the day's landings by geartype. These data were further raised to obtain overall estimates for Kerala, and then again to obtain estimates for the entire west coast of India. The data were pooled over a 5 year period (1979-83) for the entire west coast (Tables 2 and 3).

Sample weights were not actually measured but obtained from the lenght-frequencies by using the length-weight relationship (see below).

4 RESULTS

4.1 Length-weight relationship

Based on 1335 measurements taken from boatseine landings at Calicut during 1979-82, the following length-weight relationship was established:

$$W = 0.0000135\ L^{2.9268}$$

where W is the weight in grams and L the length in mm. The confidence limits of the exponent are (2.73 , 3.12).

4.2 Growth parameters

The results of a Bhattacharya analysis (Bhattacharya, 1967 and Sparre, 1985) of the length frequency data are given in Table 4. In each month only two modes (cohorts) could be separated, except for October and November, where the two first modes probably can be interpreted as a result of small differences in spawning season between the pooled years.

After assigning an arbitrary age to each of the modes the von Bertalanffy growth parameters (L_∞, t_o and K) were estimated by a non-linear regression (Sparre, 1985). The estimates and their confidence limits are given in Table 5. The resulting growth curve together with the observations is plotted in Fig. 2. A similar growth curve was obtained using the ELEFAN program (Fig. 3). Fig. 2 indicates that the growth rate shows a strong seasonal variation. This variation could, however, also be explained by a seasonal change in the availability of large fish on the fishing grounds.

Table 3 *Sardinella longiceps*. West coast of India. Average monthly catch in numbers (x 1000) at length (in cm), 1979-1983. (Input for the Bhattacharya analysis)

month length- class	1	2	3	4	5	6	7	8	9	10	11	12	Total
6.5-										4657			4657
7.0-								92		6985			7077
7.5-								626	197	22217			23041
8.0-								1953	909	44560			47421
8.5-								3813	3471	51213			58497
9.0-								4974	3768	75866	242		84849
9.5-								4212	2531	81868	634	5	89249
10.0-	2306	674	330	42				6151	4446	45869	13892	507	74216
10.5-	10810	1312	1392	235				6972	12127	38186	19285	1170	91489
11.0-	47284	7432	8386	4188	68			3968	15339	33687	46945	18725	186021
11.5-	43831	23354	20695	11032	221	201		4011	13346	32773	90502	63322	303288
12.0-	74201	23526	33875	18117	1450	85		1226	9320	43600	70886	105887	382174
12.5-	112389	47072	31293	30065	3447	179		3078	10052	58311	78376	132152	506414
13.0-	108986	61329	58329	35709	7174	536	259	5168	5132	45656	88049	176357	592684
13.5-	74852	66257	59475	41794	11961	2221	161	5971	8201	34078	111067	149935	565973
14.0-	60913	59423	61304	32973	14230	8274	1054	7694	4667	25483	111884	115991	503890
14.5-	30064	42931	24362	40673	34560	10609	2894	10406	4332	12833	78931	55715	348309
15.0-	17480	28864	8363	32997	46409	7796	10964	17564	12916	9910	50005	39283	282550
15.5-	17876	25489	19499	14635	26739	6625	14263	31751	21390	27948	41802	19666	267683
16.0-	25344	32242	7008	21289	33298	5599	7894	50002	60752	104935	9947	13778	372089
16.5-	28822	38162	12665	16755	14985	3048	6387	46834	49999	117728	8168	13089	356644
17.0-	27219	35164	11167	16711	11738	1422	2336	28937	41926	131755	13348	12569	334292
17.5-	21414	27171	8087	13309	9791	1211	1900	14227	30015	54601	10114	9330	201172
18.0-	17967	16817	4152	2178	6610	1280	2061	9802	18295	50263	10143	7288	146855
18.5-	9235	11092	3198	1663	3979	788	1521	5383	12262	25690	7762	4702	87275
19.0-	7984	4768	1214	1619	6311	177	304	2209	10775	6083	4269	1030	46743
19.5-	1514	2573	561	71	982	199	635	1060	4982	7669	1363	535	22144
20.0-	2227	2455	404	382	295	5	218	368	5547	1595	1007	1281	15785
20.5-	716	1017	133	5	479	15	30	398	248	653	105	410	4210
21.0-	87	326	2	42	72	7		397	2905	35	160	102	4135
21.5-					91	5		129	2872		1		3098
22.0-	9												9
22.5-													
23.0-								158					158
23.5-													
24.0-								158					158
Total	743528	559450	375896	336483	234890	50282	52882	279695	372722	1196706	868886	942829	6014249

