

Age and growth of larval Atlantic sailfish, *Istiophorus platypterus*

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Abstract. Of the Atlantic istiophorid billfishes, larval age–size relationships and growth rates have been examined only for blue marlin (*Makaira nigricans*). Using otolith microincrement analysis, we describe age–length and age–weight relationships for larval sailfish (*Istiophorus platypterus*) collected from the Straits of Florida. Sagittae and lapilli were dissected from 70 larvae ranging from 2.8 to 15.2 mm in (notochord or standard) length. Comparisons between otolith images obtained by light microscopy and scanning electron microscopy indicated that increment widths were well within the resolving power of light microscopy. Indirect evidence and published descriptions of larval blue marlin otoliths suggest daily increment deposition. Estimated ages of specimens ranged from 3 to 18 days. Length data were fitted to age estimates with an exponential model ($R^2 = 0.85$). The estimated size-at-hatch for sailfish was 1.96 mm notochord length, and the daily instantaneous growth coefficient was 0.14. A power curve with exponent 3.05 described the length–dry weight relationship for sailfish. The instantaneous growth coefficient for an exponential regression of dry weight, converted from length, versus estimated age was 0.41. Growth in the length of sailfish larvae from the Straits of Florida was very similar to that described for blue marlin larvae from Exuma Sound, Bahamas.

Extra keywords: billfish, Istiophoridae, otoliths, sagitta, weight–length relationship.

Introduction

The sailfish, *Istiophorus platypterus* Shaw, is one of the four istiophorid billfish species that inhabit the pelagic, tropical and subtropical waters of the western Atlantic Ocean and Caribbean Sea. Despite its ecological importance as an apex predator and economic value as a sport fish, many fundamental questions surrounding sailfish biology remain unresolved, especially concerning the earliest life stages. Studies on age and growth of sailfish have included inferences from length frequency distributions (de Sylva 1957; Koto and Kodama 1962; Maksimov 1971), tag-recapture studies (summarised in Ortiz *et al.* 2003), and analyses of growth increments in fin spines and otoliths (Jolley 1974, 1977; Radtke and Dean 1981; Hedgepeth and Jolley 1983; Prince *et al.* 1986; Alvarado-Castillo and Félix-Uraga 1996, 1998). Depending on the method of age estimation used, corresponding sizes of Atlantic sailfish at age 1 range from 108.9 to 141.5 cm lower jaw fork length (Jolley 1977; Hedgepeth and Jolley 1983; Prager *et al.* 1995) and 5.2 and 12.2 kg round weight respectively (Prager *et al.* 1995).

Young-of-the-year sailfish were included in de Sylva's (1957) length frequency analyses; however, length frequency methods are not ideal for studies of larval and juvenile growth in this species. A protracted spawning season (April through October; de Sylva and Breder 1997), combined with increased gear avoidance with size, results in a lack of strong modes in the length frequency distribution (Ueyanagi 1974). In an alternative investigation into larval sailfish growth, ages of larvae were calculated by assuming that those caught offshore were transported as passive particles by surface currents from certain near-shore spawning sites (Ueyanagi 1974). Mean current speed was used to estimate how long larvae were at-large. Results from the Ueyanagi (1974) study indicated that sailfish larvae 10–20 mm in length were 3–4 weeks old (Ueyanagi 1974). The wide range reflected in this estimate can only be refined by more direct methods of larval age estimation.

Panella's (1971) discovery that the otoliths of adult fish contain daily bipartite growth increments within the larger annular marks paved the way for more direct age and growth

studies of fishes less than 1 year old. Since Brothers *et al.* (1976) pioneered the use of daily increments in the age estimation of larval fishes, analysis of otolith microstructure has been used to examine age and growth in several hundred species (Campana 1992; Secor *et al.* 1992), but never in larval sailfish.

The objectives of the current study were to use otolith microstructure to estimate the ages of sailfish larvae and to construct growth curves in terms of both length and weight.

Materials and methods

Istiophorid larvae were collected for age estimation from the Straits of Florida with a 1 mm mesh net from 1999 to 2002, between the months of April and September. All larvae were preserved in 75–95% ethanol. Sailfish were identified using the methods described in Luthy *et al.* (2005), and notochord length (NL) or standard length (SL) was measured after soaking each larva in tap water for 1 min. No corrections were made for shrinkage. Fifty-five of the larvae were dried to constant weight at 60°C for 24 h and then weighed to the nearest 0.1 mg with an Ohaus Adventurer microbalance (Ohaus Corporation, Pine Brook, NJ) for determination of the relationship between dry weight and length.

