Age and Growth of Sailfish, *Istiophorus platypterus*, Using Cross Sections from the Fourth Dorsal Fin Spine

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ABSTRACT

Cross sections from fin spines of 1,071 sailfish, *Istiophorus platypterus*, obtained from the sport fishery in southeast Florida (1970-80), were examined to estimate age and growth rates. Growth bands on 53% (569) of the spines were legible and age estimates ranged from 1 to 7 yr. Maximum age may exceed 7 yr since we were not able to age the largest sailfish. The most abundant age groups were 3 and 4. Female sailfish were slightly larger than males and may live longer. No males were observed exceeding estimated age 6. Generally, good agreement was obtained between observed, back-calculated, and theoretical growth. The von Bertalanffy growth equations for length of males and females were:

$$l_t = 147\ [1\text{-exp}(-0.3014)(t+1.959)]$$

$$l_t = 183\ [1\text{-exp}(-0.1586)(t+3.312)],\ \text{respectively.}$$

Sailfish were found to be a relatively fast-growing, oceanic pelagic species, although we estimated annual growth rates to be slower and more gradual that previously reported in the literature. Estimates of instantaneous total mortality (*Z*) ranged from 1.14 to 1.90 for males and from 0.82 to 1.15 for females.

INTRODUCTION

Age and growth of sailfish, *Istiophorus platypterus*, were estimated first by deSylva (1957) using length frequency analysis (Petersen method). He noted three modes (year groups) in the frequency distribution, and thus concluded that sailfish were a very fast-growing, short-lived species. Variations in sailfish length-weight relationships by sex were later reported by Williams (1970), Maksimov (1971), Nakamura and Rivas,[3] Wares and Sakagawa (1974), and Jolley (1974, 1977). These studies suggested differences in growth rates or longevity between males and females. Estimates of age and theoretical growth of sailfish have been reported by Jolley (1974, 1977), Radtke and Dean (1981), and Farber.[4] Jolley (1974) explored the use of several hardparts, including vertebrae, for age estimation. Dorsal fin spines were found to be the most promising structures (particularly the fourth dorsal spine). Jolley (1974) reported a significant relationship between trunk length and spine radius ($r = 0.90$), which justified use of spines for back calculations of previous growth history. He also theorized that the maximum age of sailfish may be 9 or 10 yr; however, he was unable to verify this due to the illegibility of bands on spine sections from large sailfish. Using scanning electron microscopy, Radtke and Dean (1981) examined the morphological features of 65 sailfish otoliths and were able to use 98% of the otoliths to estimate age. The estimated age of their largest specimen was 7 yr, which concurred with Jolley (1977). Farber (footnote 4) examined historical release-recapture data of tagged sailfish and other billfish to determine growth rates, mortality rates, and migration patterns. He indicated a maximum age of approximately 6 yr and an asymptotic size achieved by age 3. Thus, questions concerning maximum longevity and growth rates of sailfish remain unresolved.

In our study, we used cross sections from the fourth dorsal fin spine to determine the age of sailfish and to obtain estimates of back-calculated and theoretical growth, and mortality.

MATERIALS AND METHODS

Dorsal fin spines were taken from 1,071 sailfish captured primarily by the sport fishery off southeast Florida between 1970 and 1980. One hundred forty-nine of the spine sections were utilized by Jolley (1977) in his preliminary analysis of sailfish age. Measurements of trunk length in centimeters (TKL, the length between the posterior edge of the orbit to the origin of the caudal keels) and total weight in kilograms were taken from each specimen. Sex was determined macroscopically. Dorsal fin spines were cut and prepared according to the methods of Jolley (1977). Only sections from the fourth dorsal fin spine were utilized in the back calculation of growth analysis. Sections from each spine were stored dry, placed in glycerine, and read under a binocular microscope (10×) equipped with reflected light and a dark background. Broad opaque bands and narrow translucent bands alternated outward from the central core (see Glossary). Translucent bands that continued around the entire circumference of the spine were considered annuli (see Glossary) and the total number of these bands were recorded in order to assign ages to each specimen. We assumed

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[3]Nakamura, E. L., and L. R. Rivas. 1972. Big game fishing in the northeastern Gulf of Mexico during 1971. Unpubl. mimeo. Southeast Fisheries Center Panama City Laboratory, National Marine Fisheries Service, NOAA, 3500 Delwood Beach Road, Panama City, FL 32407.

