PRELIMINARY STUDIES OF AGE AND GROWTH OF BIGEYE TUNA (*THUNNUS OBESUS*) IN THE WESTERN INDIAN OCEAN

B. Stequert[1] and F. Conand[2]

ABSTRACT

*The age and growth of Bigeye tuna from the western Indian Ocean was investigated using both otolith and first dorsal spine. Microincrements, considered as daily depositions , were observed on transverse section of sagittal otoliths of 154 bigeye tuna (**Thunnus obesus**); they were counted to determine age and establish growth curve. The von Bertalanffy growth curve is* $FL = 303.9\ (1 - e^{-0.000397(t+167.15)})$*, where FL is fork length in cm and t in days. The fish reaches 58 cm at 1 year, 91 cm at 2 years and 120 cm at 3 years of age.*

We also studied growth by analysing marks on the first dorsal spine of 140 fish. For fish which are 1 and 2 years old, the results obtained with spine and otoliths are comparable, but they are different for older fish .

[1] Centre IRD de Brest, BP 70, 29280 Plouzané, France
[2] Laboratoire d'Ecologie Marine, Université de la Réunion, 97715 La Réunion, France

INTRODUCTION

The bigeye tuna (*Thunnus obesus*) is a large epi- and mesopelagic fish found in all tropical and subtropical oceans. It constitutes an extremely valuable fishery resource intensively exploited by Asian longliners, and US and European purse seiners at various stages of it's life cycle. Presently, in the Indian Ocean, purse seiner landings of bigeye tuna are essentially composed of small fish (fork length <90 cm) which are immature. Because this species supports an increasing fishing effort, a suitable method for age determination is necessary to ensure effective management.

A wide variety of ageing techniques have been applied to this species, including modal length frequency analysis, tagging studies, and examination of hard pieces such as scales, vertebrae, the first dorsal spine and otoliths (Yukinawa and Yabuta 1963, Kume and Joseph 1966, Marcille *et al.* 1978, Gaikov *et al.* 1980, Cayré and Diouf 1983, Draganik and Pelczarski 1984, Miyabe 1984, Pereira 1984, Weber 1990, Pelczarski 1992, Alves *et al.* 1997, Hampton *et al.* 1998, Lehodey *et al.*1999, Sun *et al.*1999). In all these studies, estimated growth rates are relatively high, as generally expected for scombroid fish; however there is considerable variation between studies and no clear-cut data on the shape of the growth curve exist.

Except a short study conducted off Madagascar by Marcille and Stéquert (1976) from the catches of pole and line, no growth study has been published for the western part of Indian Ocean. The main objective of this study is therefore to determine age and growth of Bigeye tuna collected in this area, by using otolith microstructure and first dorsal spine.

(*) in Pallares *et al.* 1998

MATERIAL AND METHODS

Sampling

Pairs of otoliths (Figure 1) were collected from more than 600 fish caught in the western part of the Indian Ocean during the Regional Tuna Project (1989 – 1990). Most of these otoliths were extracted on board of French purse seiners based in Mahé (Seychelles) during fishing trips and some from the Port Louis tuna cannery (Mauritius) during thawing of fish caught by Mauritian purse seiners. As large bigeye tuna caught by purse seiners are generally uncommon, samples were taken from landings of longliners based in La Réunion and operating to the south of the island. Fish larger than 120 cm were obtained from additional sampling conducted from the end of 1999 to mid-2000.

First dorsal spines were collected from fish landed by longliners between September 1998 and November 1999. A total of 140 spines were collected and the fork length of the fish measured.

OTOLITH AND FIRST DORSAL SPINE PREPARATIONS

From the 600 otoliths sampled from purse seiners, a subsample of 145 pairs was selected according to the size of the individuals. The 24 pairs otoliths collected in La Réunion were taken. These 169 otoliths were embedded, cut and prepared according to the method described by Secor et *al.* (1992) and adapted for tunas by Stéquert et *al.* (1996).

Spines were sawn on the fish just above the condyle base, then cross sections approximately 400 to 500 µm thick were prepared in the laboratory using a low-speed "ISOMET" saw. These sections were observed in transmitted light (Figure 2).

