CATCH STRUCTURE OF PURSE SEINE BLUEFIN TUNA FISHING IN THE ADRIATIC SEA: THE FIRST AGE FREQUENCY DISTRIBUTION ESTIMATE BASED ON A SPINE AGE-LENGTH KEY

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SUMMARY

This study analyses the size-age structure of bluefin tuna (BFT) juveniles captured by Croatian purse seine fleet in the central Adriatic in 2016 by applying the available age-length key (ALK) of spine radius. The results indicated a relatively normal size distribution for BFT captured in central Adriatic during purse seine BFT campaign in 2016, with a large mode of fish from 75 to 85 cm that appear to belong to the age 2 class. There is a predictable and stable relationship in the size-age grouping of BFT tuna captured in the central Adriatic. Considering that the majority of BFT juveniles spend their first years feeding together with a significant degree of size homogenization, the observed schooling pattern may facilitate legal purse seine fishing for caging in Adriatic.

RÉSUMÉ

Cette étude analyse la structure de l'âge par taille des juvéniles de thon rouge (BFT) capturés par la flottille croate de senneurs opérant dans l'Adriatique centrale en 2016 en appliquant la clé âge-longueur (ALK) disponible du rayon de l'épine. Les résultats ont indiqué une distribution des tailles relativement normale pour le thon rouge capturé dans le centre de l'Adriatique pendant la campagne de pêche à la senne ciblant le thon rouge en 2016, avec un mode important de poissons entre 75 et 85 cm qui semblent appartenir à la classe d'âge 2. Il existe une relation prévisible et stable dans le groupe de taille-âge du thon rouge capturé dans l'Adriatique centrale. Étant donné que la majorité des thons rouges juvéniles passent leurs premières années à s'alimenter ensemble avec un degré important d'homogénéisation des tailles, le schéma observé de regroupement en bancs pourrait faciliter la pêche à la senne légale aux fins de la mise en cage dans l'Adriatique.

RESUMEN

Este estudio analiza la estructura edad-talla de los atunes rojos juveniles capturados por la flota de cerco de Croacia en el Adriático central en 2016 aplicando la clave edad-talla (ALK) disponible del radio de la espina. Los resultados indicaron una distribución por tallas relativamente normal para el atún rojo capturado en el Adriático central durante la campaña de cerco dirigida al atún rojo en 2016 con una gran moda de peces desde 75 a 85 cm que parecen pertenecer a la clase de edad 2. Existe una relación predecible y estable en la agrupación talla-edad del atún rojo capturado en el Adriático central. Considerando que la mayoría de los atunes rojos juveniles pasan sus primeros años alimentándose juntos con grado importante de homogeneización de tallas, el patrón de agrupación observado podrá facilitar la pesca con cerco legal para su introducción en jaulas en el Adriático.

KEYWORDS

Atlantic bluefin tuna, purse seine, juveniles, age estimate, size-age grouping, Adriatic Sea

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1. Introduction

The Central Adriatic is an important fishing ground for small bluefin tunas (BFT) up to 3 years old (Tičina and Kačić, 1998). Consequently, the fish supplied to Croatian farms primarily originate from this area. In the late spring, these migratory groups of juveniles create aggregations or schools in the Jabuka Pit area. Their movements appear to be dictated by the location of their prey rather than by reproduction.

Adults enter the Adriatic Sea from the Mediterranean Sea in the second half of July and August, making this journey after the spawning season. This migratory group of adults (60 to 300 kg) arrive lean and hungry after spawning elsewhere in the Mediterranean, then aggregate in the northern Adriatic, following the ancient migratory routes along the eastern Adriatic coast (Morović, 1971). This comes as no surprise, since the region is rich in small pelagic fish, crustaceans and other invertebrates, all of which are favourite prey of bluefin tuna (Tičina and Kačić, 1998). Young-of-the-year (YOY), up to 20 cm were also recorded sporadically along the coast of the southern Adriatic during early September (Čikeš Keč *et al.,* 2015). In the fall they reach around 1 kg and they likely spend the winter in the vicinity of the southern islands (personal communication).