[4]Farber, M. I. 1981. Analysis of Atlantic billfish tagging data: 1954-1980. Unpubl. manuscr. International Commission for Conservation of Atlantic Tunas Intersessional Workshop on Billfish, June 1981. Southeast Fisheries Center Miami Laboratory, National Marine Fisheries Service, NOAA, 75 Virginia Beach Drive, Miami, FL 33149.

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that the distance between translucent bands represents 1 yr growth based on previous work (Jolley 1974, 1977; Radtke and Dean 1981), but this assumption remains, in part, unvalidated. The size of each growth band was measured from the center of the core through the middle of the right hemisphere of the section to the outer edge of each translucent zone (annulus). Three readings of each spine by two readers were made independently. If agreement between readers could not be reached, these spines were not used in the analysis.

The relationship between TKL and spine radius was determined with regression analysis. All statistical inferences were based on a significance level of $\alpha = 0.05$. Back calculations of length-at-estimated age were obtained from the following equation (Tesch 1971; Ricker 1975):

$$L_n - c = (S_n/S)\,(L - c) \qquad (1)$$

where L_n = the length of the fish when the annulus (n) formed,
L = the length of the fish at the time of capture,
S_n = a measure of the size of each annulus,
S = the radius of the right hemisphere of the spine,
c = a correction factor (y-intercept of the regression fish trunk length vs. radius of the right hemisphere of the spine).

Estimates of theoretical growth in length of sailfish were obtained by fitting the spine measurement data to the von Bertalanffy growth equation following the Beverton method in Ricker (1975:225). Theoretical growth-in-weight was obtained by converting length to weight (Gulland 1969:39) using the length-weight relationship of Jolley (1974).

Instantaneous total mortality rates (Z) were estimated by four methods: 1) Heinke (Everhart and Youngs 1981), 2) Jackson (Everhart and Youngs 1981), 3) Chapman and Robson (Everhart and Youngs 1981), and 4) Beverton and Holt (1957). Frequency of observed age groups was used to obtain estimates of Z. Age group 4 was considered as the first fully recruited year class of sailfish to the recreational fisheries off the coast of southeast Florida (Jolley 1977).

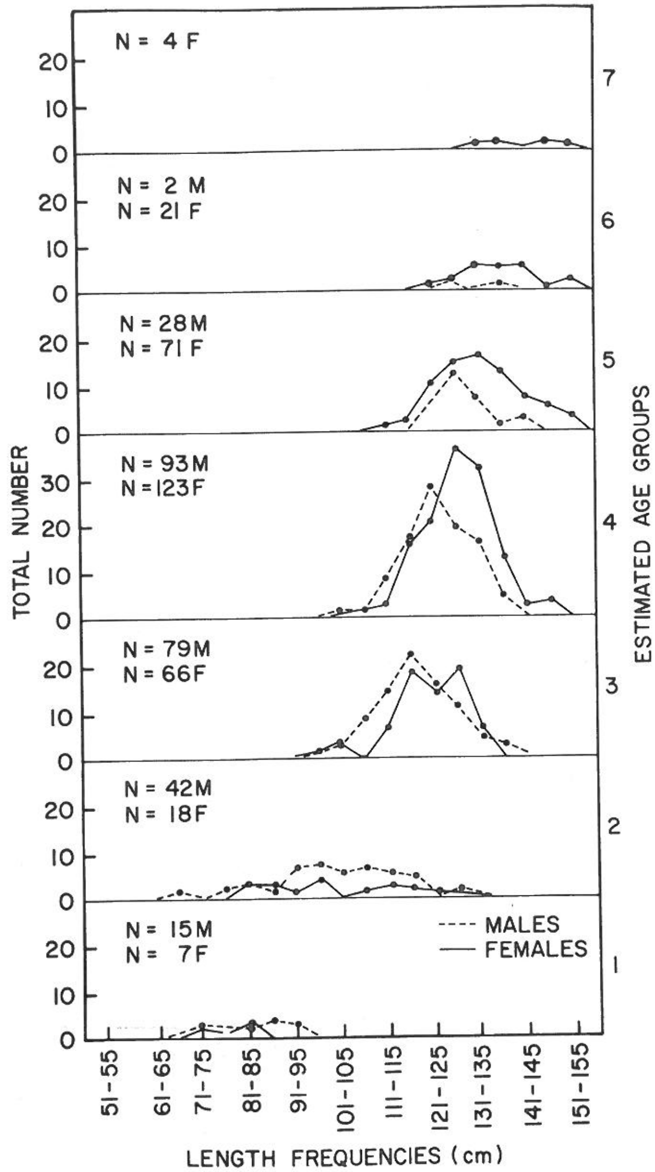

Figure 1. – Length frequencies of male and female sailfish by estimated age groups from the northwestern Atlantic Ocean.

