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Stock assessment of tunas from the Indian scas

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ABSTRACT

The tuna catch in India in the small scale sector fluctuated between 23 170 tonnes and 35 610 tonnes during 1984-88, the average catch for the period being 29 146 tonnes. In 1989, 45 240 tonnes of tunas were landed by the artisanal sector. On an average the little tunny (*Euthynnus affinis*) contributed 50%, frigate tuna (*Auxis thazard*) and bullet tuna (*A. rochei*) 16%, skipjack tuna (*Katsuwonus pelamis*) 16%, longtail tuna (*Thunnus tonggol*) 4% and other tunas (unclassified) 14% of the total tuna catch.

The stock assessment of five species of tunas viz; *Euthynnus affinis, Auxis thazard, A. rochei, Thunnus tonggol* and *Katsuwonus pelamis* were made based on the data collected during 1984-88 from nine centres along the west and east coasts of India and from Lakshadweep (Minicoy and Agatti Islands). Statewise and centrewise catch, effort and species composition are indicated. The length frequency data of different species from Madras, Tuticorin, Vizhinjam, Cochin, Calicut, Mangalore and Minicoy were utilized for estimating mortality rate and recruitment pattern and for assessing yield and biomass. The annual values of Z and F were also calculated.

The tuna stocks in the traditional fishing grounds are exploited to the maximum level. Increase in effort may not fetch enhanced returns in terms of direct operational cost (DOC) and cost benefit ratio (C:B). The economic utilization of tuna live-baits and enhanced exploitation of all the species from the northern Islands could enhance the tuna production in Lakshadweep.

Tunas constitute one of the important marine fisheries resources of our country contributing 1.5 to 2.0% of the total marine fish landings. The potential of this resource has been estimated to be 200 000 tonnes in the Indian EEZ. Popularly known as the 'chicken of the sea', tunas comprising of a number of species are exploited all along the Indian coasts. Tuna, fresh or processed in different styles, is a very important commodity in the world trade for fish and fishery products. In India, they are mostly consumed in fresh condition. Except for the traditional 'masmin' preparation in Lakshadweep and limited production of canned and frozen fillet tunas, export oriented processing is in its infant stage.

The status of tuna fisheries in India and their distribution and abundance in the Indian EEZ were reviewed in the recent past (Silas

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and Pillai 1986; James and Pillai 1987, 88, 90; James and Jayaprakash 1987, 88; James *et al* 1987 a,b; James 1991; and Pillai 1991 a,b). Studies on the biological and population parameters of different species and their stock and exploitation from Indian seas were made by Silas *et al.* (1986), James *et al.* (1987b), and Pillai and Gopakumar (1989). Studies on the population dynamics of the oceanic species, *Thunnus albacares*, in Indian seas, based on the data collected by longline fishery operations of Government of India vessels are also available (John and Reddy 1989).

MATERIALS AND METHODS

To update the information on the availability of tunas and their exploitation by the small scale fisheries sector, the stock assessment of five species, viz. *Euthynnus affinis* (little tunny), *Auxis thazard* (frigate tuna), *A.rochei* (bullet tuna), *Thunnus tonggol* (longtail tuna) and *Katsuwonus pelamis* (skipjack tuna) was carried out based on the data collected from nine centres located along the west and east coasts of India and from Lakshadweep (Minicoy and Agatti Islands) during 1984–88, as given in Table below.

Species	Gears	Centres
Euthynnus affinis	GN, HL, PS	Madras*, Tuticorin, Vizhinjam, Cochin, Calicut, Mangalore
Auxis thazard	GN, HL, PS	Tuticorin, Vizhinjam, Cochin, Mangalore
A. rochei	HL	Vizhinjam
Thunnus tonggol	GN	Tuticorin, Cochin
Katsuwonus pelamis	PL	Minicoy Island, Agatti Island

GN, Drift gillnet; HL, Hooks and line; PS, Purse seine; PL, Pole and line. *, Data collected only during 1987 and 1988.

Standard methods were used for analysis (Pauly and David 1981, Gayanilo *et al.* 1988, Pauly and Ingles 1981).

Assessment of the stock was carried out based on the values obtained by raising the annual length frequencies for different years of study (1984–88) and pooling them. The mortality rates were estimated by length cohort analysis (Jones 1984). Thompson and Bell model analysis (Sparre 1987) was employed to analyse the yield and biomass of different species of tunas.

RESULTS

Fishery

Tuna production in India showed fluctuations since 1970 and in 1988 a landing of about 30 362 tonnes was recorded (Fig. 1). On an average, the west coast of India contributed about 68%, east coast 14% and Lakshadweep and Andaman Islands 18%. A comparison of the tuna production indicated that on an average Kerala, Karnataka and Goa contributed 49.9%, Maharashtra and Gujarat 18.2%, Lakshadweep 17.4% and the east coast and Andaman Nicobar Islands contributed 14.5% of the total tuna landings during 1984–88.

In Kerala, the tuna landings varied from 6 110 tonnes in 1984 to 22 286 tonnes in 1989. Increase in landings was recorded in Karnataka also from 1 000 tonnes in 1984 to 5 300 tonnes in 1989. The tuna catch was poor and was less than 500 tonnes in Goa during the period. In Maharashtra, marginal increase from 3 000 tonnes in 1984 to 3 900 tonnes in 1989 was recorded. In Gujarat, a highest peak of 9 000 tonnes was observed in 1985 which decreased to 2 200 tonnes during 1989. On the east coast, in Tamil Nadu, the tuna landings were steady around 3 700 tonnes, but in Andhra Pradesh despite crossing 2 000 tonnes in 1985, the landings became steady around 1 200 tonnes during 1986 to 1989 (Fig. 2A).

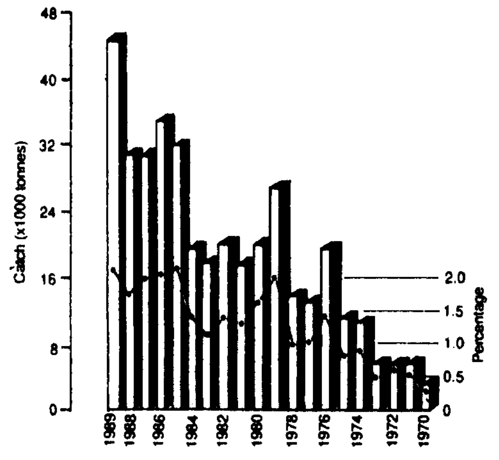

Fig. 1. All-India tuna landings (annual) and percentage contribution of tunas in the total marine fish landings for the years 1970-1989.

The catch was less than 500 tonnes in Pondicherry and Orissa, and was nil in West Bengal.

The overall seasonal pattern of the tuna fishery during the years (1984–88) indicated that along the southwest coast of India the pre-monsoon and post-monsoon months were productive periods, and along the Maharashtra and Gujarat coasts post-monsoon period was productive thereby indicating a seasonal shift in their concentration. In Lakshadweep, December to April was observed to bring maximum catches. However, the emerging pattern of mechanization/motorization of crafts employed in the tuna fishery has been changing the scenario, with continued operations during the monsoon period also. In the mechanized sector the drift gill nets contributed 54% followed by pole and line (27%), purse seines (17%) and other gears (2%). In the non-mechanized sector also the drift gill nets contributed 76% and the rest of the catch was from other indigenous gears.

The overall species composition of the tuna fishery for 1984–88 indicated that the little tunny *(E. affinis)* constituted the major component (50%) followed by frigate (*A. thazard*) and bullet (*A. rochei*) tunas (16%), skipjack tuna (*K. pelamis*) (16%), longtail tuna *(T. tonggol)* (4%) and other tunas (14%).