Otolith extraction and examination

Three sailfish larvae from every half-millimetre size class were randomly chosen for age estimation. Larvae were covered in immersion oil, and the tissues left to clear overnight. Under a dissecting microscope, with the larva ventral side up, the body was separated from the head at the isthmus, and the lower jaw, branchiostegals, and gill arches cleared away. The otoliths were then visible and birefringent under crossed polarising filters (Fig. 1). Sagittae and lapilli were gently teased out and cleaned with microprobes, and then stored, medial side down, in drops of immersion oil. The extremely small size of the otoliths (<200 µm diameter) prevented weight determination.

The ability of light microscopy to resolve fine increments is a concern in otolith analysis (Smith and Walker 2003). A preliminary comparison of light microscopy versus electron microscopy for otolith examination was performed by comparing images of the same otoliths. Sagittae and lapilli were dissected from seven larvae, in addition to those selected for age determination. Images of each otolith were captured via light microscope and growth increments were enumerated. The same otoliths were then individually embedded in Spurr resin (Electron Microscopy Sciences, Hatfield, PA) blocks and sectioned by thicknesses of 90–120 nm with a Porter-Blum microtome (Dupont-Sorrall Instruments, Newton, CT). Problems with locating otoliths within resin blocks were ameliorated by dyeing the otoliths in an ethanol-Neutral Red solution before embedding. Sections were viewed via a Philips 300 transmission electron microscope (Philips Research, Eindhoven, The Netherlands) (TEM). Sectioning ceased when the core of the otolith was approached. The surface of the resin block was immersed in 2% acetic acid for 5 s to etch the face of the embedded otolith, which was then imaged with the secondary electron detector of a JEOL JSM-5600 LV scanning electron microscope (JEOL USA Inc., Peabody, MA) in environmental mode at 20 kV. Portions of growth increments were visible in TEM sections; the narrowest of these were 2 µm, which is well above the resolution limit of light microscopy at 0.2 µm (Neilson 1992). Because of difficulties in sectioning, only one otolith was suitable for age estimation via scanning electron microscopy once sectioned and etched. Eleven increments were visible, as compared to the ten visible in the light microscope image. Though rigorous statistical testing of the hypothesis that light and electron microscopy yield the same age estimates was not possible, this preliminary datum indicated that light microscopy was adequate for the

examination of otoliths in larval sailfish and far preferable from the standpoint of ease of use and cost.

The transparency of the otoliths made sectioning and polishing unnecessary for examination with a light microscope. All available otoliths were analysed with a Leica transmitted light microscope (Leica Microsystems, Wetzlar, Germany) (oil immersion lens) at 1000× total magnification, using methods similar to those employed by Sponaugle *et al.* (2005). Analysis included image capture with a CoolSNAP-PROcf Monochrome digital camera (Media Cybernetics, Inc., Silver Spring, MD) and the use of Image-Pro Plus software (version 4.5, Media Cybernetics, Inc.) to enumerate presumed daily growth increments, measure each increment width, and measure otolith radius from the primordium to the outer edge, along the longest axis of the otolith (Fig. 2). Daily growth increments were identified using the criteria of Campana (1992), i.e. relatively regularly spaced marks that remained prominent through focal adjustments. The first increment outside the increment surrounding the core (presumed hatch check) was counted as Day 1. No corrections were made for time of the first increment deposition.

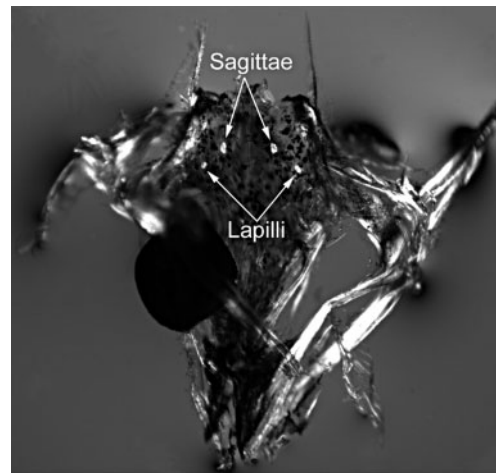


Fig. 1. Location of otoliths within a 7.1 mm sailfish larva after clearing in immersion oil, ventral view, with body, lower jaw, branchiostegals and gills removed. Asteriscii are not visible here, but when located, were very close to sagittae and exceptionally small.