Age reading

Otolith microincrements were counted from transverse sections under a light microscope (1000 x) with an MPL 100 x dry objective (Figure 3). As done for yellowfin tuna (Stéquert *et al*, 1996), counts were made along the ventral part of the sagitta (*see D in Fig.3*). Only 154 preparations were readable from the 169 selected because some were broken during preparation (bad grinding or etching) or presented some malformations. Daily periodicity of increment deposition on the otolith of bigeye tuna was demonstrated by Hallier *et al.* (in preparation) by injection of oxytetracycline. Age in days was therefore estimated by counting increments. Three counts were made at different times by the same reader without information concerning the size of fish or knowledge of the previous counts for each of these 154 fish. The fork length distribution of the 154 fish that had readable otoliths is shown in Figure 4.

Growth marks were visible on dorsal spines under a binocular microscope, but we found that counting was very subjective, depending on whether or not a mark was taken into account. Several studies point the fact that some spines are impossible to interpret and that different readers have different interpretation. Furthermore, even when two readers reach agreement, the interpretation is still questionable. An other difficulty is caused by the size of the vascularised core of the spines resulting from the destruction of bone tissue. In this study, no counting of the rings was made and we chose to measure, for each spine, the total surface of the section and the surface included in the translucent rings (S_{tot}, S_1, S_2, …S_n.). Surfaces were measured using an Image Analysis System (*TNPC* software). Only clear and obvious rings were taken into account and questionable ones were ignored. All measures of surface included within growth rings, were pooled and a frequency distribution was made. A relation between the total surface of the section and the fork length was also established.

RESULTS

Relationships between otolith , dorsal spine and body length (fork-length)

Inferring growth from changes in otolith or dorsal spine requires the assumption that growth of the calcified structure of interest is proportional to body growth.

We examined the relationship between fork length and two otolith dimensions: length (anterior-posterior axis) and external part of the transverse section (from the nucleus to the ventral edge). We established that the length of the otolith (LOT) and the external part of the transverse section (D, in mm) are directly proportional to the fork length (FL in cm) of the fish, evidence that is consistent with the assumption described above. These relations are shown in Figure 5.

LOT(cm) = 0.007 FL(cm) + 0.5212, with $r^2 = 0.917$

D (cm) = 0.0016 FL(cm) + 0.085, with $r^2 = 0.907$.

The relationship between the surface of the section and the fork length for the first dorsal spine is presented in Figure 6. Back calculation of the length (mm) of the fish for a measured surface (mm^2) of the ring is given by the equation:

FL =185.33*Stot 0.4542 with $r^2 = 0.9753$

AGE AND GROWTH

Otoliths

The standard deviation and coefficient of variation of Chang (1982) of the three counts on the otoliths were calculated. The mean coefficient of variation (CV) was 1.63 % , which indicates that the age estimates is precise and reliable. Results of the counts and CV are presented in Figure 7.

The estimates of the von Bertalanffy growth parameters were calculated using an iterative method, generated by a non-linear regression analysis. The equation of the VB growth curve estimated in this study is:

$FL = 304.9\ (1 - e^{-0.000397\,(t\ +167.15)})$ with FL in cm and *t* in days.

With this model, we observed a growth rate of 3.6 cm/month for young fish (from 6 months to 1 year old and 39 cm < FL <58 cm), 2.75 cm/month for fish between 1 and 2 years old (58 < FL <91 cm) and 2.4 cm/month for fish from 2 to 3 years old (91 to 120 cm).

As the sex was not determined for the largest fish coming from the longliners, it was not possible to see if some difference of growth exists between males and females.

First dorsal spine

The distribution frequency of the surfaces included within translucent growth rings is given by Figure 8. Modes appear to occur at 14 mm^2, 29 mm^2 and 42 mm^2, corresponding respectively to 61, 86, 101 cm fork length.

In their study of the growth of the bigeye tuna in the north western Pacific Ocean, Sun *et al*. (1999) have shown that the narrow translucent rings of the dorsal spines were formed annually during the spawning season and correspond to the slow growth period. According to this observation, we consider that each mode observed on the tuna we studied correspond to a year of age. Our results give individuals which reached 61 cm fork length at 1 year, 86 cm at 2 years and 101 cm at 3 years.

DISCUSSION

The various methods used by authors to determine age and growth of bigeye tuna from the tropical areas of the three oceans gave rather different results (Figure 9).

