TUNA FISHERIES IN THE EASTERN INDIAN OCEAN, 1993-1998

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ABSTRACT

*Since 1993, foreign purse-seine and longline tuna fleets fishing in the eastern Indian Ocean have landed their catches at Phuket Port, Thailand. Landing surveys were needed to collect fishing data on tunas (*e.g. *catch, effort, individual fork length and weight).*

*Tuna purse-seine vessels were 56-79 m in length, with steel hulls. The purse seines were 1,500-1,800 m long and 180-290 m deep. The season with peak catches was during the northeast monsoon. The highest total landings and value of tunas was recorded in 1998 (23,838 t and US$42.07 million), and the lowest in 1997 (11,991 t and US$16.91 million). The catch of tunas comprised skipjack (*Katsuwonus pelamis*), yellowfin (*Thunnus albacares*) and bigeye tuna (*T. obesus*).*

*About 200 tuna longline fishing boats were recorded in the area. They were 13-21 m in length, with wood, fibreglass or steel hulls. Peak catches were recorded during the northeast monsoon season. The highest total landings was recorded in 1996 (2,902 t) and the highest total value in 1997 (13.52 US$). The longline catch comprised yellowfin and bigeye tuna, swordfish (*Xiphias gladius*), billfish (*Makaira *spp.,* Tetrapturus *spp.,* Istiophorus *spp.), and requiem sharks (*Carcharhinus *spp).*

The size composition of tunas differed depending on the type of gears, with mainly small (immature) fish caught by purse seines and large mature) fish by longlines. Also, the production and catch per unit effort of both gears were strongly impacted by the status of tuna resources in the eastern Indian Ocean. The present study is an important data base for the analysis of stock assessment and management of tuna resources in the eastern Indian Ocean.

RÉSUMÉ

Depuis 1993, les flottes étrangères pêchant les thons dans l'Est de l'Océan Indien (seine tournante et palangre) ont débarqué leur poisson à Phuket. Des échantillonnages des débarquement furent alors nécessaires pour la collecte des données concernant le thon (eg. effort, prises, longueur à la fourche, poids)

*Les senneurs sont en acier, de 56 à 79 m de long. La taille des filets étaient de 1.500-1.800 m de long et 180 à 290 m de chute. La production était la meilleure avec un pic d'abondance très marqué pendant la mousson de N.E. La meilleure performance en terme de quantité et de valeur (23.838 t et 42.07 millions $EU) était en 1998, alors les plus mauvaise débarquements ont eu lieu en 1997 (avec 11.991 t d'une valeur de 16.91 millions $EU) Les thons pêches se composaient de listao (*Katsuwonus pelamis*), d'albacores (*Thunnus albacares*) et de thon obèse (*Thunnus obesus*).*

*Par ailleurs, on comptait environ 200 palangriers pêchant dans le zone. C'étaient des bateaux en bois, en fibre de verre ou en acier de 13 à 21 m de long. La période de production intensive avec un pic d'abondance très net, coïncidait précisément à la mousson de N.E. Des prises record ont été enregistrées en 1996 avec 2.902 t et la valeur la plus élevée fut réalisée en 1997 avec 13.55 millions de $EU. Les captures étaient composées d'albacores (*T. albacares*), thons obèses (*T. obesus*), espadons (*Xiphias gladius*), marlins (*Makaira *spp.,* Tetrapturus *spp.,* Istiophorus *spp.) et requins (*Carcharhinus *spp).*

La composition de taille des poissons dépend largement du type d'engin de pêche utilisé; les poissons petits (immatures) sont pris par les senneurs et les gros (matures) sont pêchés a la palangre. De même, la production (prise par unité d'effort) dans les deux cas étaient très nettement affectés par l'état des ressources dans l'Est de l'Océan Indien, Aussi, l'étude que voici, est elle un important recueil de données pour l'évaluation des stocks et la gestion des ressources thonières dans l'Est de l'Océan Indien.

Introduction

Tuna fishing in the Indian Ocean was initiated in 1973 by longline, purse-seine and pole-and-line vessels operated by the French, Russian, Japanese and Taiwanese fleets. In 1993 a Japanese commercial purse-seine fleet of 10 vessels, which formerly operated in the western Indian Ocean, started to operate in the eastern Indian Ocean. Their products have been landed at Phuket deep-sea port in Thailand.

The changes in fishing area from the western to the eastern Indian Ocean were due to economic reasons, as Thailand has become the main market for frozen tuna in the world. In addition, the Taiwanese longline fishery has developed remarkably in recent years in the eastern Indian Ocean. The tuna caught by longline gear are large, and command a high price as sashimi on Japanese markets. Prior to 1994, these fleets had landed their catches in Singapore, Malaysia and Indonesia, but they have since landed them at Phuket, which offers transportation advantages of the deep-sea port and the international airport.

