Appendix 1

THE TUNA FISHERY IN THE EEZs OF INDIA, MALDIVES AND SRI LANKA

K. Sivasubramaniam
Senior Fishery Biologist

Introduction

The EEZs of India (western side), Maldives and Sri Lanka, have common boundaries and hence the sea area bounded by these three countries is devoid of any international waters. In the past, the small-scale fisheries of these countries exploited the tunas and bonitos in the coastal waters while the tunas in their oceanic provinces were exploited by other nations such as Japan, Korea Taiwan and also by the Soviet Union to a small degree. With the establishment of the EEZ, exploitation of tunas in this area by distant nations has been significantly reduced, perhaps to zero, because of the absence of international waters within this area and also because, at present, there are no joint tuna fishing ventures in this area.

Exploration and exploitation of the fishery resources in this area over the past three decades have shown that the tuna resources in this area consist of the yellowfin tuna *(T.a/bacares),* the big eye tuna *(T. obsesus),* the long-tail tuna *(T. tonggol),* the skipjack tuna *(K. pelamis),* the eastern little tuna *(E. affinis),* the frigate tuna *(A. thazard),* the bullet tuna *(A. rochei),* the dog-tooth tuna *(G. un/color)* and the oriental bonito *(Sarda orienta/is).* The last five species are generally considered to be insular and with localized migratory habit. The others, particularly the first two species, are known to be widely distributed not only in the area under consideration but also in other parts of the Indian ocean and the limits of distribution of the stocks of these oceanic species are not clearly understood yet.

The two oceanic species that are exploited by the three countries at present are the yellowfin (mainly immature fish) and the skipjack tunas. The distribution of skipjack and yellowfin tuna in this area extends from the oceanic to the peripheral range of the neritic provinces of the three countries and the exploitation by the three countries is primarily along the fringes of their distribution. In the case of the yellowfin tuna, the juveniles and immature fish enter the surface fishery in the insular ranges and the adults are deepswimming in the oceanic ranges where they generally contribute to the tuna longline fishery which is supposed to be non-existent in this area at present. In view of this situation, the present paper deals mainly with these two species.

As a result of the increasing trend in tuna production in the three countries, the ab3orption of the entire sea area enclosed by these countries into their respective EEZs and subsequent withdrawal from oceanic fishery by distant nations, India, Maldives and Sri Lanka alone are responsible for the rational utilization and management of the fishery resources within this area. Cooperation in the assessment of the resources and identification of any influence of the tuna fishery of one country on those of the other two may lead to the establishment of joint management of tuna resoruces within the area under consideration.

This paper is based on information available from past publications and it is anticipated that participants at the Working Group meeting will contribute supplementary information on the fishery and tuna resources obtained in recent years by the respective countries.

Fishing methods and crafts

In all three countries, tuna fishery is on multispecies with multigears. In the Maldive islands, Minicoy islands of India and in Sri Lanka, effort is specifically directed on tuna varieties but off the mainland of India, incidental catches of tuna contribute significantly to production of these species at present.

Table 1
Types of craft, fishing methods and tuna species caught

Country	Craft	Size & Characteristics	Operation	Gear	Tuna species caught
MALDIVES	Masdhoni	Mech. & Non-mech. 12 – 14 m LOA	12 hr. day trip Bait and tuna fishing	Liftnet for bait Pole Er line for tuna	Skipjack, Yellowfin, Little tuna, Frigate tuna
	Wadudhoni	Non-mech. – sail 8—10 m LOA	12 hr. day trip Tuna Er other fish	Trolling lines Hand lines	Same as above
	Bokura	**Non-mech.** – rowing 2 – 5 m	4 – 6 hrs. day trip demersals & others	Handlines	Dog tooth Tuna
INDIA	Modern craft	Mach. 9.7 m – 14.5 m	Day boats	Gillrietting Mesh 90—130mm	Little Tuna, Frigate Tuna, Longtail Tuna
	Dugout canoes	Mech. & non-mech. 8.3 – 9.7 m			
		Non-mech. 6 m		Hand lines Trolling	
	Purse seiners	Mech 14.5 m	For Mackerels, Tuna incidental & sardines	Driftnet, Purse seine	Skipjack, Yellowfin, Little Tuna,
	'Mas odi'	Mech. & non-mech. 7.9 – 12.5 m with Bait tank	Day boats	Bait and pole Er line Trolling	Frigate Tuna
	Kattumaram	Mech. – 7.9 – 9.1 m 10—10 hp	..	Driftnet, Hook Er Line	Little Tuna
SRI LANKA	Modern craft	Mech. 28′ – 32′ LOA	Day & night op. 24 hrs.	Longline, Gillnet, Pole Er Line, Trolling	Yellowfin, Big eye, Skipjack, Little Tuna, Frigate Tuna
	Oru- Outrigger canoes	7—12mLOA		Pole Er Line, Trolling	
	Tuna longliners	315 Gr. T *	1-2 months duration oceanic	1. Longline	Yellowfin, Big eye Er Albacare

* Now suspended,

The characteristics of the crafts and methods used for catching tunas in the three countries are summarized in Table 1.

Species composition and distribution

The tuna species contributing to the fisheries in the three countries are presented in Table 2. They do not exhibit the same order of abundance or relative levels of production because of the following reasons:

(a) differences in the selectivity of the primary tuna fishing gears used in the three countries

(b) differences in the combinations of tuna fishing methods in the respective countries, and

(c) differences in the environmental characteristics of the insular area, influencing the habitat of the different species and also the distance of the fishing grounds from the shore.

Table 2

Percentage composition of the various tuna species caught by the three countries

Species	Maldives	India Mainland	India Laccadives	Sri Lanka
T. albacares	16.6		25.3	21.0
T. obsesus	?	?	1.5	1.0
T. tonggo/		0.4		±
K. pelamis	71.5	11.0	72.5	37.0
E. affinis	4.3	65.4	+	26.0
A.thazard	7.5	6.7	±	13.5
A.rochei				1.5
Gun/color	++	-F	?	+
S. oriental/s	+	F		+

(?) Unknown (H-) caught but not in large quantities
(++) caught in significant quantities but no figures available

Around Maldives, skipjack and yellowfin tunas are the most abundant of the tuna species and are caught in all areas. However the production of yellowfin is more from the western side of the islands than the eastern side, while skipjack production shows the revese trend. The percentage of yellowfin is higher in the catches off the northern atolls and declines rapidly southwards but that of skipjack is higher at the southern end of the atolls and it declines less rapidly than that of yellowfin tuna towards the northern end (Table 3).

Table 3

Percentage composition of tuna species in different areas around Maldives

Stratum	Skipjack	Yellowfin	Little tuna	Frigate tuna	Other fish
N. East – I	63.0	9.0	1.0	21	6.0
E. Central – II	81.0	7.0	1.0	7.0	4.0
S. East – III	84.0	0.0	0.0	1.0	9.0
N. West – IV	47.0	28.0	1.0	1.0	9.0
W. Central – V	33	2.9	14.0	9.0	15.0
S. West – VI	91	4.0	0.0	3.0	2.0

Around Sri Lanka also, skipjack and yellowfin tunas are caught around the island except in the north. Catches around the western coastline had a higher percentage of skipjack and yellowfin than those in the south or east coasts. Again the percentage of yellowfin tuna tends to be higher in the north–west than in the south–west but the decline of the skipjack in the reverse direction is not very marked (Table 4).

Table 4

Percentage composition of the tuna species caught in various areas around Sri Lanka, by two classes of driftnetters (Sivasubramaniam, 1970)

Coast	Yellowfin		Skipjack		Little tuna		Frigate tuna	
	11 G.T. Driftnet	3.5 G.T. D.N.	11 G.T. D.N.	3.5G.T. D.N.	11 G.T. D.N.	3.5G.T. D.N.	11 G.T. D.N.	3.5 G.T. D.N.
N.N.W.	26.3	–	47.2	–	26.2	–	0	–
NW.	64.0	56.3	31.4	62.1	3.3	0.8	1.1	0.2
W	23.6	19.5	65.9	62.7	8.2	15.4	2.1	2.2
S.W.	21.7	32.4	61.2	34.8	5.2	19.1	11.7	13.6
S	24.7	23.0	54.1	51.3	3.2	4.8	17.8	20.7
E	30.3	22.2	51.0	61.9	15.5	11.2	3.1	4.6
N.E.	32.3	30.1	34.0	40.9	13.5	17.0	19.8	12.4

The percentage of yellowfin tuna, in particular, seems to increase with increasing distance from shore. The influence of horizontal and vertical distribution of different tuna species on the catch composition is evident from Table 5.

Table 5

Percentage composition of tuna species caught by various gears operated in different fishing ranges around Sri Lanka (Sivasubramaniam, 1970).

Gear	Fishing depth	Fishing ground	Big eye	Yellow-fin	Skipjack	Little tuna	Frigate tuna
Troll	(0—3 m)						
	Surface	Inshore (<25 m)	0	12.6	27.3	31.2	28.9
Pole Er line	(0—2m) Surface	Inshore	0	2.5	87.6	4.4	5.4
		Offshore (25—50 m)	0	35.3	61.0	2.7	1.0
Driftnet	(1.20m)						
	Sub-surface	Inshore	0	28.2	57.7	7.7	6.3
Long-line	(75—125m) deep swimming	Inshore	28.1	71.2	0.7	0	0
		Offshore	31.0	68.1	1.0	0	0
		(750 m)	36.7	62.9	0.4	0	0

Even the total tuna components in the tuna longline catches show significant differences with increasing distance from shore.

Fishing area	*Tunas*	*Bi/Ifishes*	*Sharks*
Inshore	20%	7%	
Offshore	60%	10%	25%
Oceanic	65%		20%

The distribution of tunas in the surface waters of the oceanic ranges around Sri Lanka is not clearly established and exploratory pole and line fishery in this range, though not very encourga-ing, is not conclusive (Sivasubramaniam, 1974, 1975).

Off the mainland coast of India, the composition of tuna species caught is distinctly different from those of Maldive islands and Sri Lanka. The eastern little tuna and the long-tail tuna are the predominant species followed by the frigate tuna. Other species are comparatively negligible. According to available information (Silas *et al.* 1979, 1982), the predominance of long—tail tuna declines southwards while that of the little tuna increases, in the west coast catches. Even on the east coast, the little tuna is the predominant species in the southern part. Composition of the tuna species caught off the north-east coast is not available. Around Laccadive and Minicoy islands, the tuna catch composition is close to that of Maldive islands and the fishery is also similar. The tuna landings in the Andaman islands are negligible and consist mainly of little tuna and some yellowfin and big eye tuna.

Table 6

Approximate species composition of tuna catches in India
(Based on Silas *et al.* 1979, 1982)

State	Big eye	Yellow-fin	Skip-jack	Little tuna	Long-tail	Frigate	Others
Maharashtra	—	—	—	40	60		
Goa	—	—	—	++	++		
Karnataka	—	—	—	97.6	—	—	+
Kerala		+	+	70	+	H--F	
Tamil Nadu				59.7		26.3	±
Av. for mainland				90	5%	4	1
Laccadives-Minicoy	1.5	25.3	72.5				
Andaman islands	-F	H-			-F		

Latitudinally, the increase in the occurrence of long-tail tuna off the west coast of India and the general composition of tuna catches are similar to the observations along the Arabian coast on the western side of the Arabian sea (Sivasubramaniam, 1979). Exploratory tuna longline operations by "R. V. Varuna" also indicated the predominance of the long-tail tuna off the west coast of India.