The study of growth using size-frequency analysis (FL) has long been the most frequently used method. Within the framework of population studies, follow-up of a stock requires the measurement of a large number of individuals from the landings to know the sizes captured. The logical continuation was to use all these measurements to determine the growth parameters of the species studied. If the results for bigeye tuna obtained in the eastern Atlantic by Marcille *et al.* (1978), Weber (1980) and Pereira[3] (1984) are completely comparable between them, they are significantly different from those obtained previously in the eastern Pacific by Kume and Joseph (1966). Thus, for example, for individuals 3 to 4 years old, the differences in size are on average 20 to 30 cm. In the Indian Ocean, Marcille and Stéquert (1976) obtained, for young individuals only (LF<70 cm), a growth rate similar to those of the Atlantic for the same sizes.

Previously, for bigeye tuna from the Pacific Ocean, Yukinawa and Yabuta (1963) used scales to propose their growth model.

Thereafter, the spine of the first dorsal fin was preferred. The use of dorsal spine to estimate age has the huge advantage of easy sampling, treatment and storage. However, this hard structure presents a major disadvantage which is the vascularisation of the core, involving sometimes the loss of the first growth mark. In spite of this problem, Gaikov *et al.* (1980), Draganik and Pelczarski (1984) and Delgado and Santana (1986) were able to determine the growth parameters of Atlantic bigeye tuna and, more recently, Sun (1999) calculated those from the Pacific. As in the case of length-frequency analysis, the results obtained using the first dorsal spine present significant differences. For the Atlantic, for example, we observe 10 to 15 cm of difference for one year old individuals, and more than 30 cm for 6 year old fish.

In our study, before using our surface distribution method, several trials were made by counting the rings, but we found that the results depended too heavily on the interpretation of the reader. This difficulty has been pointed out in several studies using tuna dorsal fin spines for studying growth (Antoine *et al*., 1983; Cayré and Diouf, 1983). The method used here avoid this bias. Our results are comparable with those of the Atlantic Ocean for young fish (1 and 2 years) but older fish have a lower growth rate (2.1 cm/month between 1 and 2 years, decreasing to 1.25 cm/month between 2 and 3 years).

Cayré and Diouf (1984) for Atlantic Ocean and Hampton *et al.* (1998) for the Pacific Ocean, studied the growth of bigeye tuna by using tagging experiments. Theirs results were highly different from each other (more than 30 cm for fish up to 4 years old) (Figure 9).

The growth curve for bigeye tuna from the western Indian Ocean obtained from daily growth increments observed on the otoliths is fully comparable with that obtained in the Pacific Ocean by Lehodey *et al*. (1999).

From all the studies of growth undertaken on bigeye tuna, those carried out with otoliths definitely give the highest growth rates. As the daily rhythm of deposition of these microstructures was validated for bigeye tuna (Hallier *et al*, in preparation*)* we can consider this method as being the

[3] in Pallares *et al.* 1998

most precise. However, it is necessary to remain careful for the general shape of our growth curve which presents a strong slope up to 4 years. This could indicate that there is an underestimate of the number of microstructures, the distance between 2 increments being less than the resolving power of the optical microscope. That does not seem very probable because 1) bigeye tuna otoliths of look like those of yellowfin with identical microstructure sizes and 2) Stéquert *et al.*, (1996), using a scanning electron microscope, demonstrated that the optical microscope (1000 x) was sufficient to observe and count the increments on the transverse section of otoliths of yellowfin tuna.

Validation (1 increment = 1 day) may be to blame. Our validation for bigeye tuna (Hallier *et al.* in preparation) was carried out only on individuals of small sizes (42 < LF < 86 cm). Probably, like for skipjack (Adam *et al.*, 1995), the increment deposition is daily for the young individuals not having reached their size of first sexual maturity, and not daily for the largest individuals. Such an assumption still requires to be verified.

REFERENCES

ADAM M.S.,B. STÉQUERT AND R.C. ANDERSON, 1995. Irregular microincrement deposition on the otoliths of skipjack tuna (*Katsuwonus pelamis*) from the Maldives. IPTP Collective Vol. 9: 239-244.

ALVES A., P. DE BARROS AND M.R. PINHO, 1997. Age and growth of bigeye tuna *Thunnus obesus*, captured in the Madeira Archipelago. International Commission for the Conservation of Atlantic Tunas (ICCAT). Rec. Doc Sc. 48 (SCRS/97/95): 277-283.

ANTOINE L.M., J.J. MENDOZA AND P.M. CAYRÉ, 1983. Progress of age and growth assesment of Atlantic skipjack tuna, *Euthunnus pelamis*, from dorsal fin spines. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 8: 91-97.

