SCRS/1993/089 Col.Vol.Sci.Pap. ICCAT, 42 (2) : 369-376 (1994)

ASSESSMENT OF HARD PARTS OF BLACKFIN TUNA *(THUNNUS ATLANTICUS)* FOR DETERMINING AGE AND GROWTH

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SUMMARY

We compared length-age recessions obtained from examination of otoliths, vertebrae, pectoral fin rays, and dorsal and anal spines of 15 blackfin tuna. The fish ranged in fork length from 41 to 72 cm and were obtained from the Kingstown Fish Market, St. Vincent and the Grenadines, West Indies. Of the five structures, data obtained from examination of otoliths, vertebrae, and dorsal spines fit linear regressions well, but those obtained from examination of pectoral rays and anal spines were more variable. Vertebrae proved convenient to both collect and process, whereas spines and otoliths from 3 for the smallest individual to 7 or 8 for the largest, depending on the structure examined. We stress that the present study was a first step only towards developing a reliable length-age relationship for this species, and validation of the ages is now required.

RESUME

Nous avons comparé les régressions de longueur par âge obtenues en examinant les otolithes, vertèbres, rayons épineux pectoraux, et les épines dorsales et anales de 15 thons à nageoires noires. Les poissons faisaient 41 à 72 cm de longueur fourche et ont été obtenus dans le marché aux poissons de Kingstown, St. Vincent et les Grenadines, West Indies. Des cinq structures, les données obtenues en examinant les otolithes, vertèbres et les épines dorsales s'ajustaient bien aux régressions linéaires, mais celles obtenues en examinant les rayons pectoraux et les épines anales étaient plus variables. Les vertèbres se sont avérées adéquates, aussi bien pour le rassemblement et le traitement, alors que les épines et les otolithes exigeaient une préparation plus longue et élaborée. Les âges obtenues allaient de 3 pour les individus les plus petits à 7 ou 8 pour les plus grands, suivant la structure examinée. Nous insistons sur le fait que cette étude a uniquement été un premier pas pour élaborer une relation longueur-âge de cette espèce et maintenant il est nécessaire de valider les âges.

RESUMEN

Se compararon las regresiones talla-edad obtenidas por el examen de otolitos, vértebras, radios de aletas pectorales y dorsales, y espinas anales de 15 atunes aleta negra. La talla de los peces se encontraba en una gama entre 41 y 72 cm, y los ejemplares se obtuvieron en los mercados de pescado de St.Vincent y Grenadines (Indias occidentales). De las cinco estructuras, los datos obtenidos por el examen de otolitos, vértebras y espinas dorsales, se ajustaban bien a las regresiones lineales, pero los obtenidos por el examen de radios pectorales y espinas anales, eran más variables. La recogida y proceso de las vértebras resultó fácil, pero el caso de las espinas y otolitos, requirió una preparación más larga. Las edades obtenidas eran desde 3, para los peces más pequeños, hasta 7 ú 8 para los más grandes, según la estructura examinada. Insistimos en que el presente estudio era tan sólo un primer paso hacia el desarrollo de una relación talla-edad fiable para esta especie, y ahora es necesario realizar una validación de las edades.

INTRODUCTION

The CARICOM Fisheries Resource Assessment and Management Program (CFRAMP) will be initiating a program of routine collection of hard parts of blackfin tuna (*Thunnus atlanticus*), a commercially important small tuna occurring in Caribbean waters (Mahon 1990). Age and growth data obtained from examination of the hard parts will be used as inputs to CFRAMP's stock assessment activities. A common problem associated with age and growth investigations of highly-valued species, however, is a reluctance on the part of vendors or fishers to permit extraction of hard parts such as otoliths on the grounds that the fish will be mutilated and its value reduced. Under such circumstances, the investigator may be obliged to purchase all or part of the fish, thus substantially increasing the cost of the research program. To minimize such costs, we have undertaken a pilot investigation of the relative utility of five hard parts for age and growth examination before starting routine collection for stock assessment purposes. Some of these structures are more easily obtained than extracting otoliths, thus increasing the feasibility of obtaining samples large enough for use in stock assessment models.

