REPRODUCTIVE BIOLOGY OF BIGEYE TUNA IN THE EASTERN INDIAN OCEAN[1]

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ABSTRACT

Reproductive biology of bigeye tuna in the Eastern Indian Ocean was conducted from January 2000 to August 2003 which collected the data from surface longline that unloaded their catch at Phuket fishing port, Thailand.

Spawning season of female and male of BE found in December to January and June. The size at first maturity and age of female and male was reported 88.08, 1.97 years old and 86.85 cm, 1.92 years old. Monthly sex ratio varied (1:0.33 to 1:24), while, May, September and November in 2001 and January, April and October 2002 reported sex ration equal 1:1. Sex ration by length class indicated small size of BE (85.00-115.00 cm) comprise of female more than male while large size of bigeye tuna (125.00-155.00 cm) found proportion of female less than those size.

INTRODUCTION

Bigeye tuna (*Thunnus obesus* Lowe, 1839) 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, China and 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 longline catch of bigeye tuna (BE) in the Indian Ocean has increased from approximately 40,000 tonnes in the late-1980s and early-1990s to ~100,000 tonnes in the late-1990s (IOTC Fishstat Data set 1950-2000). Catches peaked in 1998 at 110,000 tonnes, and have declined slightly since then.

In response to the high exploitation rates on the full size range of BE, the Indian Ocean Tuna Commission (IOTC) initiated a research program focusing on BE in 1999. The main objectives of this program was to update the knowledge on the biology of the species, and study the stock structure and dynamics in order to assess the effect of the current fishing pressure on the resource. Among the various tasks assigned to the program, emphasis was placed on BE reproductive biology. In 2001, the IOTC Working Party on Tropical Tunas (2001) recommended that determine the growth and age (and/or size) at first maturity for BE caught in the north-east Indian Ocean.

Uncertainties exist in the reproductive biology of BE, which limits our ability to manage the stock. In lieu of validated length-at-age data, estimates of the age distribution of the catch are based on the conversion of lengths and weights to ages based on estimated growth curves. In addition, spawning season, size at first mature and sex ratio of BE from throughout the exploited population would improve our understanding of a number of aspects of the species biology and ecology all of which are of importance in the development of optimal management strategies.

Phuket is an important port of foreign purse seine and longline fleets that have landed BE caught in the north-east Indian Ocean since 1994. Then, the result of the present study on reproductive biology of BE is the useful and advantage research study on BE management in the EIO.

MATERIAL AND METHOD

Port-sampling had been conducted to collect fishing and biological data of BE e.g. fishing ground, individual of processed weight (kg), folk length (cm) (FL) and gonad by the staff of Andaman Sea Fisheries Research and Development Center (AFRDEC) and Samplers of Cooperation Project for Enhancing the Data Collection and Processing Systems for Tuna Resources in the Indian Ocean between Department of Fisheries and IOTC-OFCF on a monthly basis at landing ports, namely Phuket fishing port since January 2001 to August 2003. All of gonad samples had collected in monthly and labeled after that transferred to

[1] *This paper presented at the 6 th Working party on Tropical Tunus, IOTC, held at Victoria, Seychelles, 13 to 21 July 2004.*

AFRDEC laboratory. Total number of gonad sample was 381 samples, including ovary and testis were 251 and 130 samples, respectively.

Gonad samples was removed by worker at the processing plant, AFRDEC staff collected and labeled, placed in a sample bag and put on ice. The tuna carcass will be given a matching label so that the fish and reproductive organ can be identified when the catch is landed from which vessel. Each sample was to be labeled with sample number, vessel name and landing date matching these entries on the landings form. FL (cm) and dressed weight (kg) of each fish sampled was to be measured. 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 1.10. Gonad was classified by a visual assessment of the developmental stage and weighted in gram. In addition, coefficient valves (a and b) from length and weight relationship equal $1.4x10^{-5}$ and 3.11 followed Nootmorn *et al*. (2001).

The macroscopic appearance of gonad applied the scheme of Schaefer (1987) as follow:

Ovary: Stage 1 Immature, Thin hollow tubes 3-4 mm diameter and colour translucent/white.

