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VALIDATION OF ANNUAL GROWTH INCREMENTS IN SPINE SECTIONS AND THE EQUATION APPLIED TO THE EASTERN BLUEFIN TUNA (*THUNNUS THYNNUS*) STOCK OF THE NORTH ATLANTIC

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SUMMARY

The follow-up of marginal increments in Thunnus thynnus *dorsal spine sections permits the interpretation of wide opaque bands as corresponding to periods of rapid growth between June and October-November, when temperatures are higher. Translucent rings are formed during unique periods of slow growth between November and May-June, when temperatures are lower, and are associated with the stoppage in marginal increments. Using the growth equation applied to the eastern bluefin tuna stock as a reference, the growth of the stock is compared with length increases from tag-recovery data of the IEO and ICCAT databases. The results reveal that growth estimated by dorsal spine readings corresponds to the growth rates estimated from the tag-recovery data of both the eastern and the western Atlantic, that the values of mean lengths of eastern Atlantic and Mediterranean bluefin tuna have not undergone changes in recent decades and that the equations for the eastern and western stocks may be very similar or equal.*

RÉSUMÉ

Le suivi des incréments marginaux dans les sections de l'épine dorsale du Thunnus thynnus *permet d'interpréter les larges bandes opaques comme correspondant à des périodes de rapide croissance entre juin et octobre-novembre, lorsque les températures sont plus élevées. Des anneaux translucides sont formés pendant des périodes uniques de lente croissance entre novembre et mai-juin, lorsque les températures sont plus faibles, et sont associés au stoppage des incréments marginaux. À l'aide de l'équation de croissance appliquée au stock de thon rouge de l'Est comme référence, la croissance du stock est comparée aux augmentations de longueur obtenues des données de marquage-récupération des bases de données de l'ICCAT et de l'IEO. Les résultats révèlent que la croissance estimée par les lectures des épines dorsales correspond aux taux de croissance estimés à partir des données de marquage-récupération à la fois de l'Atlantique Est et Ouest, que les valeurs des longueurs moyennes du thon rouge de l'Atlantique Est et de la Méditerranée n'ont pas subi de changements au cours de ces dernières décennies et que les équations pour les stocks de l'Est et de l'Ouest pourraient être très similaires ou égales.*

RESUMEN

El seguimiento de incrementos marginales en secciones de la espina dorsal de Thunnus thynnus *permite interpretar las amplias bandas opacas como correspondientes a periodos de rápido crecimiento entre junio y octubre-noviembre, cuando las temperaturas son más elevadas. Los anillos translúcidos se forman durante periodos únicos de crecimiento lento entre noviembre y mayo-junio, cuando las temperaturas son inferiores y se asocian con la interrupción de los incrementos marginales. Utilizando la ecuación de crecimiento aplicada al stock de atún rojo del este como referencia, el crecimiento del stock se compara con aumentos de talla a partir de los datos de recuperación de marcas de las bases de datos de ICCAT y del IEO. Los resultados revelan que el crecimiento estimado por las lecturas de la espina dorsal corresponde a las tasas de crecimiento estimadas a partir de los datos de recuperación de marcas tanto del Atlántico este como del Atlántico oeste, que los valores de las tallas medias del atún rojo del Atlántico este y Mediterráneo no han sufrido cambios en las décadas recientes y que las ecuaciones para los stocks oriental y occidental podrían ser muy similares o iguales.*

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KEYWORDS

Age and growth, bluefin tuna, *Thunnus thynnus*, dorsal spine, tag-recovery

1. Introduction

Assessments made by the bluefin tuna assessment group (SCRS, ICCAT) follow the hypothesis of two separate stocks (ICCAT, 2008) and uses a growth equation for each of them. Turner & Restrepo's (1994) is used in the western stock and in the eastern stock, that of Cort (1991).

The aims of the present study are:

- To summarize the results on growth obtained twenty years ago (Cort, 1990), providing new information published in subsequent years related to this parameter from bluefin tuna of the North Atlantic eastern stock.
- To validate the period of increment formation in dorsal spines by means of the marginal increments analysis and tag-recapture (Campana, 2001).
- To validate the growth curve (Cort, 1991) by means of the tag-recapture data.

At the beginning of the study special interest is paid to how the hyaline rings seen in dorsal spine samples may be related to ‘tags’ in time, i.e. it may be possible to assign age according to the pattern of rings.

Another of the aspects considered was the establishment of whether there had been any variation in the growth parameters of this species as a result of human activity in recent decades. In this sense, Neilson & Campana (2008) point to the possibility that bluefin tuna growth parameters in the western Atlantic, based on the studies by Turner & Restrepo (1994), “may no longer reflect the contemporary situation”.

The ulterior aim of the study is to improve the knowledge of the growth of this species by taking advantage of the advances made over the years and to investigate whether or not the equation currently used by the assessment group is appropriate and whether it is close to the reality.

2. Material and methods

Fish collection and sample preparation

Fishes were collected from the Bay of Biscay and Mediterranean Sea bluefin tuna fisheries. According to ICCAT (1990), fishes were measured with a caliper to the fork length (zoological length, FL) or to the predorsal length (LD_1).

The methodology used was the cut, laboratory preparation and interpretation of rings in the first spine of the first dorsal fin of bluefin tuna described by Compeán-Giménez & Bard (1983).

Age estimation

To calculate fish age by counting hyaline rings the methodology described by Cort (1990) was followed, in which different prior steps are established, among others the relationship between the diameter of the spine (Ø, mm) and bluefin tuna length (FL, cm), a relationship that permitted the back-calculation of fish length corresponding to the first ring visible in samples, taking into account the reabsorption of the nucleus of spines taking place from age 3. The equation obtained was: Y (Ø) = -0.551 + 0.060 X (FL), for a range of lengths of 29-199 cm; N = 390; R = 0.9899 (Rey & Cort, 1984). The hyaline rings observed, either single or double, were considered to be a single slow growth period (Santamaria *et al*., 2009).

Validation of period of increment formation

Marginal increment analysis

The follow-up of marginal growth for ages 0-3 (length range, 46-113 cm) permitted the quantification of bluefin tuna growth in the different seasons of the year as well as the verification of the season in which rings are formed. This was done by measuring the distance from the edge of the spine to the last visible hyaline ring. Most of the 342 samples studied were from the Bay of Biscay fishery (June-November), to which others of age 0 (< 50 cm) were added, caught in winter in the western Mediterranean, and by Turkish fisheries caught in winter and spring. These latter samples were collected in Istanbul in 1992 and 1993 (De Metrio *et al.*, 1995). The back-calculation of monthly lengths corresponding to the values of marginal growth was performed applying the following equation: Y (Ø) = -0.551 + 0.060 X (FL).

Tag-recapture analysis

Tag-recovery data of fishes bearing conventional (Cort, 1990) and electronic tags (Goñi *et al*., 2009) were used. In the latter case all movements of the fish by spatial-time stratum in the year at liberty are recorded.

Growth equation

The growth equation was formulated from 167 dorsal spine samples, fish lengths ranging from 150-304 cm (ages, 6 to 19) of bluefin tunas caught by the traps of southern Spain between May and June 1983 and 1984. The sample collection and reading process was independently done by two researchers of the IEO (Rey & Cort, 1984), who in those years put into practice the technique started by Compeán-Giménez & Bard (1983) for bluefin tuna and albacore tuna (*Thunnus alalunga*) of the North Atlantic. The number of samples of tunas of less than nine years and of more than fifteen was very small (< 10 specimens) and there were no fishes of less than 6 years. This is the reason why the data series was broadened below that age (< 150 cm) by adding results of the study of growth from the Bay of Biscay, where a great deal of information was available.

In the case of samples obtained in the traps, the relationship $LD_1 = 7.812156 + 0.245880$ FL (Rey, pers. com.) was used for a >120-300 cm length range to convert predorsal length (LD_1) to fork length (FL). Similarly, the relationship FL = 1.21634 + 0.94859 CFL (Rey, pers. com.) was applied to transform bluefin tuna lengths, taken at the curve of the body (CFL), into fork length (FL).

To obtain the mean values of bluefin tuna length from 1 to 8 years in June, and thus make the sampling season in the Bay of Biscay the equivalent of that of sampling in the traps of southern Spain, one of the methods described by Cort (1990) was applied, which takes into account the modal values of the length distributions from the Bay of Biscay. The equation was: $Y = 12.780863\ X^{0.576}$, for N = 1165 (R = 0.9889), in which X is time in months, and Y the length of the bluefin tuna in cm. Values of X corresponding to June were applied for each age group; i.e. 12 for age 1; 24 for age 2; 36 for age 3, etc., up to age 8, month 96.

Grouping the mean values at age for bluefin tunas from 1 to 8 years from the Bay of Biscay with those of 9 to 15 from the traps, the von Bertalanffy (1938) growth model could be applied.

$$L_t = L_\infty [1- e^{-k(t-t_0)}]$$

$$W_t = W_\infty [1- e^{-k(t-t_0)}]$$

where:

L_t, W_t = Size (length or weight) of the animal at time t.
L_∞, W_∞ = Maximum mean asymptotic size (length or weight).
k = Physiological significance constant (catabolism coefficient).
t_0 = Theoretical moment at which L = 0 or W = 0

Growth equation validation by tag-recapture fish analysis

The present study uses recoveries of tagged fishes whose tagging and recovery data were reliable in order to check how they fit to the growth curve obtained by the fit of direct dorsal spine readings. The database, which has been revised, comes from IEO tagging surveys in the Bay of Biscay and western Mediterranean between

1978 and 1991 (Cort & de la Serna, 1994; Cort & Liorzou, 1995). The maximum age reached in these recoveries was twelve years, and so as a test some recoveries of great interest from western Atlantic tagging surveys on the ICCAT tag-recovery database whose age is over twelve years were added. Due to the lack of information, many recovery records were discarded, among them data with ICCAT code UNK (unknown type of length). In this database, however, several records have been found whose length at recovery refers to total fish length (ICCAT code, TLE). As no equation has been found in the literature that relates LTE with FL in bluefin tuna, one was calculated from samplings made in the bluefin tuna fattening farms of *Grup Balfegó* (l´Ametlla de Mar, Tarragona, Spain) in March and April 2009 for a length range between 111-277 cm. Although it derives from fishes of the eastern stock, this equation was applied to transform western Atlantic fish lengths as it was considered that the high correlation between the two measures would surely make the difference inappreciable. The best way to check the truth of this would be to calculate it using one of the western Atlantic samples.