In Croatian fisheries, the purse seine (PS) is the principal fishing gear that constitutes around 90% of the total Croatian BFT catch. Captured fish are not landed but instead are kept alive. The transfer of live fish from the seine net to the towing cage is generally performed at the site of the catch, simply by joining both nets under the sea surface (Tičina *et al*., 2002). Several catches are pulled together for a single towing operation. Juvenile seed fish, means are kept alive and placed into floating cages (diameter 50+ m) for further growth up to three years, with the aim of maximal increase of biomass. Following farming, virtually the entire declare catch is then exported overseas (Katavic *et al*., 2016).

Despite numerous implications for fishery science and population dynamics, a comprehensive, scientifically rigorous studies on the length-age and length-weight (L-W) relationships of bluefin tuna captured in the Adriatic Sea remain sparse, fragmented and unbalanced. The majority of samples have been obtained from fisheries programmes targeting specific fractions of the population, with varying seasonal patterns, using several types of fishing gear.

Implementation of data collection efforts using stereoscopic camera systems (SCS) is critical for collecting reliable information on the number and size of fish transferred to cages (Katavic *et al*., 2016). The International Commission for the Conservation of Atlantic Tunas (ICCAT) implemented a programme using SC systems or alternative technologies that provide equivalent precision to cover 100% of all caging in order to reflect the number and weight of fish in each caging operation (Rec. 13-07).

Size-based age analyses of marine fish are becoming interesting methods for understanding the population structure and dynamics of the fish population. The availability of size–age data by area and time are of the utmost importance for compliance with ICCAT rules in managing catch quotas and planning bluefin tuna farming programmes. Due to management measures, the seasonal component in sampling, especially most younger stages, is critical for improvement and adjustment of management measures by fleet, time, gear and fishing areas. This study analyses the size structure of BFT captured in the central Adriatic during 2016 PS campaign by means of SCS and by applying the available age-length key (ALK) of spine radius to estimate the theoretical age distribution of catches.

2. Material and Methods

Catch composition analyses were based on the sampling of Eastern BFT captured by PS in the central Adriatic, where the majority of catches took place during the period from 26 May to 24 June 2016. Two campaign were undertaken. The first one at the beginning of bluefin tuna purse seine season from 27 May to 1 June enabled to inspect 10 catches, TH second one started from 20 June to 24 June obtaining only one catch due to bad weather.

All catches were recorded on field by SCS and analysed, 10 of which were transferred into rearing cages. One with undersized juveniles, when encircled and recognized to be under minimum size were released. Following capturing of the fish recording time lasted approximately 30 minutes supposing that minimum 20% of bluefin tuna captured will be recorded and measured for in length. Measurement units were standardized to centimetres for straight fork length (SFL). These catches are counted against Croatian quota allocated for purse seine fleet in 2016.

Based on the spine ALK estimate provided by the ICCAT/GBYP Report (2016), the age frequency distribution was structured.

3. Results

The size frequency distribution of BFT from SCS recordings was analysed and presented. An approximately normal distribution around the mean (77 cm SFL) was found, with the majority of fish in the size range 75 and 78 cm SFL (**Figure 1**). Some characteristic catches analysed showing a clear generation based distinction (**Figure 2**).

Further analyses based on spines ALK enable a theoretical estimation age composition of the population captured in the early PS fishing season. Age frequency distribution over nine catches showed a rather uniform age class 2 in the range from 86% to 96%. (**Figure 3**).

In a sample from 24 June, a mixed size structure was found, with an average SFL 100.9 cm. In the normal size frequency distribution, the age 3 class (>90 SFL cm) dominated, 20% of fish sampled were categorized as age 4 (>100 cm SFL), 5% as age 2, and 3% as age 5 (>120 cm SFL) (**Figure 4**).

