PRELIMINARY RESULTS ON FISHERIES AND BIOLOGY OF BIGEYE TUNA (*THUNNUS OBESUS*) IN THE EASTERN INDIAN OCEAN

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ABSTRACT

Bigeye tuna (Thunnus obesus) are an important component of tuna fisheries throughout the Indian Ocean. They are the principle target species of the longliner and purse seiner that landed at Phuket during 1994 to 1998. Port sampling survey was made to collect fishing and biological data of bigeye tuna. The annual landing of bigeye tuna at Phuket was reported at 2,749 mt in 1994 afterthat showed the decreasing trend until 1998 at 1,337 mt. Purse seiner contributes over 70 % of the catch, the rest part from longliner caught. The peak of catch was found during February to April from purse seiner and during north-east monsoon from longliner. The length (FL, L_i) - weight (W_i)relationship and growth equation by von Bertalanffy method of bigeye tuna were follow: $W_i = 2.1681 \times 10^{-5} L_i^{2.9968}$ *and* $L_t = 223.288\ [\ 1 - e^{(-0.35\ (t\ +\ 0.02))}\ ]$*. Bigeye tuna is long life span, growth model by progression of length frequency distribution isn't proper to precise for length-at-age key. Consequently, we use growth parameters from Lehodey et al. (1999) for detection the age at length which caught by purse seiner was 0.33 to 2.86 years and by longliner was 1.19 to 7.45 years.*

INTRODUCTION

Bigeye tuna (*Thunnus obesus*) are an important component of tuna fisheries throughout the Indian Ocean. They are the principal target species of the large 'distant-water' longliners from Japan and China (Taiwan) and of the smaller 'fresh sashimi' longliners based in several Indian Ocean Island countries, especially Indonesia. Prices paid for both frozen and fresh product on the Japanese sashimi market are the highest of all the tropical tunas. The Indian-wide longline catch of bigeye tuns has varied between 36,000 and 88,147 metric tonnes (mt) from 1994 to 1998, which represents 28 to 61 percent of total catch form the eastern Indian Ocean (Anon., 1998).

Since about 1973, a rapid increase in purse-seine catches of bigeye, first in the western Indian Ocean from France, USSR, Japan and Taiwan, in the past 20 year in the eastern Indian Ocean from Japan, France and Spain. Purse-seine catches in the Indian Ocean increased from typical levels of less than 10,000 mt per year to approximately 30,000 mt in 1995, 25,000 mt in 1996, which represents 0 to 16 percent of total catch during 1987 to 1996 from the eastern Indian Ocean (Anon., 1998). These increases have been due to the adoption of new fishing methods involving the use of drifting fish aggregating devices (FADs) to aggregate tuna.

In addition to concerns regarding the possible impact of these increases in purse-seine catch on the bigeye tuna stock, there is also a related concern that such catches, which are processed as low-priced product for canning, will ultimately impact the catches of high-priced, sashimi-quality bigeye by longliners. Such adverse impacts, if they occur, have the potential to reduce the profitability of the longline fishery and thus significantly affect the economies of a number of Indian Ocean countries.

Since 1993, the tuna fishery in the eastern Indian Ocean by foreign fleets (tuna purse seines and tuna longlines) have landed their catch at Phuket Port, Thailand. Changes in their fishing areas from the western to the eastern Indian Ocean and moved to landing at Phuket, which were desired from a matter of economic reasons and an advantage in convenient infrastructure for transportation of the deepsea port and the international airport at Phuket.

The purpose of this report is preliminary study on the fisheries and biology of bigeye tuna, on recent work undertaken by Andaman Sea Fisheries Development Center (AFDEC). While the focus of the report is on the eastern Indian Ocean. In section 1, we studies on the fisheries the catch significant quantities of bigeye tuna and the various fishery data collection systems that are in place. In section 2, we studied those aspects of the biology of bigeye tuna (length-weight relationship, age and growth) that have an important bearing on stock assessment. Finally, in section 3, the most important information gaps are summarised and suggestions made for future research and data collection to address these shortcomings.

DATA COLLECTION AND ANALYSIS

Port-sampling and landing surveys have been made to collect fishing and biological data of bigeye e.g. catch, effort, individual fork length and weight (such as whole weight for purse seine, gilled and gutted for longline) by the staff of

AFDEC on monthly at 2 landing ports namely Phuket deep-sea port since 1993 and Phuket fishing port since 1994. Fishing effort is measured in number of days fishing (purse seine) and number of trip (longline). Landing data consist of information regarding the catch unloaded from the vessel. They usually include information concerning the vessel (name, flag, and registration number), the port of unloading, the vessel' s agent in the port of unloading, the dates of unloading (in number of fish and mt for longline, and mt for purse seine).

Of even greater importance is the need to convert the various tuna length and weight measurements taken during port sampling to whole weights, for use in monitoring longline catches. Port samplers typically sample the length, and often the weight, of fish as the vessel unloads. Total unloadings for a given trip are usually reported in numbers of fish and in processed weight, rather than in whole weight. In order to estimate the total catch of whole fish, the sampled lengths or processed weights must be converted to whole weights. Conversion factors for estimating the whole weight from the processed weight have been published by Data summary for 1987-1996 (Anon., 1998), the factor is used 1.09.

Analysis of bigeye tuna length frequency distribution derived from purse seine and longline samples at Phuket fish landing port from 1995 to 1998 was carried out with regardless sex condition. Regarding, the data on length of samples bigeye of each gear in each month have been raised to the total catch of each gear by using the raising factor (RF).

$$RF = \frac{W_t}{W_s}$$

W_t = Total weight estimated.

W_s = Sample weight.

