

STUDIES ON THE AGE AND GROWTH OF SOUTH ATLANTIC ALBACORE (*THUNNUS ALALUNGA*) SPECIMENS COLLECTED FROM TAIWANESE LONGLINERS

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SUMMARY

A total of 353 first dorsal spines and 159 vertebrae were collected from 353 albacore individuals were sampled by the Taiwanese longliners in the south Atlantic. A ring-reading method on the cross section of the spine, accompanied by a linear model to estimate the number of obscured rings in the central vascularized zone, was adopted for the age and growth of the species.

The number of obscured rings was estimated by the following formula: $-2.5363 + 0.3198 X$ the radius (in 0.1 mm) of the first readable ring on a spine. The parameters of von Bertalanffy's growth equation, by using the non-linear regression method, thus obtained are as follows: $L_{max} = 142.28$ cm; $k = 0.1454$ per year; and $t_0 = -0.6740$ year.

RESUME

En tout, 353 premières épines dorsales et 159 vertèbres ont été prélevées sur 353 germons échantillonnés par les palangriers taiwanais dans l'Atlantique sud. Une méthode de lecture de l'anneau sur la coupe transversale de l'épine, accompagnée d'un modèle linéaire pour estimer le nombre d'anneaux sombres dans la zone centrale vascularisée, a été adoptée pour l'étude de l'âge et la croissance de cette espèce.

Le nombre d'anneaux sombres a été estimé par la formule de -2.5363 plus 0.3198 multiplié par le rayon (en 0,1 mm) du premier anneau lisible de l'épine. Les paramètres de l'équation de croissance de von Bertalanffy, en utilisant la méthode de régression non linéaire ainsi obtenus sont les suivants: L_{max} égale à 142,28 cm; k égale à 0,1454 par an; et t_0 égale à -0.6740 par an.

RESUMEN

Se recogió un total de 353 radios de la primera aleta dorsal y 159 vértebras de 353 ejemplares de atún blanco muestreados en los palangreros taiwaneses en el Atlántico sur. En el estudio sobre la edad y crecimiento de la especie, se adoptó un método de lectura de anillos en el corte del radio, para estimar el número de anillos oscurecidos en la zona vascularizada central.

El número de anillos oscurecidos se estimó con la siguiente fórmula: -2.5363 mas 0.3198 multiplicado por el radio (en 0.1mm) del primer anillo detectable en un radio. Aplicando el método de regresión no lineal, se obtienen los siguientes parámetros de la ecuación de crecimiento de Von Bertalanffy: $L_{max} = a$ 142.28 cm; $k = 0.1454$ por año y $t_0 = 0.6740$ por año.

INTRODUCTION

Albacore (*Thunnus alalunga*) is one of the most economically important and abundant fisheries resources in the Atlantic Ocean. The southern Atlantic albacore stock, widely distributed in the areas between 50 degree S and 5 degree N latitude, has been fished as a target species by (1) Japanese longliners from the early 1950s to mid 1960s; and (2) Taiwanese longliners since the late 1960s. Although the development of South African surface fisheries of catching mainly small sized albacore in recent years has been remarkable, the catch in weight of South Atlantic albacore by the Taiwanese longline fleet still occupies the major part of the total albacore harvested in the South Atlantic.

As one of the major nations utilizing the resource, it is our inevitable desire to acknowledge the status of the stock. Surplus Models, based on fitting historic catch and effort data trends, have been adopted for many years (Yang and Sun 1984; Yeh and Tsou 1990) to serve this purpose. Yet, it has been also advised for some years that the age structured models are worthwhile to pursue. Unfortunately, age and growth study on the South Atlantic albacore is still missing mainly because collection of age characters from the high valued, big sized albacore specimens from the distant water fleet of longliners is very expensive and difficult. The lack of genuine growth parameters for the stock may provide greater uncertainty in the age structured stock's status.

The main purpose of this study is to investigate the age and growth parameters for South Atlantic albacore by using a dorsal spine age character accompanied by a justification linear model to adjust the ring counts in the vascularized core portion. The results of this study will provide a basis of growth parameters for analysis of the age structured stock.