At Mangalore, Calicut, Cochin, Vizhinjam and Tuticorin the drift gill net catch was dominated by the little tunny constituting more than 50% of the total tunas. But at Vizhinjam, in the mechanized hooks and line, more than 50% of the catch was contributed by bullet tuna. A comparison of the species composition during 1981–82 and 1987–88 indicated that there was an increase in the exploitation of the frigate tuna (*A. thazard*) (Fig. 2. B and C).

In the drift gill nets (1984–88) the catch per unit effort varied from 7–36 kg at Mangalore, 25–69 kg at Calicut, 22–29 kg at Cochin, 22–40 kg at Vizhinjam and a highest value of 50–119 kg was realized at Tuticorin (Fig. 3A – E and Table 1). Tunas constitute incidental catches in the purse seines at Kerala, Karnataka and Goa. The catch, effort and catch per unit effort during the period 1984–88 for Goa and Mangalore is given in Fig. 3A and for Calicut and Cochin in Fig. 3B. A declining trend in the catch per unit effort of tunas was evident in Karnataka whereas in Kerala it was around 370 kg. Considerable fluctuations in the effort input by purse seiners were noticed in Karnataka and Goa and Kerala (Fig. 3A & B).

Biology

Information on the biology of different species of tunas such as *E. affinis*, *A. thazard*, *A. rochei* and *K. pelamis* is available in the works of Muthiah (1986), Madan Mohan and Kunhikoya (1986) and Pillai and Gopakumar (1989).

E. affinis occurred in the fishery (1984–

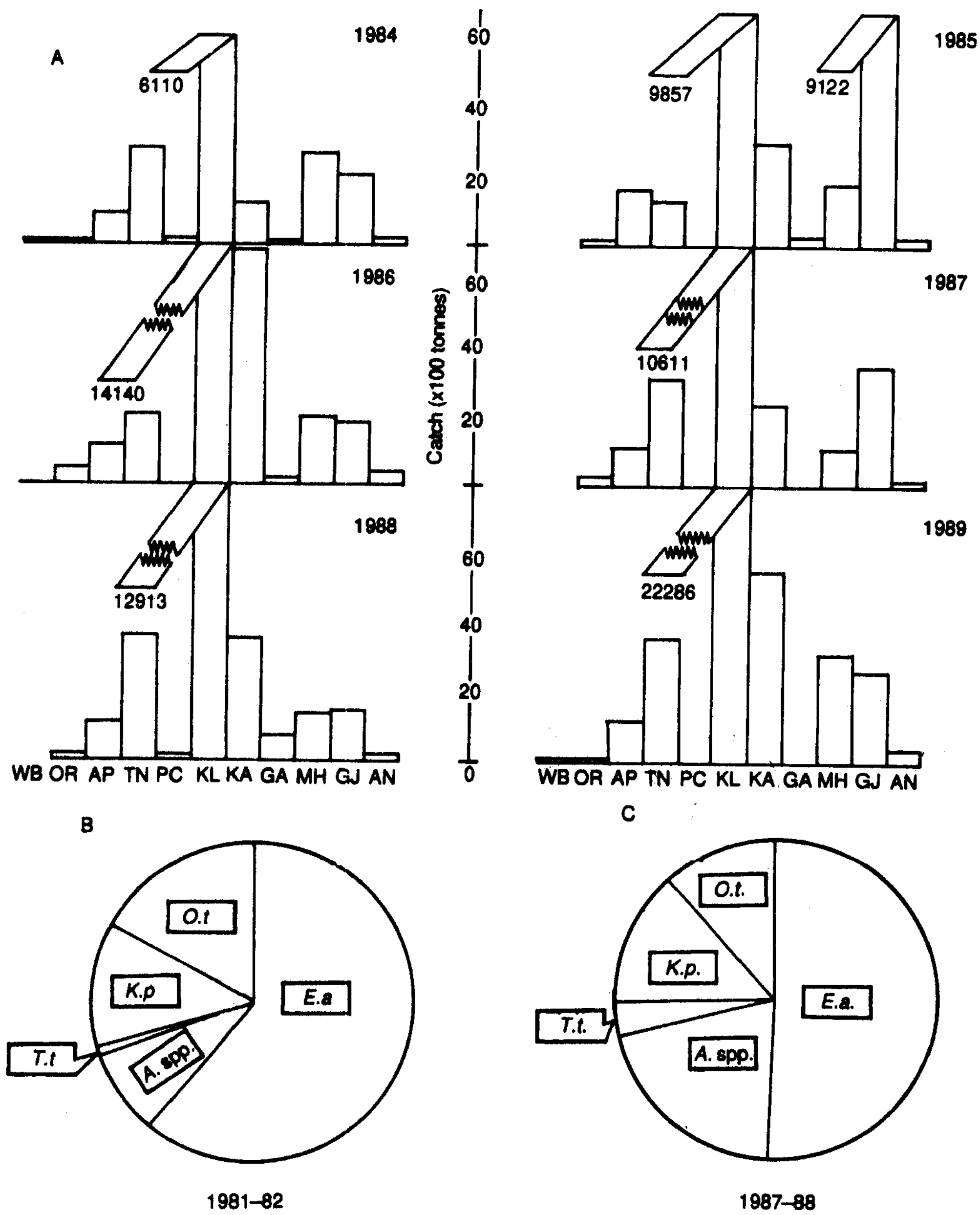

Fig. 2. **A.** Statewise production trend of tunas during 1984-88. **B.** Species composition of tunas during 1981-82. **C.** The same during 1987-88. AN, Andamans; AP, Andhra Pradesh; GA, Goa; GJ, Gujarat; KA, Karnataka; KL, Kerala; MH, Maharashtra; OR, Orissa; PC, Pondicherry; TN, Tamil Nadu; WB, West Bengal. *E. a.*, *Euthynnus affinis; A.* spp., *Auxis* spp.; *K.p.*, *Katsuwonus pelamis; O.t.*, other tunas; *T.t.*, *Thunnus tonggol.*