Under these circumstances, an updated evaluation of the status of the tuna fisheries in the eastern Indian Ocean is considered important and in urgent need of investigation. In this report, trends in tuna fisheries (fishing grounds, catch, fishing effort, catch per unit effort), stock structure, biological parameters and interaction problem are presented, using mainly the catch and effort data of foreign purse-seine and longline tuna fleets during 1993-1998.

Review of national fisheries

Japan

The Japanese commercial purse-seine fishery in the Indian Ocean started in 1991 with 10 vessels, and concentrated more

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on the eastern Indian Ocean in 1993. The primary landing port was Phuket for 7 vessels in 1993-1994 and 3 vessels in 1995. The vessels had steel hulls, 56-79 m in length, and the purse seines were 1,500-1,800 m long and 180-290 m deep. The fishing grounds were located at longitude 77° to 96°E and latitude 5°N to 12°S. Total catch peaked in 1994 at 24,486 tonnes (t), valued at US$24.29 million, but decreased to 10,551 t, valued at US$15.20 million, in 1997 (Table 1). Both monthly catch per unit effort (CPUE) and number of trips peaked from October to May, during the northeast monsoon season (Figure 1). The catch comprised skipjack (Katsuwonus pelamis), yellowfin (Thunnus albacares), and bigeye (T. obesus) tuna. The production peaks for skipjack appeared in January, May and November, for yellowfin in February, June, September and October and for bigeye in March and April and from June to October. The species composition showed a decreasing trend of skipjack with an increasing trend of yellowfin and bigeye tuna, and vice versa. A clear increase in yellowfin and bigeye production was observed in purse-seine catches from 1995 to 1996 (Figure 2), due to extensive use of fish-aggregating devices (FADs). Ninety percent of all purse-seine sets were made on FADs.

France and Spain

Prior to December 1997, the French and Spanish purse-seine fleets had operated in the western Indian Ocean. Since then, 24 vessels have concentrated in the eastern Indian Ocean. These fleets have moved in and out the area depending on resource availability and transportation expenses. Fish sold to canneries in southern Thailand was landed at Phuket, whereas fish for canneries in Bangkok or other overseas ports was transhipped at sea to carrier vessels. Table 2 illustrated total catches and their value.

Taiwan (Republic of China)

In 1994, a total of 200 Taiwanese conventional longliners fished in the eastern Indian Ocean and unloaded at Phuket. About 95 % of these vessels were between 300-400GRT, and none larger. The hulls were of wood, fibreglass or steel, and 13-21 m in length. Monofilament lines were used, and the number of hooks ranged from 600 to 1,500, depending on the size of the boat and the fishing conditions. The average number of hooks per basket was 4-5, and live milkfish and frozen squid were used as bait. The fishing grounds were located from latitude 14°N to 3°S and longitude 80° to 95°E. The total catch peaked in 1995 at 2,902t, worth US$10.21 million. The total catch decreased to 2,632t in 1997, but its value increased to US$13.52 million.

Both catch per trip and the number of trips were highest during the northeast monsoon season (Figure 3). The catch of the Taiwanese longliners is composed of yellowfin and bigeye tuna, swordfish (Xiphias gladius), billfishes (Makaira spp., Tetrapturus spp, Istiophorus spp.) and requiem sharks (Carcharhinus spp). The production peaks for yellowfin appeared in March, May and October; for bigeye in December, January, April, June and September; for billfish in July, August and December and for swordfish in September, December and June. The species composition showed a decreasing trend in yellowfin with an increasing trend in bigeye, billfishes, and swordfish (Figure 4).

Tuna stocks: status and biology

Yellowfin tuna

The total catch of yellowfin tuna from the eastern Indian Ocean has been increasing since 1994, due to the movement of a number of purse seiners from the western Indian Ocean and also, since 1995, to substantial catches by longliners (Figure 5). The total catch in 1995 was 5,347t, of which 4,389t (82 %) was taken by purse seiners and 958 t (18 %) by longliners. A similar pattern was observed in 1996 with a smaller total catch, 5,095 t, of which 4,055 t (80 %) was taken by purse seiners and 1,039t (20 %) by longliners.

Length-frequency sampling of yellowfin catches was carried out at Phuket from 1994 to 1996. Figure 6 shows the dominant size mode for yellowfin tuna caught by Japanese purse seiners in 1995, which ranged from 30 to 120 cm in fork length (FL), and for the Taiwanese longline catch, which ranged from 84 to174 cm FL. On average, purse seiners caught smaller fish than longliners.