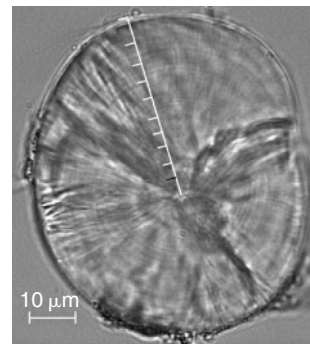


Fig. 2. Left sagitta (41.7 µm radius) from a 6.9 mm sailfish larva at a total magnification of 1000×. Presumed daily increments are marked in white; presumed hatch check, surrounding the core, is marked in black. Not all increments are clear in the same focal plane.

To determine which of the otoliths to use for age determination, growth increment counts from the first read were tested for differences between otoliths. *F*-tests ($\alpha = 0.05$) were performed to test for equality of sample variances, whereas single-factor analyses of variance (ANOVA, $\alpha = 0.05$) were used to compare mean increment counts between the right and left otoliths of each pair, and between the averaged counts of the sagittae and lapilli. Ultimately, the more easily read sagitta of each larva was used to estimate age; the remaining otoliths were not re-analysed.

To ensure reader consistency, sagittae were blind coded and read up to five times, on separate occasions, so that increment widths, averaged over all larvae, plotted against increment number converged between counts (e.g. increment widths at a given increment number were similar between the third, fourth and fifth reads). Only the last three counts were considered for age estimation. If at least two of the three increment counts matched exactly, that count was taken as the age estimate. When no two counts were the same, the coefficient of variation (CV) for all three counts was calculated; the median count was chosen when the CV was $< 10\%$, but when $CV > 10\%$ data for the larva were discarded.

Models

A power curve was fit to standard length versus dry weight data for the 55 oven-dried larvae. Lengths of larvae for which age was estimated were subsequently converted to dry weight using this relationship to yield an age-weight relationship. Age of the weighed fish was not estimated directly because the drying process made otolith extraction exceedingly difficult. Linear and exponential functions were fit via least-squares

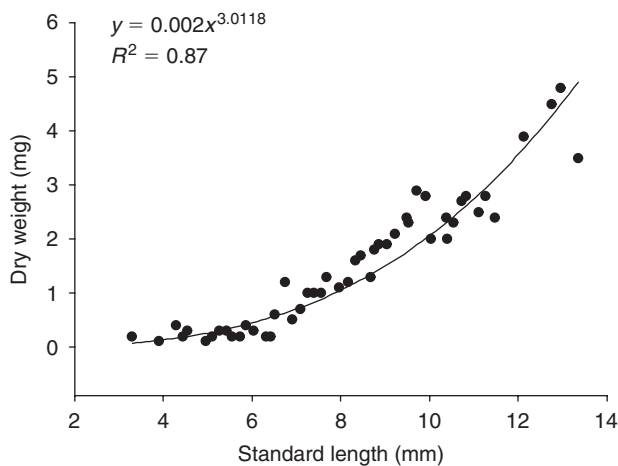


Fig. 3. Weight-length relationship for larval sailfish 3.2–13.4 mm standard length.

methods to fish length versus estimated age and to estimated dry weight versus estimated age without constraint on the intercept (an estimate of size-at-hatch), and without transformation of data. Functions that best fit the data (highest R^2 values) were chosen as mean growth trajectories. Relationships between standard length and otolith radius and between otolith radius and age were also examined.

Comparisons

Growth curves and dry weight-length relationships for other species of marine larvae were sought in the literature. Portions that encompassed similar size and/or age ranges to those examined here were plotted along with sailfish growth. Because few equations for larval growth in weight were found, weight-length relationships were used to convert growth in length to growth in weight for some species.

Results

Sailfish larvae were collected in the Straits of Florida from waters characterised by temperatures between 26.1°C and 30.6°C . Salinity ranged from 34 to 36.7. Larvae between 3.2 and 13.4 mm NL or SL were dried to constant weight. A power curve with exponent 3.01 described the relationship between dry weight and length (Fig. 3, Table 1).

Sagittae and lapilli were successfully extracted from 70 larval sailfish (2.8–16.8 mm NL or SL). Both otoliths were small (sagitta radii 15.4–96.3 μm ; lapillus radii 14.8–52.9 μm), with a shallow sulcus on the medial surface. Lapilli and sagittae of larvae < 8 mm NL or SL were disc-shaped and of similar size. Sagittae of the largest larvae were more oblong and possessed a deeper sulcus, whereas lapilli remained relatively flat and round. ANOVAs revealed no significant differences between left and right lapillus counts ($n = 60$, $F_{1 \text{ df}} = 0.035$, $P = 0.85$), between left and right sagitta counts ($n = 65$, $F_{1 \text{ df}} = 0.179$, $P = 0.67$) and between averages of pairs of lapilli and sagittae ($n = 67$, $F_{1 \text{ df}} = 3.477$, $P = 0.06$). Data from 14 larvae (20%) were discarded owing to high CV among counts of the chosen sagitta. There were strong linear relationships between sagitta radius and both standard length and estimated age (Fig. 4).