MATERIALS AND METHODS

A total of 353 spines (the 1st dorsal spine) and 159 caudal vertebrae (the 38th vertebra) were collected from 353 albacore specimens which were randomly sampled by five Taiwanese longliners from October/1990 to March/1991 in the northwestern part of the South Atlantic Ocean (Figure 1).

In order to prepare the caudal vertebra for ring-reading, we (1) boiled them in tap water for 3-5 minutes; (2) brushed off the adhesive mussels and connective tissues; (3) dipped them in 3% KOH for 12-15 hours; (4) washed and dipped them in tap water for few minutes and (5) cut them into half through apex by using round saw.

In order to prepare the spine for ring-reading, we (1) boiled them in tap water for about 1-2 minutes; (2) brushed off the adhesive membrane; (3) dipped them in the 3% KOH for 1-2 hours; (3) washed and dipped them in tap water for few minutes; and (5) sliced a 0.5-0.8 mm thin layer through the basal portion of the spine by using low speed saw.

Recognition of rings on the vertebra was based on the criteria of those rings which appeared as ridges on the centrum

surface (Partlo 1955; Utsu and Uchida 1958), and recognition of rings on the spine was based on the following criteria: (1) double-ring mark (González-Garcés and Fariña-Perez 1983); (2) triple-ring mark; (3) single thick ring mark; and (4) single thin ring mark, as shown in Plate 1.

The ring radius on the posterior-ventral axis of the vertebra was measured from the focus to the outer margin of each readable ring mark (Figure 2). The diameter of a spine (D) was measured by the horizontal distance between the outside margin above the posterior notch where the least curvature of banding occurred (Compeán-Jimenez and Bard 1983), as shown in Figure 3. The i -th ring-radius (R_i) of a spine was then determined by the diameter of the i -th growth band (d_i) minus the radius of the spine ($D/2$). Since the central portion of the spines will become vascularized when fish gets older, the earlier rings will inevitably become obscured. The radius of the first readable growth band, R_1 , will become an indicator of the size of the central vascularized area. The variable R_1 will thus be used in this study to justify the obscured rings in the central portion.

The ring-radius of both vertebra and spine cross section were measured under Nikon stereomicroscope at 10 X magnification. Two independent measurements of ring radius were made on each age character specimen. The mean value of the two measurements are adopted if the number of ring count in these two readings are identical; otherwise a third measurement shall be made and the two which are identical in number of ring counts are adopted. The age character shall be discarded if three readings in number of rings are all different with one another. There are 344 readable spines and 148 readable vertebrae were used in this study (Tab.1).

RESULTS

1. Validity of using vertebra as an age character

Figure 4 shows the frequency distribution of fork length by ring group of the species. It clearly indicates that the ring count increases as the fish grow larger. Figure 5 shows the relationship between ring radius and centrum radius for 30 specimens with 7 rings. The good linearity of ring-radius vs centrum-radius implies that the relative positions of the ring radius in different specimens with same number of rings are compatible. Figure 6 shows the frequency distribution of ring radius by ring groups measured in this study. The evidence of segregation of mode of each ring group is clearly shown. Based on these evidences, the authors believe that the vertebra of the species is a reliable and effective age character. However, the vertebra of albacore are very difficult to get mainly because of its high economic value. Any obvious damage to the fish body will severely hurts its market value. It is more feasible to acquire the first dorsal spine than to get the vertebra to use as age character.

2. Justification of ring counts from the spine age character

Of the 344 randomly sampled albacore specimens, 148 specimens were collected with both the spine and the caudal

vertebra age characters. It is reasonable to believe that the number of rings formed by the two age characters of the same fish should be the same. Thus, the difference in number of ring counts between the two age characters can be assumed to be the number of rings which disappeared in the vascularized area, the area circled by the first readable growth band 'R1' of the spine.