RESULTS

Of the 1,071 sailfish spines examined to estimate age, 569 of the cross sections were legible (259 were males and 310 were females). There was a significant linear relationship between fish trunk length and spine radius ($r = 0.77$). Estimated age groups 3 and 4 were the most abundant year classes (Fig. 1). The mean age group of both sexes was 4. Maximum age may exceed 7 yr, since spine cross sections from large sailfish (> 155 cm TKL) were not legible due to the accumulation of oil in the core of spines or masking of growth bands because of enlargement of the core. The greatest variation in length of sailfish occurred in estimated age group 2. Females grew larger than males, and were more variable in length and weight.

Mean observed, back-calculated, and theoretical growth were compared in Table 1 and Figures 2 and 3. By estimated age 1, males obtained a mean back-calculated trunk length of 90 cm and a mean back-calculated weight of 5.7 kg. Estimated age 6 males averaged 135 cm TKL and 19.3 kg; however, no males exceeded 6 yr of age. Estimated age 1 females had a mean back-calculated trunk length of 91.9 cm and a mean back-calculated weight of 9.1 kg. By estimated age 7, females averaged 151.4 cm and 34.6 kg. Growth curves for observed, back-calculated, and theoretical data agreed more closely for male sailfish (Fig. 2) than for female sailfish (Fig. 3). Mean back-calculated trunk lengths (Table 2) illustrated that both sexes grew at approximately the same rate (in length) during their first year; however, females grew faster than males in length after the first year of life.

The von Bertalanffy equations for the theoretical growth in length (l_t) and weight (w_t) for male sailfish were:

$$l_t = 147\,[1 - \exp(-0.3014)(t + 1.959)]$$

$$w_t = 28.8\,[1 - \exp(= 0.3014)(t + 1.959)]^{3.342}, \text{ respectively.}$$

The von Bertalanffy equations for the theoretical growth in length (l_t) and weight (w_t) for female sailfish were:

$$l_t = 183\,[1 - \exp(-0.1586)(t + 3.212)]$$

$$w_t = 54.1\,[1 - \exp(-0.1586)(t + 3.212)]^{2.950}, \text{ respectively.}$$

Table 1.—Summary of observed, back-calculated, and theoretical growth in length (trunk length, TKL, and total length, TL) and total weight of sailfish from the present study and other studies in the North Atlantic Ocean and the East China Sea.

		Present study						DeSylva[1] (1957)		Koto and Kodama[1] (1962)		Farber[2,3] (1981)	
		Observed		Back-calculated		Theoretical							
	Estimated age	male TKL	female TKL	male TKL	female TKL	male TKL	female TKL	(Sexes combined) TKL	TL	(Sexes combined) TKL	TL	(Sexes combined) TKL	TL
Length (TKL and TL, cm)	1	80.6	79.1	90.0	91.9	86.7	89.2	108.8	182.9	92.2	157.5	89.7	153.7
	2	100.4	100.8	102.4	104.5	102.4	102.9	130.4	215.9	110.2	185.0	119.7	199.6
	3	118.6	122.0	113.2	114.9	114.0	114.7	142.0	233.7	121.6	202.5	128.7	213.3
	4	124.2	128.6	120.2	123.8	122.6	124.7					131.3	217.4
	5	129.9	133.5	127.9	128.2	128.9	133.2					132.1	218.6
	6	132.3	139.7	135.1	136.7	133.6	140.5					132.4	218.9
	7		144.4		151.4		146.8					132.4	219.1
Total weight (kg)	1	3.9	3.2	5.7	9.1	4.9	6.5	9.5					
	2	8.5	8.5	9.6	13.1	8.6	9.9	19.5				2.0	
	3	14.6	15.8	12.3	17.7	12.3	13.6	28.6				7.4	
	4	17.2	19.0	15.1	21.8	15.7	17.4					14.8	
	5	18.7	20.9	18.1	25.0	18.6	21.2					22.0	
	6	18.9	26.9	19.3	29.2	20.9	24.8					26.8	
	7		32.4		34.6		28.2					30.5	
												33.0	

[1]Modes of total length to trunk length conversions, and mean total weights derived from length frequency analysis (sexes combined).
[2]Total length to trunk length conversions from Jolley (1977) and total weights derived from tag returns (sexes combined).
[3]See text footnote 4.