An analysis of the length-frequency distribution of yellowfin tuna, regardless of sex, derived from Taiwanese longline samples taken at Phuket from August 1995 to February 1996 was carried out. The initial growth parameters were obtained using a method which assumed that the sample represents the entire stock. Bhattacharya's method (1967) is used for splitting a composite distribution into separate normal distributions. The initial values of $L\infty$ and K were roughly estimated from modal progression analysis (MPA) using Bhattacharya's method. These initial estimates of $L\infty$ and K plus the length-frequency data were used to estimate length at age using the ELEFAN program. The following von Bertalanffy growth equation was used:

$$Lt = 194.00\ [1-e\ (-0.66\ (t-0.27))]$$

$$t0 = 0.27 \text{ (Yang et al., 1969)}$$

The growth curves in Figure 7, which follow the classical von Bertalanffy growth curve for larger fish, are derived from the growth parameters in Table 4. The apparently fast growth of yellowfin indicated by this study has also been observed in other areas, such as the Pacific Ocean. Growth can be highly variable according to time and area, as reflected in the increasing variance of length-frequency modes with age (IPTP, 1992). The age of yellowfin caught with longlines was >1 to 4 years and the modal age was 1.95 to 2.21 years.

Weight-at-length data were randomly obtained from a sample of 1,398 yellowfin tunas caught by longliners. FL was measured to the nearest millimetre, and weights in kilograms for gilled and gutted fish. The equation of Morita (1973) was used to give a conversion factor from the gilled and gutted weight to live weight, as follows:

$$\log\ ri = 0.5707-0.2445 \log Li$$

where ri = conversion factor for fork length Li (cm).

The length-weight relationship for this study was calculated by:

$$Wi = 1.8\times10^{-5}\ Li^{2.9841} \quad r^2 = 0.9080 \quad n = 1,398$$

$$Wx = 6.91\times10^{-5} Li^{2.7396} \quad r^2 = 0.8927 \quad n = 1,398$$

where Wi = gilled and gutted weight (kg), and Wx = live weight (kg).

The growth in weight equation for yellowfin tuna was therefore:

$$Wt = 127.98 [1\text{-}exp (-0.66 (t-0.27))]^{2.7396}$$

where Wt = weight at age t.

The recruitment and selection patterns in Figure 8 were derived using FiSAT (Gayanilo et al., 1994). The recruitment pattern indicated that yellowfin tuna are recruited to the fishery twice a year. The larger mode was during January to July (53 %) and the smaller one during September to May (47 %).

Bigeye tuna

The total catch of bigeye tuna from the eastern Indian Ocean fluctuated during 1994-1997 (Figure 9). In 1994 the total catch was 3,804t, of which 3,677t (97 %) were taken by purse seiners and 127t (3 %) by longliners. The percentage of longline catch increased to 27 % in 1996 and 26 % in 1997.

Length-frequency sampling of bigeye catches was carried out at Phuket from 1994 to 1996. Figure 10 shows the dominant size mode for bigeye tuna caught by Japanese purse seiners in 1995, which ranged from 35 to 90 cm FL, and for the Taiwanese longline catch, which ranged from 90 to178 cm FL.

An analysis of the length-frequency distribution of bigeye tuna derived from Taiwanese longline samples taken at Phuket from April 1995 to March 1996 was carried out, not taking account of sex. The initial growth parameters were obtained using a method which assumed that the sample represents the entire stock. Bhattacharya's method (1967) is used for splitting a composite distribution into separate normal distributions. The initial values of $L\infty$ and K were roughly estimated from modal progression analysis (MPA) using Bhattacharya's method. These initial estimates of $L\infty$ and K plus the length-frequency data were used to estimate length at age using the ELEFAN program. The following von Bertalanffy growth equation was used:

$$Lt = 211.50 [1\text{-}exp(-0.45 (t+0.1205))]$$

to = -0.1205 (Suda and Kume, 1967)

The growth curves in Figure 11, which follow the classical von Bertalanffy growth curve for larger fish, are derived from the growth parameters in Table 5. The apparently fast growth of bigeye indicated by this study has also been observed in other areas, such as the Pacific Ocean. Growth can be highly variable according to time and area, as reflected in the increasing variance of length-frequency modes with age (IPTP, 1992). The age of yellowfin caught with longlines was >1 to 4 years, and the mode of age was 2 years.

Weight-at-length data were randomly obtained from a sample of 574 bigeye tunas caught by longliners. FL was measured to the nearest millimetre and weights of gilled and gutted fish in kilograms. A conversion factor of 1.16 (Morita, 1973) was used convert gilled and gutted weight to live weight. The weight at length equation was as follows:

$Wi = 1.63x10^{-5} Li^{3.0388}$ r2= 0.9222, n = 574

$Wx= 1.89x10^{-5}Li^{3.0388}$ r2= 0.9222, n = 574

The growth in weight equation for bigeye tuna was therefore:

$$Wt = 189.82 [1\text{-}exp (-0.45 (t+ 0.1205))]^{3.0388}$$

The recruitment and selection patterns in Figure 12 were derived using FiSAT (Gayanilo et al., 1994). The recruitment pattern indicated that bigeye tuna are recruited to the fishery three times a year. The largest mode was during February to June (71 %), with smaller modes during November to February (15 %) and September to November (14 %).

