ON AGE AND GROWTH OF THE ATLANTIC BIGEYE TUNA

V. V. Gaikov, V. N. Chur,
V. L. Zharov, Yu P. Fedoseev
AtlantNIRO, Kaliningrad, USSR

SUMMARY

Different techniques for bigeye tuna ageing from the material obtained in the Atlantic Ocean in 1970-1975 are considered. The first ray sections of the first dorsal fin bearing the growth marks appeared to be most suitable for this purpose. The results of tagging experiments suggest that two light and two dark growth zones are formed within a year. Light and dark zones correspond to the periods of slow and accelerated growth, respectively.

The greatest linear growth of bigeye tuna is observed during the first years of life and the greatest weight growth after the attainment of sexual maturity.

The parameters of Bertalanffy's equation are determined and the length age key is given.

RESUME

On évalue différentes techniques de détermination de l'âge du thon obèse, à partir d'éléments d'information obtenus dans l'océan Atlantique au cours de la période 1970-1975. Les sections du premier rayon de la première nageoire dorsale portant les marques de croissance semblent être les plus adéquates à cet effet. Les résultats obtenus à partir du marquage montrent que des zones de croissance, deux claires et deux oscures, se forment dans le courant de l'année. Les zones claires et oscures correspondent respectivement aux périodes de croissance lente et accélérée.

On observe que la période de croissance la plus accusée de cette espèce est pendant la première année en ce qui concerne la taille, et à partir de la maturité sexuelle pour ce qui est du poids.

On définit les paramètres de l'équation de von Bertalanffy; la clef âge-longueur est également indiquée.

RESUMEN

Se consideraron las diferentes técnicas para determinar la edad del patudo, del material obtenido en el Océano Atlántico en 1970-1975. Las secciones del primer radio de la primera aleta dorsal con marcas del crecimiento, parecen ser las más apropiadas para este propósito. Los resultados del experimento de marcado sugieren que durante el año, se forman dos zonas de claridad y dos de obscuridad. Las zonas de claridad y obscuridad corresponden a los periodos de crecimiento lento y acelerado respectivamente. El crecimiento lineal más grande, se observa durante los primeros años de vida, y el más grande crecimiento de peso, después de la obtención de madurez sexual.

Son determinados los parámetros de ecuación de Bertalanffy y se dá la clave talla-edad.

Bigeye tuna is one of the major fishing objects in the long-line and purse-seine fishery in the Atlantic Ocean. Its stocks are intensively exploited by the fishing fleets of many countries. This is confirmed by steadily increasing catches, which totalled to 52.4 thous. tons in 1974 (ICCAT, 1977). In this connection, the necessity of studies on the dynamics of this fish species population in order to introduce the rational fishing intensity has become urgent. Unfortunately, the pertinent biological information available to date is extremely scanty to pursue a scheme of the above-mentioned control. It concerns, first of all, the problem of age and growth determination for the fish species in question.

The data on age and, consequently, on age structure of bigeye tuna commercial aggregations given by the majority of authors are based on the results of studying the shift of modal peaks of the length (or weight) frequency within one or another time period under consideration (Yukinava and Yabita, 1963; Shomura and Keala, 1963; Champagnat and Pianet, 1973). The applicability of this method for ageing is without dispute, however, the collection of the representative data in this case will call for immense observations, which should be made on one and the same commercial aggregation and cover a sufficiently long (about a year) time period. It does not always work, however, to realize such large-scale observations and this is one of the shortcomings of the method suggested. Besides, the information obtained by this method gives an idea of only the approximate mean sizes of the fish of one or another age and does not reflect the individual growth variability. Therefore, the length-age keys based on this information may hardly be useful for understanding the age structure of commercial aggregation.

Material and Methods

The fish samples were collected in the open Guinea Gulf in 1970-1975 by the scientific-research and commercial ships. In all cases the fish was caught by longlines.

A total of 122 scale preparations and 1 480 preparations of the first ray sections of the first dorsal fin were made and examined.

