AGE AND GROWTH OF ATLANTIC BONITO (*SARDA SARDA*) IN WESTERN MEDITERRANEAN SEA

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SUMMARY

A total of 136 dorsal fin spines from western Mediterranean Atlantic bonito were analyzed from 2003 to 2006 for ageing and growth studies. The length of the aged individuals ranged from 40 to 61 cm. Fish ages ranged 1 to 3 years old and the mean lengths by age were calculated for males and females. Growth parameter estimates were calculated from 136 cut spine sections which provided readable growth annuli by sex. The standard von Bertalanffy growth function was used to fit length at- age data.The growth parameters based on standard von Bertalanffy growth function are the following for both sexes: L_∞ (asymptotic length)=62.5 cm, k (growth coefficient)=0.719, t_0 (age at zero length)=-1.21. The relationships between FL and dorsal fin spine diameter were calculated for both sexes. Age-length keys were provided for catch at age calculation application.

RÉSUMÉ

Un total de 136 épines de la nageoire dorsale de bonitous de l'ouest de la Méditerranée ont été analysées de 2003 à 2006 aux fins d'études de détermination de l'âge et de croissance. La taille (longueur à la fourche) des individus dont l'âge avait été déterminé oscillait entre 40 et 61 cm. L'âge des poissons allait de 1 à 3 ans et les tailles moyennes par âge ont été calculées pour les mâles et pour les femelles. Les paramètres de croissance ont été estimés à partir de 136 sections d'épines qui ont fourni des anneaux de croissance lisibles. On a utilisé la fonction de croissance standard de von Bertalanffy pour ajuster les données de longueur par âge. Les paramètres de croissance basés sur la fonction de croissance standard de von Bertalanffy sont les suivants pour les deux sexes : L_∞ (longueur asymptote)=62,5 cm, k (coefficient de croissance)=0,719, t_0 (âge à la taille zéro)=-1,21. Les relations entre FL et le diamètre de l'épine de la nageoire dorsale ont été calculées pour les deux sexes. Des clefs âge-taille ont été fournies pour le calcul de la prise par âge.

RESUMEN

Se analizaron un total de 136 espinas de la primera aleta dorsal de bonito del Mediterráneo occidental muestreadas entre 2003 y 2006 para realizar estudios de edad y crecimiento. Las tallas (longitud a la furca) comprendieron entre los 40 y 61 cm. El rango de edad de los peces analizados estuvo entre 1 y 3 años y se determinaron las tallas medias por edad. Los parámetros de crecimiento se estimaron a partir de 136 secciones de espina que proporcionaron bandas de crecimiento legibles. Se utilizó la función de crecimiento estándar de von Bertalanffy para ajustar los datos de talla por edad. Los parámetros de crecimiento basados en la ecuación estándar de von Bertalanffy son los siguientes: para machos, L_∞ (longitud asintótica)=62.5 cm., k (coeficiente de crecimiento)=0.719, t_0 (edad a la talla cero)=-1.21. Se calcularon las relaciones diámetro de la espina y FL para ambos sexos. Se presentan las claves tallas-edad para el cálculo de capturas por edad.

KEYWORDS

Atlantic bonito, age determination, growth curves, Mediterranean, trap.

1. Introduction

The Atlantic Bonito (Sarda sarda) inhabit temperate and tropical areas of both hemispheres of Atlantic Ocean, Black Sea and Mediterranean. It forms large mixed schools with other tuna species near the surface (Collete and Nauen, 1983; Valeiras and Abad, 2007). Several authors have observed that the species spawn in the

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Mediterranean although its spawning areas are better known in the eastern part of Mediterranean and Black Sea (Mayorova and Tkacheva, 1959; Demir, 1963). Small tunas are abundant off Spanish Mediterranean coasts where has been commercially exploited by seasonal artisanal fisheries (Demir, 1963; Sabatés and Recasens, 2001; Oray *et al*., 2003). The species have been caught traditionally by Spanish seasonal coastal fisheries using several fishing gears as traps and other minor fixed gears, purse-seine and hand-line (Yoshida, 1980; Rey *et al*., 1984). In spite of the importance to local economy of these fisheries, the biology of small tuna species is not currently well known. Orsi Relini *et al*. (2005) presented a summary on current knowledge of Atlantic bonito in western and central Mediterranean.