Estimated ages of larval sailfish ranged between 3 and 18 days. Growth was best described by exponential curves (Figs 5 and 6). At hatch, sailfish were estimated to be 1.96 mm NL and 0.015 mg (dry weight). Variability in size at age increased with age.

Table 1. Reported weight-length relationships for various marine larvae
Unit of dry weight is indicated in subscript, all lengths are standard (or notochord) and in mm

Species	Length range examined	<i>n</i>	Dry weight-length relationship	Reference
<i>Chloroscombrus chrysurus</i> (Atlantic bumper)	0.8–4.8	120	$W_{\text{mg}} = 0.0016L^{3.25}$	Leffler and Shaw 1992
<i>Clupea harengus</i> (Atlantic herring)	8–30	98	$\text{Log}_{10} W_{\mu\text{g}} = -2.324 + 4.295\text{Log}_{10} L$	Laurence 1979
<i>Gadus morhua</i> (Atlantic cod)	5–12	104	$\text{Log}_{10} W_{\mu\text{g}} = -1.103 + 4.081\text{Log}_{10} L$	Laurence 1979
<i>Istiophorus platypterus</i> (sailfish)	3.2–13.4	55	$W_{\text{mg}} = 0.002L^{3.0118}$	Present study
<i>Leiostomus xanthurus</i> (spot)	2–20	125	$< 6 \text{ mm: } W_{\text{mg}} = 0.223L^{4.201}$; $\geq 6 \text{ mm: } W_{\text{mg}} = 1.4515L^{3.282}$	Warlen and Chester 1985
<i>Melanogrammus aeglefinus</i> (haddock)	5–10	23	$\text{Log}_{10} W_{\mu\text{g}} = -1.353 + 4.476\text{Log}_{10} L$	Laurence 1979

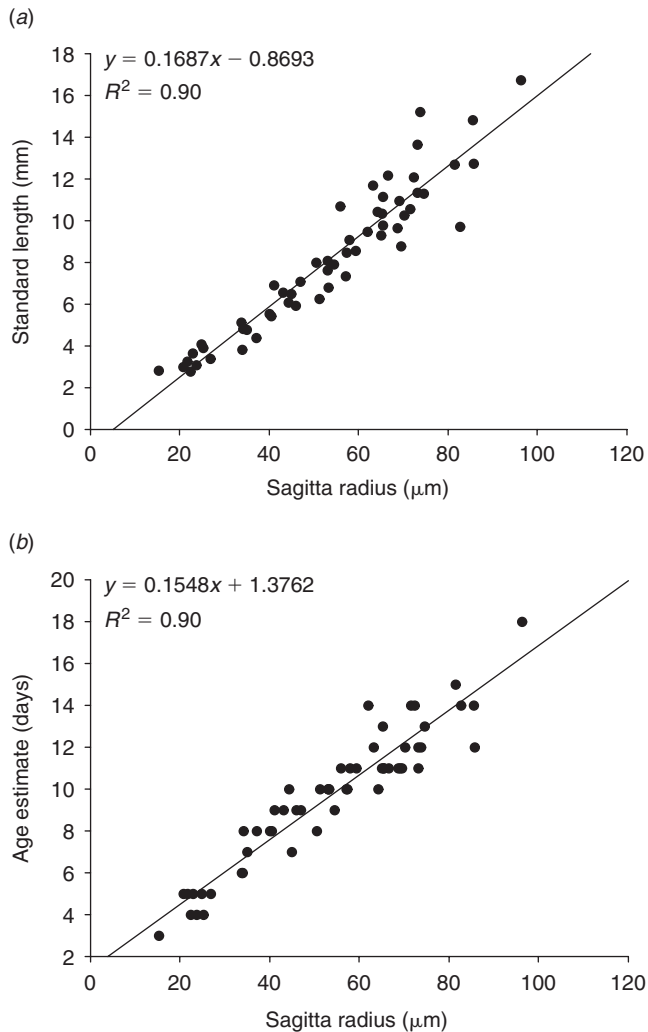


Fig. 4. Relationships between sagitta radius and larval (a) length and (b) estimated age.

