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PRELIMINARY AGE STUDY OF YELLOWFIN TUNA COLLECTED FROM THE EQUATORIAL EASTERN ATLANTIC

by

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SUMMARY

Calcareous structures removed from yellowfin tuna, Thynnus albacares, captured by purse seines in the Gulf of Guinea off the west coast of Africa were sent from Abidjan to Beaufort, NC, for age determination. Otoliths (N = 100) and vertebrae (N = 119) were used to age the fish, determine growth, and derive theoretical growth parameters. Otoliths were removed from tuna that ranged in size from 146.1 to 177.7 cm; vertebrate were taken from fish that ranged from 111.3 to 161.0 cm. Vertebrate were easier to read than were otoliths. Age structure analysis revealed the oldest tuna to be 6 years. Back-calculated fish length (fork length in centimeters) at age for ages 1 - 5 are 97.5, 112.1, 123.0, 132.6, and 140.2, respectively. The derivation of a von Bertalanffy theoretical growth model yielded the following lengths at ages for ages 1 - 6: 94, 116, 133, 148, 159, and 169 cm. The authors were unable to validate the methods used to age the tuna, therefore the results reported herein are preliminary at best.

RESUME

Les structures calcaires prélevées sur des albacores, Thunnus albacares, capturés à la senne dans le golfe de Guinée au large des côtes ouest-africaines ont été envoyées d'abidjan à Beaufort, N.C., pour en déterminer l'âge. Les otolithes (N = 100) et les vertèbres (N = 119) ont servi à déterminer l'âge du poisson, en définir la croissance, et en extraire des paramètres théoriques de croissance. Les otolithes ont été prélevés sur des thonidés qui mesuraient de 146,1 à 177,7 cm; les vertèbres sur des poissons de 113,3 à 161,0

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cm. Les vertèbres étaient plus faciles à déchiffrer que les otolithes. L'analyse de la structure démographique a montré que le thon le plus âgé avait 6 ans. La taille du poisson (longueur fourche en cm) calculée par régression à un âge donné pour les âges 1-5 était respectivement de 97,5, 112,0, 132,6 et 140,2. La dérivation d'un modèle théorique de croissance de von Bertalanffy a donné les tailles suivantes par âge pour les âges 1-6: 94, 116, 133, 148, 159 et 169. Les auteurs n'étaient pas en mesure de valider les méthodes utilisées pour déterminer l'âge des thonidés, et les résultats mentionnés dans le présent document sont donc tout au plus préliminaires.

RESUMEN

Las estructuras calcáreas obtenidas en rabiles, Thunnus albacares, capturado por cerqueros en el golfo de Guinea, frente a la costa oeste de Africa, se enviaron desde Abidjan a Beaufort, NC, para el estudio de la edad. Se usaron otolitos (N = 100) y vértebras (N = 119) para determinar la edad y crecimiento de los peces y obtener parámetros teóricos de crecimiento. Se obtuvieron otolitos de túnidos en una gama de tallas entre 111.3 y 161.0 cm. Resultó más fácil leer las vértebras que los otolitos. Los análisis de estructura de la edad revelaron que el túnido más viejo tenía 6 años. El retrocálculo de la talla del pez (longitud a la horquilla en centímetros) a las edades 1 a 5 son 97.5, 112.1, 123.6, 132.6 y 140.2, respectivamente. La derivación de un modelo de crecimiento teórico de Von Bertalanffy dio como resultado las siguientes tallas en las edades 1 a 6: 94, 116, 133, 148, 159 y 169 cm. Los autores del documento no pudieron validar los métodos aplicados para determinar la edad de los túnidos, por lo que los resultados que se presentan son solo provisionales.

INTRODUCTION

The yellowfin tuna, *Thynnus albacares*, is a pantropical species occurring in the Indian, Pacific, and Atlantic Oceans, and in each of the warm seas of the world except the Mediterranean Sea. The yellowfin tuna is a highly migratory species that forms large schools of approximately equal-sized fish. The species is of great importance to commercial and recreational fisheries throughout the world.