Instantaneous total mortality estimates ranged from 1.00 to 1.35 for all fish combined (Table 3). All four methods of estimating mortality gave higher values of Z for males (1.41-1.90) than for females (0.82-1.15). These estimates may be high due to our inability to age older fish, which would result in underestimating abundance of older age groups.

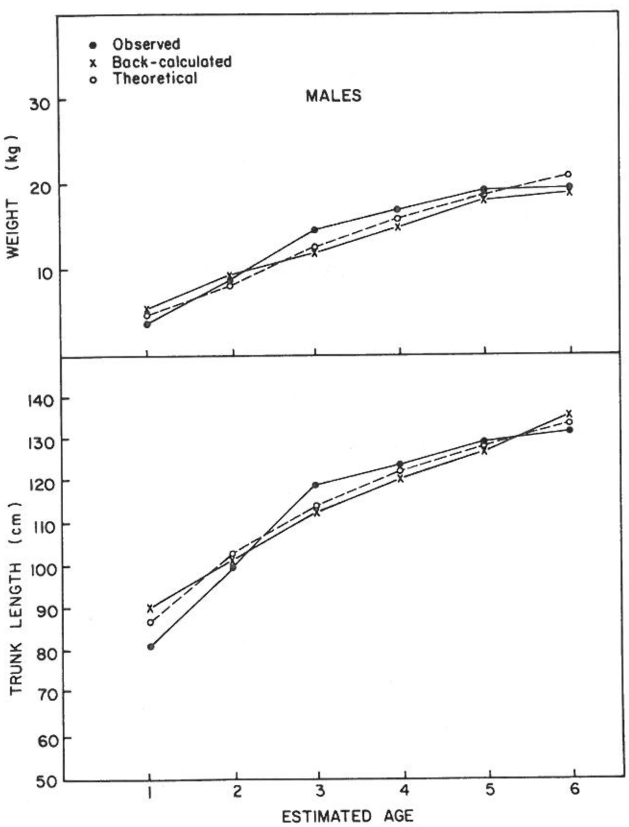

Figure 2.—Mean observed, back-calculated, and theoretical growth of 259 male sailfish from the northwestern Atlantic Ocean.

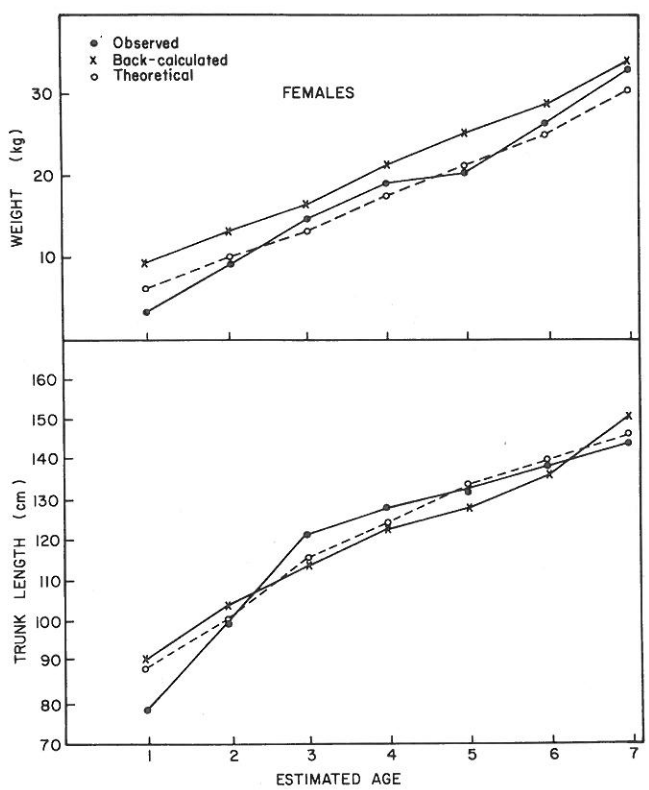

Figure 3.—Mean observed, back-calculated, and theoretical growth of 310 female sailfish from the northwestern Atlantic Ocean.

Table 2.—Mean back-calculated trunk lengths at estimated age for sailfish caught off southeastern Florida, 1970-80.