Stage 2 Early developing, recover spent, Oocytes visible on inner ovary wall. Blood vessel visible distinctly on external of ovary wall. Colour pale reddish/orange.

Stage 3 Later developing, Ovary and oocytes develop, oocytes shape not round and tight attached. Blood vessel visible less than previous stage. Colour pale orange.

Stage 4 Mature, Ovary has well develop. Oocytes slip off inner of ovary wall, shape rounded and translucent area surround opaque oocytes. Colour pale orange/yellow.

Stage 5 Spawned, Characteristic ovary soften, deflated and flaccid. The rest of oocytes found in ovary. Colour dark orange/yellow

Testis: Stage 1 Immature, Thin hollow tubes 3-4 mm diameter and colour translucent/white.

Stage 2 Early developing, recover spent, Testis tubes develop and blood vessel visible in the tube. Spermatogonia and spermatocytes present and mitotically divide in nests. Colour pale white/reddish.

Stage 3 Later developing, Testis tubes well develop and blood vessel visible in the tube less than previous stage. All stages of sperm development, ripe sperm becoming abundant in cysts and lobule lumen but not in ducts. Colour white/reddish.

Stage 4 Mature, Gonad full of sperm, packed with ripe sperm in lobules and ducts. Colour white/reddish.

Stage 5 Spawned, Gonad soften, deflated and flaccid. Colour dark white.

Data Analysis

Sex ratio, the monthly proportion of male and female was used to expect the spawning capability of fish (Hamano and Matsuura, 1987). In this study is hypothesis that sex ratio of male and female equal 1 at 95 % of confident interval, the method to analyze is Chi-square test (Snedecor and Cochran, 1973) (= 3.8415) followed the equation as :

$$\chi^2 = \sum \frac{(Observed - Expected)^2}{Expected}$$

When, Observed = Value from sampling
Expected = Value from calculation

The relationship of FL frequency of male and female of BE with female sex ratio in each length class interval were calculated followed Boonyanich (1998) as:

$$Rf = a+bL$$

When, Rf = Nf/(Nf+Nm) = Female sex ratio
L = Median of each length class
Nf = Number of female
Nm= Number of male
a, b = Coefficient valve from regression model

The average of maturity stage by monthly follow Dixon and Massey (1957) method as:

$$\bar{x} = \left(\frac{f}{N}\right)x100$$

When, $\bar{x}$ = Average of maturity stage
f = Number of maturity stage 3 and 4
N = Total number of ovary

Gonadosomatic Index (GSI) is followed the Kikawa (1964) and Shingu (1970) method as the equation:

$$GSI = (w_i/FL_i^3)\ x10^4$$

When, w_i = Ovary or testis weights (gram) and FL_i=Folk length (cm). The individual GSI will be calculated the mean of GSI (Mean Gonadosomatic Index).

Mean of maturity stage and GSI in 3 years data was calculated again by STATISTICA Program and plotted the spawning season of BE.

Size at first maturity was estimated follow Bakhayokho (1983), 50 % of maturity stage 3-5 of female and male is used to be initial value to estimation. The proportion of maturity stage each frequency of length class is followed Somerton (1980) as:

$$Y = \frac{1}{(1+e^{(A+Bx)})}$$

When, Y = Proportion of maturity stage from total number at length x.
X = Mode of FL in each class interval.
A, B = Coefficient valve from regression model.

FL was calculated back to age followed Stequert (2003) using von Bertalanffy growth function that L_∞, K and t_0 of BE was 169 cm, 0.32 per year and -0.336 per year.

$\chi^2_{0.05,1}$

RESULT AND DISCUSSION

Fishing ground and Size frequency distribution

Their fishing grounds were located from latitude 15° N to 6° S and longitude 78° to 96° E, the Eastern Indian Ocean (Fig. 1).

