SUMMARY PAPER

Estimating Age and Growth of Little Tunny, *Euthynnus alletteratus*, off the Coast of Senegal, Using Dorsal Fin Spine Sections

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ABSTRACT

Estimates of age were made from counts of growth bands on dorsal spine sections of 491 little tunny, *Euthynnus alletteratus*, captured off the coast of Senegal during 1979. Analysis of marginal growth bands (by month) indicates that these bands are probably formed during the cold season (November-May). Mean size at estimated age was determined for the first 8 yr of life. These results, though not validated, closely approximated other studies for young fish (estimated ages 1-3), but were highly variable for older age categories. The index of average percent error (*E*) for age nates from our study was 10.5% and infers good precision.

RÉSUMÉ

La determination de l'age de 491 thonines, *Euthynnus alletteratus*, a été faite par comptage des anneaux de croissance sur des coupes transversales du premier rayon de la nageoire dorsale. L'analyse mensuelle de la nature du bord externe des coupes, indique que les annuli (i.e., zones translucides) se formeraient au cours de la saison froide (novembre a mai). Les tailles moyennes correspondant aux ages de 1 a 8 ans sont données. Ces resultats, bien que non validés par d'autres methodes, sont tres voisins de ceux exposés dans d'autres travaux pour les ages de 1 a 3 ans; des différences non negligeables apparaissent cependant pour les poissons plus agés. L'index de pourcentage moyen d'erreur (E) entre les ages attribués par les deux auteurs est de 10.5% ce qui indique une bonne précision de la methode utilisée.

INTRODUCTION

Commercial tuna fisheries in the eastern tropical Atlantic seem to have reached their maximum sustainable yield for most species (ICCAT 1977-82). Thus, recent economic interest has developed for the less intensively fished little tunny, *Euthynnus alletteratus*, along the Atlantic coast of Africa.

The age and growth of little tunny has rarely been studied off the coast of Africa, except with the Petersen method (length frequency analysis) applied to a relatively small number of specimens (Postel 1955). Vertebrae have been used by Landau (1965) for age determination of little tunny from the Mediterranean Sea. More recently, Rodriguez-Roda (1979) used counts of growth bands on vertebrae to fit the von Bertalanffy growth model for this species off Spain. Cayré and Diouf (1981) analyzed dorsal spine sections to estimate age and growth of little tunny collected off the coast of Senegal. However, conclusions in that initial report were limited because of small sample size (100) and the restricted time of year (June-August) the data were collected. Therefore, we felt that increasing sample size and expanding the collection of samples to all months was warranted. The objectives of this study were to: 1) Estimate age of little tunny collected off Senegal by counting growth bands on sections of dorsal spines, 2) determine the time of band formation by analysis of marginal growth band spine sections, and 3) estimate the degree of precision (repeatability) of our counts of growth bands on spine sections.

METHODS AND MATERIALS

Little tunny were collected during 1979 at different commercial landings near Dakar, Senegal, along the Atlantic coast of Africa. We collected data on sex (i.e., males, females, and immature fishes), maturation stage, gonadal weight, fork length (FL), total weight, and obtained the first dorsal spine from each specimen. We attempted to sample all size classes for each sex during each month.

We used the first dorsal spines because they are easy to collect and were often used in many similar studies (Batts 1972; Cayré 1979). In addition, we previously reported (Cayré and Diouf 1981) that dorsal spines of little tunny are good structures to use as a source of age and growth information.

An Isomet[3] low-speed saw, with a circular diamond wafering blade, was used to cut three 450 μm thick serial cross sections from the lower portion of the first dorsal spine, near its condyle base. Three serial sections were cut in case the first was difficult to read or was broken. The sections were immersed in an alco-

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hol and water solution and observed in transmitted light with a binocular microscope equipped with an ocular micrometer. The following measurements (Fig. 1) were taken from each section using the method described by Cayré and Diouf (1981): 1) Spine diameter (d)—the distance between the outside margins of the spine just above the notch in the posterior face, and 2) diameter of growth band (d_i)—the distance from the outside spine margin through the spine center to the outside margin of each successive growth band.

