Age and Growth of Larval Sailfish, *Istiophorus platypterus*, in the Northern Gulf of Mexico

JEFFREY R. SIMMS[1], SCOTT HOLT[2], G. JOAN HOLT[2], JESSICA BANGMA[1], and JAY R. ROOKER[1]
[1]*Department of Marine Biology, Texas A&M University at Galveston, Galveston, Texas 77551 USA*
[2]*Department of Marine Science, University of Texas Marine Science Institute, Port Aransas, Texas 78373 USA*

ABSTRACT

Sailfish, *Istiophorus platypterus*, are commonly taken by anglers in the Gulf of Mexico and larvae are frequently reported in this region, indicating the Gulf's potential role as spawning and/or nursery ground. Ichthyoplankton surveys were conducted in the northern Gulf of Mexico in waters off Texas and Louisiana (27 – 28° N 89 - 94° W) from 2005 – 2007 to collect larvae for age and growth investigations. During the three year survey, over 2,000 sailfish larvae were collected, and sagittal otoliths were extracted from 669 sailfish larvae, ranging in size from 2.0-24.3 mm standard length (SL). Otolith microstructure analysis indicated that sailfish ages ranged between 3 and 18 days, and hatch-date distributions indicated fish were from early May to mid September spawning events. Instantaneous growth coefficients ranged from 0.132 to 0.158 with an overall rate of 0.144. Growth rates varied by season and year, indicating temporal changes in environmental conditions may influence the survival and recruitment success of sailfish in this region.

KEY WORDS: Sailfish, otolith, larval growth

Edad y Crecimiento de Larvas del Pez Vela, *Istiophorus platypterus*, en la Parte Norte del Golfo de México

El pez vela, *Istiophorus platypterus*, es capturado comúnmente por pescadores en el Golfo de México y la presencia de larvas es reportada con frecuencia en esta región, indicando el papel potencial del Golfo como area de desove y o campo de cultivo. Larvas del pez vela fueron capturadas, en la parte norte del Golfo de México en aguas de los estados de Texas y Louisiana (27 – 28° N 89 - 94° W) del 2005 al 2007, para investigar edad y crecimiento de las larvas. Durante los tres años del estudio, mas de 2000 larvas del pes vela fueron recogidas y otolitos sagitales fueron extraído de 669 larvas del pez vela, abarcando en tamanno de 2,0 a 24,3 mm de longitud estandar (SL). El análisis de la microestructura de otolitos indicó edades del pez vela entre 3 y 18 días, y las distribuciones de eclosion indicaron que el periodo de desove fue a principios de mayo a mediados de septiembre. Coeficientes instantáneos de crecimiento abarcaron de 0,132 a 0,158 con una tasa promedio de 0,144. La taza de crecimiento vario por estacion y por año, sugiriendo que cambios temporales en condiciones ambientales pueden influir el éxito de sobrevivencia y enlistamiento del pez vela en esta región.

PALABRAS CLAVES: El pez vela, otolitos, crecimiento de larvas

INTRODUCTION

Sailfish, *Istiophorus platypterus*, is one of four istiophorid species found in the Gulf of Mexico and Caribbean Sea. It is an economically and ecologically important apex predator, yet little is known about the early life history of this species. Previous studies indicated that sailfish are fast growing, late maturing, and long-lived (Hoolihan 2006, NMFS 2002, Ortiz *et al* 2005). Maximum sizes reach 58 kg and 3.1 m lower jaw fork length, with sexual maturation occurring at three years of age and a life expectancy up to 17 years (Ortiz *et al* 2005). Pelagic longline fishery data indicates sailfish are caught throughout the Gulf of Mexico and experience high mortality in the region as bycatch in fisheries targeting tuna and swordfish (Ortiz *et al* 2002). Sailfish are now considered overfished and current population estimates indicate the Atlantic sailfish population is at 62% of the level needed to achieve maximum sustainable yield (MSY) (NMFS 2002).