In this context, a linear regressive model is proposed to estimate the disappeared number of ring counts in vascularized core of spine by using (1) the number of readable ring counts and (2) the radius of the first readable growth band ($R1=d1-D/2$) obtained from the spine, and (3) the number of ring counts from vertebra. The model is as follows:

$$DC = Vno - Sno = a + b * R1 \dots\dots\dots(1)$$

where DC : number of ring counts disappeared in vascularized core of spine.

Vno: number of ring counts from vertebra.

Sno: number of ring counts from spine.

R1 : radius (in 0.1 mm) of the 1st readable growth band in spine.

The obtained coefficients for equation (1), based on the 148 specimen data set, is as follows:

$$DC = -2.5363 + 0.3198 * R1$$

Therefore, a justified (assuming no vascularization) number of ring counts of a spine, Sno' , will be:

$$Sno' = Sno + DC = Sno + (-2.5363 + 0.3198 * R1)$$

In order to demonstrate the results obtained from such a justification, plots of Vno versus Sno (before justification) and Sno' (after justification) are shown in Figure 7. The agreement between Vno and Sno' is 85.6% for identical ring counts and 14.4% for a ± 1 ring count.

3. Growth parameter estimation by non-linear regression methods

Non-linear regression techniques (SAS package) were used to estimate the parameters of a von Bertalanffy growth equation. All justified ring counts of the spine age character and fork length data set were used in this study. It is also believed that one ring group is formed per year (Chi and Yang 1973; González-Garcés and Fariña-Perez 1983).

The results are: $L_{max} = 142.28$ cm; $k = 0.1454$ per year; and $t_0 = -0.6740$ year. A plot of the obtained growth equation is shown in Figure 8.

DISCUSSION

Two readings, separated by one month interval, for the same group of specimens have been carried out in this study. The results showed that (1) 271 (77%) out of 353 specimens are identical in number of ring count; and (2) only 9 (2.55%) specimens showed their differences between the two readings are greater than ± 1 .

Albacore is a highly valued and large fish species; therefore, it is costly to collect age characters from their bodies. As compared to the vertebra age character, scales and dorsal spines are much more convenient and inexpensive age characters to collect. González-Garcés and Fariña-Perez (1983) indicated, however, that spines than scales have a higher percentage can be read, and growth characteristics of spines are stable throughout the entire life cycle, while scales can be regenerated.

The disadvantage of using the spine is the vascularization in the central portion of the spine and the tendency of the area to extend proportionally with the age of fish. Both Cayre and Dioufe (1983) and Compeán-Jimenez and Bard (1983) used the average location of rings which appeared in spine of small albacore to estimate the number of rings which disappeared in the central vascularized zonation of the larger ones. Since the specimens used in this study all were collected from Taiwanese longliners, which primarily catch larger adult albacores, it is very difficult for us to get smaller fish for such a manipulation.

Several studies (Yang 1970; Beardsley 1971; Bard 1974; González-Garcés and Fariña-Perez 1983; Cayre and Dioufe 1983; Compeán-Jimenez and Bard 1983) have been carried out on the age and growth of albacore resource in the North Atlantic. Parameters of von Bertalanffy's growth equation for Atlantic albacore resources obtained by four studies are shown in Table 2. The contrasts in growth equation parameters between the North and the South Atlantic albacore stocks appears not significantly remarkable, although the L_{max} and k values obtained in present study appeared a little higher than those from the North Atlantic stock.

