LONGEVITY AND AGE VALIDATION OF A TAG-RECAPTURED ATLANTIC SAILFISH, *ISTIOPHORUS PLATYPTERUS*, USING DORSAL SPINES AND OTOLITHS

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ABSTRACT

A tagged female Atlantic sailfish, *Istiophorus platypterus*, of 24.6 kg (54 lb) was recaptured on 14 January 1984, after being at large for 10 yr and 10 mo (4,025 d). Approximate age based on tagging records ranged from at least 13 to 15+ yr. Maximum estimated longevity of this species was therefore revised upwards from previously reported ≥7 yr to at least 13-15+ yr. Estimates of age based on sections of dorsal spine numbers 3-6 ranged from 2 to 8 yr and substantially underestimated the range in age known from tagging records (13-15+ yr). This discrepancy was due to enlargement of the porous, vascularized core of spine sections which obscured zonations associated with early growth history. Thus, dorsal spines do not appear to be useful in ageing older sailfish (i.e., ≥5 yr). Age estimates from sagittae (otoliths) were 13 yr based on scanning electron microscope counts of external ridges and analysis of internal otolith microstructure. Otolith age, therefore, agreed with age known from tagging records. The relatively large size of the sagitta (7.84 mg) also provides additional evidence that the otolith could be from a very old sailfish. These data strongly suggest that in older, larger sailfish (≥5 yr, 22.7 kg), sagittae, rather than dorsal spines, should be used as the source of age and growth information.

The Atlantic sailfish, *Istiophorus platypterus*, is one of the most popular recreational fishes along the U.S. Atlantic coast, Gulf of Mexico, and Caribbean Sea. In fact, this species has been described as the most sought after fish by southeast marine charter boat anglers, particularly in south Florida (Ellis 1957). Although most landings of Atlantic sailfish in the southeastern United States are made by recreational anglers, many are also taken incidentally by domestic and foreign commercial longline vessels (Lopez et al. 1979). The biological information presently used in stock assessments of Atlantic sailfish (Conser 1984) consists of age and growth data derived exclusively from analysis of dorsal spines (Jolley 1974, 1977; Hedgepeth and Jolley 1983). However, uncertainties remain concerning Atlantic sailfish age structure, longevity, choice of skeletal structure for ageing, and rate of growth because of inconsistencies reported in the literature. In addition, the accuracy of age and growth estimates from skeletal structures and length-frequency analyses have not been validated for all age classes (de Sylva 1957; Jolley 1974, 1977; Radtke and Dean 1981; Hedgepeth and Jolley 1983).

One problem in using spines as a source of age and growth information is the tendency of the vascularized core to obscure zonations associated with early growth history. The enlargement of the vascularized core and subsequent reabsorption of tissues are most severe in the largest and oldest specimens (causing underestimates of true age) and have contributed to the lack of detailed information for older age classes. Several studies have also reported difficulty in interpreting the double and triple bands often observed in Atlantic sailfish spines (Jolley 1977; Hedgepeth and Jolley 1983). These problems are not unique to sailfish (Casselman 1983; Compean-Jimenez and Bard 1983) and have resulted in an unusually large proportion of spine samples (as much as 76%) being rejected for age and growth analysis (Jolley 1977). Radtke and Dean (1981) reviewed this problem and suggested that otoliths (sagittae) may be a better skeletal structure for age and growth assessment in sailfish because these structures do not have the disadvantages associated with the spinal core. For example, 98% of the otolith samples examined by Radtke and Dean (1981) were reportedly suitable for age and growth estimation. Even though these preliminary findings were

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encouraging, use of otoliths to resolve age and growth discrepancies for Atlantic sailfish has not been reported, and no conclusive evidence is available to validate the accuracy of age estimates for this species using any method. We present an analysis of dorsal spines and otoliths obtained from one tag-recaptured Atlantic sailfish, where age was very closely approximated from tagging records, to help resolve the problems associated with ageing this species.

METHODS

The Cooperative Gamefish Tagging Program of the Southeast Fisheries Center Miami Laboratory recovered a tag from a female Atlantic sailfish, which had been recaptured on 14 January 1984, off Boynton Beach, FL (Prince and Lee 1984). This fish was originally tagged and released off the Florida Keys (Islamorada) on 5 March 1973, at an estimated weight of 18.2 kg (about 40 lb). When recaptured it weighed 24.6 kg (54 lb) and had a lower jaw fork length (LJFL) of 176.5 cm. The sailfish appeared to have a healthy external appearance when caught and body proportions and overall morphology were within the normal range for a specimen of this size. The entire fish was made available to us by J. T. Reese Taxidermist, Inc. (Ft. Lauderdale, FL), and both sagittae and the first six dorsal spines were sampled for age determination.