The Bhattacharya’s method (1967) is used for splitting a composite distribution into separate normal distributions. The initial values of L_∞ and K were roughly estimated from modal progression analysis base on results of Bhattacharya ’s analysis and related mean lengths of the cohorts which derived growth from shifting of the means in a time series of length frequency samples. Growth parameters, L_∞ and K, were used to estimate length at age from von Bertalanffy growth equation by Gulland and Holt plot (Sparre *et al*., 1989).

BIGEYE TUNA FISHERIES

The total bigeye tuna catch from the eastern Indian Ocean had fluctuated during 1994 to 1998 (Fig. 1), which these catches have been operated by Japanese purse seine and Taiwanese and Chinese longline. In 1994 the total catch was 2,749 mt of which 2,622 ton was taken by purse seine (95%) and 127 ton by longline (5%), which was a slight decrease of catches in 1995 and was a increase to be 3,553 mt in 1996 and a slight decrease to be 2,610 in 1997 and 1,337 mt in 1998. In later years, a shape increasee percentage of longline catch was observed, i.e. 27% in 1996, 26% in 1997 and 32 % in 1998.

Purse seine: The monthly variations of catch per unit effort (CPUE), catch and fishing effort are reported in table 1 from 1994 to 1998. The average seasonal of purse seine effort and CPUE were calculated for a 5-year period (1994-1998). Effort was high during January to March, October and December, CPUE was pronounced from February to April, June and September.

Longline: The monthly variations of CPUE, catch and fishing effort are reported in table 2 from 1995 to 1998. The average seasonal of longline effort and CPUE were calculated for a 4-year period (1995-1998). Effort and CPUE were pronounced from November to March, northeast monsoon season.

Length-frequency sampling of bigeye tuna catches was carried out at Phuket port, from 1995 to 1998. Figs 4 and 5 present the monthly length frequency distribution of bigeye tuna taken by purse seine and longline, respectively. The percent of length frequency of bigeye plotted by raising factor of the total catch each gear. Range of size distribution by purse seine is 30 cm to 120 cm, mostly to be unimodal. The dominant size range for bigeye tuna caught by longline from 1995 to 1998 to be 70 to 190 cm FL. The longline size data is mostly multimodal. Bigeye tuna catch by surface fisheries is predominantly of small size to be juvenile, whereas longline catch gave a big size. Due to fishing method of surface fisheries used the drifting fish aggregating devices (FADs) to aggregate tuna, the target species of this method are small size of tuna for canning. Whereas the target species of longline is the depth free swimming school are the big size of tuna for the Japanese sashimi market.

BIOLOGY OF BIGEYE TUNA

Weight-at-length data were randomly obtained from 2,707 bigeye tunas caught by purse seiner and longliner. The bigeye fork length and whole weight data were used to estimate the parameters of a length-weight curve. Given fork length, L_i, and whole weight, W_i , we have

$W_i = a \cdot L^b \cdot e^e$ Where $e \sim N(0,s^2)$.

Noting that our modal assumes longnormal errors, and taking logarithms, we obtain

$\ln W = \ln a + b \cdot \ln L + e$.

The l-w equation can be used to estimate the whole weight given a value of the fork length. Usually $a \cdot L^b$ is used as the estimate of the whole weight. However, this is not exact, since in general, the expected value of a function of a random variable is not a function of the expected value of the random variable. In our case, the expected value of e^e is not $e^0 = 1$, but $e^{s2/2}$ However, the value of $e^{s2/2}$ for the data considered here is about 1.004, and therefore it can be ignored (Lawson, 1996).

Results of the regression using the entire sample of 2,842 fish indicated the presence of outliers (Fig. 6); therefore, all standardized residuals greater than 2.0 were removed

(Lawson, 1996). There were 135 outliers, which accounted for 4.75 percent of the original sample. The estimated values of the parameters *a* and *b*, with outliers removed, were 2.1681 x 10^{-5} and 2.9968 respectively. R^2 was 0.995 and the residual mean square was 0.0085. The 2,707 fish comprising the AFDEC sample, with outliers removed, include 1,693 fish (63 percent) sampled form purse seiner and 1,014 fish (37 percent) sampled from longliners. The frequency of fork lengths on the sample (with outliers removed) is shown in Fig. 7.

A scatter plot of lengths and weights is shown in Fig. 8 and a plot of the residuals against fork length is shown in Fig. 9. The residuals are evenly distributed with regard to fork length, and the regression line in Fig. 9 indicates that the residuals do not depend on fork length; there is therefore no lack of fit.

The results were compared with those from Nakamura & Uchiyama (1966) in the central Pacific Ocean and Morita (1973) in the west Pacific Ocean (Fig.10). For the model based on the AFDEC data, are similar to those of the other two models in the Pacific Ocean.

Length frequency distribution analysis of bigeye tuna derived from purse seiner and longliner samples at Phuket landing port during 1995 to 1998 reported in Fig. 11. The progression of mean length for each mode of length frequency distribution, which these results are polymodal progression of bigeye tuna recruited into the fisheries. If we assume that all cohorts in Fig. 11 have the same growth parameters. The determine of growth parameters which produce the growth curve used the best fit to the pairs of mean age and mean length data are indicated by heavy lines in Fig. 11.

Growth parameters, L_∞ and K, were used to estimate length at age from von Bertalanffy growth equation. It's growth equation were obtained as follow:

$L_t = 223.288\ [l\text{-}e^{(-0.35\ (t+0.02))}]$

t_o = -0.02 (Suda and Kume (1967) in Miyabe and Bayliff (1998)).