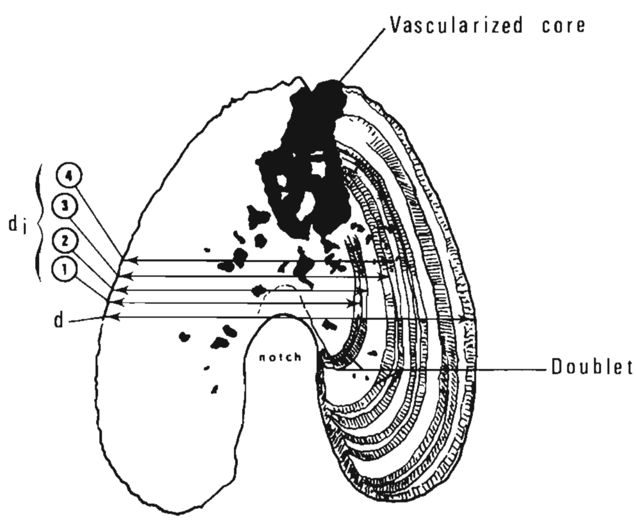

Figure 1.—Cross section of the first dorsal spine of little tunny. Measurements taken: spine diameter (d) and diameter (d_i)of translucent bands (1, 2, 3, 4). The vascularized core, notch, and bands interpreted as doublets (see text) are also shown.

Growth bands observed under the above optical conditions were distinguished by two types of alternating growth zonation; translucent zones, assumed to be indicative of slow growth, were separated by opaque zones, assumed to represent fast growth (see Glossary). We use the term annulus as synonymous with translucent zone (see Glossary). For purposes of assigning an age to each fish, we each read the most anterior of the three cross sections twice by counting translucent zones. When discrepancies occurred, the first section and the other two sections from the same spine were examined by us to arrive at a mutual estimate of age.

Antoine et al. (1983) used a series of coded descriptions of the types of growth bands observed on each section to document how different readers interpreted bands and assigned ages. This methodology was also adopted for our study. The precision (repeatability) of the counts of annuli (translucent zones) was assessed using the method described by Beamish and Fournier (1981). This method uses an index (E) to estimate average percent error:

$$E = \frac{1}{N} \sum_{j=1}^{N} \left[\frac{1}{R} \sum_{i=1}^{R} \frac{X_{ij} - X_j}{X_j} \right] 100 \qquad (1)$$

where N = number of fishes aged
R = number of times each fish was aged
X_{ij} = ith age estimate of the jth fish
X_j = average estimated age calculated for the jth fish.

The vascularized core (center) of little tunny spines increases in size and complexity with increases in the size and age of fish. In little tunny > 45 cm FL, early growth bands tend to be obscured because of the enlarged core (also see Antoine et al. 1983; Johnson 1983; Compeán-Jimenez and Bard 1983; Berkeley and Houde 1983); fish ≤ 45 cm FL were not affected. Therefore, we estimated the average location of the first annual mark (d_i) from young fishes and used these measurements to determine the number of bands obscured in larger fishes.

The relationships between R and fork length for each sex (male, female, and immature) and for total sample (all sexes combined) were determined with least square regressions and the degree of significance set at $\alpha = 0.05$.

The time of annuli formation was assessed by observing the type (translucent or opaque) and frequency of growth bands occurring on the outside margin of each section. This type of marginal growth (see Glossary) was difficult to determine because the truncated cone shape of sectioned spines caused problems with light diffraction. This difficulty was partially resolved by placing the largest section surface down before microscopic examination. In addition, distinguishing marginal growth was also enhanced by alternately switching the light source from transmitted to reflected light.

RESULTS

Monthly Sample Sizes

Dorsal spines were collected from 497 little tunny (26.4-86.0 cm FL). Cross sections of spines from 491 specimens (239 males, 232 females, 20 immatures) were used in the ageing analysis; six abnormally shaped spines were rejected. Monthly samples ranged from a high of 61 fish in March to a low of 13 fish in December (Fig. 2). Both sexes and the entire size range were well represented in monthly samples, except for the relatively narrow size range of fish collected in January and December (Fig. 2).

Characteristics of the Annulus

We define annuli as translucent bands but the quality of annuli varied considerably among individual fish, ranging from a very well-defined narrow band to a wide diffuse one. The description code we used (see Antoine et al. 1983) allowed us to note all these different types of annuli.

We defined and assumed an annual mark to be a fairly well identified and clear annulus which extends around the entire circumference of the spine. In addition, we often observed double bands (termed "doublets"), formed by two annuli separated by a relatively narrow opaque zone (compared with others on the same section) that tend to merge as they curve toward the spine core. We also considered these doublets as annual marks. Moreover, we also observed multiple bands and considered them as annual marks when the distance between them was less than the distance to the preceding and following bands.

