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SUMMARY – This paper studies the growth and age of East Atlantic bluefin tuna based on the observation and analysis of hard parts (fin ray sections). The different parts and types of rings observed on the fin ray sections are defined. From this study it can be deduced that: (i) hyaline rings are winter rings, which are formed between fall and winter (October-March); (ii) areas of active growth start forming in spring and concludes their formation in the fall (March-October); (iii) for younger aged bluefin (age-classes 1 to 3), size increases 3 to 4 times more in summer than in winter and weight increases 4.5 to 6 times more in summer than in winter; and (iv) winter hyaline rings can be single (thin or thick) or double. From the growth equation obtained by combining data from the juvenile bluefin fishery of the Cantabrian Sea (north of Spain) with that from the adult bluefin fishery of the Strait of Gibraltar area, a value of $L\infty$ = 318.35 cm is obtained, which corresponds to a $W\infty$ = 615.90 kg.

Key words: Bluefin tuna, seasonal growth, fin ray sections.

RESUME – *"Age et croissance du thon rouge (*Thunnus thynnus thynnus*) du nord-est de l'Atlantique". Cet article examine la croissance et l'âge du thon rouge de l'Atlantique oriental en se basant sur les observations et l'analyse des parties dures (sections des rayons des nageoires). Les différentes parties et types d'anneaux observés sur les sections des rayons des nageoires sont définies. A partir de cette étude on peut déduire que : (i) les anneaux hyalins sont des anneaux d'hiver, qui se forment entre l'automne et l'hiver (octobre-mars) ; (ii) les zones de croissance active commencent à se former au printemps et terminent de se former à l'automne (mars-octobre) ; (iii) pour les jeunes thons rouges (classes d'âge 1 à 3), la croissance d'été est 3 à 4 fois supérieure en taille et 4,5 à 6 fois supérieure en poids que la croissance d'hiver ; et (iv) les anneaux hyalins d'hiver peuvent être simples (fins ou épais) ou doubles. A partir de l'équation de croissance obtenue en combinant des données de pêches de thons rouges juvéniles de la mer cantabrique (nord de l'Espagne) avec celles des pêches de thons rouges adultes de la zone du détroit de Gibraltar, on obtient une valeur de $L\infty$ = 318,35 cm, ce qui correspond à $W\infty$ = 615,90 kg.*

Mots-clés : *Thon rouge, croissance saisonnière, sections des rayons des nageoires.*

Introduction

The age and growth of the bluefin tuna is studied paying special attention to the interpretation of the signs manifested in some hard parts of its body (in this case, the spinal sections).

Materials and methods

The sampling was done in northern and southern ports of Spain between the months of May and November.

The range of sizes covered is between 45 and 200 cm in the fishery of the Cantabrian Sea (northern of Spain), and between 170 and 304 cm in the traps of the Gulf of Cadiz (southern of Spain). In both cases fork length as reference was taken.

The method of extraction, preparation and the cutting of the spine, is the one described by Compean-Jimenez and Bard (1980a,b).

Following their same method, some cross sectional cuts ranging from 0.5 to 0.7 mm in thickness on the first dorsal fin using a slow rotating diamond saw were made**.**

The cuts were prepared on slides covered with a highly transparent resin, and a slide cover.

The measuring and reading of the spinal sections was carried out with a profile projector using a zoom of about 10 to 50.

The back-calculated growth size of the fish and the diameter of its spine were calculated for a sample of 300 tunas, by Rey and Cort (1984). The range of sizes in this relation is from 29 to 200 cm fork length (FL); those fish under 50 cm were from the Mediterranean Sea. Including those fish gave us a better fit to the back-calculated growth (including those fish which gave us a better fit to the back-calculated growth). The growth model used was Von Bertalanffy (1938).

The average value by age, of bluefin tuna, from the Cantabrian Sea, between 1 and 8 years of age, was estimated from the following equation: $Y = 12.780863\ X^{0.576}$ (for 12, 24, 36. 46, 60, 72, 64 and 96; X = month).

The equation is obtained by potential adjustment of the modal values of monthly size distributions (Cort, 1989).

Results

Growth in hard parts (spine sections)

The cross sectional cuts of the spines show an alternation of wide areas (active growth) and translucent bands (slow growth). The correct interpretation of these marks is fundamental in order to develop the study on growth as well as to come to conclusions on the biological and ecological aspects of this species. The parts of a dissected spine and the different types of rings observed are shown in Fig. 1).