Table 4 Results of Bhattacharya analyses on the pooled length-frequencies of S. longiceps from the West coast, 1979-83 (see Table 3)

Month	Modal sizes (mm) I	II	III
January	130.6	171.0	-
February	137.2	170.7	-
March	133.4	171.9	-
April	139.1	171.5	-
May	150.2	176.5	-
June	153.7	181.9	-
July	158.3	189.6	-
August	102.6	165.8	-
September	114.5	173.2	-
October	92.8	126.6	171.1
November	120.5	143.8	179.1
December	135.1	172.7	-

See also Fig. 2

Table 5 Estimates of growth parameters obtained from a Bhattacharya analysis on pooled data (1979-83) from the west coast of India (see also Fig. 2)

Parameter	Estimate	Confidence limits	Unit
L_∞	197.2	173.4 , 221.0	mm
K	1.006	0.44 , 1.56	per year
t_o	-0.08	-0.43 , 0.28	year

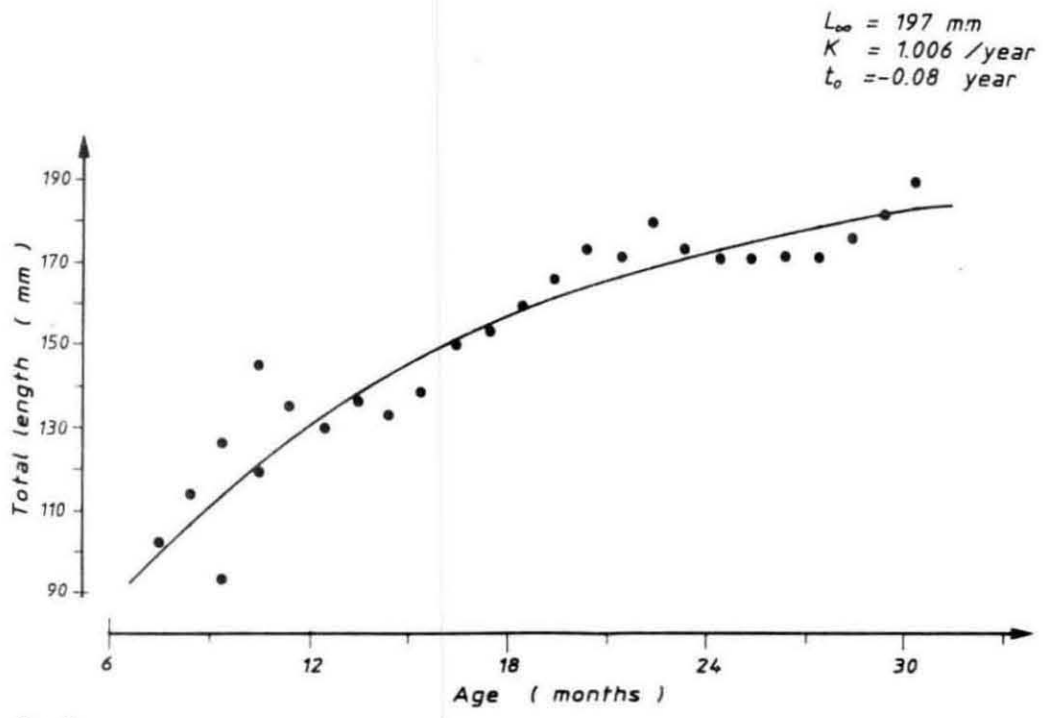

Fig. 2 Growth curve and monthly modal sizes obtained from a Bhattacharya analysis on pooled length-frequency data (1979-83) from the West coast of India of S. longiceps

Table 6 Results of the VPA analysis for S. longiceps with parameters M = 1.08, L_∞ = 197 mm, K = 1.006, t_o = 0, a = 0.0000135 and b = 2.9268

group	age	catch *) numbers x 10^6	stock	F	Z **)
1	.622	38	33718	0.01386	
2	.7053	85	30780.5	0.034	
3	.7887	679	28051.6	0.305	
4	.872	833	24993.8	0.42415	
5	.9553	896	22049.3	0.52088	
6	1.0387	577	19295.7	0.38113	
7	1.122	389	17083.7	0.28913	
8	1.2053	310	15241.1	0.25794	I
9	1.2887	275	13833.1	0.25579	
10	1.372	176	12196.1	0.18245	
11	1.4553	46	10977.3	0.05270	
12	1.5387	50	9988.5	0.06297	
13	1.622	235	9081.6	0.3291	
14	1.7053	279	8875.4	0.44143	
15	1.7887	514	7113.7	0.94217	
16	1.872	57	6010.5	0.11958	
17	1.9553	56	5438.7	0.12989	
18	2.0387	161	4917.1	0.41795	
19	2.122	189	4340.0	0.55907	
20	2.2053	54	3786.0	0.18030	II
21	2.2887	57	3408.6	0.21166	
22	2.372	47	3060.7	0.19423	
23	2.455	4	2752.4	0.01825	
24	2.5387	4	2511.7	0.02	

