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Stock assessment of silverbellies of India with particular reference to Andhra Pradesh and Tamil Nadu

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ABSTRACT

Along Indian coasts, the silverbellies are exploited by trawl and artisanal gears but bulk of the landings are obtained by trawls which operate up to 50 m depth. During 1979–83, the estimated annual average silverbelly landings were 69 000 tonnes, whereas during 1984–88 these were 62 000 tonnes. Maximum silverbelly landings were obtained in Tamil Nadu which contributed 70.5% of total all-India silverbelly landings followed by Andhra Pradesh (9%), Kerala (8.4%), Karnataka (6%) and other states (6.1%). Out of 20 species of silverbellies, known to occur in the seas around India, *Leiognathus bindus* and *Secutor insidiator* were most dominant along Andhra Pradesh and northern Tamil Nadu coasts, together contributing to 64% and 55% respectively of silverbelly landings. Along southern Tamil Nadu, *L. jonesi* and *L. dussumieri* were most dominant together forming about 60% of silverbelly catch in the region.

The available information on the biology of different species from several localities along Indian coast was reviewed. Parameters of growth and mortality of dominant species were estimated. Stock assessment was made separately for *L. bindus* and *S. insidiator* and then mixed fisheries assessment made for these two species combined from Andhra Pradesh and northern Tamil Nadu. From southern Tamil Nadu coast, stock assessment was made for *L. jonesi* and *L. dussumieri* separately and combined. Along Andhra Pradesh coast, the effort level was found greater than the one yielding MSY in the existing fishing grounds. In northern Tamil Nadu there was scope to increase the fishing effort to get MSY. In southern Tamil Nadu yield can be increased by about 1.5% through increasing the effort by 40%. The assessment of yield of *L. bindus* and *S. insidiator* in relation to cod end mesh size of trawl along Andhra Pradesh showed the need to reduce the cod end mesh size by about 40%. In northern Tamil Nadu also more or less similar situation existed. In southern Tamil Nadu, the MSY corresponded to the existing cod end mesh size and, therefore, did not warrant any change in the latter.

The fishes of the family Leiognathidae, popularly called as silverbellies or ponyfishes, are among the important demersal fishes contributing to the fisheries along Indo-west Pacific region. Though these are small and are considered as trash fish at certain places, the quantities landed make them important both from fishery and management point of view. Silverbellies are known to be more abundant in shallower regions in the sea (James 1973; Pauly 1977a, b; Pillai and Dorairaj 1985; Sudarsan *et al.* 1988; Sivaprakasam *et al.* 1991) up to about 40 m depth though they are available in depths of 100–150 m also (Sudarsan *et al.* 1988). These fishes are known to undertake diurnal vertical migrations staying at the bottom during day time and moving up to surface and subsurface waters during nights (Venkatraman and Badrudeen 1974, Murty

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1986b). A lot of work has been done on various aspects of these fishes as evidenced by two bibliographies exclusively on these fishes (Pauly and Pauly 1981, James *et al.* 1992). In India an estimated 53 876 tonnes of silverbellies landed during 1990 (Anonymous 1991) which formed 5.7% of the total demersal fish and 2.5% of total marine fish landings.

Total 20 species of silverbellies are known from India and a lot of work on distribution, taxonomy, biology and fishery has been done (Arora 1952; Balan 1967; James, 1967, 1969, 1973, 1975, 1986; Pillai 1972; Venkatraman and Badrudeen 1974; James and Badrudeen 1975, 1981, 1986, 1991; Rani Singh and Talwar 1978a, 1978b; Annam and Dharmaraja 1981; Kurup and Samuel 1983; Murty 1983, 1991; Jayabalan 1985, 1986, 1988a, 1988b; Jayabalan and Ramamoorthy 1985a, 1985b, 1985c, 1986; Pillai and Dorairaj 1985; Vivekanandan and Krishnamoorthy 1985; James *et al.* 1987; Reuben *et al.* 1989 and Srinath 1989). Population dynamics of dominant species from particular localities have also been studied (Venkatraman *et al.* 1981; Murty 1985, 1986a, 1986b, 1991 and Karthikeyan *et al.* 1989). An attempt is made here to study the dynamics of the exploited silverbelly resources making use of data obtained during 1984–88 on dominant species of the group from Andhra Pradesh and Tamil Nadu coasts. The results are presented in this paper.

MATERIALS AND METHODS

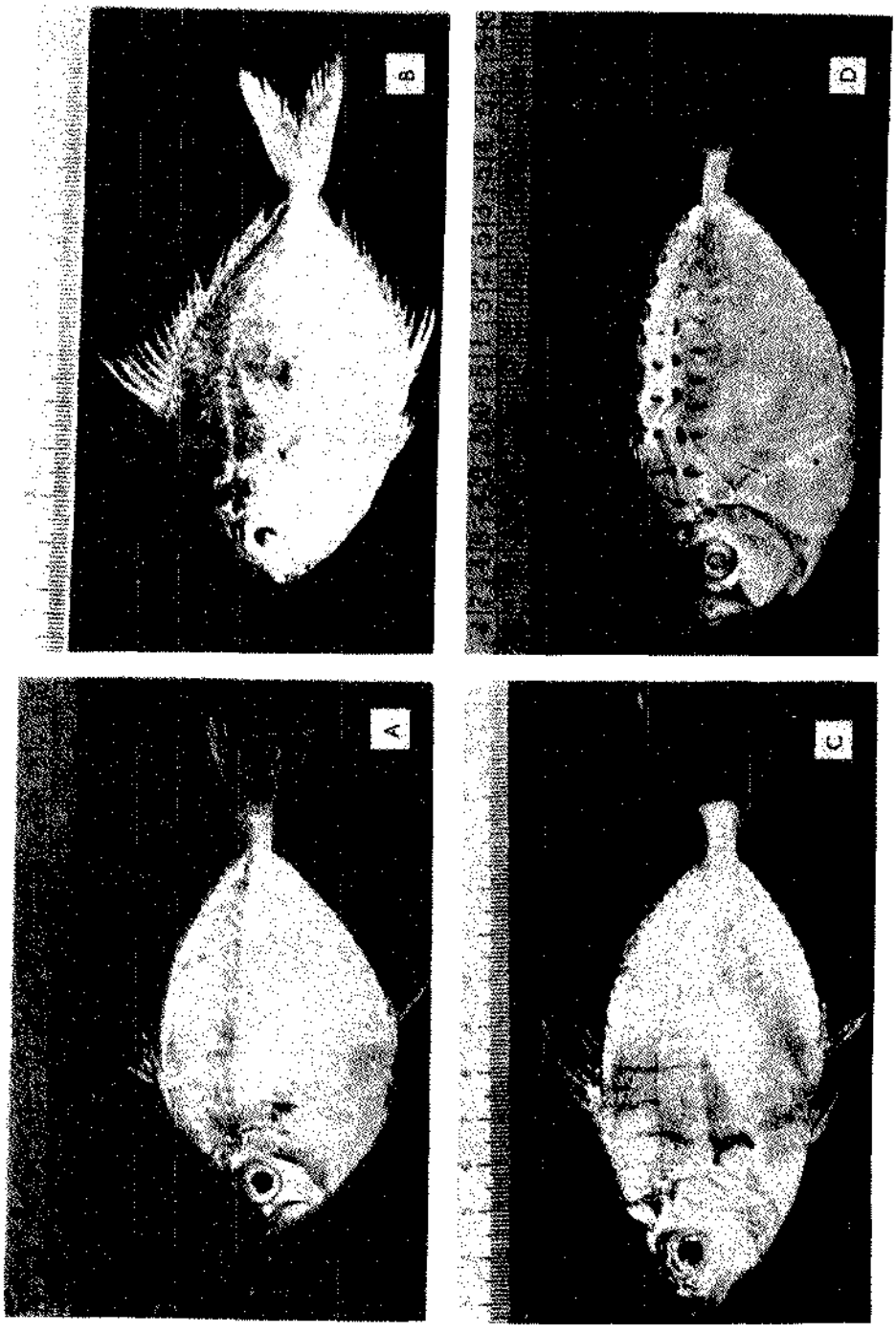
Data obtained from trawl landings only were considered. Bulk of the silverbelly landings in India were obtained from Tamil Nadu–Pondicherry and Andhra Pradesh and considerable data were generated from this region. The stock assessment in the present study was, therefore, restricted to this region.

The estimates of districtwise and gearwise effort and districtwise, gearwise and groupwise/specieswise landings made by the Central Marine Fisheries Research Institute for the years 1984–88 were used for the present study. Further, the estimates of catch for each maritime state pertaining to the period 1979–88 were also used.