Only data of fishes measured at the moment of tagging, to which age could be assigned with hardly any margin of error, were used, i.e. fishes between 1 and 3 years, with one single exception of a four year old fish whose recovery was of great interest (PE 313). In that case the criteria was applied that in August, the month in which it was tagged, the length-age relationship attributed 100% of age 4 to fishes of 120 cm (Cort, 1990), which was the length of the fish at the time of tagging.

The growth curve refers to June, therefore the recoveries used were assigned age assuming the months of birth to be June for the eastern stock of bluefin tuna (García *et al*., 2003) and May for the western Atlantic (Baglin, 1982). That means that if a two year old fish, of 80 cm for example, was recovered in the eastern Atlantic in August, the age assigned was 2.2 years.

The length measurement of the recovery was valued depending on the person; e.g. if it was an observer or a scientist fork length was used (FL) whenever this was supplied; otherwise weight was used, which is the measurement generally reported, and from this the corresponding length was obtained using length-weight relationships.

The conversion of weight to length for large adult specimens before the spawn was that of Rodríguez-Roda (1964):

$P = 0.000019\ L^3$

If they were young fishes or small adults, the following equations (Cort, 1990) were used:

$P = 0.00004549\ L^{2.814}$ (June-September)
$P = 0.00003856\ L^{2.859}$ (October-December)

To determine the goodness of the fit of these recoveries to the curve, spines reading data were also added.

Environmental data

Temperature data from the Bay of Biscay were obtained from the oceanographic buoy Augusto González de Linares (http://www.boya_agl.st.ieo.es/boya_agl/HTML/), located at 43º 50.67' N - 03º 46.2' W.

3. Results and Discussion

Validation of period of increment formation

By marginal increments

From the identification of translucent rings as periods of slow growth due to hypermineralization (Meunier *at al*., 1979), the first exercise consisted of determining what these visible rings really represented in the cross sections of the bluefin tuna spines.

One way of tackling the matter of the formation of hyaline rings and opaque bands was to follow up marginal growth (**Figure 1**). The results of the study for age groups 0-3 (< 1 kg–30 kg) are shown in **Figure 2**, where values of marginal increments and corresponding monthly lengths are superimposed (numerical values, **Table 1**). In the fisheries studied, the stoppage in the formation of marginal increments, which coincides with the formation of hyaline rings and the start of slow growth, extends from November to May-June the following year. The hyaline rings, whether they be single or double (**Figures 3 and 4**), are periods of slow growth.

From June to October-November, there is a gradual rise in the marginal increments, revealed as broad opaque bands and coinciding with rapid growth.

The highest growth phases coincide with higher temperatures in the Bay of Biscay (**Figure 5**).

Megalofonou & De Metrio (2000), studying dorsal spine of Greek and Italian fisheries of the Aegean, Adriatic and Ionic seas, found that the formation of the ring takes place between February and April. This difference from the Atlantic and Mediterranean fisheries may be due to the different environmental conditions of the two areas.

By tag-recapture (conventional tags)

Figure 6 shows the section of the spine of a three-year old bluefin tuna tagged in the Bay of Biscay in August 1984 and recovered in June of the following year in the eastern Atlantic (tag record, KA 9760; **Appendix 1**). This sample confirms that between the date of tagging (summer, 1984) and the recovery date (end of spring, 1985) the simple ring that appears at the edge the spine has been formed. According to the values and parameters from measuring the winter rings (Cort, 1990; 1991), the chronology of this bluefin tuna would be as follows:

- The formation of the first hyaline ring took place when the fish measured 46 cm (Ø of the spine, 2.2 mm) and weighed 2.5 kg, which possibly occurred in December 1982 in the Mediterranean (Rey & Cort, 1986) or in waters of the Moroccan Atlantic coast (Furnestin & Dardignac, 1962).

- The second hyaline ring appeared when the fish measured 74 cm (Ø of the spine, 3.9 mm) and weighed 8 kg, possibly between November 1983, while still in the Bay of Biscay (Arrizabalaga *et al*., 2008; Goñi *et al*., 2009), and June 1984 in the Bay of Biscay (Arrizabalaga *et al*., *op. cit.*; Goñi *et al*., *op. cit.*).

- On 29 August 1984 it was tagged and liberated in the Bay of Biscay; the length at tagging was 82 cm (11 kg).

- The third hyaline ring was formed when the fish measured 84 cm (Ø of the spine, 4.5 mm) and weighed 12 kg, possibly between November, while still in the Bay of Biscay (Arrizabalaga *et al*., *op. cit.*; Goñi *et al*., *op. cit.*) and the end of spring 1985.

- On 13 June 1985 it was recovered off the coast of Galicia (Spain) when it seemed to be heading for the Bay of Biscay once again (Arrizabalaga *et al*., *op. cit*.; Goñi *et al*., *op. cit*.); the length at recovery was 84 cm and the weight was 13 kg.

By tag-recapture (electronic tags)

The paper by Goñi *et al*. (*op. cit*.) presents the results of several recoveries of *Thunnus thynnus* tagged using electronic tags. Courtesy of AZTI-tecnalia (http://www.azti.es/), the section of the dorsal fin of one of these recovered fishes is included (code LTD 1443).

A three-year old bluefin tuna was tagged in the Bay of Biscay in August 2008 and recovered in the Bay of Biscay in August 2009. As shown in the paper, all movements by spatial-time stratum from tagging to recapture are known for this fish (see Figure 10 from Goñi *et al*., 2009). As in the case described above, it is confirmed that between the date of tagging and the recovery date, hyaline rings are formed, in this case double (**Figure 7**).

According to the values and parameters from measuring the visible winter rings (Cort, 1990), the chronology of this bluefin tuna would be as follows:

- The first visible hyaline ring appeared when the fish measured 71 cm (Ø of the spine, 3.7 mm) and weighed 7 kg, possibly between November 2007, while still in the Bay of Biscay (Arrizabalaga *et al*., 2008; Goñi *et al*., 2009), and June 2008 in the Bay of Biscay (Arrizabalaga *et al*., *op. cit.*; Goñi *et al*., *op. cit.*).

-Tuna length at the start of the active growth season (opaque ring) was 74 cm (Ø of the spine, 3.9 mm) and weight was 8 kg.

- On 28 August 2008 it was tagged and liberated in the Bay of Biscay; the length at tagging was 89 cm; 13 kg (Ø of the spine, 4.8 mm).

-Tuna size at the end of the active growth season (opaque ring) was 94 cm (18 kg). That means it surpassed double the weight from the beginning of summer (June) to the start of autumn.

The data from the following pair of visible rings are:

- The first ring of the pair was formed when the fish measured 94 cm (Ø of the spine, 5.1 mm) and weighed 18 kg.

- The second ring of the pair was formed when the fish measured 100 cm (Ø of the spine, 5.5 mm) and weighed 19 kg; i.e. From the start of the slow growth season (autumn and winter) until the return to the Bay of Biscay in June 2009, the fish is in constant movement between the Bay of Biscay, the Azores and Madeira, but only grows 6 cm and increases 1 kg in weight.

- On 10 August 2009 it was recovered in the Bay of Biscay once again; the length at recovery was 103 cm (20 kg).

The differences between the two specimens studied are as follows:

- In the first case (conventional tag), the recovery was made at the end of spring (13 June); the last hyaline ring is still at the edge of the dorsal spine; marginal growth is very small.

- In the second case (electronic tag), the last hyaline ring, which in this case is double, is already far from the edge of the spine, given that the recovery came in the middle of summer (10 August). The marginal increment is greater in this case than in the previous one.

These two examples confirm that hyaline ring formation, either single or double, and slow growth take place in the periods of time established above (November to May-June). Thus, the hyaline rings may be related to 'tags' in time that permit age to be assigned according to a pattern of rings.

Growth equation

The problem of the comprehensive study of bluefin tuna growth based on dorsal spine readings lies in the fact that samples from different areas must be used, since the lengths of tunas differ among areas, as does the season of the appearance of these fishes. The paper by Cort (1990) dealing with growth of bluefin tuna in the Bay of Biscay from June to November permitted the application of one of the methods described therein to obtain the mean values of the lengths of bluefin tunas from 1 to 8 years in June. All these groups are present in the Bay of Biscay. Using samples of bluefin tuna spines from the traps of the south of Spain and the Bay of Biscay, the growth equation was calculated:

$$Lt = 318.85\,[1- e^{-0.093\,(t + 0.97)}]$$

The estimate of W_∞ was made by applying the length-weight relationship of Rodríguez-Roda (1964) for pre-spawning fishes: $W = 0.000019\,L^3$.

Accordingly,

$$W_\infty = 0.000019\,L_\infty^{\;3}$$

For $L_\infty = 318.85$ cm,

$$W_\infty = 615.90 \text{ kg}$$

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

The growth studies performed since are presented in **Table 2**.

The studies by Farrugia & Rodríguez-Cabello (2001), El-Kebir *et al.* (2002), Rodríguez Marín *et al*. (2004), were made using dorsal spine cross-sections; that of Olafsdottir & Ingimundardottir (2003) with vertebrae; all those papers cited by Rooker *et al*. (2007). The most recent paper, also using the methodology of dorsal spine, is that of Santamaria *et al*. (2009). Also, Orsi Relini *et al.* (1997) published the mean values of age groups 1 to 4, obtained by length samplings in 1992-96, and Rodríguez-Cabello *et al*. (2007) presented the results of obtaining growth parameters through the use of tag-recovery data.