Little is known about bonito migration patterns. The species migrates along the coast large distances as prove by recaptures of tagged fish in the Black Sea and Alboran Sea (Western Mediterranean Sea) (Rey *et al*., 1984). A genetic migration from Atlantic to Alboran and from Aegean to Black Sea was proved by tagging in spring. After spawning season, bonito migrates in opposite route. In western Mediterranean Sea, 32% of recaptured fish were found in Atlantic Ocean. Some studies suggest that the Atlantic bonito is resident in western Mediterranean Sea all over the year and the mature fish migrate from coastal areas to open sea to spawn (Sabatés and Recasens, 2001). In eastern Mediterranean Sea, the species migrate towards the Black Sea at time of spawning (May to July) and from the end of July a reverse migration takes place, although there are a number of exceptions to these migratory movements (Nümann, 1954)

Knowledge of the early life stages in bonito is very scarce. It is assumed that larval period is short. The beginning of the juvenile period has been established arbitrarily as to sizes escaping from plankton nets, around 2 cm (Bard, 1981). During the first life stages bonitos are not caught and juvenile life history is unknown. Inmature fish first appear in fishery from around 15 cm of fork length (Zengin, 2005). The first maturity size has been stated in 38 cm (FL) when the fish is one year old (Rey *et al*., 1984; ICCAT, 2006).

Atlantic bonito age determination and growth have been studied by means of different methodologies: otoliths, vertebrae, spines and size frequency. The maximum reported age is 5 years. Most of the studies are from Mediterranean stocks. There are several studies on growth biology of bonito in the Black Sea (Yoshida, 1980) and Western Mediterranean.

From 2003, sampling effort in a Spanish tuna trap was focused on collect Atlantic bonito samples to improve biological knowledge in western Mediterranean. The aim of this paper is to present first results from the western Mediterranean Sea fisheries from spine analysis and provide age-length keys and parameter estimates of Atlantic bonito growth in the area.

2. Material and methods

2.a Fish sampling

136 specimens were collected from tuna trap of "La Azohía" at Mediterranean coast of Spain during sampling from 2003 to 2006. Sampling was done according to a random stratified design covering the length range of the species in the study area. Size FL (fork length in cm) and sex were recorded from all sampled specimens.

2.b Spine preparation

Methodology for spine analysis was based on Ortiz de Zárate *et al*. (2007). The first spine of the first dorsal fin was collected from each specimen. The spine was preserved in a dry state within a paper envelope and labelled. The spine was cut near to the base coinciding with the bulge in the spine (the part with the greatest diameter) and close to the ridge. Series of spines were encased in a matrix of plastic resin. A cross section of 0.5 mm thick was cut using an ISOMED 5000 Cutter. Two consecutive cuts were made in order to choose the best one when taking the reading. The sections were washed in a 70% ethanol solution. They were later mounted onto labelled holders and embedded in Eukitt highly transparent mounting resin.

2.c Age interpretation

The clearest of the two sections was examined using a profile projector (model: Nikon 4C) with transmitted light at 20x – 40x magnification depending on the size of section. The diameter of each growth band (annulus) was measured and recorded. Spine sections were read twice by one reader and unresolved differences in readings resulted in spine elimination. Alternative pairs of a translucent band and an opaque band were considered to be a

year annuli. When present, multiple annuli and disappearance of the first annulus in older fish were carefully considered to assess the age classes.

2.d Growth parameters

Age length keys were produced for males, females and for the two sexes combined, and their mean lengths at age and standard deviations calculated.

Von Bertalanffy growth curves were fitted to the data applying the standard von Bertalanffy growth function (von Bertalanffy, 1938). Growth parameters were computed for females and males using non-linear least square estimation.