Detailed data on effort and catch were collected for 18 days in a month and on species composition, length composition and biology of dominant species for 4–8 days every month from the trawl landing centres at Visakhapatnam, Kakinada, Madras and Mandapam. These data of 1984–88 formed the major input for this study.

For stock assessment, *Leiognathus bindus* and *Secutor insidiator* from Andhra Pradesh and northern Tamil Nadu–Pondicherry; and *L. jonesi* and *L. dussumieri* from southern Tamil Nadu were selected because these species were most dominant in these regions and determined the success or failure of silverbelly fishery in the respective areas.

Species composition and length frequency distribution: At each of the above four trawl landing centres, samples were collected from different boats and brought to the laboratory for taking data on species composition, length composition and biology. Total length was considered for length frequency and other studies. The data on species composition and length composition collected on each observation day were first weighted respectively to the estimated total catch of the group and species obtained on that day and such estimates in a month were pooled and then raised to the estimated catch of the month as per Alagaraja (1984). The monthly estimates were pooled to get quarterly and annual estimates. To obtain estimates of total catch (weight) of each species as well as catch (numbers) at length also of each species, the data obtained at the observation centres were suitably weighted to get estimates for each



A. Lissognathus bimlax. **B.** *L. jonesi.* **C.** *L. dassumieri.* **D.** *Secutor insidiator.*

state. As the data on production from each district were available in the form of quarterly estimates, the monthly estimates from each observation centre pooled for each quarter (January–March: I quarter, April–June: II quarter, July–September: III quarter, October–December: IV quarter) were weighted to get quarterly estimates. For this purpose, the data obtained at Visakhapatnam were raised to those obtained in the northern districts of Srikakulam, Vijayanagaram and Visakhapatnam together, and those from Kakinada to the data obtained in the remaining coastal districts (East Godavary, West Godavary, Krishna, Guntur, Prakasam and Nellore) of Andhra Pradesh (Fig. 1). The former is referred as northern Andhra Pradesh and the latter as southern Andhra Pradesh. In Tamil Nadu–Pondicherry (Fig. 2), the data obtained at Madras were weighted to those of Madras, Chengalpattu, South Arcot and Pondicherry together and those obtained at Mandapam (Mandapam, Pamban and Rameswaram) to the ones from the southern coastal districts of Thanjavur, Pudukkottai, Ramanathapuram (presently Muthuramalingam and Ramanathapuram), Tirunelveli (presently Chidambaranar and Kattabomman) and Kanyakumari. These two areas are referred to as northern Tamil Nadu (A in Fig.2) and southern Tamil Nadu (B in Fig. 2) respectively. Stock assessment was done separately with these sets of data. For Andhra Pradesh, the two estimates were pooled to get estimates for the state because the species dealt with from the two regions were the same. For Tamil Nadu-Pondicherry, however, the species dealt with were not same from the two centres as the dominant species were different in the two regions. The estimates obtained, therefore, were treated separately.

Biology: The results of detailed studies made on aspects of biology of particular species were taken from published work.

Estimation of von Bertalanffy growth parameters: The parameters of growth in length were estimated following the ELEFAN method (Pauly and David 1981, Gayanilo *et al.* 1988); the estimates were made using the monthly length frequency distribution of catch of the species, separately from each of the four centres. In the data of each year, different starting lengths and 'samples' were used and best fit values were taken. Thus, 2-4 sets of growth parameters in each year from each centre were obtained for each species. Of all such estimates in all the five years, the smallest and largest L_∞ values and their associated K values were selected from each centre for all further studies. The results obtained by using the largest L_∞ and its associated K were referred to as having been obtained by using 'higher parameters' and those obtained by using the smallest L_∞ and its associated K by 'lower parameters'.

Mortality rates: The estimates of instantaneous total mortality rate (Z) were made using length-converted catch curve method (Pauly 1982) using the data of all the five years pooled and the LFSA package of Sparre

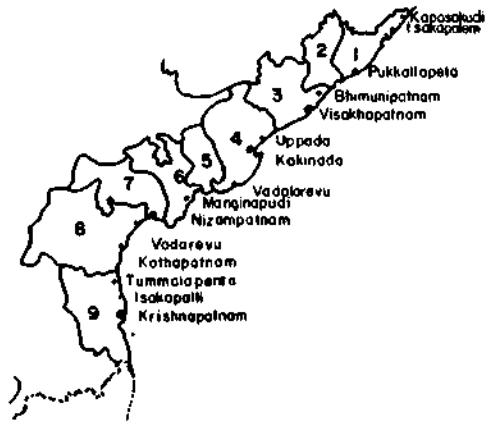


Fig. 1. Map of coastal districts of Andhra Pradesh. 1, Srikakulam; 2, Vijayanagaram; 3, Visakhapatnam; 4, East Godavary; 5, West Godavary; 6, Krishna; 7, Guntur; 8, Prakasam; 9, Nellore.

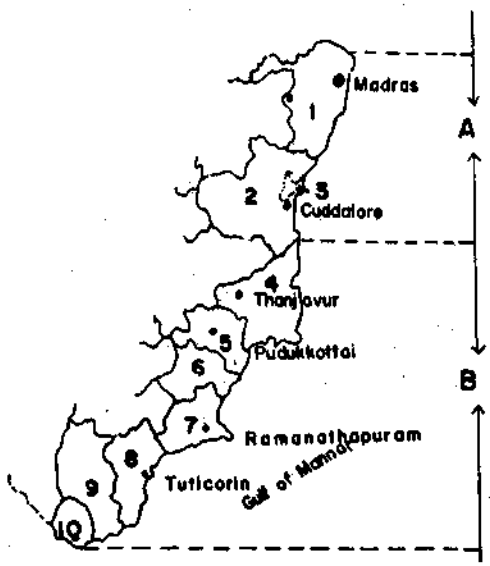


Fig. 2. Map of coastal districts of Tamil Nadu and Pondicherry. 1, Chengalpattu and Madras; 2, South Arcot; 3, Pondicherry (U.T.); 4, Thanjavur; 5, Pudukkottai; 6, Muthuramalingam; 7, Ramanathapuram; 8, Chidambaranar; 9, Kattabomman; 10, Kanyakumari.

(1987). The natural mortality rate (M) was estimated using the empirical formula of Pauly (1980) and then the fishing mortality (F) as Z–M. For each species from each centre estimates of mortality rates were made separately using both the sets of growth parameters.

Lengths at recruitment and first capture: The mid point of the smallest length group in the catch during the five-year period was taken as length at recruitment (L_r). The lengths corresponding to the first values in the descending limbs of the length-converted catch curves (with both the sets of growth parameters separately) were taken as lengths at first capture (L_c).

Yield and biomass: The data on catch (numbers) at length of each species at each centre weighted to total catch of the species of the region(north Andhra, south Andhra, north Tamil Nadu, south Tamil Nadu) in each year were pooled for the five years (1984–88) and average annual values obtained; these were used as input for the study. Yield and biomass at different effort levels were estimated by the length-converted Thompson and Bell (1934) analysis (Sparre 1985, Murty 1989) and the programme MIXFISH of LFSA package of Sparre (1987). In each species, the yield and biomass at different effort levels were first estimated separately using the statistics obtained with the help of 'lower' and 'higher' growth parameters. The average of the values corresponding to each effort level were then obtained and were considered in this study.

The assessment of different species was done separately and combined from each region of Andhra Pradesh and Tamil Nadu.

Yield and cod end mesh size: Trawl data alone were considered for this purpose. For studying the effects of changes in cod end mesh size on the yield, the following procedure was adopted using the data of each region in Andhra Pradesh and Tamil Nadu-Pondicherry:

a. For each species the present t_c values (corresponding to L_c values as stated above) were taken. These values in each species were decreased and increased by the same factor (as 10%, 20%,. . . . . 150% . . . . . 200% of present t_c).
b. Using these resultant t_c values, the present F and other required parameter values, the Beverton-Holt (1957) yield-per-recruit (Y_w/R) analysis was made.
c. Taking the value of yield-per-recruit (Y_w/R) at current F and t_c and the value of annual average yield of the species during 1984–88, the recruitment in numbers ($R = Y + Y/R$) was estimated.
d. The Y_w/R at each t_c in each species as obtained at 'b' above, was weighted by

the value of R obtained in 'c' above to obtain values of yield in weight at different t_c values (i.e. percentage of present t_c).

e. In each species, the yield corresponding to different t_c levels was first estimated separately using the statistics obtained with 'lower' and 'higher' growth parameters and averages of yield corresponding to each t_c level were then obtained and used for this study.

f. The values of yield at different t_c levels for different species in each region were pooled to get the combined yield-mesh curves for the species considered.

