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UPDATING THE LENGTH AT AGE DATABASE OF BLUEFIN TUNA (*THUNNUS THYNNUS*) FROM THE EASTERN ATLANTIC AND MEDITERRANEAN SEA STOCK

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SUMMARY

This document describes the updated length at age database (DB) of Atlantic bluefin tuna, obtained from readings of calcified structures (i.e., fin spines and otoliths). The previous version of the DB (2022) was updated using recent age adjustments criteria and also with the addition of samples (N =13 566). Samples range from 1984 to 2023 and originate from three sources: IEO (Spanish Institute of Oceanography), GBYP (Great Bluefin Tuna Year Program) and SABS (St. Andrews Biological Station). It includes mostly specimens caught in the Eastern Atlantic, i.e., east of 45º W. However, it also includes specimens captured in the Western Atlantic, a large proportion of which have been shown to have an eastern genetic signature. Preparation of calcified structures followed a standardized methodology and age estimates (calendar and biological age) were derived using updated annuli count to age conversion factors.

RÉSUMÉ

Ce document décrit la base de données actualisée sur la taille par âge du thon rouge de l'Atlantique, obtenue à partir de lectures de structures calcifiées (c'est-à-dire les épines des nageoires et les otolithes). La version précédente de la base de données (2022) a été mise à jour à l'aide de critères d'ajustement récents liés à l'âge et avec l'ajout d'échantillons (N = 13.566). Les échantillons couvrent la période allant de 1984 à 2023 et proviennent de trois sources : IEO (Institut espagnol d'océanographie), GBYP (Programme de recherche sur le thon rouge englobant tout l'Atlantique et SABS (Station biologique de St Andrews). Il comprend principalement des spécimens capturés dans l'Atlantique Est, c'est-à-dire à l'est de 45º O. Cependant, il comprend également des spécimens capturés dans l'Atlantique Ouest, dont une grande partie présente une signature génétique orientale. La préparation des structures calcifiées a suivi une méthodologie standardisée et les estimations d'âge (âge calendaire et âge biologique) ont été obtenues au moyen de facteurs de conversion actualisés du nombre d'anneaux par âge.

RESUMEN

Este documento describe la base de datos (BD) actualizada sobre la talla por edad del atún rojo del Atlántico, obtenida a partir de lecturas de estructuras calcificadas (es decir, espinas de la aleta dorsal y otolitos). La versión anterior de la BD (2022) se actualizó utilizando criterios de ajuste de edad recientes y añadiendo muestras (N = 13 566). Las muestras abarcan desde 1984 hasta 2023 y proceden de tres fuentes: el IEO (Instituto Español de Oceanografía), el GBYP (Programa de investigación para el atún rojo de todo el Atlántico) y la SABS (Estación Biológica de St. Andrews). Incluye principalmente especímenes capturados en el Atlántico oriental, es decir, al este de 45º O. Sin embargo, también incluye especímenes capturados en el Atlántico occidental, muchos de los cuales han demostrado tener una firma genética oriental. La preparación de las estructuras calcificadas siguió una metodología estandarizada y las estimaciones de edad (edad según año natural y biológica) se obtuvieron utilizando factores de conversión de edad actualizados a partir del recuento de anillos.

KEYWORDS

Age-length key; growth; bluefin tuna; direct ageing; otolith; fin spine

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1. Introduction

The annual program of the International Commission for the Conservation of Atlantic Tunas (ICCAT) for the study of ABFT has contributed to the collection of samples and has enabled the development of direct age estimation in a coordinated manner in laboratories on both sides of the Atlantic.

The use of calcified structures to obtain age estimates was validated for otoliths, by Neilson and Campana (2008), using bomb radiocarbon dating. Whereas spines were indirectly validated, by comparing age estimates from paired structures (i.e., otolith vs. spine age estimates), for age estimates of specimens under 14 years old (Rodriguez-Marin *et al*., 2022b).

Multiple international ageing workshops (Luque *et al*., 2014; Busawon *et al.,* 2015; Rodriguez-Marin *et al*., 2020; 2021) resulted in the establishment for standardised preparation and reading protocols for each calcified structure. This standardization constituted the starting point for the present compendium.