The scales were sampled from different body parts of each specimen in order to discover most readable ones. Sampled scales were processed in the water ammonia solution and examined in the penetrating polarized light under the binocular microscope. Forestalling events, we may note that in the process of examination of preparations no vivid centres were revealed in the majority of cases, and the growth marks were illegible. Besides, the number of sclerites on the scales taken even from the same body part differs. So, for instance, the number of screlites on the most readable scales of one and the same specimen taken below the lateral line under the second additional finlet varied between 32 and 57. It is small wonder, therefore, that in counting the growth marks we faced different results. It should be noted that differences in reading were found not only among different observers but also in cases when the counting was repeated by the same observer. The difference in counts amounted to 1-3 rings in 55% of cases. As a result, we came to a conclusion that the scales are unacceptable as the material for age determination, although, according to Mimura (1963), the limited application of scales as a control in age determination by other methods is possible.

The method used for determination of the bigeye tuna age from the growth marks on the sections of the rays of dorsal fins was first suggested by Boiko (1951) for determination of the Black Sea bonito age. Later Shabotinets (1968) and Solovjev and Kuzmin (1970) applied this method for ageing of the Indian Ocean tuna. The latter authors used it for bigeye tuna age determination and noted the satisfactory coincidence of the growth mark numbers both on the ray sections and on the vertebrae. We adopted this method with a certain modification, which in brief is as follows. The rays were sawn off by means of the electric fret-saw at the base of the first spiny ray of the first dorsal perpendicularly to its axis. The thickness of the section ranged between 1.0-1.5 mm. The preparations were examined in the penetrating polarized light under the binocular microscope. Readability of preparations was satisfactory, at least in 70% of total number.

The results of measurement of various section radii and the comparison of those with the fish body length showed that the central radius is most acceptable for back calculations of the growth rate. In this case the dependence of the radius length across the section on the fish length is rectilinear, identical both in males and females and meets the regression equation R = 0.352, L - 2.05, where R is the radius length across the section given in points of the optical micrometer and L is the fish body length in cm. The side radii of the sections (fig. 1) were measured by means of the optical micrometer, and the Bryuzgin's method (1969) was applied for back calculations of the growth rate.

The structure peculiarities across the preparations of the ray sections are as follows: a feebly marked nucleus, a constantly present ray center, alternating dark and light zones which we regarded as growth zones, the secondary zones of slow growth, the edge of dark and light zone along the peripheral region of sections.

We agree with Menon (1953) that the alternation of dark and light zones across the ray sections results from the irregular fish growth throughout the year and that the light zones, which are always narrower than the adjacent dark zones, correspond to the periods of slow growth while dark once correspond to the periods of accelerated growth. The reasons stipulating the variability of the growth rate during the year may be considered only hypothetically. It seems likely that even under the conditions of the tropical ocean zone the seasonal variations in the environment may exert a certain influence, weak as it is, on the growth rate. The major factors, however, are most likely to be the variations in the variations in the fish activity during the year and the alternation of the spawning and feeding periods. Our long-term observations of the distribution of bigeye tuna commercial aggregations in the Guinea Gulf indicate two types of movement performed by these aggregations: rapid movements for considerably long distance and slow movements within the local area. Such a change of the activity (in addition to the habitat) is most likely to entail the variability in the growth rate. Besides, all the ray sections available had a light zone along the edge mostly in cases when the material was collected in the period of mass spawning of bigeye tuna in December-March (fig. 2). The influence of the spawning upon the growth rate is without dispute.

The question of the number of the light and dark zones appearing within a year is the one of an extreme difficulty. Inadequacy of the material and, first of all, the absence of round-the-year data prevented us from making more or less well-grounded conclusions. The results of observations of the bigeye tuna growth rate based on length measurements of tagged and recovered fish (Aloncle and Delaporto, 1977) appeared to be very useful. According to these authors one tuna of 53 cm in length tagged on 11 July 1973 and recovered on 19 June 1975 was of 121 cm in length; the second specimen of 75 cm tagged on 4 July 1974 was about 100 cm in length (22 kg in mass) when recovered on 11 June 1975. These data indicate that the mean annual growth increment was 34 cm in the first case and about 25 cm in the second case. On comparing these data with the results of our growth rate calculations from the marks on the ray sections we came to a conclusion that in the course of the year 2 dark and 2 light growth zones are laid alternating in the fin rays of bigeye tuna.

Results

The data of direct ageing of bigeye tuna from the Guinea Gulf enabled us to built the growth curve for this species. The curve has the logarithmic dependence and corresponds to the equation: $L = 197.2 \lg n + 13.1$, where L is the fish length, cm, and n is the age.