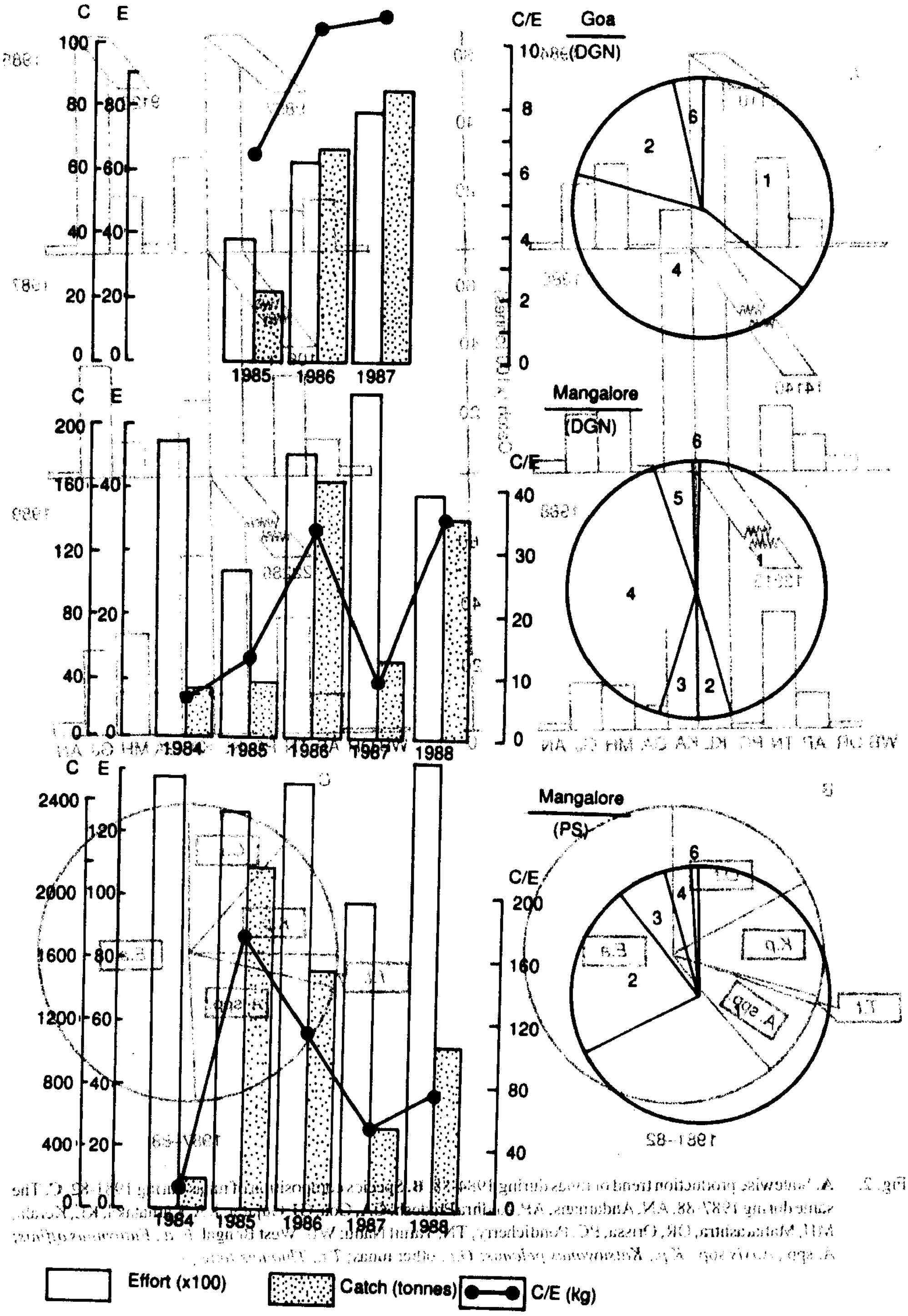

Fig. 3A. Catch (tonnes), effort, catch per unit effort (kg) and species composition of tunas at Goa and Mangalore (1984-88). DGN, Drift gill net; PS, purse seine. 1, *Euthynnus affinis;* 2, *Auxis thazard;* 3, *A. rochei;* 4, *Thunnus tonggol;* 5, *T. albacares;* 6, *S. orientalis;* 8, *T. obesus;* 9, Billfishes.

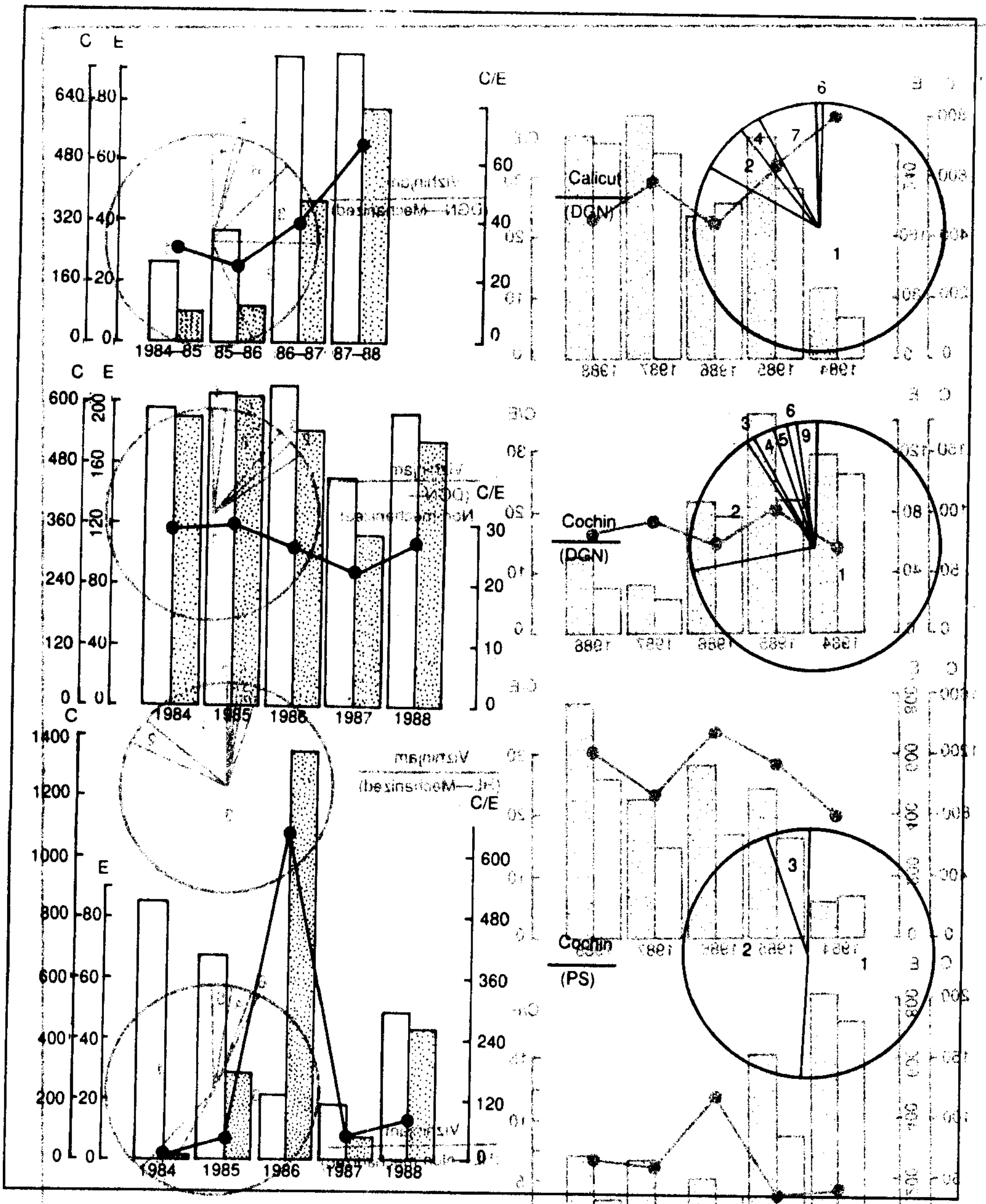

Fig. 3B. Catch (tonnes), effort, catch per unit effort (kg) and species composition of tunas at Calicut and Cochin (1984-88). For abbreviations *see* Fig. 3A.