An initial length at age database for the ABFT was presented in 2022 and was used as additional information (i.e., conditional age-at-length, CAAL) to the growth curve in the Stock Synthesis model (Rodriguez-Marin *et al*., 2022b). Since then, updated annuli count to age conversion factors were established from a Marginal Increment Analysis (MIA) study (Rodriguez-Marin *et al*., 2022a), resulting in updated biological/calendar age estimates. Furthermore, the database was also updated with additional samples/age estimates.

Recently Stewart *et al*. (2022), applied mixed effects growth models to back-calculated size at age data for ABFT and found no significant differences in growth between the two Atlantic stocks (Eastern and Western). Consequently, the data from both stocks were included in this study. The utilisation of these additional samples has the potential to enhance assessment models, including Management Strategy Evaluation (MSE).

The aim of this document is to give an overview of the available ABFT length at age data for the assessment of the Eastern Atlantic and Mediterranean ABFT stock after the incorporation of new readings, updated age estimates and quality assurance and control of the database.

2. Material and methods

The length at age database is based on the GBYP database presented in 2017 and improved by Rodríguez-Marin *et al.* (2022b). Age estimates can be derived from either of the calcified structures, however in cases where both otolith and spines were used otolith age estimates were used as it is deemed the most reliable structure. Similarly, in cases where age estimates were obtained from multiple readers, age estimate from the most experienced reader was selected.

The database structure consists of the following fields: “Source”, “Samp ID”, “ICCAT Sampling Area”, “Fishing Gear”, “Country Capture”, “Year Catch”, “Month Catch”, “SFL (cm)”, “SFL Type”, “RWT (kg)”, “RWT Type”, “Reading Lab ID”, “Structure Aged”, “Otolith band counting (including FAS corrected ages over 13)”, “Band Type Count” (Opaque or Translucent), “Reading Criterion”, “Light type”, “Edge type”, “Edge Confidence”, “Sample Readability”, “ID Reader”, “Ager Experience”, “Biological Age” (Result of the band counting after applying the biological adjustment), “Calendar year Age” (age after applying the calendar year adjustment), “Prob (East)” (Probability of being from the East stock).

The length at age data included otolith samples collected in the management area west of 45 degrees W. A large proportion of them show an eastern genetic signature, but some samples lack stock identification information. The samples were provided by: 1) CN Spanish Institute of Oceanography – CSIC (IEO, 60%), 2) ICCAT – GBYP (GBYP, 38%) and St. Andrews Biological Station – DFO (SABS, 2%, All these samples, although captured in the western Atlantic, have an eastern genetic signature).

Spines (n = 8 406) were read by experts according to Luque *et al*. (2014) criteria. Historical sampling (1984-1996) was included after a diagnosis of paired age agreement (Rodriguez-Marin *et al*., 2022b). Spine age estimates remained identical to previous iteration of the DB, however for specimens with paired structures spine age estimates were substituted by otolith age estimates.

The analysis of otoliths yielded a total of 5 160 samples. It was developed following two standardized protocols: Busawon *et al*. (2015) and Rodriguez-Marin *et al*. (2020). Fish Ageing Services (FAS) aged 4000 otoliths samples however calibration exercises found a bias between FAS age estimates and other age estimates. This was corrected using a correction factor (Rodriguez-Marin *et al.,* 2021). In addition, band counts were age-adjusted in accordance with the protocol described in Rodriguez-Marin *et al*. (2022a) to determine biological and calendar age estimates. This adjustment criterion was not applied to yearlings (lower than 44 cm SFL) caught between June 1st (spawning date) and December 31stas it is not necessary.

Natal Origin, obtained from 2017 data, was not updated. The cut off for eastern stock assignment was set at 70% probability.

Outliers were filtered out by interquartile range applied by Calendar year age. Only a 1% were excluded. No bias by reader, reading data or reading Criterion were detected.

3. Results and discussion

Spines analysed in this study were collected from the East management area between 1984 and 2013 (see **Table 1** and **Figure 1**) with the majority of these specimens being captured in the Bay of Biscay. In the case of otoliths, 2011 is effectively the beginning of the series, with the highest numbers recorded in the 2000s decade, due to the GBYP sampling in most geographical areas of distribution of the eastern stock.