Skipjack

The total skipjack catch from the eastern Indian Ocean has been decreasing since 1995, owing largely to the development of the purse-seine fishery (Figure 13). In 1994 the total purse-seine catch was 17,043t, but this decreased from 1995 to 1997.

Length-frequency sampling of catches of skipjack tuna was carried out at Phuket from 1994 to 1995. The size of the fish ranged from 33 to 68 cm FL (average 46.47 cm (sd+6.95)), with two modes, at 36-48 cm and 50-60 cm.

Fisheries interactions

The results of this study and others in the eastern Indian Ocean describe the population of tunas in the area. Maldeniya and Joseph (1985) stated that the spawning season of yellowfin tuna was during February to May and September to November. At 5 months of age, the juvenile fish migrate to the purse-seine fishing ground in large schools. Small yellowfin and bigeye tunas generally aggregate in large schools in the subsurface layer, usually under floating objects (e.g. FADs, logs). The age of the fish caught by purse seiners was estimated at 7 months to 1 year. Yellowfin tuna over 1 year old move from the subsurface layer to deeper waters, and fish between 1 and 4 years of age are seen in the longline catch. Fish between 1 year and 18 months old are taken by both gears.

Bigeye tuna has its spawning season during January and March (Nikaido et al., 1991). When they reach the age of 3 months they move to the purse-seine fishing ground. They are caught in purse seines until the age of 1 year and 1 month. Bigeye over 1 year old move from the subsurface layer to deeper waters, and fish up to four years of age are caught by longliners.

The size distribution of the catch depends upon the type of gear: smaller fish are caught by purse seiners and larger fish by longlines. The increasing catch and extensive fishing effort may lead to a reduction of stock size. It should be kept in mind that as the immature tuna caught with purse seines become smaller and smaller, this will give rise to a reduction in the number of spawners and recruitment will be reduced. As a consequence, purse seining will eventually lead to overfishing. This practice is still going on intensively, and will affect the longline fishery. On the other hand, if longliners overfish, the tuna resources will be in danger.

Progress made in research and data collection

Further work is needed to address the questions of stock structure, migration, maturation, spawning, sex ratios, growth parameters, recruitment, and maximum yield and effort in terms

of gears and species. Also, the catch, effort and size composition in the longline fishery need to be carefully monitored in future. The results will form an important data base for stock assessment and management of tunas in the eastern Indian Ocean.

References

Bhattacharya, C.G. 1967. A simple method of resolution of a distribution into Gaussian component. Biometrics 23 :115-135.

Gayanilo, F.C., P. Sparre and D. Pauly. 1994. The FAO-ICLARM Stock Assessment Tools (FiSAT) User's Guide. FAO Computerized Information Series Fisheries. FAO, Rome, 1994.

IPTP. 1992. Report of the workshop on stock assessment of yellowfin tuna in the Indian Ocean. IPTP/91/GEN/20. 90 pp.

Kume, S., and J. Joseph. 1969. The Japanese longline fishery for tunas and billfish in the eastern Pacific Ocean east of 130°W, 1964-1966. Bull. IATTC, 13(2): 275-418.

Maldeniya, R. and L. Joseph. 1985. On the distribution and biology of yellowfin tuna from the western and southern coastal waters of Sri Lanka. Collective Volume of working documents presented at the Expert Consultation on Stock Assessment of Tunas in the Indian Ocean, held in Colombo, Sri Lanka, 28 Nov.-2 Dec. 1985. 51-61.

Morita, Y. 1973. Conversion factors for estimating live weight from gilled-and-gutted weight of bigeye and yellowfin tunas. Bull. Far. Seas Fish. Res. Lab., 9:109-121.

Nikaido, H., N. Miyabe, and S. Ueyanagi. 1991. Spawning time and frequency of bigeye tuna, Thunnus obesus. Bull. Nat. Res. Inst. Far Seas Fish., 28:47-73.

Suda, A. and S. Kume. 1967. Survival and recruitment of bigeye tuna in the Pacific Ocean, estimated by the data of tuna longline catch. Rep. Nankai Reg. Fish. Res. Lab., 25:91-104.

Wankowski, J.W.J. 1981. Estimated growth of surface-schooling skipjack tuna, Katsuwonus pelamis, and yellowfin tuna, Thunnus albacares, from the Papua New Guinea region. Fish. Bull. NOAA-NMFS, 79(3):517-545.

Yabuta, Y., M. Yukinawa, and Y. Warashima. 1960. Growth and age of yellowfin tuna II. Age determination (Scale method).[In Jpn.; Engl. summary]. Rep. Nankai Reg. Fish. Res. Lab., 12:63-74.