Catch, effort and catch rates

In the Maldive islands, catch is estimated by total enumeration of the number of each species caught. This has been practicable because the pole and line method is the primary fishing method and trolling is the secondary method in the country and their marine fishery is almost entirely concentrated on a few tuna species. The following conversion factors are applied for converting catch number to catch weight: small skipjack—2.12 kg, large skipjack—6.18 kg, yellowfin—2.12 kg, little tuna—0.95 kg, frigate tuna—0.95 kg. The effort is presented as the number of fishing trips made by both mechanized and non-mechanized pole and line craft. The relative efficiencies of the two types of crafts and the trolling crafts (non-mechanized) were observed to be as follows:

mech. pole and line	1 for skipjack and yellowfin
non-mech. pole and line	0.23 for skipjack and 0.30 yellowfin (1980—82 data)
troll fishery pole and line	0.01 for skipjack and 0.16 yellowfin (1980—82 data)

Table 8 shows the annual change in the composition of various types of crafts:

Table 8

Tuna fishing crafts in the Maldives (Ministry of Fisheries, Male, Maldives, 1983)

Year	Non-mech P Er L	Mech. P Er L	Sub-total	Troll	Total
1970	1801		1801	2710	4511
1971	2011		2011	2893	4909
1972	2089		2089	2936	5075
1973	2146		2146	3012	5158
1974	2131	1	2132	3056	5188
1975	2074	42	2116	3154	5270
1976	2122	218	2340	3284	5624
1977	2085	413	2498	3383	5883
1978	1725	548	2273	3480	5753
1979	1574	767	2341	3546	5887
1980	1314	805	2119	3405	5524
1931	1061	970	2031	3364	5395
1982	952	1074	2026	3428	5454

The increase in the number of mechanized crafts has been compensated by the decrease in the number of non-mechanized crafts but because of the higher efficiency of mechanized crafts, the effectiveness of the effort applied has increased even though the total number of craft has not increased significantly.

The annual production of skipjack has fluctuated and a decline has been observed in recent years. Yellowfin tuna production has been fluctuating b3tween 4,000 and 5,000 tons during the last decade without clear evidence of any trend.

The production of skipjack is moderate in the north, low in the central part and high in the south of the country. Ye)lowfin shows a reverse trend. The catch rates of skipjack and yellowfin showed only slight variations but have shown a tendency to decline in recent years. The effort has been, and is continuing to be, low in areas of high catch rates and higher in the areas of moderate catch rates. Thus, the distribution of effort does not correspond to the catch rates in various strata.

Table 7

Skipjack and yellowfin tuna catch, effort and catch rates

(Source: *IPTP* Data Survey No. 1, 1983; Sivasubramaniam 1970, 1972; Ministry of Fisheries, Maldives)

Country	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
India	—		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11648	—	—
E. Little Tuna																				
Skipjack																		1803		
Tunnies								6032	5760	5678	10839	11285	19322	13005	13893	26595	20371	170803		
Maldives							27300	28900	16000	19385	22922	15103	19536	14006	13612	17670	23075	19957	19661	19491
Skipjack C																				
Effort (P & L)										210278	203097	175859	172534	139944	108539	99468	85932	174526	106510	123511
Mech. & non-mech. E																				
kg/boat/day C/E										91.2	109.1	83.8	111.2	103.3	137.4	288.3	236.9	211.3	151.0	lR.8
Yellowfin Catch							2100	7300	5000	5569	3965	3787	4351	4123	3214	3692	3647	4740	3850	5984
kg/boat/day										26.0	20.3	21.4	27.0	32.2	36.8	67.6	42.5	54.1	42.5	48.4
Sri Lanka C	1000	2500	3000	3700	6000	10000	11800	2500	13200	10400	12321	15243	12232	11339	10994	8309	12700	13758		
Skipjack C/E	*1000*	11.6	13.3	16.4	25.0	45.5	53.4													
		1700	1900	2400	4000	3000	4000	4700	6500	6100	6070	6611	6955	5720	5369	6166	6906	7662		
kg/boat/day		7.0	8.4	10.6	16.6	17.7	18.0													

in Sri Lanka, production of both skipjack and yellowfin tunas has shown an increase but at a slow rate. The western side appears to be richer in yellowfin than the eastern side but on the western side the northern part produced higher catch rates which declined towards the south, as in the case of Maldives. Skipjack tuna catch rates were higher from the southern part of the west coast to the south coast (Table 9). The catch rates of skipjack and yellowfin tuna around Sri Lanka are much less than those of the Maldive islands, even if their pole and line fisheries alone are compared.

Table 9

Mean catch rates *(lbs.)* of skipjack tuna around Sri Lanka for various classes of crafts and gear (1967—71) (Sivasubramaniam 1972)

Fishery	NNW	NW	W	SW	S	E Er NE		Efficiency factor
11 Gr.T. Driftnet	6.7	154.8	311.6	280.9	254.3	132.7	30.0	2.36
3.5 Gr.T. Driftnet	—	58.9	143.4	89.0	115.7	69.8	*	1
3.5 Gr.T. P Er L	—	—	*	178.6	176.5	105.0	—	1.73
3.5 Gr.T. Troll	*	*	17.6	27.3	22.8	13.9	*	0.20
Outrigger P Er L	—	—	92.3	140.4	127.6	87.7	—	1.14

(—)No fishery (*) insufficient samples

The tuna landings in India were 3015 ton in 1970, 19,332 ton in 1976, 13,005 ton in 1977, 13,745 ton in 1978 and a record 26,595 ton in 1979. Information on production by species is not available but skipjack and yellowfin are primarily caught around Laccadive-Minicoy islands where tuna production increased from 500 ton in 1970 to about 2,000 ton in 1975 and declined to 1,000 ton in 1978. A catch of 1,803 ton of skipjack has been recorded for 1979. Catch rates for skipjack and yellowfin tuna off Indian coasts are not available for comparison.

Surface fishery for tunas does not extend beyond 25—30 miles from the shore in any of the three countries. Surveys from Sri Lanka showed that the pole and line fishery can be successful mainly within 60 miles. Even within this limit, the catch rates for pole and line fishery declined towards the outer boundary. However, these results were not conclusive because of various limitations in the survey3. The catch rates realized in the offshore range were 180 kg/day at sea, 682 kg/pole and line fishing day and 1395 kg/effective pole and line fishing day. The best average catch was in the south-west for both skipjack and yeltowfin tunas, followed by areas off the west, south and east coasts of Sri Lanka (Sivasubramaniam, 1975 and 1977). Analyses of incidental catches of skipjack by tuna longline fishery showed that this species is widely distributed in the area under discussion and the relative density appears to **be** greater in the oceanic ranges west of Sri Lanka than in the eastern side (Sivasubramaniam, 1972) (Fig. 1). This trend supports the hypothesis that the skipjack tuna caught by the three nations may be from a common stock or from intermingling stocks. Though there is unofficial evidence of foreign vessels fishing for oceanic surface tunas in this area, no records of the catches are available.

It is estimated that over 2,500 ton of tunas were taken by foreign longliners operating within the area under consideration in the late 1970s. The distribution pattern of the catch rates of yellowfiri and big eye tuna within the area, based on catch rates realized by Japanese and Sri Lankan tuna longliners operating in the area between 1966 and 1970 is shown in Fig. 2. Legally the effort on the production of larger tunas in this area should be zero at present, as none of the three nations with rights to the exploitation of this area, have an offshore or oceanic longline fishery. Analyses of more recent data are not readily available for consideration. Latitudinally, hooked rates of both yellowfin and big eye tuna are equally high near the equator and that of big eye tuna tends to decline towards higher latitudes. Yellowfin tuna shows higher hooked rate in the higher latitudes on the eastern side of Sri Lanka. There is evidence of improvement in the hooked rate of yellowfin tuna in the higher latitudinal areas but not so in the areas near the equator, until 1970. Recent exploratory tuna longline operations conducted by India and Sri Lanka also tend to show good catch rates in the higher latitudinal locations within the area (Anonymous 1983).

Seasonal variations

There is some similarity in the peak seasons for skipjack and yellowfin tuna catch rates around. Maldives, Minicoy and Sri Lanka (Table 10).

Table 10

Peak seasons for skipjack and yellowfin tuna

Area	Gear	Peak seasons	
		Skipjack	Yellowfin
Maldives	Pole & line	May—July & Sept.—Feb.	August—December
Sri Lanka	Driftnet	Jan. & May—October	July—Aug. & Oct.—Feb.
	Pole & line	Sept.—March	February—March
	Troll	June to August	June to August
India (Minicoy)	Pole & line	Sept.—December	
Calicut	Driftnet		November

There is some degree of annual shift in the peak seasons. Off Sri Lanka, there are some differences in the peak seasons according to the geographic location of the fishing area. In the south, skipjack tuna shows a peak for driftnet fishing in January and another in May which declines gradually until August; in the south-west coast, it is January and August. It is September on the west, October in the north and August on the eastern side. The yellowfin peak season beginning with the south-west monsoon shifts from east to south, south-west, west and then to the north-west (Sivasubramaniam, 1970, 1971 & 1972). During the pole and line fishery survey from December 1973 to March 1975, 32.5% of the total tuna catch was made in November alone. The survey vessel averaged one tonne/day during the peak seasons and caught more than two tonne/day off the south-west and west coasts during February—March and November and April, respectively.

Longline catches of both yellowfin and big eye tunas in the inshore waters were high during the north-east monsoon and the inter-monsoon period following it. In the oceanic province too, catch rates were higher during the first quarter and the first half of the second quarter. Close to the equator, the catch rates declined rapidly during the second quarter (Sivasubramaniam, 1971).

The reasons for seasonal variations in the availability of tuna and in the schooling behaviour are not fully understood. However, environmental factors such as temperature may be contributing to this phenomenon (Fig. 3).

Length composition

Around Sri Lanka, the size range of the exploited population of the skipjack tuna is 30—78 cm and graphical separation of polymodal length frequency distribution, using probability paper, revealed five modes—34.2, 43.0,52.4,63 and 71.5cm (Fig. 4). The first modal group occurs commonly in the south-west and east coasts; second, fourth and fifth modal groups in all areas, but predominantly in the north-west and east and the third group which is the most significant mode, was predominant in the west, south-west and south coasts. Since the introduction of driftnetting, significant quantities of the fourth and fifth modal groups enter the catches. The selectivity of driftnets, in contrast to the polo and line method, is evident from Fig. 5. In the oceanic province, the skipjack caught with tuna longline were found to be of the fourth and fifth modal groups, with very few fish of the third modal group (Fig. 6).

Length frequency distribution in the catches by various gears show that the driftnet is very selective but the popular use of multiple mesh sizes in each set of nets permits the sampling of a wide size range of the population.

In the Maldive islands, length frequency sampling was initiated with the training conducted there in 1983 and only a few months of sampling have been conducted so far. According to the available data (June—September 1983) from one area, the size of skipjack caught ranges from 25–71cm with polymodal distribution (Fig. 7). The peak modal lengths were smallerthan those from Sri Lankan waters for the corresponding months but in different years.