Dorsal Spine Analysis

Dorsal spines were collected from the tagged Atlantic sailfish following the procedures of Prince and Lee (1982). Past efforts to age sailfish using dorsal spines have relied on spine number 4 as the source of age and growth information (Jolley 1974, 1977; Hedgepeth and Jolley 1983). We collected the first six anterior dorsal spines to insure that the number assigned to each spine was accurate for identification and analysis and to gain information about possible differences between spines. The first two anterior dorsal spines of sailfish are greatly reduced in size compared with spines 3-6 and were not used to estimate age. In addition, spines posterior to spine number 6 have a smaller diameter and were not used for age determination. This decision was based, in part, on a report by Robins[4] and Robins and de Sylva (1963) who believed that the posterior dorsal spines of billfish do not grow throughout their entire lifetime and recommended that only anterior spines be used for age and growth studies.

Dorsal spines 3-6 were cleansed of tissue, labeled with a collection number, and preserved in isopropyl alcohol (98%). The methods of sectioning dorsal spines given by Hedgepeth and Jolley (1983) and Prince et al. (1984) were used in this study. Dorsal spine number 4 was sectioned by M. Y. Hedgepeth at the laboratory of the Florida Department of Natural Resources (FDNR), West Palm Beach, FL, to ensure that processing of this spine was identical with methods previously reported. We sectioned spines 3, 5, and 6 using a Buehler ISOMET[5] saw and a 10.16 cm diameter diamond wafer blade. At least 2 or 3 sections (0.44-0.46 mm thick) were taken from each spine. Additional sections were taken from spine number 4 after it had been processed by FDNR personnel. All spine sections were placed into labeled vials with isopropyl alcohol (98%) for storage and extraction of oil. A single section was selected and allowed to air dry before microscopic examination.

Dorsal spine sections were examined initially using a compound stereoscope (6.0×) with transmitted light in order to assess that portion of the section not affected by the vascularized core. Measurements (in millimeters, mm) of the solid bone area in the distal portion of the right lobe of each section were taken along a straight-line counting path from the focus to the outside margin of the structure.

We assigned an age to each spine by counting only concentric translucent bands that were continuous around the circumference of the entire section. In transmitted light, the zonations consisted of a dark opaque zone followed by a light translucent zone. D. W. Lee made three repeated counts of translucent zones using a compound stereoscope at 12.0 to 25.0× magnification.

Otolith Analysis

The general methods of Radtke and Dean (1981) and Wilson and Dean (1983) were used to extract and prepare the sagittae for examination by scanning electron microscopy (SEM) and light microscopy. The sagittae were removed from the tagged Atlantic sailfish, cleaned with sodium hypochloride solution, and rinsed in xylene and then 95% ethanol.

[4]Robins, C. R., Professor, Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149, pers. commun. 1982.

[5]Reference to trade names and products does not imply endorsement by the National Marine Fisheries Service.

The weight of one air-dried otolith was measured to 0.001 mg (±5%) using a Perkin Elmer AD2Z ultra-microbalance. The sagitta was attached to an aluminum stub, coated with gold, and examined by SEM at 15.0-1500× to observe the surface morphology. External ridges on the rostral lobe of sailfish sagittae, first described by Radtke and Dean (1981), was one of the features used in this study for age estimation.

Following the methods of Haake et al. (1982) and Wilson and Dean (1983), the other member of the pair of sagittae was embedded in epoxy resin, and a section was made in the transverse plane by polishing both sides to 0.5 mm thickness with 600 grit sandpaper and 0.3 μm alumina polish. The internal structure of the sectioned sagitta was examined with an Olympus BH_2 compound microscope at 4.0 to 1200× to aid overall orientation and understanding of the growth of the structure and to interpret the external ridges used for age estimation.

RESULTS AND DISCUSSION

Our tagging records indicate that the tagged Atlantic sailfish recaptured on 14 January 1984, was at-large for 10 yr and 10 mo or 4,025 d. An experienced charter boat captain estimated its size when tagged to be 18.2 kg (40 lb). Bias in overestimating the size of billfish during tagging has been a common problem since the inception of the Cooperative Gamefish Tagging Program in 1954 (Prince 1984). However, we feel that such an error would probably not exceed ±4.6 kg (10 lb) in a fish of this size, particularly when the experience of the captain making the estimate is considered. The estimated age of a sailfish of about 18.2 kg (40 lb) would be 2-4 yr based on dorsal spine analysis (Jolley 1974, 1977; Hedgepeth and Jolley 1983) and 3-5 yr based on otolith analysis (Radtke and Dean 1981). Therefore, the approximate range in age of this sailfish based on tagging information is 13-15+ yr. We feel these are conservative figures based on the available information and it is highly unlikely that this fish could be younger than 13 yr.