Due to the complexity of the quality of annuli, a consultation between readers, in order to obtain a mutual interpretation of bands, was necessary for 30% of the spines (147 samples). After this mutual interpretation, an agreement was always reached.

Season of Annuli Formation

The highest percentage of marginal annuli (terminal slow growth) appears to occur from November to May (Fig. 3), suggesting that annuli are formed during this period. The seasonal occurrence of slow growth (Fig. 3) is inversely related to mean sea surface temperatures (i.e., slow growth appears to occur during periods of low temperatures).

Diouf (1980) reported that the period of maximum spawning for little tunny takes place from June to October. Thus, if annulus formation occurs in November-May, then the age at first annulus formation would be about 6 mo. The wide range in potential slow growth (November-May = 7 mo) makes it difficult to make definitive statements on the time of first band formation. Three females (Table 1) and two immatures, sampled during this period, had only one incomplete and one thin marginal annuli and were estimated to be 0.5 yr. These observations tend to support our statement on the period of the first band formation.

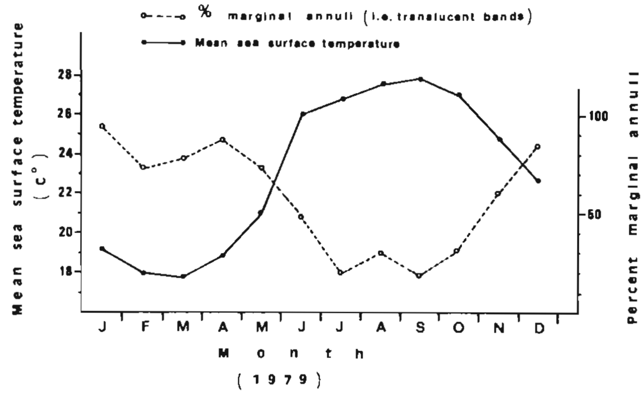

Figure 3.—Monthly mean sea surface temperatures off the Senegal coast in 1979 (solid line) and corresponding percentages of spine sections of little tunny caught off Senegal, 1979, showing a marginal translucent band (dotted line).

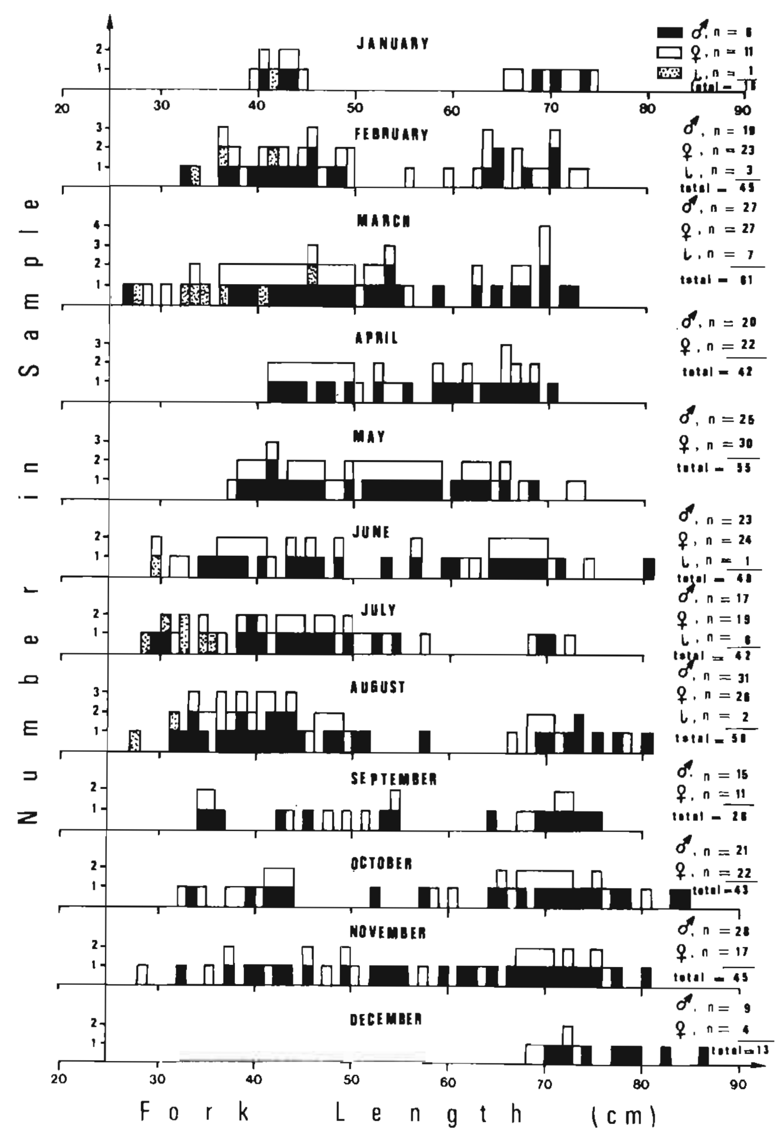

Figure 2.—Fork lengths of monthly samples of 491 little tunny caught off Senegal during 1979.