Commercial fishermen use purse seines, poles and lines, gill nets, longlines, and surface handlines to land the species. In the pole and line fishery, large boats with live-bait wells pursue schools of tuna. When a school is sighted, live bait is thrown overboard to attract the tuna, which are hoisted aboard with long fiber glass poles, heavy monofilament lines, and barbless hooks and jigs. The longline fishery is practiced worldwide. Fishing units, or baskets, are composed of a horizontal mainline, buoyed at the surface between two floats, and four to six branch lines, each with a hook. A single longline may consist of 400 baskets with a total of 2,000 hooks. Purse seines are set from one or two purse boats launched from a tender vessel. The net is set around a school and retrieved, forcing the fish into a small area of the net. The tuna are then pumped aboard the vessel. Recreational fishermen catch yellowfin tuna by trolling brightly-colored artificial lures at relatively high speeds. Once tuna are located, fishermen may let their boats drift and use jigs or spoons.

Most research on the life history of yellowfin tuna has been conducted on fish collected in the Pacific Ocean. Spawning takes place at sea in spring and summer where water temperatures are at least 20°C. A few fish attain sexual maturity during their first year, but most do not reproduce until they are 2 or 3 years old. The species has great reproductive potential. A fish 50.8 cm in length may lay 319,000 eggs, a fish 127 cm may lay 4,000,000 and a 165 cm female may produce over 8,000,000 ova. Females may spawn two or three times a year, releasing pelagic eggs in short, sporadic bursts. Yellowfin tuna feed in open ocean waters on fishes and invertebrates often associated with floating material such as *Sargassum*. Foods include larval crabs and shrimps, squids, filefish, triggerfish, and jacks. Like other scombrids, *Thynnus albacares* is believed to be a relatively short-lived species with a rapid rate of growth. Unfortunately, age and growth studies have usually been less than conclusive and have often been formulated on length frequency analyses. (Most of the above background information was taken from Manooch 1984).

The authors of this preliminary study were asked to age yellowfin tuna by examining otoliths and vertebrae from fish collected off the west coast of Africa. Sample sizes were small, the fish represented a relatively narrow size range, and were captured during a brief period of the year. These constraints made it impossible for the authors to validate their techniques and therefore undermines the reliability of results obtained. Nevertheless, the objectives of the study were to determine age by counting rings on both otoliths and vertebrae, calculate growth, and derive a theoretical growth equation.

METHODS

Otoliths and vertebrae were shipped by air from Abidjan to the United States. Each hard structure was individually packed and labeled with information pertaining to capture date, area of collection, fish size and sex of the fish. Most materials arrived in good condition, although a few of the otoliths were broken. Otoliths required no additional treatment before they were analyzed, however, the vertebrae were cleaned, scrapped, and sanded prior to examining.

Otoliths were first inspected whole with the aid of a dissecting microscope. This provided nonproductive, therefore sections (0.3 mm thick) were made using a low-speed saw. The plane of sectioning is of major importance to age and growth determinations. Therefore, before sectioning we examined the otolith carefully to identify the field where rings were most legible. The otoliths were sectioned and three sections per otolith were submerged in clove oil in a black-bottomed watchglass and were viewed through a binocular microscope at 12X. The sections were illuminated by high-intensity, reflected light. Opaque and dark translucent rings were evident. We hypothesized that the opague rings represented one year's growth, and counted them as annuli. After enumerating the rings, we measured distances from the otolith section core to the center of each opaque ring, from the core to the section edge, and from the last ring to the section edge with an ocular micrometer. Legibility for the sectioned otoliths was poor.

Vertebrae were cut longitudinally with an industrial band saw. The bones were placed in blocks to anchor them before cutting. What appeared to be growth rings and growth zones were visible with the naked eye. The vertebrae were polished with a very fine grade sandpaper to enhance legibility. Rings were counted and measurements were taken with a dial micrometer.