Larval sailfish growth in length was comparable to that of other pelagic species as larvae (Fig. 7, Table 2). The instantaneous (length) growth rate ($G = 0.137$) resulting from the current study is slightly higher than any of the year- and location-specific growth rates reported for larval blue marlin (*Makaira nigricans*, $G = 0.0856$ – 0.1282) from the Straits of Florida and Exuma Sound (Serafy *et al.* 2003; Sponaugle *et al.* 2005). Growth in length and weight was much faster in sailfish than in the larvae of more temperate species (Figs 7, 8).

Discussion

Larval sailfish sagittae, although tiny and fragile, require little preparation for viewing under a light microscope. Increments were sufficiently wide for observation with a light microscope, but, in some cases, primary increments were obscured

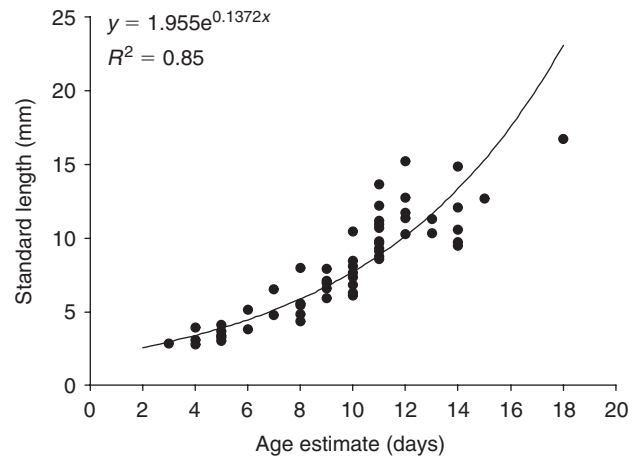


Fig. 5. Relationship between length and age for larval sailfish 2.8–16.7 mm standard length.

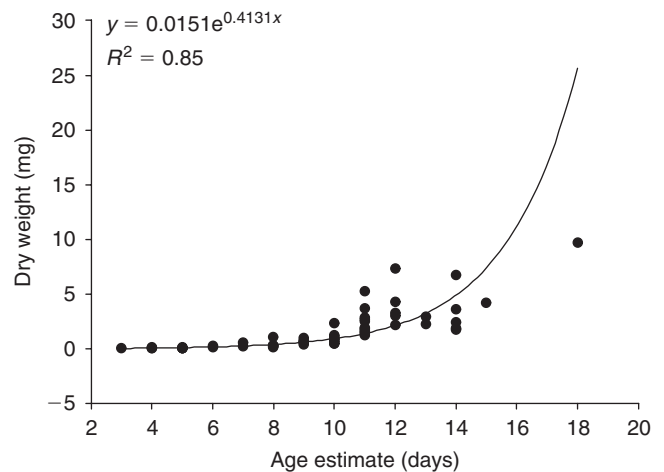


Fig. 6. Relationship between dry weight and age for larval sailfish 2.8–16.7 mm standard length. Dry weights were obtained by conversion of the length measurement with the weight–length relationship shown in Fig. 2 and in Table 1.

or sub-daily increments were prominent, making age determination difficult and resulting in a high CV between repeated analyses. When otoliths are difficult to read, a viable alternative may be to estimate age from the sagitta radius, as the relationship between age and radius was strong. The results presented here represent the first otolith-based study of larval sailfish age and growth, but they must be regarded in context of the assumptions made.

Assumptions

Two prerequisites for age determination by otolith microstructural analysis are (1) knowledge of time of the first increment deposition and (2) validation of daily deposition. Timing of the deposition of the first increment surrounding the core is species-specific and may occur before hatching