Table 1.—Total number of little tunny caught off Senegal by size interval (cm FL), number of fishes with obscured growth marks due to enlargement of the vascularized core, and correction rate for obscured growth marks.

Size interval FL (cm)	Total number of fishes	Number of fishes with obscured growth marks			Total correction rate (%)
		1 growth mark	2 growth marks	Total	
46-55	97	22	1	23	24.7
56-65	66	25	1	26	39.4
66-75	115	53	25	78	67.8
> 75	17	3	10	13	76.5
Total	295	103	37	140	47.5

Fish Size-Fin Spine Diameter Relationship

A significant linear relationship (Fig. 4) was found between spine diameter and fork length of female (r = 0.89), male (r = 0.90), and immature little tunny (r = 0.69). However, the small sample and restricted size range of immature fish make the results of this category tentative. A significant linear relationship was found between spine diameter and fork length of all samples (with all sexes combined). This relation was:

$$\text{FL} = 0.01456\,d + 16.215 \qquad (r = 0.907)$$

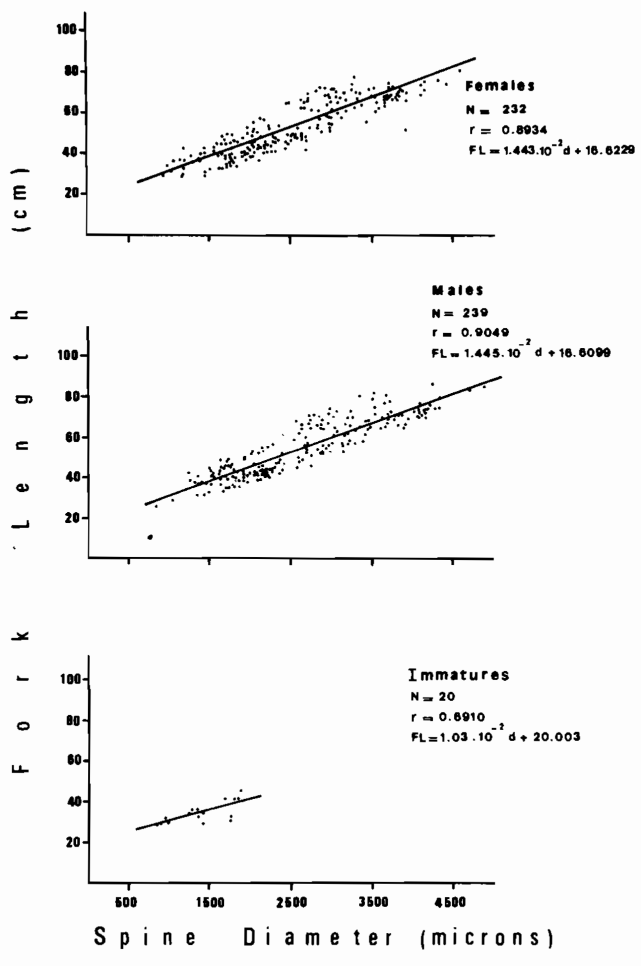

Figure 4.—Relationship between fork length (cm) and first dorsal spine diameter (microns), for females, males, and immature little tunny from Senegal.

where FL = fork length (cm)
d = first dorsal fin spine diameter (μm)
r = correlation coefficient.

Precision of Readings

The average percent error (E) of the counts of annual marks was 10.5%. Differences between our counts exceeded two annual marks for 8% of the samples.

Correction of Assigned Ages

We found that in little tunny < 45 cm FL, it was not necessary to correct for bands obscured due to enlargement of the vascularized core. However, in the 295 fish ≥ 45 cm FL, we had to estimate the number of obscured growth marks. The corrections, which did not exceed two growth marks, were applied to 140 fishes (Table 1). The number of growth marks obscured and needing correction increased with fish size.