The comparative growth curves between this study and others, using a classical von Bertalanffy growth curve for bigeye tuna was shown in Table 3 and Fig 12. It was noted that an apparently fast growth of bigeye in this study has already been observed in Pacific Ocean and previous study in the Indian Ocean. In order to see if this study used the raising data for purse seiner and longliner, this effect might be related to the greater proportion of smaller fish represented and small sample size between 90 to 100 cm in the AFDEC data. The predicted growth parameters of previous studies were different from this study based on data for the size distribution of fork length greater than 80 cm for longliner, while the predicted growth parameters at size distribution between 36 to 190 cm. It was also pointed out that growth can be highly variable according to time and area, this phenomenon was being reflected in the increasing variance of length frequency modes with age (IPTP, 1992).The age at size of bigeye tuna for purse seiner was 0.48 to 2.18 year and for longliner was more than 1.05 year.

PROGRESS MADE IN RESEARCH AND DATA COLLECTION

The uncertainties regarding the impact of the fisheries on the stock, and fishery interaction exist for several reasons. First, in the western and eastern Indian Ocean, estimates of bigeye catches by purse-seiners and other surface fisheries are less precise than the catches of the other target species, skipjack and yellowfin tuna. Bigeye catches are not specifically recorded in the fishing logs of many vessels because of the difficulty in separating catches of juvenile bigeye and yellowfin (which are of similar appearance) during bulk handling of the catch. Bigeye catches must therefore be estimated from species composition samples taken in unloading ports by staff of AFDEC.

In addition to concerns regarding the possible impact of these increases in purse-seine catch on the bigeye tuna stock, there is also a related concern that such catches, which are processed as low-priced product for canning, will ultimately impact the catches of high-priced, sashimi-quality bigeye by longliners. Such adverse impacts, if they occur, have the potential to reduce the profitability of the longline fishery and thus significantly affect the economies of a number of Indian Ocean countries.

Uncertainty also results because gaps in understanding of various aspects of the biology of bigeye tuna, such as stock structure, migration, maturation, spawning, sex ratio, age and growth (by tagging and otolith reading), recruitment, natural mortality rates, mean that the response of the stock to fishing pressure cannot be accurately predicted and maximum yield and effort in terms of gear. Further work is needed to address the previous question on the biological and fisheries.

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Table 1 Total catch(mt) effort (day) and CPUE (mt/day) of bigeye tuna by Japanese purse seine landed at Phuket Province, Thailand. Symbol:' - ' = no landing.

Month	1994			1995			1996			1997			1998		
	Catch	Effort	CPUE	Catch	Effort	CPUE	Catch	Effort	CPUE	Catch	Effort	CPUE	Catch	Effort	CPUE
Jan	40	81	0.49	141	115	1.23	327	114	2.87	265	99	2.68	70	20	3.50
Feb	-	123	-	577	108	5.34	201	75	2.68	-	76	-	269	90	2.99
Mar	671	150	4.48	150	58	2.59	419	90	4.65	348	64	5.44	177	96	1.84
Apr	-	80	-	-	-	-	86	74	1.16	-	-	-	108	21	5.14
May	198	80	2.48	218	152	1.43	-	-	-	45	25	1.80	35	41	0.85
Jun	223	102	2.19	237	27	8.77	116	31	3.76	227	52	4.37	60	56	1.07
Jul	-	84	-	261	69	3.78	132	38	3.47	182	80	2.28	-	-	-
Aug	278	81	3.43	55	29	1.90	78	23	3.40	-	-	-	-	-	-
Sep	190	50	3.80	181	50	3.62	360	70	5.14	-	-	-	-	-	-
Oct	400	115	3.48	310	93	3.33	264	72	3.67	311	80	3.89	61	34	1.79
Nov	352	110	3.20	63	23	2.74	90	62	1.45	295	42	7.02	-	-	-
Dec	270	110	2.45	177	90	1.97	516	75	6.88	261	60	4.35	125	76	1.64
Total	2,622	1,166	2.25	2,370	814	2.91	2,589	724	3.58	1,934	578	3.35	905	434	2.09

Table 2 Total catch(mt) effort (trip) and CPUE (mt/trip) of bigeye tuna by longline landed at Phuket Province, Thailand.

Month	1995			1996			1997			1998		
	Catch	Effort	CPUE	Catch	Effort	CPUE	Catch	Effort	CPUE	Catch	Effort	CPUE
Jan	42.85	25	1.71	270.24	49	5.52	72.93	100	0.73	118.39	54	2.19
Feb	1.74	16	0.11	171.50	49	3.50	143.02	90	1.59	194.25	97	2.00
Mar	1.35	5	0.27	79.00	50	1.58	118.50	77	1.54	21.79	86	0.25
Apr	3.47	7	0.50	102.21	30	3.41	91.33	50	1.83	27.80	51	0.55
May	0.88	6	0.15	6.60	17	0.39	40.96	34	1.20	7.74	28	0.28
Jun	3.47	5	0.69	21.55	26	0.83	10.54	8	1.32	3.34	23	0.15
Jul	7.45	6	1.24	10.10	31	0.33	6.34	6	1.06	8.49	38	0.22
Aug	5.11	9	0.57	44.22	58	0.76	11.45	12	0.95	10.63	48	0.22
Sep	0.87	7	0.12	31.56	53	0.60	17.84	14	1.27	5.18	28	0.19
Oct	13.54	18	0.75	11.77	58	0.20	15.49	44	0.35	2.20	29	0.08
Nov	22.37	35	0.64	82.84	64	1.29	25.17	46	0.55	9.41	55	0.17
Dec	98.02	48	2.04	131.65	82	1.61	122.28	77	1.59	22.93	118	0.19
Total	201.11	187	1.08	963.24	567	1.70	675.86	558	1.21	432.15	655	0.66

Table 3. Growth parameters (K, L¥) of bigeye tuna in the Indian Ocean and the Pacific Ocean. Symbol:'1'= Miyabe and Bayliff (1998).