The results pertaining to the two regions in Andhra Pradesh were pooled and those pertaining to northern Tamil Nadu-Pondicherry and southern Tamil Nadu were treated separately for reasons stated earlier.

RESULTS

Fishery

Along Indian coasts, the silverbellies are exploited by trawl and a variety of artisanal gears such as shore seine, boat seine, gillnet, etc. However, these fishes are caught in large quantities by trawls which are operated in shallower regions up to 50 m depth.

All-India silverbelly catch: The landings in India during 1979–88 (Fig. 3) showed that they ranged from about 53 000 tonnes (1985) to 92 000 tonnes (1983). During the first half of 1979–88 period, the average annual landings were estimated at 69 000 tonnes whereas during the second half of this period the same was 62 000 tonnes. Though the fluctuations in the annual landings were not very large (except 1983), with the annual average during 1979–88 at 69 000 tonnes, the landings showed a declining trend. In fact, in 1989 and 1990, the annual silverbelly landings in India were estimated as 49 000 tonnes and 54 000 tonnes respectively (Anonymous 1991).

Catches in different states: The silverbelly landings in different maritime states and union territories during the decade 1979–88 showed that maximum landings were obtained in Tamil Nadu (70.5%) followed by Andhra Pradesh (9%), Kerala (8.4%), Karnataka (6%) and others. The maximum estimated landings in any year were about 62 000 tonnes in Tamil Nadu in 1983, followed by 11 500 tonnes in Karnataka in 1986, 9 900 tonnes in Andhra Pradesh in 1981, and others (Table 1). Thus the southeast and southwest coasts contribute to over 90% of silverbelly landings in India.

Districtwise landings: In Andhra Pradesh (Fig. 4.A), maximum silverbelly production was obtained in Srikakulam district with annual average of 2 100 tonnes during 1986–88 forming 35% of total silverbelly landings in Andhra Pradesh. This was followed by East Godavary (1 645 tonnes, 27.7%), Nellore (992 tonnes, 16.7%), Visakhapatnam (709 tonnes, 11.9%), Prakasam (234 tonnes, 3.9%), Guntur (170 tonnes, 2.9%), Vijayanagaram (51 tonnes, 0.9%), West Godavary (23 tonnes, 0.4%)

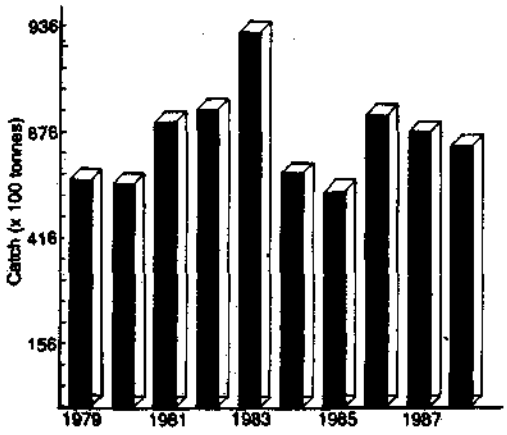


Fig. 3. Estimated annual landings of silverbellies in India during 1979–1988.

Table 1. Estimated landings (tonnes) of silverbellies in different maritime states and union territories of India during 1979–88

Years	West Bengal	Orissa	Andhra Pradesh	Tamil Nadu	Pondicherry	Kerala	Karnataka	Goa	Maharashtra	Gujarat	Andamans	Total
1979	96	1 108	3 585	43 083	746	3 597	156	881	724	–	78	54 054
1980	34	707	3 832	38 237	681	4 148	4 713	1 727	406	–	102	54 587
1981	–	733	9 856	50 942	975	2 826	1 638	2 075	129	–	275	69 449
1982	24	1 133	5 132	52 577	538	8 730	2 417	1 011	169	–	937	72 668
1983	75	587	8 154	62 116	1 763	9 511	7 024	1 342	929	37	195	91 733
1984	95	363	5 035	39 912	924	3 911	3 355	1 669	1 016	456	381	57 118
1985	399	708	5 348	37 410	1 359	3 419	2 518	764	62	357	381	52 725
1986	179	211	5 392	44 515	1 095	6 029	11 541	1 445	144	57	742	71 350
1987	81	428	8 904	46 276	871	6 027	2 314	860	195	151	643	66 750
1988	20	469	3 505	46 790	329	6 522	2 615	1 664	273	1 094	476	63 757
Annual average	100	645	5 874	46 186	928	5 472	3 829	1 344	405	215	421	65 419

and Krishna (20 tonnes, 0.3%) districts. In Srikakulam and Vijayanagaram there was no trawling and maximum silverbelly production was obtained by boat seine followed by shore seine and other artisanal gears. In West Godavary the trawl landing was almost nil and shore seine landed the bulk of silverbelly catch. In Prakasam district, trawls contributed to about 40% of silverbelly production and in all the remaining districts the contribution of trawl to the production of these fishes ranged from 61% to 93%. In Andhra Pradesh as a whole, the trawl accounted for 47% of silverbelly landings and the remaining by other gears.

In Tamil Nadu (including Pondicherry) (Fig. 4.B), Ramanathapuram (presently Muthuramalingam and Ramanathapuram districts, Fig. 2) contributed to bulk of silverbelly landings with annual average of 17 323 tonnes during 1986–88 forming 45% of silverbelly landings in Tamil Nadu–Pondicherry. This was followed by Pudukkottai (10 650 tonnes, 27.5%), Thanjavur (5 216 tonnes, 13.5%), Tirunelveli (presently Chidambaranar and Kattabomman districts, Fig.2) (5 211 tonnes, 13.4%), South Arcot (3 150 tonnes, 8.1%), Madras (2 913 tonnes, 7.5%), Chengalpattu (1 075 tonnes, 2.8%), and Kanyakumari (352 tonnes, 0.9%) districts and Pondicherry (749 tonnes, 1.9%). In all the districts except Chengalpattu, there were considerable landings by trawlers and the contribution of trawl to total silverbelly production ranged from 77% to 99.5%; in Kanyakumari district, however, the trawlers contributed to only 25% of silverbelly landings. In northern Tamil Nadu, the trawl catch formed about 80% of total silverbelly catch and in southern Tamil Nadu it was 96%.

Trawl fishery: In Andhra Pradesh, commercial trawlers of three different sizes rang-

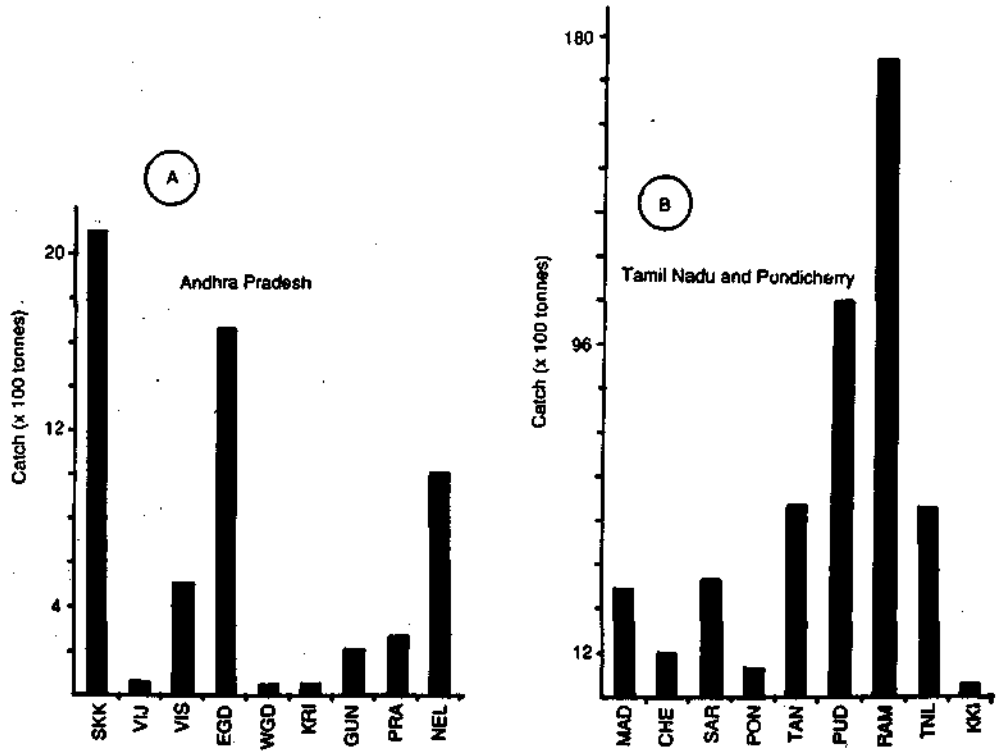


Fig. 4. Average districtwise landings of silverbellies during 1986–88. A. In Andhra Pradesh (SKK: Srikakulam, VIJ: Vijayanagaram, VIS: Visakhapatnam, EGD: East Godavary; WGD: West Godavary, KRI: Krishna, GUN: Guntur, PRA: Prakasam, and NEL: Nellore district). B. In Tamil Nadu–Pondicherry [MAD: Madras, CHE: Chengalpattu, SAR: South Arcot, PON: Pondicherry, TAN: Thanjavur, PUD: Pudukkottai, RAM: Ramanathapuram (presently Muthuramalingam and Ramanathapuram), TNL: Tirunelveli (presently Chidamberanar and Kattabomman), and KKI: Kanyakumari districts].

ing from 10 to 11.4 m OAL operated in the depth range 5–50 m during greater part of the year and during November–February in depths extending up to 80 m. Most of the boats returned the same day but some conducted fishing continuously for 2–4 days . Shrimp trawl with cod end mesh size of 15–20 mm was operated by all these boats. Silverbelly was considered as a 'trash' fish and used mostly in poultry feed.