The number of rings was recorded for each legible otolith and vertebrae sample. Data were then stratified by number of rings, and mean fish length at capture was calculated (i.e., observed length at age). Following this analysis, we back-calculated mean lengths at age using a fish length - vertebrae radius relationship: $L = a + b\cdot(VR)$, where L = fish length (fork length in centimeters), and VR = vertebrae radius. We then substituted the means of the distances from the vertebrae core to each ring for VR in the above equation, calculated the mean length at the time of each ring formation, and then calculated mean growth increment for each age group. The von Bertalanffy growth equation: $L_t = L\infty\ (1 - e^{-K(t-t_o)})$, where t = age in years, L = asymptotic mean maximum length, and K = growth coefficient was fitted by the SAS PROC NLIN program (SAS Institute 1979).

RESULTS AND DISCUSSION

Whole otoliths, sectioned otoliths, and vertebrae were evaluated for aging yellowfin tuna. We felt that best interpretations were made by examining vertebrae. This left us at somewhat of a disadvantage since we had no experience aging fish by this method.

We were able to count rings on 92 vertebrae. The number of rings on these vertebrae ranged from 2 to 5. We hypothesize that rings counted represent annuli. Mean lengths observed for fish with 2-5 rings are 120.1, 128.6, 140.1, and 148.0 cm, respectively (Table 1). Otoliths were removed from larger fish than were vertebrae, therefore more older fish and fewer younger fish are represented in the otolith sample (Table 1). Rings were evident on 84 samples. Mean observed lengths for fish aged by otoliths with 4-6 rings are 150.6, 156.2, and 169.8 cm, respectively. Since the number of examined structures was low (92 and 84), we combined samples. This is certainly an unusual procedure; we do no endorse it. Mean observed lengths at ages for the combined samples for fish with 2-6 rings are 120.1, 128.6, 144.9, 154.0, and 168.9, respectively (Table 1).

Vertebrae-aged fish could be used to back-calculate fish lengths at the time of annulus formation; otolith-aged fish could not be used. This was because we could not establish a strong relationship between the size of otolith sections and the size of the tuna. Our failure to establish a good relationship was probably due to our inability to correctly section the otoliths. The sample size was so small, therefore valuable, that we were unable to adequately experiment with different sectioning planes. However, we were able to derive a moderately strong relationship for vertebrae - aged fish: L = 50.1208 + 3.5972 (VR); r = 0.83. By substituting the means of the distance from the vertebrae core to each annulus for VR in the above equation we calculated the fish length at the time of annulus formation, and the mean annual growth increment (Table 2). Back-calculated lengths for fish with 1-5 rings are 97.5, 112.1, 123.0, 132.6, and 140.2 cm, respectively. Growth was exceptionally rapid for the first year (97.5 cm) and declined thereafter. We do not believe that the incremental growth for the first year is accurate. The true value is probably within the 70-80 cm range.

Theoretical growth models provide growth parameters such as asymptotic size ($L\infty$), and growth coefficient (K) that may be used in constructing dynamic pool yield models. The most frequently used curve is the von Bertalanffy equation: $L_t = L\infty\ (1\text{-}e^{-K(t-t_o)})$. The curve is typically fitted to back-calculated lengths (Everhart *et al.*, 1975; Ricker 1975). We followed this procedure using data presented in Table 2 and derived the following growth parameter values: $L\infty$ = 172 cm; K = 0.21; and t_o = -2.97. The resultant values, and theoretical lengths at ages, are compared with growth parameters and theoretical lengths at ages obtained by other researchers for yellowfin tuna studied in the Pacific (Table 3). Our growth parameters appear suspect. We also used observed lengths at ages for otolith - and vertebrae-aged tuna combined to derive theoretical growth parameters. We realize that using observed data is very unusual, however, we did so to involve as many data points as possible. The results are presented in Table 3.