The smallest fish estimated age 1 and/or young of the year (YOY) captured on 30th of May demonstrate clear homogeneity in size/age distribution. They were on average 54 cm SFL with a virtually absent share of older stages (**Figure 5**).

Comparisons of the average length at respective age of BFT at 1 to 3 years in the Adriatic and Mediterranean is shown in **Table 1**.

4. Discussion

There seems to be a predictable and rather stable relationship in the size-age grouping of the Eastern bluefin tuna juveniles (**Figure 1)**. Length frequency distribution indicating clear generation based distinction, outlining the fact that younger tunas are grouping within their own generations flock (**Figure 2**). Considering that the majority of bluefin tuna juveniles spend their first years feeding together, this enables fisherman to track the desired size class and to avoid undersized individuals. In view of the significant degree of size homogenization found in juvenile schooling, this can also facilitate legal purse seine fishing for caging. The observed schooling pattern, characterized by a significant degree of BFT size homogenization in the central Adriatic during the PS fishing season, indicated that the highest portion of fish captured and destined for caging in the size range between 70 and 85 cm SFL likely belong to age class 2 (**Figure 3**).

Length-based analyses of BFT tuna are becoming important methods for understanding of population structure, and may have many applications in fisheries assessment (Santos et al., 2002). Biomass from length obtained by SCS as a non-invasive methods of measurement is recommended by ICCAT rules in managing catch quotas and planning BFT tuna farming programme. However, it is also increasingly used Croatian mariculture practice as a means of determining the growth of fish famed in cages, and to calculate feed ratio accordingly.

In age estimate spine based ALK was applied due to its reduced variability in comparison to the very high variance in age length relationships determined from otoliths (ICCATT/GBYP, 2016). Even this ALK differs in size age composition, making tracking length at age quite difficult. Some smaller tuna, in the range from 60 to 64 cm SFL, obtained unusual ages (two years old), or these in the range from 90 to 94 cm SFL get two, three and four years respectively (**Figure 4 and Figure 5**). This may come either due to subjective factors (experience of readers) or due to age adjustments for the difference in the catch time. From the information available, BFT hatched in June reach about 4 kg in weight and 60 cm long after one year (Mather *et al*., 1995). After two years BFT in the Mediterranean is about 80, and with three years reach 100 cm (ICCAT/GBYP, 2016). This closely fits with the findings presented here (**Table 1**).

The count of annuli on hard fish structures may also be subjected to the various sources of errors due to the coalescence or the disappearance of the first marks or conversely to multiple markings due to migration patterns (Cort 1991). The variability in both length and age may also be further explained by the fact that BFT exhibit rapid growth during the early years of life up to full sexual maturity. Mather *et al.* (1995) found that eastern BFT length at maturity is about 110–120 cm and 30–35 kg in weight at approximately 4 years of age. Corriero *et al.* (2005) reported that 100% maturity was reached above 135 cm FL with a spine-based age estimate between 4 and 5 years. Difference in growth and growth rate variability could also be connected to the time of spawning and a range of environmental factors. Two important abiotic and biotic factors are temperature and food supply, which influence ecosystem functioning and thus the growth rate of fish (Rutherford and Houde, 1995). It is obvious that central Adriatic is inhabited with immature BFT during PS fishing season that last from 26 May to 24 June.

The present results should contribute to the proper management of BFT in the Adriatic Sea. Nonetheless, further research is needed to obtain finer details of Eastern BFT biological parameters. The best sample coverage occurred in May and June in the Adriatic, and the population underrepresented in relation to timing of BFT catches by other fishing gears should be investigated. Furthermore, in addition to estimating biomass from length observations, direct length-weight measurements in the field are required to give relationships based on stereoscopic camera recording and length measurements. Direct measurements, though time consuming, are required to revise and standardize the size-weight relationship used in the stereo-video algorithms. This would enable applicable, documented, and more precise procedures to fit the RWT - SFL relationship of eastern bluefin juveniles caught in the Adriatic Sea for farming.