In Tamil Nadu–Pondicherry, the trawlers (9.8–11.0 m OAL) operated shrimp trawl with a cod end mesh size ranging from 15 to 25 mm. In the northern districts, fishing was mostly conducted during day time up to depths of about 50 m. In the southern districts particularly along Ramanathapuram coast both night and day fishing was carried out regularly up to depths of about 40 m. In this region silverbelly was used for human consumption and a small quantity was reduced to fish meal.

Seasonal variation in silverbelly landings: The quarterly catch estimates (as percentage of each year) from the northern Andhra Pradesh, southern Andhra Pradesh, northern Tamil Nadu and southern Tamil Nadu during 1985–88 are shown in Fig. 5.

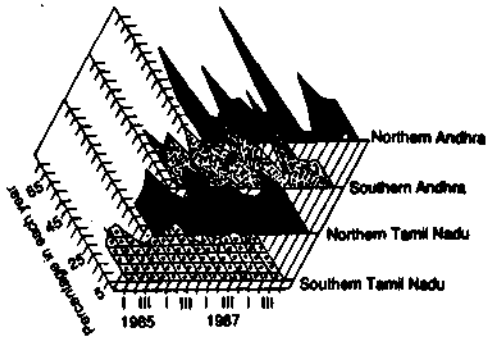


Fig. 5. Seasonal (quarterly) variations in catches of silverbellies.

There were year to year variations in periods of peak landings in the four regions. However, the second quarter was the peak period in northern Andhra Pradesh, first quarter in southern Andhra Pradesh and third or fourth quarter in both the regions of Tamil Nadu.

Species composition: Out of 20 species of silverbellies known to occur in the Indian seas (James and Badrudeen 1991) most of them occur in varying proportions in the Palk Bay and Gulf of Mannar along southern Tamil Nadu coast. Off the coasts of Andhra Pradesh and northern Tamil Nadu, 9–12 species contribute to the fishery. Along Andhra Pradesh coast, *Leiognathus bindus* was the most dominant species forming 40% of silverbelly catch followed by *Secutor insidiator* (24%); all other species together formed the rest (36%). Along northern Tamil Nadu coast also these two species were most dominant together forming about 55% of silverbelly catch; among these two, *S. insidiator* was more abundant. These two species occurred along southern Tamil Nadu coast also but in negligible quantities. In this area *L. jonesi* was the most dominant species forming 44% of silverbelly catch. The other important species was *L. dussumieri* which formed about 15% of silverbelly catch followed by other species. *L. dussumieri* occurred along Andhra and northern Tamil Nadu also, but in small quantities. *L. jonesi*, however, is known from the southern Tamil Nadu coast only.

Biology

Various aspects of biology of different species were studied from different localities along Andhra Pradesh and Tamil Nadu and on one species (*Leiognathus bindus*) from Kerala. The results are briefly given below for each species.

Leiognathus bindus: According to Balan (1967), this fish spawns off Calicut in relatively deeper waters during December–February. The length at first maturity was estimated as 87 mm and fecundity as ranging from 4 950 to 7 735 in fishes of the length range 98–114 mm. Copepods were the most dominant food item followed by polychaetes, cladocerans, larval bivalves and larval crustanceans; phytoplankton occurred in stomachs frequently during monsoon period.

From Kakinada, Murty (1983) reported that this species is a fractional spawner releasing the ova in at least two spawning acts during the course of one year; this species spawns almost throughout the year with a peak during December–February. The length at first maturity was estimated to be 80 mm.

According to James and Badrudeen (1986) the spawning is continuous in batches over prolonged period along southeast coast of India.

This species exhibits sexual dimorphism. The males have a black spot under the pectoral fin near its base which is absent in females (Jayabalan and Ramamoorthi 1985a).

Leiognathus dussumieri: According to James and Badrudeen (1981), this species releases the ova in batches during shorter periods and spawns in the Gulf of Mannar during April–May and November–December.

The length at first maturity was estimated at 78 mm in males and 83 mm in females. The maximum length recorded was 161 mm.

According to Pillai (1972), this species spawns off Tuticorin during prolonged period. The fecundity was estimated to range from 5 400 to 32 500 with an average of 14 300.

Leiognathus brevirostris: In the Palk Bay and Gulf of Mannar this species spawns throughout the year with peaks during May–June and October–November (James and Badrudeen 1975). The lengths at first maturity were estimated as 68 mm in males and 63 mm in females and fecundity 3 650–16 240 in fishes of the length 106–132 mm. The maximum recorded length was 142 mm. Diatoms, copepods, *Lucifer*, nematodes and polychaetes were important food items.

Leiognathus jonesi: James (1986) gave a detailed account of the biology of this species from Palk Bay and Gulf of Mannar. It was concluded that spawning takes place throughout the year with individual fish spawning at least twice in a year; the prolonged spawning period was also indicated by the occurrence of smaller fish of the length range 14–39 mm round the year. Length at first maturity was determined at 70 mm in males and 75 mm in females. Fecundity was estimated to range from about 700 to 39 800 in fishes of the fork length range 65–104 mm. Maximum length recorded was 152 mm. The most important food items were *Pleurosigma*, *Triceratium*, *Coscinodiscus*, nematodes, copepods and foraminiferans.

Leiognathus splendens: From Porto Novo, Jayabalan (1986) reported that spawning takes place almost throughout the year with two peaks during April–May and October–December. Length at first maturity was estimated as 89–90 mm in males and 89–94 mm in females. The relationship between fecundity and total length was determined as:

$$\text{Log } F = -7.4897 + 6.6970 \log L$$

and between fecundity and fish weight as

$$\text{Log } F = 0.8056 + 2.3838 \log W.$$

According to James and Badrudeen (1986), this species spawns in batches in quick succession over a short period.

Secutor insidiator: Pillai (1972) estimated the fecundity from Gulf of Mannar as ranging from about 7 250 to 15 700 with an average of 10 620.

According to Jayabalan and Ramamoorthi (1985b), this species spawns during March–April and July–November in the sea off Porto Novo. The length at first maturity in males was estimated as 79–82.5 mm and in females as 81–82.5 mm. The relation between fecundity and total length was determined as:

$$\text{Log } F = -5.2479 + 4.50 \log L$$

and between fecundity and total weight as:

$$\text{Log } F = 2.3155 + 1.3806 \log W.$$

Murty (1991) reporting on the biology of *S. insidiator* from Kakinada stated that the spawning is throughout the year with a peak during January–March. There was predominance of males up to 87 mm group and of females above this length group. The maximum length in the fishery was 117 mm and length at first maturity of females was estimated as 90 mm.

Gazza minuta: Pillai (1972) estimated the fecundity as ranging from about 7 950 to 28 430 with an average of 13 530 in the Gulf of Mannar.

From Porto Novo, Jayabalan (1988b) determined the spawning period as August-February. The length at first maturity in males was estimated as 99 mm and in females as 102 mm. Fecundity was estimated as ranging from about 11 650 to 26 750 in 15 fishes of the length range 110–114 mm.