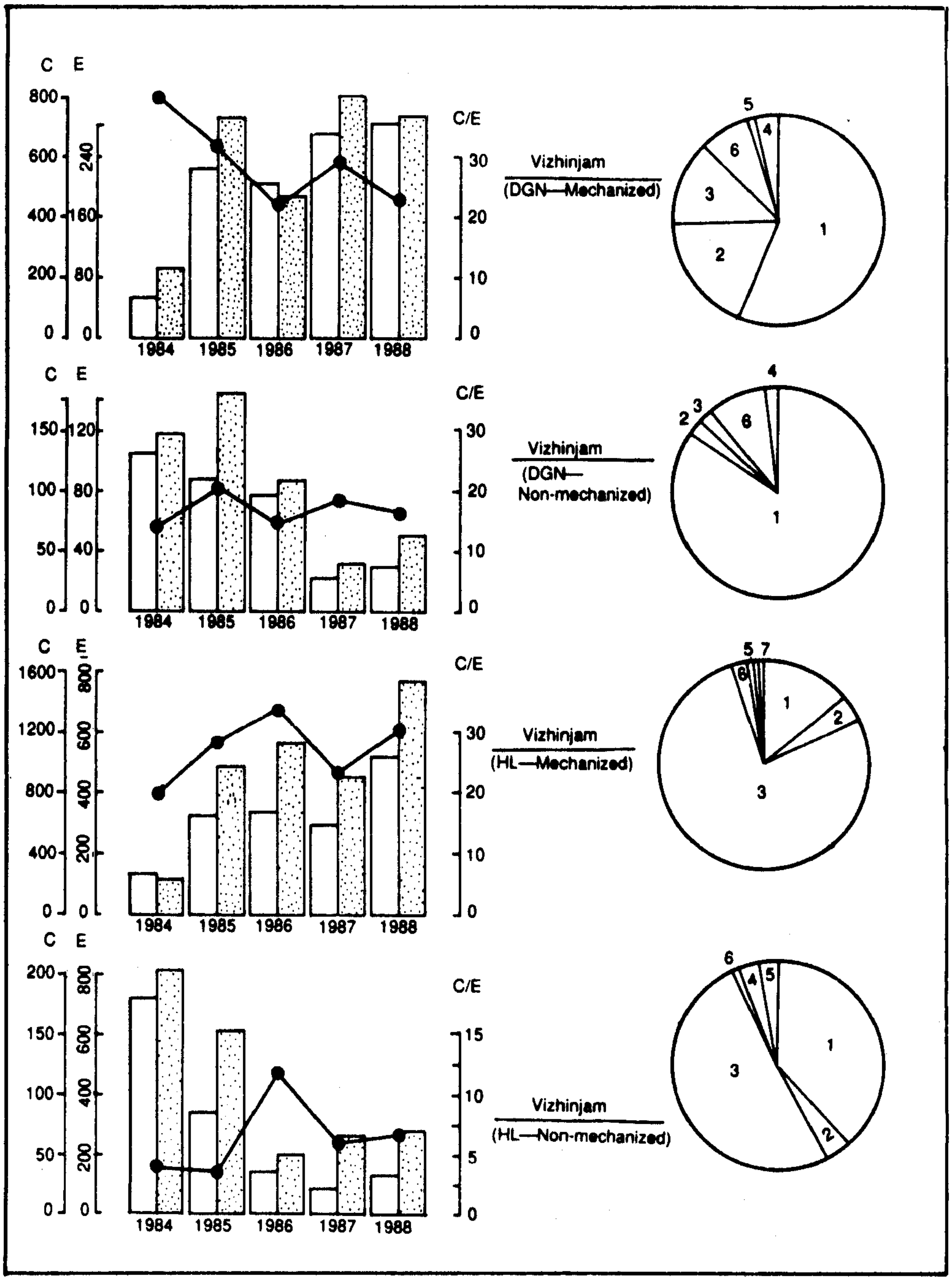

Fig. 3C. Catch (tonnes), effort, catch per unit effort (kg) and species composition of tunas at Vizhinjam (1984-88). HL, Hooks and line; for other abbreviations *see* Fig. 3A.

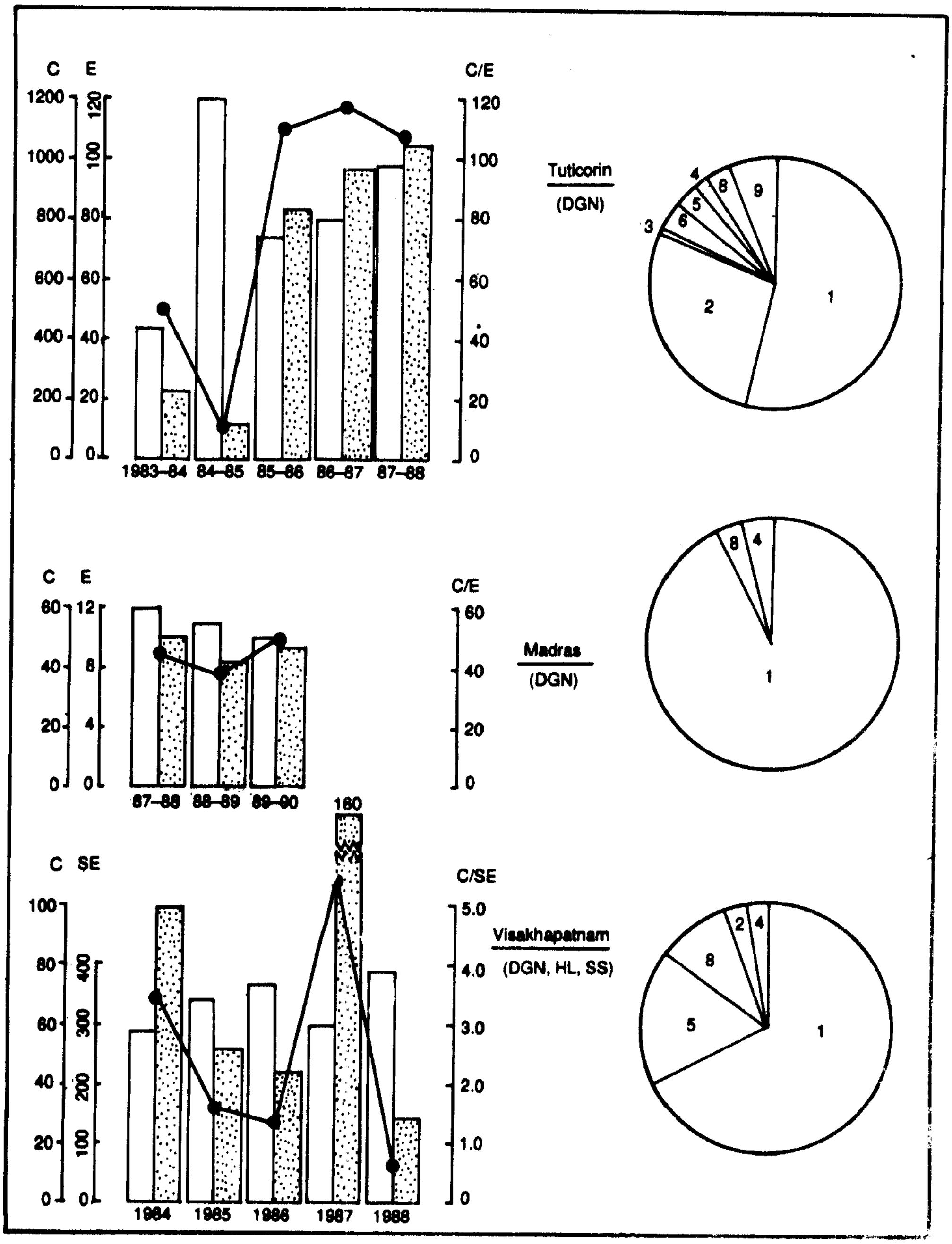

Fig. 3D. Catch (tonnes), effort, catch per unit effort (kg) and species composition of tunas at Tuticorin, Madras and Visakhapatnam (1984-88). SS, Shore seine; for other abbreviations *see* Fig. 3A and 3C.