Sizes analysis (**Table 2**) showed a size range from 19 to 299 cm, exhibiting adequate representation across all size classes from 30 to 270 cm. Most samples were collected from the East Management area and had adequate size and area representation for both structures. However, otolith samples collected from central Atlantic and western areas exhibited a greater degree of dispersion across size classes. In a cohort analysis using only readings from otoliths, the 2003 cohort appears to be well represented and is shown to be an exceptional year class, as highlighted in various bluefin tuna group documents (**Figure 2**).

It is important to improve the information on the age structure of both management units, East and West in order to better the management of the stocks. Representative sampling of the population is an essential part of this process. However, the complex migratory pattern of ABFT is a challenge to the sampling process. Currently, GBYP has been the only contributor to provide a significant number of samples with national institutions (e.g., IEO, SABS…) contributing to a lesser extent. The results show that sampling has been representative across size classes and areas. However, it is important to maintain or expand the level of sampling to better characterize age structure of the management units.

Age estimates can either be derived by direct ageing or epigenetic ageing. However, until the latter is fully implemented, direct aging is the only option to examine growth of ABFT. Although, the results show adequate representativeness gaps still exist in the data. Methodologies, such as a combination of direct and inverse ALK (Hoenig *et al.,* 2002, Anon., 2018), should be further explored to cover incomplete data (i.e., when not all ages or sizes are covered in a single year) in order to obtain catch at age (CAA) for virtual population analysis (VPA). Alternatively, one could use the age error matrix derived from the current database in the SS model.

Limited efforts have been made to link stock identification of aged samples. Thus far, 852 (0.06%) samples have been examined and the results showed that 230 samples captured in the West management area were reassigned to the East stock, while a mere 23 samples have been transferred from the East to the West. Since 2017, GBYP's natal origin methods have evolved and improved. Further efforts are needed to obtain a more complete stock identification of aged samples. This will improve the data entered into the SS3 models and assist with MSE scenarios.

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Table 1. Number of spine and otolith readings of Atlantic bluefin tuna by year and ICCAT sampling areas.

	Spines				Otoliths								
Year	**BF54 (E-Atl)**	**BF58 (E-Atl)**	**BF59 (Med)**	**Total**	**BF50 (W-Atl)**	**BF51 (W-Atl)**	**BF52 (W-Atl)**	**Central Atl**	**BF53 (E-Atl)**	**BF54 (E-Atl)**	**BF58 (E-Atl)**	**BF59 (Med)**	**Total**
1984	42	156		198									
1985	577			577									
1986	541		1	542									
1987	398			398									
1988	505			505									
1989	231			231									
1990	270	75		345									
1991	314			314									
1992	245		2	247									
1993	251			251									
1994	206			206									
1995	230		2	232									
1996	348			348									
1997	376			376									
1998	374			374									
1999	162			162									
2000	196			196									
2001	169			169									
2002	170			170									
2003	101		52	153									
2004	187		52	239									
2005	208	144	100	452									
2006	92			92						1			1
2007	96		82	178									
2008	97	29	260	386									
2009	122		81	203									
2010	122	44	96	262		2	2		1		36		41
2011	138	36	274	448	10	23	5			65	178	388	669
2012	83	14	46	143	12	12	17		7	37	172	349	606
2013			9	9	19	3	24	5	41	103	82	181	458
2014					39	21	20		54	150	36	86	406
2015					28	46	30	9	107	136	58	173	587
2016									7	84	70	925	1086
2017											56	832	888
2018											211	62	273
2019											54		54
2020											11		11
2021											14		14
2022											32		32
2023											34		34
Total	**6851**	**498**	**1057**	**8406**	**108**	**107**	**98**	**14**	**217**	**576**	**1044**	**2996**	**5160**

Table 2. Number of spine and otolith readings of Atlantic bluefin tuna by size range (10 cm) and ICCAT sampling areas.