CHANG W.Y.B., 1982. A statistical method for evaluating the reproductibility of age determination. Can. J. Fish. Aquat. Sci. 39 : 1208 – 1210.

CAYRÉ P.M. AND T. DIOUF, 1983. Estimating age and growth of little tunny *Euthynnus alleteratus*, off the coast of Senegal, using dorsal fin spine sections. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 8: 105-110.

DRAGANIK B. AND W. PELCZARSKI, 1984. Growth and age of bigeye and yellowfin tuna in the central Atlantic as per data gathered by R/V Wieczno. International Commission for the Conservation of Atlantic Tunas (ICCAT). Rec. Doc Sc. 20 (SCRS/83/30): 96-103.

GAIKOV V.V., V.N. CHUR, ZHAROV V.L. AND Y.P. FEDOSEEV, 1980. On age and growth of the Atlantic bigeye tuna. International Commission for the Conservation of Atlantic Tunas (ICCAT). Rec. Doc Sc. 9 (SCRS/79/40): 294-302.

HALLIER J-P, B. STÉQUERT, F. CONAND AND F. MÉNARD, (*in preparation*). Age and growth of the bigeye tuna (*Thunnus obesus*) from the eastern Atlantic Ocean, based on tagging experiments, sagittal otolith microstructures and first dorsal spines.

HAMPTON J., K.A. BIGELOW AND M. LABELLE, 1998. A summary of current information on the biology, fisheries and stock assessment of bigeye tuna (*Thunnus obesus*) in the Pacific Ocean with recommendations for data requirements and future research. New Caledonia, Nouméa. SPC, Technical Report 36: 1-46.

KUME S. AND J. JOSEPH, 1966. Size composition, growth and sexual maturity of bigeye tuna, *Thunnus obesus* (Lowe), from the Japanese longline fishery in the eastern Pacific Ocean. Bull. IATTC, 11 (2): 45 –99.

LEHODEY P., J. HAMPTON AND B. LEROY, 1999. Preliminary results on age and growth of bigeye tuna (*Thunnus obesus*) from the western and central Pacific ocean as indicated by daily growth increments and tagging data. Standing Committee on Tuna and Billfish. 16-23 juin 1999; Tahiti: BET-2: 17 pp.

MARCILLE J. AND B. STEQUERT, 1976. Croissance des jeunes albacores (*Thunnus albacares*) et patudos (*Thunnus obesus*) de la côte nord-ouest de Madagascar. Cah. ORSTOM, sér. Océanogr., XIV (2) : 153 – 162.

MARCILLE J., C. CHAMPAGNAT AND N. ARMADA, 1978. Croissance du patudo (*Thunnus obesus*) de l'océan Atlantique tropical. Doc. Scient. Centre Rech. Océanogr. Abidjan. Vol IX, n°1, pp 73-81.

MIYABE N., 1984. On the growth of yellowfin tuna and bigeye tuna estimated from the tagging results. International Commission for the Conservation of Atlantic Tunas (ICCAT), Madrid. Rec. Doc Sc. 20 (SCRS/83/45): 117-122.

PALLARES P., J. PEREIRA, N. MIYABE AND A. FONTENEAU, 1998. Atlantic bigeye tuna: overview of present knowledge (November 1996). In Deriso, R. B., Bayliff,W.H. and Webb, N.J. *Proceedings of the first world meeting on bigeye tuna.* Inter-American Tropical Tuna Commission, La Jolla, California. Spec. Report 9: 20-80.

PELCZARSKI W., 1992. Differences in age structure and growth rate of yellowfin and bigeye tuna caught with longlines in the central Atlantic. ICES; Pelagic Comm. C.M. 1992/H.12: 15 pp.

SECOR D.H., J.M. DEAN AND E.H. LABAN, 1992. Otolith removal and preparation for microstructural examination. In D.K. Stevenson and S.E. Campana (eds.), Otolith microstructure examination and analysis, p 19-57. Can. Spec. Publ. Fish. Aquat. Sci. 117.

SUN C.L., C.L. WANG AND S.Z YEH, 1999. Age and growth of the bigeye tuna *Thunnus obesus* in the western Pacific Ocean. Standing Committee on Tuna and Billfish. 16-23 juin 1999; Tahiti: BET-3: 13 pp.

STÉQUERT B., J. PANFILI AND J.M. DEAN, 1996. Age and growth of yellowfin tuna *Thunnus albacares*, from the western Indian Ocean, based in otolith microstructure. Fish. Bull. 94:124-134.