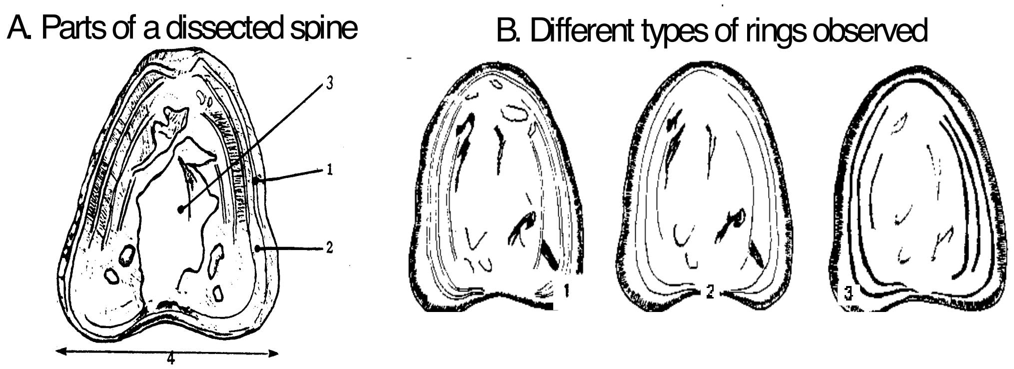

Fig. 1. Part of a dissected spine of a bluefin tuna and different types of rings observed. A (1: traslucent area of slow growth; 2: opaque area of fast growth; 3: vascularized nucleus; 4: diameter of the spine). B (1: double ring or couplet; 2: fine single ring; 3: thick translucent ring).

In the cross sectional cuts on the spines, the following parts can be noticed (Fig. 1A): (1) translucent area of slow growth, which can be formed by two rings or just one; (2) opaque area of fast growth; (3) vascularised nucleus, which in fish over two years old has a reabsorbed part in which the transparent bands disappear; and (4) diameter of the spine.

In young individuals (up to 3 years old) it is easy to find all the hyaline rings of a spine. However, in fish over 3 years the central area of the spine is reabsorbed and consequently the bands are gone. Therefore, for those fish a back calculation of the size of the fish at the moment of the formation of the first visible rings must be made.

Winter growth

For samples of the spinal sections of bluefin caught in the Cantabrian Sea during the 1985 fishing season, different observations and measurements have been carried out on the translucent rings to study the development of the sizes by age in 1-7 year old fish (50 to 175 cm).

The translucent rings found respond to different interpretations due to their shape and apparent composition (see Fig. 1B):

(1) In some cases two thin translucent rings can be seen separated by an opaque band. This is called couplet and the interpretation of these is as follows: the first ring indicates the beginning of the cold season (this translucent band shown poor protein doses that causes a visible accumulation of minerals in the bonny parts) which can coincide with the outward migration from the Cantabrian Sea to the wintering areas. The opaque band, which appears next (between the two rings that form the couplet), is the winter growth. Finally, there is the second ring that shows the end of winter. This one, which can coincide with the migration to the areas of active feeding, has the same composition as its twin.

(2) Fine single rings. These show that the fish scarcely grow during winter. Since the beginning of the cold season until the fish return to the active feeding area (in spring), the growth slowed down quite notably.

(3) Thick translucent rings. This indicates that the bluefin had a more active growth than in the previous case. Here the growth is the same as in the first case, but the diet had no proteins.

After having explained the different cases of spinal rings, the growth of bluefin tuna during the winter can be shown. To do so, measurements of the diameter of the translucent rings were taken from the beginning of these (whether simple or double) till the end of them.

Using a sample of 363 bluefin tuna aged 1 to 7, the distribution of frequencies of the diameter of the winter rings were obtained. The results and their corresponding parameters are shown in Cort (1991).

Using this equation:

$Y = 0.551 + 0.060\ X$ (Rey and Cort, 1984)

which relates Y (diameter of the spine) with X (zoological length of the tuna), the results shown in Cort (1991) were obtained.

In these tables the size distribution back-calculated to the beginning of the winter ring are expressed as TC (1-7) and by TP (1-7) an the and of the winter ring. The parameters of these back-calculated size distribution are shown in Cort (1991).