	Spines				Otoliths								
SFL (cm)	**BF54 (E-Atl)**	**BF58 (E-Atl)**	**BF59 (Med)**	**Total**	**Central Atl**	**BF50 (W-Atl)**	**BF51 (W-Atl)**	**BF52 (W-Atl)**	**BF53 (E-Atl)**	**BF54 (E-Atl)**	**BF58 (E-Atl)**	**BF59 (Med)**	**Total**
10-20												1	1
20-30			2	2							1	22	23
30-40			99	99							2	23	25
40-50			13	13								109	109
50-60	267		55	322						12		44	56
60-70	933		73	1006						63		4	67
70-80	854		62	916						20	1	48	69
80-90	1096		57	1153						38		58	96
90-100	801		56	857						7	2	43	52
100-110	699	4	59	762						30	7	90	127
110-120	526	3	116	645						12	46	144	202
120-130	410	1	75	486						9	33	117	159
130-140	295	4	44	343						10	26	102	138
140-150	275	6	30	311						1	6	82	89
150-160	228	2	14	244		1					5	99	105
160-170	160	4	29	193	5		3		1	2	11	47	69
170-180	113	16	27	156	3		2		9	4	20	24	62
180-190	90	21	31	142	4	1	6	1	35	30	39	33	149
190-200	42	51	54	147		4	12		34	75	78	78	281
200-210	22	62	41	125	1	9	11	10	44	109	122	178	484
210-220	13	88	36	137	1	19	12	17	49	85	161	299	643
220-230	13	88	35	136		13	21	23	32	45	154	403	691
230-240	7	92	29	128		18	14	22	13	18	138	435	658
240-250	3	36	11	50		16	13	12		4	99	342	486
250-260	4	16	4	24		12	8	5		1	56	122	204
260-270		4	4	8		5	2	6		1	29	40	83
270-280			1	1		3	2	2			7	8	22
280-290						5	1				1	1	8
290-300						2							2
Total	**6851**	**498**	**1057**	**8406**	**14**	**108**	**107**	**98**	**217**	**576**	**1044**	**2996**	**5160**

1 Maps (temperate tunas)

1.1 BFT (*Thunnus thynnus)*

Name (UK): Atlantic bluefin tuna
Name (FR): Thon rouge de l'Atlantique
Name (ES): Atún rojo del Atlántico

Stocks: 2
Stat. areas: n/a
SA's: 19

SA codes by Stock

Stock code	SA code
BFT-E	BF53
	BF54
	BF57
	BF58
	BF59
	BF62
	BF65
	BF66
BFT-W	BF50
	BF51
	BF52
	BF55
	BF56
	BF60
	BF61
	BF63
	BF64
	BF67
	BF68

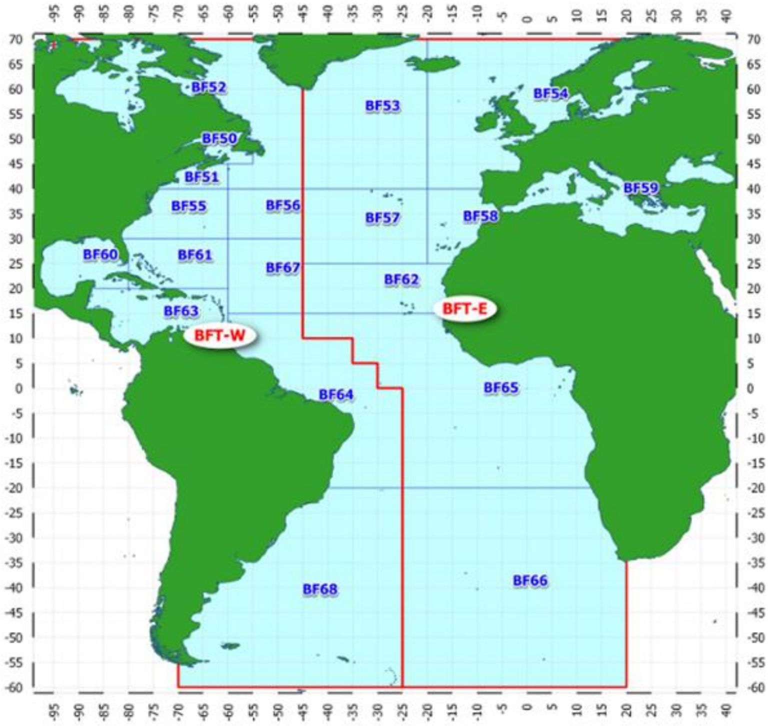

Figure 1. ICCAT sampling areas for Atlantic bluefin tuna.