Maximum longevity of Atlantic sailfish was first inferred by de Sylva (1957) to be at least 3 or 4 yr based on length-frequency analysis (Fig. 1). A modal group beyond 4 yr was indicated in his analysis but year class designation was not discussed. Since 1957, estimated longevity of Atlantic sailfish has been revised upwards (Fig. 1) to ≥7 yr. Our tagging records indicate, however, that the oldest Atlantic sailfish aged by dorsal spine analysis (Jolley 1977; estimated age 8) probably underestimates the maximum longevity of this species by a considerable margin. Although Jolley (1977) speculated that sailfish may live as long as 9 or 10 yr because the one age 8 individual was not the largest specimen in his sample, his estimated ages did not exceed 8 yr. In addition, the maximum estimated age reported in other recent studies was ≥7 yr (Radtke and Dean 1981; Hedgepeth and Jolley 1983). An Atlantic sailfish of estimated age 7 or 8 from the above sources corresponds to an average size of about 25 kg (55 lb). Since our records indicate the age of the tag-recaptured 24.6 kg (54 lb) sailfish was 13-15+ yr, it appears that maximum longevity of Atlantic sailfish could be considerably older, perhaps over 20 yr, because numerous specimens exceeding 45.5 kg (100 lb) have been caught during the last decade (Beardsley 1980). This reasoning assumes that sailfish have indeterminate growth throughout their entire lifetime and that their size is proportional to age. It also appears from tagging data that Atlantic sailfish may

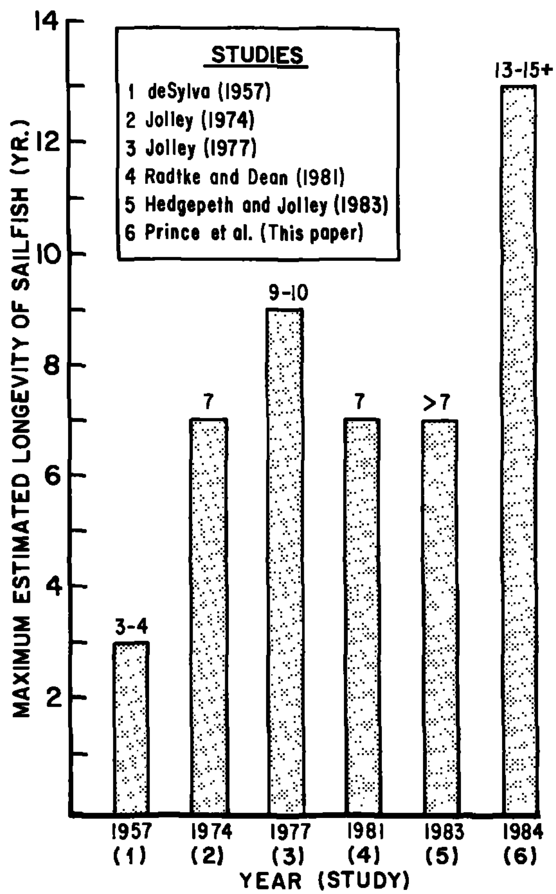

FIGURE 1.—Estimates of maximum longevity (yr) for Atlantic sailfish from six different studies, 1957-84.

grow very slowly after sexual maturity (sexual maturity for female Atlantic sailfish reported at 13-18 kg, Jolley 1977). For example, tagging records indicate that this fish, which was tagged at 18.2 kg, gained only about 6.4 (14 lb) while being at-large almost 11 yr. Our analysis of spines and otoliths support these findings.

Dorsal Spines

Examination of sections from dorsal spines 3-6 (Fig. 2) indicated that the vascularized core comprised an extensive area in all sections. The solid bone area where zonations were not disrupted varied in size and comprised 14, 19, 30, and 37% of the right lobe of spine sections 3, 4, 5, and 6, respectively (Table 1). The vascularized core severely restricted the zonation counts because increments associated with early growth history were totally disrupted and could not be enumerated. Counts of zonations on the four spine sections ranged from 2 to 8 (Table 1). This suggests that spine number 4, which had been used in past studies to assign ages, may not necessarily be the best choice for ageing sailfish, particularly for the larger, older specimens. For example, spines 5 and 6 both had a higher percentage of solid bone, and counts of zonations in these spines were proportionately higher than in spines 3 and 4 (Fig. 2, Table 1). However, all spines substantially underestimated the age of this sailfish, where approximate age (13-15+ yr) was known from tagging records. Hedgepeth[6] reports that spine number 4 would not have been included in the data sets of previous published studies because of the extensive size of the vascularized core area. We conclude from these data that dorsal spine sections are probably only useful for ageing sailfish from >1 to 5 yr. Although there may be some bias associated with ageing these young sailfish because of the vascularized core, this bias is probably minimal. However, for sailfish older than estimated age 5 and about ≥22.7 kg (50 lb), the bias substantially underestimates age and this bias increases with an increase in size and age of the fish. In addition, spines have not been shown to be useful in ageing sailfish <1-yr-old (Jolley 1974, 1977).