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LITERATURE CITED

- Beardsley, G.L. 1971.
Contribution to the population dynamics of Atlantic albacore with comments on potential yields. Fish. Bull., 69:845-857.
- Cayre, P.M. and T. Diouf. 1983.
Estimating age and growth of little tunny, Euthynnus alletteratus, off the coast of Senegal, using dorsal fin spine sections. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 8:105-110.
- Chi, K.S. and R.T. Yang. 1973.
Age and growth of skipjack tuna in the waters around the southern part of Taiwan. Acta Oceanographica Taiwanica. 3:199-222.
- Compeán-Jimenez, G. and F.X. Bard. 1983.
Growth increments on dorsal spines of eastern Atlantic bluefin tuna, Thunnus thynnus, and their possible relation to migration pattern. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 8:77-86.
- González-Garcés, A. and A.C. Fariña-Perez. 1983.
Determining age of young albacore, Thunnus alalunga, using dorsal spine. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 8:117-122.
- Otsu, T. and R.N. Uchida. 1958.
Study of age determination by hard parts of albacore from central North Pacific and Hawaiian waters. Fish Bull. 150:353-363.
- Partlo, J.M. 1955.
Distribution, age and growth of eastern Pacific albacore (Thunnus alalunga). J. Fish. Res. Bd. Can. 12(1):35-60.
- Yang, R.T. 1970.
Studies of age and growth of Atlantic and Pacific albacore and a critical review on the stock structure. China Fish. Monthly. 213:3-16.
- Yang, R.T. and C.L. Sun. 1984.
Stock assessment of South Atlantic Albacore by production model analysis, 1967-1982. Acta Oceanographica Taiwanica. 15: 130-140.
- Yeh, S.Y. and T.S. Tsou. 1990.
Assessment of the South Atlantic Albacore resource by using surplus production models, 1967-1988. ICCAT Scientific Paper, Vol. 34:166-170.

Table 1. Length distribution by age character of monthly sampled albacore (Thunnus alalunga), from the South Atlantic Ocean.

a) vertebra

FORK LENGTH	MONTH						TOTAL
	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	
81 - 85			1	1			2
86 - 90				3			3
91 - 95	1	2	3	15			21
96 - 100	3	8	12	25			48
101 - 105	8	6	10	19			43
106 - 110	7		9	9			25
111 - 115		1	1	2			4
116 - 120				2			2
TOTAL	19	17	36	76			148

b) spine

FORK LENGTH	MONTH						TOTAL
	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	
51 - 55			1				1
56 - 60			6				6
61 - 65			2				2
66 - 70							0
71 - 75			2	1			3
76 - 80			1	3			4
81 - 85			11	8			19
86 - 90			4	13			17
91 - 95	1	2	5	24			32
96 - 100	2	8	14	22	1		47
101 - 105	10	9	13	20	2		54
106 - 110	10	8	11	22	12	5	68
111 - 115	6	12	11	8	3	2	42
116 - 120	3	2	5	12	16	8	46
121 - 125		2					2
126 - 130					1		1
TOTAL	32	43	86	133	35	15	344

Table 2. The von Bertalanffy growth parameters of present study compared with North Atlantic albacore.

Region	Authors	Method	Age	Lmax	k	t ₀
North Atlantic Ocean	González-Garcés & Fariña-Perez (1983)	Spine	1- 7	140.08	0.129	-1.57
	Beardsley (1971)	Size freq.	1-10	140	0.141	-1.63
	Bard (1974)	Size freq. + Scale	1-13	134.4	0.183	-0.35
South Atlantic Ocean	Present study	Spine	2-13	142.28	0.1454	-0.674

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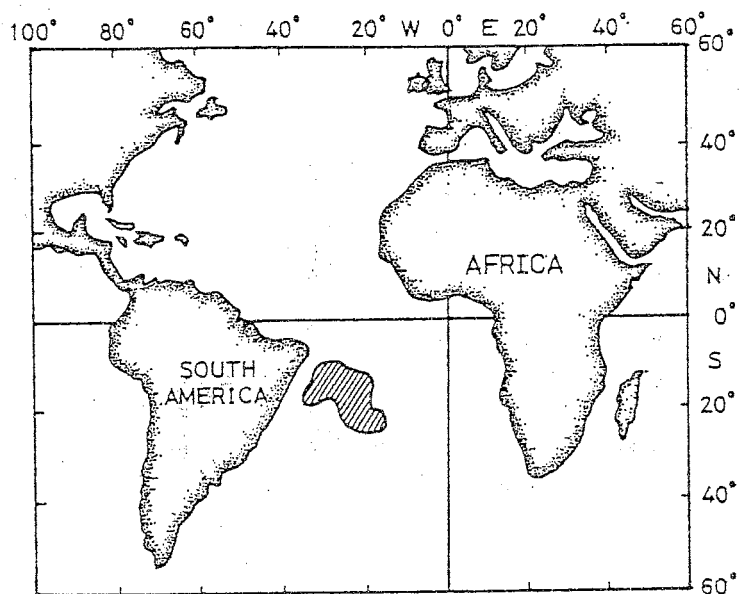


Fig. 1. Shaded area showing the sampling area of albacore (*Thunnus alalunga*) in the South Atlantic Ocean.