Standard VB model: $L_t = L_\infty (1-e^{-k(t-t_0)})$

where,

L_t is length (FL) at age t;
L_∞ is asymptotic length;
k is the growth coefficient;
t_0 is theoretical age at zero length.

2.e Backcalculation

The relationship between FL and dorsal spine diameter (*S*) was determined by using two procedures:

- Standard linear regression: $FL = a+bS$
- Power function: $FL=aS^b$

3. Results and discussion

A total of 136 sections of first dorsal spines were aged successfully (59 males and 77 females). Other 12 spines were indeterminate sex fish. A summary of samples collected for this work is presented in **Table 1**.

Mean sizes by age for both sexes are presented in **Table 2**. Assigned ages of spine sections were from 1 to 3 years. 77% of fish were 1 year old. Age length key is presented in **Table 3**.

Growth parameter estimates for the standard von Bertalanffy are presented in **Table 4**. Equations results were the following:

Standard VB model for both sexes: $L_t = 62.5(1-e^{-0.719(t+1.21)})$

In **Table 4** are also compiled the parameter estimates from several authors in east Atlantic and Mediterranean waters.

In **Figure 1**, growth curves of observed lengths at age data and von Bertalanffy estimates are plotted. Also growth curves from results of other authors are included. Mean FL at age for present paper and other articles are presented in **Table 5** (Atlantic and eastern Mediterranean Sea).

The obtained relationship between FL and anal fin spine radius were the following **(Figure 2)**:

Linear regression relationship:

Males: FL = 16.857S+15.294, $r^2=0.526$.
Females: FL = 15.83S+16.98, $r^2=0.6705$.
All sexes: FL = 15.979S+16.758, $r^2=0.6442$.

Power function relationship:

Males: $FL = 31.6688S^{0.6173}$, $r^2=0.4913$.
Females: $FL = 31.276S^{0.6368}$, $r^2=0.6486$.
All sexes: $FL = 31.44S^{0.6297}$, $r^2=0.6182$.

Figure 3 presents annual size distributions from 2003 to 2005 (Macías *et al*., 2006). Annual distributions show a bimodal shape. The first and highest modal value was around 42-45 cm, and the second mode was around 55 cm. These modes correspond respectively to 1 and 2 age classes respectively. The largest size was 61 cm (age 4). These data agree with those obtained by Rodriguez-Roda (1966) and Demir (1963).

Von Bertalanffy growth parameters are showed in **Table 4** for different areas. Rey *et al*. (1986) studied otoliths, vertebrae, spines and length frequencies and developed a growth equation based on a large number of specimens from area of Gibraltar Strait. Recently, Santamaria *et al* (2005) presents an estimate of growth rate, based on otolith analysis of juvenile fish from Mediterranean Sea (18-110 days). Growth rates with in this fish size were 5.83 mm per day (range= 4.85-6.81 mm per day) and 4.15 g per day (range= 1.88-6.42 g per day). There is some information from tagging of bonitos. Data from two fish recaptured in the western Mediterranean Sea agreed with growth equation (Rey and Cort, 1978; Rey *et al*., 1986).

In this work, we obtain different results on growth parameters and mean lengths at age of Atlantic bonito in western Mediterranean compared to north Atlantic (Gibraltar Strait, Morocco) and Black and eastern Mediterranean Sea estimates. Results are more similar to Rey *et al*. (1984) and Santamaría *et al*.(1998) although lengths at ages 3 and 4 are smaller. The migratory pattern of the species in western Mediterranean Sea and area of Gibraltar Strait are not well defined, although tagging information suggests a mixing of Mediterranean and Atlantic fish.

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Table 1. Summary of Atlantic bonito from western Mediterranean Sea used in this study (M, males; F, females; I, indeterminate).

	M	F	M+F+I
Number	59	77	136
Size range cm)	41-60	40-61	40-61
Age range (years)	1-3	1-3	1-3

Table 2. Summary statistics of male and female aged Atlantic bonito from the western Mediterranean Sea. FL: furcal length in cm.