Subtle variations in growth and mortality rates during the early life stages of fishes can greatly affect recruitment success (Houde 1987). Rapid growth has been suggested to enhance larval survival due to high predation during the early life stages (Rooker *et al* 1997). Studies have suggested that individuals that grow rapidly and achieve a larger body size spend less time in the most vulnerable early life stages (Bailey 1989). Thus, understanding the factors responsible for differences in growth during early life stages of sailfish can be used to assess important factors regulating survival as well as recruitment potential. Here we use otolith microstructure analysis to estimate age and growth of sailfish larvae over three consecutive years in the northern Gulf of Mexico. In addition, we examined intra- and interannual variation in growth to help identify factors that may affect survival and year class strength of sailfish in the region.

METHODS

Sample Collections

Ichthyoplankton surveys were conducted in shelf and slope waters of the northern Gulf of Mexico (27–28° N and 88–94° W) during the summer in 2005, 2006 and 2007. This area was sampled because a large fraction of the commercial bycatch of sailfish comes from this region (Goodyear 1999). Larvae were obtained using two neuston nets (2m width x 1m height frame, one 500µm and one 1200µm mesh size) pulled through the upper meter of the

Table 1. Growth equations for Gulf of Mexico sailfish larvae. y = standard length (mm), x = age

Collection Trip	n	Size Range (SL in mm)	Growth Rate Equation	r^2
May 2005	63	2.2-11.3	$y = 1.452e^{0.132x}$	0.81
July 2005	135	2.2-24.3	$y = 1.406e^{0.152x}$	0.83
June 2006	83	2.1-15.9	$y = 1.567e^{0.137x}$	0.75
July 2006	243	2.7-21.2	$y = 1.779e^{0.134x}$	0.71
June 2007	105	2.7-14.9	$y = 1.623e^{0.158x}$	0.83
July 2007	40	2.0-19.5	$y = 1.616e^{0.148x}$	0.88
Overall	669	2.0-24.3	$y = 1.584e^{0.144x}$	0.76

water column at approximately 2.5 knots for 10 minutes. Tows were conducted at locations approximately 8 nautical miles apart throughout the sampling corridor. At each tow location, GPS start and stop points, water temperature, salinity, dissolved oxygen and water flow were recorded. Material caught during tows was collected in the net's cod end and sorted onboard. Collections were preserved in 95% ethanol for further sorting in the laboratory. Preserved samples were sorted in the lab with the use of Leica MZ stereomicroscopes and all istiophorid larvae were counted and removed. Certain istiophorid larvae >8 mm SL can be identified visually (i.e. sailfish vs. blue marlin), but specimens < 8 mm SL had trunk tissue or an eyeball removed and preserved in 95% ethanol for genetic identification following the methods of McDowell *et al.* (2002).

Otolith Microstructure Analysis

Sailfish were photographed, measured (SL in mm) and dissected. Sagittal and lapillar otoliths were extracted, cleared in immersion oil, and preserved in mounting media (Flotexx). Mounted otoliths were photographed at high magnification with an Olympus BX41 light microscope. Daily growth increments were enumerated using Image-Pro Plus 4.5 software. Otolith radius along the longest axis (core to outer edge) and the radius from the core to the first increment were measured. Two independent readings were made of each otolith; when two readings were within 10% of each other a random measurement was used for analysis. When readings differed by >10% a third independent reading was performed. If the third reading differed from the others by >10%, the otolith was not used for age and growth assessments. If the third reading was < 10% of one of the former readings one of these two measurements was randomly selected for analysis.

Data Analysis

Exponential models were applied to age-length data to determine instantaneous growth rates of sailfish. Growth rates were calculated for six cohorts (two each summer) and all cohorts were combined to yield an overall estimate of growth. Growth rates between months and years were tested for significant differences in slopes using analysis of covariance (ANCOVA), with SL as the dependent variable, month or year as a fixed factor and age as the covariate (SPSS 14.0). Age-length keys were used to predict the age of all remaining sailfish (n = 1362) and hatch date was estimated by subtracting age from catch date.

