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Sardine fishery with notes on the biology and stock assessment of oil sardine off Mangalore-Malpe

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Abstract

Sardines form an important resource off Mangalore-Malpe and the success/failure of their fishery in a way determined the status of marine fishery landings of this region. They contributed to an annual average (1997-98 to 2001-02) catch of 9,060 t. Since a number of gears are employed, the sardines are landed throughout the year along this coast. The fishery has registered a steep increase with the highest catch being observed in 2001-02. Several species of sardines supported the fishery, however the oil sardine, *Sardinella longiceps* comprised more than 90% of the catch. Length of *S. longiceps* varied from 40 mm to 220 mm and the length-weight relationship was estimated as $W= 0.01189L^{2.86}$. Growth parameters estimated separately for the different years as well as for all five years combined showed that the L_∞ ranged from 212 mm to 228 mm and K from 0.85 to 1.09 yr^{-1}. Total mortality rate ranged from 1.95 to 4.58 and natural mortality rate from 1.77 to 2.06. The exploitation rate ranged from 0.08 to 0.55. The study revealed that oil sardine is presently underexploited (E = 0.34) and the yield can be optimised by increasing the effort by 21%. However, economically remunerative management option would be to increase the size at first capture from the present 0.76 year to 0.97 year.

Introduction

Sardines comprising several species of *Sardinella* collectively contribute to a major share of the marine pelagic fisheries resource of India. They formed 15% of the total marine fish landings of the country during 2001. In Karnataka, the sardines formed a major marine fish resource contributing to 13% of the total sardine catch of the country. The Mangalore-Malpe coast plays an important role in the marine capture fishery scenario of Karnataka and the sardines caught along this region formed 32 % of the total sardine catch of the state in 2001. During the past few years, the catch registered a steep increase in the landings from this area making significant contribution to the total fish catch of the state. Like many other tropical pelagic resource groups, the landings of sardines also exhibited seasonal and annual fluctuations. Among the several species of sardines, the oil sardine, *Sardinella longiceps* was the dominant species, comprising >90% of the total sardine catch. Some of the detailed studies on the fishery, biology and the stock structure of oil sardine from the west coast of India include reports by Nair (1960), Antony Raja (1969), Balan (1968, 1984), Kurup *et al.* (1987), Annigeri *et al.* (1992)

and Ganga (2000). The present paper gives details of the fishery of sardines and the biology, growth and stock structure of oil sardine along the Mangalore-Malpe coast based on the investigations made during 1997-98 to 2001-02.

Material and methods

Weekly visits were made to Mangalore and Malpe fishing harbours and data on the effort expended by different gears and sardine catch were collected from 10-20% of the boats landed. Using the raising factor N/n, where 'N' is the total number of units landed on the observation day and 'n' the number of units observed, the weight of sardine landed on that day by that particular gear was estimated. Monthly estimates were obtained by raising the estimated day's catch to the number of fishing days in the month. Random samples of sardine landed by different gears were collected and brought to the laboratory for biological studies. Total length (mm) and wet weight (g) were taken and the fishes were cut open to identify the sex as well as to determine the stages of gonad maturation. The gonads were classified into five groups and seven stages as: Immature (stages I and II), Developing (stages III and IV), Mature or Gravid (stages V, VI and VIIa), Spent (stage VIIb) and Resting (stage IIb). Fishes in stages III and above were considered for the purpose of estimating the length at first maturity and fishes above this length were considered for determining the spawning season.

Length frequency data grouped into 10 mm intervals were used to estimate the growth parameters of the von Bertalanffy growth equation. The L_∞ and K were estimated using the ELEFAN module of FiSAT (FAO-ICLARM Stock Assessment Tools Ver.1.1) and t_0 was calculated using Pauly's empirical equation (Pauly, 1979).

The total instantaneous mortality coefficient (Z) was estimated using the length-converted catch curve method (Pauly, 1983). The natural mortality coefficient (M) was estimated following Pauly (1980). The ambient water temperature in degree centigrade considered in the present study was 28.5°C. The fishing mortality coefficient (F) was derived from the relation Z = F + M. Length-structured population analysis (VPA) of FiSAT was used to obtain population sizes and fishing mortalities per length class.

The exploitation ratio (U) was estimated from the equation $U = F/Z\ (1-e^{-z})$ and average standing stock (Y/F) and the total annual stock of biomass (Y/U) was estimated separately for each year as well as for the five year period by taking the annual average sardine stock. The relative yield per recruit (Y'/R) was obtained by Beverton and Holt equation (Beverton and Holt, 1966).