Yang, R-T., Y. Nose, and Y. Hiyama. 1969. A comparative study on the growth of yellowfin tunas from the Atlantic and Pacific Oceans. Bull. Far. Seas Fish. Res. Lab., 2:1-21.

Yukinawa, M.,and Y. Yabuta. 1963. Age and growth of bigeye tuna, Parathunnus mebachi (Kishinouye). Rep. Nankai Reg. Fish. Res. Lab., 19:103-118.

Table 1. Total catch (tonnes) landed by the Japanese tuna purse-seine fleet at Phuket Province, Thailand, and value (million US$)

Year	Total catch	Value	Recorded
1993	1,750	1.88	December
1994	24,487	24.29	January-December
1995	16,706	14.04	January-December
1996	13,697	12.85	January-December
1997	10,551	15.20	January-December
1998	5,014	5.86	January-June

Table 2. Total catch (tonnes) of French and Spanish tuna purse-seine fleets landed and transhipped at Phuket, Thailand, and its value (million US$)

Year	Total catch	Value	Recorded
1997	1,440	1.71	December
1998	18,824	36.21	January-June

Table 3. Total catch (tonnes) and value (million US$) landed at Phuket, Thailand, by the tuna longline fleet,

Year	Total catch	Value	Recorded
1994	622	2.07	August-December
1995	1,416	3.60	January-December
1996	2,902	10.21	January-December
1997	2,632	13.52	January-December
1998	1,733	6.18	January-June

Table 4. Growth parameters (K, L_∞) of yellowfin tuna in the Indian Ocean and the western Pacific Ocean

Area	L_∞	K	t_0	Source
1 Eastern Indian Ocean	194.00	0.66	0.27	This study
2 Western Pacific Ocean	190.00	0.33	0	Yabuta *et al.* (1960)
3 Western Pacific Ocean	195.20	0.36	0.27	Yang *et al.* (1969)
4 Western Pacific Ocean	180.90	0.292	0	Wankowski (1981)
5 West and south of Sri Lanka	178.00	0.47	-0.208	Maldeniya and Joseph (1985)
6 West and south of Sri Lanka	179.00	0.48	-0.213	Maldeniya and Joseph (1985)

Table 5. Growth parameters (K, L_∞) of bigeye tuna in the Indian and Pacific Oceans

Area	L_∞	K	t_0	Source
1 Eastern Indian Ocean	211.50	0.45	-0.1205	This study
2 Pacific Ocean	215.00	0.1041	-0.0105	Yukinawa and Yabuta (1963)
3 Pacific Ocean	186.95	0.095	2.11	Kume and Joseph (1969)
4 Pacific Ocean	214.80	0.2066	-0.1205	Suda and Kume (1967)

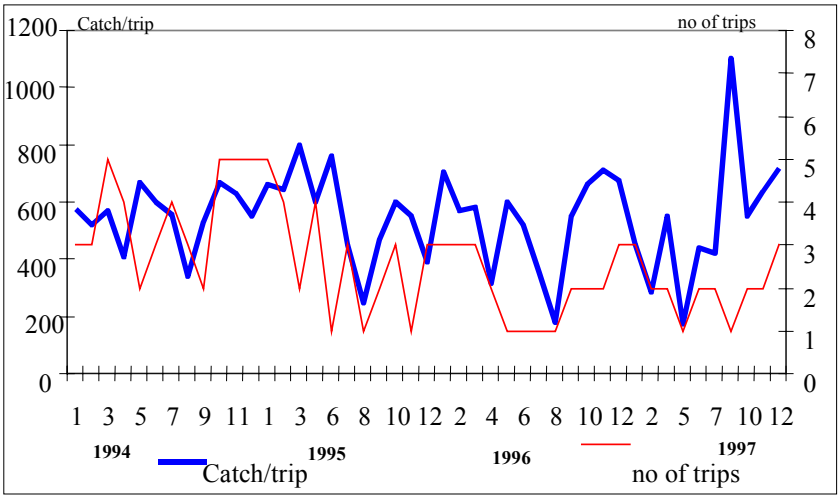

Figure 1. Catch per trip (tonnes) and number of trips by the tuna purse-seine fleet, 1994-1997.