Area	Sampling range (FL ,cm)	L_∞	K (yr)	t_0	Source
1 East Indian Ocean	36-190	223.288	0.35	-0.02	AFDEC
2 Indian Ocean		209.8	0.171	-0.86	Tankevich (1982) Female
3 Indian Ocean		423.0	0.058	-1.773	Tankevich (1982) Male
4 Pacific Ocean	192	156.82	0.427	0.53	Hampton *et al*. (1998)
5 Pacific Ocean	46-185	228.59	0.226	-0.425	Lehodey *et al*.(1999)
6 Pacific Ocean	60-150	215.00	0.208	-0.0105	Yukinawa and Yabuta (1963)[1]
7 Pacific Ocean	82-150	186.95	0.38	0.53	Kume and Joseph (1966)[1]
8 Pacific Ocean		214.80	0.2066	-0.02	Suda and Kume (1967)[1]

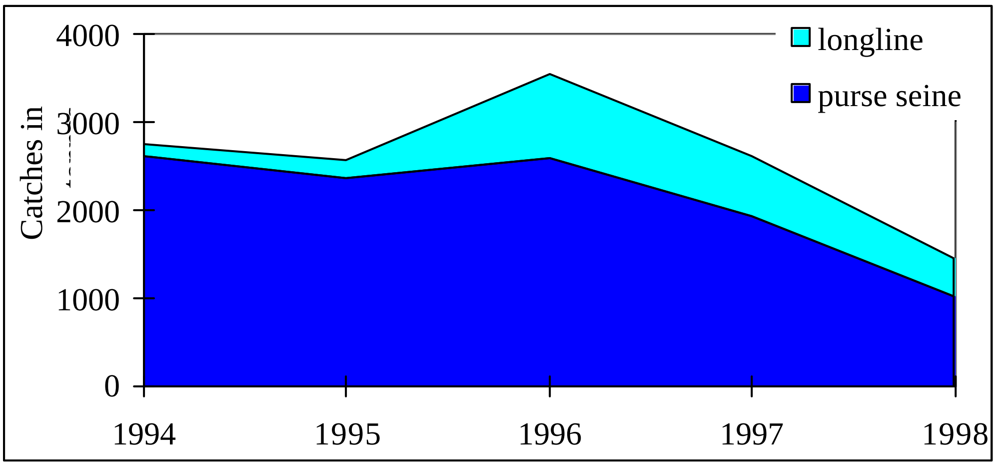

Figure 1. Catch of bigeye tuna by gear.

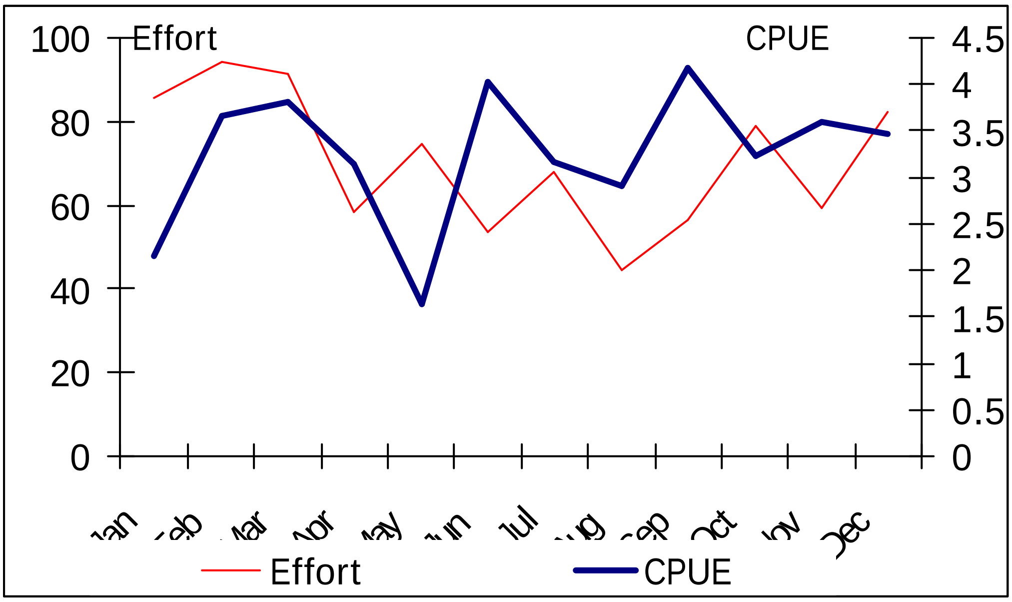

Fig. 2 Average monthly effort (days) and CPUE (mt/days) in the eastern Indian Ocean for the Japanese purse seine fleet (1994-1998).

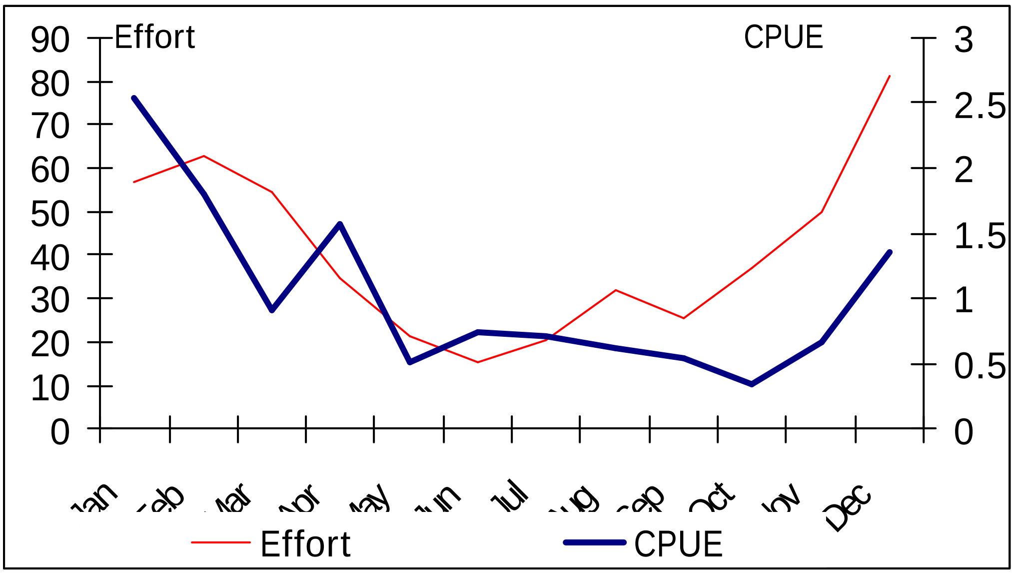

Fig. 3 Average monthly effort (days) and CPUE (mt/days) in the eastern Indian Ocean for the longline fleet (1995-1998).