[6]Hedgepeth, M. Y., Fisheries Biologist, Florida Department of Natural Resources, 727 Belvedere Rd., West Palm Beach, FL 33405, pers. commun. 1984.

TABLE 1.—Mean count of zonations (3 repetitions) and percentage solid bone in the distal portion of the right lobe of sections taken from dorsal spines 3-6 of Atlantic sailfish (see text and Fig. 2). Measurements and counts were taken along a straight line counting path bisecting the spine laterally from the focus to the edge of each section.

Dorsal spine number	Mean count (range)	Solid bone (%)	Solid bone measurement (mm)	Total measurement (mm)
3	2.0	14	1.89	13.52
4	3.7(3-4)	19	3.55	18.76
5	5.0	30	4.90	16.56
6	7.3(7-8)	37	6.08	16.39

Otoliths

Sagittae from the tagged Atlantic sailfish had external and internal morphologies that were characteristic of sailfish reported by Radtke and Dean (1981), as well as other istiophorids (Radtke et al. 1982; Wilson and Dean 1983; Radtke 1983). For example, major features of these sagittae include a rostrum and antirostrum separated by a deep sulcus (Fig. 3). The external ventral and lateral surfaces of the rostrum consist of a series of ridges that are perpendicular to the axis of growth (Fig. 4). Radtke and Dean (1981) suggested that the number of rostral ridges can be used to estimate age of Atlantic sailfish. To make an accurate count of external ridges for age estimation, it is necessary to understand the internal and external otolith growth pattern so that the location and number of the first few rostral ridges can be firmly established. These initial ridges are often covered by excess calcium carbonate (Wilson 1984), particularly in older specimens, and are not always visible on the external features of the lateral surface (Fig. 4).

The growth of the rostrum occurs in two directions (Figs. 3, 4). During early stages, incremental growth of the rostral lobe occurs in the ventral direction out to a bend where growth shifts to a more medioventral and then to a medial direction (Fig. 3). This same pattern of otolith growth has been reported for blue marlin, *Makaira nigricans*, and white marlin, *Tetrapturus albidus* (Wilson 1984). However, it is difficult to illustrate a complex three-dimensional otolith on a two-dimensional photograph. Therefore, Figures 3 and 4 should be examined consecutively to obtain a proper orientation of the structure.

Although rostal ridges on the external lateral surface (Fig. 4) are not distinct because of the excess calcium carbonate, after the change in the axis of growth, the ridges on the ventral surface (ridges 3-10) can be counted easily (Fig. 4). Several lines of evidence points towards the first two growth zones occurring within the boundaries of the lateral surface. For example, a distinct internal translucent