WEBER E. 1990. An analysis of Atlantic bigeye tuna (*Thunnus obesus*) growth. International Commission for the Conservation of Atlantic Tunas (ICCAT), Madrid. Rec. Doc Sc. 9 (SCRS/79/77): 303-307.

YUKINAWA M. AND Y. YABUTA, 1963. Age and growth of bigeye tuna, *Parathunnus mebachi* (Kishinouye). Rep. Nankai Reg. Fish. Res. Lab., n° 19: 103 – 120.

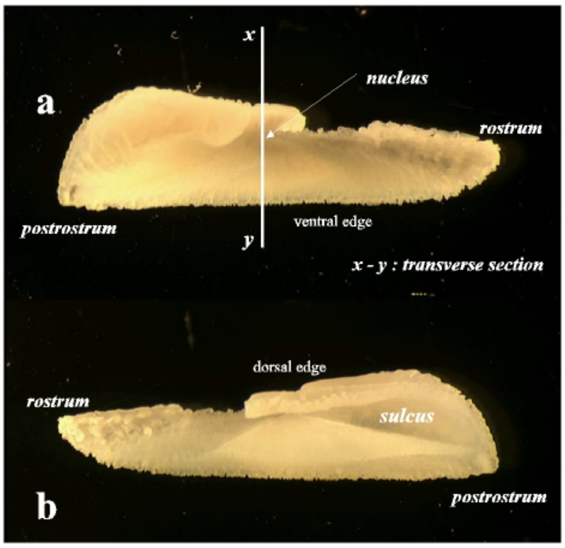

Figure 1. Right sagitta of bigeye tuna, Thunnus obesus.(a: external view; b: internal view; x-y: axis of section).

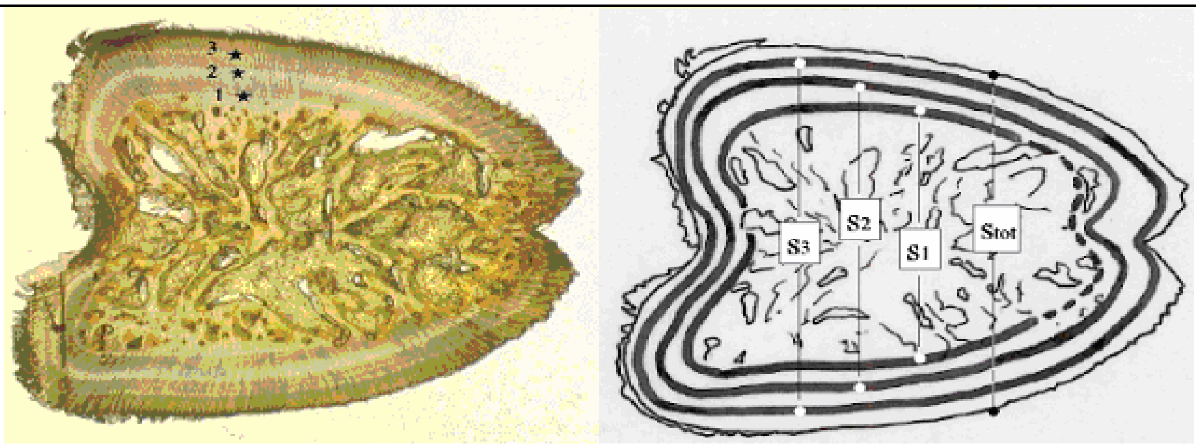

Figure 2. Section of first dorsal spine of bigeye tuna, Thunnus obesus.