Length frequency distributions are not available for the Indian waters but bar charts available indicate that the size range of skipjack caught is 32—70 cm with modes between 40 and 50 cm occurring almost throughout the year and additional modes between 60 and 70 cm only from January to April (Jones and Silas, 1963). This trend, to a certain degree, resembles the pattern observed around Sri Lanka.

Yellowfin tuna caught around Sri Lanka range from 20 to 145 cm. Heavy entry of <50cm group (0 gp) is found in the south-west and east coasts. The entry in the south-west is generally high accounting for nearly 35% of the total catch from that area. The 50–100 cm group (gp I) contributes 60—95% to the total production of yellowfin by Sri Lanka (Fig. 8). The main size ranges were 50—55 cm in the south-west, 55—60 cm in the south and east, 65—70 cm in the west and 70–75 cm off the north-west coasts. The shift in size range and catch rates indicate probable entry of the 0 group into the south-west area. In the insular longline fishery, yellowfin are of 125—135cm group (gp III) and 140—1 50 cm group (gp IV) with a relatively small proportion of the 100–120 cm group (gp II). Considering that recruitment to the surface fishery is around June, the length frequency of oceanic samples for this period indicated entry of group II fish into longline catches. The occurrence of group II and III fish in the surface and longline fisheries exhibit their distribution throughout the vertical column of the mixed layer. The 0 and I groups remain in the insular surface fishery at least for one year during which period they tend to shift northwards and on becoming group II size range, they commence to spread into the deep-swimming layer. This process is accomplished by the time they reach the end of the group III size range and they are available to the longline fishery (Fig. 9).

Limited length frequency data on yellowfin tuna available from the Maldive islands fishery showed that the size range caught by pole and line method is similar to that of the skipjack tuna. Only one distinct peak was observed at 39—41 cm in June and 40—42 cm in August, but the size range was 20–55 cm during June to September (Fig. 10). Occasional landings of yellowfin over 100 cm were also observed in the first quarter of 1983. Very little information is available on the yellowfin tuna around India, based on which the size range of this species caught in the southwest coast of India is 63—78 cm (Silas *et al.*, 1979). It is noted that this size range is in keeping with the larger size entering the surface fishery on the north-west coast of Sri Lanka. An increase within the same size range was also observed from April to September.

Length-weight relationships

Regressions available for the two species from the area under consideration are given below:

Source	Locality	Size range	Log *a* or *a*	Log b or b	Weight unit	Length unit	Calculated weight at 55cm
(a) Skipjack							
Sivasubramaniam (1966)	(East & West) Sri Lanka	20–70 cm	–3.0250	2.8977	oz	cm	3.0 kg
Anonymous (1983)	Maldives	30—70cm	9.62539×10^{-6}	3.2050	g	cm	3.5kg
Joseph et al. (1983)	West coast of Sri Lanka		0.006	3.3	kg	cm	3.3 kg
(b) Yellowfin							
Sivasubramaniam (1956)	(East & West) Sri Lanka	25—110 cm	—3.0403	2.8992	oz	cm	
Anonymous (1983)	Maldives	30—70cm	8.3249x106	3.2304	g	cm	
Joseph *et al.* (1983)	West coast of Sri Lanka		0.041	2.8	kg	cm	

Calculated weight of a 55 cm skipjack varied between 3.00 and 3.50 kg for the regressions. The units used in the three cases were not identical, besides other differences. Similar calculations based on various regressions for the skipjack in the Pacific Ocean, varied between 3.33 and **3.58 kg.**

Maturity and spawning

Raju (1963) estimated that the skipjack tuna around Minicoy reach sexual maturity around 40—45 cm and the smallest mature female recorded from this area was 39.6 cm. Around Sri Lanka, skipjack tuna of 45—50 cm are generally mature and a large quantity of this size range entering the pole and line fishery in the south coast were spent females (Sivasubramaniarn 1965 and 1972). Mimura (1962) stated that yellowfin of 0-age are immature, some individuals at 1-age show sexual maturity. Generally, yellowfin smaller than 70 cm have been considered to be in the non-spawning condition. However, studies have shown that yellowfin in coastal waters attain sexual maturity at about 50 cm whereas fish captured by longline in the oceanic province mature at about 110 cm. More recent studies by Japanese researchers indicate that spawning potential of fish smaller than 110 cm in the oceanic province may have been underestimated (Yesaki 1983). Maturity studies of yellowfin tuna in the specific area under consideration are yet to be undertaken.

Off the southwest coast of Sri Lanka, spent female skipjacks were observed around January indicating that spawning may be around that period. Near Minicoy, skipjack with mature ovaries have been observed during November—July and with spent ovaries in June—August. Eggs, larvae and juveniles of skipjack have been observed in the Indian waters from January—April and possible spawning from January to April and June to September has been suggested (Raju 1963). The possibility of multiple spawning has also been indicated by the same author. This is supported by the occurrence of more than a single entry of small fish into the fishery, as evident from the length frequency distribution. This point is also supported by evidence on recruitment pattern, to be discussed later in this paper.

However it is not clear whether the spawning of skipjack is restricted or widely spread over the area under consideration. Skipjack larvae have been collected from waters close to all these countries (Jones and Silas, 1963). Spawning of yellowfin takes place during February to April in the Laccadive sea as evidenced by the capture of larvae from the sea. Though spawning in the tropical part of Indian Ocean is supposed to occur during October to April, capture of mature fish in the northern and western parts of the Indian ocean has been used to indicate spawning during January to May (Jones and Kumaran, 1963). Yellowfin larvae have been found to be widely distributed in the equatorial belt and with concentrations in the central equatorial region. It is conjectured that spawning in this vicinity may be contributing to the recruitment to the fishery around Sri Lanka and Maldives. Juvenile yellowfin entering Sri Lankan waters each year would have been spawned during the first or second quarter of the previous year. Recruitment to Maldives fishery as in the case of Sri Lankan fishery, appears to be greater along the western side of the country.

Raju (1953) determined the regression for fecundity on length of skipjack tuna around Minicoy as Y =2.713 X-100494. No similar estimate is available for yellowlin in the Indian Ocean region but June (1953) devised the regression Y==125,000 X-2853000 (X is the weight of fish and Y the number of maturing ova) for the yellowfin in the Pacific Ocean.

Schooling behaviour

Though different size ranges of these two species have been found to occur in an area, each school tends to be made up of fish mainly of one size group and more than one species may occur in a schoo!. As a result, the species and the size compositions of the catch by one boat can be different from those of another boat operating from the same port and on the same day. Schooling behaviour also changes seasonally and hence the number of surface schools of tunas sighted varies significantly with seasons. During the pole and line fishery survey in 1974—75 around Sri Lanka, it was observed that the average number of schools sighted per day was 1.4 and the maximum was six schools/day. The catch/school seldom exceeded two ton and the mean value was 798 kg/school. Except for two occasions when 10 ton/day was obtained the catch/day varied under four ton and the mean value was 682 kg/fishing day. This indicated that the school sizes are generally small and remain the same throughout the year except for a slightly higher concentration during the second peak season in the south-west. The number of schools sighted per day declined to almost zero during the south-west monsoon season and increased to an average of two schools/day between February and April.

Around Maldives, the number of schools sighted per day may be slightly higher but even there sightings become extremely poor periodically. Such periods differ from area to area around the country. Around Laccadives, it has been reported that two or more schools may be sighted half a km apart but it is not clear whether this behaviour is generally prevalent throughout the year and in the entire fishing range.

During experimental pole and line fishery around Sri Lanka, 25% of the attempts resulted in no biting response to chumming. There was a mean interval of two days between fishing attempts and 3.2 days between successful attempts. These intervals were larger during June to September. During peak seasons, response to chumming is good and hence relatively less live bait is used. The average bait to tuna catch ratio was 1: 5.9 but in January to March and in November, the rates improved to 1:16. During seasons when surface school formation is reduced the fish appear to be either sparsely scattered close to the surface or concentrated in the sub-surface layer. At such times they contribute to the troll fishery or driftnet fishery. This has been shown in the section dealing with seasonal variations and has also been confirmed by aerial survey (Sivasubramaniam, 1971, 1975 Er 1977).

Fish aggregating devices have been successfully applied to aggregate skipjack and yellowfin tunas in the Pacific and were attempted in the Ma!dives and Sri Lanka. The Maldives claimed that the results were good but, due to lack of proper monitoring, it is not possible to evaluate the effectiveness of the device. In Sri Lanka, the results were not encouraging; perhaps the experimental period was too short. Even off the west coast of Thailand, experiments with FAD were not successful. Aggregating devices are presumably being used with success around Seychelles but details are not available. Behavioural characteristics of the same species appear to differ with location and environmental factors. Evidence shows that fewer schools are met with beyond 40/50 miles from Sri Lanka shores but incidental catches of skipjack by tuna longline indicates the presence of this fish even in the oceanic province.

Age and growth parameters

Relatively less information on these parameters is available for skipjack and yellowfin tunas in the Indian Ocean than in the other two oceans. Parameters K and L_∞ of the Von Bertanlaffy equation computed according to the procedure developed by Pauly and David (1980), using available length frequency data, are presented in Table 11 which also includes information from other areas in the region.

The drift gillnet is the main type of gear used in the tuna fishery in Sri Lanka and hence length compositions derived from the data obtained during the pole and line survey in 1974—75 were used to avoid influence of selectivity in the former fishing method. In the case of yellowfin tuna only the juveniles and young fish enter the surface fishery. Therefore, the best fit of the growth curve was obtained for the length frequency distribution of this fish with protracted and seeded value of L_∞ based on maximum size observed (Figs. 14 and 15). The original data were not available and hence the length frequency data were read off Sivasubramaniam (1977).

Length frequency data are available from the skipjack and yellowfin tuna fishery in the Maldives for only four months, and hardly any modal progression is evident from these samples. Hence, a reasonably good growth curve could not be fitted at this stage. Even in the case of skipjack tuna caught around Minicoy islands, the percentage length frequency distribution (Tables 2 and 3 presented in Raju's paper (1963)) exhibited very poor modal progression over a one-year period. This contributed to the unimodal distribution pattern of the size range in the fishery, as described by the author. Good fit for the growth curve could not be achieved without attributing a very low value for K and a high value for L_∞.

Mortality and selection pattern

L_∞, K estimates and length frequency data were used with ELEFAN II programme prepared by Pauly (1982) and Pauly *eta!* (1981), which constructs a length converted catch curve, a selection curve and the recruitment pattern and derives an estimate of the natural mortality rate (M) on the basis of Pauly's equation (1980).

$$\text{Log}_{10} M = 0.0066 - 0.279 \text{Log}_{10} L_\infty + 0.6543 \text{Log}_{10} K + 0.4634 \text{Log}_{10} T$$

(where T is the mean environmental temperature in °C).

The length converted catch curve obtained with the skipjack tuna data was reasonably straight and indicated a total mortality rate (Z) of 1.88 (Fig. 11-A). Using the estimated M value of 0.87 (T °C=28.5)the fishing mortality (F) was found to be 1.01. The exploitation rate (E=F/Z) was 0.54 which exhibits a rather optimal level of exploitation of the stock.