With respect to the results of the studies carried out by dorsal spine readings, differences are found between them and not all of them cover the same ages. In the study that used vertebrae, these differences are even more considerable.

With the aim of comparing studies published in recent years with the present study, two were selected which were made using the methodology of dorsal spine and which spanned a greater range of ages. These are shown in **Table 3** and **Figure 6**. The similarity of the mean values at age obtained in the three studies reveals that eastern Atlantic bluefin tuna growth has not varied, at least in the last twenty years. Nevertheless, it should be pointed out that several age groups of the studies by Santamaria *et al*. (2009) and Rodríguez-Marín *et al*. (2004) presented a very small number of samples.

In spite of the fact that the mean values/age of Cort (1990; 1991) and Santamaria *et al*. (2009) are practically the same, the parameters t_0 (-1.76 cm) and L_∞ (373.08 cm) of these authors are significantly greater in Santamaria *et al*. (2009) than in Cort (1990; 1991), surely owing to the difference in the length of age 1: 62 cm, and 53.48 cm respectively. The reason behind this difference is that 53.48 cm corresponds to the value calculated for fishes of age 1 in June, whereas 62 cm is the length of this same age in August-September. Thus the importance that samplings for growth studies should always refer to the same month. Studies cannot be compared when samples have been taken in different months, especially in those concerning active growth.

Validation by tag-recapture

With the aim of testing the growth curve obtained by dorsal spine readings used in the stock assessment, observations of tag-recovery of the Spanish IEO surveys between 1978 and 1991 were added, from which bluefin tunas were obtained that had been at liberty for up to eleven years. Then, as a test, some recoveries of fishes from the western Atlantic were aggregated that had spent between eleven and eighteen years at liberty. The recoveries from the western Atlantic that referred to total length (TLE) rather than fork length (FL) were converted by means of the equation Y (TLE) = 0.277409 + 1.074101 X (FL) [regression values, R = 0.99945; N = 101] (**Figure 8**).

Once the conversions had been made, the observations on the growth curve were represented (**Figure 9**). There is a very good fit for ages from 0 + to 5, and also the rest, though from age 6 to twelve there were very few recoveries. Most of the ten recoveries of the western Atlantic fit to the curve very well. The database used contains considerable information of great value and utility since the recoveries up to five years have very valid information. From that age, many records had to be discarded as they failed to offer sufficient reliability for a precision study of this nature.

To test the fit of the observations of specimens of greater length (> 12 years), another test was performed by adding the dorsal spine readings to the growth curve (**Figure 9**). The data came from the traps in 1984, those used to build the growth equation and from the Bay of Biscay in 1985 (Cort, 1990). This time all the values observed except the two oldest fishes of the western Atlantic were within the range of the observations (**Figure 9**), or even, in most of the cases, within the confidence intervals of the mean lengths at age shown in **Table 4**.

Growth, eastern and western stocks

After converting the lengths of total length (LTE) into fork length (FL) we see that most of the recoveries of the western Atlantic used fit to the growth curve of the eastern stock.

In a recent paper by Neilson & Campana (2008) age estimates are validated using nuclear tests on radiocarbon deposits in old otoliths, but the shortage of samples of the younger ages leads the equation to underestimate lengths of these.

Lastly, one recent study (Restrepo *et al*., 2009) presents a new equation that the authors recommend for adoption in the future as the equation of the western stock to substitute the present one (Turner & Restrepo, 1994). The parameters of this new equation are practically the same as in the one applied to the eastern stock. The equation is the following:

$$Lt = 314.90\ [1- e^{-0.089\ (t+1.13)}]$$

According to the authors: "In this study, we combine the otolith-based age-length readings with the size frequency distributions of small (ages 1-3) bluefin caught by purse seiners in the 1970s where the age classes are distinctly visible to the eye. We analyzed the two datasets jointly using a maximum likelihood approach and assumed that variability in length at age increases with age. The resulting growth curve predicts sizes at young and old ages that are very consistent with observed data such as the maximum sizes observed in the catch, or the modal sizes for very young bluefin. The resulting curve is also very similar to the curve used by ICCAT for eastern Atlantic and Mediterranean Bluefin."

Growth in juveniles

A review is made of the juvenile bluefin tuna growth studies in order to verify whether there have been any variations in growth over time.

Regarding growth of young-of-the-year group (< 50 cm) very similar results are seen in most of the studies in which the evolution of this group has been followed monthly over the last fifty years (Table 5). In the eastern Atlantic and Mediterranean, Furnestin & Dardignac (1962); Sarà (1965); Scaccini *et al*. (1973); Orsi Relini *et al*. (1997) and La Mesa *et al.* (2005), coincide in their results; those of Santamaria *et al*. (2003) differ slightly. In the western Atlantic, Rivas (1954); Mather III & Schuck (1962) and Brothers *et al*. (1983) all obtained results equal among them, which were very close to those of the eastern Atlantic. The small variations in the results of the studies carried out on both sides of the ocean are due to the different follow-up methods employed, which in some cases were length distributions (the oldest papers) and in others the counting of daily rings in otoliths. The difference in the timing of the tunas' birth between western Atlantic (May) and the Mediterranean (June) is patent up to the beginning of the cold season. From November the length of fishes is similar on both sides of the ocean, although a small difference remains until they reach age 1: 52 cm in May in the western Atlantic, and 52 cm in June in the eastern and Mediterranean.

The small difference in the length of tunas due to the fact that in the western Atlantic they reach the next age group one month earlier may continue to show up through successive years and be more perceptible in fishes of ages 1-3, which are those that have a higher growth rate during the active growth season. If, on top of this, massive transoceanic migrations of these age groups take place from west to east, as happens in certain years as demonstrated by Mather *et al*. (1967), Ortiz de Zárate & Rodríguez-Cabello (1999; 2000) and Rooker *et al*. (2008), this small difference may lead to interannual variations in mean length of juveniles groups (less than five years) of the eastern stock, as shown in Liorzou & Bigot (1995).

Rodríguez-Marín *et al*. (2001), in reference to three different methods to estimate catch at age in juveniles of the Bay of Biscay, among them the length-age keys by dorsal spine reading, did not find significant differences ($P<0.05$), and so "the results obtained using the three methods validate each other".

The growth observed in group 0 (< 50 cm) shows very similar results over the last fifty years both in the western and the eastern Atlantic, including the Mediterranean.

Conclusions

- The hyaline rings visible in dorsal spine samples may be related to 'tags' in time for age assignation.

- The hyaline rings of the juvenile tunas caught in Atlantic fisheries are already visible at the beginning of the cold season of the northern hemisphere in November. The rings, whether single or double, represent unique periods of the growth stoppage taking place between November and May-June of the following year. The wide opaque bands, which coincide with marginal increments, correspond to seasons of rapid growth and are formed between June and October-November.

- The samples of dorsal spine of fishes tagged and recovered (with conventional and electronic tags) confirm that the formation of hyaline rings and opaque bands takes place in the time period described in the previous paragraph.

- Samplings for growth studies should always refer to the same month. Studies compared when samples have been taken in different months may show significant differences.

- The growth curve of the eastern stock of bluefin tuna, now in use in bluefin tuna assessment sessions, fits well to the recoveries of the eastern and western Atlantic.

- The ICCAT tag-recovery database presents numerous records in which the length at recovery refers to total length (code, TLE). The measurement cannot be considered as fork length (FL), since it is significantly different. If precision studies are to be made, these lengths must be converted into fork length by means of a conversion equation.

- Many recoveries of the ICCAT database do not have any record of the length at tagging. The most reliable data of fishes tagged in the western Atlantic come from the purse seine tagging surveys in 1960´s and 1970´s.
- Up to age five very numerous and reliable recoveries are obtained with respect to length. From this age a lot of caution is required regarding recovery data.

- The fit of bluefin tuna tag-recovery data from the east and west and the identical growth of juveniles on both sides of the ocean reveals that the growth equations of these two stocks, if not equal, may be very similar. A recent growth study with samples from the western Atlantic have shown this to be true.

- The growth studies carried out by dorsal spine readings and other studies using different methods (length and weight distributions) show that mean lengths at age have not changed and therefore the growth of the bluefin tuna population has remained constant over the last decades.

- The growth observed in group 0 (< 50 cm) has shown very similar results over the last fifty years both in the western and the eastern Atlantic including the Mediterranean.

- Lastly, it can be concluded that the arguments applied in building the growth equation of the eastern stock as used in the assessment group are appropriate, and that it provides a good fit to the existing knowledge on the biology of this species.

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Table 1. Numeric values of the figure on marginal growth.