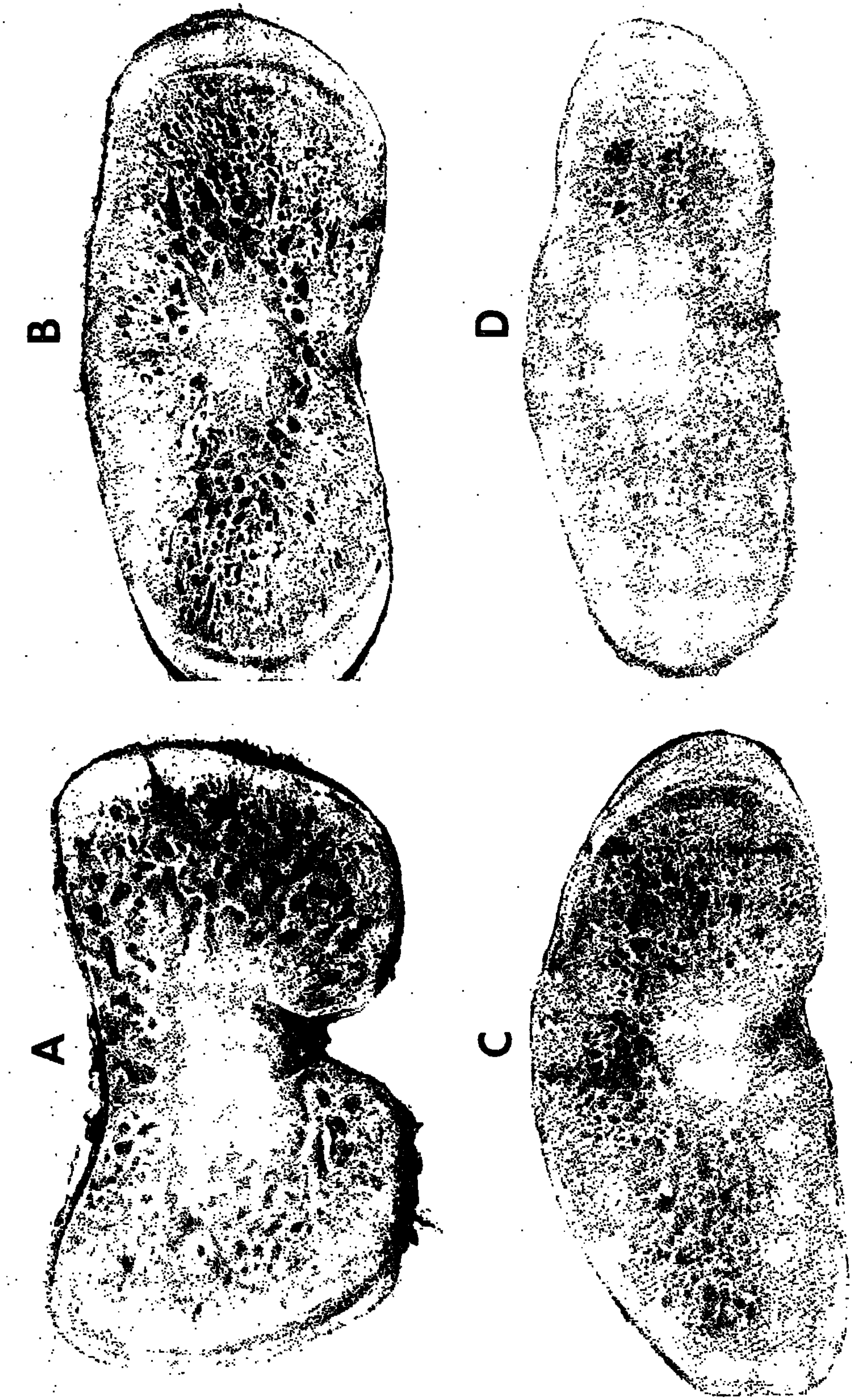

FIGURE 2.—Sections of dorsal spines 3(A), 4(B), 5(C), and 6(D) from a tag-recaptured Atlantic sailfish at-large for 10 yr, 10 mo. Age based on tagging records was 13-15+ yr.