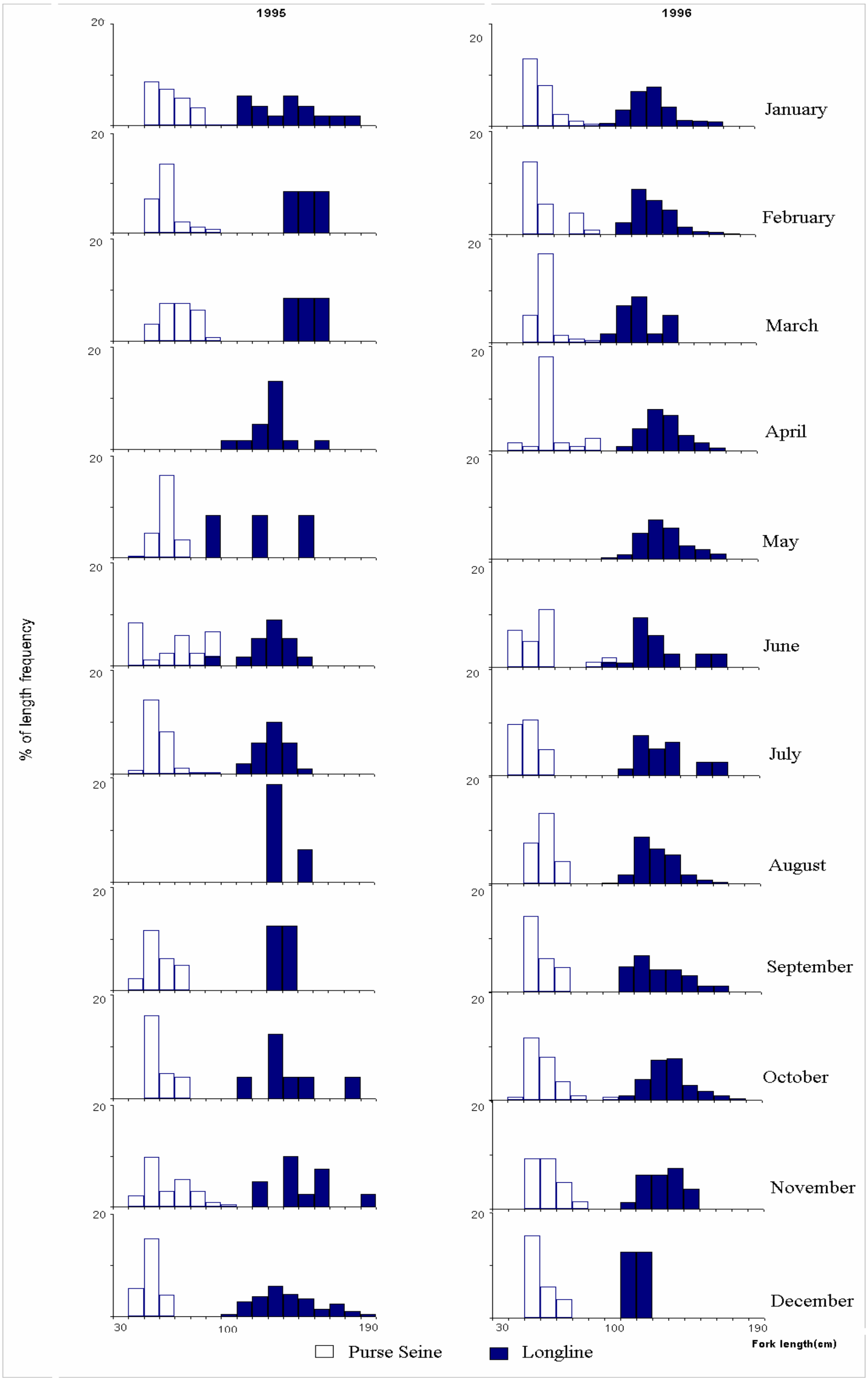

Fig. 4 Length frequency distribution of bigeye by purse seine and longline from 1995 to 1996.