Monthly Size frequency distribution of male and female BE in weight and FL illustrated in Fig. 2., while Fig 3 show combination of size distribution from 2001-2003 where range of size in weight and FL of male and female are 14.30-132.00 and 13.20-96.80 kg and 85.55-174.82 and 83.38-158.23 cm. Mode in weight and FL of male BE is 30, 80 kg and 110-120 cm, respectively, while mode of female is 30-40, 60, 90 kg and 110-120, 160 cm. The present study has result similar with Chantawog *et al.*(1999) that reported BE size distribution in FL was 70 to 190 cm from longliner. They reported that BE was caught by surface fisheries was predominantly of small size to be juvenile, whereas longline catches give a big size to be mature. Due to fishing method of surface fisheries use 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 are the depth free swimming school is the big size of tuna for the sashimi market.

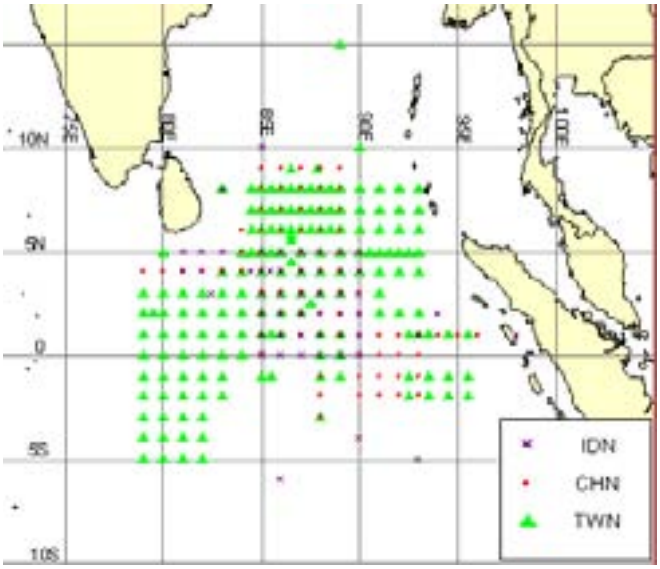

Fig. 1 Fishing ground of tuna longline fleets in the EIO. Symbol:CHN=Chinese,IDN=Indonesian, TWN=Taiwanese.

Sex Ratio, Spawning Season and Size at first maturity

Sex Ratio of BE male and female was 1:1.84, varied from 1:0.32 to 1:24.00. Figure 4 show monthly percentage of male and female, the ratio equal 1:1 that only reported in May, September and November in 2001 and January, April and October 2002. Farley *et al.* (2003) reported sex ratio of BE from longliner that found the proportion of male more than female (1.24:1) only in Coral Sea, while sex ratio in other areas (Southern Queensland/New South Wales, Western Australia, Southern of Indonesia Water) found proportion about 1:1. In addition, sex ratio by length class in present study indicated small size of BE (85.00-115.00 cm) comprise of female more than male while large size (125.00-155.00 cm) found proportion of female less than small size (Figure 5). The present result is similarly the report of Farley *et al.* (2003) especially in Southern Queensland/New South Wales and Western Australia areas, but their report showed the reverse result in the Southern of Indonesia Water, female dominated than male in all size classes over 130 cm FL.