Our assessment of the utility of the various structures is comprised if two parts, addressing different aspects of the question of whether a given structure is suitable for age and growth investigations. The first part focusses on whether periodic bands are formed in a predictable fashion as fish grow, and this question is addressed in this report. We also comment on the comparative ease with which it was possible to obtain estimates of age from the various structures. The second aspect of the problem is commonly referred to as validation, or the determination of the frequency with which periodic bands are formed, and will be the subject of a future report.

The parts we selected were based on a literature review of the results of other workers who have investigated the age and growth of tunas, some of which are summarized in Table 1. Our review indicated that no information existed on the age and growth of blackfin tuna.

METHODS

Sagittal otoliths were removed from the cranium by making a cut parallel to the frontal plane, which exposed both sacculi. Fine forceps were then used to locate and remove the otoliths. Because of the small size of the otoliths, it was sometimes difficult to locate both members of the pair. Surrounding membranes were then removed, and the otoliths stored dry in small envelopes.

Pectoral fin rays were cut using bone shears near the base of the structure. In the case of dorsal fin spines and anal fin rays, the whole fin structure (including the condyles) was excised from surrounding muscle. A stiff knife was used to cut the vertebrae near the caudal peduncle, ensuring that at least the last three vertebrae were always obtained. All such hard parts and surrounding tissues were then frozen prior to further processing of the samples.

After frozen samples were thawed, body tissue adhering to the anatomical structures was removing by boiling, then soaking the structure in Axion (a household detergent containing a proteolytic enzyme) overnight. The enzymatic action was stopped by briefly rinsing the structure in a 10% ammonia solution (Jearld 1983).

Whole otoliths and portions of pectoral fin rays were embedded in a low viscosity resin and allowed to harden overnight in an oven at 60° C. Three transverse sections were then cut from each of these structures using a high-speed circular saw. Otolith sections were cut as close as possible to the otolith nucleus, Sections from the dorsal and anal fin spines were cut just above the condyles. All sections were ground and polished using varying grades of silicon carbide abrasive paper. Little preparation was required for vertebrae once surrounding tissue was removed, with the exception that the inner surface of the anterior cone of each vertebra was stained with the calcium-specific dye Alizarin Red.

All periodic bands were counted by two readers. Otolith sections were covered with immersion oil and viewed against a black background with a binocular stereomicroscope and reflected light. Alternating hyaline (translucent) and opaque bands were observed and the latter enumerated. Sections of dorsal spines and fin rays were viewed using a compound microscope and transmitted light. To assist the two readers with obtaining a consensus, images were occasionally obtained with a closed-circuit video camera and viewed on a black and white monitor. A film of immersion oil was applied to vertebrae surfaces which were illuminated with a microscope lamp and viewed with the naked eye as well as a magnifying glass.

Previous workers have suggested that dorsal spine sections become more difficult to age as fish grow, due to an increasing proportion of the cross section becoming occluded by vascularized material. To document this for blackfin tuna, we made a variable number of photomicrographs, depending on the size of the section, and then mounted them to reconstruct an image of the cross section. We then digitized the perimeter of the section, and also the extent of the area occluded by vascularized material. The area of the non-readable zone was then compared with the total cross-sectional area of the spine.

RESULTS

Examples of preparations of the various hard parts are shown in Fig.1a-1e. Dorsal spine sections (Fig. 1a) had easily enumerated periodic bands, but sometimes the lacunae associated with central vascularization interfered with counts. Pectoral fin rays (Fig. 1b) often appeared to exhibit a rather complex structure of alternating major and minor bands. We could obtain counts comparable with other hard parts only by ignoring the minor bands. Anal fin ray sections (Fig. 1c), although often having readily discernable periodic bands, sometimes had counts which were considerably lower than other structures. Periodic bands on otoliths (Fig. 1d) were also easy to count, but finding the correct point to begin counting from was difficult, as there appeared to be periodic bands evident during the first year of life which could be confused with presumed annuli. Periodic bands on vertebrae were relatively easy to detect and count (Fig. 1e). Using the methods outlined earlier, our ranking of the time required to prepare each structure from shortest to longest is: 1. vertebrae, 2. dorsal spine, 3. pectoral fin ray and anal fin ray, and 4. otolith.