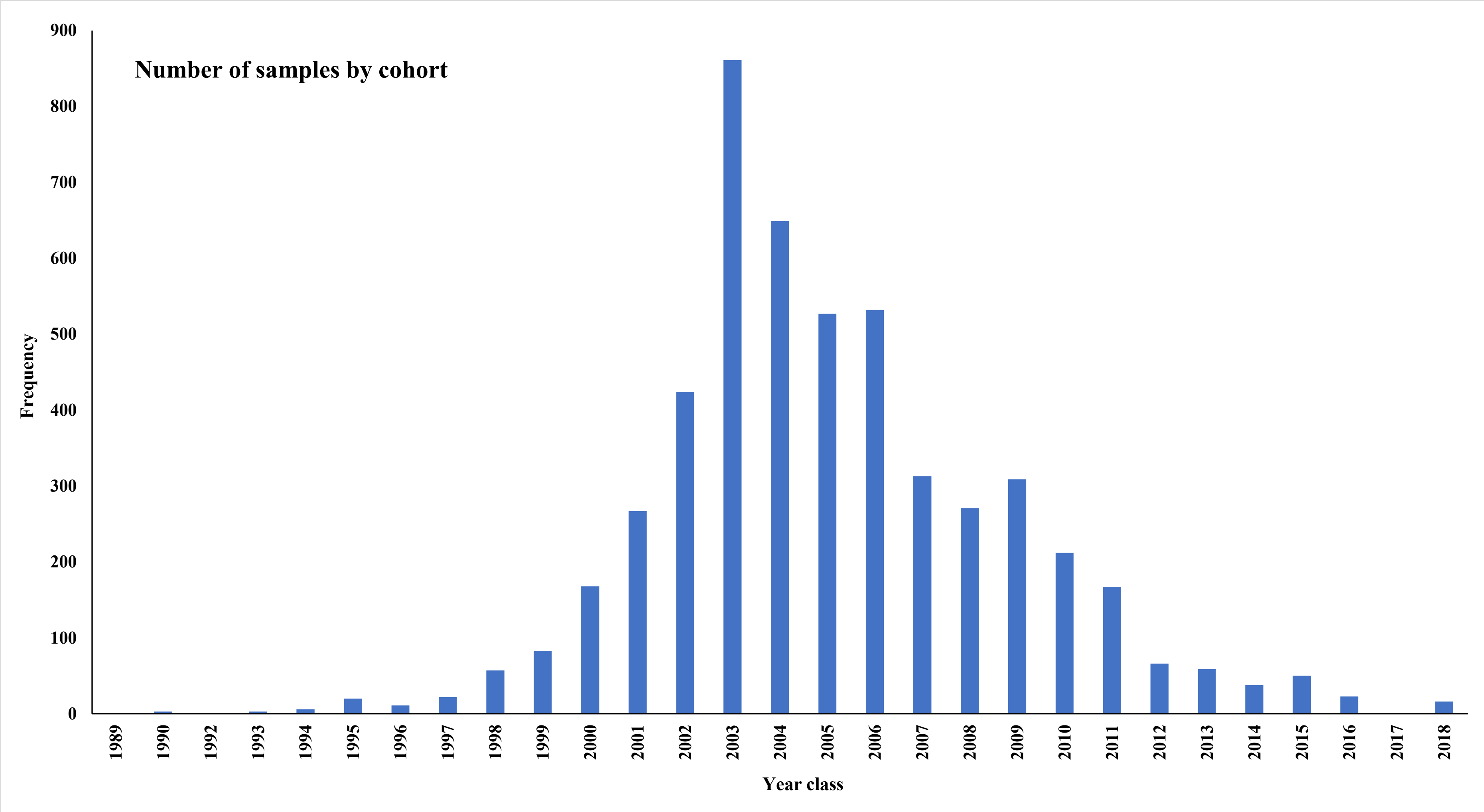

Figure 2. Number of Atlantic Bluefin tuna otoliths by year class by applying the new age adjustment criteria to otolith band counts.