The results, therefore, show that silverbellies are fractional spawners spawning throughout the year with one or two peaks or over longer durations each year; the estimates

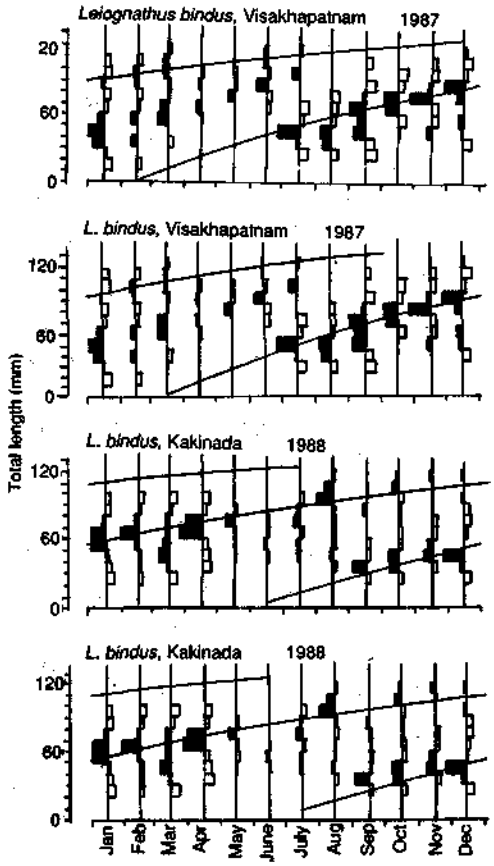


Fig. 6. Restructured length frequency data (ELEFAN I) and growth curves of *Leiognathus bindus*. Visakhapatnam 1987: L_∞ = 151 mm, K = 0.95 per year, SS=9, SL=65 mm; Visakhapatnam 1987: L_∞ = 163 mm, K=0.95 per year, SS=7, SL=45 mm; Kakinada 1988: L_∞=154 mm, K=0.77 per year, SS=9, SL=30 mm; Kakinada 1988: L_∞=165 mm, K=0.70 per year, SS=10, SL=100 mm.

of length at first maturity are within 63–102 mm with majority of the values falling in the length 80–95 mm; these fishes are mainly zooplankton feeders; and though some estimates of fecundity are made; in view of the fractional spawning habits in these fishes, the estimates cannot be taken as total annual fecundity, and can at best be referred to as batch fecundities.

Stock assessment

Growth parameters: The smallest and largest L_∞ values and their associated K values of the four species under study along with the corresponding Phi values (Pauly and Munro 1984) are shown in Table 2; the corresponding length frequency (restructured) data with growth curves are shown in figures 6–9. In *L. bindus* (Table 2), the estimated

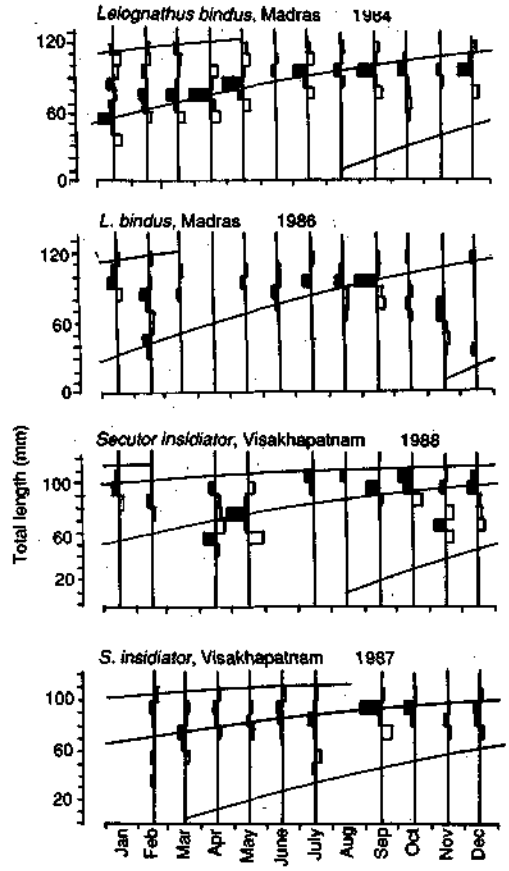


Fig. 7. Restructured length frequency data (ELEFAN 1) and growth curves of *Leiognathus bindus*. Madras 1984: L_∞=153 mm, K=0.90 per year, SS=1, SL=55 mm; Madras 1986: L_∞=167 mm, K=0.96 per year, SS=8, SL=90 mm. *Secutor insidiator*. Visakhapatnam 1988: L_∞=120 mm, K=1.2 per year, SS=7, SL=90 mm; Visakhapatnam 1987: L_∞=130 mm, K=0.85 per year, SS=7, SL=95 mm.

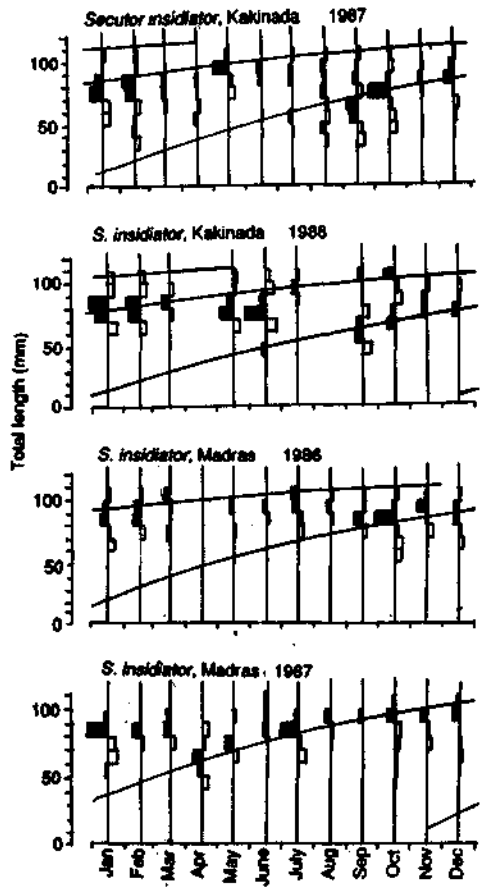


Fig. 8. Restructured length frequency data (ELEFAN I) and growth curves of *Secutor insidiator*. Kakinada 1987: L_∞ = 125 mm, K = 1.06 per year, SS = 1, SL = 85 mm; Kakinada 1988: L_∞ = 130 mm, K = 0.85 per year, SS = 7, SL = 65 mm; Madras 1986: L_∞ = 125.5 mm, K = 1.22 per year, SS = 9, SL = 80 mm; Madras 1987: L_∞ = 138 mm, K = 1.30 per year, SS = 4, SL = 65 mm.

values of L_∞ and K in both the sets ranged from 151 mm to 167 mm and from 0.70 to 0.96 respectively. The maximum known length of this species was 155 mm (Anonymous 1977) from Madras. The estimated values within each set (lower or higher) were found to be close to each other. The values estimated earlier by Murty (1986a) were closer to the values of this study but those estimated from Calicut (Pauly and David 1981), Samar sea (Silvestre 1986) and Java sea (Dwiponggo *et al.*, 1986) were different: the values of L_∞ were much smaller (Tables 2 and 3).

In *L. jonesi* (Table 2), the L_∞ values were slightly larger than L_{max} known. While the

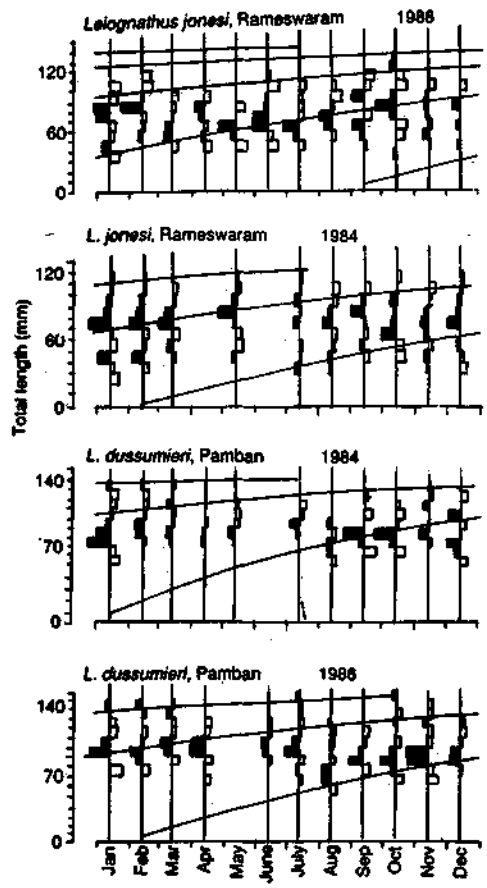


Fig. 9. Restructured length frequency data (ELEFAN I) and growth curves of *Leiognathus jonesi*. Rameswaram 1988: L_∞ = 155 mm, K=0.70 per year, SS=3, SL=50 mm; Rameswaram 1984: L_∞ = 160 mm, K=0.6 per year, SS=1, SL=70 mm. *Leiognathus dussumieri*. Pamban 1984: L_∞ = 162 mm, K=1.2 per year, SS=7, SL=85 mm; Pamban 1986: L_∞ = 175 mm, K=0.80 per year, SS=7, SL=60 mm.