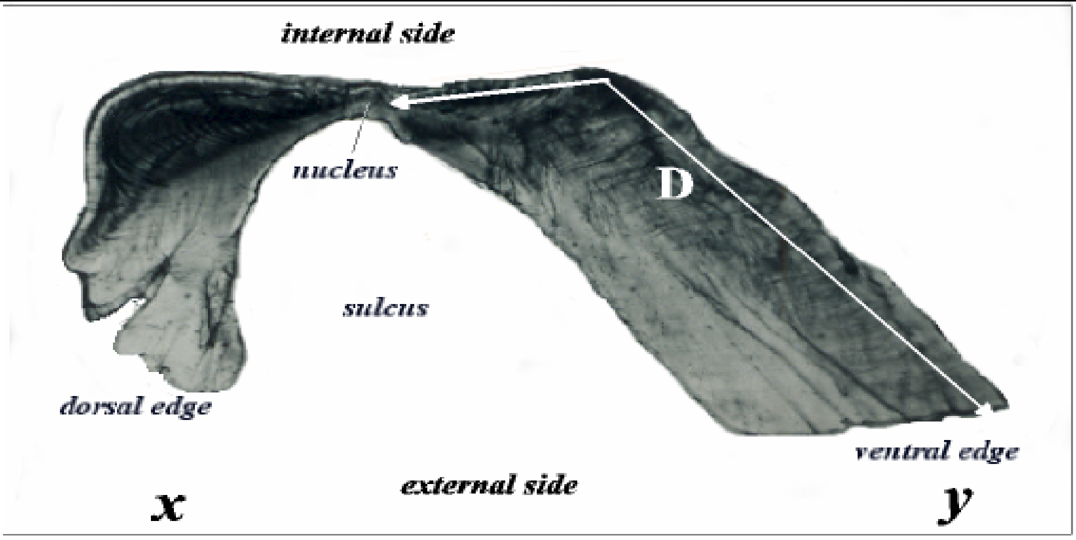

Figure 3. Transverse section x-y of the right sagitta of bigeye tuna. (D corresponds to the path where readings were made).

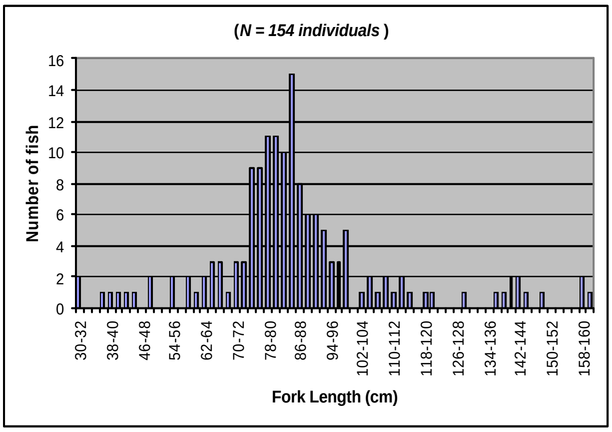

Figure 4. Length frequencies of bigeye tuna, Thunnus obesus, for which otolith transverse sections were readable.

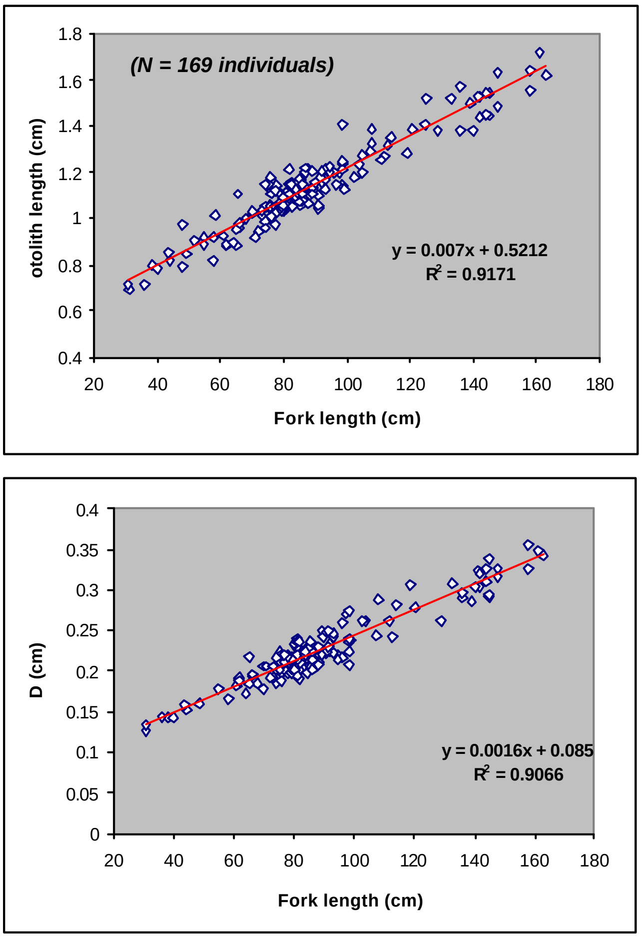

Figure 5. Relations between otolith sizes and fork length. a) otolith length measured along anterior-posterior axis, b) D (mm) as ventral part on tranverse section.