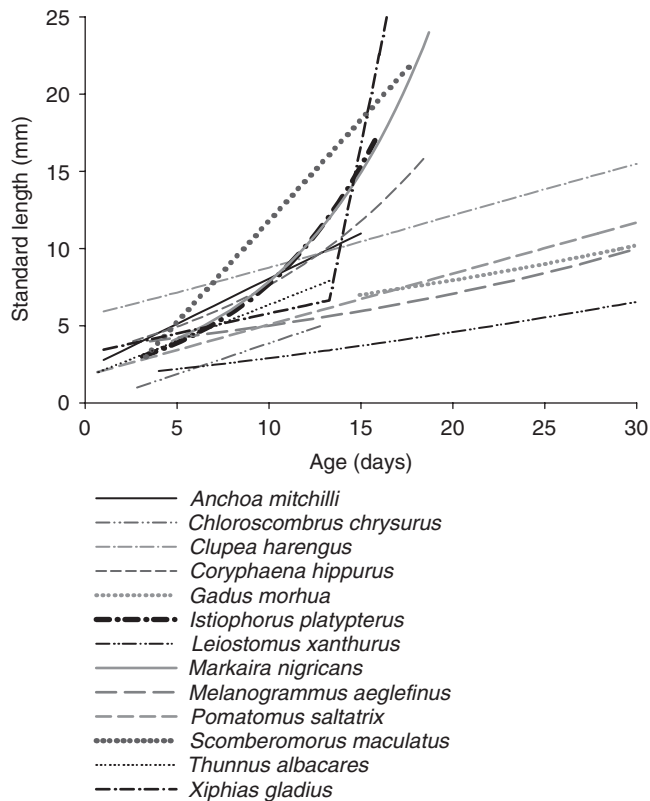


Fig. 7. Growth in length for the larvae of various marine fishes. Growth equations, size range examined and information sources are provided in Table 2. In the cases where more than one growth equation was reported, only the fastest growth is shown.

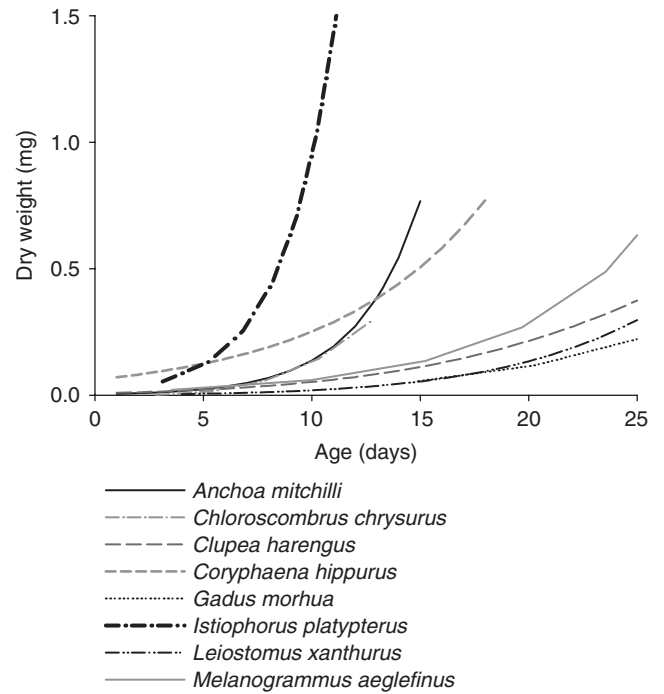


Fig. 8. Growth in weight for the larvae of various marine fishes. The equations for *Istiophorus platypterus*, *Coryphaena hippurus* and *Anchoa mitchilli* growth curves are presented in Table 2. For other species, growth in length from Table 2 was converted to growth in weight using the weight-length relationships provided in Table 1. In the cases where more than one growth equation was reported, only the fastest growth was plotted.

Table 2. Reported growth equations for various marine larvae

All lengths are standard or notochord. With the exceptions of *Anchoa mitchilli* and *Coryphaena hippurus*, growth equations are for wild-caught larvae

Species	Size range (mm)	Growth in length (mm)	Growth in dry weight (mg)	Reference
<i>Anchoa mitchilli</i> (bay anchovy) ^A	3–11	$L = 0.586age + 2.195$	$W = (4.387e^{0.3443age})/1000$	Houde and Schekter 1981
<i>Chloroscombrus chrysurus</i> (Atlantic bumper) ^A	0.8–4.8	$L = 0.40age - 0.13$	N/A	Leffler and Shaw 1992
<i>Clupea harengus</i> (Atlantic herring)	5.7–35.0	$L = 30.9e^{-1.7exp(-0.03age)}$	N/A	Lough <i>et al.</i> 1982
<i>Coryphaena hippurus</i> (dolphin) ^A	3.3–20.0	$L = 3.19e^{0.087age}$	$W = 0.062e^{0.14age}$	Benetti 1992
<i>Gadus morhua</i> (Atlantic cod)	7.8–24.9	$L = 4.82e^{0.025age}$	N/A	Bolz and Lough 1983
<i>Istiophorus platypterus</i> (sailfish)	2.8–16.8	$L = 1.955e^{0.1372age}$	$W = 0.0151e^{0.4131age}$	Present study
<i>Leiostomus xanthurus</i> (spot)	~2–20	$L = 1.609e^{2.624(1-exp(-0.0255age))}$	N/A	Warlen and Chester 1985
<i>Makaira nigricans</i> (blue marlin) ^A	3.5–23.3	$L = 2.18e^{0.1282age}$	N/A	Sponaugle <i>et al.</i> 2005
<i>Melanogrammus aeglefinus</i> (haddock)	3.5–12.7	$L = 3.54e^{0.0346age}$	N/A	Bolz and Lough 1983
<i>Pomatomus saltatrix</i> (bluefish)	2.0–25.0	$L = 0.33age + 1.78$	N/A	Hare and Cowen 1994
<i>Scomberomorus maculatus</i> (Spanish mackerel)	2.8–22.0	$L = 1.31age - 1.3$	N/A	De Vries <i>et al.</i> 1990
<i>Thunnus albacares</i> (yellowfin tuna)	2.57–7.48	$L = 0.47age + 1.67$	N/A	Lang <i>et al.</i> 1994
<i>Xiphias gladius</i> (swordfish)	~4–120	<13.29 days: $L = 0.26age + 3.2$; ≥13.29 days: $L = 5.86age - 71.22$	N/A	Govoni <i>et al.</i> 2003