RESULTS AND DISCUSSION

A total of 2,031 sailfish larvae was collected with sizes ranging from 2.0 - 24.3 mm SL. Length distributions were similar among years with a peak size of 4.0 – 6.0 mm SL each summer (Figure 1). Otoliths were extracted from 669 of the samples to determine age, which ranged from 3-18 days post hatch. Age distributions indicated no interannual variation with peak age at 8 - 9 days post hatch each summer (Figure 2).

Instantaneous growth coefficients ranged from 0.132 to 0.158, with an overall growth rate of 0.144 (Figure 3, Table 1). Analysis of covariance showed an influence of season on growth with a significant difference in slopes between months in 2005 ($p = 0.000$) and 2006 ($p = 0.000$). Additionally, annual variation in growth was observed for three consecutive Julys ($p = 0.008$) indicating both seasonal and annual variation in larval growth rates in the northern Gulf of Mexico. The instantaneous growth rates observed here are comparable to that reported for sailfish in the Straits of Florida (0.137, Luthy *et al.* 2005) and larval blue marlin, *Makaira nigricans*, in the Straits of Florida and Exuma Sound, Bahamas (0.086 - 0.128, Sponaugle *et al.* 2005). Similar to other studies on pelagic fishes (Wexler *et al.* 2007), this study showed that growth of sailfish varies both seasonally and annually. Pronounced temporal variation within and among years has also been reported for other istiophorids during early life (Sponaugle *et al.* 2005). Growth variation is often linked to temporal changes in environmental conditions (e.g. temperature, prey availability, Sponaugle *et al.* 2006, Folkvord 2005, Power *et al.* 2007), and further work is needed in the northern Gulf of Mexico to determine the relative importance of changing conditions on the growth, survival and recruitment potential of sailfish.

Hatch dates ranged from early May to mid September, with peak hatch during July (Figure 4). The maximum estimate of egg incubation for Istiophoridae is three days