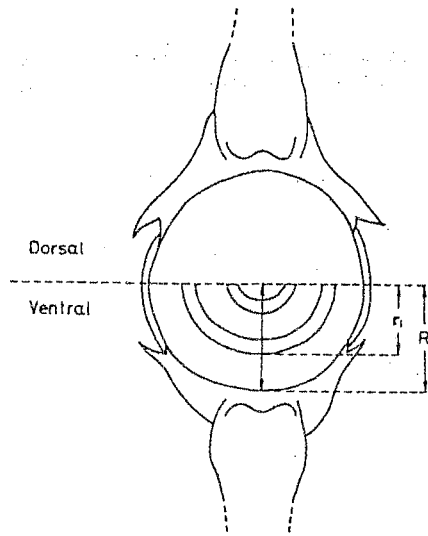


Fig. 2. The measuring parts of vertebra and centrum radius. (R : Centrum radius; r_i : ring radius)

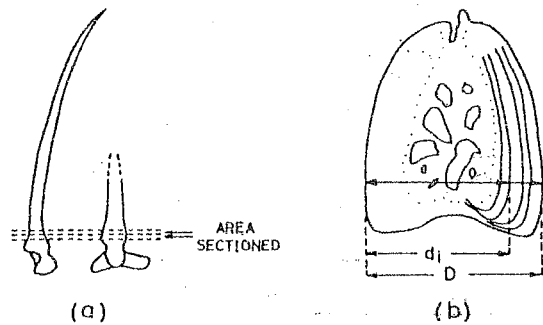


Fig. 3. Position of section removed from the first dorsal spine (a), and a cross section of this spine showing areas of zonation and measurements taken (b). (D = diameter of spine; d_i = diameter of growth band)

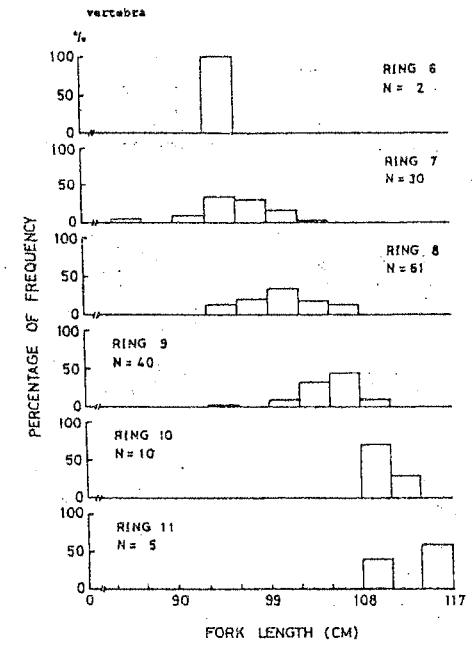


Fig. 4. Frequency distribution of fork length (cm) by ring group of albacore. (N: number of specimen)

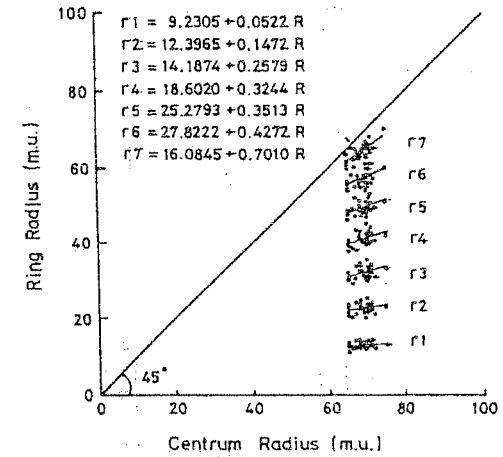


Fig. 5. Example showing the similarity in ring formation of ring groups on centrum taken from 30 caudal vertebrae of albacore specimens (m.u. = 1/10mm)