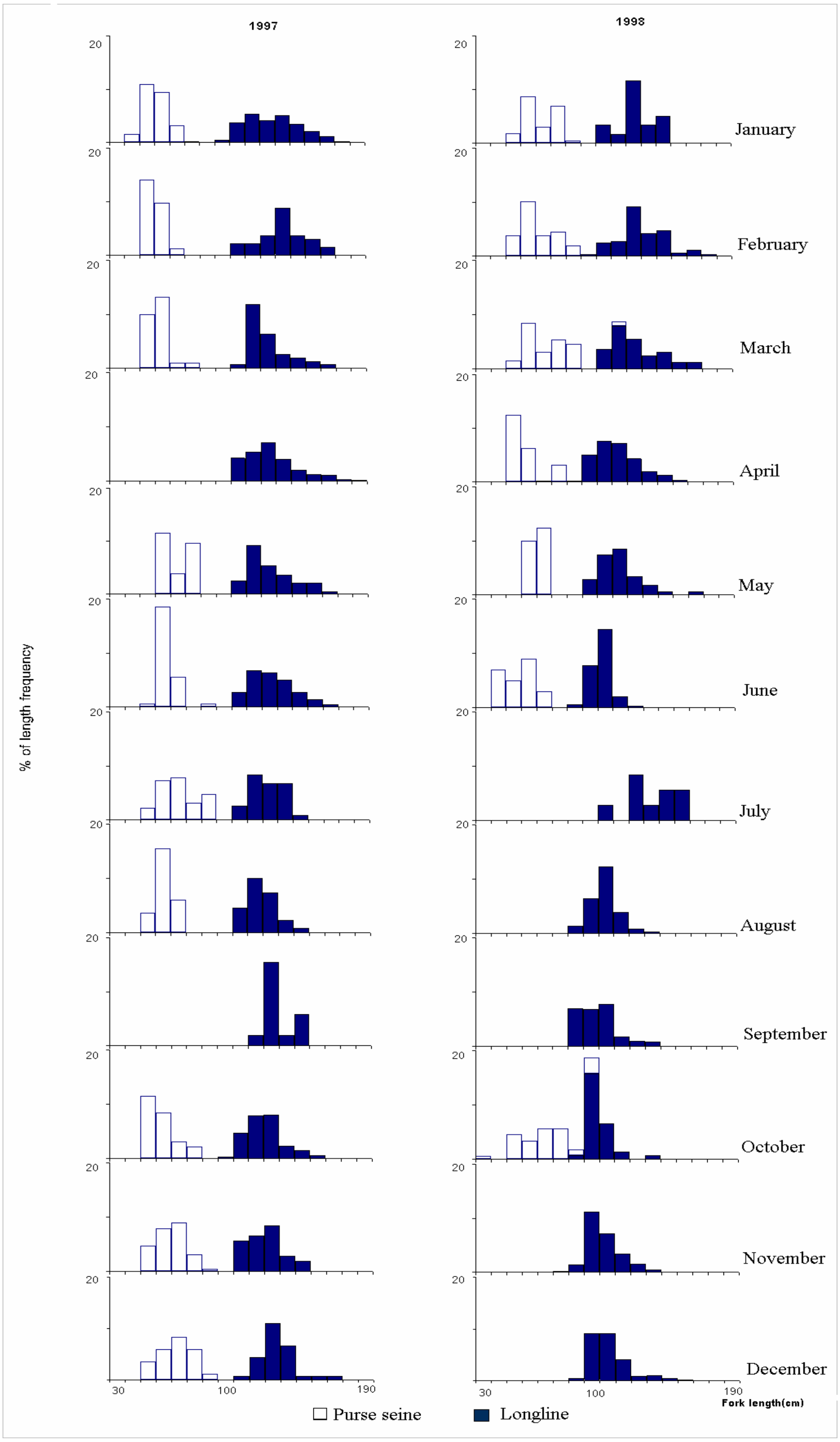

Fig. 5: Length frequency distribution of bigeye by purse seine and longline from 1997 to 1998.

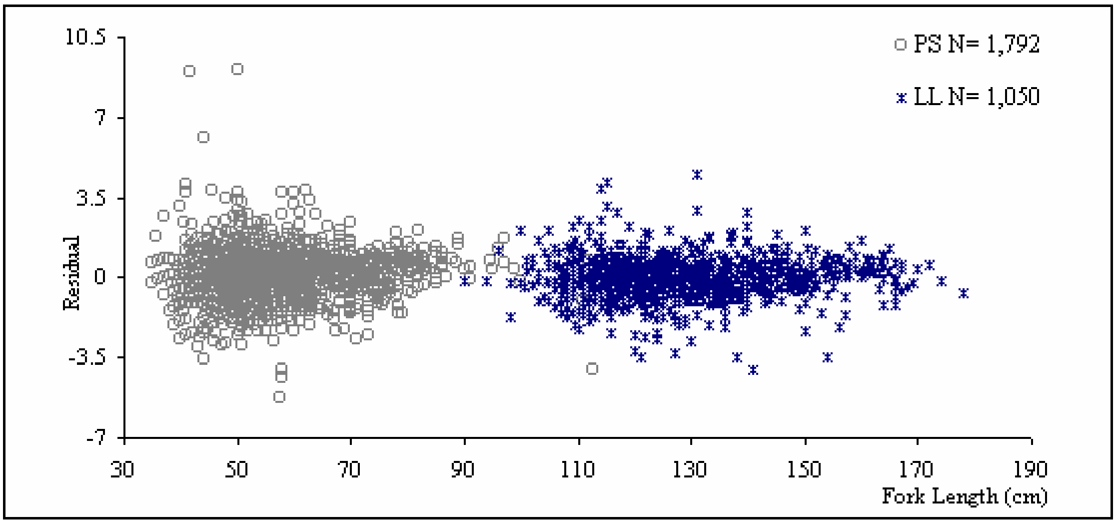

Fig. 6 Standardised residuals from bigeye length-weight regression vs FL (cm), with presence of outliers.