In addition, the results of our observations were compared with the data submitted by other scientists (table 1). We would like to emphasize the fact of high-degree coincidence of our results with those reported by Champagnat and Pianet (1973), although both sets of data were obtained by different methods. A high degree of coincidence is also observed between our data and the results reported by Yukinawa and Yabuta (1963) for the Pacific tunas which were obtained by the method of shifting the modal peaks of the sample size composition.

Simultaneously, our data differ markedly from those presented by Mimura (1963) and Solovjev and Kuzmin (1970) for bigeye tuna of the Indian Ocean. We may admit that the growth rate of the fishes of one and the same species belonging to two neighbouring populations is twice as large, however, in our opinion, the differences result from the erroneous interpretaion of growth marks on the skeletal formations, since, according to the latter authors, the annual growth zone consisted not of two light and two dark growth zones, but of only one light and one dark zone.

Back calculations of the bigeye tuna growth rate are presented in table 2.

For the purpose of using these data as the length-age kea the relative occurrence frequency of tunas of the same size in different age groups is given in per cent.

The curves of the linear and weight growth are shown in Fig.3

The weight growth was calculated using the "length-mass" dependence which meets the tentative equation deduced earlier

$$P = 1.8117\ L^{3.0386}\ \times\ 10^{-5},$$

where P is the mass in kg and L is the length in cm.

The largest growth increments are observed in the first years of life of this fish species, therefore, a 9 year old bigeye tuna may achieve 200 cm in length and 178 kg in mass.

The growth parameters calculated according to Bertalanfi's equation are as follows:

$$L = 253.75\left[1 - e^{-0.173(t - (-0.15)}\right];$$

$$W = 363.83\left[1 - e^{-0.173(t - (-0.15)}\right]^{3.029}$$

where $L_{\infty} = 253.75$ cm

$W_{\infty} = 363.83$ kg

$t_o = -0.15$

$k = 0.173$

Conclusions

The ageing and back calculation of the bigeye tuna growth rate may be made using the marks on such bone formations as spiny rays and, in particular, the first spiny ray of the first dorsal fin.

Growth marks of the cross section of these rays look like alternating light and dark zones. The formation of those zones most likely results from the change of the fish activity in the course of the year and from the interchange of the spawning and feeding periods.

As is evident from the data on the growth rate of tagged and recovered fishes, two light and two dark growth zones corresponding to the periods of slow and accelerated growth are laid within the year.

The highest linear growth is observed in the first years of life of bigeye tuna, and the highest weight growth is recorded in the third year of life after the attainment of sexual maturity.

By the nine year of life a bigeye tuna may achieve 200 cm in length and 178 kg in mass. The maximum length and mass are 253.75 cm and 363.83 kg according to the growth parameters of the Bertalanfi's equation.

We believe that satisfactory readability, simplicity of data sampling, no special difficulties in storing and processing are telling arguments in favour of ageing from the sections of the first dorsal fin rays, and we recommend this method as most acceptable for determination of age composition of the Atlantic bigeye tuna aggregations.

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Table 1

Age and mean length of bigeye tuna from the data reported by different authors, cm

Age, years	Atlantic Ocean: Our data from ray sections	Atlantic Ocean: Champagnat and Pianet [4] from size composition	Pacific Ocean: Shomura and Keala [9] weight composition: males	Pacific Ocean: Shomura and Keala [9] weight composition: females	Pacific Ocean: Yukinawa and Yabuta [11] from size composition	Indian Ocean: Mimura [7] scales	Indian Ocean: Solovjev (1970), ray sections and vertebrae as control
0	-	-	-	-	-	35.5	-
1	49	(50)	79	76	44	49.5	-
2	72.5	79	107	105	76	62.0	-
3	107.2	104	128	127	102	73.6	67–82
4	131.9	128	144	142	123	85.3	80–105
5	151.0	-	156	153	140	97.5	100–130
6	166.6	-	165	161	154	114.7	110–140
7	179.8	-	173	167	165	-	120–155
8	191.2	-	178	171	174	-	135–165
9	201.3	-	-	-	182	-	145–175
10	-	-	-	-	-	-	160–190
11	-	-	-	-	-	-	192