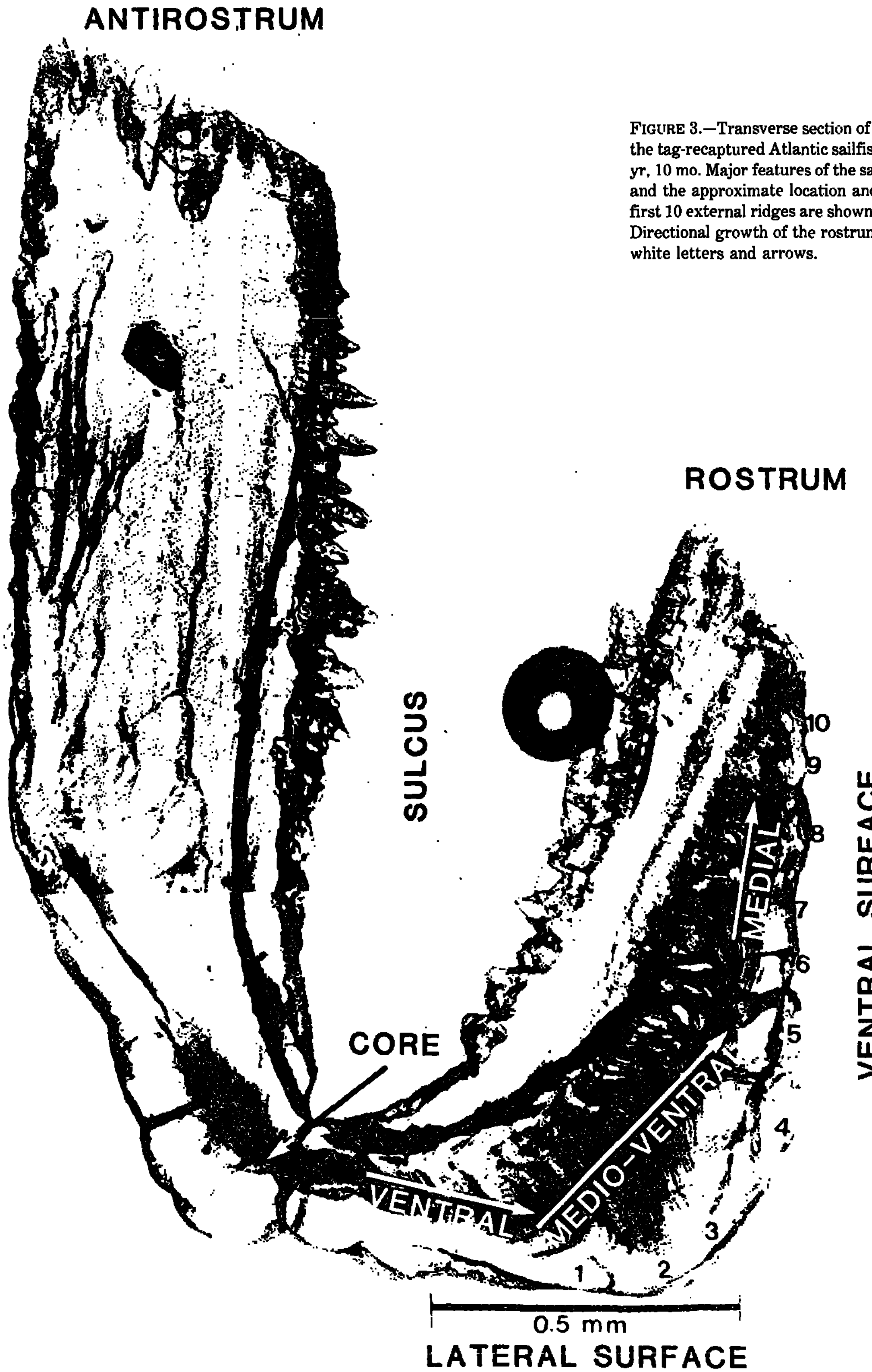

FIGURE 3.—Transverse section of the sagitta from the tag-recaptured Atlantic sailfish at-large for 10 yr, 10 mo. Major features of the sagitta are labeled and the approximate location and number of the first 10 external ridges are shown on the rostrum. Directional growth of the rostrum is indicated by white letters and arrows.