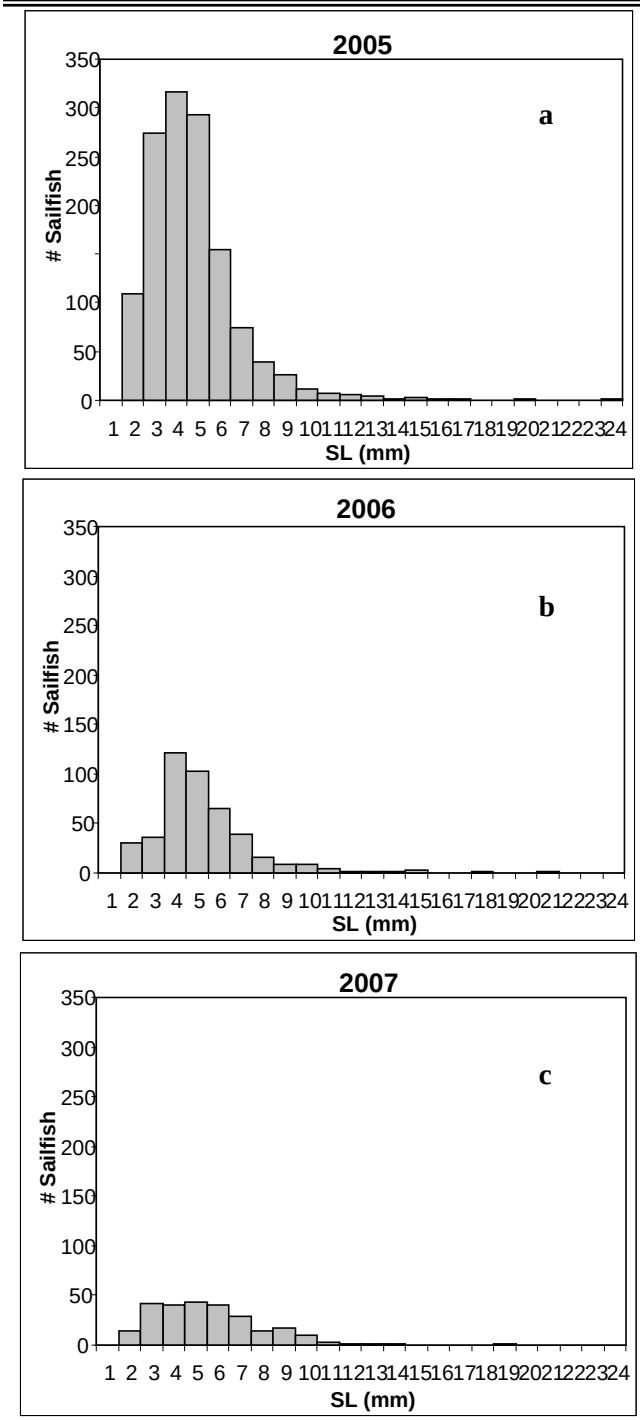

Figure 1. Larval sailfish length distributions arranged by year. x-axis label indicates starting size for bin. a) 2005, n = 1327 b) 2006, n = 441 c) 2007, n = 263.

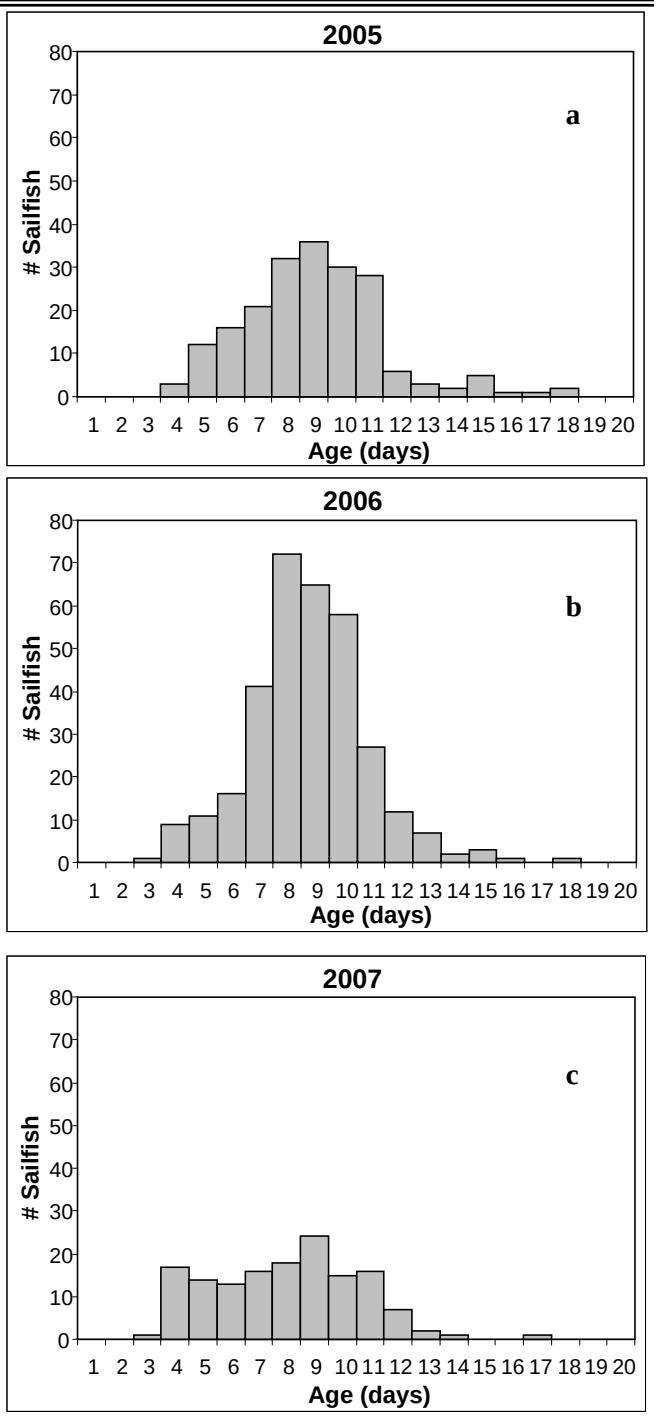

Figure 2. Sailfish age distribution arranged by year a) 2005, n = 198 b) 2006, n = 326 c) 2007, n = 145.