Table 2

Length-age key for bigeye tuna, %

Age, years / Length, cm	0	1	2	3	4	5	6	7	8+
0–30	100.0								
31–56		100.0							
57–58		75.0	25.0						
59–82			100.0						
83–84			96.7	3.3					
85–86			58.8	41.2					
87–88			9.5	90.5					
89–90			7.7	92.3					
91–100				100.0					
111–112				82.9	17.1				
113–114				69.7	30.3				
115–116				45.5	54.5				
117–118				42.9	57.1				
119–120				25.6	74.4				
121–122				13.5	86.5				
123–136					100.0				
137–138					75.0	25.0			
139–140					75.0	25.0			
141–142					58.8	41.2			
143–144					38.5	61.5			
145–146					26.7	73.3			
147–148					12.5	87.5			
149–150					12.5	87.5			
151–154						100.0			
155–156						88.9	11.1		

Table 2 (continued)

Age, years / Length, cm	0	1	2	3	4	5	6	7	8+
157–158						80.0	20.0		
159–160						50.0	50.0		
161–162						33.3	66.7		
163–164						33.3	66.7		
165–166						25.0	75.0		
167–168						20.0	80.0		
169–174							100.0		
175–176						50.0	50.0		
177–178						50.0	50.0		
179–180						25.0	75.0		
181–182							100.0		
183–184							75.0		25.0
185–186							50.0		50.0
187–188							25.0		75.0
189–200									100.0

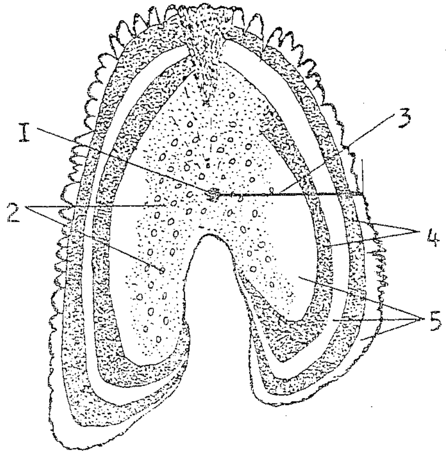

Fig. 1. Schematic ray section (1- nucleus; 2 - porous central part; 3 - a scheme of measuring the central section radius; 4 - dark growth zones; 5 - light growth zones).

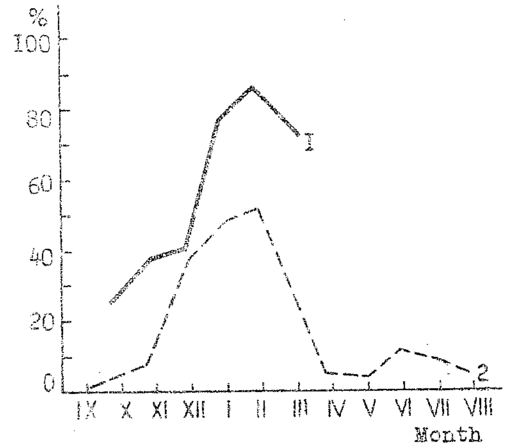

Fig. 2. The number of ray setions having a light zone along the edge (1) and the number of pre-spawning and spawning specimens (2).

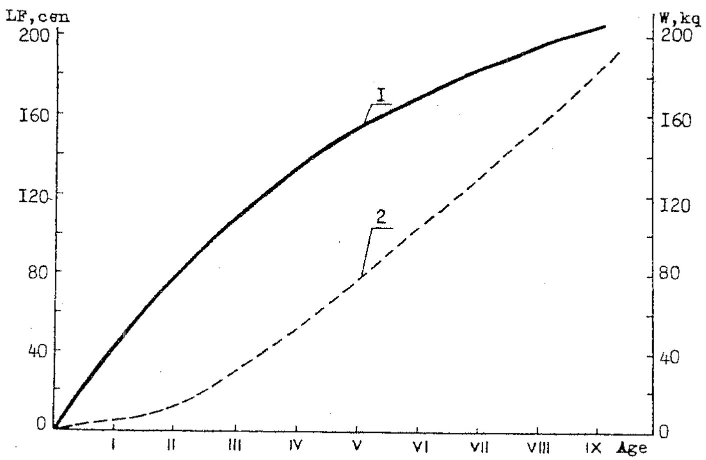

Fig. 3. Linear and weight growth of the Atlantic bigeye tuna.