Table 2. Estimated values of growth parameters, mortality rates, lengths and ages at entry and first capture of different species of silverbelly as used in the present study (the ϕ values are also shown)

Species	Locality	L_{max}	Log a	Log b	L_∞	K	Z	M	F	t_r	t_c	ϕ (phi)	M/K
					Lower L_∞ and related K and other parameters								
Leiognathus bindus	Visakhapatnam	130	–4.77709	2.96182	151	0.95	4.14	2.05	2.09	0.087	0.275	2.34	2.16
	Kakinada	142	–4.77709	2.96182	154	0.77	5.26	1.78	3.48	0.152	0.412	2.26	2.31
	Madras	155	–4.77709	2.96182	153	0.90	5.22	1.98	3.24	0.172	1.022	2.32	2.20
L. jonesi	Rameswaram	152	–5.20211	3.2167	155	0.70	5.36	1.67	3.69	0.330	0.961	2.23	2.38
L. dussumieri	Pamban	161	–5.02993	3.1136	162	1.20	6.70	2.35	4.35	0.250	0.630	2.50	1.96
Secutor insidiator	Visakhapatnam	119	–5.73713	3.43654	120	1.20	4.88	2.55	2.33	0.258	1.052	2.24	2.13
	Kakinada	117	–5.73713	3.43654	125	1.06	4.69	2.33	2.36	0.279	1.100	2.22	2.20
	Madras	120	–5.73713	3.43654	125.5	1.22	5.67	2.55	3.12	0.334	1.011	2.28	2.09
					Higher L_∞ and related K and other parameters								
L. bindus	Visakhapatnam	Same as above			163	0.95	4.72	2.01	2.61	0.080	0.257	2.40	2.12
	Kakinada	"			165	0.70	5.43	1.64	3.79	0.155	0.412	2.28	2.34
	Madras	"			167	0.96	7.44	2.01	5.43	0.147	0.814	2.43	2.09
L. jonesi	Rameswaram	"			160	0.60	4.95	1.50	3.45	0.372	1.076	2.19	2.50
L. dussumieri	Pamban	"			175	0.80	5.46	1.76	3.70	0.343	0.851	2.39	2.20
S. insidiator	Visakhapatnam	"			130	0.85	5.28	1.99	3.29	0.332	1.310	2.16	2.34
	Kakinada	"			130	0.85	4.36	1.99	2.37	0.332	1.291	2.16	2.34
	Madras	"			138	1.30	8.72	2.59	6.13	0.279	0.810	2.39	1.99

Note: All lengths in mm, weights in grams and ages in years. The Z values are those obtained by length-converted catch curve method; Log a and b are constants of length-weight relationship.

ϕ values are calculated following Pauly and Munro 1984.

estimates of Venkatraman *et al.* (1981) were close to the estimates of this study, those obtained by Karthikeyan *et al.* (1989) were not so (Table 3); the L_∞ was much smaller than these estimates.

In *L. dussumieri* the L_∞ was closer to the L_{max} (Table 2).

In *S. insidiator* the estimates obtained were close to each other (Table 2). The lone earlier estimate (Murty 1991) was closer to the present estimated values (Tables 2 and 3).

Mortality rates: Taking the two sets of parameters (Table 2), the total mortality rates were estimated using the length-converted catch curve. In *L. bindus*, the estimated values of Z varied from 4.14 to 5.26 under 'lower parameters' and from 4.72 to 7.44 under 'higher parameters' (Table 2). In *L. jonesi*, the Z values were 4.95 and 5.36 under 'higher' and 'lower' parameters respectively. In *L. dussumieri*, they were 5.46 and 6.70 (Table 2). In *S. insidiator* under 'lower parameters', the Z values varied from 4.69 to 5.67 and from 4.36 to 8.72 under 'higher parameters' at different centres (Table 2).

The estimated values of natural mortality rate (M), under both the sets of parameters ranged from 1.64 to 2.05 in *L. bindus*, from 1.50 to 1.67 in *L. jonesi*, from 1.76 to 2.35 in *L. dussumieri* and from 1.99 to 2.59 in *S. insidiator*. The M/K values (Table 2) in all the cases showed that they were well within the range of 1.0–2.5 (Beverton and Holt 1959) known in fishes.

Effort and yield: In Andhra Pradesh, maximum yield of about 2 500 tonnes of *L. bindus* is obtainable at 60% of the present effort whereas the yield of *S. insidiator* increases to 1 560 tonnes at 200% of present effort. The mixed fisheries assessment of these two species showed that maximum yield of 3 700 tonnes will be obtained at 80% of the present effort (Fig. 10.A). The present estimated yield of these two species is 3 680 tonnes. Hence, the increase in yield by decreasing the effort by 20% will not be significant.

In northern Tamil Nadu (Fig. 11.A), the maximum yield of 1 860 tonnes of *L. bindus* corresponds to 120% of present effort. In *S. insidiator* the yield increases to about 2 270 tonnes at 200% of present effort. The combined yield of these two species increases to 4 100 tonnes at 200% of present effort. The present yield of these two species is estimated to be 3 930 tonnes. Thus, a 100% increase in effort can result in about 4% increase in yield.

In southern Tamil Nadu (Fig. 12) the yield of *L. dussumieri* increases to 5 720 tonnes at 200% of present effort whereas the MSY of 16 500 tonnes of *L. jonesi* corresponds to 120% of present effort. The maximum combined yield of 22 100 tonnes of these two species corresponds to 140% of present effort. The estimated yield of these species during the study period was 21 800 tonnes. Thus a 20% increase in effort will result in about 1.3% increase in yield of the two species and 40% increase in effort will increase the yield by about 1.5%.

Cod end mesh size of trawl and yield: In Andhra Pradesh, the yield of *L. bindus* increases up to 200% of present t_c. In *S. insidiator*, on the other hand the MSY corresponds to 60% of the present t_c (Fig. 10.B). The situation thus, shows that under the current effort level there is need to reduce the cod end mesh size by 40% to get MSY of one species and to increase the same by at least 100% for another species. The combined maximum yield of the two species, however, corresponds to 60% of present t_c. This implies that the present cod end mesh size which is already small (15–20 cm) has to be reduced further by 40% (to 9–12 mm). This reduction can only result in 1–6% increase in yield.

Table 3. Parameters of growth, mortality, lengths and ages at entry and first capture of different silverbelly species from Indo-Pacific region

Species	Area/Locality	Source	L_∞ (mm)	K (per year)	t_0 (year)	L_r (mm)	t_r (year)	L_c (mm)	t_c	Z	M	F	ϕ
Leiognathus bindus	Kakinada, India	Murty 1986	158.4	0.58	–0.024	17	0.18	57.0	0.75	5.20	1.50	3.7	2.16
	Samar sea	Silvestre 1986	121.0	0.98	0	–	–	–	–	4.28	2.21	2.07	2.16
	Java	Dwiponggo *et al.* 1986	125.0	1.38	0	–	–	50.3	–	8.84	2.83	–	2.33
	Calicut, India	Pauly and David 1981	122.0	1.3	–	–	–	–	–	–	–	–	2.29
L. jonesi	Mandapam, India	Venkatraman *et al.* 1981	161.20	0.528	0.111	–	–	48	0.56	3.20	2.28	0.92	2.14
	Mandapam, India	Karthikeyan *et al.* 1989	146.62	0.917	0	15	–	–	–	5.26	1.25	4.01	2.29
L. splendens	Porto Novo, India	Jayabalan 1988 a	170.00	0.3259	–1.4159								1.97
	Samar sea	Silvestre 1986	131.00	0.90	0					3.13	2.02	1.11	2.19
	Java	Dwiponggo *et al.* 1986	145.00	1.25	0			96.5	–	4.64	2.55	2.09	2.42
	"	"	169.00	1.10	0			62.3	–	4.00	2.25	1.75	2.50
	"	"	167.00	0.90	0			62.3	–	3.27	1.98	1.25	2.40
L. equulus	Samar sea	Silvestre 1986	240.00	0.56	0	–	–	–	–	2.20	1.26	0.94	2.51
	Java	Dwiponggo *et al.* 1986	215.00	1.50	0	–	–	134.0	–	5.68	2.50	3.10	2.84
L. elongatus	Malaysia	Chan and Liew 1986	135.00	0.80	0	–	–			3.10	1.80	1.30	2.16
L. leuciscus	Samar sea	Silvestre 1986	137.00	0.93	0	–	–	–	–	3.86	2.12	1.74	2.24
	Java	Dwiponggo *et al.* 1986	135.00	1.80	0	–	–	47.6		6.15	3.31	2.84	2.52