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Table 1. Mean length at age of bluefin tuna juveniles based on the spines multi-year age length key from 11 catches obtained during purse seine campaign in central Adriatic 2016 in comparison with age-length data from Mediterranean Seas.*

Age estimate	*Adriatic*			*Mediterranean**		
	Mean length (cm, SFL)	*S. D.*	*Number*	*Mean length (cm, SFL)*	*S. D.*	*Number*
1	54.2	4.1	85	60.6	5.1	20
2	77.0	3.1	889	80.3	4.6	67
3	100.9	5.4	110	101.2	10.6	45

*Source: ICCAT/GBYP 2016.

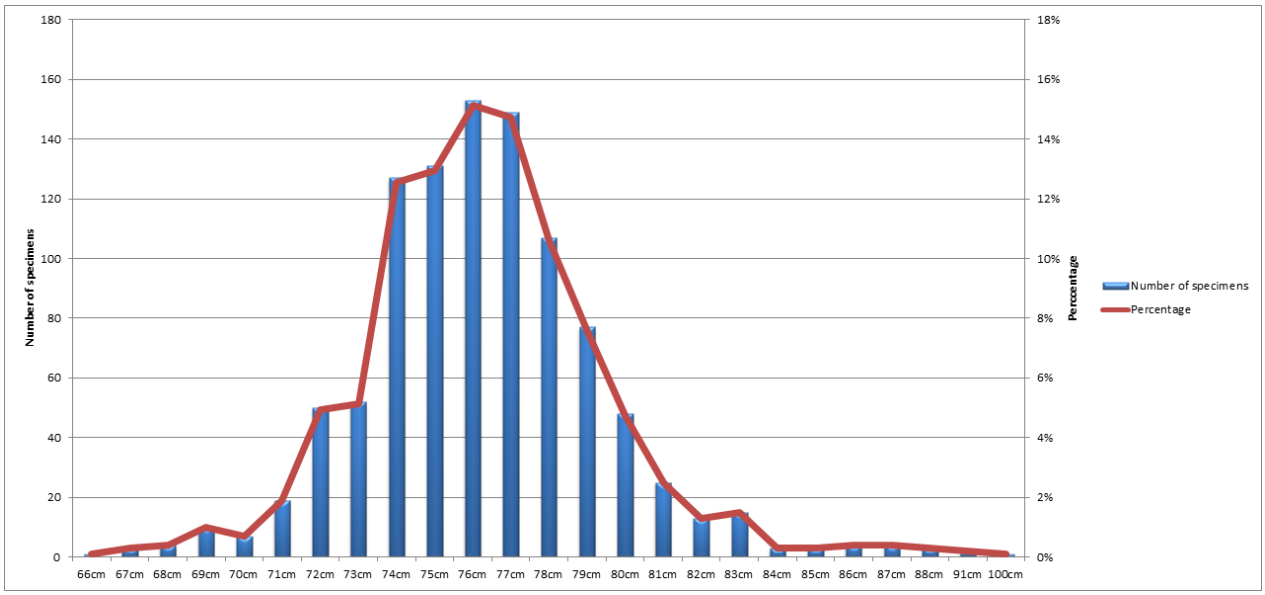

Figure 1. Length frequency distribution of eastern bluefin tuna captured and recorded by means of stereo camera in central Adriatic during 2016 PS campaign given for 9 individual catches analysed - size range of 1 cm Straight Fork Length (n =1011 specimens).