NUMERIC VALUES OF THE LAST VISIBLE RING ON THE SPINES AND THEIR CORRESPONDING CONVERSION TO SIZES FOR ATLANTIC BLUEFIN TUNA, EASTERN STOCK (AGES O-3)									
LAST RING					VALUES FROM SAMPLES				OBSERVATIONS
AGE	Spines (N)	δ (mm)	x (mm)	SY/SX	N	δ (cm)	FL (cm)	SY/SX	
Age 0									
December	6	0.036	0.068	0.039 0.097	6	1.21	46	45 47	Samples, western Mediterranean
January	-	-	-	- -	-	-	-	- -	
February	-	-	-	- -	-	-	-	- -	
March	-	-	-	- -	-	-	-	- -	-
April	10	0.021	0.096	0.083 0.11	10	2.3	49	47.6 50.4	Samples, western Mediterranean
May	-	-	-	- -	-	-	-	- -	-
Age 1									
June	23	0.069	0.22	0.19 0.25	23	1.48	57.7	57.1 58.3	Samples, Bay of Biscay
July	21	0.096	0.28	0.23 0.32	21	2.73	57.7	56.5 58.9	Samples, Bay of Biscay
August	10	0.078	0.32	0.27 0.37	9	2	60	58.7 61.3	Samples, Bay of Biscay
September	32	0.13	0.51	0.46 0.56	32	2.38	61.1	64.3 65.9	Samples, Bay of Biscay
October	35	0.2	0.67	0.6 0.74	34	3.47	67.4	66.3 68.5	Samples, Bay of Biscay
November	13	0.12	0.71	0.64 0.77	13	2.57	73.6	72.2 75	Samples, Bay of Biscay
December	-	-	-	- -	-	-	-	- -	-
January	14	0.14	0.82	0.75 0.89	14	1.9	74	73 75	Samples, Turkey
Age 2									
November	10	0.029	0.1	0.08 0.12	10	1.78	74.4	73.3 75.5	Samples, Bay of Biscay
December	-	-	-	- -	-	-	-	- -	-
January	11	0.05	0.17	0.14 0.2	14	1.9	74	73 75	Samples, Turkey
February	-	-	-	- -	-	-	-	- -	-
March	-	-	-	- -	-	-	-	- -	-
April	-	-	-	- -	-	-	-	- -	-
May	-	-	-	- -	-	-	-	- -	-
June	40	0.062	0.16	0.14 0.18	40	2.95	75.3	74.3 76.1	Samples, Bay of Biscay
July	35	0.12	0.27	0.23 0.31	35	5.16	80	78.3 81,7	Samples, Bay of Biscay
August	33	0.12	0.38	0.34 0.42	33	4.88	80.3	78.7 82	Samples, Bay of Biscay
September	39	0.17	0.66	0.61 0.71	39	4.34	88.4	87.1 89.8	Samples, Bay of Biscay
October	36	0.14	0.75	0.7 0.8	35	3.2	88.4	89.5 87.3	Samples, Bay of Biscay
November	14	0.14	0.83	0.76 0.9	14	2.77	94	92.5 95.4	Samples, Bay of Biscay
December	-	-	-	- -	-	-	-	- -	-
January	-	-	-	- -	-	-	-	- -	-
February	-	-	-	- -	-	-	-	- -	-
March	-	-	-	- -	-	-	-	- -	-
April	31	0.18	1	0.94 1.06	33	2.92	100.2	99.2 101.2	Samples, Turkey
Age 3									
November	5	0.03	0.09	0.06 0.12	5	2.61	96.4	94.1 98.7	Samples, Turkey
December	-	-	-	- -	-	-	-	- -	-
January	-	-	-	- -	-	-	-	- -	-
February	-	-	-	- -	-	-	-	- -	-
March	-	-	-	- -	-	-	-	- -	-
April	19	0.03	0.1	0.05 0.14	33	2.92	100.2	99.2 101.2	Samples, Turkey (external ring)
May	-	-	-	- -	-	-	-	- -	-
June	35	0.046	0.15	0.13 0.17	35	5.49	93.9	92.1 95.7	Samples, Bay of Biscay
July	44	0.067	0.28	0.26 0.3	44	6.14	101.8	99.9 103.6	Samples, Bay of Biscay
August	42	0.13	0.46	0.42 0.5	41	8.65	102.8	100.1 105.4	Samples, Bay of Biscay
September	20	0.11	0.76	0.71 0.81	20	2.48	109.5	110.5 108.4	Samples, Bay of Biscay
October	35	0.15	0.81	0.76 0.86	35	3.58	109.3	108.1 110.5	Samples, Bay of Biscay
November	10	0.15	1.04	0.95 1.13	10	2.36	112.7	111.2 114.2	Samples, Bay of Biscay

Table 2. Mean lengths/age. Eastern Atlantic and Mediterranean.

Age	Farrugia & R. Cabello, 2001	El-Kebir et al., 2002	Olafsdotir & Ingin., 2003	R-Marin et al., 2004	Santamaria et al., 2009
1					62.00
2					79.60
3			134.00		101.40
4	108.00	127.00	128.00	123.70	115.90
5	133.20	126.60	160.40	142.20	134.50
6	150.70	150.20	171.10	156.00	149.00
7	148.00	152.20	184.00	172.30	161.70
8	197.80	176.50	199.50	182.80	180.00
9	194.20	181.80	205.30	194.00	186.50
10	213.70	183.70	208.80	199.30	202.60
11	214.10	217.00	219.80	211.00	205.70
12	239.50	215.80	216.10	235.50	223.30
13	220.70		221.20	233.50	230.90
14	256.60	209.90	236.30	245.00	236.60
15	258.00		241.70	253.70	252.20
16		287.00	247.30	263.50	
17			265.00	267.00	

Table 3. Mean lengths/age. Eastern Atlantic and Mediterranean. ( ) number of samples.

Age	Cort, 1990/91	R-Marin et al., 2004	Santamaria et al., 2009
1	53.48		62 (23)
2	79.72		79.6 (33)
3	100.69		101.4 (27)
4	118.84	123.7 (1)	115.9 (35)
5	135.14	142.2 (1)	134.5 (18)
6	150.1	156 (2)	149 (13)
7	164.04	172.3 (2)	161.7 (5)
8	177.15	182.8 (10)	180 (5)
9	190.91 (23)	194 (7)	186.5 (2)
10	206.21 (24)	199.3 (17)	202.6 (5)
11	216.11 (38)	211 (16)	205.7 (11)
12	222.52 (21)	235.5 (9)	223.3 (21)
13	232.38 (21)	233.5 (11)	230.9 (14)
14	241.58 (19)	245 (12)	236.6 (12)
15	247.24 (21)	253.7 (13)	252.2 (4)
16		263.5 (9)	
17		267 (4)	

Table 4. Mean lengths at age (Cort, 1990; 1991).

Age	9	10	11	12	13	14	15
N	23	24	38	21	21	19	21
Int. conf. (95 %)	188	201	213	219	228	235	242
FL (cm)	191	206	216	222	232	242	247
Int. conf (95 %)	194	211	220	226	236	248	252

Table 5. Growth, age 0.

Easte Atl. & Medit.	**October**	**November**	**December**	**May (1 year)**	**June (1 year)**
Furn. & Dard. (1962)	33	41	45	-	52
Sara (1965) (1)	33	42	-	-	-
Scacc. et al. (1973)	33	-	-	-	-
Orsi R. et al. (1996-97)	32	42	45	-	52
Sant. et al. (2003)	39	47	-	-	-
La Mesa et al. (2005)	32	40	46	-	-
West Atl.					
Rivas (1954)	37	42	44	-	-
Math. & Sch. (1962)	37	41	43	52	-
Broth et al. (1983)	37	40	-	-	-

(1) Applying the length-weight relationship of La Mesa *et al*. (2005).

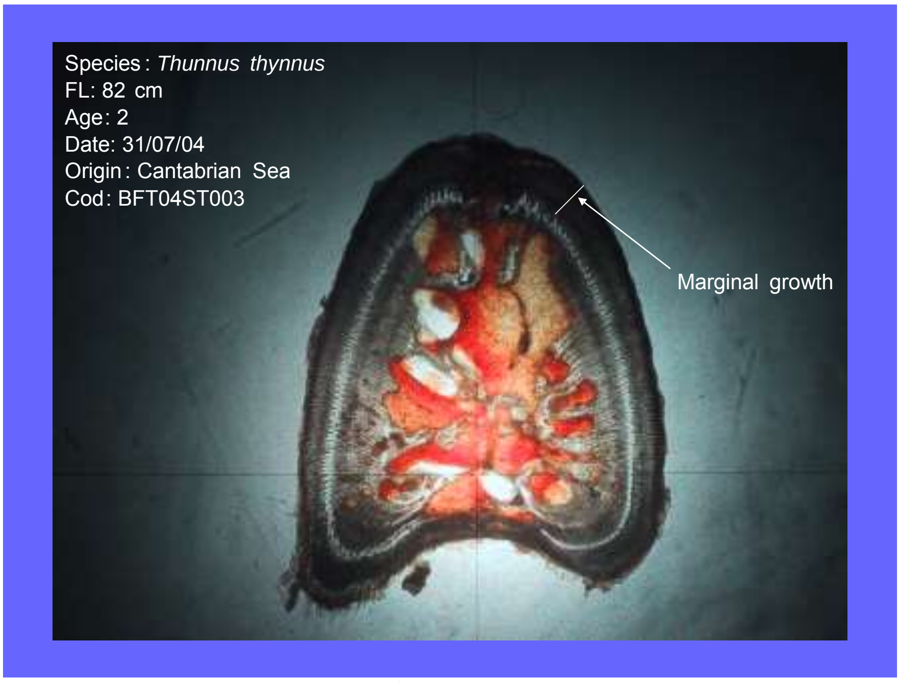

Figure 1. Marginal growth in a bluefin tuna aged 2 years.
(see text for explanation)