(Luthy *et al.* 2005, Yasuda *et al.* 1978), so spawning is presumed to peak in July three days prior to hatch. Since the majority of sailfish were 10 days of age or less, hatch dates were grouped around the sampling dates, and thus the gaps between hatch-date modes is an artifact of monthly sampling rather than natural variability in spawning. Our hatch-date profile is consistent with earlier reports by de Sylva (1997) and Luthy (2005), and supports the premise of peak spawning in the summer. Also, a wide range of larval ages and sizes were collected during early and late summer sampling periods, indicating that spawning is protracted in the Gulf of Mexico.

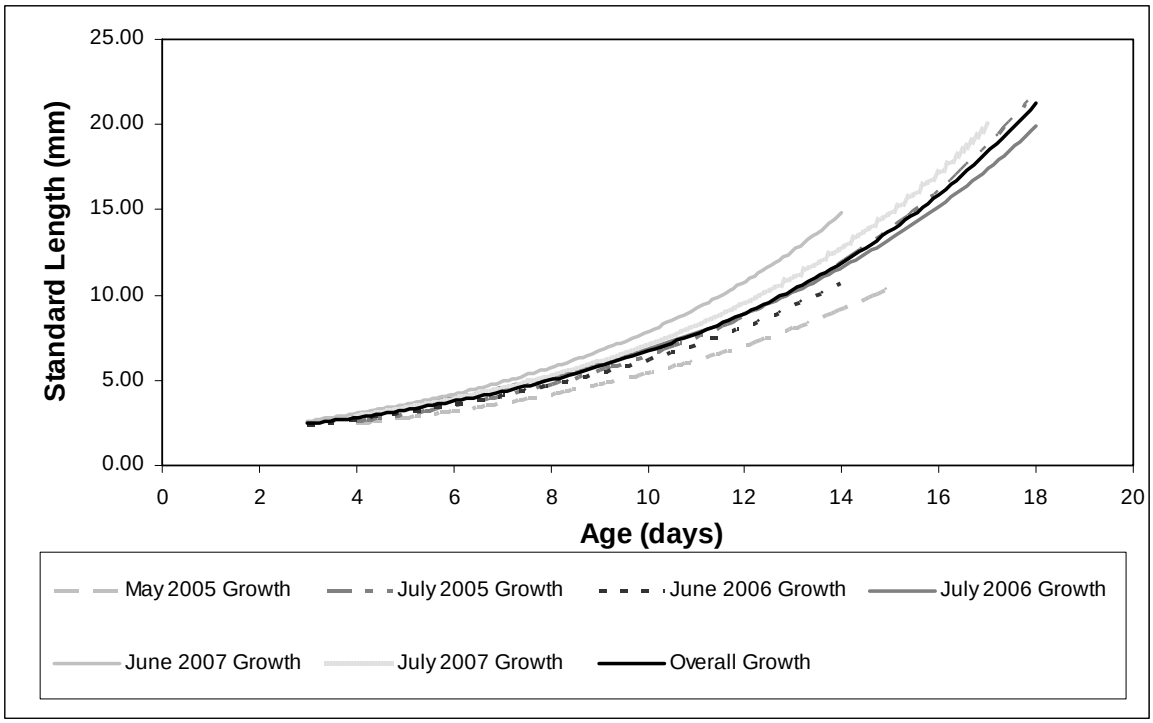

Figure 3. Age-length relationships from 6 cohorts in the northern Gulf of Mexico

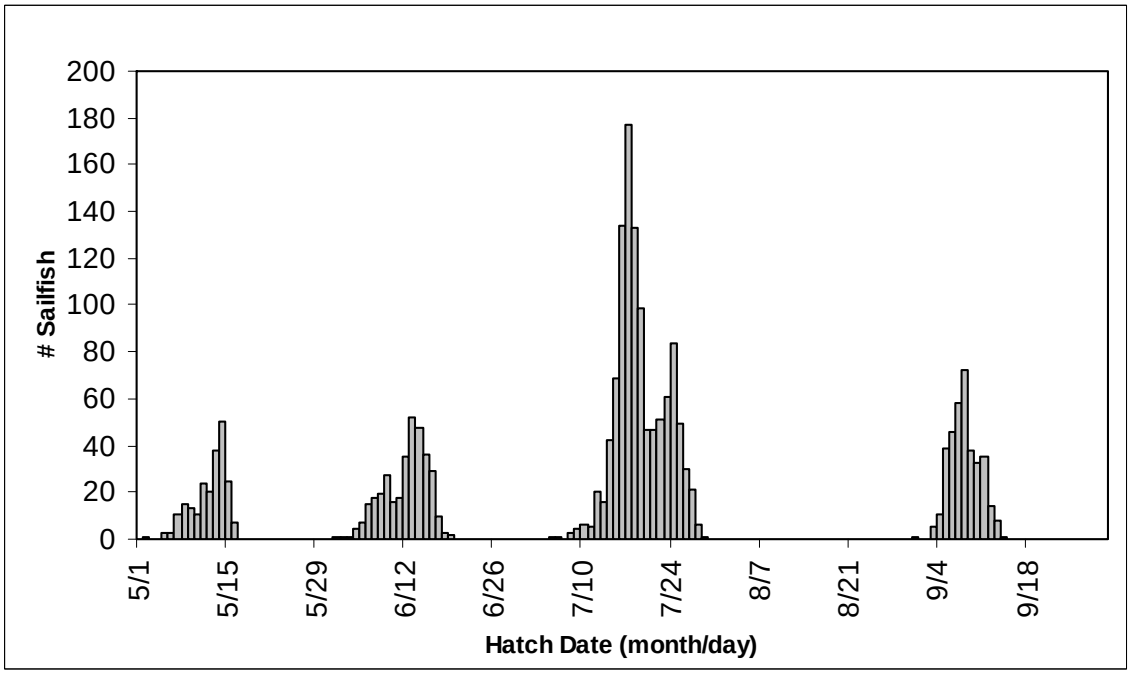

Figure 4. Larval sailfish hatch date distribution (month/day) for all cohorts in the northern Gulf of Mexico.

ACKNOWLEDGEMENTS

A special thank you to the many past and present members of the Rooker and Alvarado labs who assisted in the field and lab: Bert Geary, Dave Wells, Jess Beck, Ryan Schloesser, Jennifer Purviance, Brandon Saxton, Brad Smith, Lynn Wetmore, Brynn Devine, Erik Lang and Marie Hebert. Thank you to the members of the Holt labs at UTMSI who assisted in the field and in