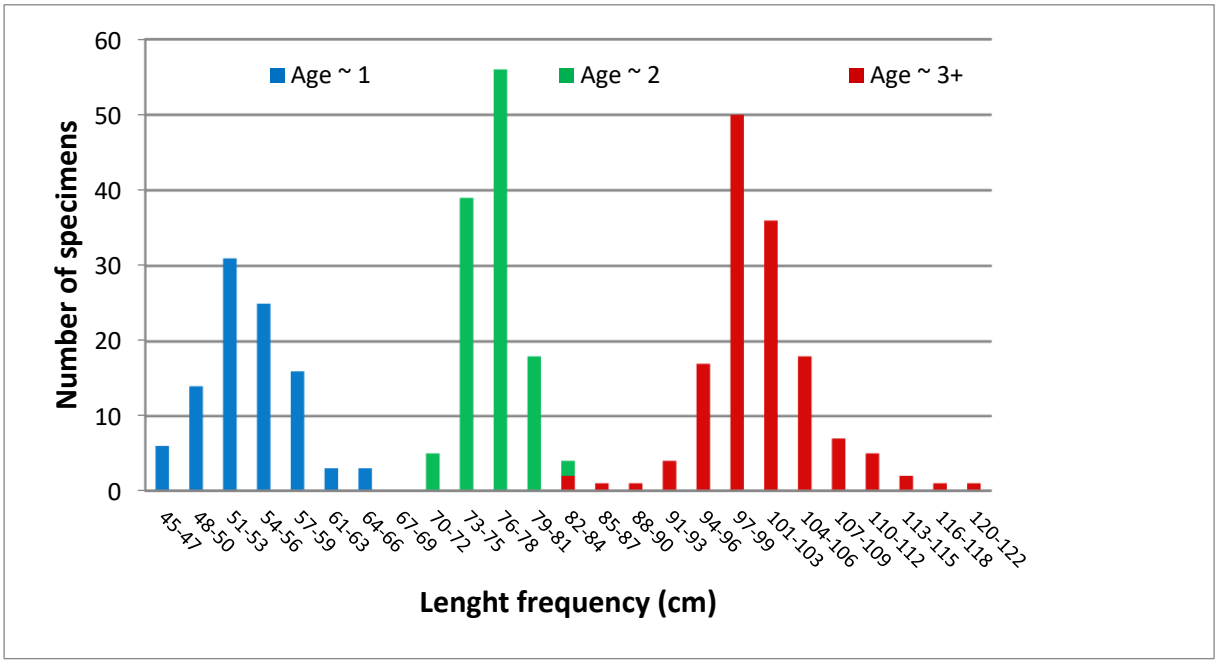

Figure 2. Length frequency distribution of bluefin tuna sampled by stereo camera in the central Adriatic during 2016 purse seine campaign in relation to the age estimated by the spines multi-year age length key (ICCAT/GBYP, 2016) (n=363 specimens).