The winter growth of bluefin from the Cantabrian Sea was obtained by calculating the difference between the average values by age at the end and at the beginning of the rings (data obtained from Cort, 1991). The final results are expressed in Table 1.

Table 1. Winter growth of bluefin from the Cantabrian Sea by age

Age	Winter growth (cm)	Age	Winter growth (cm)
1	2.90	5	7.00
2	3.11	6	6.21
3	3.83	7	6.03
4	6.39		

Summer growth

To estimate the summer growth of bluefin tuna, sampling of spines from fish of age groups 1, 2 and 3 was carried out. These fish are normally found in the Bay of Biscay from the beginning of the summer season (June), until the end of the season (October).

The idea in to follow, from the beginning, the distance from the last visible ring in the cuts of the spines to the end of the ring.

As the fishing season advances, the ring becomes farther and farther from the end of the cut. In the beginning of the season (June) this ring was at the edge of the spine. The results are shown in Cort (1991).

Therefore, the average increase in length and weight for the different age classes of bluefin tuna in the Cantabrian Sea which were studied is as indicated in Table 2.

Table 2. Average increase in length (FL) and weight (W) for the different age classes of bluefin tuna in the Cantabrian Sea. Average values taken from Cort (1991)

Age	Autumn-winter		Summer-autumn	
	FL (cm)	W (kg)	FL (cm)	W (kg)
1	2.90	0.4	9.7	2.5
2	3.11	1.3	13.5	5.8
3	3.83	1.7	15.4	10.3
4	6.39	4.0	13.0†	10.5 (June-Sept.)
5	7.00	6.4	14.0††	14.8 (June-Sept.)
6	6.21	7.4		
7	6.03	8.4		

†Between October and March.
††Between June and October.

Summer growth in relation to winter growth is as indicated in Table 3, for the ages studied.

Table 3. Summer growth in relation to winter growth, for the ages studied

Age	Multiple of growth in size (cm)	Multiple of growth in weight (kg)
1	3.34	6.2
2	4.23	4.5
3	4.02	6.1
4	2.03	
5	2.00	

That is, for age classes 2 and 3, summer growth (in cm) is four times more than winter growth. For the other age classes, summer growth is at least twice as much, and in age class 1 it is over three times more. As regards weight for the first 3 age groups, summer growth is on the average, five to six times more than winter growth.

Von Bertalanffy growth model

One general model has been used for the whole species, using the age-class values (1-8) of the Bay of Biscay, and the 1984 bluefin trap fishery in the Gulf of Cadiz (age classes 9 to 19), from which fin ray spines are available (Cort, 1991).

The parameters of Von Bertalanffy equation, applying the fit of the model by Ford and Walford, are: $L\infty = 318.85$ (cm); $t_o = -0.97$ (year); $k = 0.093$ (annual).

And the equation resulted was: $Lt = 318.85\ [1 - e^{-0.093\ (t + 0.97)}]$

The estimated of $W\infty$ is difficult for bluefin tuna due to the numerous size/weight equations calculated in areas where there are immature and adult tunas.

Out of these, the equation by Rodriguez-Roda (1964) was selected since it has a wider range of sizes (25-279 cm, FL). This equation in as follows:

$W = 0.000019\ L^3$

Replacing in this equations: $W\infty = 0.000019\ L^3\infty$

where $W\infty = 615.90$ kg (for $L\infty = 318.85$ cm)

the Von Bertalanffy weighted equation would be:

$Wt = 615.90\ [1 - e^{-0.093\ (t + 0.97)}]$

The only information available on the integral growth of eastern bluefin tuna is from Rodriguez-Roda (1964), Compean-Jimenez and Bart (1980a,b) and Compean-Jimenez and Bard (1983), although the last studies are very similar with slight variations.

Applications of the described study

Studies on bluefin growth, as noted in the preceding chapter, show a considerable metabolic activity of this species during the months they spend in the Cantabrian Sea (from the end of spring to mid-fall).

Due to the almost complete stop in growth in the months corresponding to the cold season (November to March), it is important to point out that bluefin return to the Cantabrian Sea the following year and are the same size they were when they left 7 months before (see Cort, 1991).

Because of this, the applications of the size/age keys have to be done seasonally. The use of only one key for at the catches would distort the size distribution of these catches.

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