Results

Sardines were the major contributors to the total marine fish landings of Mangalore-Malpe region. An annual average of 9,060 t of sardines were landed along Mangalore and Malpe coast during 1997-98 to 2001-02. The catch showed an increasing trend varying from 5,019 t to 13,650 t forming 7%

to 14% of the total marine fish landings of Mangalore-Malpe area. Highest catch was recorded during 2001-02 and lowest in 1999-2000 (Fig.1).

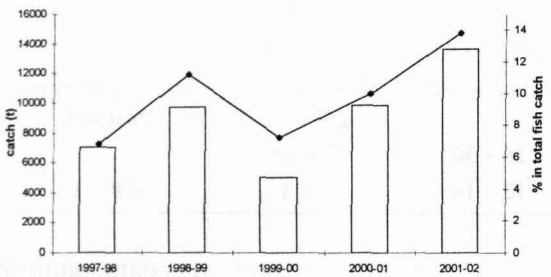

Fig. 1. *Annual sardine landings (all gears pooled) and its contribution to total fish catch at Mangalore - Malpe.*

Gearwise contribution to sardine fishery

Sardines were exploited throughout the year by a number of gears such as purse seine, trawl, boat seines (*ranibale* and *kotibale*) and gill net (Fig.2). The annual landings made by different gears are given in Figure 3. The details of different crafts and gears used in sardine fishery are given in Tables 1 and 2. Of these, the seines (purse seine and boat seine) were the most efficient, landing 94.2% of the annual total

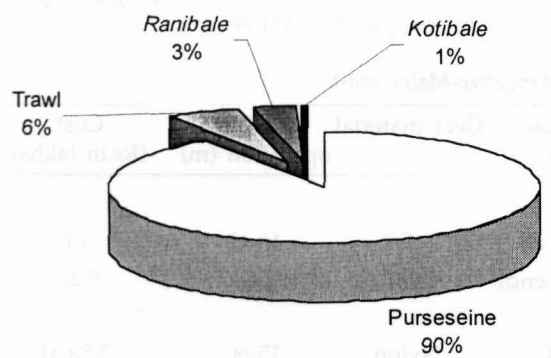

Fig. 2. *Contribution of different gears to sardine fishery at Mangalore-Malpe*

sardine catch. During 1997-98 to 2001-02 the purse seine landed an annual average catch of 8,218 t forming 90.7% of the total sardine catch by all gears. Depth-wise analysis of sardines caught by purse seine showed that they were abundant in 11-20 m depth. Of the total catch made by the purse seine, 75.7% came from 11-20 m depth, 23.2% from 20-40 m and 1.1% from less than 10 m.

Boat seines were operated only during the monsoon months (June to August) at depths up to 20 m. The gear contributed to 3.5% of the sardine catch made by all gears and 3.7% of the sardines landed by seines. The boat seines are popularly referred to as *ranibale* or *kotibale* depending on the minor modifications such as mesh size in use, operational depth, etc (Table 2). The *ranibale* and the *kotibale* landed an annual average of 256 t and 62 t respectively during the period.

Trawls landed 5.8% of the total sardine catch. Depending on the size and endurance of the craft and gear, the duration and depth of fishing, the trawlers are classified as Single-Day Trawlers (SDT) or Multi-Day Trawlers (MDT). Sardines are caught by the MDT during some months (September- May) and occasionally by the SDT. Of the total sardine catch made by the trawls, MDT contributed 80% and SDT 20%. Sardines were generally caught by trawlers at depths ranging from 20 - 70 m. The hand trawl, which is operated only during the monsoon months, rarely landed sardines.

Sardines were rarely caught by gill net.

Table 1. *Details of crafts used in sardine fishery along Mangalore-Malpe coast*

Type	Single-day trawl	Multi-day trawl	Purse seiner	Motorised canoe	Non-motorised canoe
Craft material	Wood	Wood/ Steel	Wood/ Steel	Wood/ Fibre	Wood
Mechanisation	Inboard	Inboard	Inboard	Outboard	
Horsepower	37- 88	98 -120	98 -120	8 - 25	
OAL (m)	9 -10.9	13.6 -14.5	13.6 -14.85	9.6 -12.5	
Type of gear	Fish Trawl	Shrimp Trawl	Purse seine	Shore seine/ gill nets	Seines/gill nets/ cast net
No. of crew	2 - 3	2 - 5	26 - 30	3 - 30	1 - 2
Cost (lakhs)	9.5	14 - 20	12 - 16	3 - 4	0.8 - 1

Generally, large sized lesser sardines are trapped accidentally by gill net and the annual average catch of 63 kg formed an insignificant quantity.

Period of peak production

The period of peak production of sardine along the Mangalore-Malpe coast by all gears together was during September-October (Fig. 4). The general overall trend depended on the landings of oil sardine. The pattern was similar to the catch made by the purse seine, the most dominant gear in sardine fishery. Lowest sardine catch in purse seine was observed in May. Trawls recorded peak catches during October-December and low catches during April-June. Among the indigenous gears, *ranibale* landed maximum catch during July and *kotibale* during August (Fig. 4).