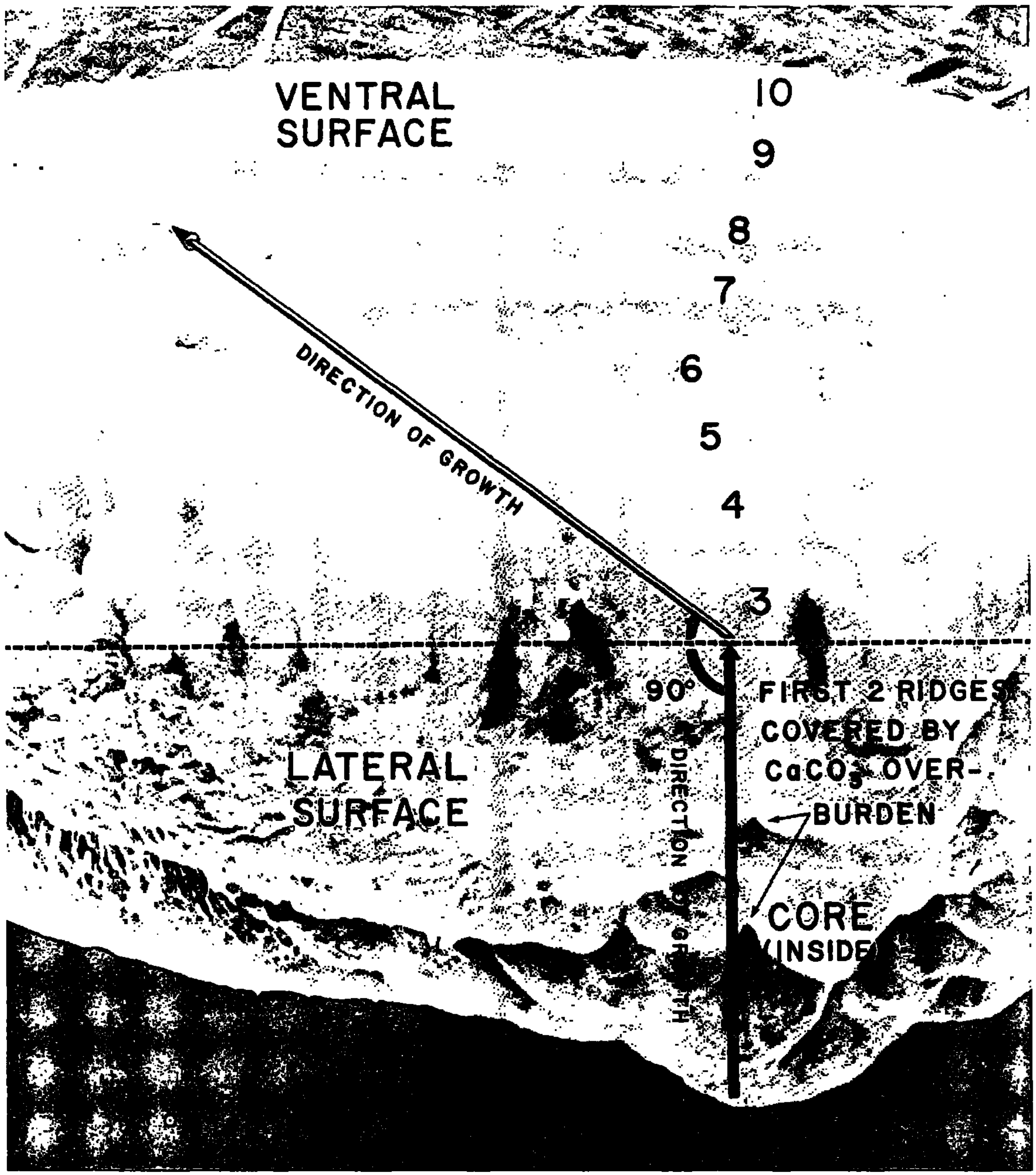

FIGURE 4.—Lateral and ventral view of the sagitta rostrum from the tag-recaptured Atlantic sailfish showing the overall pattern of otolith growth and the approximate location and number of the first 10 external ridges.

zone exists between the boundary of many of the external ridges shown in Figure 3. This zone extends from the surface to deep within the internal structure of the rostrum (Fig. 3). The distinct change in optical density of the first of these prominent zones marks what we believe is the boundary between the 1st and 2d ridges and suggests that the first major growth zone is located between the core and the bend (Fig. 3). Further, using the SEM we counted 150-200 finely spaced increments between the core and the first prominent translucent zone. This count also supports our interpretation of the location of the first annual zone if these increments are assumed to form daily, the fish was born sometime in late spring or early summer (as reported by Beardsley et al. 1975), and the annual zonations are being formed in the winter. Jolley (1977) reported that annual zones in Atlantic sailfish spines tend to be formed in late fall or winter and he also speculated that sailfish may form the first annuli on spines prior to a full year's growth. The location of the second translucent zone, based on similar evidence, appears to be at the beginning of the bend (Fig. 3). The width of the first two major growth zones (≥0.5 mm) are considerably larger than the zones beyond the end. Wide spacing of year marks during early growth have been observed in many fishes when growth rates are most rapid (Dean et al. 1983). Therefore, these data support our contention that at least two ridges should be accounted for as occurring within the boundaries of the lateral surface.

Rostral ridges 3 through 10 were easily distinguished and counted on the sagitta's ventral surface within the same plane of focus (Fig. 5, bottom). After the 10th ridge, however, the rostrum changes direction slightly (Fig. 3), and it was necessary to refocus to observe ridges 11 through 13 (Fig. 5, top). We feel that potential sources of error in our counts of rostral ridges would have most likely occurred at the beginning and end of the counting path. In addition, we feel that if errors were made at these locations, they would have increased the count. Therefore, otolith age of the tagged Atlantic sailfish was estimated to be 13 yr. However, it should be recognized that potential errors in this estimate could have resulted if one or two ridges were unaccounted for on the lateral surface or on the tip of the rostrum on the ventral surface. Otolith age under these circumstances should be presented conservatively as ranging from 13 to 15+ yr.

The weight of one sagitta from the tagged Atlantic sailfish (7.84 mg) was extremely heavy for an istiophorid of comparable size. For example, it was 1.24 mg heavier than the sagitta from a 29.6 kg (65 lb) sailfish caught in 1985 off Miami and was 1.18 mg heavier than the largest sagitta from Pacific blue marlin reported by Radtke (1983). In addition, the tagged sailfish sagitta was in the upper range in weight (0.51-8.16 mg) of more than 500 blue and white marlin sagittae examined by Wilson (1984). Since the relationship between the size of otoliths and the age of fishes has been shown to be positively correlated for some teleosts (Somerton 1985), we feel that the relatively large size of this sagitta provides additional indirect evidence that this structure could be from a very old sailfish.