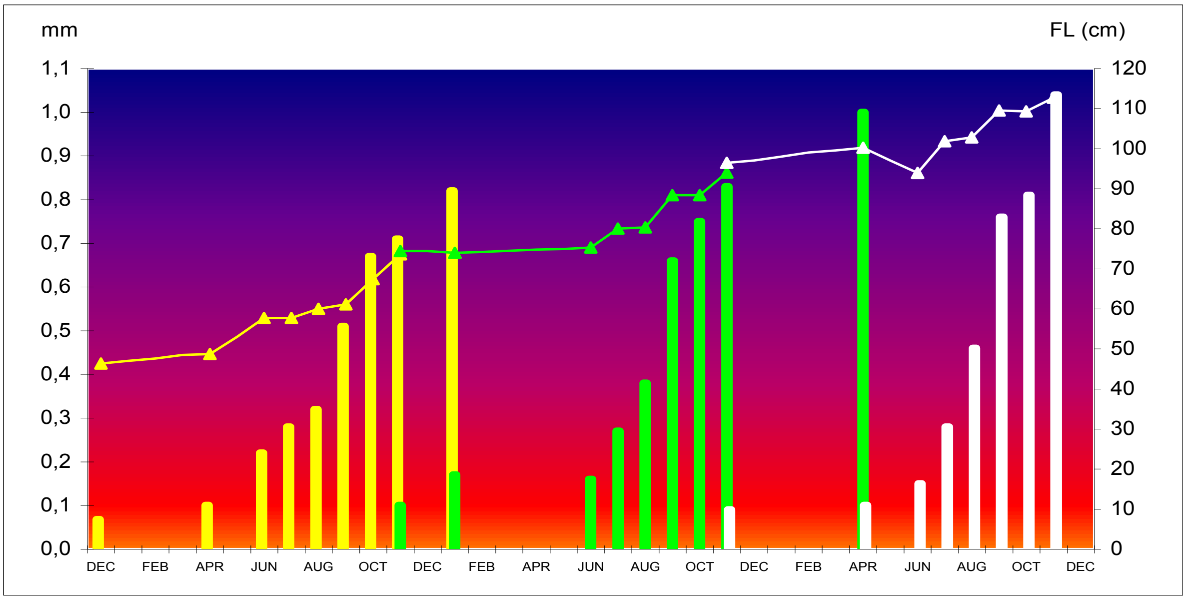

Figure 2. Monthly marginal increments for age groups 0 to 3 (bars, left axis) and lengths of the fishes corresponding to each (line, right axis).

(In yellow, ages 0 & 1; in green, ages 1 & 2; in white, ages 2 & 3)

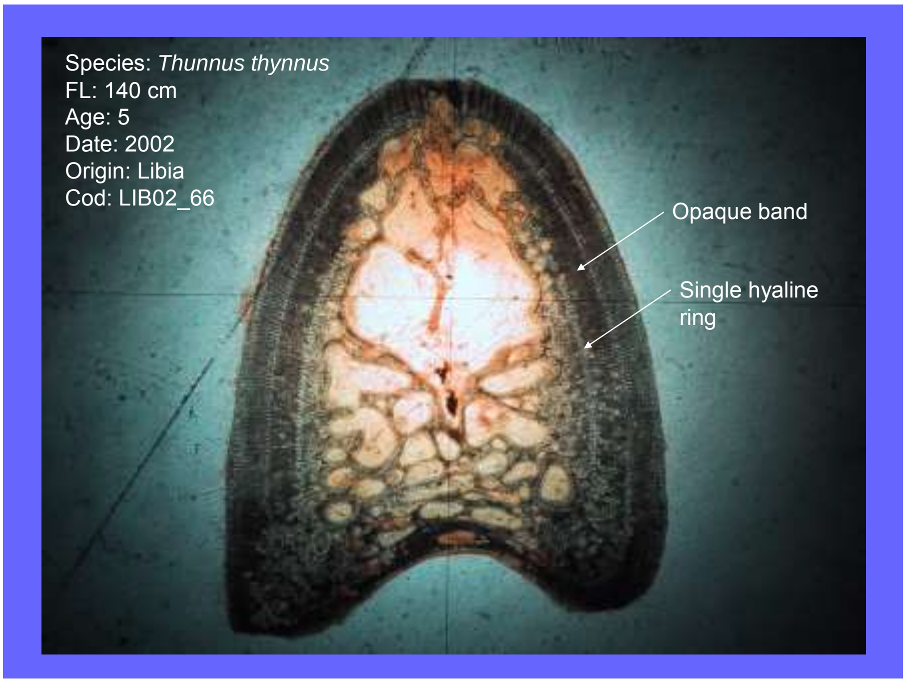

Figure 3. Bluefin tuna
(see text for explanation)

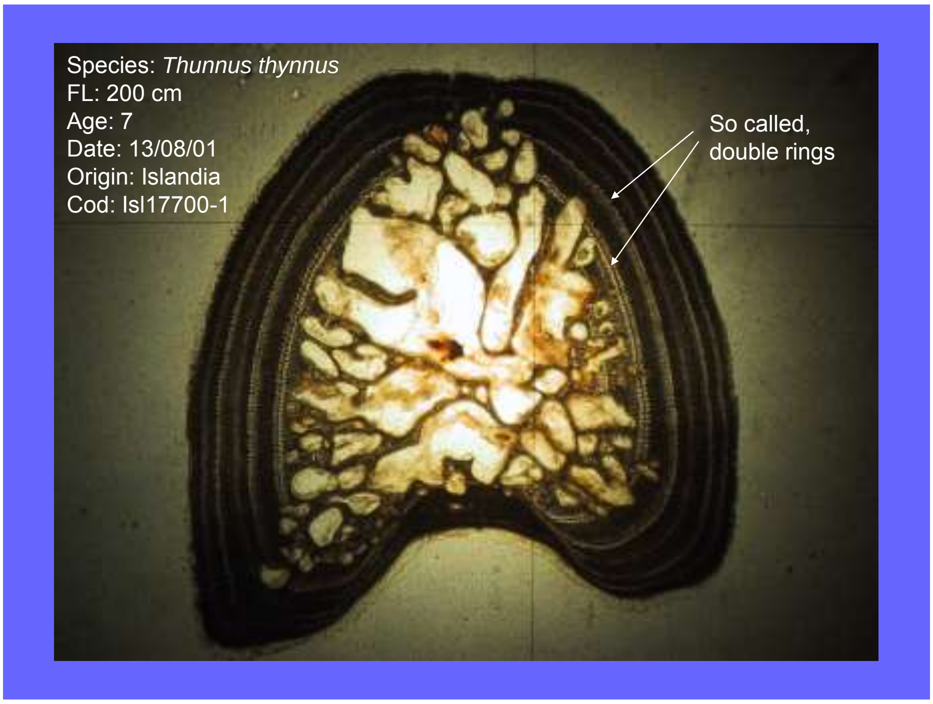

Figure 4. Bluefin tuna
(see text for explanation)

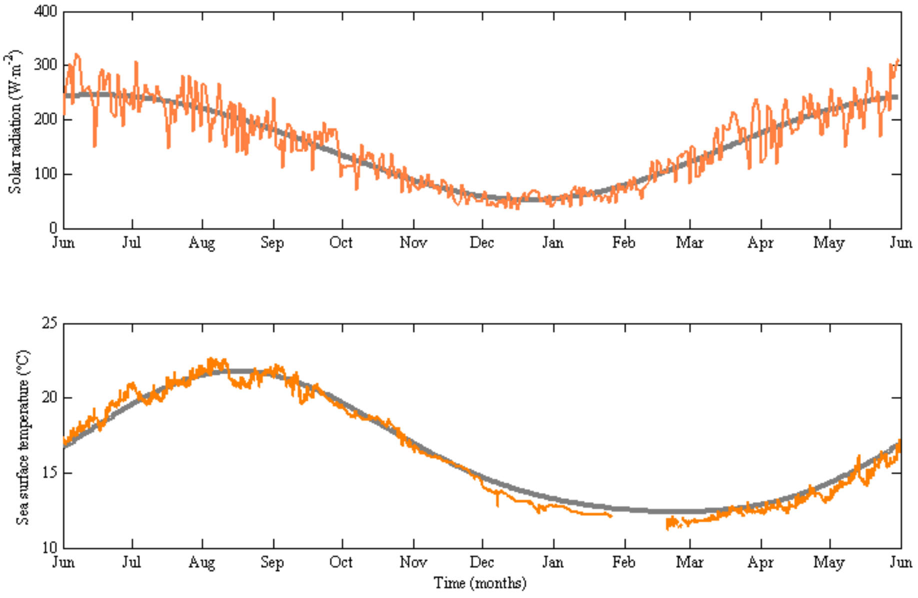

Figure 5. Surface sea water temperature bay of biscay (buoy, agl)

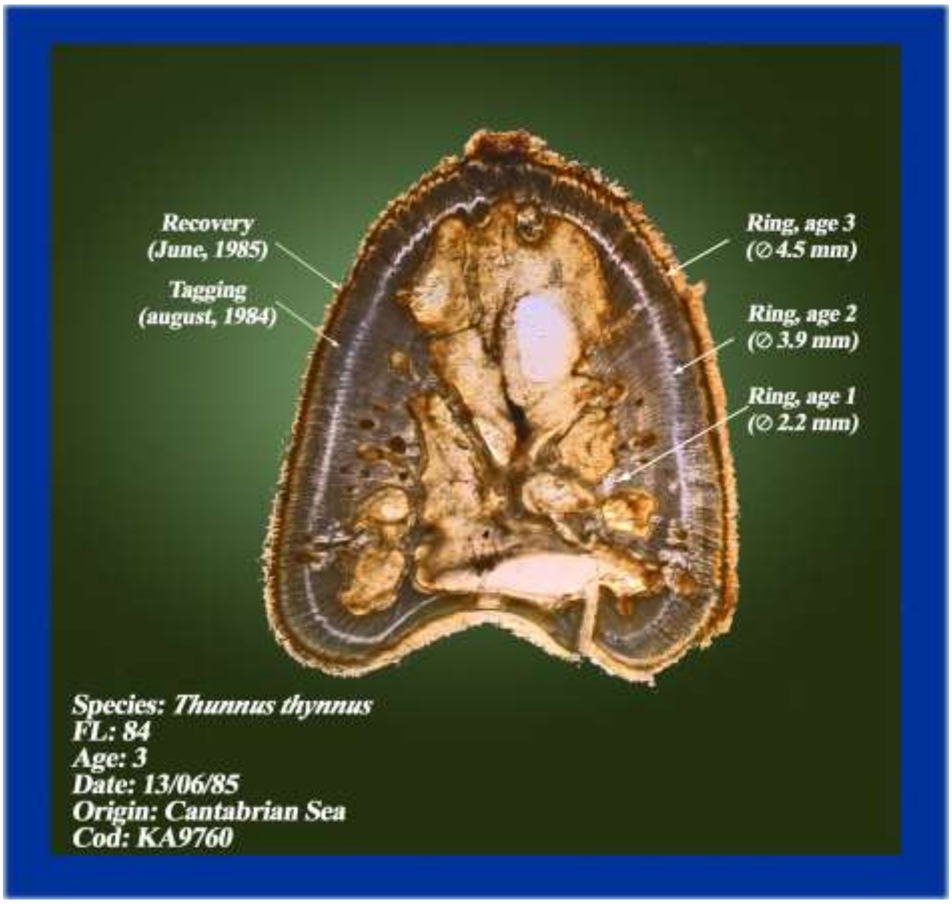

Figure 6. Bluefin tuna (conventional tag)
(see text for explanation)