the lab: Travis Tidwell, Cameron Pratt and Jason Williams. Thank you to the crews of the Holo-Kai and Lady Bride. This work was supported by grants to Jay R. Rooker from NOAA fisheries, The McDaniel Charitable Foundation and The Oceanic Conservation Organization.

LITERATURE CITED

Bailey, K.M., and E.D. Houde. 1989. Predation on eggs and larvae of marine fishes and the recruitment problem. *Advances in Marine Biology 25*:1-83.

Brothers, E.B., C. Matthews, and R. Lasker. 1976. Daily growth increments in otoliths from larval and adult fishes. *Fishery Bulletin*. **74**:1-8.

De Sylva, D.P., and P.R. Breder. 1997. Reproduction, gonad histology and spawning cycles of North Atlantic billfishes (Istiophoridae). *Bulletin of Marine Science*. **60**: 668-697.

Folkvord, A. 2005. Comparison of size-at-age of larval Atlantic cod (*Gadus morhua*) from different populations based on size- and temperature-dependent growth models. *Canadian Journal of Fisheries and Aquatic Sciences* **62**:1037-1052.

Goodyear, C.P. 1999. An analysis of the possible utility of time-area closures to minimize billfish bycatch by U.S. pelagic longlines. *Fishery Bulletin* **97**:243-255.

Hoolihan, J.P. 2006. Age and growth of Indo-Pacific sailfish, *Istiophorus platypterus*, from the Arabian Gulf. *Fisheries Research* **78**:218-226.

