Back-calculation of length at age of Atlantic bluefin tuna (*Thunnus thynnus*) based on dorsal fin spine annuli



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AIMS

i) To estimate back-calculated lengths at age of Atlantic bluefin tuna (ABFT) (*Thunnus thynnus*) for obtaining new **growth parameters**, including lengths at young ages.

ii) To improve the knowledge of the fish´s **growth at early ages**. The measurements of the first annuli are needed to estimate the age of larger ABFT, due to the first annuli disappears because of the nucleus vascularisation.

iii) To **compare the growth pattern** obtained here with those of previous studies.

What is back-calculation?

Procedure for estimating **fish length at an earlier time** on the basis of measurements of calcified structure size and fish length (Francis, 1990). This methodology has strong resemblance to the study of tree-ring structures. Some main assumptions have to be fulfilled for validating back-calculation (Francis, 1990): i) the assumed time of formation of the mark (annulus) is correct (e.g. to show that there is a season of the year in which the spine forms a translucent edge); ii) the back-calculation function relates accurately fish length to spine size for each fish; iii) the size of the spine mark is the same as the size of the spine at the time the mark was formed (i.e. no deformation of the spine).

MATERIAL & METHODS

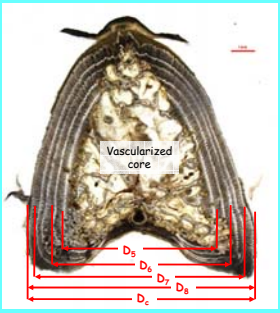
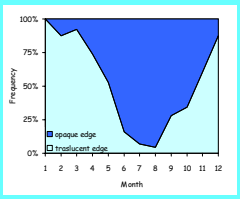


Fig. 1. Spine section of *T. thynnus* showing how to measure the translucent band diameters

• **Sampling: 2680** ABFT were sampled from port landings of different fisheries from the East Atlantic stock that includes the Mediterranean Sea (Atlantic, n=2078; Mediterranean, n=602) over 21 year period from 1990 to 2010 (including some samples from 1984) and covering as much as possible the whole length range and all months.

• **Age** was estimated by counting translucent bands (annuli) of the spine sections (**Fig.1**). The procedure for preparation, age interpretation, and measurements of spine sections described by Rodriguez-Marin *et al.* (2011) was followed.

• **Seasonality at annuli formation**. The monthly proportion of edge type indicated an annual periodicity in the formation of the translucent bands and showed that the translucent band occurs from September to May (Luque *et al., under review*).



• **Fish length - spine radius relationship**. Two fits were performed for **2668** pairs of values available, following two models:

(1) **linear** regression: SFL = a + bR (2) **power** regression: SFL = a R^b

where SFL = straight fork length when ABFT was caught (cm), a, b = parameters of the regression function and R = spine radius when the specimen was caught (mm) (Dmax/2).

• **Back-calculated lengths** were obtained using the two following methods recommended by Ricker (1992):

(3) **Fraser-Lee**: SFLi = a + (SFLc – a)(Ri / Rc) (4) Body Proportional Hypothesis (**BPH**): SFLi = SFLc (a + b Ri) / (a + b Rc)

where SFLi = straight fork length when spine radius was Ri (cm), SFLc = straight fork length when caught (cm), Ri = spine radius of the i-th ring of the spine (= Di/2) (mm), Rc = spine radius when caught (= Dc/2) (mm), a, b = parameters of the linear regression (1).

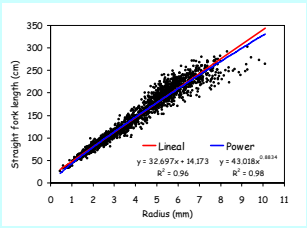
Three **scenarios** were finally used:

- A: linear SFL-spine regression model (1) with the BPH back-calculation equation (4);
- B: power SFL-spine regression model (2) with the Fraser-Lee back-calculation equation (3);
- C: power SFL-spine regression model (2) with the BPH back-calculation equation (4).

• **Von Bertalanffy growth parameters** (von Bertalanffy, 1938) were estimated from observed and back-calculated lengths at age, by applying a nonlinear regression using sequential quadratic programming (SPSS 15.0).