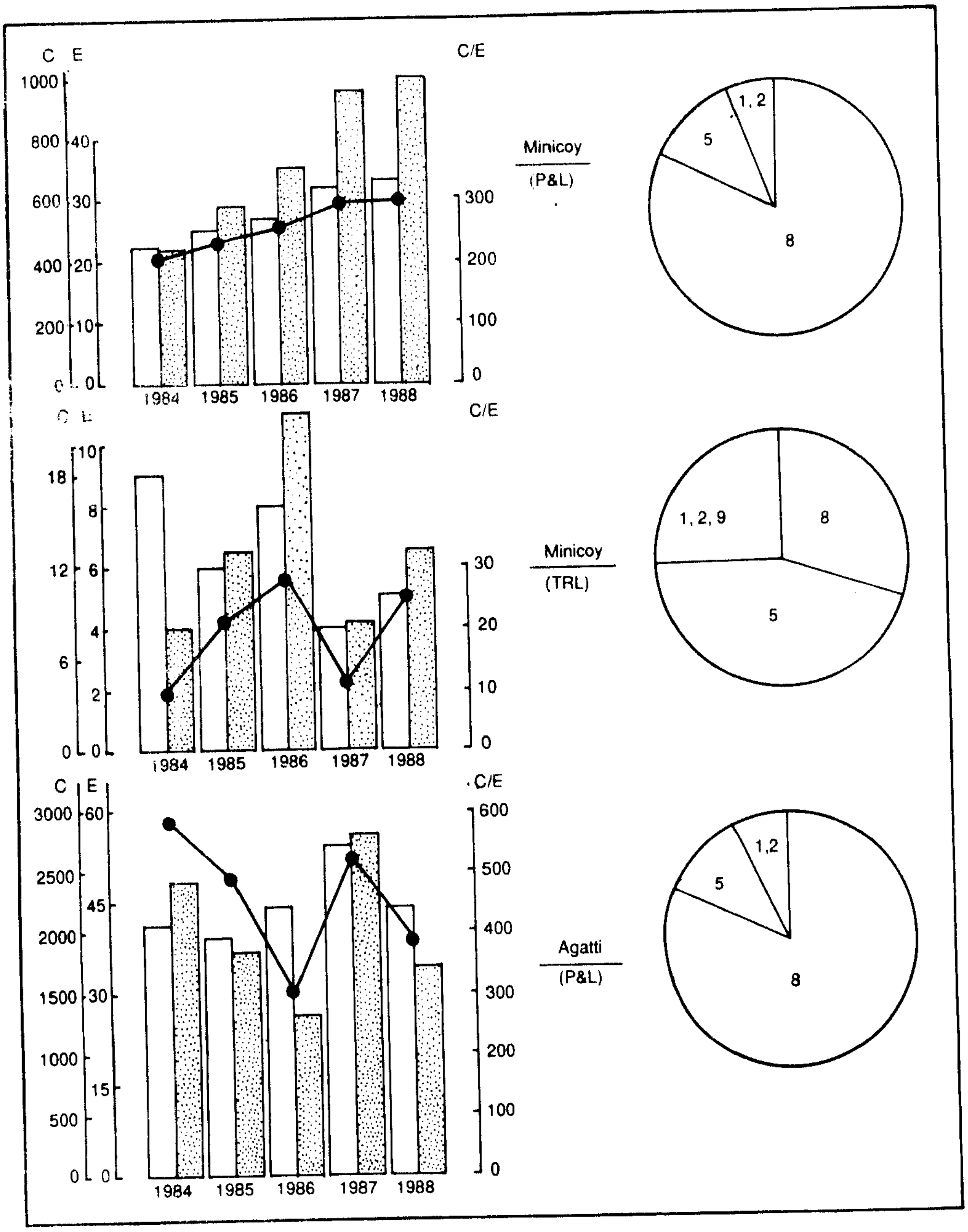

Fig. 3E. Catch (tonnes), effort, catch per unit effort (kg) and species composition of tunas at Minicoy and Agatti (1984–88). P&L, Pole and line; TRL, Troll lines; for other abbreviations *see* Fig. 3A.

Table 1. Trend in catch rate (kg) of tunas at different Research Centres

Centre	Gear	1984	1985	1986	1987	1988	Average
Goa	DGN (M)	ND	6.22	10.42	10.85	ND	9.52
Mangalore	DGN (M)	6.75	13.19	35.97	9.12	35.40	19.60
	PS (M)	13.80	173.55	112.18	51.54	74.08	85.55
Calicut	DGN (M)	29.56	25.37	39.07	64.96	68.71	45.53
	Ringnet	-	-	-	-	69.57	69.57
Cochin	PS (M)	0	42.02	649.55	44.27	87.64	87.64
	DGN (M)	29.48	29.87	25.91	22.16	27.16	27.16
Vizhinjam	DGN (M)	40.2	31.7	22.1	28.9	25.4	27.81
	DGN (NM)	14.0	20.3	14.2	18.0	15.5	16.15
	HL (M)	19.6	27.8	33.8	22.6	30.4	27.96
	HL (NM)	2.8	4.4	13.4	7.0	5.3	4.74
Tuticorin	DGN (M)	50.13	9.54	110.66	119.48	107.28	75.79
Madras	DGN (M)			*(12.6)	**(43.3)	+(37.0)	
Waltair	HL (M)			*(1.6)	**(5.5)		N.D.
Minicoy	P&L (M)	203.61	227.33	256.76	299.12	297.49	262.52
	TRL (M, NM)	8.82	20.53	29.12	10.76	24.80	18.66
Agatti	P&L (M)	581.7	471.0	300.8	517.1	382.9	451.4
	TRL (M, NM)	N.D.	N.D.	N.D	32.8	34.6	33.8

ND, No data; DGN (M), Drift gill net (mechanized); DGN (NM), Drift gill net (non-mechanized); PS (M), Purse seine (mechanized); HL (M), Hooks and line (mechanized); HL (NM), Hooks and line (non-mechanized); P&L (M), Pole and lines (mechanized); TRL (M, NM), Troll lines (mechanized, non-mechanized).
*, 1986–87; **, 1987–88; +, 1988–89.

88) in the size 18–69 cm with size groups less than 40 cm well represented during July–November. Size at first maturity was 43–44 cm; spawning season appeared to be during October–November and April–May. Studies on fecundity and length of fish indicated the following relation:

$$\log F = -3.66219 + 2.36111 \log L$$

A. thazard was in the size 20–48 cm with fishes of less than 40 cm occurring predominently during October to December. Length at first maturity was estimated as 30 cm. Spawning season was mainly during August–November. The relationship between length and fecundity of this species is expressed by

$$\log F = -9.77991 + 4.75748 \log L$$

A. rochei occurred in the fishery in the size 14–28 cm during the study. Small-sized specimens were observed in the fishery during July and August. Length at first maturity was estimated to be 23 cm. Spawning season was chiefly confined to September–October. The relationship between length of fish and fecundity is expressed by the formula

$$\log F = -1.70881 + 1.50244 \log L$$

K. pelamis occurred in the size 21–72 cm, and relatively small specimens were present in the fishery during September–December. Size at first maturity of the species was estimated at 44–45 cm. Although mature specimens occurred in the fishery almost throughout the year, two spawning peaks were observed during January–April and September–December. The fecundity of the species has been worked out earlier and the relationship between size and fecundity is expressed by

$$\log F = -918.5705 + 23.27525 \log L$$

T. tonggol occurred in the fishery in the size 28–84 cm, with younger groups (less than

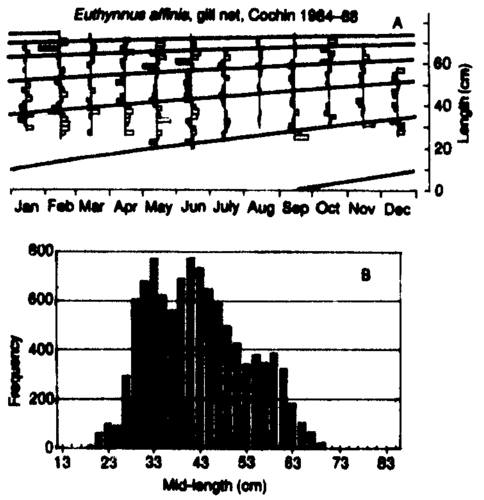

Fig. 4. A. Estimation of L_∞ and K of *Euthynnus affinis* (L_∞ = 83.5 cm, K = 0.42/year, starting sample = 9, starting length = 29 cm). B. Length frequency distribution (all-India raised) of *E. affinis*.