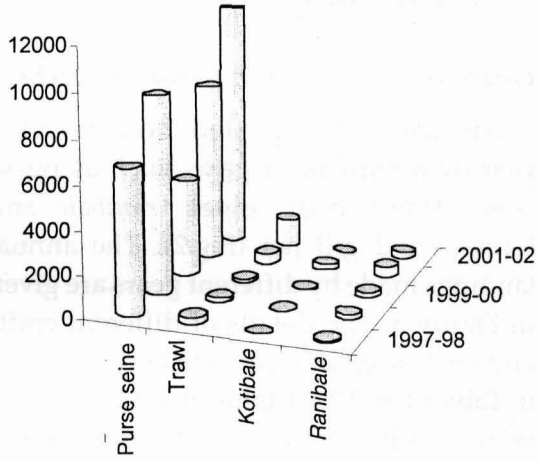

Fig. 3. *Annual sardine landing(t) by different gears at Mangalore - Malpe*

Table 2. *Details of gears used in sardine fishery along Mangalore-Malpe coast*

Type of gear	Length (m)	Height (m)	Mesh size (mm)	Gear material	Depth of operation (m)	Cost (Rs.in lakhs)
TRAWLS						
Single-day	36	-	7-16 (cod end)	HDP	10-40	0.1
Multi-day	144	-	7-16 (cod end)	HDP	50-600	0.25
SEINES						
Purse seine	450-900	35-54	16-24	Nylon	15-60	3.5-6.0
Ranibale	300-600	41.5	18-22	Nylon	5-10	1.8-3.0
Kotibale	300-600	41.5	30-32	Nylon	5-10	1.8-3.5

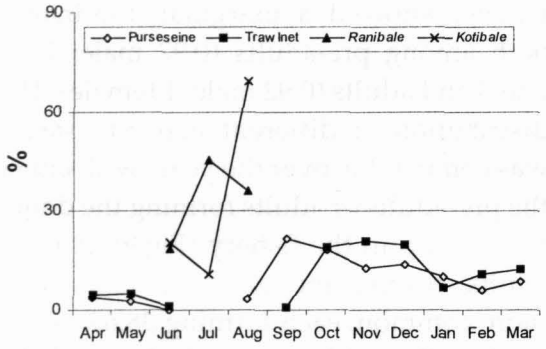

Fig. 4. *Average monthwise production (%) of sardine in different gears at Mangalore-Malpe*

Species composition

Several species of sardines contributed to the sardine fishery of this region. Of these, the oil sardine, *S. longiceps* was the most dominant and commercially important species. Over the years (1997-98 to 2001-02), it contributed 33.6% to 98.4% of the total sardine catch with an average annual of 78.9% (7,068 t). The other species which contributed to the total sardine catch were : *S. gibbosa* (16.2%, 1,557 t), *S. fimbriata* (4.7%, 417 t), *S. brachysoma* (0.2%, 15 t) and *S. albella* (0.02%, 1 t) (Fig. 5). *S. longiceps* was the dominant sardine species in all gears. It comprised 77.4% of total sardine landings by purse seines, 79.6% in trawls and 92.1% in indigenous gears.

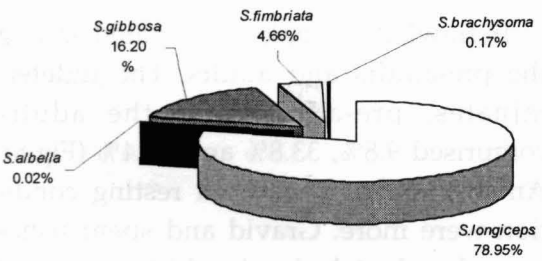

Fig. 5. *Species composition of sardines at Mangalore-Malpe (all gears pooled)*

Fishery of oil sardine

Oil sardine was landed throughout the year by one gear or the other operating along the Mangalore-Malpe coast. The annual catch fluctuated between 3,653 t in 1998-99 and 13,328 t in 2001-02 (Fig. 6). The catch generally showed an increasing trend over the years except in 1998-99. Purse seine landed bulk of the catch (90%) followed by indigenous gears (5.9%) and trawls (4.1%). Peak landing of oil sardine in purse seine was during September-October and in the trawl it was during October-November. The indigenous gears landed maximum catch in July.