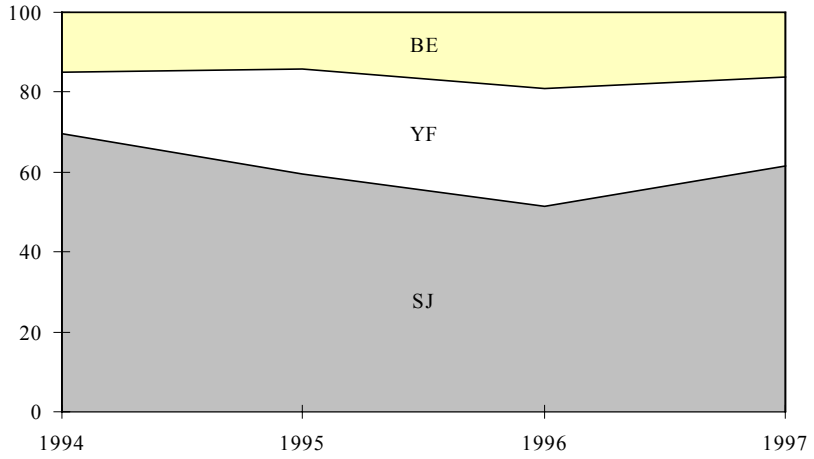

Figure 2. Species composition of catches of the tuna purse-seine fleet, 1994-1997.

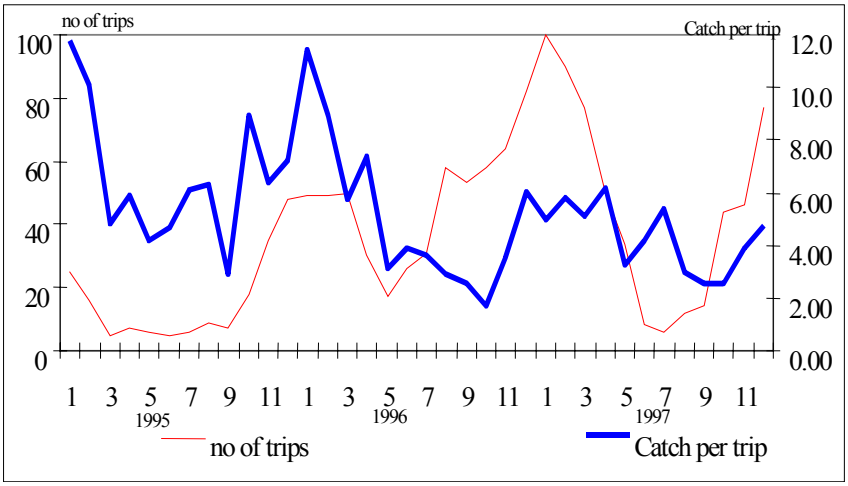

Figure 3. Catch per trip (tonnes) and number of trips by the longline fleet, 1995-1997.

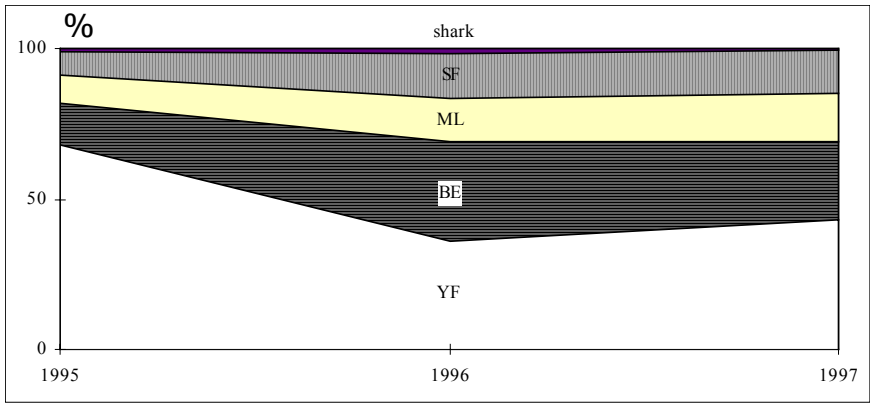

Figure 4. Species composition of catches by longline fleet, 1995-1997.

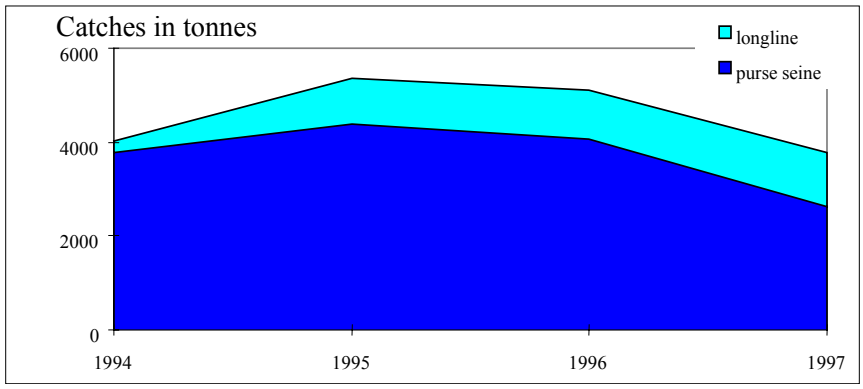

Figure 5. Catch of yellowfin tuna by gear, 1994-1997.