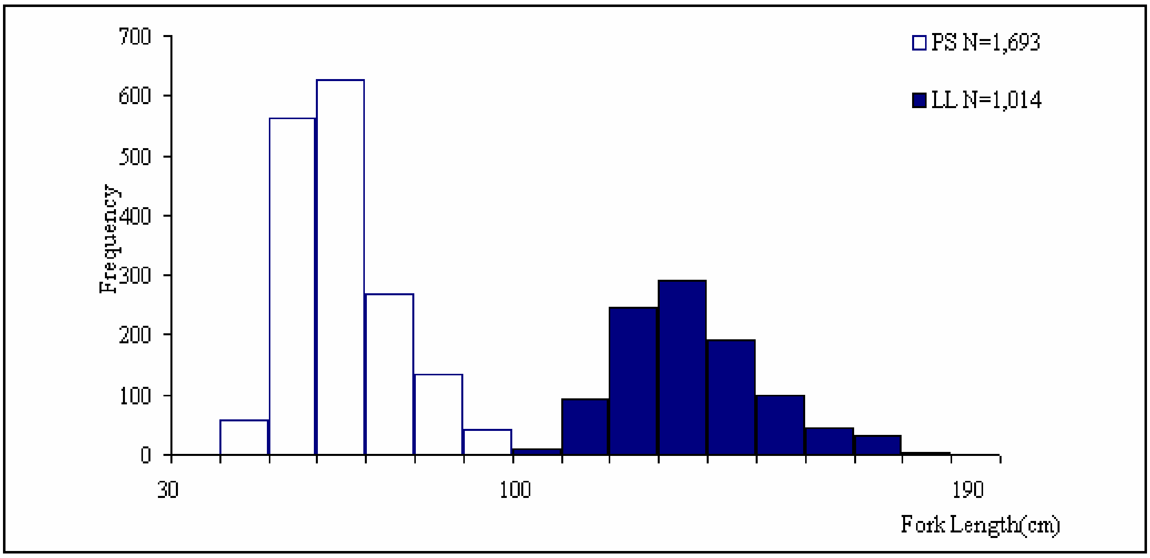

Fig. 7. Frequency of fork length (cm) for bigeye length-weight data, with outliers removed.

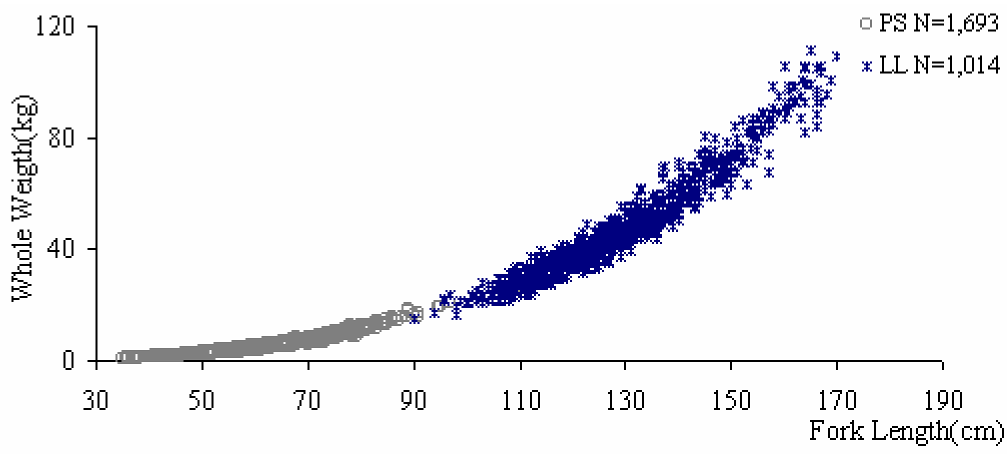

Fig. 8. Bigeye tuna whole weight (kg) vs fork length (cm) for bigeye tuna, with outliers removed.

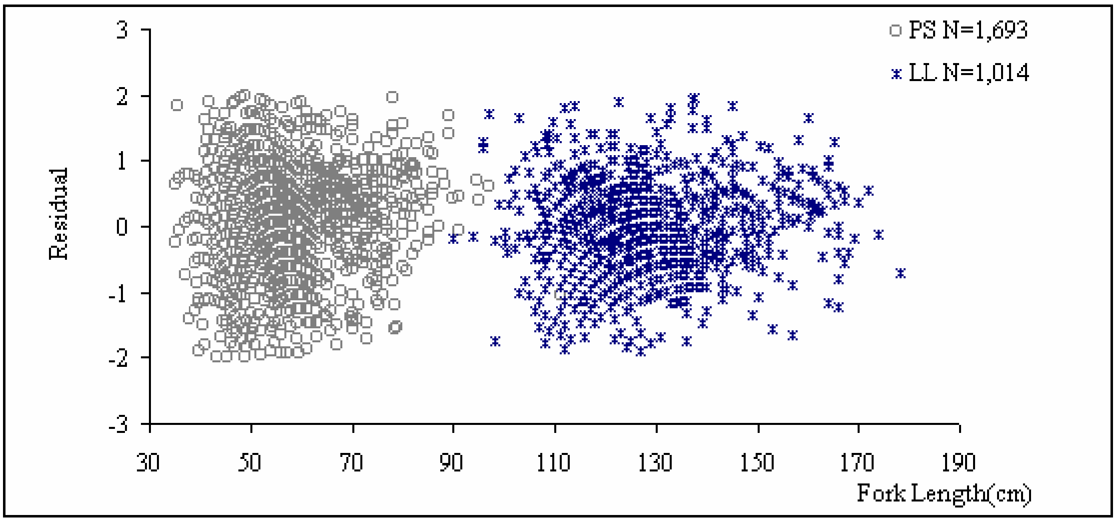

Fig. 9. Standardized residuals from bigeye length-weight regression vs FL (cm), with outliers removed.