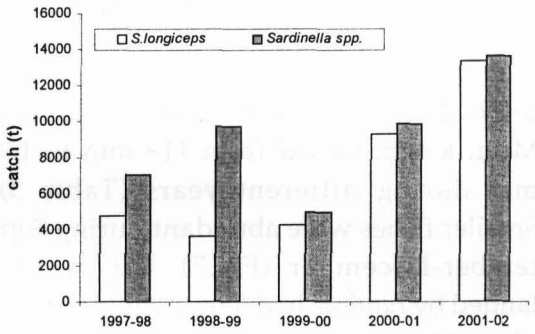

Fig. 6. *Annual landings of* Sardinella longiceps *and* Sardinella *spp. at Mangalore-Malpe (all gears pooled)*

Length distribution of oil sardine

The length distribution of oil sardine by all gears along the Mangalore-Malpe region ranged between 40mm and 220 mm with multiple modes. The mean length of the fish ranged between 138 mm and 146 mm during the five years of observation. Gearwise length distribution revealed that the length range was wide in the trawl catch as compared to seines. The boat seine landed mostly larger fishes whereas the

purse seine and trawl net landed more of smaller sized fishes (Fig.7). The length of oil sardine landed by the purse seiners ranged from 60 mm to 215 mm with a major mode at 125 mm and a minor mode at 175 mm (Fig.7). Smaller sized fishes were abundant during September-December. The annual mean length of oil sardine caught by purse seine ranged from 137 mm to 148 mm (Table 3).

Table 3. *Annual gearwise mean lengths of* S.longiceps

Gear	1997-'98	1998-'99	1999-'00	2000-'01	2001-'02
Purse seine	143	137	144	145	148
Trawl net	141	168	138	151	119
All gears	143	138	143	146	138

In trawl, the length ranged from 40 mm to 215 mm with a major mode at 110 mm. Mean length varied from 119 mm to 168 mm during different years (Table 3). Smaller fishes were abundant during September-December (Fig.7). Oil sardine landed by *ranibale* had length ranging from 65 to 220 mm with a major mode at 165 mm and a minor mode at 110 mm. The annual mean length of the fish during the observation period ranged between 132 mm and 180 mm (Table 3). Young fishes were observed in July (Fig.7). In *kotibale* the length of oil sardine ranged from 90 to 205 mm. Major mode was at 165 mm. Smaller sized fishes were observed in August (Fig. 7).

Sex and maturity of oil sardine

Indeterminates, pre-adults and adults formed 4.8%, 45.8% and 49.4% respectively of the total catch (Fig.8). Overall, the females showed a marginal dominance both among pre-adults (0.97 male: 1 female) and adults (0.92 male: 1 female). The distribution of different maturity stages was comparable over the years with either the pre-adults or adults forming the dominant group in the fishery (Fig.9). Among adults, resting and gravid gonads were more common, each forming 38.6% of the catch, followed by spent (16.3%) and developing (6.1%) (Fig. 10). During 1997-98 the pre-adults formed the major group (66.1%) (Fig.10). Of the adults, the gravid stage comprised (61.8%) the major group (Fig.10). So during the period, the percentage of adult fishes was less and further most of the adults were caught before they could spawn.

Oil sardine caught by purse seine showed a similar trend with females being marginally more among pre-adults (51.1%) and adults (51.7%). The indeterminates, pre-adults and adults comprised 3.3%, 54.7% and 42.1% respectively (Fig.8). Resting stage dominated among adults (41.9%) (Fig.11). Fishes with gravid and spent gonads occurred more frequently during June-August. Indeterminate fishes were abundant during September-November (Fig.7).

In trawl, the females dominated among the pre-adults and adults. The indeterminates, pre-adults and the adults comprised 9.8%, 33.8% and 56.4% (Fig.8). Among adults, gonads in resting condition were more. Gravid and spent fishes were abundant during April-May followed by young fishes during September-