Age_Males	n spines	Mean FL	FL range	Std. Error
1	51	43.7	41-52	0.362
2	7	52.4	49-54	0.782
3	1	60.0	60-60	-

Age_Females	n spines	Mean FL	FL range	Std. Error
1	54	43.8	40-50	0.24
2	12	53.5	51-55	0.34
3	11	57.5	55-61	0.72

Age_Males+Females	n spines	Mean FL	FL range	Std. Error
1	105	43.7	40-52	0.214
2	19	53.1	49-55	0.366
3	12	57.7	55-61	0.689

Table 3. Age length key (ALK) of Atlantic bonito from the western Mediterranean Sea.

FL	1	2	3
40	100		
41	100		
42	100		
43	100		
44	100		
45	100		
46	100		
47	100		
48	100		
49	-	100	
50	50	50	
51	50	50	
52	67	33	
53		100	
54		100	
55		40	60
56			100
58			100
60			100
61			100

Table 4. Parameter estimates for the standard von Bertalanffy for Atlantic bonito from several authors and areas.

Growth Parameter			Area	Country	Reference
$L\infty$	k	t_0			
64	0.693	-1.42	Atlantic	Morocco	Dardignac, 1962
103	0.132	-1.8	Black Sea and Eastern Mediterranean	Russian Fed	Zusser, 1954
67.8	0.795		Black Sea and Eastern Mediterranean	Turkey	Tkacheva, 1958
81.5	0.525		Black Sea and Eastern Mediterranean	Turkey	Mayorova and Tkacheva, 1959
64	0.86		Black Sea and Eastern Mediterranean	Turkey	Demir, 1963
95.6	0.237	-1.24	Black Sea and Eastern Mediterranean	Bulgaria	Kutaygil, 1967
80.87	0.352	-1.7	Gibraltar Strait	Spain	Rey et al, 1986
80.6	0.36	-1.37	Mediterranean: Ionian Sea	Italy	Santamaría et al., 1998
62.5	0.719	-1.21	West Mediterranean	Spain	Valeiras et al, 2007

Table 5. Estimated size at age for Atlantic bonito from studies in the Atlantic and Mediterranean.

Age BON	Postel, 1955	Nümann, 1955	Rodríguez-Roda, 1966	Rodríguez-Roda, 1981	Rey et al., 1984	Santamaría et al., 1998	This paper Observed	This paper vonBertalanffy
	Senegal	Black Sea	Gibraltar	Gibraltar	Gibraltar	Central Mediterranean	West Mediterranean	West Mediterranean
0	<45				37.03	34.8		
1	45-60	38-41	43.48	42.59	51.71	50.9	43.7	49.8
2	45-60	53-57	51.46	50.51	57.04	57.5	53.1	56.3
3	>60	60-64	62	60.5	63.15	64.8	57.7	59.5
4				64	71.00	70.4		61.0