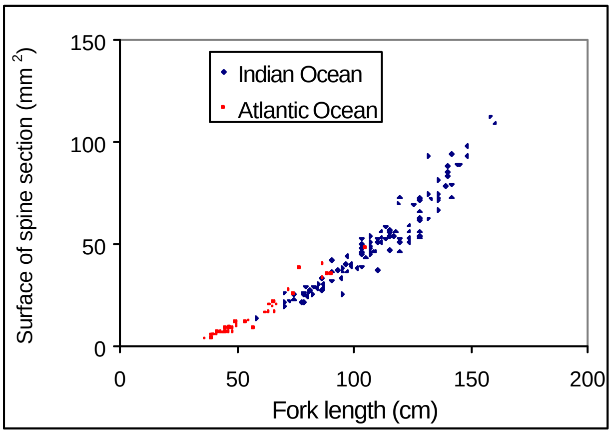

Figure 6. Relation between the surface of spine section and fork length for bigeye tuna, Thunnus obesus.

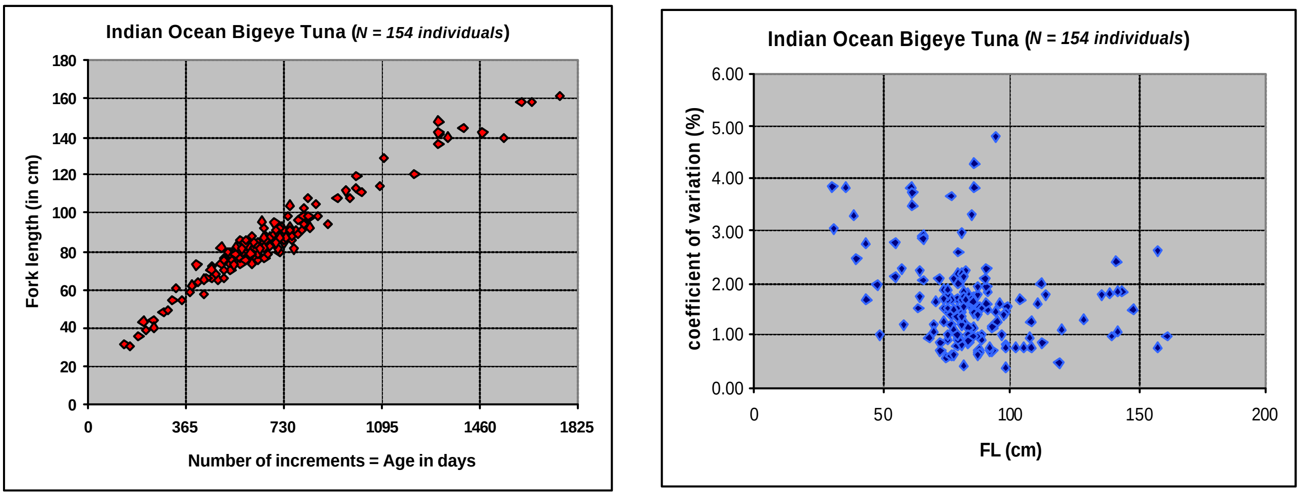

Figure 7. – a) Estimated age vs fork length of bigeye tuna, Thunnus obesus; – b) distribution of the coefficient of variation of the counts in relation with the size of fish.

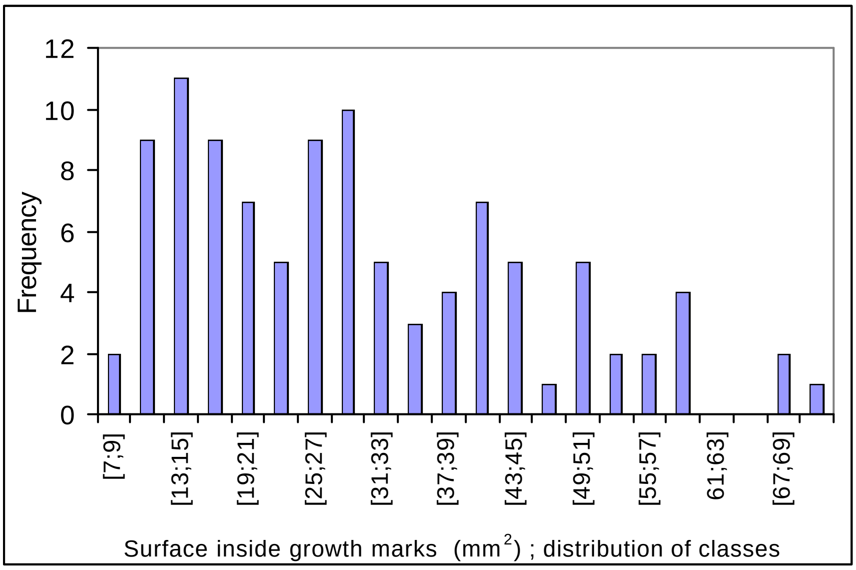

Figure 8. Frequency distribution of the surfaces included into growth marks observed on sections of dorsal spine.