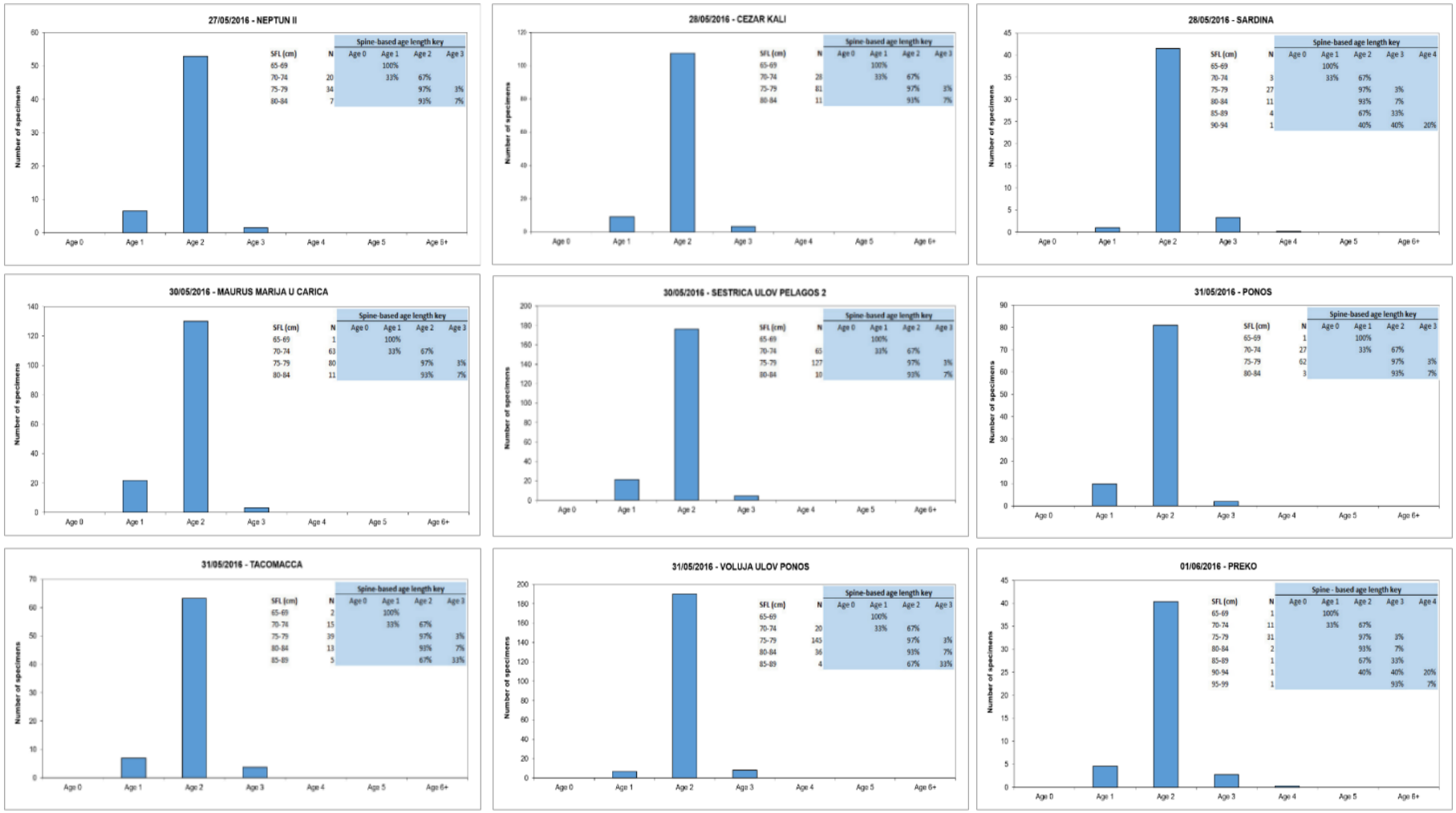

Figure 3. Age estimate based on spines multi-year age length key (ICCAT/GBYP, 2016) of nine (9) purse seine catches randomly selected during bluefin tuna fishing campaign from 27th of May to 1st of June 2016 in the central Adriatic.