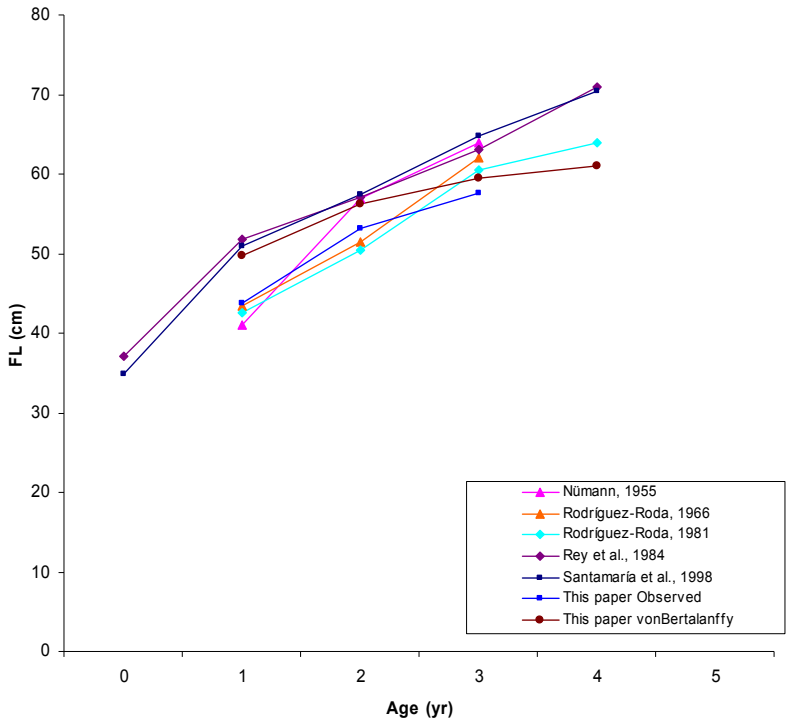

Figure 1. Growth curves for this paper (observed and von Bertalanffy model) and other authors.