^AMore than one growth equation reported in original, fastest growth reported here.

or not until yolk-sac absorption is complete (Brothers *et al.* 1976). Particularly if back-calculation to spawning areas is an objective, a correction factor for otolith-derived age is necessary to obtain absolute age. The periodicity of increment formation should also be validated for each otolith type examined in a previously unstudied species. Although most fish otoliths examined to date do exhibit daily increment deposition (Jones 2002), this is not always the case. For example, bluefish (*Pomatomus saltatrix*) sagittal increments are deposited daily, but one increment is added to the lapillus every 2 days until flexion, at which point deposition becomes daily (Hare and Cowen 1994). Use of the lapillus for age estimation in bluefish would result in underestimation of true age. Apparent cessation or slowing of increment deposition when the fish experiences suboptimal growth conditions (e.g. Geffen 1982; Neilson and Geen 1982) can also lead to inaccurate age determination. Under these circumstances, growth increments may still form on a daily basis, but be too narrow for observation with light microscopy, hence requiring the higher resolution of electron microscopy (e.g. Jones and Brothers 1987). Both the timing of first increment deposition and the periodicity of deposition may be determined by raising larvae in the laboratory or in mesocosms. Periodicity may also be determined from wild-caught larvae exposed to an otolith-marking substance such as oxytetracycline and held for known time periods. Unfortunately, neither sailfish nor any other member of the family Istiophoridae has been successfully raised from the egg, and wild-caught istiophorid larvae, when they survive capture, display an extreme stress response and tend not to live long in captivity (Post *et al.* 1997; Idrisi *et al.* 2003).

Because of the impediments to the direct assessment of deposition periodicity and time of first increment formation for sailfish, assumptions about these values must be made. Prince *et al.* (1991) present evidence that increments are deposited daily in the sagittae of another istiophorid, the blue marlin: (1) back-calculated spawning dates of larvae, juveniles, and young adults match the spawning season reported in the literature when an increment periodicity of 1 day is specified; and (2) larval blue marlin otolith microstructure is comparable to that of other species for which deposition rates have been directly validated. In the present study, the back calculation of spawning dates was not helpful in determining increment periodicity because the available larvae were so young, and all were caught within the protracted spawning season of this species. However, as in the blue marlin, sailfish sagittal microstructure appeared to be consistent (e.g. similar banding pattern) with published descriptions of otolith microstructure in species with validated daily deposition. In the otoliths of most tropical fishes, the first increment forms within a week of fertilisation (Brothers 1979). Here it is assumed that the core increment forms at hatch and that the first daily increment forms 1 day later. This timing of first increment formation has been validated in tropical

tunas (Radtke 1983; Tanabe *et al.* 2003), and is supported for sailfish by a reasonable estimate of hatch size (2.0 mm SL) using an exponential growth model. For back calculations of spawning date, length of egg incubation would be added to the otolith-derived age estimate of each larva. This value is also unknown for istiophorids, but has been observed in the laboratory as 60–70 h at 22.5–25.2°C for a related family, Xiphiidae (Yasuda *et al.* 1978). Because increased temperature can shorten incubation time (Pepin 1991), 3 days is a maximum estimate of incubation time for sailfish in the present study, which were caught in waters at 26.1–30.6°C. The uncertainties involved in both the timing of first increment deposition and length of egg incubation at the environmentally appropriate temperatures require that caution be used in back-calculating spawning dates.