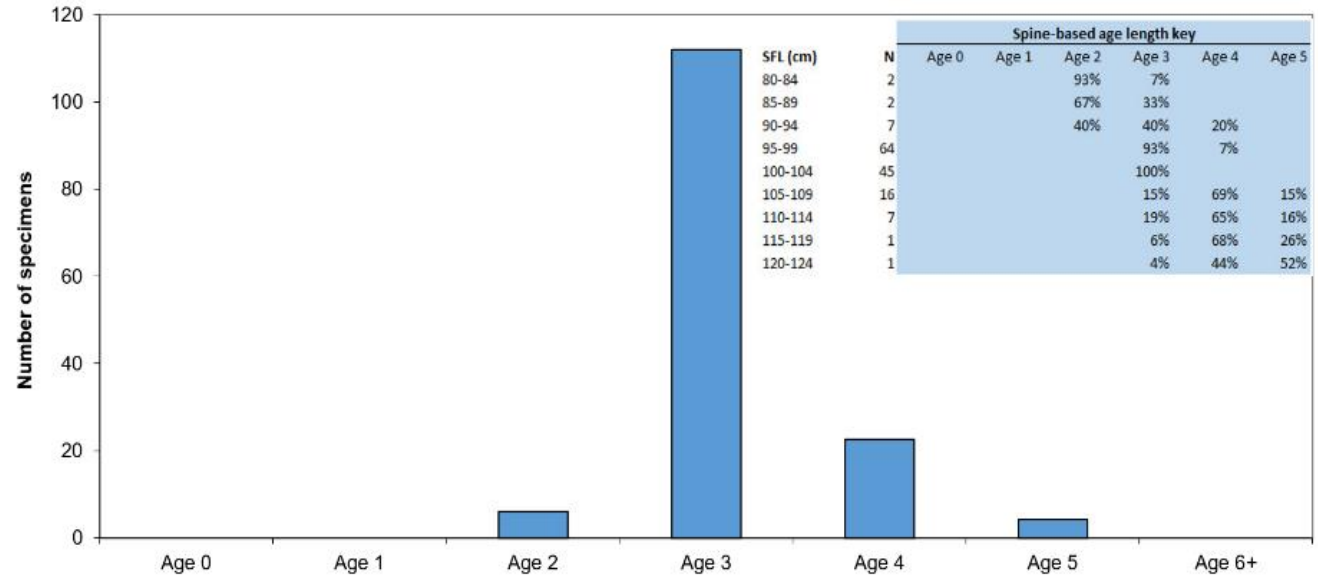

Figure 4. Age distribution of sampled advanced bluefin tuna juveniles in central Adriatic during 2016 purse seine campaign based on spines multi-year age length key (ICCAT/GBYP, 2016). n = 145 specimens; an average ± SD (straight fork length, cm) 100.9 ± 5.4.

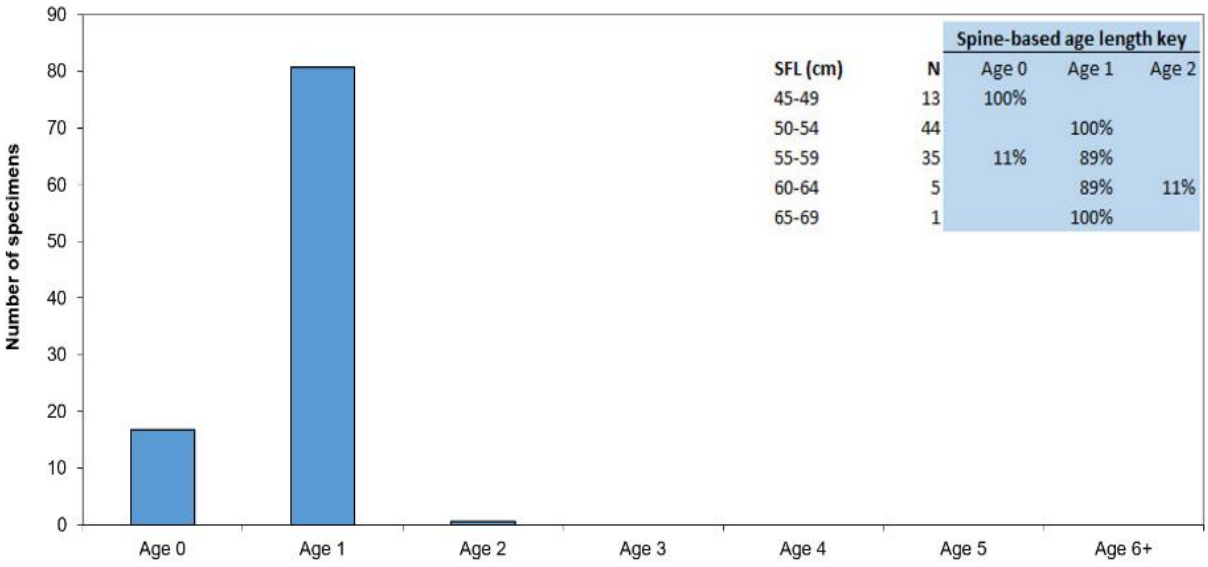

Figure 5. Age distribution of a young of the year and/or age 1-year class that were encircled and released after being recorded by stereo camera.
n =98 specimens; an average ± SD (straight fork length, cm) 54.2 ± 4.1.