*) See Fig. 4
**) Mean Z I = 1.353 ; Mean Z II = 1.393

4.3 Mortality rates

The natural mortality, M, was estimated to 1.08 per year by inserting the growth parameters obtained and an average sea temperature of 29.5 °C (P.P. Pillai pers. comm.) into the empirical formula of Pauly (1980).

The Bhattacharya analysis produced also estimates of the total number caught from each cohort in successive months. In order to study the seasonal fluctuations in the fishery the catch in numbers was plotted against age (Fig. 4).

These numbers were used as inputs to a Virtual Population Analysis (VPA) as presented in Table 6. The terminal fishing mortality F was chosen in such a way that the average fishing mortality from January to May was the same for both 1 and 2 year old fish i.e. assuming that the same fraction of the stock of 1 year old and 2 year old fish was available on the fishing ground in the first 5 months of the year. This yielded mean values of Z = 1.35 and 1.39 respectively, based on M = 1.08 per year. The estimate of the biomass obtained by this method was around 550,000 tonnes.

A catch curve analysis was performed based on the summed average catches from 1979 to 1983 on the West coast of India. The analysis is presented in Fig. 5. The estimate of Z obtained was 1.62 per year, with confidence limits (1.04, 2.20). This estimate is a bit higher than the one obtained through VPA.

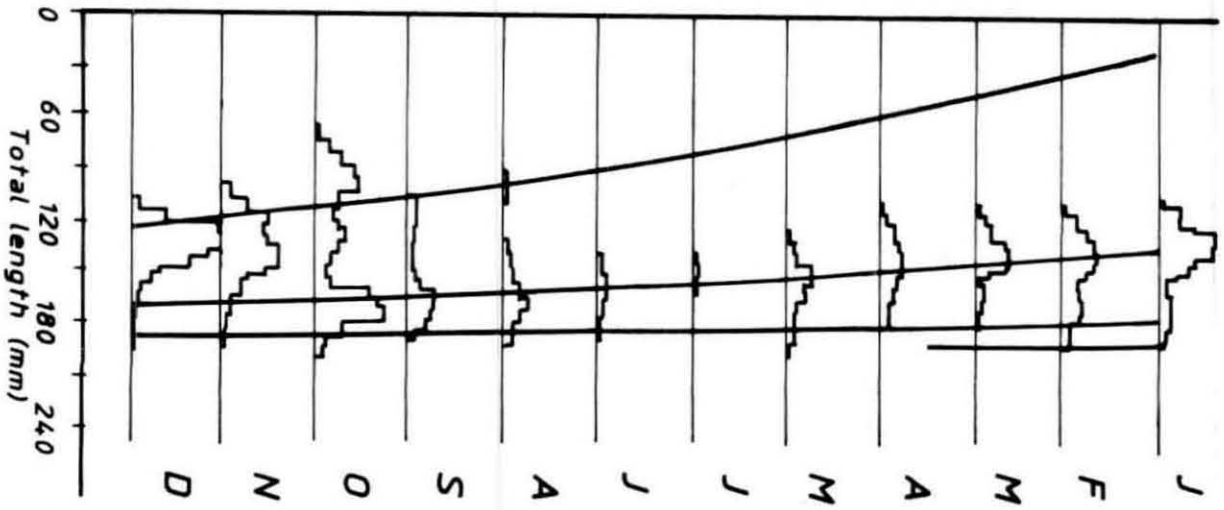

Fig. 3 Growth curve of S. longiceps based on an ELEFAN I analysis (pooled data 1979-83), West coast of India). Parameters: L_∞ = 197.2 mm, K = 1.006 per year (C = 0, WP = 0, SS = 7, SL = 157.5 mm)