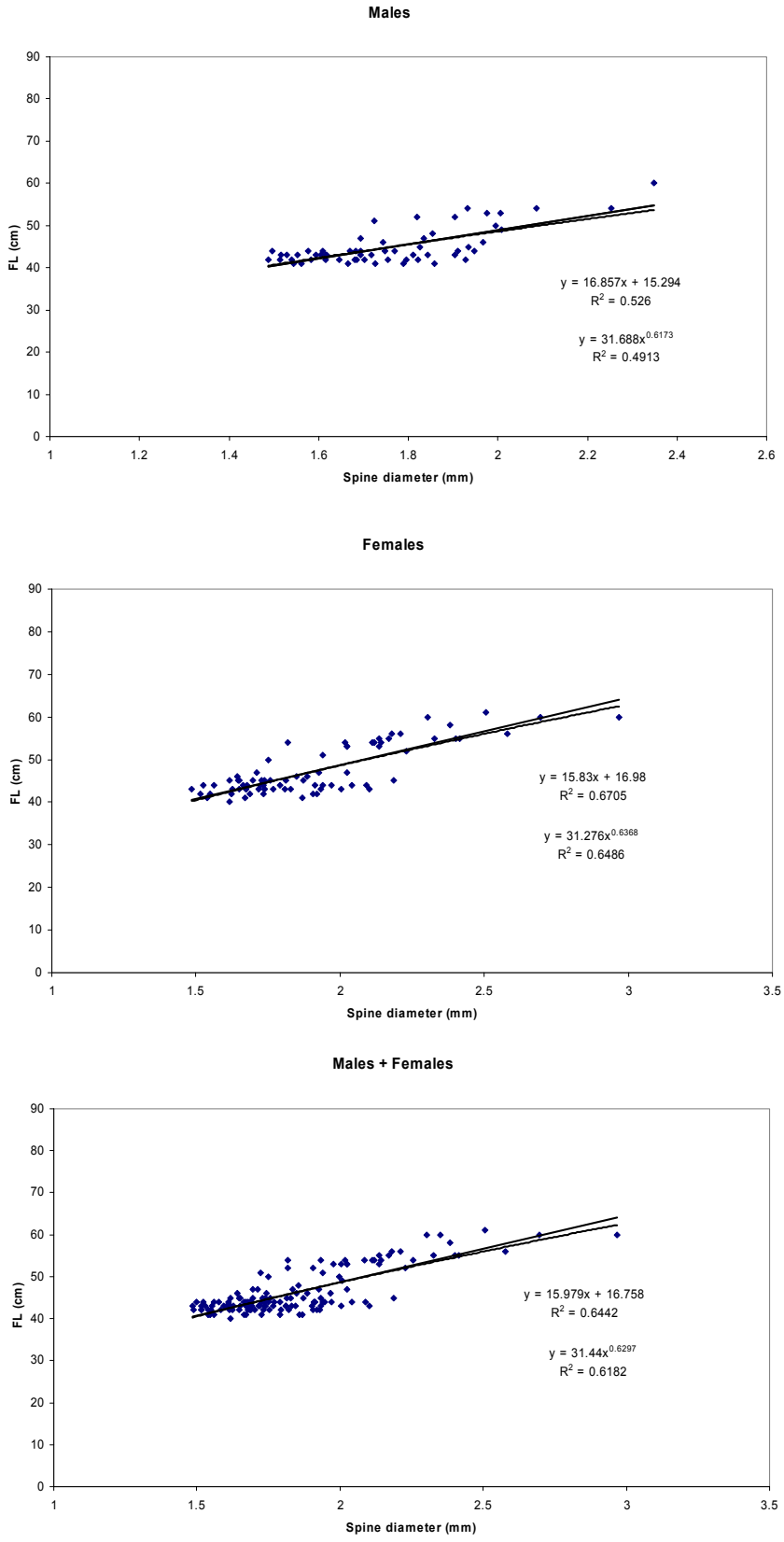

Figure 2. Relationship between FL and dorsal spine diameter for male, female and both sexes Atlantic bonito from the western Mediterranean Sea.

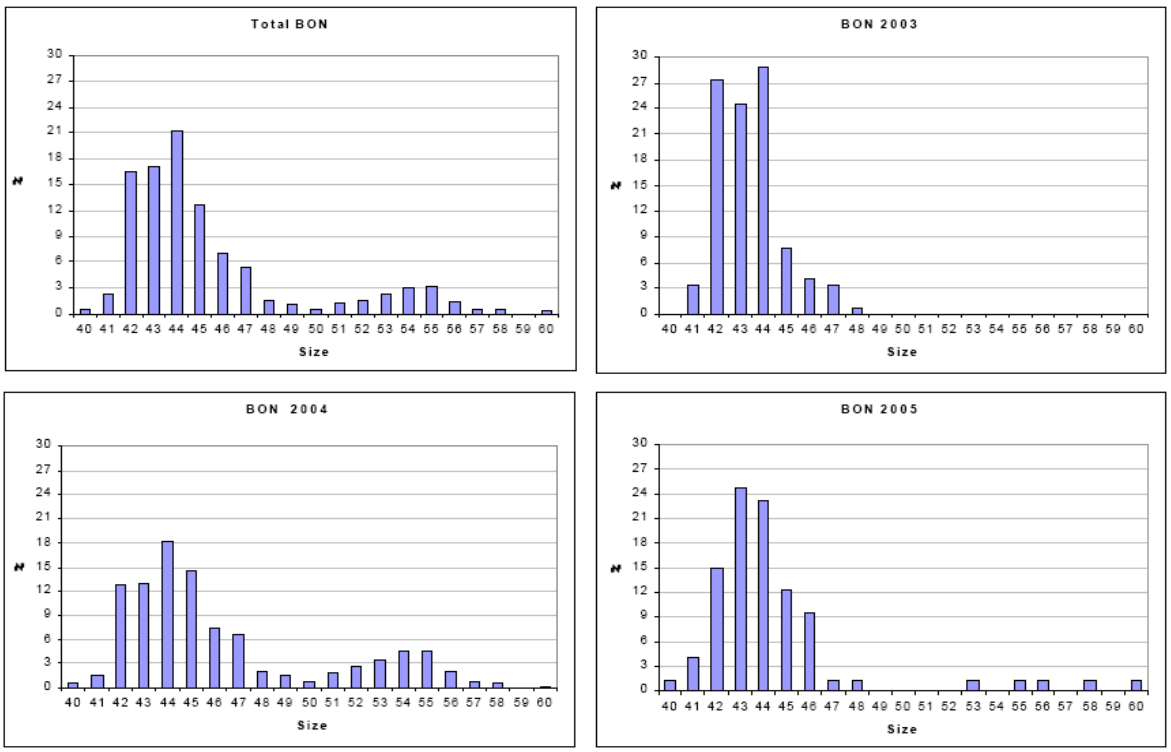

Figure 3. Atlantic bonito annual size distributions from 2003 to 2005 and the combined size distribution. Extracted from Macías *et al*., 2006.