The results of counts obtained is shown in Table 2. The ages obtained ranged from 3 to 7 or 8, depending on the structure examined. The resulting age-length regressions are shown in Fig. 2. Summary statistics associated with the regressions are shown in Table 3.

DISCUSSION

Based on ease of preparation and a precise fit to a linear regression, we concluded that vertebrae of blackfin tuna offer the greatest promise for age determination purposes. Age-length data from cross sections of otoliths also appear to offer a precise fit to a linear model, but were somewhat more time consuming to prepare and sometimes difficult to collect. Moreover, local fishermen or vendors would likely be less reluctant to permit cutting the tail at the caudal peduncle for collection of vertebrae than dissection of the cranium to remove otoliths.

We found cross sections of pectoral fin rays to be unsuitable for age and growth studies, due to the complex nature of periodic bands apparent, and the high degree of subjectivity which would be necessary to count them. We discounted cross sections of anal fin spines because of a poor fit to the linear regression of ages derived from anal fin spines versus length. We thought dorsal fin spines were not promising because of vascularization in the central area, a problem which appeared to increase with age. When we examined the percentage of the cross section occluded by vascularization versus length, we found that the extent of vascularization remained constant up until about 50 cm when it increased rapidly, then again remained roughly constant when the fish reached 55 cm (Fig. 3). Other workers have noted such a problem for bluefin (Compéan-Jimenez and Bard 1983) and skipjack tuna (Antoine et al. 1983), but the striking and unexplained S-shaped relationship has not yet been documented, to our knowledge. This effect may represent a systematic bias which reduces the effectiveness of this structure for age determination purposes. In fact, investigators using dorsal spine sections for ageing of other tuna species would be well advised to check for this possible bias.

A further problem has been the appearance of presumed annuli as "doublets" in dorsal spine sections of other tuna species, including albacore (Gonzáles-Garcés and Fariña-Perez 1983) and little tunny (Cayré and Diouf 1983). Such bands were defined as two periodic bands separated by a relatively narrow opaque zone that tends to merge as they curve towards the spine core, and are usually considered a single annulus. We did not observe such bands in our preliminary study.

The next phase of our investigation will focus on validation. If the assumption that the periodic bands enumerated in this study are annuli is confirmed, then the ages at length of blackfin tuna appear comparable with skipjack tuna. For example, Antoine et al. (1983) reported mean fork lengths at age of 43.6 47.9 and 53.3 cm for skipjack tuna caught off Venezuela, for ages 3,4 and 5 respectively. Examination of our small sample indicated a mean length at age of 43.8, 52.5 and 65 cm for blackfin tuna of the same age, using the data obtained from examination of the vertebrae.

ACKNOWLEDGEMENTS

We thank David Gopaul for his assistance with the sampling, and analyses of the photographs of the dorsal fin spine sections. Peter A. Murray and Karl A. Aiken provided useful comments on a previous version of this manuscript.

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Table 1. Examples of other studies of age and growth of tuna species, which used the same anatomical structures as used in this study.

Structure	Species	Investigators
Sagittal Otoliths	Yellowfin tuna (*Thunnus albacares*)	Manooch and Hinkley (1991)
	Bluefin tuna (*Thunnus thynnus*)	Lee and Prince (in press)
Vertebrae	Yellowfin tuna (*Thunnus albacares*)	Manooch and Hinkley (1991)
		Romanov and Korotkova (1988)
	Little tunny (*Euthynnus alletteratus*)	Johnson (1983)
	Bluefin tuna (*Thunnus thynnus*)	
	Bigeye tuna (*Thunnus obesus*)	
	Skipjack tuna (*Katsuwonus pelamis*)	Kubo and Asano (1990)
	Bluefin tuna (*Thunnus thynnus*)	Lee and Prince (in press)
Dorsal fin spine	Little tunny (*Euthynnus alletteratus*)	Johnson (1983)
	Albacore (*Thunnus alalunga*)	Lee and Kuo (1988)
Pectoral fin ray	Albacore (*Thunnus alalunga*)	Prince et al. (in press)
Anal fin ray	Albacore (*Thunnus alalunga*)	Prince et al. (in press)