(Contd)

Table 3 *(Contd)*

Species	Area/Locality	Source	L_∞ (mm)	K (per year)	t_0 (year)	L_r (mm)	t_r (year)	L_c (mm)	t_c (year)	Z	M	F	ϕ
L. brevirostris	Java	Dwiponggo *et al.* 1986	120.00	0.95	0	–	–	71.0	–	2.79	2.20	0.59	2.14
Secutor insidiator	Kakinada, India	Murty 1991	123.00	1.20	–0.01	27.00	0.20	80.0	0.86	6.10	2.60	3.50	2.26
S. ruconius	Java	Dwiponggo *et al.* 1986	90.00	2.20	0	–	–	36.0	–	8.91	4.22	4.69	2.25
	Java	- do -	83.00	1.45	0		–	49.0	–	8.86	3.29	5.57	2.00
Gazza minuta	Ponto Novo	Jayabalan and Ramamurthi 1986	160.00	0.8649	–0.2316	–	–	–	–	–	–	–	2.34

In northern Tamil Nadu (Fig. 11. B) the MSY corresponds to 80% of present t_c for *L. bindus* and to 60% of present t_c for *S. insidiator*. The combined maximum yield of these two species corresponds to 60% of present t_c. Here also, the implication is reduction in cod end mesh size by 40% which results in 13% increase in yield.

In southern Tamil Nadu (Fig. 13) the MSY of the two species corresponds to present t_c only suggesting that under the present effort level and in the present fishing grounds, mesh regulation is not necessary.

DISCUSSION

Two species (*L. bindus* and *S. insidiator*) were considered for the study from Andhra Pradesh and northern Tamil Nadu coasts and two other species (*L. jonesi* and *L. dussumieri*) from southern Tamil Nadu. As these species formed about 60% by weight of silverbelly catches in the respective regions, assessment of these species could be taken as nearly reflecting the situation in the silverbelly fisheries of the regions.

The problems in arriving at realistic estimates of growth parameters and the consequent need to take into account at least two sets of growth parameters (lowest and highest L_∞ and related K) from among many sets of values estimated and the types of conflicting management options one would encounter in mixed fisheries assessments, have been discussed in the paper on threadfin breams in this issue. As these are common to most of the multi-species/mixed fisheries, they are not dealt with here.

By the very abundance of silverbellies, both in terms of number of species as well as quantities landed, and the species dominant in the fishery, the southern Tamil Nadu is distinct and requires separate treatment for

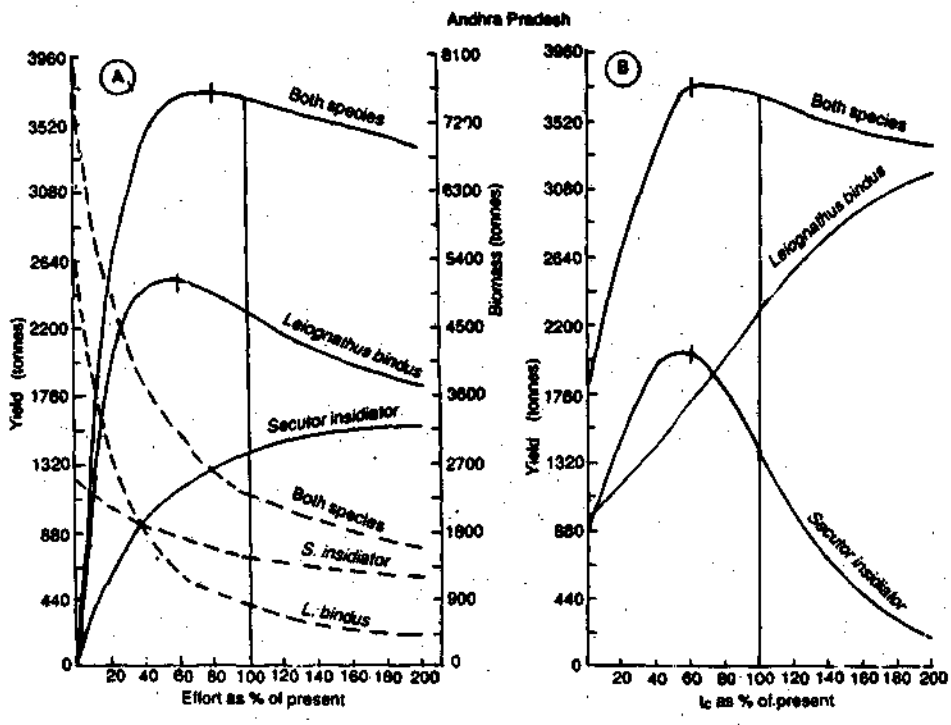


Fig. 10. Yield of *Leiognathus bindus* and *Secutor insidiator* from Andhra Pradesh. A. At different effort levels expressed as percentage of present effort. B. At different t_c levels expressed as percentage of present t_c (the small vertical lines on the curves indicate MSY in the present fishing ground and the long vertical lines the current effort or t_c levels and yields).

fisheries management. Northern Tamil Nadu and Andhra Pradesh, however, do not show greater difference with regard to the species composition and dominant species. The assessments were, however, treated separately for the three regions due to the above reasons and mainly because the fisheries management is within the administrative control of maritime states.

The Thompson and Bell long-term forecast in Andhra Pradesh indicated the need to decrease the present effort level for one species and increase the same for another species in the same fishery to get MSY (Fig. 10.A). In northern Tamil Nadu (Fig. 11.A), situation was that increased effort was required to harvest MSY but the levels of effort required to get the same were different in both the species. In southern Tamil Nadu, in both the species (Fig. 12), increased effort was necessary to get MSY but at different maximum levels. The combined assessment of the two species (in each region) lead to a still different situation in that the effort corresponding to maximum combined yield was different from the effort corresponding to MSY of constituent species. A more or less similar situation was seen in case of yield-mesh curves of the species from the three regions making the task of formulating effective management measures difficult. If all other species in the mixed fishery are also

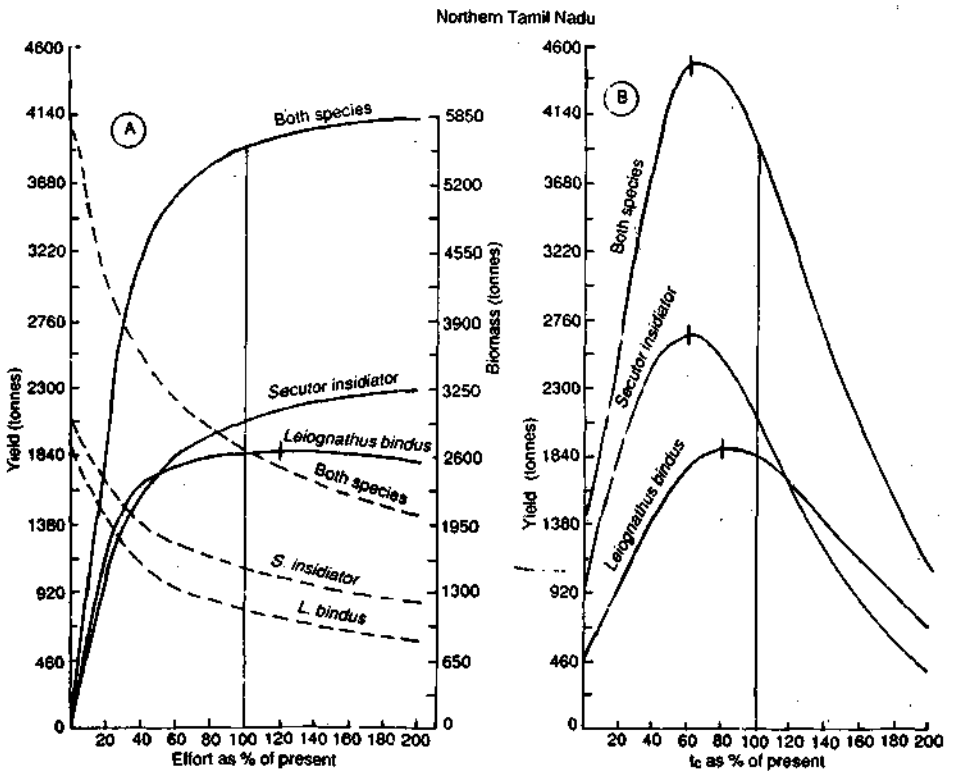


Fig. 11. Yield of *Leiognathus bindus* and *Secutor insidiator* from northern Tamil Nadu. A. At different effort levels expressed as percentage of present effort. B. At different t_c levels expressed as percentage of present t_c.