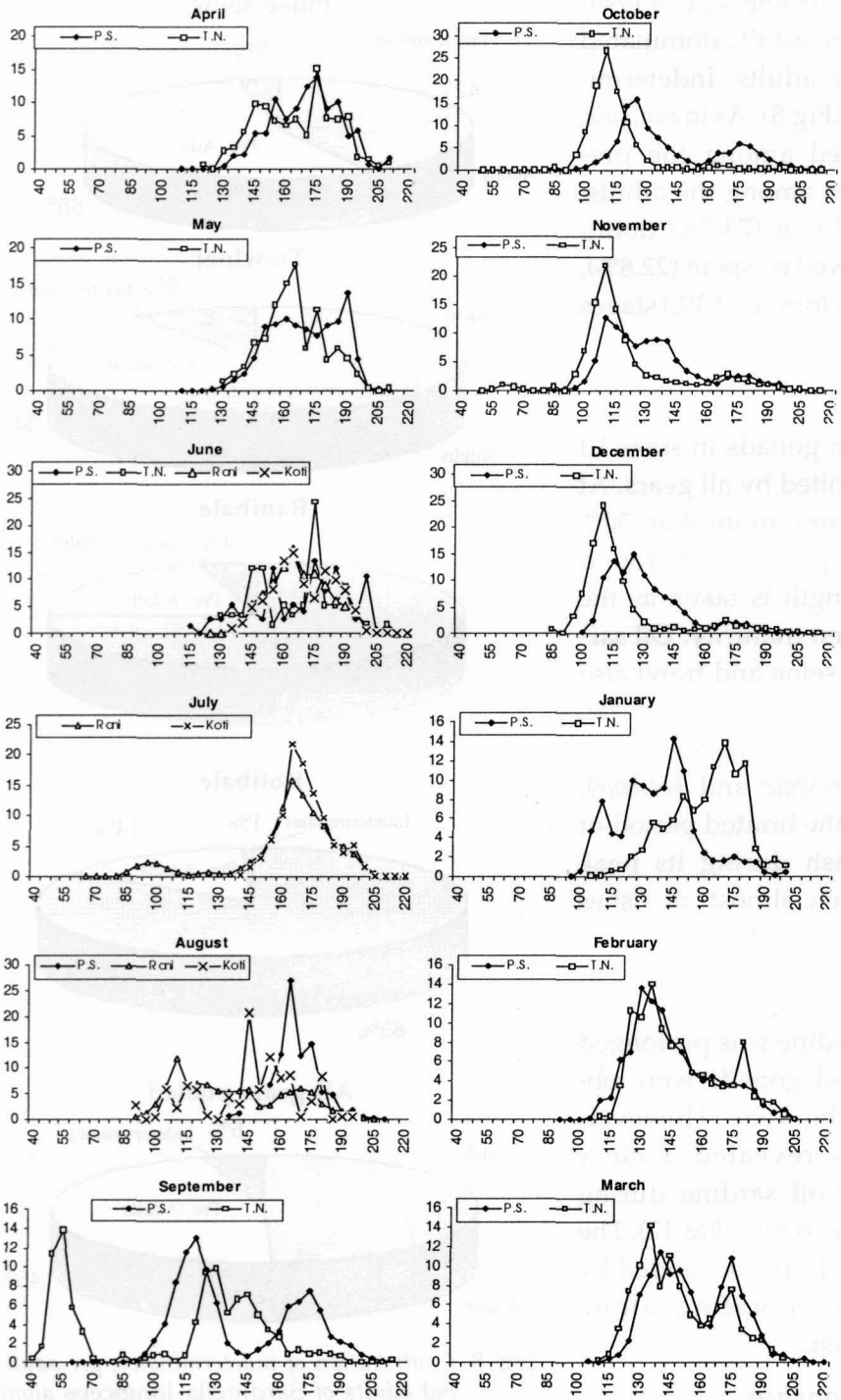

Fig. 7. *Monthly gearwise length frequency distribution of* Sardinella longiceps *Mangalore - Malpe*

October (Fig.7).

The sex ratio and gonad maturity of oil sardine landed by the *ranibale* showed a slight variation with the males being dominant among the pre-adults and the females among the adults. The indeterminates, pre-adults and the adults comprised 5.2%, 22.8% and 72.0 % respectively (Fig.8). Among adults, spent fishes were the major contributors (89.3%). Fishes with gravid, resting and developing gonads comprised 6.4%, 2.1% and 2.6% respectively. The dominance of fishes with gravid and spent gonads indicated that they were actively spawning during monsoon months (Fig.12).

Kotibale operated only at Malpe Fisheries Harbour during the monsoon

months and landed oil sardine only in 1999-2000 and 2000-2001. Pre-adults dominated the catch followed by adults. Indeterminate fishes formed 5% (Fig.8). As in *ranibale*, the females dominated among the pre-adult group and males among the adults. Fishes in gravid condition (73.7%) dominated the fishery followed by spent (22.8%), resting (3.6%) and developing (0.3%) stages (Fig.11).

Size at first maturity

Mature fishes (with gonads in stage III and above) were exploited by all gears. At a total length of 160 mm, more than 50% of oil sardine (all gears pooled) were found to be mature. This length is taken as the minimum length at first maturity. Oil sardine landed by purse seine and trawl also attained maturity at a total length of 180 mm compared to 150 mm in fishes caught by the boat seine (*ranibale* and *kotibale*). This might be due to the limited period of exploitation of the fish during its peak spawning period when almost all fishes caught were in stages V-VII.

Spawning season

Spawning in oil sardine was prolonged and fishes with gravid gonads were observed throughout the year. However, monthwise analysis revealed a clear spawning period for oil sardine during June-August with peak in July (Fig.12). The trend was similar in oil sardine landed by the different gears operating along Mangalore-Malpe coast.