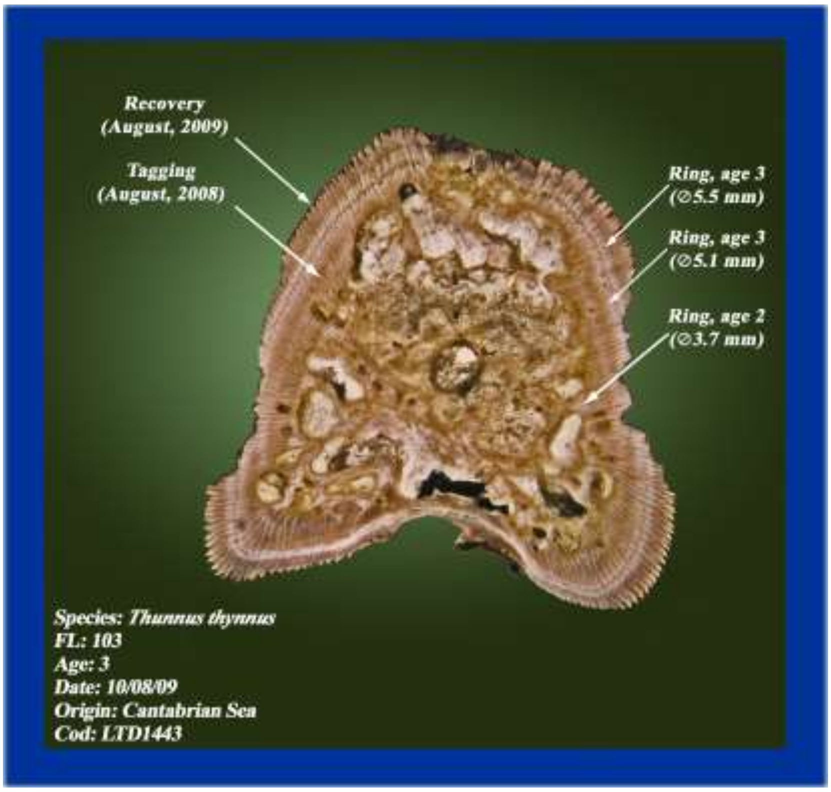

Figure 7. Bluefin tuna (electronic tag). Foto: AZTI
(see text for explanation)

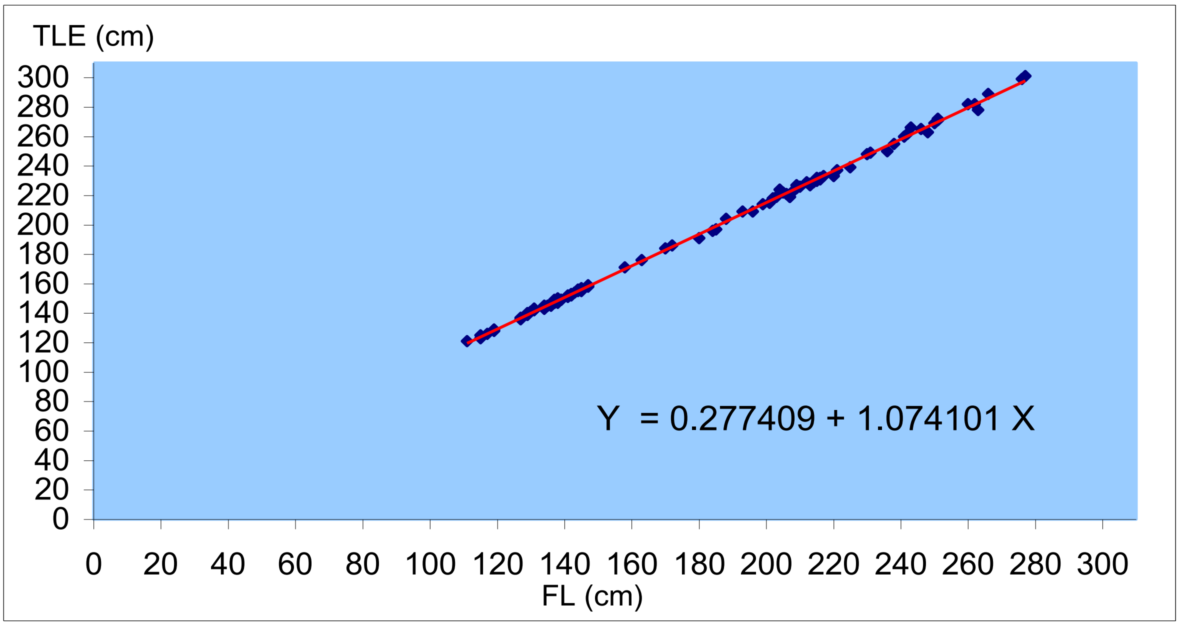

Figure 8. Relation between total length (TLE) and fork length (FL).
(R=0.99945; N=101)

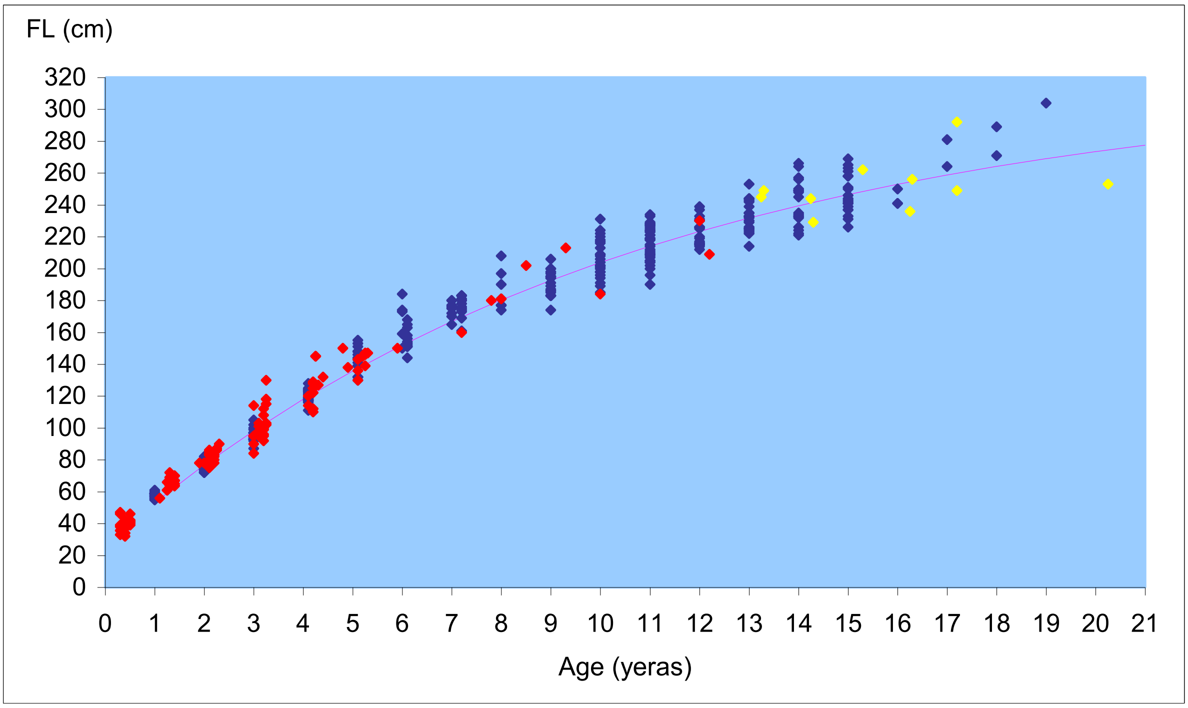

Figure 9. In blue (♦), spine readings; in red (♦), tag recoveries of the eastern Atlantic; in yellow (♦), tag recoveries of the western Atlantic.

Appendix 1. Spanish recoveries superimposed on the curve.