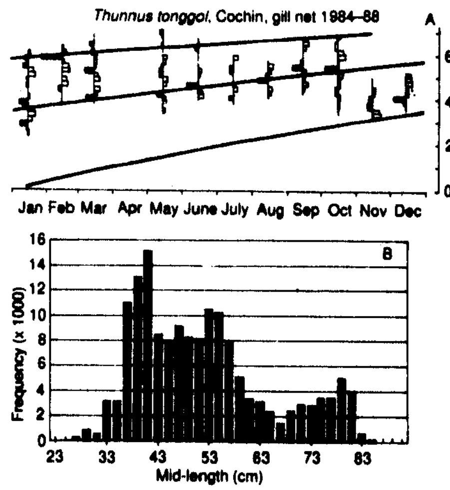

Fig. 5. A. Estimation of L_∞ and K of *Thunnus tonggol* (L_∞ = 94 cm, K = 0.4/year, starting sample = 10, starting length = 54 cm). B. Length frequency distribution (all-India raised) of *T. tonggol*.

40 cm size) occurring during October to December.

Stock assessment

Estimation of growth parameters: The length frequency data were converted into 2 cm class intervels and estimates of the asymptotic length (L_∞) and growth coefficient (K) were obtained using the ELEFAN programme for fitting the growth curves (Table 2). Further, the data from different gears on all-India basis were utilized for each species to delineate the peaks in size.

For *E. affinis* the size ranged from 18–69 cm with dominant peaks observed in the size groups 34–36 cm and 40–42 cm. The tertiary peak observed in the size group 60–62 cm indicated the landing of these groups by drift

Table 2. Input parameters for length converted cohort analysis (tunas) (mean F and Z values are also indicated)

Parameters		*Euthynnus affinis*	*Auxis thazard*	*A. rochei*	*Thunnus tonggol*	*Katsuwonus pelamis*
L_∞ (cm)	:	83.50	56.00	37.00	94.00	80.19
K (per year)	:	0.420	0.770	0.638	0.480	0.650
M	:	0.616	1.024	1.024	0.656	1.058
Terminal exploitation rate	:	0.80	0.81	0.74	0.79	0.85
M/2K	:	0.733	0.664	0.800	0.683	0.646
q in $w = qL^b$	:	0.0190906	0.008916	0.00000518749	0.0000830	0.0000497
b in $w = qL^b$	:	2.9524	1.1915	3.1711	2.7046	2.7249
Mean F	:	0.9002	1.0311	1.7147	0.5841	1.3937
Z	:	1.515	1.981	2.739	1.470	3.362

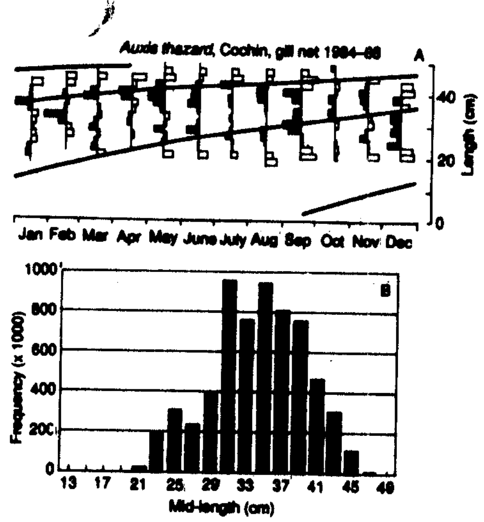

Fig. 6. A. Estimation of L_∞ and K of *Auxis thazard* (L_∞ = 56 cm, K = 0.77/year, starting sample = 1, starting length = 37 cm). B. Length frequency distribution (all-India raised) of *A. thazard*.

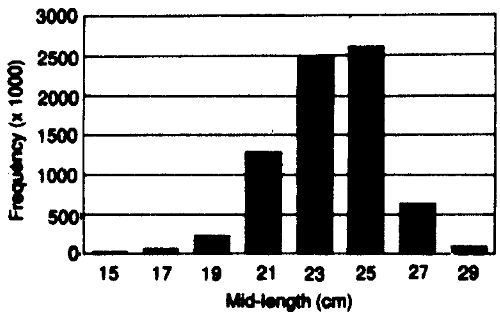

Fig. 7. Length frequency distribution (all-India raised) of *Auxis rochei*.

gill net fishery employing large-sized mesh of 12 cm (Fig. 4 A & B).

For *T. tonggol* the size range recorded was 28–84 cm with major modes observed at 40–42 cm, 54–56 cm and 78–80 cm (Fig. 5. A and B).

For *A. thazard* the size ranged from 20–48 cm with major mode at 30–32 cm (Fig. 6. A & B).

In the case of *A. rochei* the size range recorded was 14–28 cm with major mode at 24–26 cm, which are mainly taken by hooks and line at Vizhinjam (Fig. 7.).

K. pelamis occurred in the size of 21–72 cm with two modes at size groups 50–52 cm and 60–62 cm (Fig. 8 A & B).

The length observed at relative age of the above 5 species are presented in Fig 9.

Recruitment pattern: The annual recruitment pattern was obtained for different species by projecting the 12 months of length frequency backward on to an one year time axis. The value of t_0 used in the calculation was zero and, therefore, the exact time of recruitment could not be determined (Fig. 10). It is inferred that recruitment occurred in the form of different pulse (s) of unequal strength for various species which are as

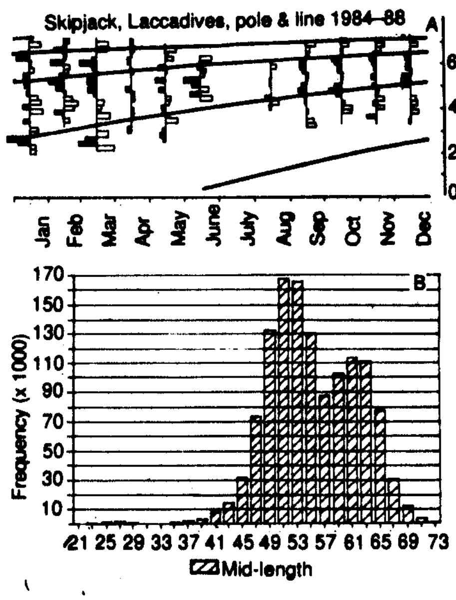

Fig. 8. A. Estimation of L_∞ and K of *Katsuwonus pelamis* (L_∞ = 80.19 cm, K = 0.65/year, starting sample = 9, starting length = 48 cm) at Lakshadweep. B. Length frequency distribution (Lakshadweep) of *K. pelamis*.