Length-weight relationship

A common length-weight relationship

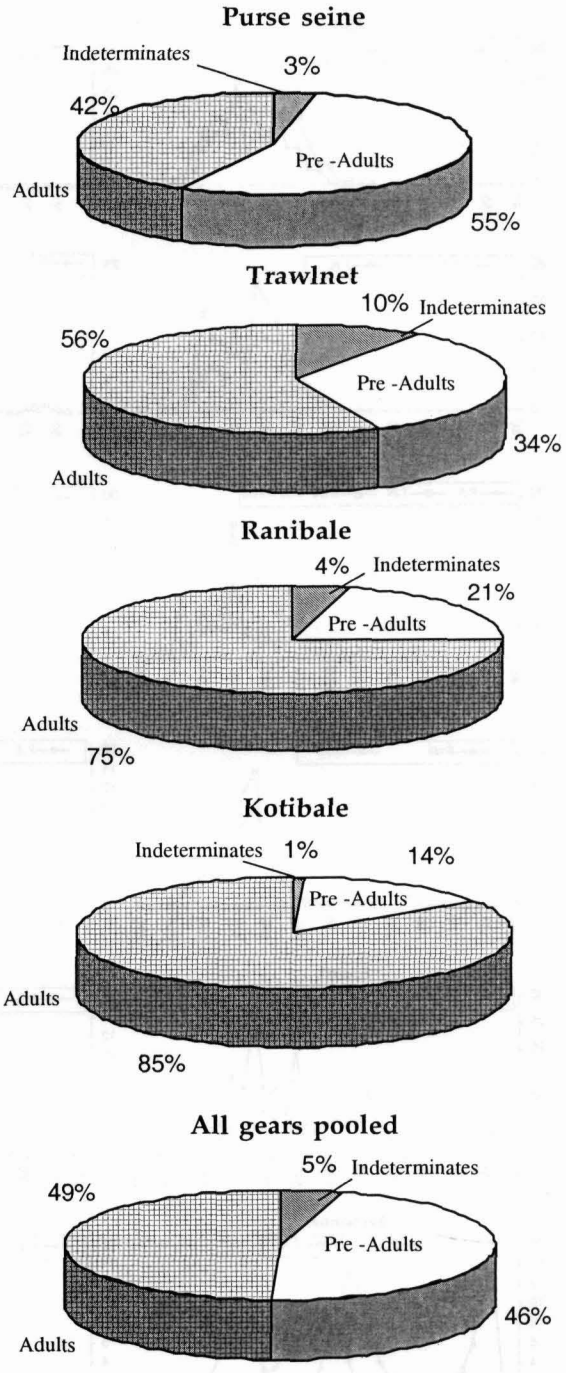

Fig. 8. *Contribution of indeterminates, pre-adults and adults of* Sardinella longiceps *along Mangalore-Malpe coast during 1997-98 to 2001-02*

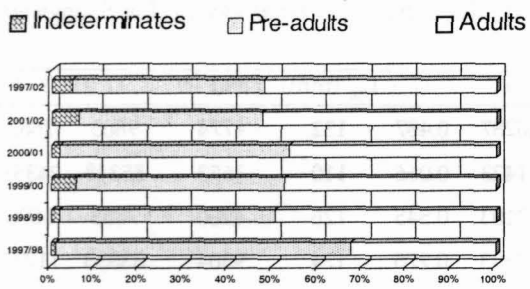

Fig. 9. *Annual distribution of indeterminate, pre-adult and adult stages in* S. longiceps *along Mangalore-Malpe coast (all gears pooled)*

for males and females of oil sardine was estimated (W = weight of sardine in gm and L = total length of fish in cm.) as:

$$W = 0.01189*L^{2.86}$$

Growth and stock structure

Growth of oil sardine was studied separately for five consecutive years. The L_∞, K and t_o with the length at age observed during the consecutive years are given in Table 4. The growth curves were fitted through the restructured length frequency histograms derived by ELEFAN-I. The growth, mortality parameters (F, M and Z), exploitation ratio (E), survival (S), exploitation rate (U), L_{50}, standing stock (Y/U), biomass (Y/F) and MSY estimated for the different years are given in Table 5. L_∞ values of oil sardine ranged from 212 to 228 mm over the years and the growth curvature, K from 0.85 to 1.09 $year^{-1}$. The exploitation ratio varied between 0.18 and 0.55. The values estimated for the five year period showed that the fish attain a maximum average length of 228 mm with a K value of 0.9 yr^{-1}.