Growth

Growth rates can vary because of such factors as temperature, i.e. seasonal and/or latitudinal effects (Houde 1989), and food availability and quality (Peck *et al.* 2003). Variability can exist from 1 month to the next and even within regions of a relatively restricted area (e.g. *Anchoa mitchilli* in Chesapeake Bay; Rilling and Houde 1999; *Sciaenops ocellatus* in the Aransas Estuary; Rooker *et al.* 1999). Growth of larval blue marlin has been shown to vary between the Straits of Florida and Exuma Sound, Bahamas, and between years (Sponaugle *et al.* 2005). The sailfish larvae examined in the current study were collected over 4 years, throughout the entire spawning season, and from several locales within the Straits of Florida. In life, they were exposed to a range of environmental conditions, and possibly to disparate food resources. Therefore, the growth rates reported here, and especially their variability, likely integrate over these differences in the timing and location of sample collection and/or post-spawning 'histories'. These differences, in addition to growth depensation (increasing variability with increasing age) and genetic variation, may have driven the variability around the growth curves estimated here.

The growth-mortality hypothesis states that survival and growth rates are directly related through processes of feeding and predation (Anderson 1988). Sailfish grow quickly in their first few weeks of life, with an average growth trajectory similar to that reported for blue marlin from Exuma Sound (Sponaugle *et al.* 2005). Other fast-growing species include dolphin (*Coryphaena hippurus*), swordfish (*Xiphias gladius*) and Spanish mackerel (*Scomberomorus maculatus*). Young epipelagic fishes such as these consistently yield higher metabolic rate measurements than the young of benthopelagic or even inshore-pelagic species (Lipskaya 1974). Brill (1996) postulates that the 'high performance' physiology enabling the high metabolic rates characteristic of pelagic fishes evolved to promote high rates of growth. In turn, these high rates of growth, in accordance with the growth-mortality hypothesis, may be advantageous for survival of the young.

Transition to piscivory is often accompanied by an acceleration of growth (Juanes and Conover 1994; Olson 1996; Fitzhugh *et al.* 1996; Govoni *et al.* 2003). A striking illustration of the effect of diet on growth trajectory is the abrupt shift in slope in the larval swordfish growth curve (Govoni *et al.* 2003). This shift in growth rate is accompanied by an equally abrupt shift in larval swordfish diet from copepods and chaetognaths to exclusively fish larvae (Govoni *et al.* 2003). Differences among taxa in early growth trajectories may also be partially explained by diet. Of the species compared here, the Spanish mackerel has the steepest growth trajectory in the first 10 days, likely reflecting the precocious development of the digestive system and nearly exclusive piscivory from first feeding (Tanaka *et al.* 1996). Sailfish larvae, like swordfish, begin feeding on zooplankters such as copepods, but their transition to piscivory is more gradual, starting at 6 mm SL. Sailfish are primarily piscivorous by 13 mm SL (Gehringer 1956). The relationship between larval sailfish growth and diet may be more fully explored by a coupled study of otoliths and gut contents, accounting for the variation-inducing effects of environmental variables such as temperature.

Increase in length, although an important component of growth, does not fully convey the changes in size occurring in fish. Taxa as diverse as those compared here represent a myriad of shapes, some characteristically deep-bodied, whereas others are relatively slender. Weight–length relationships of larvae cannot reliably be used to compare condition as they are in adults because changes are caused more by development than by condition, particularly in larvae that are poorly developed at hatch (Jones 2002). However, the length exponent of the weight–length relationship is somewhat useful as an indicator of shape in larvae, and an examination of growth rates in weight and length provides perspective as to the importance of each. The typical length exponent for marine larvae is 4.0 (Laurence 1979; Power 1989). Compared to this value, and to the published length–weight relationship of other species of marine larvae, the length exponent of sailfish larvae (3.0) is low, reflecting its elongate body form. Yet, despite the relatively low length exponent, sailfish larvae grow faster in weight as well as length compared to the larvae of other species.

Studies of larval age and growth are fundamental to understanding the life history of a species. The growth curves presented here are the first empirical assessments for larval sailfish. As such, they will be useful for gaining insight into possible size-at-hatch and, ultimately, for delineating spawning times and areas for this species in the western Atlantic Ocean. Of course, further work is required to replace many of the assumptions made here with empirically based data, especially those that address the processes influencing growth variability, such as diet shifts and the oceanographic conditions experienced after hatch. Finally, because Atlantic sailfish are managed as western and eastern Atlantic stocks (Graves and McDowell 2003), an analogous effort on larval

sailfish collected in eastern Atlantic waters is warranted, as is age and growth work on Pacific and Indian Ocean specimens.

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