Estimated Ages and Mean Fork Lengths

The ranges in mean fork lengths for estimated ages 0.5 through 8 yr were 33.2 to 80.2, 30.1 to 77.2, and 29.4 to 80.2 for males, females, and all samples combined, respectively (Table 2). Relatively small differences were observed for mean size at estimated ages between sexes (Table 2), and the combined sample (males, females, immature) illustrated in Figure 5 shows a progressive increase in mean size and variation about the mean as estimated age increases.

DISCUSSION

Two sources of bias in spine measurements appear to be a direct result of little tunny spine morphology. First, the spine sections were asymmetrical and this irregular shape would have influenced measurements of spine diameter (d) and diameter of annuli (d_i). Secondly, the tapering of the spine could have also affected these measurements. Both sources of bias were not considered to have a significant influence on spine measurements and if they occurred, they probably were consistent between size categories and sexes because of the strong relationship observed between fork length and spine diameter (Fig. 4). The strong relationship between fork length of little tunny and spine diameter also suggests that this structure would be appropriate for use in back calculation of previous growth history.

It was beyond the scope of this study to investigate the cause of annuli formation. The occurrence of maximum slow growth

Table 2.—Estimated ages, corresponding mean fork lengths, interval of fork lengths, and standard deviations (SD) for males, females, and total sample (males, females, immatures) for 491 little tunny caught off the coast of Senegal during 1979.

	Males				Females				Males, females, immatures			
Estimated age (yr)	N	Mean FL	FL intervals (cm)	SD	N	Mean FL	FL intervals (cm)	SD	N	Mean FL	FL intervals (cm)	SD
0.5	0				3	30.1	28.6-33.0	2.484	5	29.4	27.6-33.0	2.094
1	13	33.2	26.5-36.5	3.218	12	34.3	29.5-44.9	4.057	39	33.4	26.4-44.9	2.249
1.5	14	38.4	32.4-43.3	3.440	21	38.0	32.8-44.0	2.927	38	38.5	32.4-45.0	3.238
2	47	41.8	33.6-52.8	3.730	43	42.0	35.2-49.6	3.810	91	41.9	33.6-52.8	3.730
2.5	14	43.5	40.5-49.5	2.507	16	46.4	39.6-51.5	3.721	30	45.0	39.6-51.5	3.453
3	39	49.6	41.5-62.0	5.327	46	49.6	41.5-61.1	5.129	85	49.6	41.5-62.0	5.186
4	32	58.6	47.7-67.0	6.275	28	58.0	49.7-66.3	6.078	60	58.3	49.7-66.3	6.123
5	30	66.9	52.5-79.5	5.806	25	65.3	52.5-72.5	6.010	55	66.2	52.5-79.5	5.895
6	25	68.9	57.0-78.8	5.333	30	69.5	62.8-76.6	3.311	55	69.3	57.0-78.8	4.257
7	20	73.5	66.0-86.0	4.661	8	72.2	65.5-80.8	4.831	28	73.1	65.5-86.0	4.658
8	5	80.2	75.5-84.8	4.011					5	80.2	75.5-84.8	4.011
Total	239				232				491			

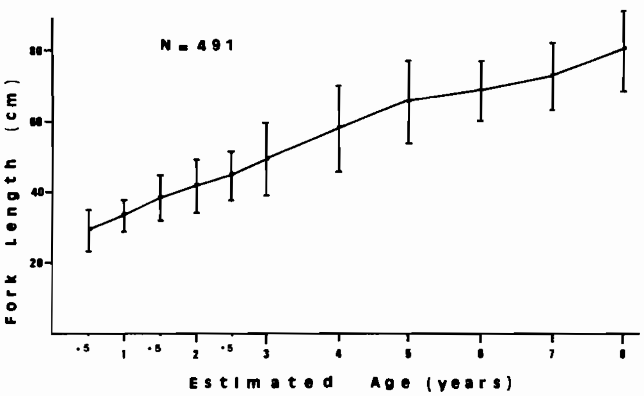

Figure 5.—Estimated age (years) and corresponding mean fork length (cm) ± standard deviation (vertical bars) for 491 little tunny caught off Senegal during 1979.

in spines during months of low water temperatures (November-May) suggests that these factors are related but does not in itself provide an adequate explanation for the variance in number and shape of annuli observed on different fish and also on the same fish. The formation of annuli on little tunny spines probably has several causes, including migration, spawning, and other environmental or biological events that work either in combination or separately to affect the physiology and growth of little tunny. Compeán-Jiminez and Bard (1983) suggested that migration patterns were related to formation of growth bands in spines of eastern Atlantic bluefin tuna, *Thunnus thynnus*, but also acknowledged the shortcomings of their findings. Therefore, more research efforts should be directed towards investigating the cause of annuli formation in scombrids before definitive statements can be made.