Price structure

The price of oil sardine ranged from Rs.12/- to 25/- per kg. The price was higher during the initial years when the catch was comparatively less (Table 6). However,

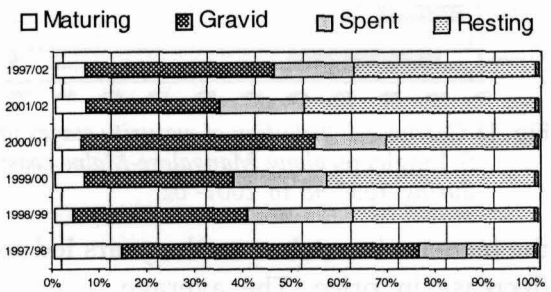

Fig. 10. *Annual distribution of different maturity stages in adult* S. longiceps *along Mangalore-Malpe coast (all gears pooled)*

Table 4. *Annual growth parameters and length at age of* S.longiceps

Year	L_∞(mm)	K yr^{-1}	t_o	Length (mm) at age (yrs.)				
				1	2	3	4	5
1997-98	220	0.85	-0.0121	127	180	203	212	217
1998-99	212	0.86	-0.0119	123	174	196	205	209
1999-00	225	1.09	-0.0068	150	200	217	222	224
2000-01	218	0.93	-0.0099	133	184	205	213	216
2001-02	226	0.90	-0.0106	135	189	211	220	224
1997-02	228	0.90	-0.0106	136	191	213	222	225

Table 5. *Annual mortality rates, exploitation rates, survival rates, exploitation ratios and yield of* S.longiceps *along Mangalore-Malpe coast*

Year	L_∞(mm)	Z	M	F	E	S	U	L_{50} (mm)	Yield (t)	Y/U (t)	Y/F
1997-98	220	3.55	1.77	1.78	0.5	0.0287	0.487	132	4774	9803	2682
1998-99	212	1.95	1.8	0.15	0.08	0.1423	0.066	110	3653	55348	24353
1999-00	225	4.58	2.06	2.52	0.55	0.0103	0.545	126	4280	7853	1698
2000-01	218	2.67	1.88	0.79	0.3	0.0693	0.275	124	9304	33833	11777
2001-02	226	2.23	1.82	0.41	0.18	0.1075	0.164	105	13328	81268	32507
1997-02	228	2.74	1.51	0.93	0.34	0.0646	0.317	113	7068	22297	7600

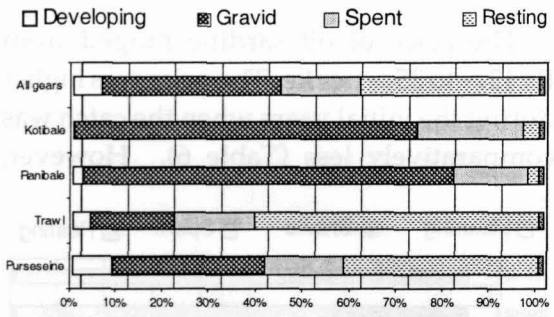

Fig. 11 *Gearwise distribution of maturity stages in* S. longiceps *along Mangalore-Malpe coast during 1997-98 to 2001-'02*

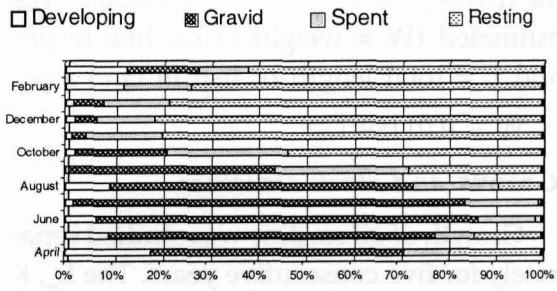

Fig. 12 *Average monthwise distribution of maturity stages in* S. longiceps *(all gears pooled) along Mangalore-Malpe coast during 1997 to 98 - 2001-02*

the increase in catch over the years led to decrease in price. The average revenue generated by oil sardine during the study period was Rs.11.7 crores. This formed 93.1% of the total revenue generated by sardines landed at Mangalore and Malpe. The price of lesser sardines ranged from Rs. 4/- to 6/- per kg. On an average, lesser sardines contributed to Rs. 0.87 crores forming 6.9% of the total revenue generated by sardines.