The selection pattern (Fig. 11-B) indicates that the mean length at first capture is 47.26 cm which corresponds to a reasonably large fraction of L_∞. The recruitment pattern (Fig. 11-C) suggests that skipjack tuna in the area are recruited at least twice a year, with one recruitment being very much stronger than the other.

The same exercise with data on yellowfin tuna entering the surface fishery around Sri Lanka, gave the following values: Z==2.68, M==0.7, F=1.99, E=0.74. The rate of exploitation in this case is indicated as high and the recruitment pattern exhibits at least two recruitments with different pulses, as in the case of skipjack tuna (Fig. 12). In view of the various limitations mentioned earlier, the results are to be viewed cautiously.

The application of the ELEFAN programmes has been attempted to consider the possibility of using this methodology for fish population studies in this region where reliable data are not available for traditional methods of analyses.

Potential yields

The two tuna species under consideration have a widespread distribution in the Indian Ocean and there is no knowledge available on the separation of these stocks according to geographical

Table 11

Growth parameter and age in years estimated for skipjack and yellowfin tuna in the Indian Ocean

Source	Locality	Age in years 0	1	2	3	4	5	6	7	8	t_0	K	L_∞	Method
SKIPJACK														
Shabotinets (1968)	Indian Ocean					40—45	40—60							First dorsal spine
Yesaki (1981)	West Coast Thailand										0	0.0420	75	Length frequency
Sivasubramaniam **(1983)**	Sri Lanka	<27	34	43	52	83	71				0	0.52	77	Length frequency
YELLOWFIN														
Shabotinets (1983)	Indian Ocean					75—**90**	80—**100**							
Yesaki (1983)	Indonesia	48 46	82 79	107 104	122 123	138 136	148 146		155 154	164 159	0	0.3— 0.32	173 175	Length frequency
Sivasubramaniam (1983)	Sri Lanka	50	90	110							0	0.50	174	Length frequency

areas. As such, potential yields must be cautiously estimated for any small part of the whole ocean regime. Potential yields for skipjack and yellowfin tuna from the whole Indian Ocean, has been estimated to be 200,000—300,000 tonne (Kawasaki, 1972) and 39,000 tonne (Lee and Yang, 1983), respectively.

Reliable and required data are not available in the three countries concerned for a proper estimation of the potential yields. In the case of Maldive islands, some form of catch and effort (number of trips by mechanized and non-mechanized pole and line craft) data are available for a number of years. These data were analysed as part of a training course conducted in that country in 1983 (TCP/MDV/2202), to estimate the MSY. The results obtained were as follows:

	MSY skipjack	*Optimum effort* (No. of trips)
Schaefer model	19,261	113,966
Fox's model	18,035	114,086

The tuna catch rates around Maldives have shown a declining trend in recent years and considering the present level of production of the main tuna species (skipjack) *vis-a-vis* the MSY, it appears that a significant increase in the production mdy not be achieved within the presently exploited range. The fishery may have to be extended beyond the presently exploited range and the economic viability of such an expansion has to be investigated. Maldives is exploiting only that component of the stocks which lies within a very small part of its EEZ.

The present status of the tuna fishery in Sri Lanka indicates an increasing trend in production but there are indications that the catch rates may be declining. There have been changes in the combination of tuna fishery methods but changes in the overall effort on tunas are not known. The exploitation rates obtained in the previous section also tend to show that expansion of the fishery within the presently exploited range may not be rational and increase in the fishing intensity within this range, even during peak seasons, may not result in very significant improvements. Again, expansion into the offshore and oceanic ranges within the EEZ has to be considered but results of experimental fishing by FAO (1977) and Nichiro Fishing Company (1975) should be studied carefully.

Sivasubramaniam (1977) made crude estimates of the potential in the offshore and oceanic ranges of the EEZ around Sri Lanka as follows:

Skipjack	—	15,000 t
Yellowfin	—	3,000 t

In view of the withdrawal of the longline fishery by distant nations, the potential for the exploitation of yellowfin may perhaps be higher than the value given. However, the economics of the fishing operation should receive primary consideration, in view of the catch rates that can be obtained.

Dwivedi and Devaraj (1983) estimated a tuna biomass of 6,000 t and an MSY of 3,000 tin the EEZ of India. This was based on the proportion of the 220,000 t tuna biomass in the Indian Ocean that is expected to be distributed within the EEZ of India (2.8%). George *et al.* (1977) have estimated the following potential exploitable yields for all tuna species within the EEZ around India:

North-west coast (Gujarat and Maharashtra)	10,000 ton
South-west coast (Goa, Karnataka and Kerala)	60,000 ton
Lower east coast (Tamil Nadu and Andhra)	10,000 ton
Upper east coast (Orissa, W. Bengal)	10,000 ton
Laccadive islands	50,000 ton
Andaman islands and Nicobar	100,000 ton
	240,000 ton

(Source: Silas *et al,* 1982)

Unfortunately, the original source of these estimates was not accessible and hence the method of estimation is unknown to the present author. However, there is significant discrepancy in the potential estimated by the two groups mentioned above. Indirect approaches to estimation of potential yields have to be viewed very cautiously. It is understood that India conducts sampling for catch, effort and length frequency for tuna but such data have not been published. If such data are available then some direct estimation can be attempted.

Suggestions for consideration by the Working Group

1. All available data on tuna catch, effort applied and length composition should be compiled by the respective countries.
2. Tuna biologists in the respective countries to present results of recent research/investigations conducted on tunas and their fisheries, to update the information in this Working Paper and enhance the value of the deliberations at the Working Group meeting.
3. Information on size, characteristics and operation of various crafts and gears used for tuna fishing, to be compiled and discussed at the Working Group Meeting.
4. Intensified systematic/random sampling for length compositions of tunas caught is necessary for length-based approach to fish population studies.
5. Morphometric and meristic characters may be examined for comparison between areas.
6. Sampling programmes should be standardized for compatibility of data from the three countries.
7. Selectivity of the gears used and relative efficiencies of different classes of vessels should be determined.
8. Special sampling programmes should be established for collecting information on spawning seasons and areas. A standardized methodology for determining maturity stages, to avoid discrepancies arising from different approaches.
9. Sampling programme for estimates of catch and effort, catch rates, independent of the routine sampling programme of the statistical division/units.
10. Exploratory fishing should be undertaken in the ranges beyond the presently exploited range. Use of gillnets, for catching tunas in the offshore and oceanic ranges, may be experimented with.

References

Anonymous. 1983 — Management of fisheries in the Republic of Maldives, Ministry of Fisheries, Maldives. (Manuscript)

—. 1983 — *Exploratory Fisheries Project News!etler;* Vol. IV No. 1, Ministry of Agriculture, India.

1983 — MV "Wennapuwa Maru" cruise, 1982/83 – cost and earnings, Fisheries Training Institute, Ministry of Fisheries, Sri Lanka (Manuscript).

Dwivedi, S. N. and Devaraj, M. 1983 — Tuna fisheries of the Indian Ocean and development prospects in the Indian EEZ; Central Institute of Fisheries Education, India (Mimeographed).

F.A.O. 1983 — Training course on fisheries statistics and Biology in the Republic of Maldives (TCP/MDV/2202) – Notes and exercises (Manuscript).

1983 Indo-Pacific Tuna Fisheries Data Summary (Draft), *IPTP Data Summary No. 1;* Indo-Pacific Tuna Development and Management Programme, Colombo.

George, P. C., Anthony Raja, B.T. and George, K.C. 1977 Fishery Resources of Indian Economic Zone. *Silver Jubilee Souvenir,* IFP October 1977, 79–116.

Jones, S and Silas, E. G. **1963** Synopses of biological data on skipjack *K. pelamis* (Indian Ocean); *Proc. World Sd. meeting on Biology of Tunas,* California, *FAQ Fisheries Report* No. 6 Vol. 2.

Jones, S. and Kumaran, M. 1962 Distribution of larval tuna collected by the Calesberg Foundation, DANA expedition from the Indian Ocean, *Ibid.,* Vol.6 No.3.

Kawasaki, T. 1972 The skipjack tuna resources; *Fishing and Food Industry Weekly* (July 1972). English Translation: US Dept. Commer. *Nat!., Mar. Fish. Serv. Rev.* **35 (5—6) 1—7.**

Loe Jang Uk and Yang Won Seok. 1983 **A study of the population analyses of** yellowfin tuna *T. a!bacares* and big eye tuna *T. obsesus* exploited by longline fishery for 1971–1977. *Bull, Fish. Res. and Devel. Agency* No. 31, Korea.

Mimura, Koya. 1963 Synopsis of biological data on yellowfin tuna *N. macropterus* (Indian Ocean), *Proc. World Sd. Meeting on Biology of Tunas,* California; F.A.O. Fisheries Report No. 6 Vol. 2.

Pauly, D. 1980 On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks; *Journ. Cons. Inter. Explori. Mer.* **39 (3).**

Pauly, D. and David, N. 1981 ELEFAN I — A basic program for the objective extraction of growth parameters from length - frequency data. *Meeresforch* 28(4): 205—211.

Pauly, D. 1982 Studying single species dynamics in a multi-species context, pp. 33—70 in 0. Pauly and G.l. Murphy (eds.) *Theory and Managment of Tropical Fisheries.* ICLARM Conf. Proc. 9, 360 p.

Raju, G. 1963 Spawning of the oceanic skipjack *K. pelamis* in the Laccadives. *Proc. World Sci. meeting on Biol. of Tunas,* California, F.A.O. Fisheries Report No. 6, Vol. 3.

Silas, E. G., Rajagopalan, M. S. and parameswaran, P. 1979 Tuna Fisheries in India. Recent trends. *Mar. Fish. In! Serv.* (CMFRI) No. 13.

Silas, E. G. and PiIIai, P. P. 1982 Resources of tunas and related species and their fisheries in the Indian Ocean. *Bu!l. C.M.F.R.I.* Cochin India, No. 32.

Sivasubramaniam, K. 1970 Surface and subsurface fisheries for young and immature yellowfin tuna *(T. albacares)* around Ceylon. *Bull Fish. Res. Stn. Ceylon,* Vol. 21, No. 2.

1971 Apparent abundance of yellowfin and big eye tuna in the inshore, offshore and oceanic ranges around Ceylon. *Ibid.* Vol. 22, No. 1 +2.

1971 An aerial survey for surface tuna resource in the seas around Ceylon. *Ibid.* Vol. 22 No. 1 **+2.**

1972 Skipjack tuna *(K. pelamis)* resource in the seas around Ceylon. *Ibid.* Vol. 23, No. 1+2.

1966 Distribution and length – weight relationships of tunas and tuna-like fishes around Ceylon. *Ibid.* Vol. 19.

1975 An analyses of the experimental pole and line fishery conducted around Sri Lanka by Nichiro Fishing Company of Japan. *Ibid.* Vol. 26 No. 1 +2.

1977 Experimental Fishery Survey for skipjack and other tuna species by pole and line and driftnet fishing method in Sri Lanka. F.A.O./UNDP Fishery Development Project in Sri Lanka (SRL/72/051). Tech. Rept. No. 4 (Mimeographed).

1977 Pelagic Fishery Resources of Sri Lanka and its present level of exploitation with special reference to offshore and deep sea waters. *Bull. Fish Res. Stn. Ceylon* Vol. 28, No. 1 +2.

1979 Resources of the large pelagics in the Gulf and Gulf of Oman – FAO Regional Fishery Survey and Development Project Report DP/RAB/71/278/11.