An age-length key was constructed so that one wishing to assign ages to unaged tuna landed by the fishery may do so. Fish that we aged were stratified by 5 cm length intervals and the percentages of fish of different ages within each size interval are presented (Table 4). As an example, of the fish that we aged that occurred within the 125-129.9 cm length interval, approximately 5.6% were age-2, 88.9% were age-3, and 5.6% were age-4.

The results of our preliminary study indicate that yellowfin tuna from the eastern Atlantic may be aged by examining otoliths and vertebrae. Vertebrae appear to be more legible than otoliths. We were unable to validate the occurrence of rings on the hard structures as annuli due to the relatively small sample sizes, and because the samples were collected over a short period of time. Future age and growth studies of the species should involve more samples, a wider range of fish sizes, and collections from as many months of the year as possible.

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Table 1. Observed lengths at ages (= number of rings) for fish aged by vertebrae and sectioned otoliths. Length refers to fish fork length recorded in centimeters, S.D. is standard deviation, and N is number of samples.

	Vertebrae			Otoliths			Combined		
Rings	N	Length	S.D.	N	Length	S.D.	N	Length	S.D.
2	6	120.1	4.89	-	-	-	6	120.1	4.89
3	40	128.6	6.45	-	-	-	40	128.6	6.45
4	27	140.1	6.13	23	150.6	3.64	50	144.9	7.35
5	19	148.0	5.37	51	156.2	5.93	70	154.0	6.81
6	-	-	-	10	169.8	4.88	10	169.8	4.88
Total	92			84			176		

Table 2. Mean back-calculated fork lengths (cm) at age for yellowfin tuna aged by vertebrae.

		Hypothesized Age in Years				
Rings	Samples	1	2	3	4	5
1	-	-				
2	6	95.1	110.7			
3	35	97.3	111.4	122.4		
4	27	98.4	113.1	123.6	132.7	
5	19	97.3	112.2	123.4	132.5	140.2
Total	87	87	87	81	46	19
Weighted Means		97.5	112.1	123.0	132.6	140.2
Annual Increments		97.5	14.6	10.9	9.6	7.6

Table 3. A comparison of theoretical growth parameters and lengths at ages for yellowfin tuna aged in this study and by other researchers.

						Age			
Source	*K*	$L\infty$	t_o	*1*	*2*	*3*	*4*	*5*	*6*
Yabuta *et al.* (1960)	0.33	190	0	53	92	119	139	154	164
Yang *et al.* (1969)	0.36	195	0.27	72	109	135	153	166	175
Moore (1951)	0.44	192	0.22	80	120	145	162	173	180
Yabuta and (Yukinawa (1957))	0.55	168	0.35	88	122	141	153	159	163
Mean Lengths				73	111	135	152	157	170
This Study:									
Back-Cal.	0.21	172	-2.97	97	111	123	132	140	
Observed	0.20	212	-1.95	94	116	133	148	159	169

Table 4. Fish age - fish length key for all yellowfin tuna aged by otoliths and vertebrae combined. Data are observed lengths at age, percentages are in parentheses.

Length Interval (cm)	*Hypothesized Age* *2*	*3*	*4*	*5*	*6*	*Total*
110-114.9	1 (100.0)					1
115-119.9	1 (14.3)	6 (85.7)				7
120-124.9	3 (42.9)	4 (57.1)				7
125-129.9	1 (5.6)	16 (88.9)	1 (5.6)			18
130-134.9		7 (70.0)	3 (30.0)			10
135-139.9		5 (33.3)	9 (60.0)	1 (6.7)		15
140-144.9		2 (14.3)	7 (50.0)	5 (35.7)		14
145-149.9			16 (51.6)	15 (48.4)		31
150-154.9			10 (37.0)	17 (63.0)		27
155-159.9			4 (16.7)	20 (83.3)		24
160-164.9				6 (85.7)	1 (14.3)	7
165-169.9				6 (66.7)	3 (33.3)	9
170-174.9					5 (100.0)	5
175-179.9					1 (100.0)	1
Totals	6	40	50	70	10	176