CONCLUSIONS

Our tagging records indicate that estimates of maximum longevity for Atlantic sailfish should be revised upwards to at least 13-15+ yr, and that sailfish of this age can grow at a very slow rate (about 0.59 kg/yr during its time at large). Dorsal spines do not appear to be an accurate source of age and growth information for older, larger sailfish (≥5 yr, ≥22.7 kg or 50 lb), while sagittae do provide more accurate estimates of age for these older age groups. Since current stock assessments of Atlantic sailfish (Conser 1984) rely exclusively on dorsal spine ageing data as input, these assessments offer little insight into the more mature segments of the population. If skeletal structures from the larger, older fish are systematically rejected for ageing analyses, an underestimate of age and longevity and an overestimate of growth rate can occur (Nammack et al. 1985). Therefore, future assessments should be revised using otolith ageing methods to clarify that portion of the age structure that can not be reliably appraised using dorsal spines.

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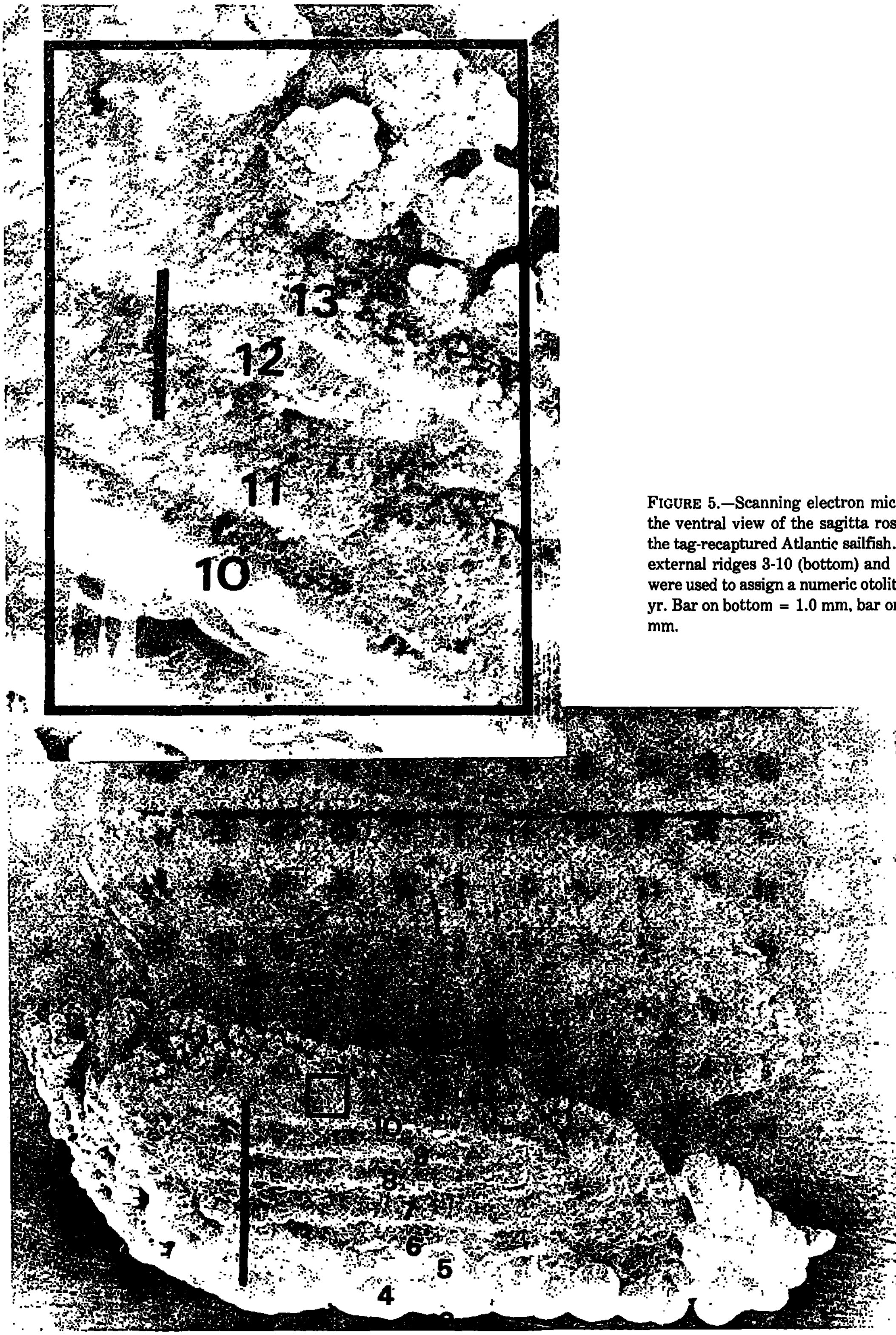

FIGURE 5.—Scanning electron micrograph of the ventral view of the sagitta rostrum from the tag-recaptured Atlantic sailfish. A count of external ridges 3-10 (bottom) and 10-13 (top) were used to assign a numeric otolith age of 13 yr. Bar on bottom = 1.0 mm, bar on top = 0.1 mm.

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