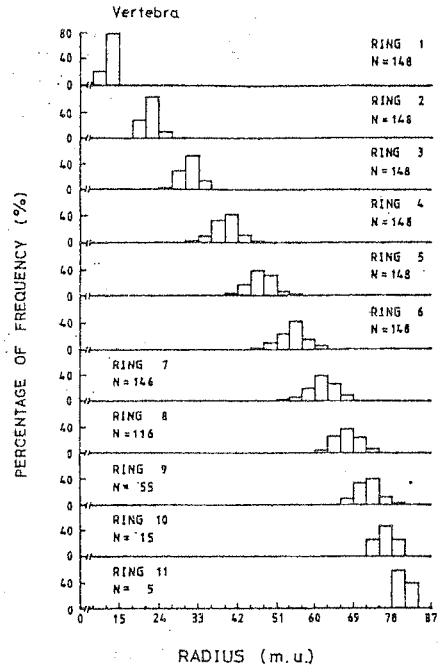


Fig. 6. Frequency distribution of ring radius by ring group of albacore. (N: number of specimen; 1m.u.=1/10mm)

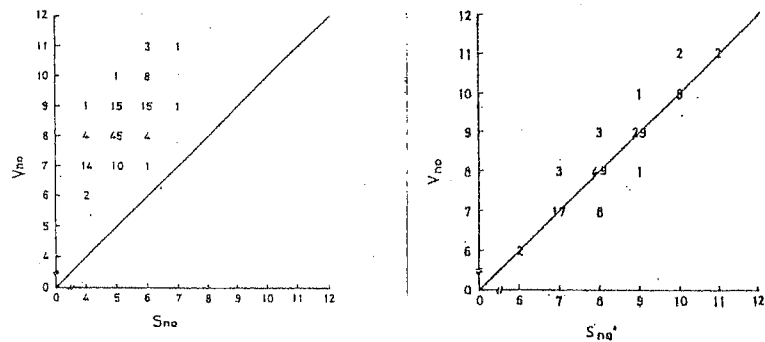


Fig. 7. Plots of Vno (number of ring counts from vertebra) versus Sno (number of ring counts from spine before justification) and Sno' (number of ring counts from spine after justification).

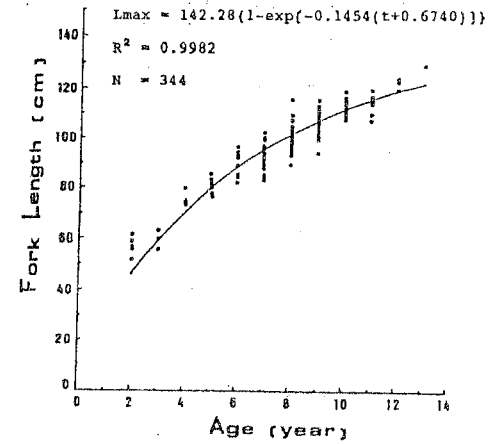


Fig. 8. Von Bertalanffy's growth curve, obtained by nonlinear fitting of fork length versus adjusted spine ring counts by using justification model.

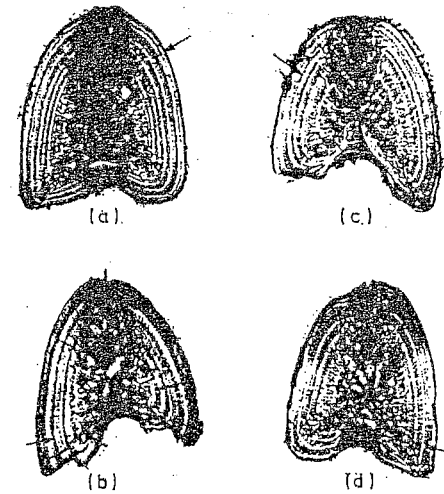


Plate 1. Spine section of albacore, arrow showing the type of ring.
 (a) Double ring.
 (b) Triple ring.
 (c) Single, thick ring.
 (d) Single, thin ring.