White, 1. F. and Yesaki, M. 1982 The status of tuna fisheries in Indonesian and Philippines, Indo-Pacific Tuna Development and Management Program Report IPTP/82/WP/3.

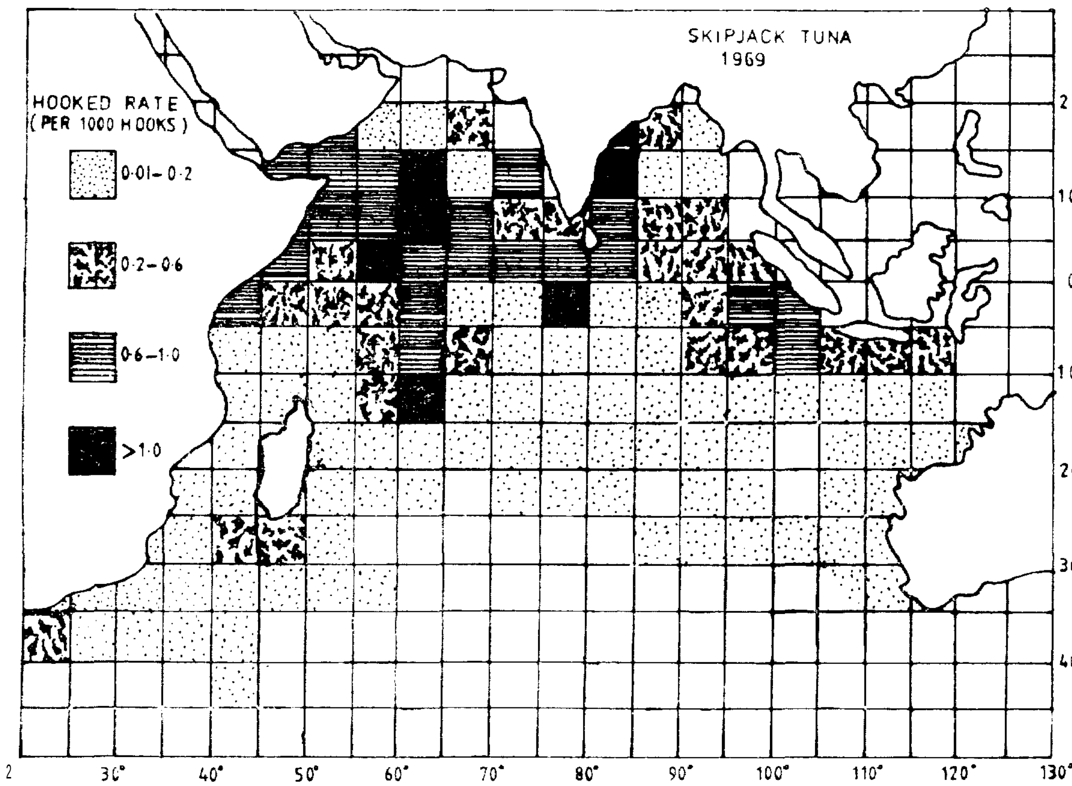

Fig. 1. Hooked rate of skipjack tuna on tuna long//ne (Sivasubramaniam 1972).

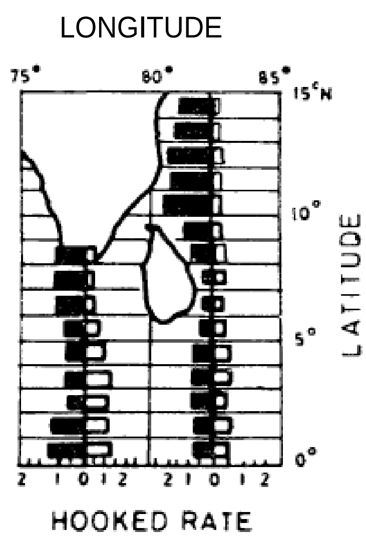

Fig. 2. Hooked rates for ye//owl/n tuna (shaded Portion) and
big eye tuna in the oceanic range (Sivasubraman/am 1971).

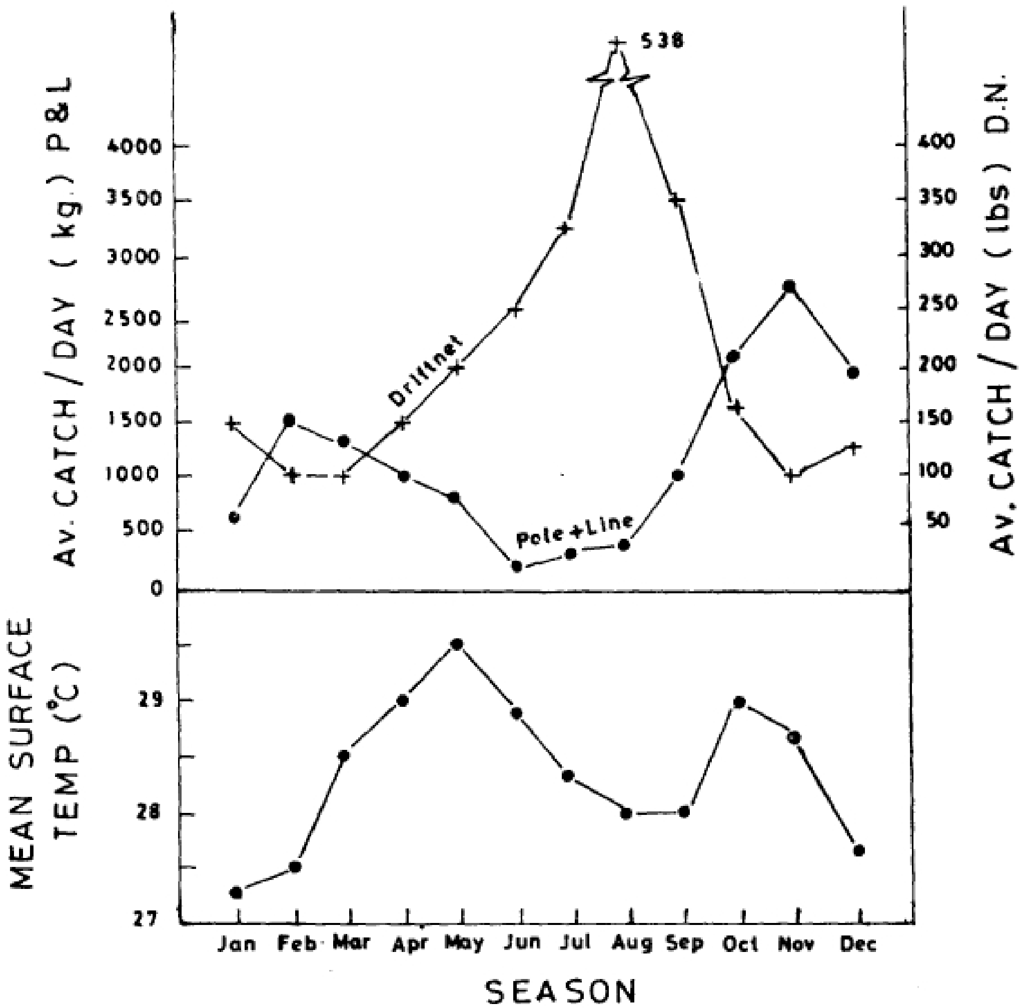

Fig. 3. Comparisons of seasonal variation in the catch rates realised by pole and line fishery and 11-ton class driftnet fishery (Sivasubramanlam 1975).

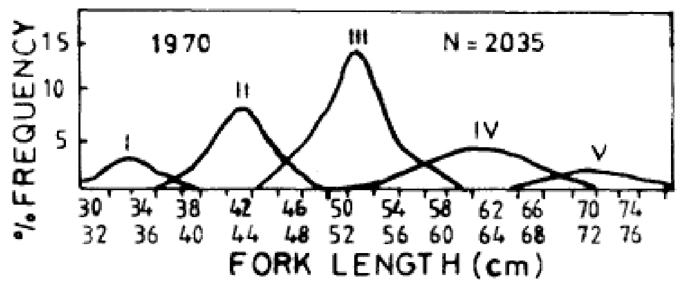

Fig. 4. Graphical analysis of polymodal distribution of length frequency of skipjack around Sri Lanka (Sivasubramaniam 1976).

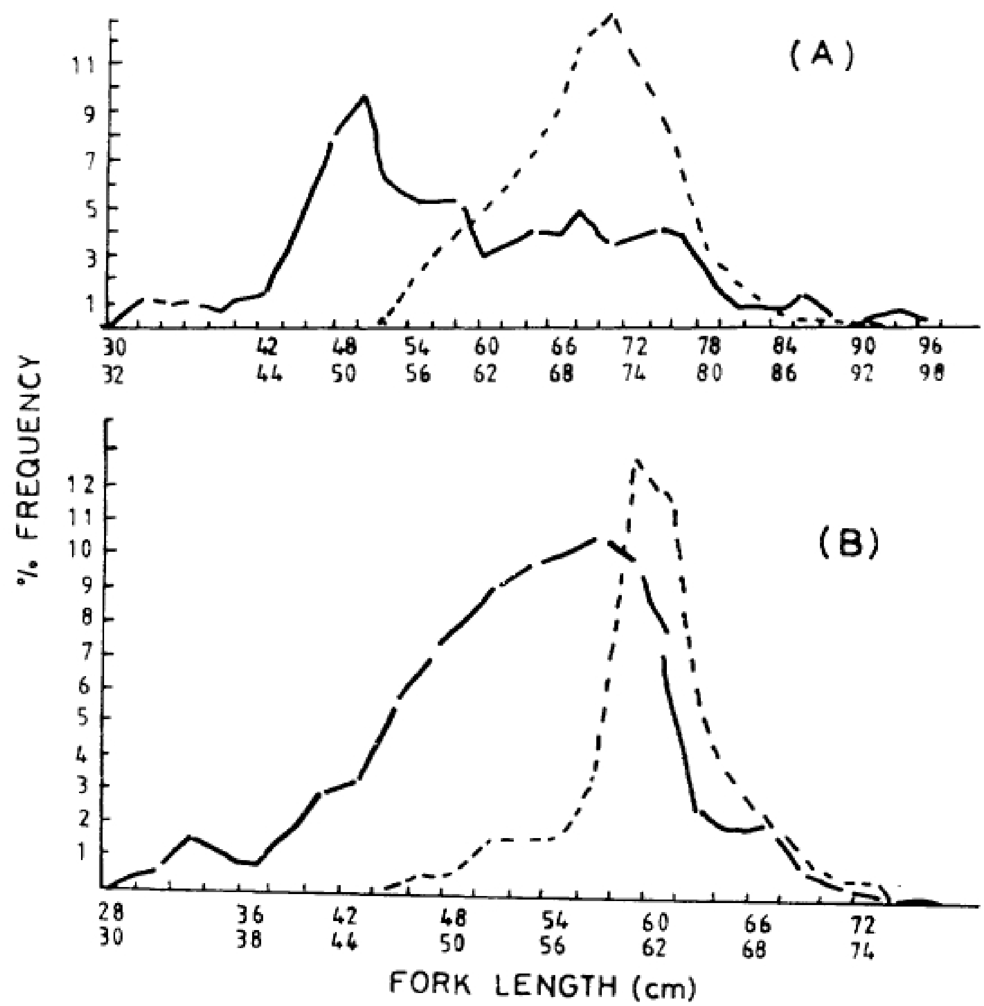

Fig. b. Length frequency distribution of yellowfin (A) and skipjack (B) tuna caught by pole and line and 7" mesh dr/knot (Broken lines) around $ri Lanka, 1974—75 (Sivasubramanlam 1977).