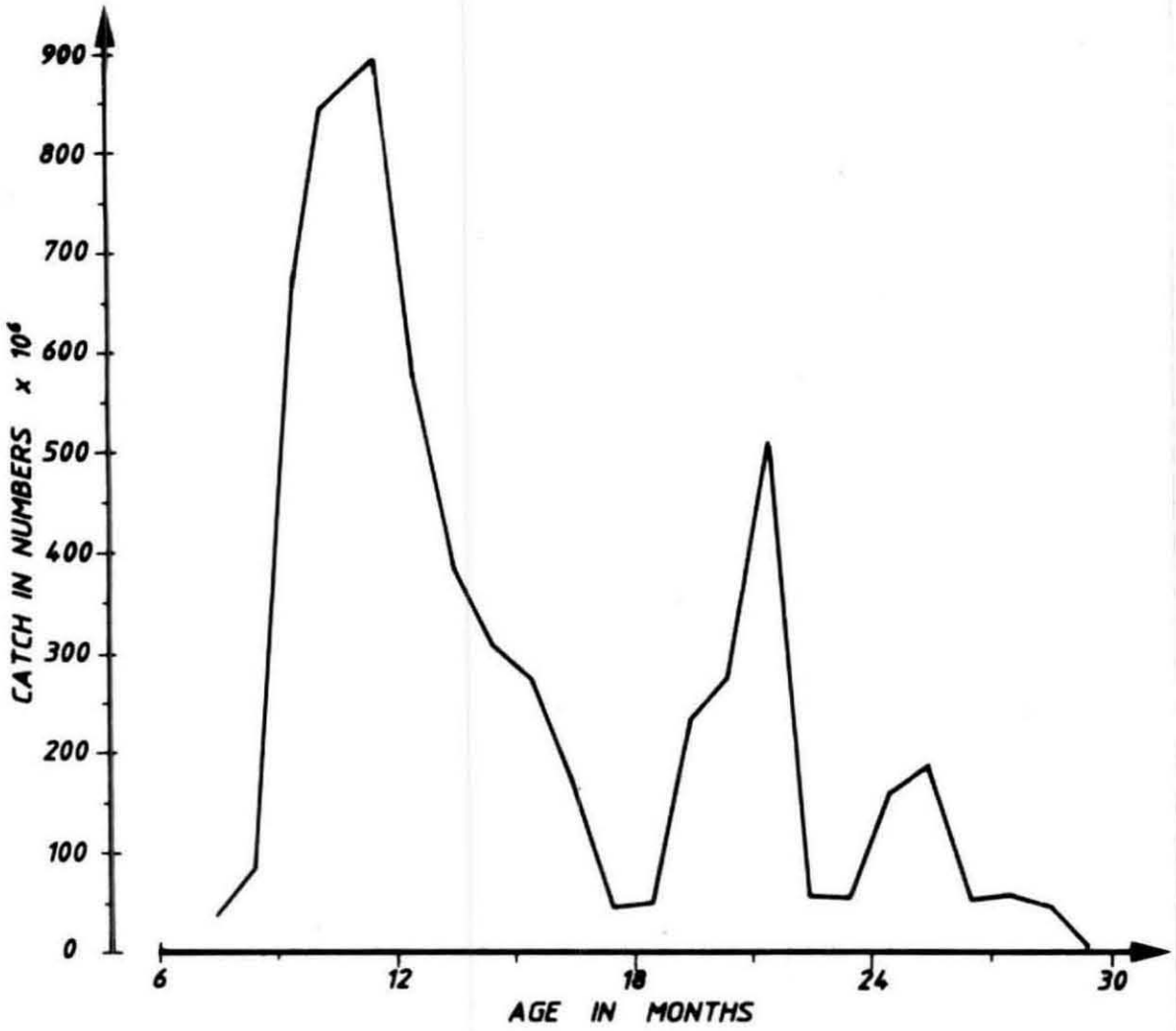

Fig. 4 Average catch in numbers at age of S. longiceps (same data base as in Figs. 2 and 3)