TAG	DATE_T	CUAD_T	LAT_T	LONG _T	FL_T (cm)	CUAD_R	LAT_R	LONG_R	FL_R (cm)	W_R (kg)	DATE_R	AT LIBERTY (years)	AGE_R	OBSERV ATIONS
AT 3070	01/08/ 1985	4	44,10	2,08	80	4	44,35	2,28	**86**	11	23/09/ 1985	-	**2.25**	< 2 months at liberty
AT 3138	02/08/ 1985	4	44,10	2,10	60	4	43,26	1,43	**79**	10	13/07/ 1986	1	**2.10**	-
AT 3311	06/07/ 1985	4	43,45	3,45	103	4	43,55	2,48	**118**	30	16/09/ 1985	-	**3.25**	< 3 months at liberty
AT 3584	10/08/ 1985	4	43,25	1,50	80	4	43,26	1,41	**98**	18	27/07/ 1986	1	**3.10**	-
AT 3611	10/08/ 1985	4	43,25	1,50	81	4	43,50	3,16	**136**	45	07/07/ 1988	3	**5.10**	-
AT 3680	30/09/ 1986	4	43,47	2,59	65	4	40,20	71,55	**147**	68	16/10/ 1990	4	**5.30**	-
AT 3869	30/09/ 1986	4	43,43	2,55	64	4	38,50	73,58	**114**	32	25/06/ 1988	2	**3.00**	-
AT 3878	30/09/ 1986	4	43,43	2,55	62	4	43,26	1,41	**95**	16	10/07/ 1988	2	**3.10**	-
AT 3884	30/09/ 1986	4	43,43	2,55	63	4	44,04	3,13	**90**	15	26/10/ 1987	1	**2.30**	-
AT 3930	30/09/ 1986	4	43,43	2,55	63	4	44,03	2,55	**64**	6	15/11/ 1986	-	**1.40**	< 2 months at liberty
AT 3991	30/09/ 1986	4	43,43	2,55	63	4	43,50	2,50	**67**	6	12/11/ 1986	-	**1.40**	< 2 months at liberty
EM 7221	05/10/ 1986	4	43,57	2,27	67	4	43,56	2,46	**92**	15	08/08/ 1988	2	**3.20**	-
EM 7320	06/10/ 1986	4	43,49	2,27	65	4	43,50	2,50	**67**	6	12/11/198 6	-	**1.40**	< 2 months at liberty

EM 7340	06/10/ 1986	4	43,49	2,27	66	4	43,27	2,47	**69**	7	25/10/ 1986	-	**1.30**	< 2 months at liberty
EM 7351	06/10/ 1986	4	43,49	2,27	62	4	44,39	2,26	**87**	-	18/09/ 1987	1	**2.25**	-
EM 7361	06/10/ 1986	4	43,49	2,27	64	4	43,54	2,57	**64**	6	13/11/198 6	-	**1.40**	< 2 months at liberty
EM 7431	06/10/ 1986	4	43,57	2,28	67	4	43,50	2,50	**67**	6	12/11/ 1986	-	**1.40**	< 2 months at liberty
EM 7458	07/10/ 1986	4	43,57	2,32	67	4	43,57	2,45	**72**	8	14/10/ 1986	-	**1.30**	< 1 month at liberty
EM 7465	07/10/ 1986	4	43,58	2,32	61	4	44,02	3,54	**77**	9	15/07/198 7	1	**2.10**	-
EM 7476	07/10/ 1986	4	43,58	2,32	65	4	43,50	2,50	**65**	6	12/11/ 1986	-	**1.40**	< 2 months at liberty
EM 7486	07/10/ 1986	4	43,55	2,31	64	4	39,20	73,45	**100**	18	13/08/ 1988	2	**3.20**	-
EM 8001	27/07/ 1988	4	43,55	2,44	59	4	44,30	2,35	**64**	8	20/10/198 8	-	**1.30**	< 3 months at liberty
EM 8015	27/07/ 1988	4	44,15	2,49	58	4	43,40	2,20	**61**	5	15/09/ 1988	-	**1.25**	< 2 months at liberty

EM 8137	31/07/1988	4	44,22	2,20	58	4	43,48	2,45	**83**	11	16/07/1989	1	**2.10**	-
EM 8168	31/07/1988	4	44,22	2,20	58	4	44,30	2,40	**70**	7	10/11/1988	-	**1.40**	< 4 months at liberty
EM 8182	31/07/1988	4	44,22	2,20	58	4	43,31	1,44	**78**	9	08/08/1989	1	**2.20**	-
EM 8242	31/07/1988	4	44,26	2,20	60	4	44,30	2,40	**70**	7	10/11/1988	-	**1.40**	< 4 months at liberty
EM 8286	31/07/1988	4	44,26	2,20	60	4	44,30	2,40	**70**	7	10/11/1988	-	**1.40**	< 4 months at liberty
EM 8321	02/08/1988	4	44,18	2,24	60	4	44,10	3,05	**77**	9	12/07/1989	1	**2.10**	-
EM 8322	02/08/1988	4	44,18	2,24	60	4	43,50	2,45	**84**	12	21/07/1989	1	**2.10**	-
EM 8431	02/08/1988	4	44,18	2,24	60	4	0,00	0,00	**85**	12	23/07/1989	1	**2.10**	-
EM 8566	04/08/1988	4	44,17	2,22	58	4	43,40	2,20	61	**5**	15/09/1988	-	**1.25**	< 2 months at liberty
EM 8639	04/08/1988	4	44,20	2,23	60	4	43,59	3,25	85	**12**	13/08/1989	1	**2.20**	-
KA 6043	27/08/1983	4	44,00	2,33	87	1	37,35	0,40	146	**53**	12/09/1986	3	**5.25**	-
KA 6096	27/08/1983	4	44,30	2,30	83	4	43,40	2,45	110	**25**	17/08/1985	2	**4.20**	Double tagging
KA 6097	27/08/1983	4	44,30	2,30	83	4	43,40	2,45	110	**25**	17/08/1985	2		Double tagging
KA 6800	21/08/1984	4	43,40	2,06	104	4	43,47	3,00	122	**-**	23/08/1985	1	**4.20**	-
KA 6916	22/08/1984	4	43,45	2,40	88	4	43,34	2,14	95	**16**	22/08/1985	1	**3.20**	-
KA 6924	22/08/1984	4	43,45	2,40	84	4	43,26	1,40	114	**27**	29/07/1986	2	**4.10**	-
KA 9694	26/08/1984	4	43,50	2,40	85	4	44,15	2,08	103	**20**	01/09/1985	1	**3.25**	-
KA 9713	26/08/1984	4	43,50	2,40	85	4	0,00	0,00	99	**18**	20/08/1985	1	**3.20**	-
KA 9730	27/08/1984	4	43,35	2,20	84	4	0,00	0,00	101	**-**	23/08/1985	1	**3.20**	-

KA 9754	29/08/1984	4	43,50	2,10	87	4	43,34	1,52	102	**20**	02/09/1985	1	**3.25**	-
KA 9760	29/08/1984	4	43,50	2,10	82	4	42,00	12,00	84	**13**	13/06/1985	1	**3.00**	-
KA 9779	29/08/1984	4	43,50	2,10	87	4	43,40	1,55	95	**16**	15/06/1985	1	**3.00**	-
KA 9834	29/08/1984	4	43,20	2,10	115	4	44,54	3,13	160	**-**	14/08/1988	4	**7.20**	-
NO 5817	17/08/1991	4	45,02	3,53	86	1	43,07	4,01	150	**57**	19/04/1994	3	**4.80**	-

NO 7368	28/08/1991	4	44,06	3,20	65	4	44,43	2,47	66	**6**	14/09/1991	-	**1.25**	< 1 month at liberty
NO 7646	22/10/1991	4	36,06	4,22	74	4	44,02	2,41	132	**48**	14/11/1994	3	**4.40**	-
PE 259	23/11/1983	4	37,08	1,48	32	4	37,08	1,48	32	**-**	27/11/1983	-	**0.40**	< 1 month at liberty
PE 273	23/11/1983	4	37,08	1,48	37	4	37,08	1,48	37	**-**	28/11/1983	-	**0.40**	< 1 month at liberty
PE 285	23/11/1983	4	37,08	1,48	40	4	36,59	1,52	40	**-**	28/11/1983	-	**0.40**	< 1 month at liberty
PE 313	16/08/1982	4	44,20	2,30	120	4	35,10	12,11	180	**113**	22/04/1986	4	**7.80**	-
PE 472	21/08/1984	4	43,40	2,06	112	4	43,48	2,55	125	**-**	22/08/1985	1	**4.20**	-
R 1697	19/08/1978	4	43,47	2,40	63	4	44,10	3,40	83	**12**	12/07/1979	1	**2.10**	-
R 6610	13/07/1977	4	33,40	8,10	56	4	28,00	12,00	78	**-**	28/05/1978	1	**1.90**	-
R 7388	13/09/1979	4	44,20	2,40	85	4	41,02	51,01	202	**150**	15/12/1985	6	**8.50**	-
R 8618	14/09/1979	4	44,30	2,40	62	4	43,58	2,48	83	**11**	04/08/1980	1	**2.20**	-
R 8629	14/09/1979	4	44,35	2,40	70	4	43,54	3,03	80	**10**	19/08/1980	1	**2.20**	-
R 8645	15/08/1980	4	43,44	2,56	80	4	43,32	2,26	101	**-**	20/07/1981	1	**3.10**	-

R 8657	15/08/1980	4	43,38	2,47	115	4	34,30	9,30	150	**-**	03/05/1983	3	**5.90**	-
R 8823	28/11/1983	4	37,08	1,48	38	4	37,07	1,49	41	**-**	12/12/1983	-	**0.50**	< 1 month at liberty
R 8841	30/11/1983	4	37,07	1,49	41	4	37,07	1,49	41	**-**	01/12/1983	-	**0.50**	< 1 month at liberty
R 9706	17/08/1980	4	43,40	3,15	60	4	40,36	72,03	112	**-**	13/08/1982	2	**3.20**	-
S 2258	10/08/1980	4	43,40	2,45	60	4	43,23	2,06	95	**17**	16/06/1982	2	**3.00**	-
S 2469	04/08/1980	4	43,55	3,03	80	4	39,40	72,40	99	**-**	10/08/1981	1	**3.20**	-
S 2479	04/08/1980	4	43,55	2,45	60	4	43,24	1,40	90	**17**	21/06/1982	2	**3.00**	-
S 2488	04/08/1980	4	43,55	2,40	60	4	43,55	2,45	75	**8**	27/07/1981	1	**2.10**	-
S 2496	04/08/1980	4	43,55	2,40	60	4	0,00	0,00	82	**12**	15/08/1981	1	**2.20**	-
S 5587	23/08/1981	4	43,26	2,26	78	4	43,46	2,45	96	**-**	15/08/1982	1	**3.20**	-
S 5598	23/08/1981	4	43,26	2,25	82	1	42,20	4,00	127	**-**	06/10/1983	2	**4.30**	-