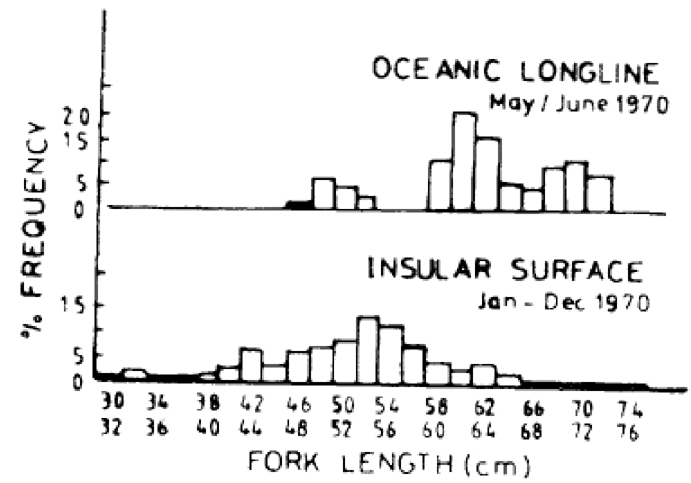

Fig. 6. Size composition of skipjack in the insular surface and deepswimming oceanic ranges west of Sri Lanka (Sivasubramaniam 1972).

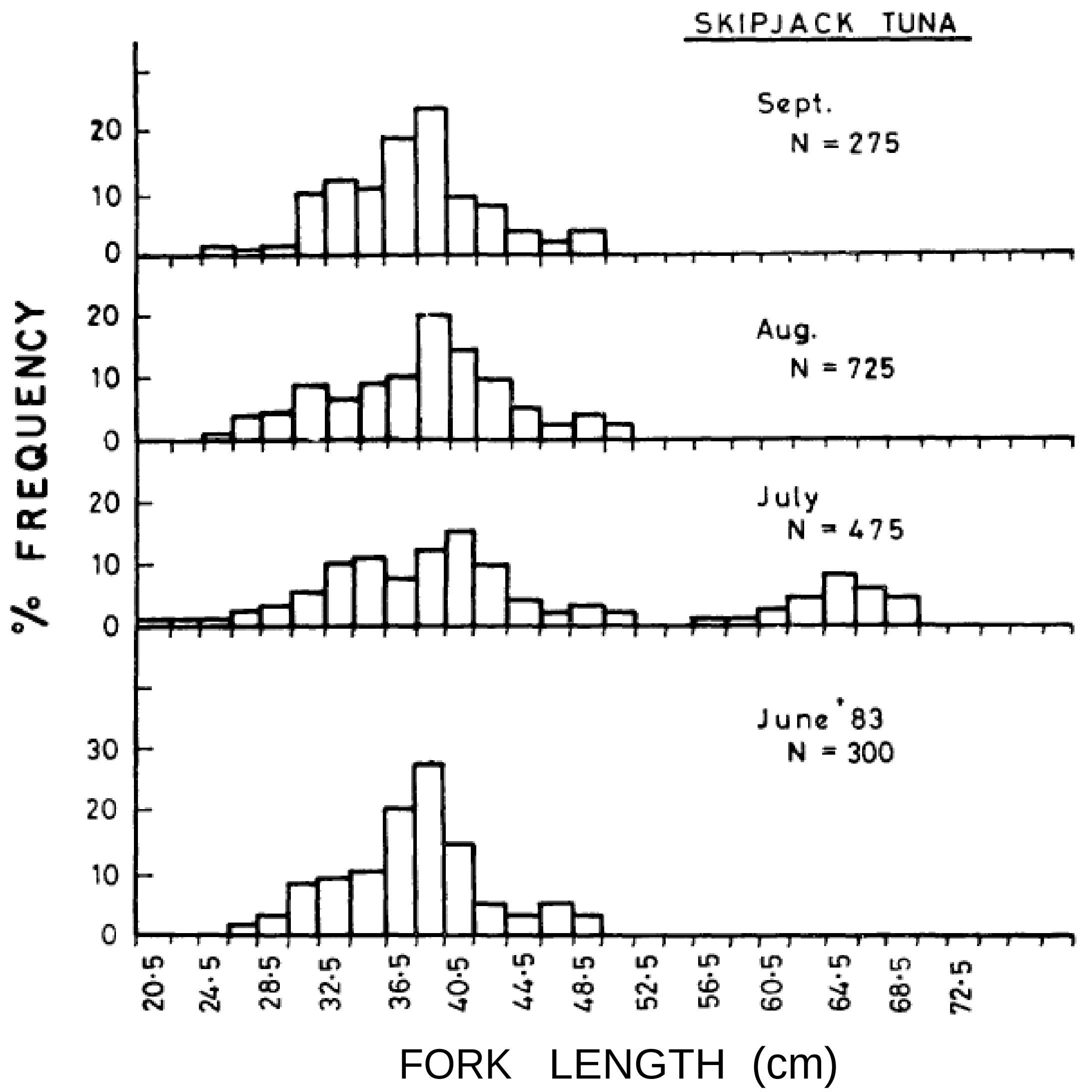

Fig. 7. Length frequency distribution of skipjack tuna around Ma/dive islands – pole and line catch, 1983.

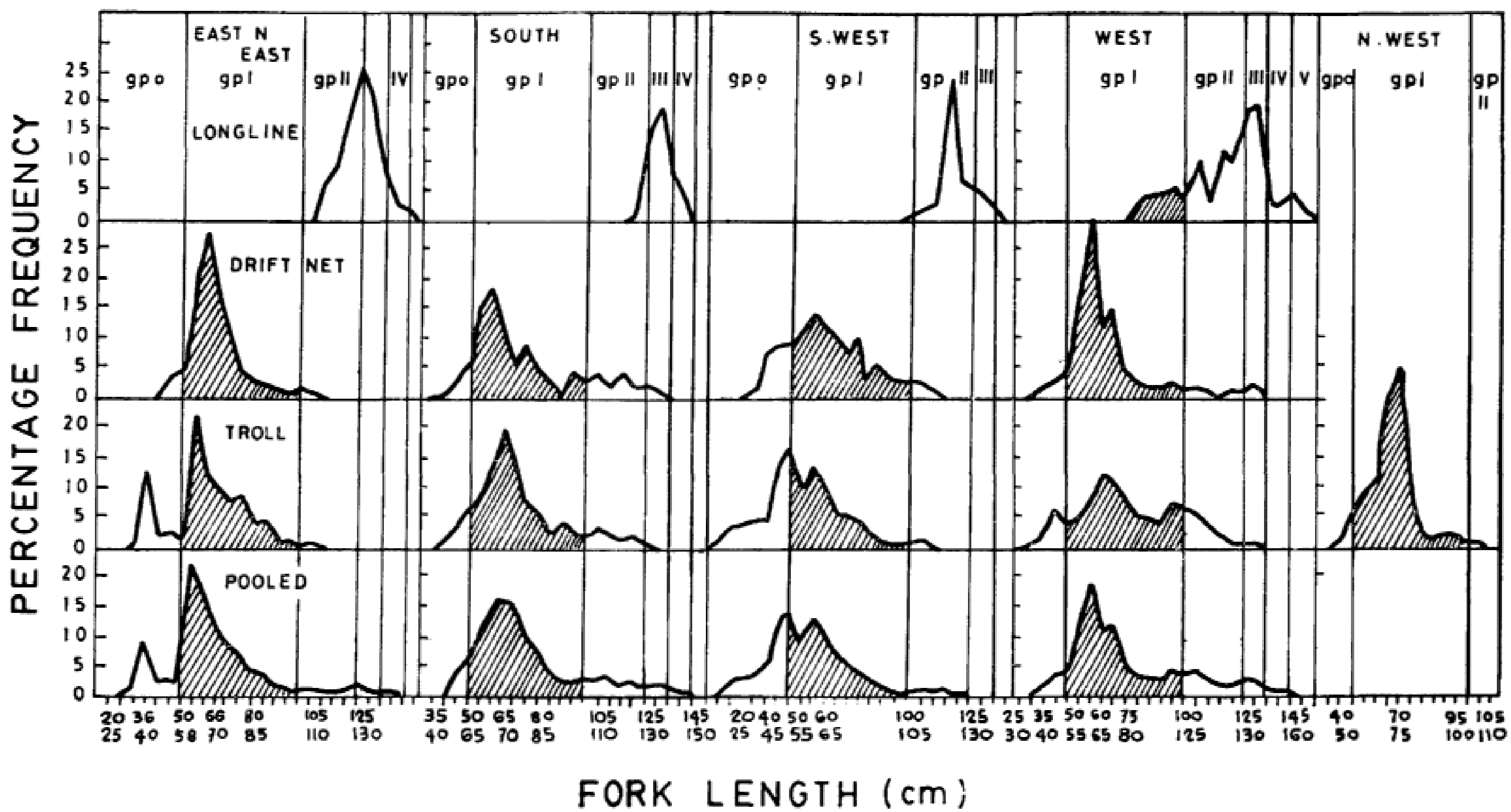

Fig. 8. Length frequency distribution by area and gear around Sri Lanka, 1969—70 (Sivasubramaniam 1970).

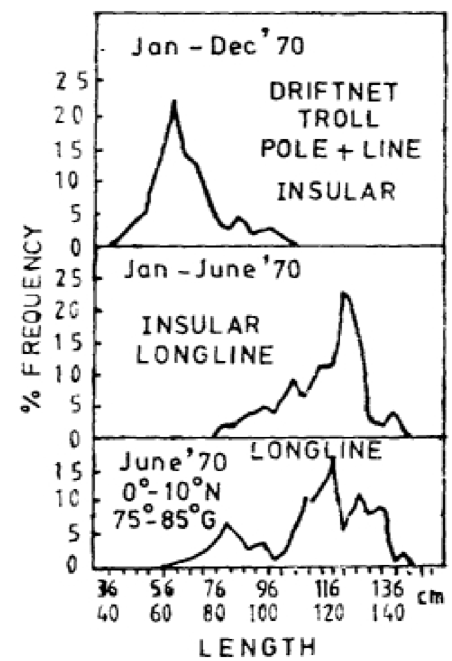

Fig. 9. Length frequency distribution of yellowi/n tuna in the surface and deep swimming layers around Sri Lanka (Sivasubramaniam 7971).

