Age and growth of the young swordfish *Xiphias gladius* L. in Taiwan waters using otolith

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**Introduction**

Swordfish is a cosmopolitan species found in the tropical, subtropical and temperate waters of the world’s oceans and adjacent seas (Sakagawa, 1989; Sun *et al.*, 2002). In the waters of Taiwan, the swordfish is an incidental by-catch of the offshore tuna longline and harpoon fisheries. Both fisheries contributed an estimate of 1,692 metric tons or 98% to the total swordfish landings from Taiwan waters in 2001. Sun *et al.* (2002) studied the age and growth of swordfish in Taiwan waters using anal fin rays. The results indicate that Swordfish is about 90 cm in lower jaw fork length (LJFL) at its first year of age. Apparently, the juvenile swordfish grows very fast from birth to age one. Knowledge of the growth of swordfish in young stage is extremely limited (Megalofonou *et al.*, 1995). The purpose of this study is to estimate age and growth of young swordfish in Taiwan waters using otolith.

**Material and methods**

Sixty young swordfish were collected from the catch of Taiwanese offshore longliners landed at three Taiwanese local fish markets from September 2000 to January 2002. LJFL (in cm) and weight (in Kg) were measured and recorded. The heads were cut, frozen and shipped to our laboratory in National Taiwan University, Taipei for further processing. In the laboratory, semicircular canals were removed from the heads and put into distilled water for 30 min. Otoliths in the semicircular canals were removed from the tissues and immersed in 1% KOH, washed in distilled water, and dried. Details of methods of preparation followed the techniques of Secor *et al.* (1991). The sagitta (Figs. 1A and 2A) which is the largest of the three otoliths (Figs. 1 and 2) in billfishes and had previously shown the most promise for age determination (Wilson and Dean, 1983; Radtke *et al.*, 1982; Prince *et al.*, 1984) was used in this study. Sagittae were successfully recovered from 29 of the 60 fish.
sampled. Some loss of Sagittae occurred during sampling because the semicircular canal (containing sagitta) broke off and remained in the skull after removing the canal. Some sagittae were also lost during preparation.

**Results and discussion**

The swordfish used in this study ranged in size from 65 to 114.3 cm LJFL and weighted from 1.5 to 14.2 kg. The length-weight relationship for the 60 specimens was $W_t = 8.0 \times 10^{-7} \text{LJFL}^{3.5453}$ (Fig. 3). Examining the core area of a sagitta using a scanning electron microscope (SEM) found this area surrounded by growth increments structurally similar to the growth units described in other species (Fig. 4) (Campana and Nielsen, 1985; Megalofonou et al., 1995). The growth increment counts, presumed to be daily, were made for age estimation. Using a light microscope or a SEM for the incremental counts of sagittae produced no significant difference ($P<0.05$). Estimated ages for 29 swordfish, varying in size from 71.2 to 96.2 cm LJFL, ranged from 145 to 354 days (Figs. 5 and 6). Estimates of spawning dates, based on the otolith analysis, ranged from February to October (Fig. 7).

The regression analysis for the 29 young swordfish within the size interval of 71.2 to 96.2 cm LJFL showed that growth in this range was linear with a growth rate of 0.97 mm per day. This is much smaller than Megalofonou’s _et al._ (1995) estimate of 2.3 mm per day for fish within the size interval of 51 to 74 cm LJFL. The difference may be due to the different size interval, the smaller the fish the faster the growth, which needs to be further confirmed. However, the linear regression of LJFL on the estimated age in days shown in Fig. 5 seems to be unreasonable in relation to the big intercept. Using a power function to describe the relationship between LJFL and the estimated age in days (Fig. 6) obtained a plausible result. The average growth rate within the size interval of 51 to 74 cm is 1.82 mm, which is comparably close to Megalofonou’s _et al._ (1995) 2.3 mm per day for the same size interval. Average growth rate within the size interval of 71.2 to 96.2 cm is 0.98 mm per day and the intercept is zero. In addition, the estimated size at 365$^{th}$ days (age one) is 94 cm LJFL, which is consistent with the results of Sun _et al._ (2002). Therefore, the power function best describes the relationship between LJFL and age estimates in days for juvenile and young swordfish at the present stage.

Our results of back-calculated spawning dates compare most consistently with Yabe’s (1959) spawning activity information for adult swordfish.

To date we have not yet examined otoliths from smaller swordfish (<71.2 cm LJFL) from Taiwan waters because such small fish are not available. We hope to
collect smaller specimen in the near future in order to provide information necessary to form a better understanding of growth of juvenile swordfish (Megalofonou et al., 1995).

References cited


Fig. 1. Otoliths from a 4.5 kg (84 cm LJFL) young swordfish (25×). (A) Sagitta, (B) Asteriscus, (C) Lapillus, bar = 1 mm. The sagitta is usually the largest otolith and the one most often used for age determinations.
Fig. 2. (A) Scanning electron micrograph of a sagitta from a 87 cm lower jaw fork length swordfish *Xiphias gladius*. (B) Scanning electron micrograph of an asteriscus. (C) Scanning electron micrograph of a lapillus. (P = primordium)
Fig. 3. Relationship between lower jaw fork length (cm) and weight (kg) of the young swordfish collected.

\[ Wt = 8 \times 10^{-7} LJFL^{3.5453} \]

\[ r^2 = 0.8937 \]

\[ n = 60 \]
Fig. 4. Scanning electron micrograph of the core region of a sagitta otolith showing daily increments. (bar =10µm, magnification =1500)
Fig. 5. Linear relationship between lower jaw fork length (cm) and the estimated age in days for the young swordfish.

\[ y = 0.0965x + 60.95 \]
\[ r^2 = 0.9033 \]
\[ n = 29 \]

Fig. 6. Power function relationship between lower jaw fork length (cm) and the estimated age in days for the young swordfish.

\[ y = 20.568x^{0.2577} \]
\[ r^2 = 0.896 \]
\[ n = 29 \]
Fig. 7. Back-calculated spawning dates for 29 young swordfish. Total increments count on the otolith (sagitta) and date of capture were used to back-calculate spawning month.