considered, the situation will only become more complex. This is the real problem faced in fisheries resources management particularly in tropical countries like India. While knowledge of the biological interactions between species contributing to the multi-species/mixed fisheries is essential for effectively formulating regulatory measures, on the basis of available knowledge, the only option appears to be fit is to regulate the effort at a level where MSY (or MSE) of the most economically important species is obtained. As long as the effort is stabilized at a required level (in the well-defined fishing grounds), the yield of all the species including the targetted species, also gets stabilized as long as the steady state assumption is fulfilled. Thus the importance of stock assessment lies in making available strategies for regulating fisheries of several species stocks so that the fishery managers can select the strategy most required for the industry. In the case of silverbelly resources considered here, the present effort can be maintained in the present fishing grounds, because in cases where increase in effort to get MSY is warranted, the increase in yield will be very marginal and can result in reduction in catch rates. Only in Andhra Pradesh there is need to decrease the effort by about 20%; here also the increase in yield and catch rates is not significant warranting such a reduction in effort. Though the analysis in certain instances indicated the need to reduce cod end mesh size of trawl net, particularly in

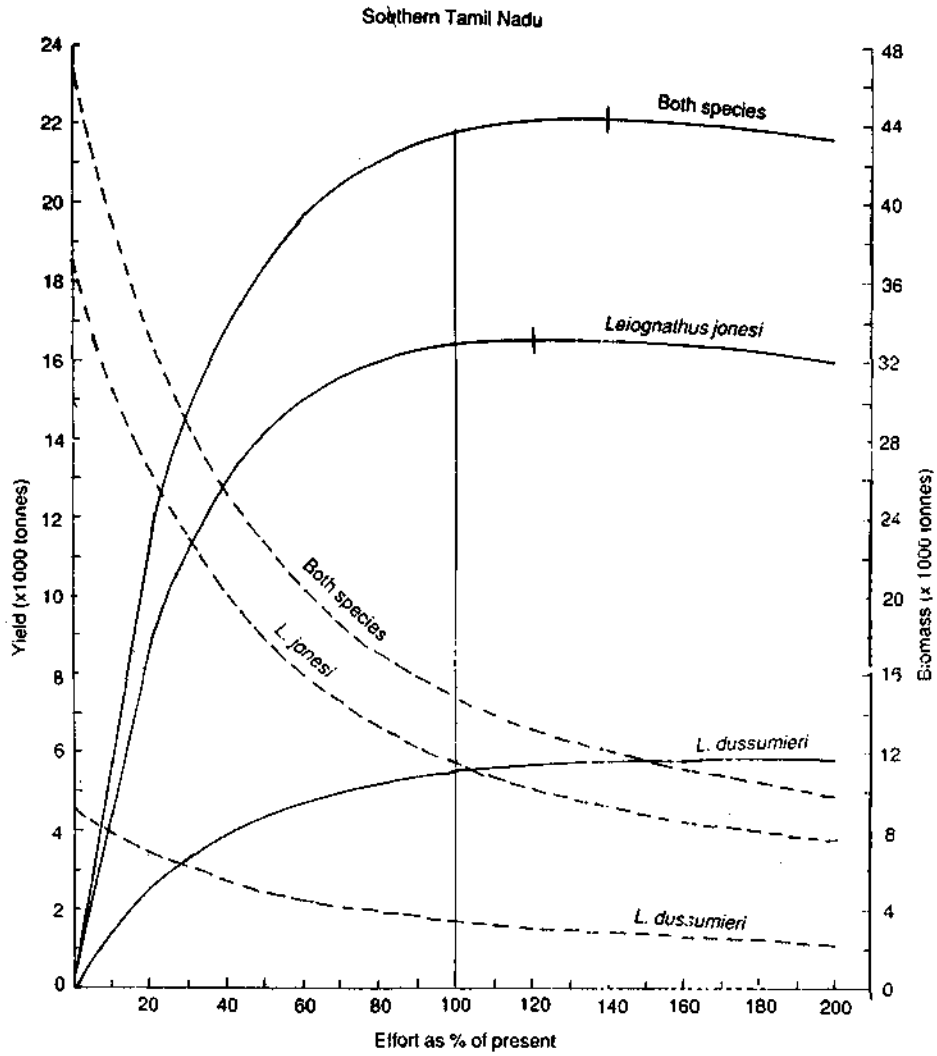


Fig. 12. Yield of *Leiognathus jonesi* and *L. dussumieri* at different effort levels expressed as percentage of present effort in southern Tamil Nadu.

northern Tamil Nadu, such a regulation will not result in substantial increase in yield and even if so, the contribution will be from much smaller fish (of the already small, considered as trash fish) not valued by the industry in any significant manner.

It is known that silverbellies are predominantly inhabitants of shallower regions where active fishing both by mechanized and non-mechanized gears is taking place. Considerable caution is necessary before any effort increase in the present fishing grounds is thought of because of its possible impact on other resources. Moreover, silverbelly landings are showing declining trends in recent years.

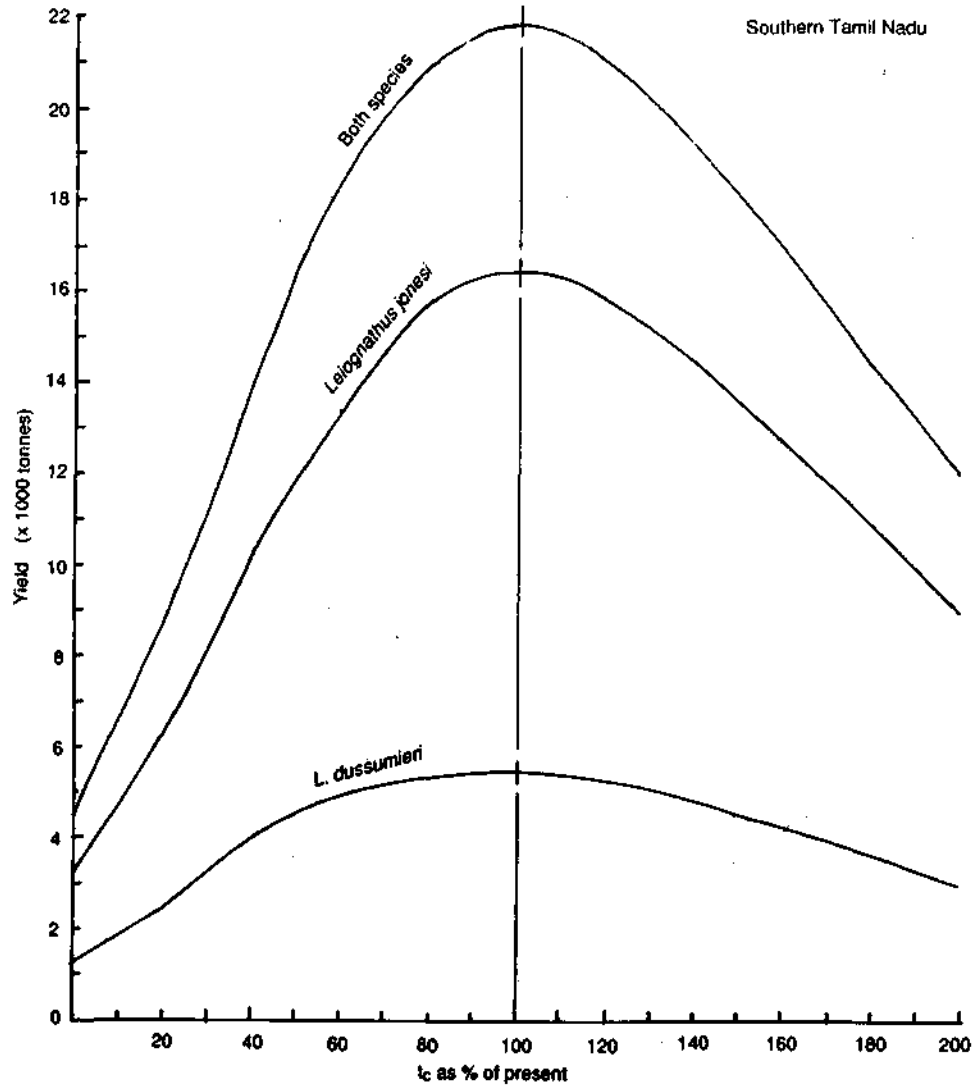


Fig. 13. Yield of *Leiognathus jonesi* and *L. dussumieri* at different t_c levels expressed as percentage of present t_c in southern Tamil Nadu.

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