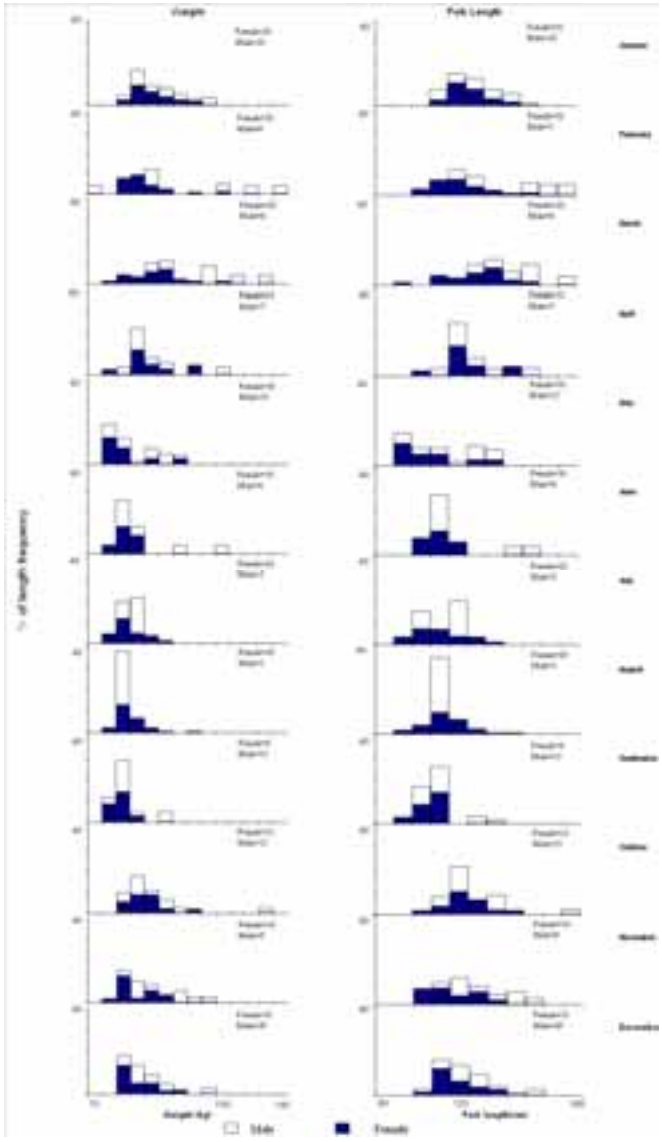

Fig 2. Monthly weight and length frequency distribution of BE from 2001 to 2003.

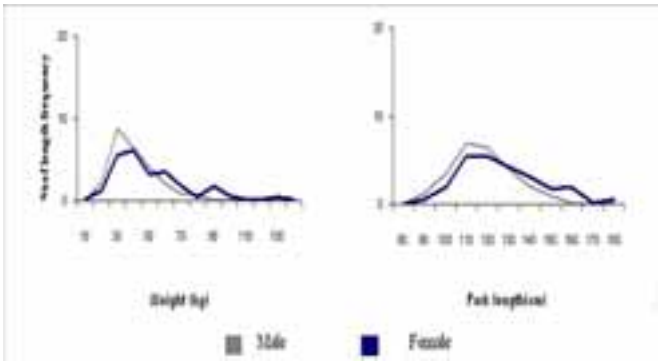

Fig 3. Weight and length frequency distribution of BE from 2001 to 2003.

Maturity stage of female and male BE was classified 1-5 stage and 2-5 stage, respectively. Mean GSI of female varied from 1.37 to 4.28 while male ranged 0.60 to 2.89 (Table 1).

Figure 6 and 7 illustrated the percentage of female and male maturity and GSI in monthly that indicated spawning season of BE illustrated in December to January and June. In addition, the spawning season of male show the similar result of female while high percentage of maturity stage found all year round. Size at first maturity of female and male was observed from sampling data equal 83.38 cm (12 kg) and 85.55 cm (13 kg) respectively. Using Somerton (1980) model length at 50% maturity (L_{50}) was estimated to be 88.08 cm for female and 86.85 cm male (Figs. 8 and 9), that bigger more the observed data. In addition, age at first size at maturity of male equal 1.41 year old and female equal 1.47 year old.

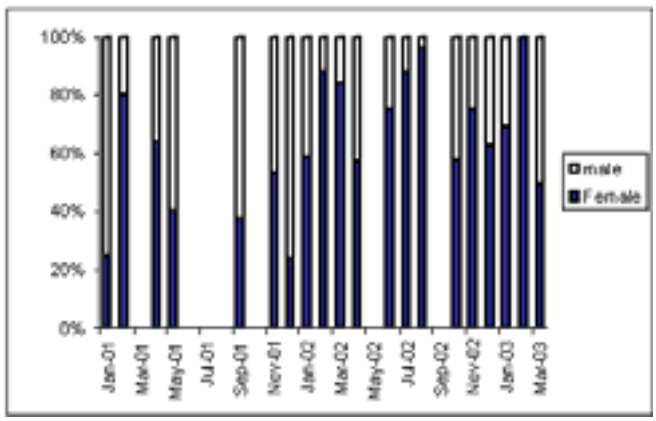

Fig 4. Monthly sex ratio BE from January 2001-March 2003.