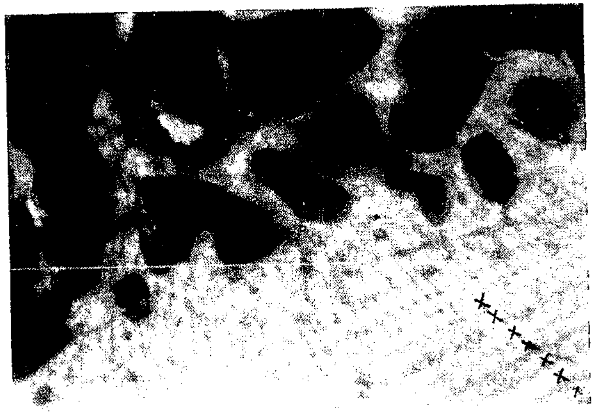
Table 2. Ages of blackfin tuna (*Thunnus atlanticus*) determined by consensus of two age readers, shown with respect to length. The hard parts examined were dorsal fin spines, pectoral fin rays, anal fin spines, sagittal otoliths and vertebrae.

	Structure				
Length	Dorsal fin spine	Pectoral fin ray	Anal fin spine	Otolith	Vertebrae
46	3	3	5	4	3
57	4	4	4	5	4
65	5	3	3		5
54	4	4	4	6	4
41	3	4	3	3	3
56	4	4	4	5	4
51	5	4	3	4	4
67	7	6		8	7
51	5	4	3		4
63	6	6	5	6	6
72	7	8	7	8	7
66	6	7	3	7	7
46	3	5	3	3	4
44	3	3	3	3	3
44	4	4	3		3

Table 3. Estimated regression equations and F test statistics for the relationship between length (cm) and age (yr) of fish estimated from reading various hard parts.

Hard part	Estimated regression equation for relationship between length (L) and age (A) - (y = a + b * x)	R^2	*F*-value	Probability of obtaining a higher *F*-value
dorsal fin spine	L= 26.3 + 6.2 * A	0.78	46.9	.0000
pectoral ray	L= 34.0 + 4.5 * A	0.48	11.9	.0043
anal fin spine	L= 37.7 + 4.3 * A	0.28	4.7	.0498
otolith	L= 28.3 + 5.2 * A	0.92	110	.0000
vertebra	L= 27.4 + 6.1 * A	0.86	78.2	.0000

(a)



(b)

(c)

(d)

(e)

(e) Whole vertebra, stained with Alizarin Blackfin tuna.

Fig. 1

(a) First dorsal fin, second spine cross section, showing periodic structures. Blackfin tuna, 72 cm, magnification 422X.

(b) Pectoral fin ray, cross section showing periodic structures. Blackfin tuna, 72 cm, magnification 1056X.

(c) Anal fin spine, cross section showing periodic structures. Blackfin tuna, 72 cm, magnification 1056X.

(d) Sagittal otolith cross section, showing periodic structures. Blackfin tuna, 72 cm, magnification 1056X.