The relatively wide range in months when slow growth occurs (7 mo) makes it difficult to pinpoint the exact time of annuli (translucent zones) formation (Fig. 3). There may be several periods of increased and decreased growth from November to May, and this could account for some of the variation in the number and size of the translucent zones observed. Indistinct and narrow translucent zones were often observed in opaque zones near the margin of spines of larger fish. These thin, incomplete annuli appeared to correspond to periods of spawning (June-October as reported by Diouf 1980), but further speculation needs to be tempered by the relatively long duration of the spawning period.

A comparison of mean fork lengths at estimated age from our results with four other studies indicates relatively close agreement for young fish (e.g., estimated age 1 = 34 ± 2 cm), but differences between studies become increasingly more variable in larger fish (Table 3). Age and growth studies of other scombrids (such as bluefin tuna) have also noted close agreement with young tuna and greater disparity in estimates of older age categories (Lee et al. 1983). However, the work on little tunny from the Gulf of Mexico reported by Johnson (1983) was similar to our results through age 6. Johnson's ageing techniques on the dorsal spines were similar to those we used on spines of little tunny from Senegal. Comparisons of our results with others obtained with different techniques by other authors does not constitute validation, but does tend to verify that our results are relatively consistent.

The Beamish and Fournier (1981) method for calculating the average percent error (E) in age estimates was not used in other similar works presented at this workshop; this makes it difficult to compare the precision (repeatability) of our estimates with that of other studies. However, the average percent error (E) we found in our study (10.5%) was smaller than that reported by Antoine et al. (1983), probably because only two readers were involved in our study (compared with eight by Antoine et al.). Cailliet et al. (1983) reported a similar agreement between two readers counting bands on vertebrae from 22 species of sharks.

The increase in number of annuli with size of little tunny from Senegal indicates a strong temporal relationship. However, our interpretation of growth bands on little tunny spines remains unvalidated and this aspect needs to be addressed before further progress can be made.

SUMMARY

1) Spines were collected from 491 little tunny caught off Senegal. They ranged in size from 26.4 to 86.0 cm FL and estimated ages ranged from young-of-the-year to 8+ yr.

2) A strong relationship was observed between fork length and spine diameter. Thus, spines appear to be a good structure for use in back calculating previous growth history.

3) The highest percentage of slow growth bands (translucent

Table 3 – Comparison of mean fork lengths at estimated ages for different studies of little tunny using vertebrae, spines, and length frequencies analysis (Petersen method) to assign ages.

Author Method Place	Landau (1965) Vertebrae Mediterranean Sea	Postel (1955) Petersen Cap-Vert	Rodriguez-Roda (1979) Vertebrae Spain	Cayré and Diouf (1981) First spine Senegal	Cayré and Diouf Present study First spine Senegal	Johnson (1983) First spine Gulf of Mexico
Number of specimens	365	983	19	100	491	201
Estimated age (yr)	Mean FL (cm)	FL range (cm)	Mean FL (cm)	Mean FL (cm)	Mean FL (cm)	Mean FL (cm)
0		<30				
1	35.8	30 to 45		32.9	33.4	35.1
2	53.9	45 to 60	58.1	41.1	41.9	46.2
3	63.7	60 to 75	67.9	49.2	49.6	53.0
4	70.1	>75	76.2	57.4	58.3	56.1
5	75.5		86.0	65.6	66.2	59.9
6	80.1			73.6	69.3	62.4
7	81.0			77.0	73.1	
8					80.2	

zones) occurred on the margins of little tunny spines in November through May. Although annuli appear to be formed during this period, the wide duration (7 mo) makes it difficult to pinpoint annulus formation in individual fish.

4) The average percent error (E) in this study was 10.5% and this was relatively high precision compared with other studies.

5) Annual marks obscured by the vascularized core were estimated in fish $\geq$ 45 cm FL based on the location and number found in young fishes.

6) Our interpretation of annuli on spines of little tunny from Senegal was similar to other studies for young fish but increased variation was evident in older age categories. However, the accuracy of estimates of age remains unvalidated.

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