Age group	N	Back-calculated trunk length (cm) at estimated age						
		1	2	3	4	5	6	7
		Combined data						
1	21	77.2						
2	58	87.0	97.8					
3	141	92.7	106.5	116.2				
4	214	92.6	103.9	114.7	123.4			
5	98	92.0	101.7	111.2	120.4	128.4		
6	24	89.5	101.0	112.4	121.8	128.8	135.3	
7	5	87.4	100.8	115.3	126.8	133.9	139.2	144.5
Total	561							
		Male						
1	14	77.3						
2	40	86.8	97.1					
3	75	92.0	106.7	115.2				
4	93	92.3	102.7	112.8	121.1			
5	28	91.2	101.0	111.5	120.0	127.8		
6	2	—	93.8	105.0	116.8	124.5	130.2	
Total	252							
		Female						
1	7	76.9						
2	18	87.3	99.4					
3	66	93.4	106.2	117.4				
4	120	92.8	104.8	116.2	125.2			
5	68	92.2	102.0	111.1	120.5	128.5		
6	22	89.5	101.7	113.1	122.2	129.2	135.8	
7	5	87.4	100.8	115.3	126.8	133.9	139.2	144.5
Total	306							

Table 3.—Instantaneous total mortality (Z) estimates for sailfish caught off southeastern Florida, 1970-80.

Method[1]	Male	Female	Combined
Heinke	1.41	0.82	1.00
Jackson	1.41	0.82	1.00
Chapman and Robson	1.57	1.01	1.15
Beverton and Holt	1.90	1.15	1.35

[1]Methods of calculating total mortality (Z) given in Everhart and Youngs (1981).

DISCUSSION

Sailfish age distributions and sizes at age closely paralleled those proposed by Jolley (1977). However, the relationship between fish trunk length and spine radius in this study ($r = 0.77$) was not as high as reported by Jolley ($r = 0.99$, 1977). This may be due to the nonsymmetrical growth of some spines and/or differences in sample sizes between studies.

Mean observed, back-calculated, and theoretical lengths and weights-at-estimated age appeared to be realistic and relatively consistent for the sailfish we examined. Growth in weight was very rapid (exponential) during the first 3 yr of life, but appeared to become asymptotic thereafter. Thus, the von Bertalanaffy growth model more accurately reflected growth in later years. Other growth models were not used and we did not intend to imply that the von Bertalanaffy model was the most appropriate. This model was used for the convenience of making comparisons with other studies. Sailfish seem to have a particularly rapid growth rate when compared with other billfishes (Berkeley and Houde 1983). However, growth rates in this study were slower than those suggested for sailfish by deSylva (1957), who estimated an annual growth rate of approximately 130 cm TKL in the first 2 yr; we estimated about 5 yr to attain a length of 150 cm TKL in this study. Growth data analyzed by Farber (footnote 4) suggested that an asymptotic size is reached by age 3, followed by some minor growth after this period; whereas, we found a more gradual rate of growth, as Jolley (1977) initially proposed in his comparison of age-weight relationships. Radtke and Dean (1981) reported good agreement between their ageing technique using otoliths and spine analysis by Jolley (1977) and these data also tend to support a more moderate rate of growth. However, modes in length of sailfish from the East China Sea as observed by Koto and Kodama (1962) indicated that sailfish from this region may grow somewhat faster than sailfish in the western Atlantic Ocean.

As evident from reports of several authors (Antoine et al. 1983; Berkeley and Houde 1983; Cayré and Diouf 1983; Compeán-Jimenez and Bard 1983; González-Garcés and Fariña-Perez 1983; Johnson 1983), many oceanic pelagic fishes exhibit doubling or tripling of growth bands on spines. Sailfish were no exception. We attributed multiple banding to the actual splitting of the annulus which was observed ventral and/or dorsal to the core of the spine. The cause of this multiple banding was unclear; however, if one annulus was double or triple, generally, other annuli formed thereafter exhibited the same trend. These multiple bands were observed in all age groups.

Our combined estimates of instantaneous total mortality, which ranged from 1.00 to 1.35, were similar to those values reported by Farber (footnote 4; $Z = 0.90$) and Buchanan et al.[5] ($Z = 1.112$). Farber's mortality estimates, which were based on release and recapture data, ranged from 0.405 to 2.197. Slight differences between our current estimates of Z and those of other studies were probably the result of variations in proposed growth rates and age estimations (including the inability to age older fish) and methods of analysis. To further substantiate estimates of age and growth rates, studies on validation using mark-recapture or tetracycline marking should be incorporated into future research.

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