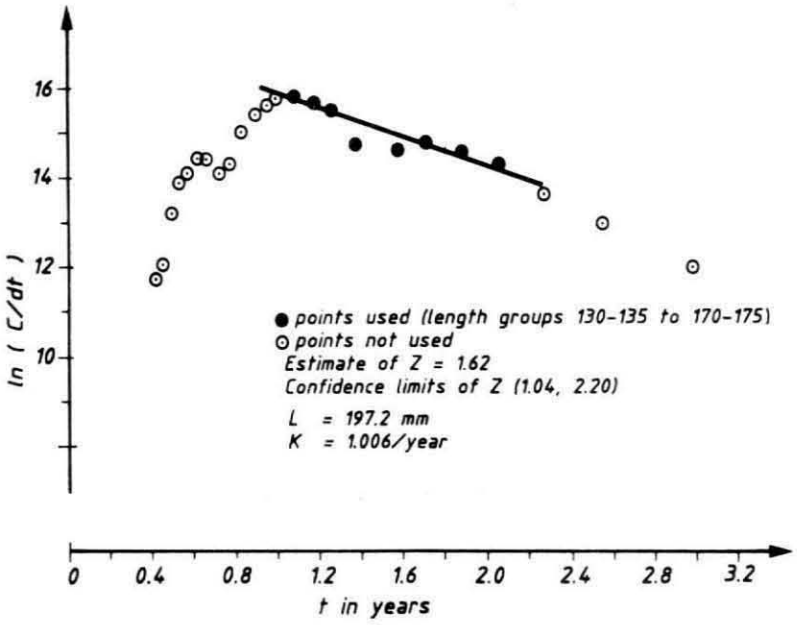

Fig. 5

Fig. 5 Catch curve for S. longiceps, based on the summed average catch on the West coast of India from 1979-1983

5 DISCUSSION

The assessment of tropical fish stocks is usually beset with problems of determining the growth parameters. The growth rates of the Indian oil-sardinella have been studied by many researchers, who used ages read from scales or length frequency analyses. Their results expressed in terms of length-at-age are presented in Table 7, together with our own results.

Sekharan (1965), Prabhu & Dhulkhed (1967) were of the opinion that juveniles measuring about 10.0 cm are one year old and that those between 10.0 and 15.0 cm are of the second year. Antony Raja stated that the fish attains 6.0-9.5 cm, 9.5-11.0 cm, 11.0-12.5 cm and 12.5-14.0 cm at the end of one, two three and four month respectively. The mean length of 18.5 cm is attained on completion, of 2 1/2 years. Bensam (1968) stated that this species grows very fast in the juvenile stage before it is 12 months old.

Antony Raja (1972) and Banerji (1973) have estimated the growth parameters which are given below:

	L_∞ (mm)	K (per year)	t_o (month)
Antony Raja (1972)	209.8	0.6	1.12
Banerji (1973)	207	0.53	-1.133

Juveniles start appearing in the fishery during the August-October period. They remain on the fishing grounds till they attain a size of 15.0-16.0 cm. Then they migrate again off shore to reappear when they have grown to 17.0 cm in the period September-October. The rate of growth of this larger size group is found to be very low. The fish of sizes above 18.0 cm, which appear in June-July are likely to be of the 2+ year group.

The estimates of L_∞ = 197.2 mm and K = 1.006 per year obtained in this study do differ from the earlier results, but the confidence limits for the parameters are very wide. The maximum size recorded in the samples is higher than our estimate of L_∞, however, in an analysis, where estimates are obtained through the method of least squares such results are expected.

Table 7 Estimates of length-at-age of S. longiceps obtained by various authors

Length at age in cm				Authors	Remarks
1	2	3	4		
15.0	16.0			Hornell and Nayudu (1924)	They estimated 12.5-14.0 cm growth in 6 months and suggested a T_{max} of 2.5 years
10.0	14.5	18.3	20.5	Chidambaram (1950)	T_{max} 4 years
10.0	15.0	19.0		Nair (1949, 1952 and 1960)	
13.0	16.0	17.5		Balan (1968)	based on length frequency data
15.0	17.8			Antony Raja (1969)	18.5 cm in 2.5 years
12.5	17.1	18.8	19.4	This paper	L_∞ = 197.2 mm K^∞ = 1.006/year t_o = 0

Balan et al. (1979) have estimated 'Z' following Beverton and Holt for oil-sardinella fisheries at Cochin and Calicut during the season 1976 to 1978 and their estimates varied from 0.46 to 0.78. The same authors obtained a different set of estimates of Z by resolving the frequency data into component cohorts and these estimates were in the range 1.47 to 2.21. Banerji (1973) by a similar procedure estimated 'Z' as 1.42. Sekharan and Dhulkhed (1967), by considering the decrease of the same year class through 5 years 1957-58 to 1962-63 estimated Z as 1.66. But for the estimate of Balan et al. (1979) all the previous estimates of Z were in the range 1.30-3.45. The estimate obtained by Balan et al. are probably underestimates due to a very low L_c or t_c.

In the present study, the estimates of Z obtained through the length converted catch curve (Z = 1.62) and VPA (Z = 1.35 to 1.39) seem quite reasonable. However, these values could be overestimates, since there is no information on the proportion of the stock that migrates to deeper waters from the fishing area. It is therefore essential to obtain better information on the stock sizes outside the fishing seasons through independent data collection.

The present analysis has been carried out on the basis of pooled data obtained from a large area, while most of the earlier assessments were based on data sets that were limited in time and area of coverage. Improvements of datacollection and collation systems will be necessary for future analyses.

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