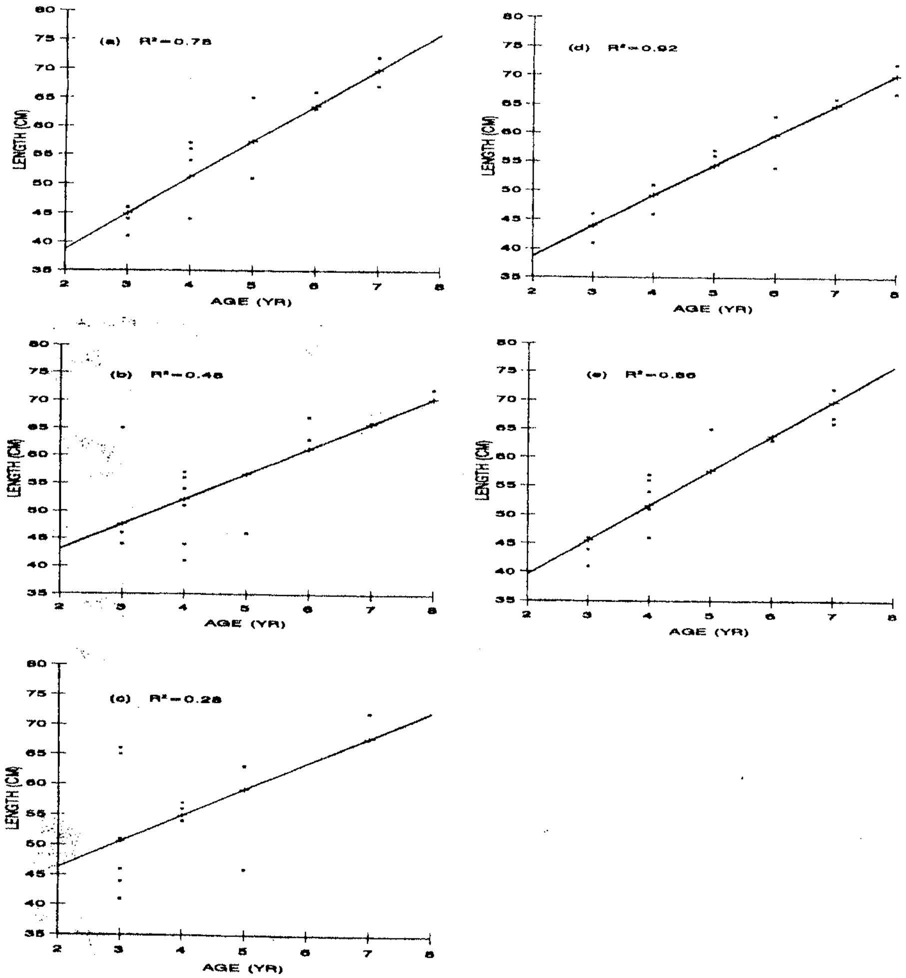


Fig. 2. Raw data points and estimated regression lines showing relationship between length (cm) of fish and age (yr) as estimated from the following hard parts: (a) dorsal fin spine, (b) pectoral ray, (c) anal fin spine, (d) otolith and (e) vertebra.

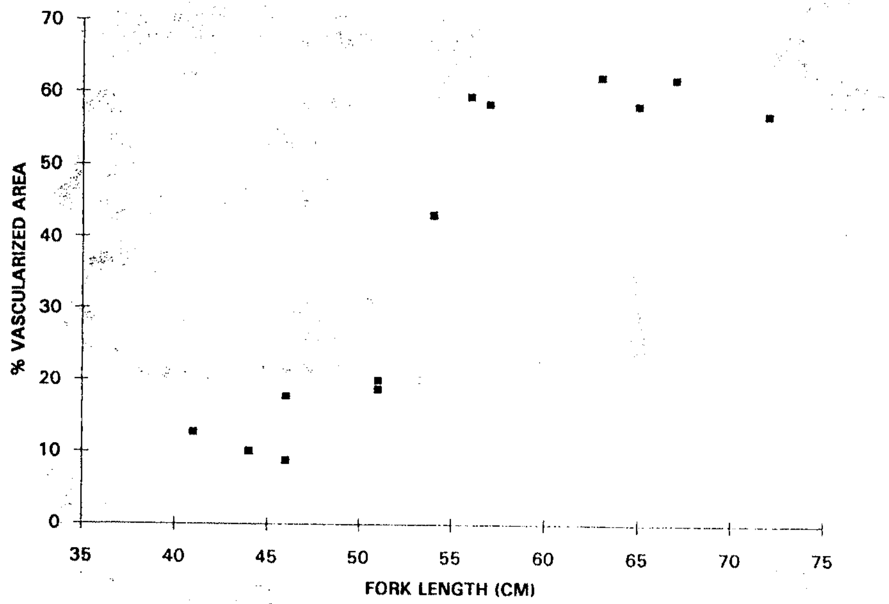


Fig. 3. Relationship between vascularized area of dorsal spine cross section and fork length of blackfin tuna.