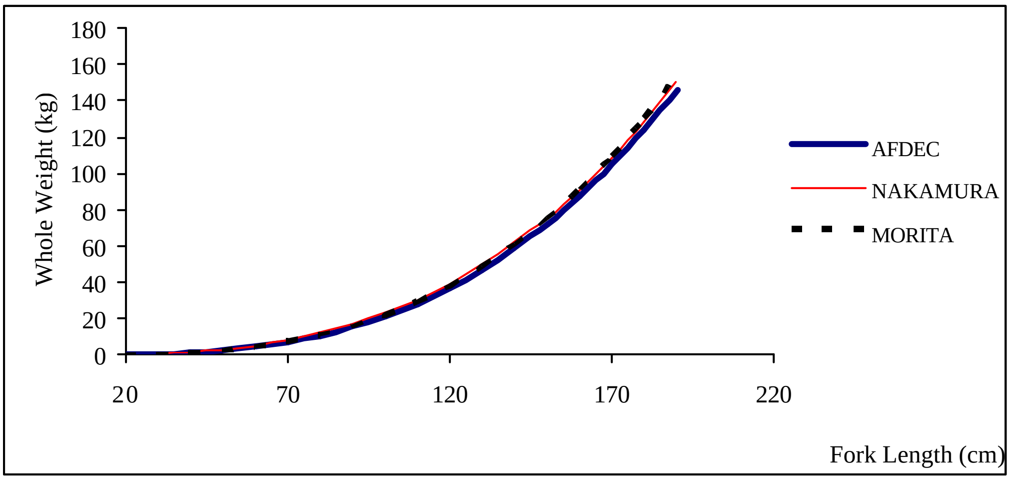

Fig. 10. Fitted bigeye tuna whole weight (kg)-fork length (cm) curves from Nakamura & Uchiyama (1966), Morita (1973) and AFDEC data.

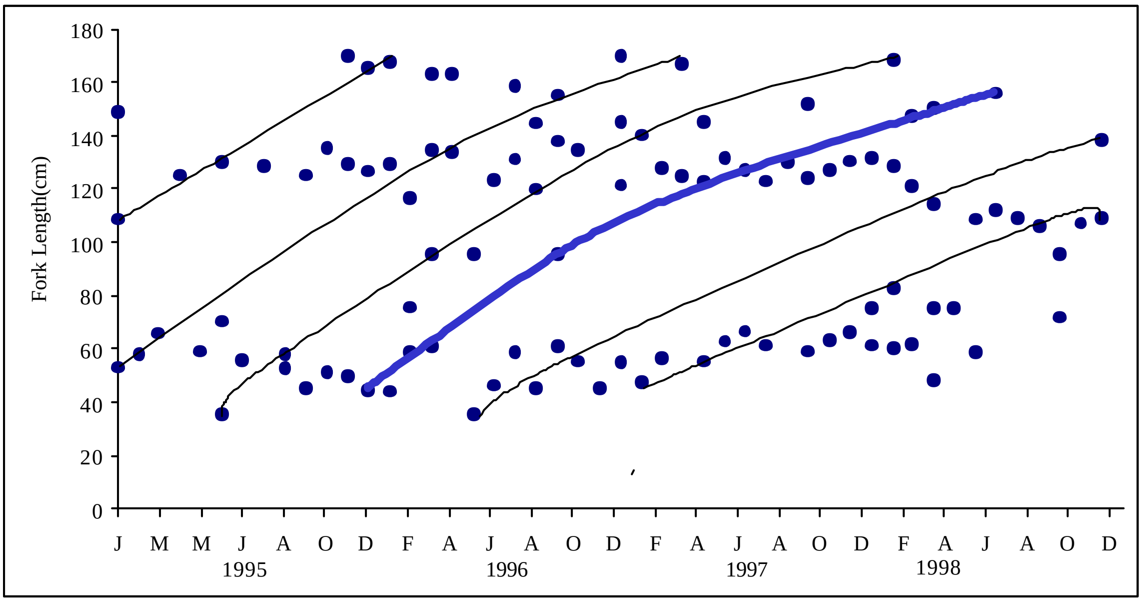

Fig. 11. Mean length of bigeye tuna in the eastern Indian Ocean during 1995 to 1998 from Bhattacharya method.

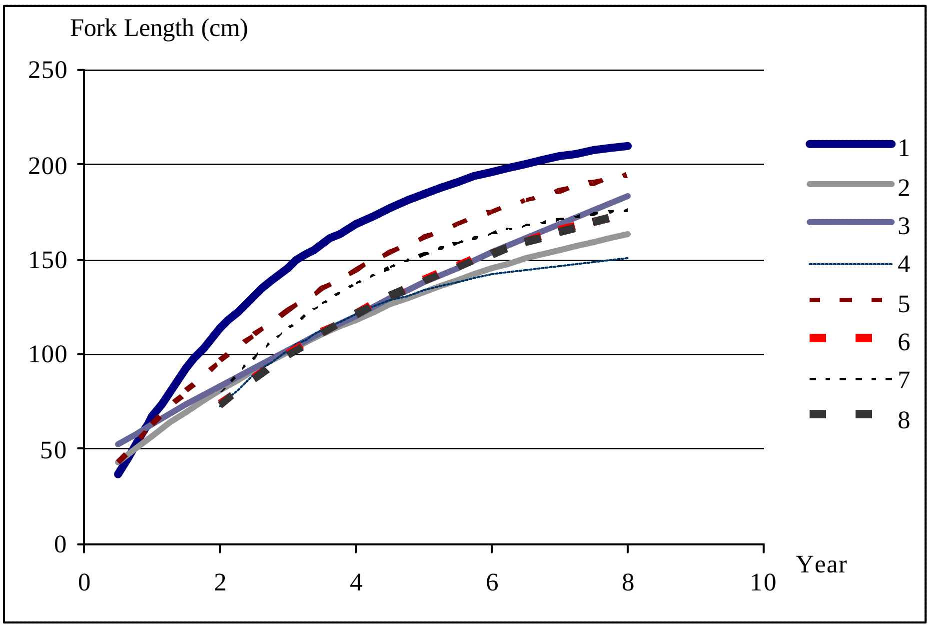

Fig. 12 Growth curves of bigeye tuna estimated by various authors. Curve line numbers refer to Table 3. *Dotted line = studies in Pacific; thin continuous line = studies in Indian; thick continuous line = this study.*