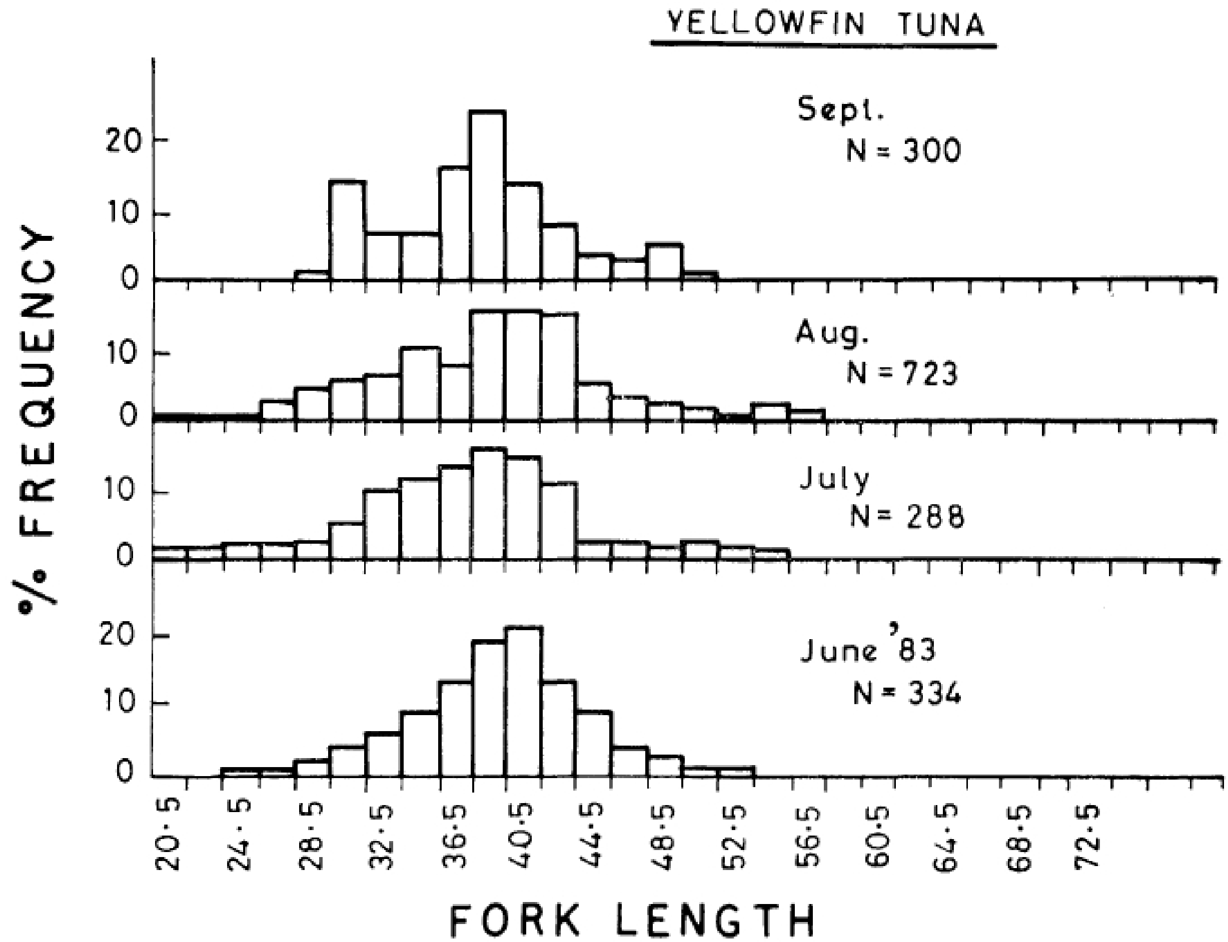

Fig. 10. Length frequency distribution of ye//owl/n tuna around Ma/dive islands, pole and line catch, 1983.

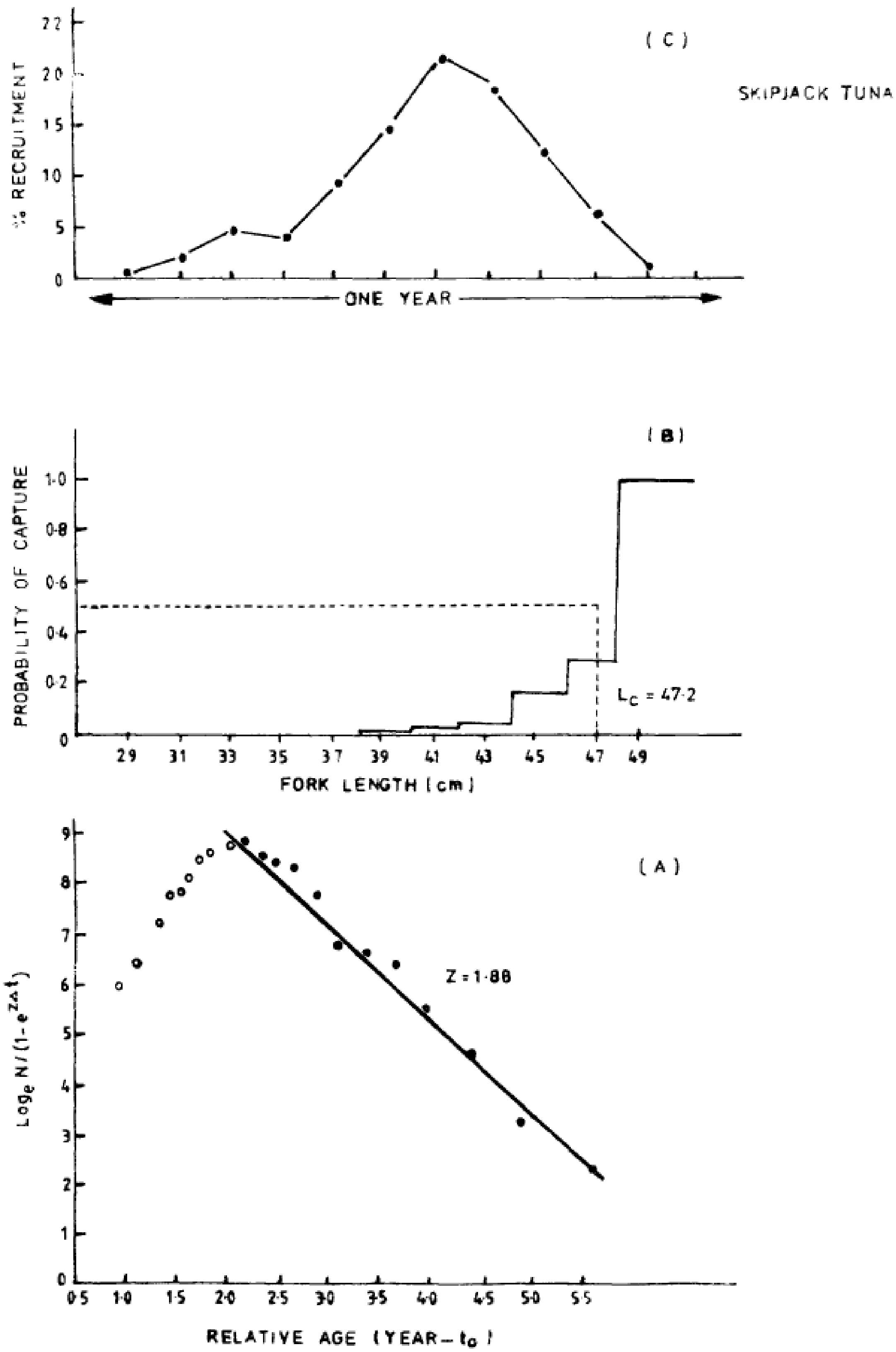

Fig. 11. Length converted catch curve, selection pattern and recruitment pattern for K. pelamis *caught around Sri Lanka.*

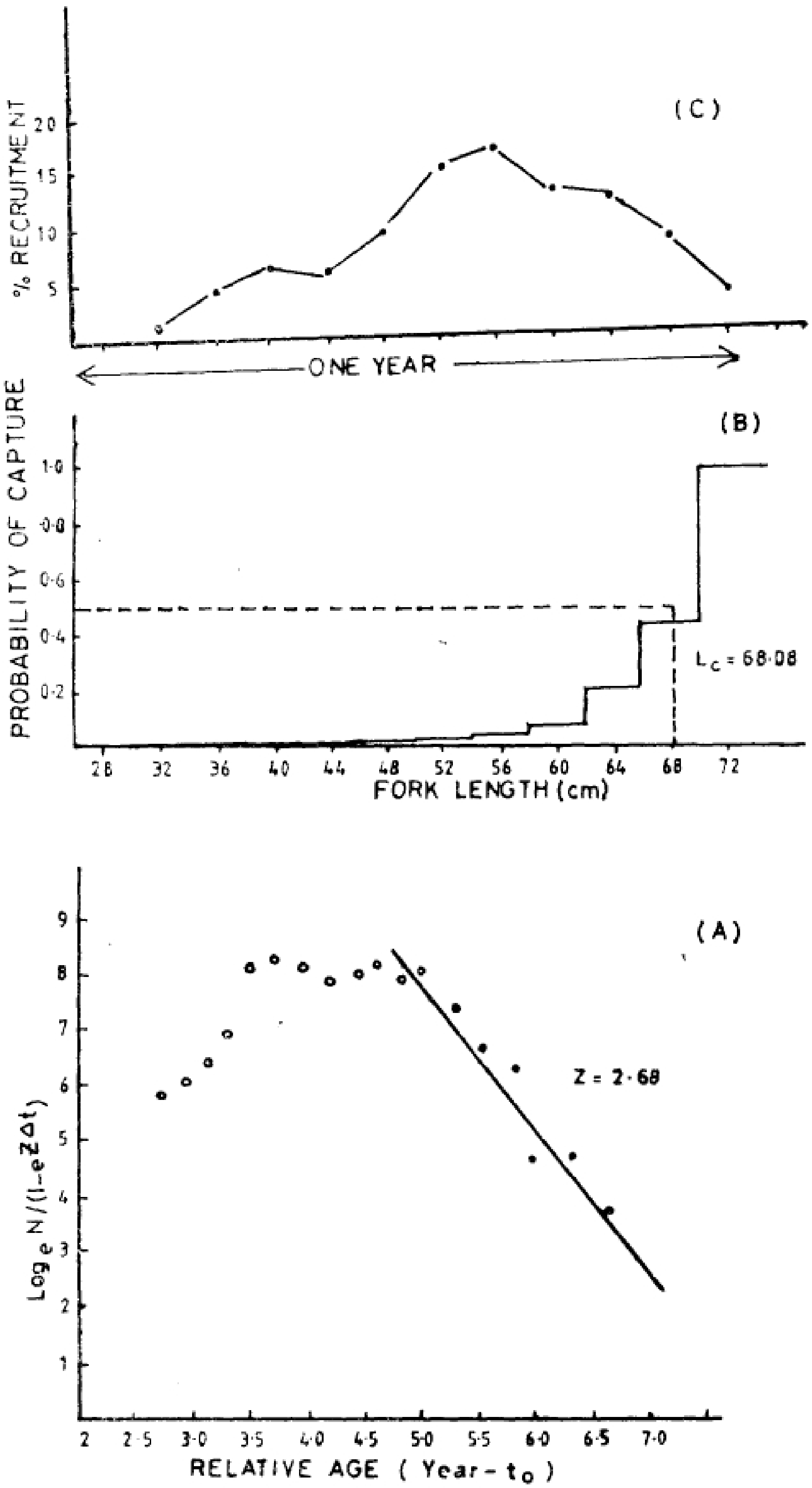

Fig. 12. *Length converted catch curve. selection pattern and recruitment pattern for* 1. albacares *around Sri Lanka.*