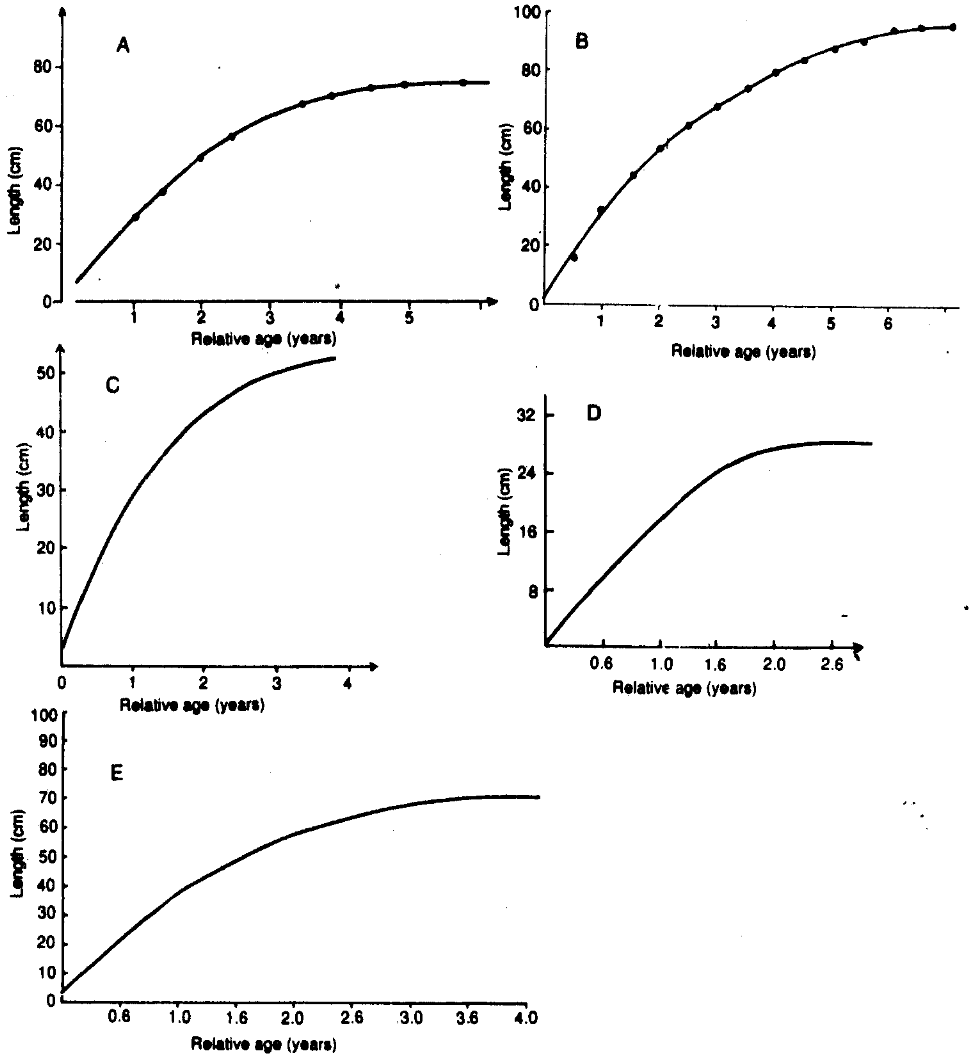

Fig. 9. Relative age of (A) *Euthynnus affinis*, (B) *Thunnus tonggol*, (C) *Auxis thazard*, (D) *A. rochei* and (E) *Katsuwonus pelamis*

follows:

Species	Per cent of recruitment
E. affinis	11.54, 19.62
T. tonggol	20.06, 20.43
A. thazard	14.93, 14.85
A. rochei	7.47, 23.95
K. pelamis	19.93

Mortality estimates: The natural mortality rate (M) estimated for *E. affinis* was 0.616 for *A. thazard* 1.024, *A. rochei* 1.024, *T. tonggol* 0.656 and for *K. pelamis* 1.058.

The total mortality values Z for *E. affinis* was 1.515 for *A. thazard* 1.981, *A. rochei* 2.739, *T. tonggol* 1.470, and for *K. pelamis* 3.362 (Table 2).

Length cohort analysis and Thompson

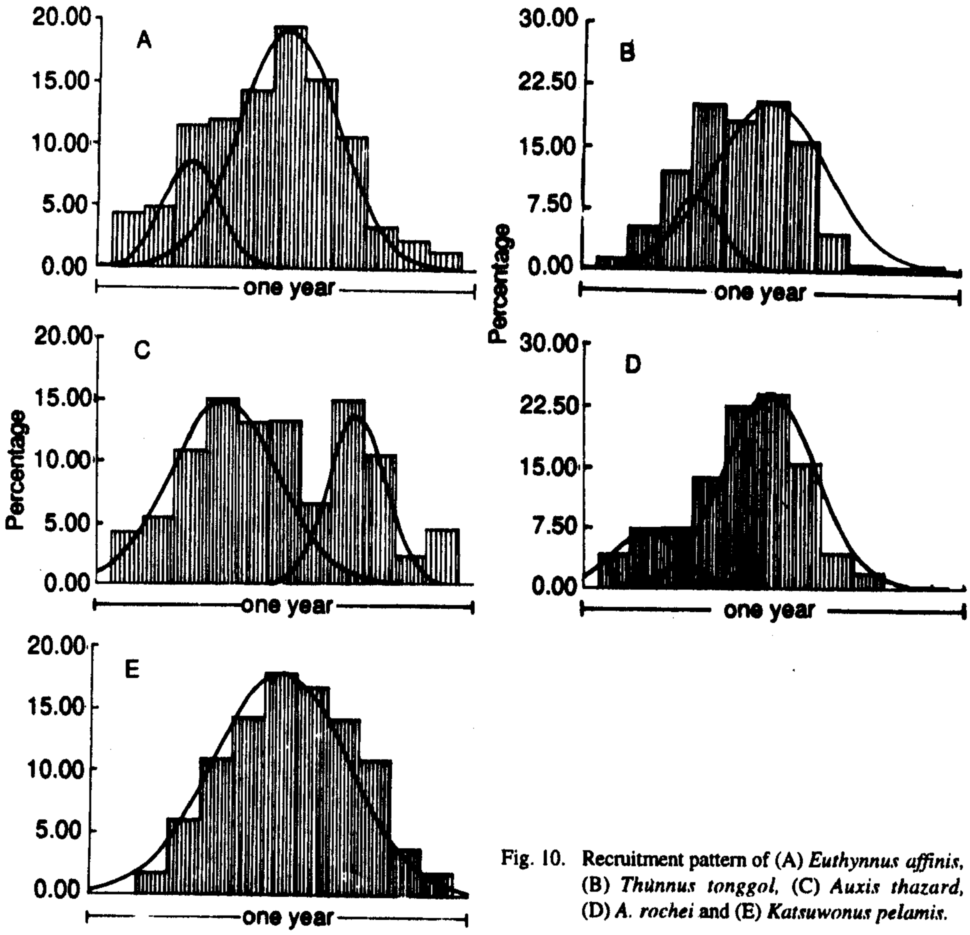

Fig. 10. Recruitment pattern of (A) *Euthynnus affinis*, (B) *Thunnus tonggol*, (C) *Auxis thazard*, (D) *A. rochei* and (E) *Katsuwonus pelamis*.

and Bell yield per recruit analysis: The results of analysis indicated that for all the species studied, the exploitation rate (F/Z) ranged from 0.74 to 0.85.

For *E. affinis* the mean value of F was estimated as 0.9002. The size group at maximum F value attained for this species was 68–70 cm. The present catch of the species was estimated as 15 185 tonnes, the estimated MSY 15 526 tonnes and the biomass MSY 24 310 tonnes. A decrease in effort to 66% of the current level would yield an additional landing of 341 tonnes (increase of 4.4% over the present yield) suggesting a need to reduce the fishing effort for this species (Fig. 11. A).

For *T. tonggol* the mean value of F was estimated as 0.5841 and the size group at maximum F value attained was 80–82 cm. The present catch of this species is 623 tonnes, the estimated MSY 641 tonnes and the biomass MSY 722 tonnes. The MSY could be obtained by increasing the effort by 1.6 times from the present level, but the yield will be only 18 tonnes (Fig. 11. B).