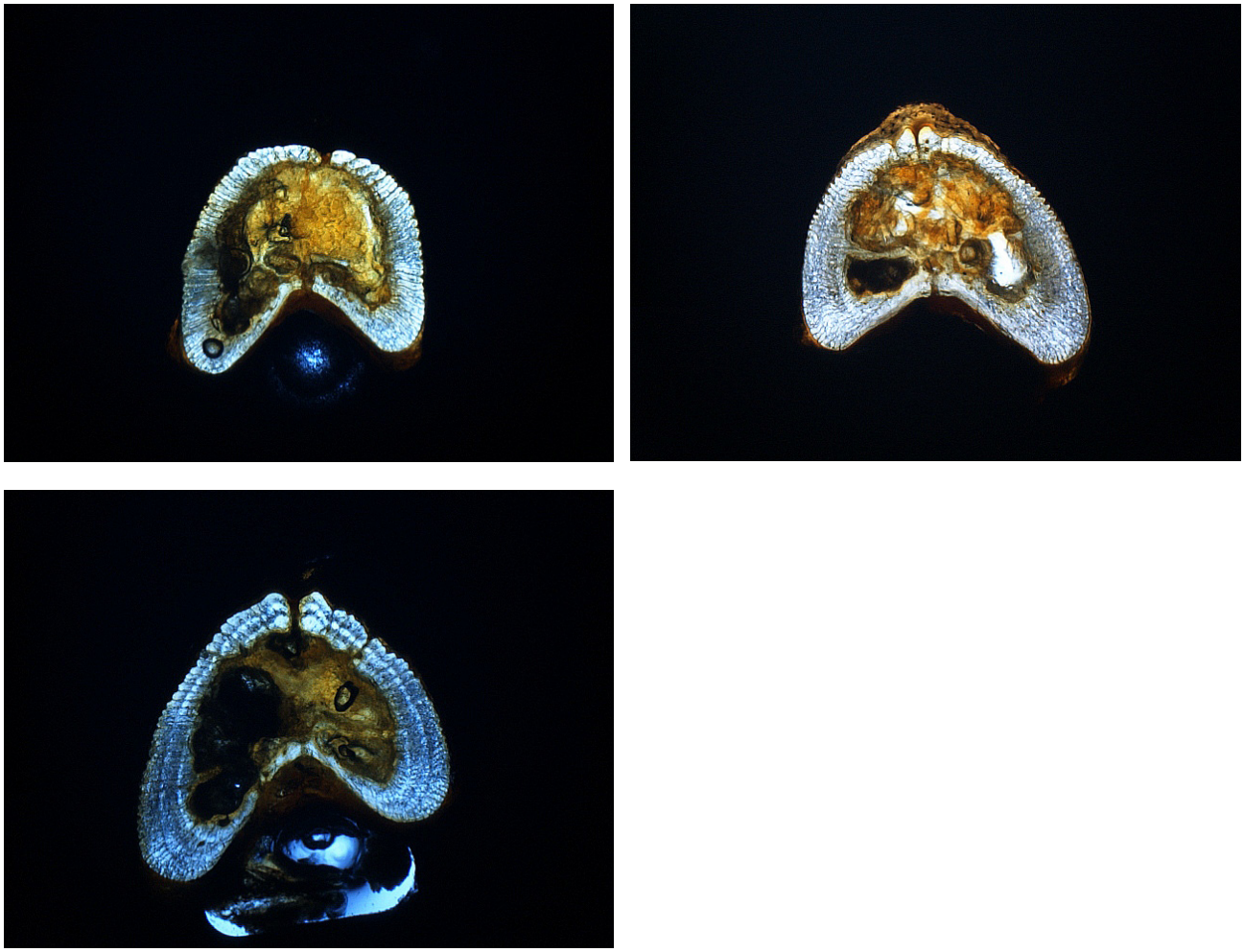

Figure 4. Atlantic bonito spine sections examples. A: age1, B: age 2, C: age 3 (Not proportional sizes of spine pictures).