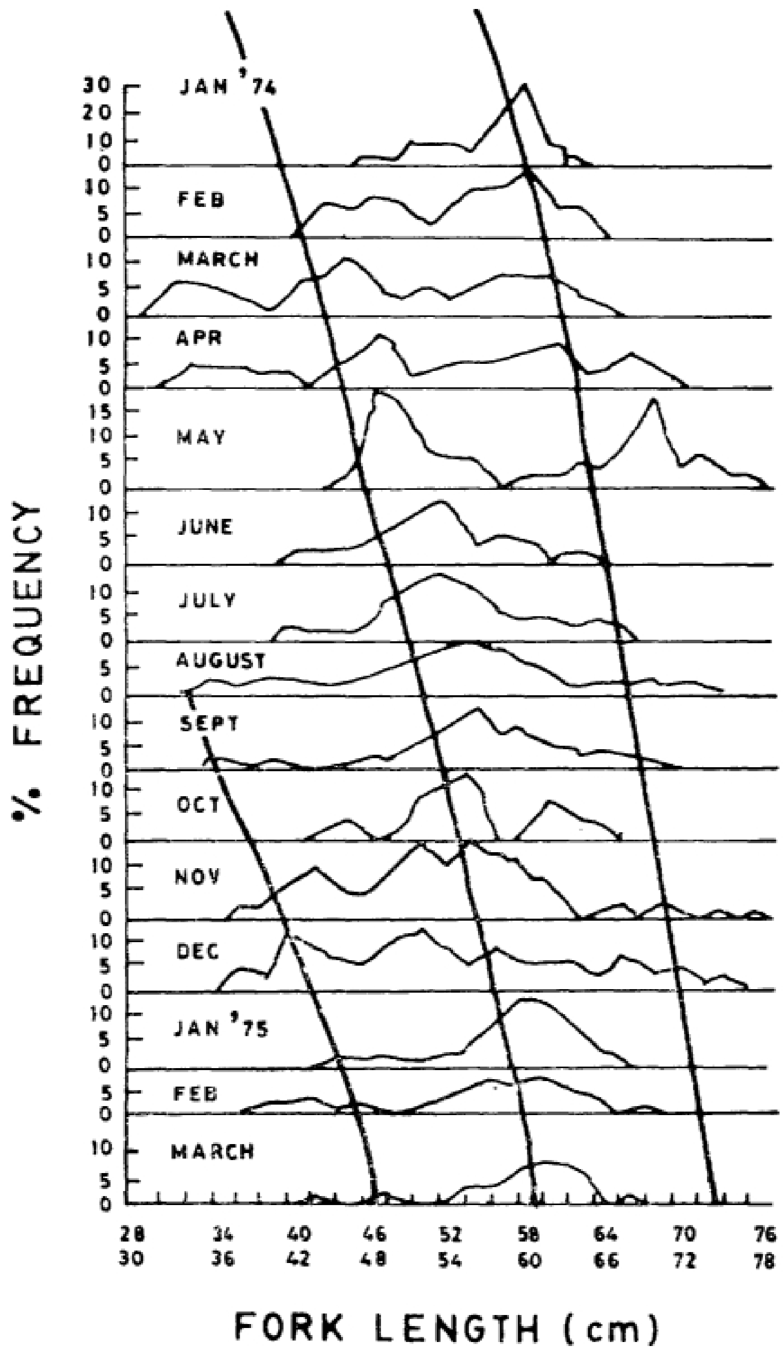

Fig. 13. Length frequency distribution of skipjack tuna caught by pole and line method, 1974—75, and growth curve fizied by ELEFAN I.

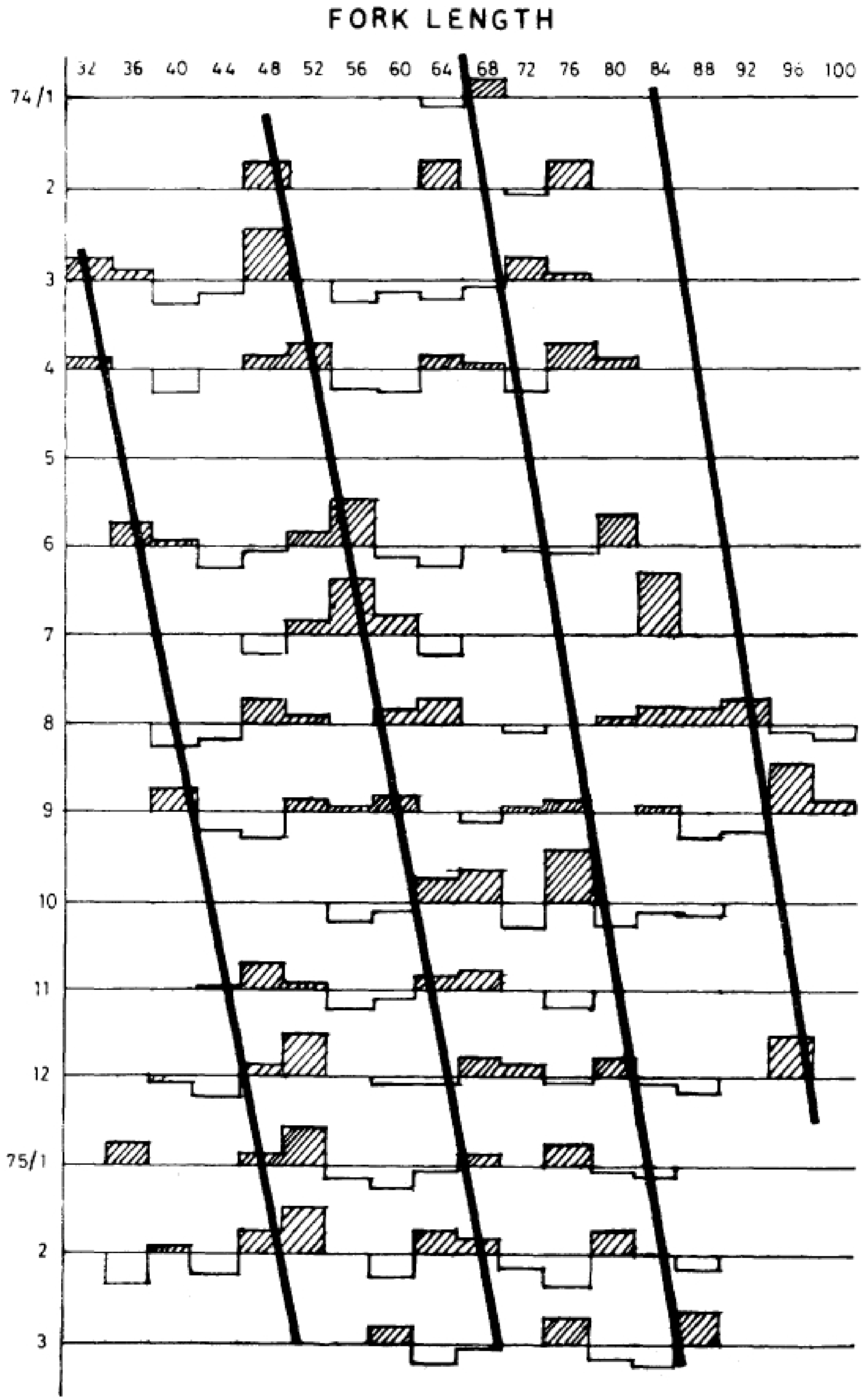

Fig. 14. Restructured length frequency distribution of yellowfin tuna caught with pole and line method and growth curves fitted by ELEFAN I.

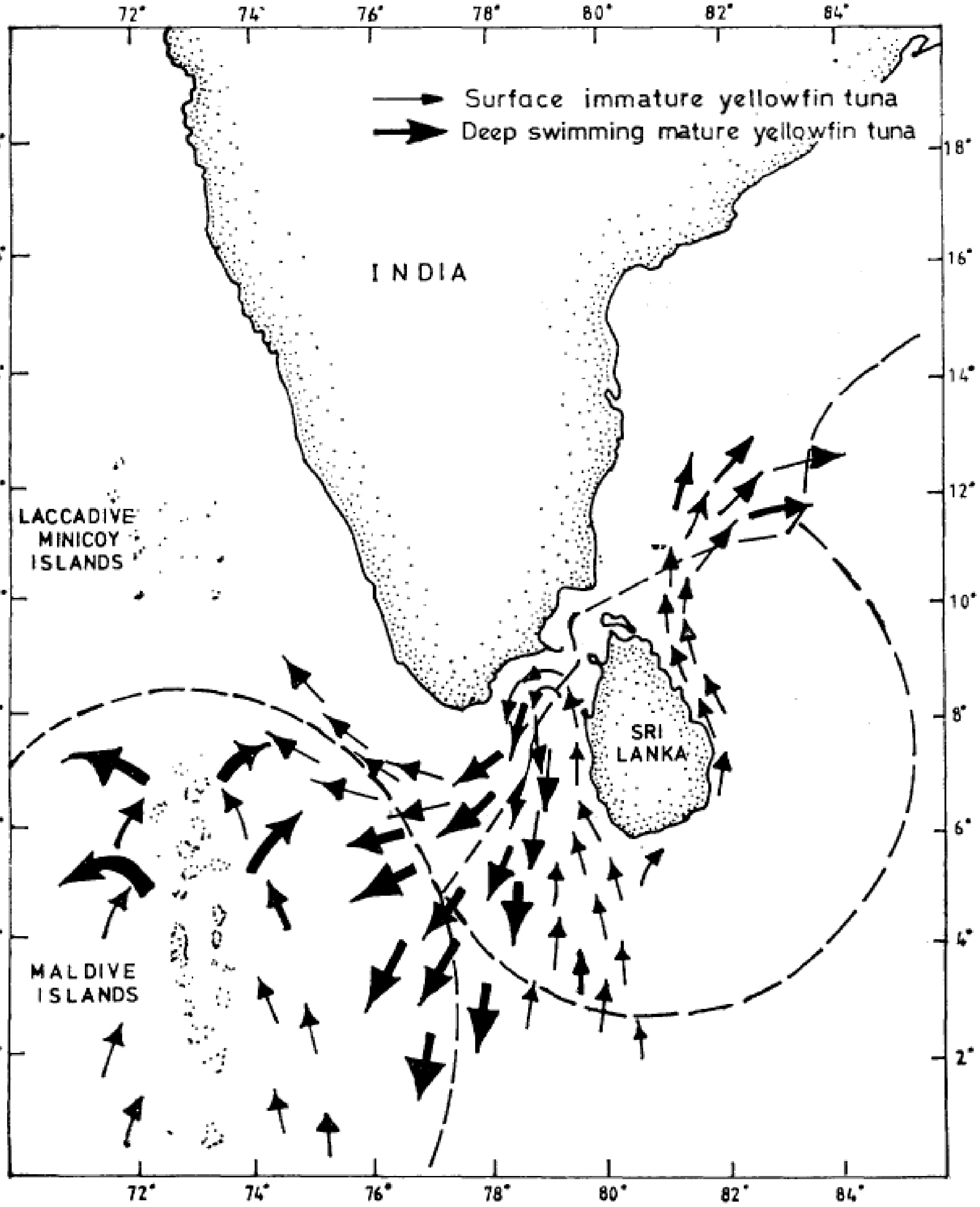

Fig. 15. Hypothetical migratory pattern for yeio wi/n tuna near Sri Lanka.