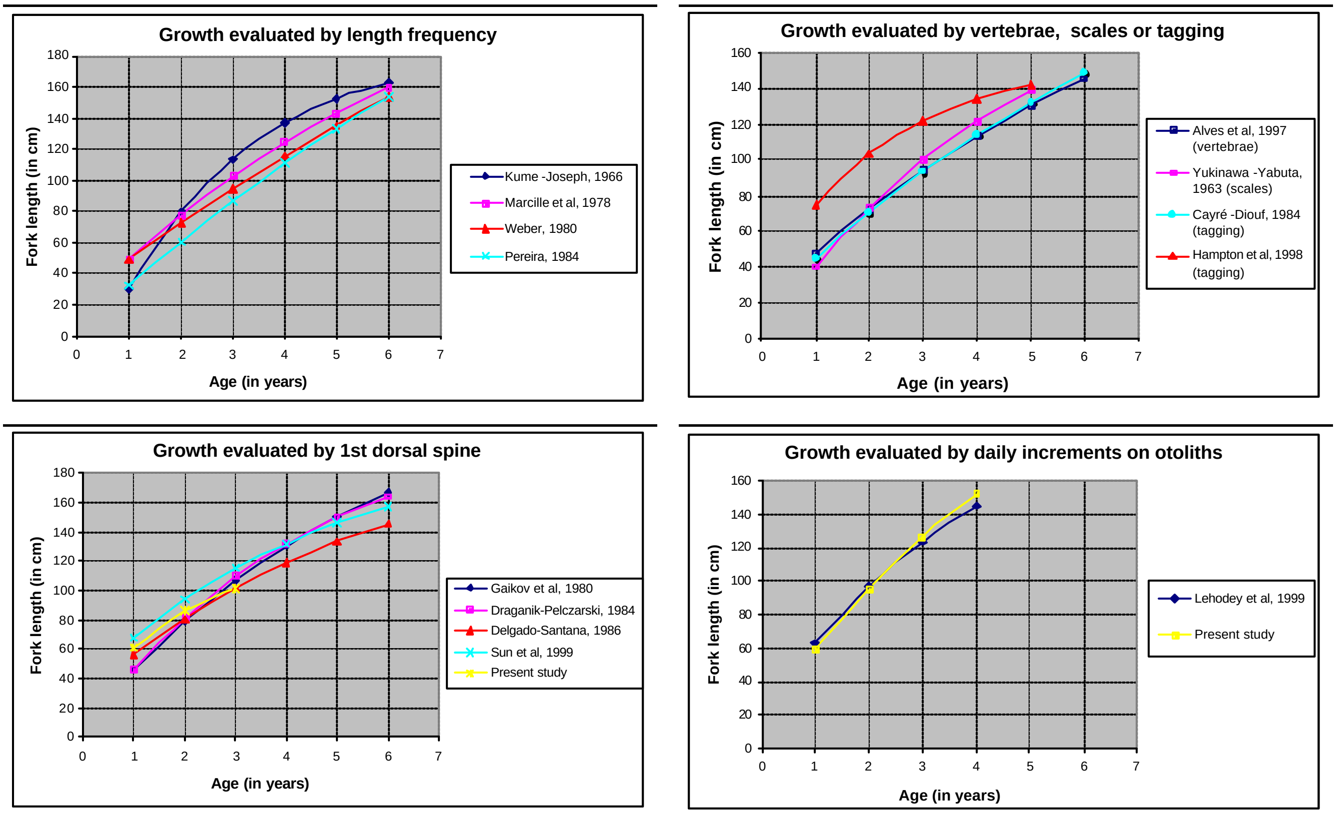

Figure 9. Comparison of growth curves for bigeye tuna, Thunnus obesus, evaluated by different methods of investigation in the 3 tropical oceans