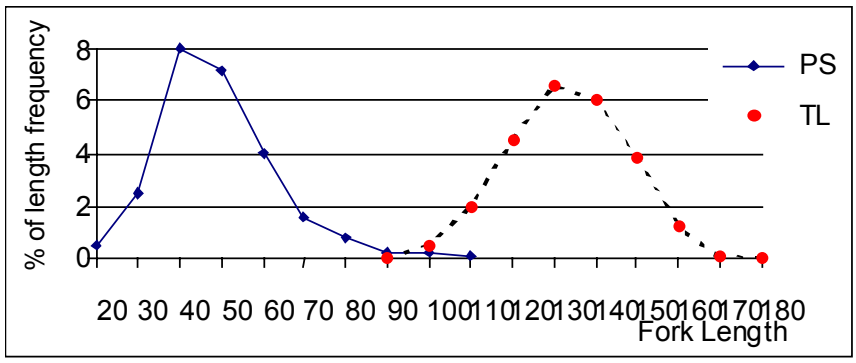

Figure 6. Length-frequency distribution of yellowfin tuna caught by Japanese purse seiners (PS) and Taiwanese longliners (TL)in 1995.

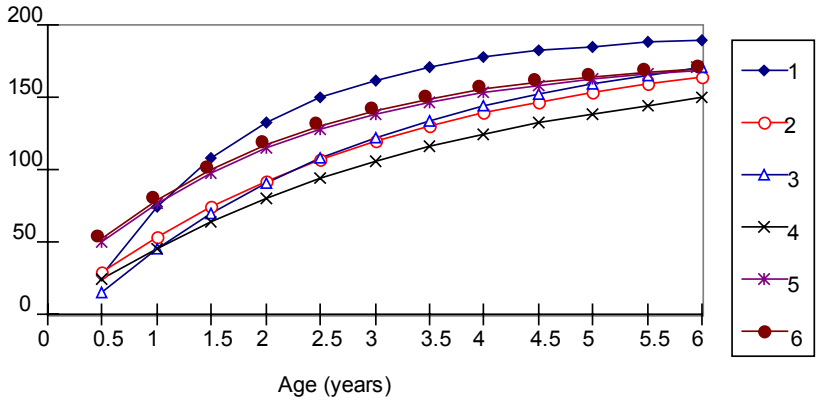

Figure 7. Growth curves of yellowfin tuna estimated by various authors. Line numbers refer to Table 4.

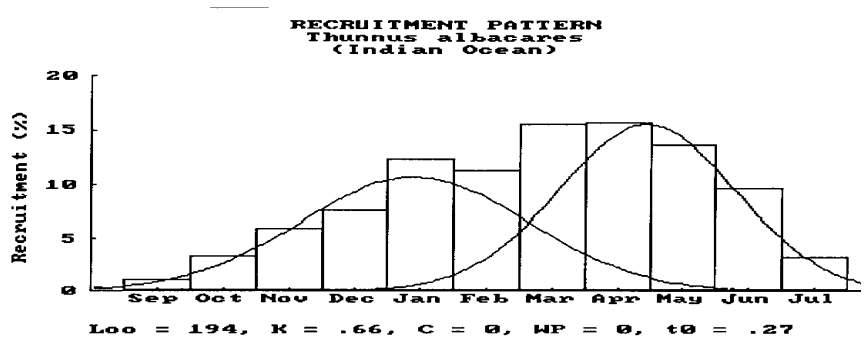

Figure 8. Recruitment pattern of yellowfin tuna in the eastern Indian Ocean.

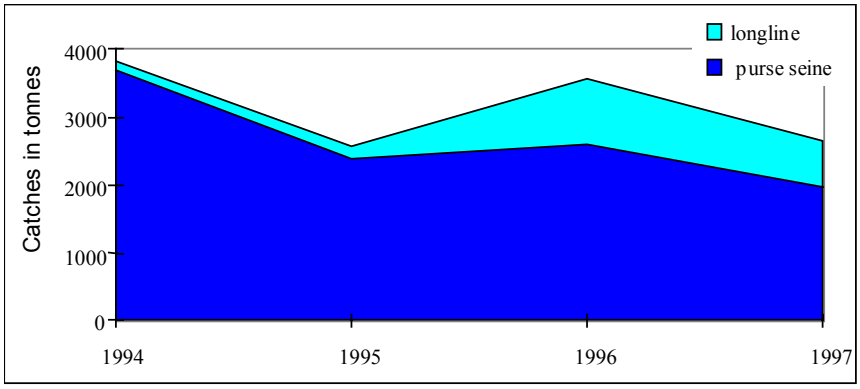

Figure 9. Catch of bigeye tuna, by gear, 1994-1997.