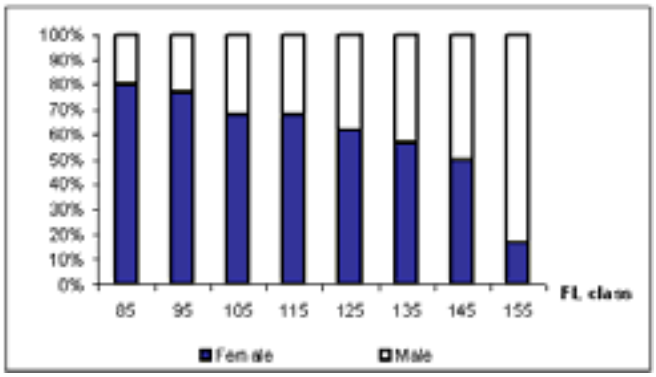

Fig 5. Change of Sex ratio by FL class of BE.

Nootmorn et al. (2001) reported reproductive biology of BE that caught from Thai Purse seine in EIO that will be found the small size 32 - 69.7 cm and mostly juvenile that maturity stage was reported stage 1-2. Sex ratio of male and female equaled 1:0.82.

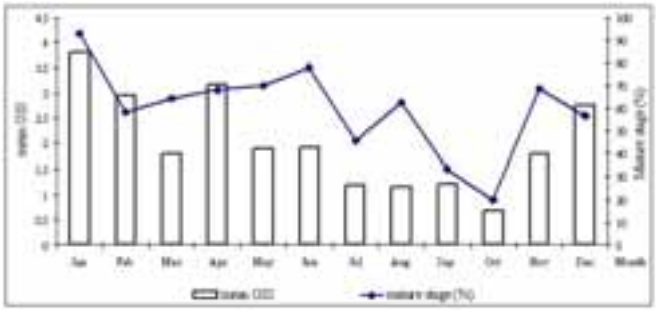

Fig 6. Monthly change of percent of maturity and GSI of female BE from January 2001-August 2003.

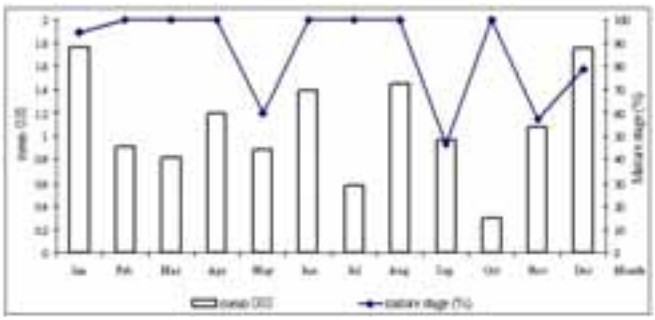

Fig 7. Monthly change of percent of maturity and GSI of male BE from January 2001-August 2003.

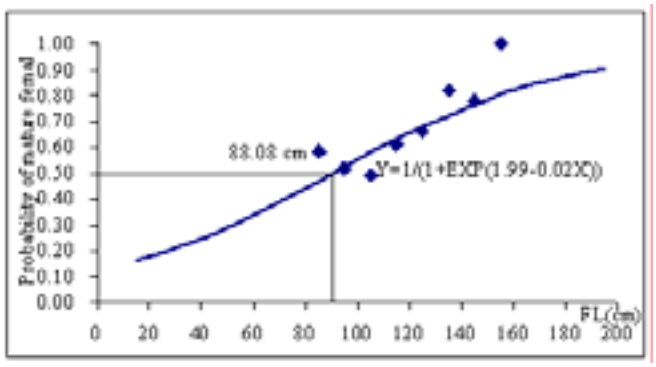

Fig 8. Probability of mature female and FL class of BE.