Houde, E.D. 1987. Fish early life dynamics and recruitment variability. *American Fisheries Society Symposium Series* **2**:17-29.

Idrisi, N.T., T.R. Capo, S. Luthy, and J.E. Serafy. 2003. Behavior, oxygen consumption and survival of stressed juvenile sailfish, Istiophorus platypterus, in captivity. *Marine and Freshwater Behavior and Physiology* **36**(1): 51-57.

Luthy, S.A., J.E. Serafy, R.K. Cowen, K.L. Denit, and S. Sponaugle. 2005. Age and growth of larval Atlantic sailfish, *Istiophorus platypterus*. *Marine and Freshwater Research* **56**:1027-1035.

McDowell, J.R., and J.E. Graves. 2002. Nuclear and mitochondrial DNA markers for specific identification of istiophorid and xiphiid billfishes. *Fishery Bulletin* **100**:537-544.

NMFS. 2002. Stock Assessment and Fishery Evaluation for Atlantic Highly Migratory Species.

Ortiz, M., and C.A. Brown. 2002. Standardized catch rates for sailfish (*Istiophorus platypterus*) from the pelagic longline fishery in the Northwest Atlantic and the Gulf of Mexico. *Col. Vol. Sci. Pap. ICCAT* **54**:791-804.

Ortiz, M., E.D. Prince, J.E. Serafy, D.B. Holts, K.B. Davy, J.G. Pepperell, M.B. Lowry, and J.C. Holdsworth. 2005. Global overview of the major constituent-based billfish tagging programs and their results since 1954. *Marine and Freshwater Research* **54**:489-507.

Post, J.T., J.E. Serafy, J.S. Ault, T.R. Capo, and D.P. de Sylva. 1997. Field and laboratory observations of larval Atlantic sailfish (*Istiophorus platypterus*) and swordfish (*Xiphias galdius*). *Bulletin of Marine Science* **60**:1026-1034.

Power, M. and M.J. Attrill. 2007. Temperature-dependent temporal variation in the size and growth of Thames estuary smelt *Osmerus eperlanus*. *Marine Ecology Press Series* **330**:213-222.

Prince, E.D., D.E. Lee, J.R. Zweifel, and E.B. Brothers. 1991. Estimating age and growth of young atlantic blue marlin, *Makaira nigricans*, from otolith microstructure. *Fishery Bulletin* **89**:441-459.

Rooker, J.R., and S.A. Holt. 1997. Utilization of subtropical seagrass meadows by newly settled red drum *Sciaenops ocellatus*: patterns of distribution and growth. *Marine Ecology Progress Series* **158**:139-149.

Secor, D.H., J.M. Dean, and E.H. Laban. 1992. Otolith removal and preparation for microstructural examination. Pages 19-57 in: D.K. Stevenson and S.E. Campana (Eds.) *Otolith Microstructure Examination and Analysis. Canadian Special Publication of Fisheries and Aquatic Sciences* **117**.

Sponaugle, S., K.L. Denit, S.A. Luthy, J.E. Serafy, and R.K. Cowen. 2005. Growth variation in larval *Makaira nigricans*. *Journal of Fish Biology* **66:**822-835.

Sponaugle, S., K. Grorud-Colvert, and D. Pinkard. 2006. Temperature-mediated variation in early life history traits and recruitment success of the coral reef fish Thalassoma bifasciatum in the Florida Keys. *Marine Ecology Progress Series* **308**:1-15.

Wexler, J.B., S. Chow, T. Wakabayashi, K. Nohara, and D. Margulies. 2007. Temporal variation in growth of yellowfin tuna (*Thunnus albacares*) larvae in the Panama Bight, 1990-97. *Fishery Bulletin* **105**:1-18.

Yasuda, F., H. Kohno, A. Yatsu, H. Ida, P. Arena, F.L. Greci, and Y. Taki. 1978. Embryonic and early larval stages of the swordfish, *Xiphias gladius*, from the Mediterranean. *Journal of the Tokyo University of Fisheries* **65**:91-97.