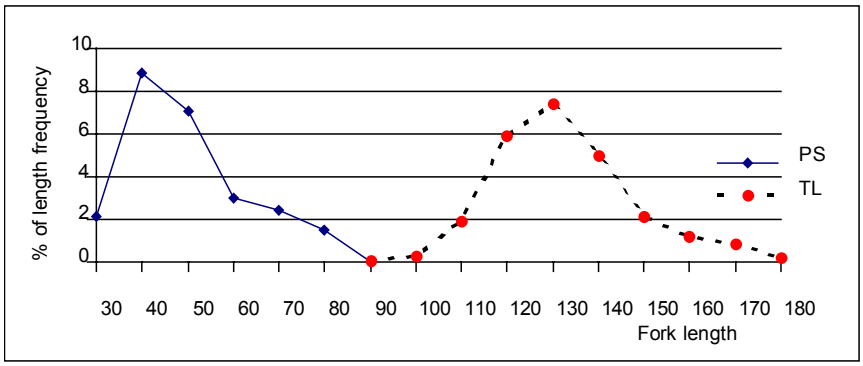

Figure 10. Length-frequency distribution of bigeye tuna caught by purse seiners (PS) and longliners (TL) in the eastern Indian Ocean.

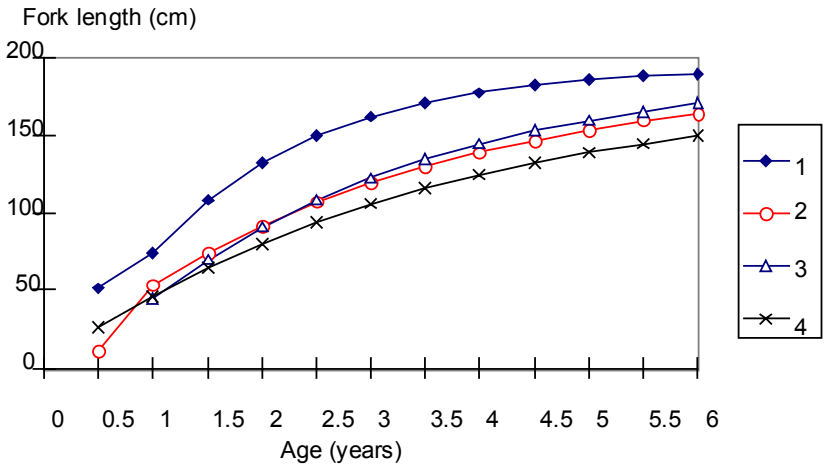

Figure 11. Growth curves of bigeye tuna estimated by various authors. Line numbers refer to Table 5.

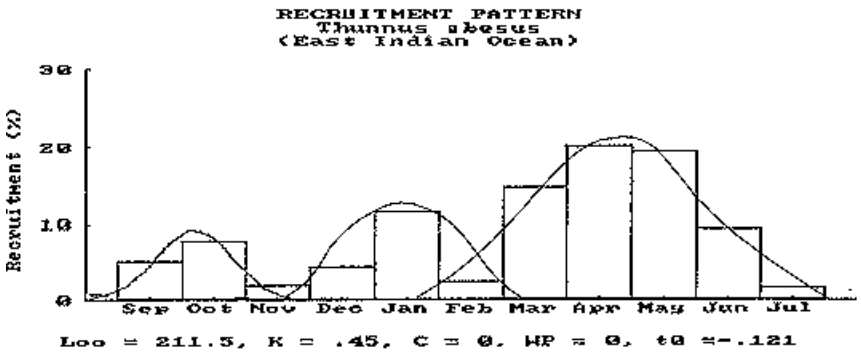

Figure 12. Recruitment pattern of bigeye tuna in the eastern Indian Ocean.

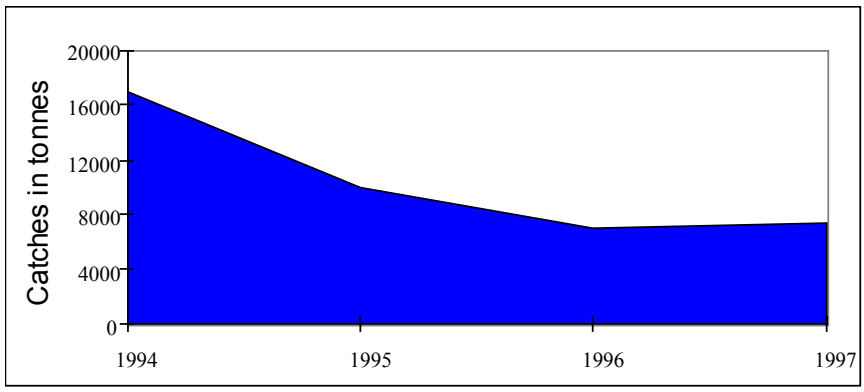

Figure 13. Purse-seine catch of skipjack, 1994-1997.