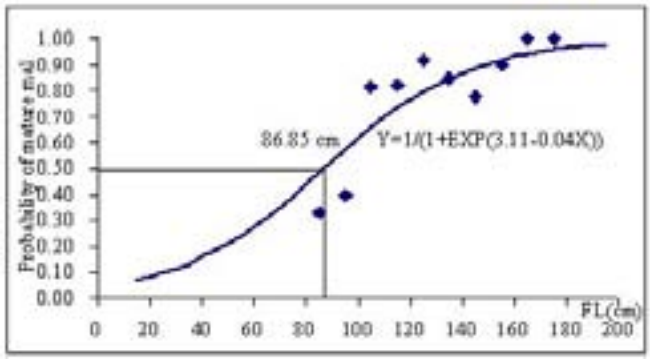

Fig 9. Probability of mature female and FL class of BE

Farley *et al.* (2003) reported the size at first maturity and age of BE from longliner was 102.4 cm and 1.8 years old in females and 86.6 cm and 1.1 years old in males. If compare with the present study was the size at first maturity smaller than those study while male was similar result. In addition, BE had previous reported on size at first maturity as 91-100 cm (14-20 kg) in Pacific Ocean (Kikawa, 1953;Yuen, 1955), in addition, Kume (1962) reported size at first maturity as 92 cm (3 year) in Indian Ocean that bigger than present study. Whereas, Solovieff (1970) reported the spawning season of BE in Indian Ocean pronounced during January to March. Kume (1969) found proportion of male greater than female in fish caught from longliner, and, the proportion of male increased follow larger FL class. BE will have the proportion of male equal female in the size class below 75 cm after that the proportion of female will increase in length class 80-115 cm and the proportion of female will decrease again in length class more than 115 to 155 cm.

Table1. Development of BE maturity stage in EIO.

	Number of specimens			mean GSI		Mature stage	
month	female	male	total	female	male	female	male
Jan-01	2	6	8	4.28	1.61	100.00	83.33
Feb-01	8	2	10	2.85	1.48	87.50	100.00
Mar-01						0.00	
Apr-01	7	4	11	3.19	1.30	85.71	100.00
May-01	10	15	25	3.78	1.75	70.00	60.00
Jun-01							
Jul-01							
Aug-01							
Sep-01	9	15	24	2.40	1.92	33.33	46.67
Oct-01							
Nov-01	8	7	15	2.48	1.27	87.50	14.29
Dec-01	6	19	25	2.48	1.96	33.33	57.89
Jan-02	13	9	22	4.10	1.94	84.62	100.00
Feb-02	22	3	25	1.83	1.22	36.36	100.00
Mar-02	21	4	25	1.75	0.96	28.57	100.00
Apr-02	4	3	7	3.16	1.10	50.00	100.00
May-02							
Jun-02	18	6	24	3.83	2.77	77.78	100.00
Jul-02	22	3	25	2.37	1.15	45.45	100.00
Aug-02	24	1	25	2.27	2.89	62.50	100.00
Sep-02							
Oct-02	15	11	26	1.37	0.60	20.00	100.00
Nov-02	6	2	8	1.08	0.88	50.00	100.00
Dec-02	15	9	24	3.00	1.54	80.00	100.00
Jan-03	18	8	26	3.11	1.73	94.44	100.00
Feb-03	2		2	4.14		50.00	
Mar-03	2	2	4	3.66	1.47	100.00	100.00
Total	232	129	361				

CONCLUSION

1. Monthly sex ratio of BE was 1:1.8. The proportion of male and female equal 1:1 only in May, September and November in 2001 and January, April and October 2002.
2. Sex ratio by each length class indicated small size of BE (85.00-115.00 cm) comprise of female more than male while large size of BE (125.00-155.00 cm) have the proportion of male more than the small size.
3. Spawning season of female and male of BE found in December to January and June.
4. The size at first maturity and age of female and male was reported 88.08, 1.47 years old and 86.85 cm, 1.41 years old .

RECOMMENDATION

1.The lack of gonad sample of BE in some months, especially during the low fishing season (May to September).
2.Histological classification for determine gonad stage and spawning activity should be conduct and combine data with the present study in future.
3.Including, the study on fecundity of BE should conduct e in the future.
4. Should study on long term of BE reproductive biology that will be data base for BE management in Indian Ocean.

PROBLEMS ENCOUNTERED AND

REFERENCES

ANON. 1998. Indian Ocean Tuna Fisheries Data Summary, 1986-1996. IOTC Data Summary No.18. 180 p.