Table 6. *Annual and total revenue generated by oil sardine and lesser sardines along Mangalore-Malpe coast*

	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002
Oil sardine					
Catch (t)	4774	3653	4280	9303	13328
Value (Rs.in crores)	**10.50**	**9.13**	**9.84**	**13.02**	**15.99**
Lesser sardines					
Price per kg	5	4	4	5	6
Catch (t)	2300	6041	738	552	321
Value (Rs.in crores)	**1.15**	**2.42**	**0.30**	**0.28**	**0.19**
Total value (Rs. in crores)	**11.65**	**11.55**	**10.14**	**13.3**	**16.18**

Discussion

Sardines, the major marine fishery resource group of Karnataka determined the trends in marine fishery production of the state. Annual and seasonal fluctuations inherent to the fishery are directly reflected in the total fish catch of the state. Environmental parameters like temperature, rainfall intensity, thermocline, upwelling, solar periodicity, etc. are known to greatly influence the spawning, recruitment and yield of pelagic stocks like sardine (Chidambaram, 1950; Murty and Edelman, 1970; Annigeri, 1971, 1989; Antony Raja, 1972; Balan, 1984; Kawasaki, 1989; Longhurst and Wooster, 1990; Annigeri *et al.*, 1992; Madhuprathap *et al.*, 1994; Devaraj *et al.*, 1997; Yohannan *et al.*, 1998; Ganga, 2000; Jayaprakash, 2002). It has now been nearly proved that rainfall intensity and periodicity directly have a bearing on the long term fluctuations and abundance of oil sardine (Jayaprakash, 2002). Short term fluctuations are further affected by fishery related factors like fishing intensity, improved fishing techniques and expansion of fishing grounds, spawning success, food availability, etc. Though the sardine catch registered a general increasing trend along Mangalore-Malpe coast, a reduction(20%) was observed during 1999-2000 as compared to the previous year. All gears operating along this coast registered a reduction in total catch during that year. Such short-term fluctuations in catch are common along this coast and are due to several biotic and abiotic factors (Muthiah *et al.*, 2000). Year-wise biological analysis of oil sardine landed along this coast showed that during 1997-98 the adults formed only 32.7% of the total catch (the least observed during the five year period). Furthermore, fishes in gravid condition formed 61.8% of the adults landed (highest observed for the five year period). The large scale exploitation of adults mainly with gravid gonads must have affected the recruitment and thus the fishery in the following year to a certain extent.

Stock assessment studies on oil sardine have shown that Y/R is 2.38 g and B/R at 2.56 g, comprising 38% of the virgin biomass. Maximum Y/R (MSY/R) was estimated as 3.26 g with the F_{MSY} at 4.4. The present yield (7,068 t) is less than the estimated MSY (9,677 t) (Fig. 13). Hence it is evident that the resource is under exploited and optimum yield could be obtained by increasing the present effort by 21%. However, such a steep increase in effort may not necessarily result in higher remuneration from the fishery, as the catch-per-unit-effort will considerably decrease. Increasing the age at first capture from the present 0.76 years to 0.97 years can profitably increase the yield. Future, short-term management plans will have to aim at in-

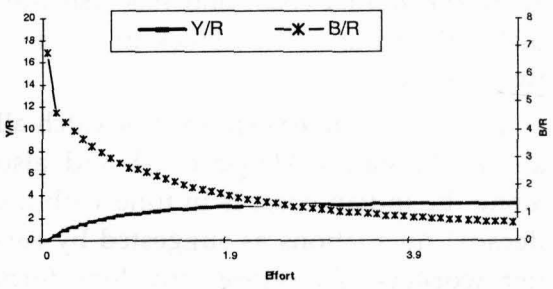

Fig. 13. *Y/R and B/R curves for* S. longiceps (1997-98 to 2001-02)

creasing the size at first capture of oil sardine and limit capture of fishes during the peak breeding season so as to get long-term benefits. Appropriate management measures can be suggested to limit the effort to obtain maximum yield. However, in the case of pelagic fishes as observed by Devaraj *et al.* (1997), the catch of small pelagics does not bear any significant relationship with the effort after a certain level and so the regulation of effort becomes a function of fisheries economics. So the economic returns of the fishery play an equally important role in suggesting appropriate management options to obtain optimum yields within the short-term fluctuations inherent in the fisheries of small pelagics.

Long-term fluctuations in pelagic clupeids especially sardines have been closely related with changing environmental parameters like earth's rotation (Tameishi *et al.*, 1988), sunspot activity (Srinath, 1998), mean sea level (Longhurst and Wooster, 1990) and rainfall intensity (Jayaprakash and Pillai, 2000; Jayaprakash, 2002). Jayaprakash (2002) has described the relationship between rainfall intensity and the decadal fluctuation in oil sardine fishery along the Kerala coast and has also predicted the future of the stock in the next two decades.

The steady increase in sardine catch all along Mangalore-Malpe coast and also along the Indian coast is in tune with the decadal fluctuations as suggested by earlier workers. Therefore, any long-term management measures to be taken will have to consider non-fishery related factors affecting the sardine fishery. Time series data of non-fishery related factors will have to be analysed in detail and compared with the health of the sardine stocks on a periodic basis to suggest effective management measure for the optimal exploitation on a long-term basis.

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