RESULTS & DISCUSSION

1. Fish length - spine radius relationship



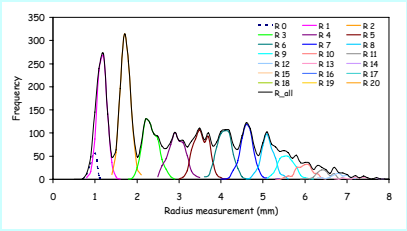
The lineal and power models showed good fit, although the **power** was slightly better.

The power model was also used in the ABFT back-calculation study of Santamaria *et al.* (2009).

2. Frequency distribution of annuli

• The distribution of each presumed annuli is **unimodal**, increasing the overlapping with age, and corresponding to a mode of the distribution of all the annuli combined.

• A mode was also observed before the first annulus, corresponding to a non-annual increment.



3. Back-calculated lengths

Values of 5455 back-calculated SFLs were obtained from 2280 specimens. The big amount of back-calculated SFLs from young age classes (> 400 values by age class in the range of 1 to 7 years) suppose a **valuable** source of **information** on the **growth at early ages**. Back-calculation allows obtaining a large amount of information on growth of each hard part analyzed (several back-calculated lengths at age) compared to the direct age estimation (one length at age).

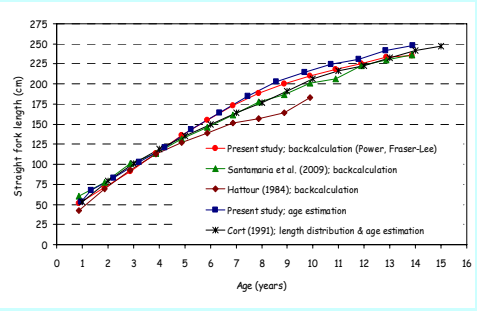
4. Growth pattern

• **Similar** mean back-calculated SFLs at age were observed among the **three scenarios** (only slight differences of ~ 1-2 cm at age).

• **Similar** growth pattern was obtained by **back-calculation** and by **direct age estimation**. Only differences lower than one age class were observed after age 9, where fewer samples were available.

• **Similar** overall growth pattern among the present **back-calculation** study and that of Santamaria *et al.* (2009) was obtained, with differences of around 1 age class at ages older than 6 years. Hattour (1984) showed a much slower growth pattern from age 6.

• In comparison with the currently adopted growth pattern for the **assessment** of the eastern Atlantic and Mediterranean ABFT management unit (Cort, 1991), a **similar** overall growth pattern was observed, with differences of around one age class between the ages 6 and 10.



5. Growth parameters

Author	Method		Hard part	Area	Sampling period	Linf	k	t_0	n	Data for obtaining parameters
Present study	**Back-calculation**	**(Power, BPH)**	**Spine sections**	**East Atlantic & Mediterranean (western)**	**1984,1990-2010**	**352.71**	**0.085**	**-0.824**	**2280**	**Length-age data**
Present study	**Back-calculation**	**(Power, Fraser-Lee)**	**Spine sections**	**East Atlantic & Mediterranean (western)**	**1984,1990-2010**	**356.29**	**0.083**	**-0.842**	**2280**	**Length-age data**
Santamaría *et al.* (2009)	Back-calculation	(Power, BPH)	Spine sections	Mediterranean (central)	1998-2005	368.54	0.070	-1.630	228	Mean length at age
Hattour (1984)	Back-calculation	(Linear, Lea)	Otoliths	Mediterranean (central-south)	1979-1983	330.00	0.095	-0.366	-	Mean length at age
Cort (1991)	Length distribution & direct age estimation		Spine sections	East Atlantic	1975-1986	318.85	0.093	-0.970	-	Mean length at age
Luque *et al.* (*under review*)	Direct age estimation		Spine sections	East Atlantic & Mediterranean (western)	1984,1990-2010	327.40	0.097	-0.838	3862	Mean length at age

Table shows estimated **growth parameters** fitting the von Bertalanffy model to back-calculated SFL at age, together with those obtained in previous literature. Although different growth parameters were obtained among studies, most of them showed the aforementioned similar growth pattern based on mean lengths at age findings, which are considered more suitable for growth comparison (Zivkov *et al.*, 1999). Furthermore, the inverse relationship between Linf and k has to be taken into account for growth parameters comparison. Thus, overall it is observed that those studies showing Linf ~ 320-330 cm, correspond to k values of ~ 0.095; for Linf ~ 355 cm, k are ~ 0.085; and for Linf ~ 370 cm, k is 0.070.

ACKNOWLEDGEMENTS

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