S 5775	13/08/1982	4	44,30	2,25	60	4	36,50	7,40	139	**50**	12/09/1986	4	**5.25**	-
S 5805	13/08/1982	4	44,20	2,10	63	4	44,30	2,50	108	**23**	15/08/1984	2	**3.20**	-
S 5815	13/08/1982	4	44,20	2,10	62	4	43,50	2,54	128	**-**	22/08/1985	3	**4.20**	-
S 5837	13/08/1982	4	44,30	2,25	62	4	43,48	2,55	125	**-**	22/08/1985	3	**4.20**	-
S 5881	13/08/1982	4	44,30	2,25	60	4	37,22	3,27	184	**118**	03/06/1991	9	**10.00**	-
S 5896	13/08/1982	4	44,30	2,25	62	4	43,38	2,31	115	**28**	03/09/1984	2	**3.25**	-
S 5942	14/08/1982	4	44,20	2,10	78	4	36,20	5,30	143	**57**	24/07/1985	3	**5.10**	-
S 5964	14/08/1982	4	44,20	2,10	83	4	44,00	2,50	112	**-**	27/08/1984	2	**4.20**	-

TG 521	08/10/1986	4	43,56	2,27	66	4	43,45	2,40	145	**49**	24/08/1990	4	**5.20**	-
TG 575	08/10/1986	4	43,50	2,16	66	4	43,25	1,45	120	**31**	11/07/1989	3	**4.10**	-
TG 4792	04/08/1988	4	44,20	2,23	59	4	43,25	2,38	78	**10**	06/06/1989	1	**2.00**	-
TG 4854	04/08/1988	4	44,20	2,23	59	1	40,52	3,30	209	**130**	04/08/1999	11	**12.20**	-
TG 7111	04/08/1988	4	44,20	2,23	59	4	44,30	2,30	147	**55**	02/09/1992	4	**5.25**	-
TG 8114	01/09/1990	4	44,34	3,07	67	4	39,11	0,46	130	**40**	16/07/1994	4	**5.10**	-
TN 69	17/08/1990	4	44,41	3,20	65	4	39,20	0,20	138	**48**	17/05/1994	4	**4.90**	-
TN 348	25/08/1990	4	44,05	3,26	67	4	43,35	1,48	83	**10**	09/07/1991	1	**2.10**	-
TN 380	25/08/1990	4	43,59	3,53	66	4	36,14	6,07	181	**150**	03/06/1997	7	**8.00**	-
TN 411	25/08/1990	4	43,59	3,53	62	4	60,04	8,00	213	**172**	06/10/1998	8	**9.30**	-
VR 7323	24/11/1983	4	37,08	1,48	40	4	36,57	1,52	40	**-**	30/11/1983	-	**0.40**	< 1 month at liberty
VR 7326	24/11/1983	4	37,08	1,48	34	4	37,05	1,48	34	**-**	30/11/1983	-	**0.40**	< 1 month at liberty
VR 7337	24/11/1983	4	37,08	1,48	34	4	37,08	1,48	34	**-**	25/11/1983	-	**0.40**	< 1 month at liberty
VR 7349	24/11/1983	4	37,08	1,48	38	4	37,08	1,48	38	**-**	25/11/1983	-	**0.40**	< 1 month at liberty
VR 7401	25/11/1983	4	37,09	1,48	40	4	37,09	1,48	40	**-**	27/11/1983	-	**0.40**	< 1 month at liberty
VR 7443	25/11/1983	4	37,09	1,48	41	4	37,09	1,48	41	**-**	28/11/1983	-	**0.40**	< 1 month at liberty
VR 7484	25/11/1983	4	37,09	1,48	42	4	37,09	1,48	42	**-**	28/11/1983	-	**0.40**	< 1 month at liberty
YF 969	25/08/1990	4	44,00	3,37	65	4	43,34	1,49	86	**13**	17/07/1991	1	**2.10**	-
YF 992	25/08/	4	44,00	3,37	64	4	43,29	1,37	79	**10**	18/07/1991	1	**2.10**	-

	1990													
YF 3661	14/10/1989	4	43,50	3,17	70	4	44,25	2,30	129	**41**	04/08/1992	3	**4.20**	-
YF 3816	17/08/1990	4	44,41	3,20	62	4	43,27	1,47	78	**9**	27/07/1991	1	**2.10**	-
YF 5433	14/10/1989	4	43,50	3,17	70	4	43,25	1,40	103	**21**	13/07/1991	2	**3.10**	-
YF 5893	18/08/1990	4	44,13	3,21	60	4	43,29	1,51	77	**10**	02/07/1991	1	**2.10**	-
YF 6023	18/08/1990	4	44,11	3,11	62	4	44,02	3,05	79	**10**	15/07/1991	1	**2.10**	-
YF 6934	25/08/1990	4	44,03	3,30	60	1	38,10	1,30	230	**-**	04/06/2001	11	**12.00**	-
YF 6942	25/08/1990	4	44,03	3,30	63	4	43,48	2,17	145	**58**	23/09/1993	3	**4.25**	-
YF 6954	25/08/1990	4	44,03	3,30	64	4	44,10	3,13	77	**10**	15/07/1991	1	**2.10**	-
YF 6960	25/08/1990	4	44,03	3,30	62	1	44,18	2,20	130	**42**	05/09/1992	2	**3.25**	-
YF 6984	25/08/1990	4	44,03	3,30	64	1	44,18	2,20	145	**-**	19/09/1993	3	**4.25**	-
YF 6988	25/08/1990	4	44,03	3,30	62	4	43,26	1,46	80	**10**	08/07/1991	1	**2.10**	-
YF 6997	25/08/1990	4	44,03	3,30	63	4	43,20	1,40	80	**10**	13/07/1991	1	**2.10**	-
YF 7552	18/09/1994	4	39,30	0,12	30	4	39,10	0,07	33	**1**	09/10/1994	-	**0.30**	< 1 month at liberty
YF 7584	24/09/1994	4	39,30	0,12	34	4	39,32	0,13	39	**1**	02/10/1994	-	**0.30**	< 1 month at liberty
YF 7593	24/09/1994	4	39,30	0,12	30	4	39,39	0,04	36	**1**	30/10/1994	-	**0.30**	< 2 months at liberty
YF 7595	24/09/1994	4	39,30	0,12	36	4	39,09	0,04	38	**1**	02/10/1994	-	**0.30**	< 1 month at liberty
YF 7615	24/09/1994	4	39,30	0,12	38	1	40,28	0,51	46	**-**	25/10/1994	-	**0.30**	< 1 month at liberty
YF 7617	24/09/1994	4	39,30	0,12	38,0	4	39,40	0,04	47	**2**	26/10/1994	-	**0.30**	< 1 month at liberty
ES 6086	22/10/1994	4	39,33	0,01	39	1	40,02	0,06	42	**1**	01/12/1994	-	**0.50**	< 2 months at liberty

ES 6008	15/10/1994	4	39,35	0,07	38	1	39,54	0,05	46	**2**	01/12/1994	-	**0.50**	< 2 months at liberty
ES 6135	29/10/1994	4	39,33	0,01	37	4	39,40	0,10	39	**1**	02/12/1994	-	**0.50**	< 2 months at liberty
ES 1859	30/10/1994	4	37,07	1,46	40	4	37,10	1,40	42	**-**	03/12/1994	-	**0.50**	< 2 months at liberty
ES 1922	02/11/1994	4	37,04	1,47	40	4	37,30	1,20	40	**1**	03/12/1994	-	**0.50**	< 2 months at liberty
ES 2028	08/10/1997	4	39,36	0,04	30	4	44,20	2,48	56	**4**	28/07/1998	1	**1.10**	-

Appendix 2. Recoveries of the western Atlantic superimposed on the curve.

REG. NUMICCAT	TAG	DATE_T	LAT._T	LONG._T	FL_T (cm)	LAT._R	LONG._R	FL_R (cm)	W_R (kg)	DATE_R	AT LIBERTY (years)	AGE_R	OBSERVATIONS
6715	D-006205	22/07/1965	73, 26 W	39, 22 N	81.28	42, 43 N	70, 25 W	256	397	09/09/1979	14	**16.3**	LJF
51073	H-075281/H-075282	22/08/1978	71, 22 "W	41, 00 N	80	41, 15 N	69, 15 W	**244**	232	28/08/1990	12	**14.25**	**TLE (262)**
91735	H-055672	16/07/1976	75, 30 W	36, 50 N	106	43, 10 N	70, 09 W	292	353	26/07/1990	14	**17.2**	FL
132422	H-075400	28/06/1980	75, 38 W	36, 35 N	86	42, 50 N	70, 40 W	**229**	177	18/09/1991	11	**14.3**	**TLE (246)**
179323	H-042942/H-042943	16/07/1974	73, 39 W	39, 59 N	53	41, 32 N	69, 40 W	**236**	263	16/08/1989	15	**16.25**	**TLE (254)**
240965	M-002407	07/09/1967	72, 06 W	40, 38 N	76.2	42, 20 N	70, 30' W	**253**	272	19/08/1985	18	**20.25**	**TLE (272)**
243591	H-070598/H-070599	03/07/1977	75, 22 W	37, 20 N	78	42, 18 N	70, 25 W	**245**	333	17/08/1988	11	**13.25**	**TLE (264)**
262243	R-086654	13/08/1985	71, 00 W	41, 00 N	101.6	42, 40 N	70, 30 W	249	220	03/09/1995	10	**13.3**	FL
267757	H-073108	03/07/1977	75, 30 W	37, 11 N	79	43, 22 N	69,49 W	249	299	22/08/1992	15	**17.2**	FL
351006	H-006915	21/07/1966	73, 34 W	39, 52 N	78.74	41, 51 N	70, 26 W	262	329	11/09/1979	13	**15.3**	LJF