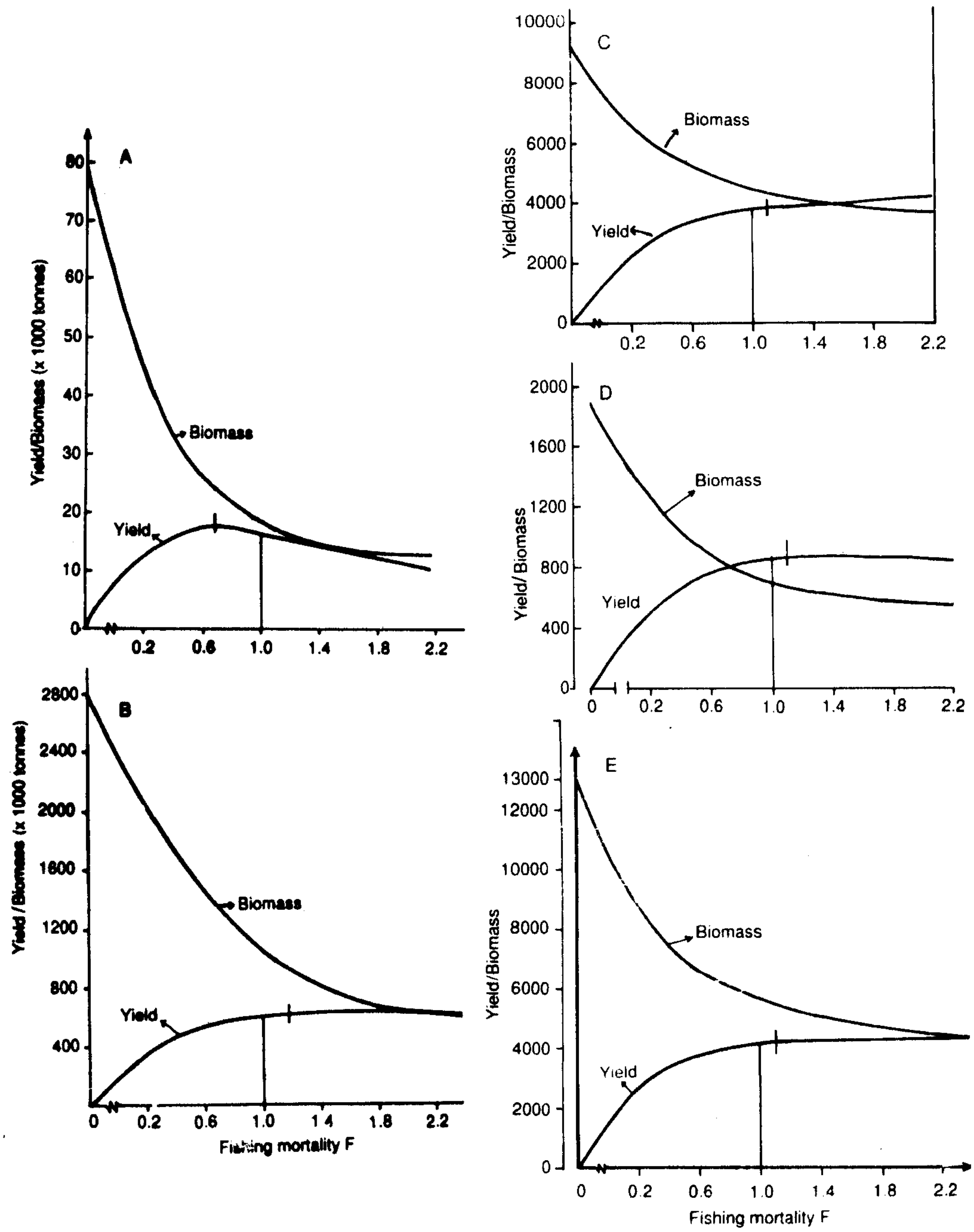

Fig. 11. Yield and biomass of *Euthynnus affinis* (A), *Thunnus tonggol* (B), *Auxix thazard* (C), *A. rochei* (D) and *Katsuwonus pelamis* (E) at different levels of fishing mortality (the small vertical line indicates MSY and the long vertical line the current yield).

In case of *A. thazard* the mean value of F was estimated as 1.0311 and the size group at maximum F value attained was 44–46 cm. The present catch of this species is 3 972 tonnes, the estimated MSY 4 852 tonnes and the biomass MSY 1 982 tonnes. The MSY could be obtained by increasing the effort by 1.2 times from the present level, but this will result in an increase of only 880 tonnes (21% increase over the present yield) (Fig. 11. C).

For *A. rochei* the mean value of F was estimated as 1.7147 and the size group at maximum F value attained was 23–25 cm. The present catch of this species is 880 tonnes, the estimated MSY 896 tonnes and the biomass MSY 612 tonnes. By increasing the effort by 1.6 times from the present level the MSY could be attained (Fig. 11. D).

In case of *K. pelamis*, the mean F was estimated as 1.39 and the size group at maximum F value attained was 68–70 cm. The present catch of this species is 4 140 tonnes, the estimated MSY 4 440 tonnes and the biomass MSY 3 702 tonnes. The MSY could be obtained by increasing the effort by 4.1 times and this increase in effort will yield an additional catch of 300 tonnes (Fig. 11. E).

DISCUSSION

Tunas contribute 1.5–2.0% of the total marine fish landings in India. Though they are large growing pelagic fishes and their meat is in good demand, targeted fishing for tunas by the pole and line is carried out only in Lakshadweep. Along the mainland coast, in the traditional sector, only the coastal tunas such as the little tunny (*E. affinis*), frigate tuna (*A. thazard*), bullet tuna (*A. rochei*) and few other species are exploited by various gears like the drift gill nets, hooks and line and purse seines. The drift gill nets, being more economical with guaranteed returns, are popular. As it is a multispecies gear, tunas constitute 20–50% of the catch. This study (1984–88) indicated that gill nets contributed 54%, pole and line 27%, purse seine 17% and other gears 2% to the total tuna production in India.

Tunas are highly migratory. This habit is utilized by the fishermen in their exploitation. The pre-monsoon and post-monsoon along the southwest coast and post-monsoon along the Maharashtra and Gujarat coasts are most productive periods. The little tunny (*E. affinis*), frigate tuna (*A. thazard*) and bullet tuna (*A. rochei*) appear in shoals and form a peak fishery at Vizhinjam area in the pre-monsoon period. It appears that a part of the stock migrates to the east coast and is exploited at Tuticorin mostly during the monsoon period. A major portion migrates northward from Vizhinjam along the west coast and forms a peak fishery at Cochin from May to August. It migrates further north and is exploited at Mangalore during the post-monsoon period. Depending on the demand for tunas the drift gill net fishermen concentrate at these centres for exploitation during the season.

Over the years the tuna catch increased from 4 000 tonnes in 1970 to 45 240 tonnes in 1989. Recently, Pillai (1991a) reviewed the changing pattern of the tuna fishery in the small-scale sector and opined that factors such as the introduction of improved variety of gears and mechanization/motorization of fishing craft have enabled fishermen to increase the radius of fishing operations and venturing into deep sea. This is especially evident at Vizhinjam where the hooks and line (mechanized) have started exploiting the hitherto non-exploited stock of the bullet tunas (*A. rochei*) from deeper grounds. The placid waters of the northwest coast facilitate the use of large craft capable of stay fishing. The gill net operations in these areas have resulted in exploiting the neritic species like the longtail tuna (*T. tonggol*) and the pre-adults of oceanic yellowfin tuna (*T. albacares*). The spurt in the landings during recent years is mainly due to the increase in fishing operations beyond the traditional fishing grounds to meet the demand for tuna meat in the domestic and foreign markets as fresh, chilled, canned and pre-cooked, and sundried (*masmin*) products.

This study (1984–88) showed that the exploitation of tunas from the traditional fishing grounds has reached the optimum level or near it. Increase in effort may not fetch enhanced returns in terms of direct operational cost (DOC) and cost benefit ratio (C:B). In the case of little tunny (*E. affinis*) overexploitation is already there and a decrease in effort to 66% of the current level only can maintain the MSY of 15 526 tonnes. For frigate tuna (*A. thazard*) there is scope for increasing the effort by 1.2 times from the present (1984–88) level to net another 880 tonnes for attaining the MSY of 4 852 tonnes. An effort input by 1.6 times would be required to attain the MSY of 641 tonnes in the case of longtail tuna (*T. tonggol*) and 896 tonnes in the case of bullet tuna (*A. rochei*). But the increase in production will be marginal and hence uneconomical.

In Lakshadweep, the exploitation of the skipjack tuna (*K. pelamis*) by the pole and line is carried out in the vicinity of the islands. The present catch (1988) is 4 140 tonnes. Increasing the effort by 4.1 times will yield an additional catch of 300 tonnes. But future expansion of the pole and line fishery beyond the traditional grounds is possible by maximum utilization of the live-baits, their large-scale confinement/culture and supply, and proper conservation of their natural fishing grounds.

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