BOONYANICH, T. 1998. Reproductive biology of coastal tunas in the southern area of Gulf of Thailand. *In:* Proceeding on The marine fisheries seminar 1998, Marine Fisheries Division. 526-568 p. (in Thai)

CHANTAWONG, P., S. PANJARAT AND W. SINGTONGYAM. 1999: Preliminary Results on Fisheries and Biology of Bigeye Tuna (*Thunnus obesus*) in the Eastern Indian Ocean: Paper presented at the 1 st Working party on Tropical Tunas,

Farley, J., N. Clear, B. Leroy, T. Davis and G. Mcpherson. 2003. Age and growth of bigeye tuna (*Thunnus obesus*) from the eastern and western AFZ. Report No. 2000/100. CSIRO Marine Research. GPO Box 1538, Hobart Tamania 7000 Australia. 93p.

IOTC, held at Victoria, Seychelles, 4 to 9 September 1999. 15 p.

DIXON, W.J. and F.J. MASSEY, JR. 1957. **Introduction to Statistical Analysis.** 2nded., McGraw-Hill Co., Inc., New York. 488 p.

IOTC. 2001. Report of the Third Session of the IOTC Working Party on Tropical Tunas. Paper presented at the 4 th Working party on Tropical Tunas, IOTC, held at Victoria, Seychelles, 19 to 27 June 2001. 38 p.

KIRAWA, S. 1953. Observastion on the spawning of the big-eyed tuna (*Parathunnus mebachi*, Kishinouye) near the southern Marshall Islands. **Contr. Nankai Rig. Fish. Res. Lab**. 1(42):10 p.

KIRAWA, S. 1964. A study of the indomaguro (*Thunnus thynnus maccoyi*) in the area south of 20 . S lat. From the examination of ovary weight and maturity. **Rep. Nankai Reg. Lab**. 20:37-57.

KUME, S. 1962. A note on the artificial fertilization of bigeye tuna, *Parathunnus mebachi* (Kishinouys). **Rep. Nankai Fish. Res. Lab**.(15): 79-84.

KUME, S. 1969. Ecological studies on bigeye tuna -VI. A review on distribution and size composition of bigeye tuna in the equatorial and south Pacific Ocean. **Bull. Far Seas Fish. Res. Lab**. (1):77-98.

NOOTMORN, P., S. PANJARAT, S. HOIMUK, and W. SINGTONGYAM. 2001. Thai tuna purse seine fishery, Mukmanee, in the Indian Ocean, 1998 to 2000. *In:* Proceeding on The seminar on fisheries 2001, 19-21 September 2001, DOF Meeting Hall, Bangkhaen, Bangkok, Thailand. pp 230-248. (in Thai)

SCHAEFER, K. M. 1987. Reproductive biology of black skipjack, Euthynnus lineatus, an Eastern Pacific tuna. *Inter-Am. Trop. Tuna Comm. Bul.* 19(2):169-260.

SHINGU, C. 1970. Studies relevant to distribution and migration of southern bluefin tuna. **Bul. Far Seas Res. Lab**. 3:57-113.

SNEDECOR, G.W. AND W.G. COCHRAN. 1973. **Statistical Method**. 6thed.,The Iowa State Univ. Press, Iowa. 539 pp.

SOLOVIEFF, B. S. 1970. Distribution and biology of bigeye tuna in the Indian Ocean. **Rybn. Khoz**. 1970 (3).

SOMERTON, D.A. 1980. A computer technique for estimating the size of sexual maturity in crabs. **Can. J. Fish. Aquat. Sci**. 37:1488-1494.

Stequert , B. and F. Conand. 2003. Age and growth of bigeye tuna (*Thunnus obesus*) in the Western Indian Ocean: Paper presented at the 5th Working party on Tropical Tunas, IOTC, held at Victoria, Seychelles, 3 to 12 June 2003. 10 p.

YUEN, H. S. H. 1955. Maturity and fecundity of bigeye tuna in the Pacific. **Spec. Sci. Rep. U. S. Fish wild. Serv. (Fish)**. (150):3 p.