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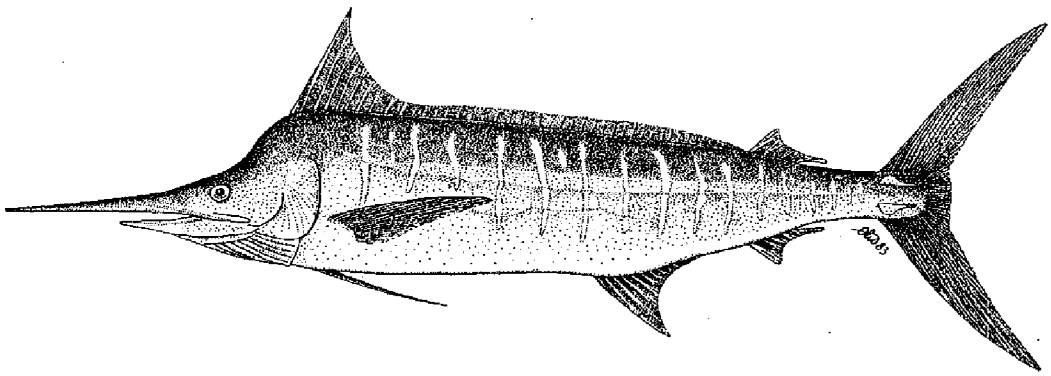
Age and Growth of Broadbill Swordfish (*Xiphias gladius*) from Eastern Australian Waters – preliminary results



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Abstract
An annual cycle of marginal increment formation was indirectly validated in the second anal fin spines of swordfish from eastern Australia using both measured and subjective interpretations of spine edge characteristics. The latter was quicker and gave more information as to the status of the spine margin. Presumed daily otolith increments also fell within the size range of 1 year old fish. A standard Von Bertalanffy curve was fitted with parameters L inf, k and t0 of 323.2, -0.082 and 4.0 respectively for females and 249.2, -0.13 and 3.3 for males falling within the range of previous estimates for swordfish elsewhere. The lack of clarity in some spines and the relatively high differences in readings within and between laboratories may explain some of the variation shown across studies. A validated age and growth study of swordfish is needed.

Introduction
The recent development of the eastern Australian longline fishery has seen catches of broadbill swordfish increasing to their present annual catch of 2,400 tonnes. Annual catches in the western Australian fishery and off New Zealand for this species are now at ~1,000 tonnes. To determine whether this level of fishing is sustainable, a series of investigations are underway to determine the population parameters of broadbill swordfish within the Eastern Tuna and Billfish fishery.
The operational model presently being developed for swordfish in Australian waters by Campbell and Dowling (in prep) is based on an age length relationship (from the Atlantic Ocean) rather than direct ageing. Thus, the resulting conversions have the potential to introduce uncertainty into the catch at age distribution translating into uncertainty in the assessment results. The wide variation in size at age estimates is underlined by the estimates summarized in Ward and Elscott (2000). For example, length at 8 yr for female swordfish can range from 181 to 254 cm depending on location.

A pilot study was initiated by CSIRO Marine Research to determine the feasibility of ageing this species and to test which techniques would be suitable (Clear and Davis 2000). The study supported Berkley and Houde's (1983) finding that the bands found in cross sections of the second anal fin spine showed the greatest potential to accurately determine the age of the fish, and that a full project was logistically feasible. Clear and Davis (2000) examined fin spines from 50 fish and found indications of a seasonal cycle in the widths of the marginal increment – a technique to determine whether bands are laid down annually - from the swordfish they examined. They cautioned, however, that many more fish needed to be examined before a seasonal cycle in annual ring formation could be validated. This conclusion reiterated the earlier work of Berkley and Houde (1983) who noted in their study of the age and growth of Atlantic swordfish that further validation was essential. More recently, fin spines were used to show a clear cycle in 5 year classes of swordfish off Taiwan (Sun et al 2002). Given the highly variable nature of swordfish growth, and the potential for environmental effects off eastern Australia to interfere with ring formation, we sought, albeit indirectly, to validate these structures as annual off eastern Australia.

This paper describes initial analyses used to determine whether ring patterns consisting of an opaque and translucent band as viewed by transmitted light were laid down annually. A preliminary growth curve is provided and compared with those from other studies of the age and growth of swordfish.

Methods
Sample collection began during a FRDC-funded study of the reproductive biology of swordfish off eastern Australia (Young and Drake 2002)(Fig. 1). That study started in 1999 and collections have continued through a separate FRDC grant specifically on age and growth of swordfish in the region.

At sea, swordfish were measured (OFL and LJFL measurements, cm), sexed and their otoliths and anal fins collected with position and date of capture and stored on ice until returned to the laboratory. In the laboratory samples were thawed and the second anal fin spine removed. Once the spine was removed from the fin all tissue was removed and the bilaterally paired spine split in two. The distance (D) where the spine flares (condyle) was measured. Four transverse sections approximately 1.0 mm were cut at a distance D/4, D/2, 3/4 D and D from the condyle base with a high speed diamond saw. Once sections were cut they were placed for 1 hour in alcohol followed by a further hour in dichloromethane to remove excess oil. Once dry, sections were mounted on slides using Aramco crystal bond. They were further polished to maximise band visibility using wet and dry (used wet) sand paper. Sections were read under a Leitz stereo microscope fitted with a Phillips CCD camera in conjunction with the NIH Image 1.5.4 computer software program. Each section was aged by counting the number of paired opaque and hyaline bands as viewed with transmitted light. Spine radius was measured as were increments from the start of each dark band. At the margin the presence of either a hyaline, new opaque or wide opaque band was recorded. Finally, each section was scored from 1 (best) to 5 (worst) depending on readability.

Sagittal otoliths from 22 swordfish were embedded in resin and sectioned transversely. Sections were ground using 220, 600, and 1000 grit wet-dry emery paper. Sections were then polished with an automatic lapping and polishing machine (Kent Mk 2A), using 6μm and 3μm diamond paste, to remove surface scratches. The radius of each sectioned sagittae (primordium to ventral edge) was measured to the nearest 0.1mm under light microscope. Increments were observed in the sectioned otoliths using light microscopy (Magnification*100 with oil) adapted for video viewing.

Marginal increment analysis was determined following Prince et al (1988). A separate edge analysis was used based on the visual characteristics of the spine edge where edge type was divided into hyaline, narrow opaque and wide opaque (Pearson 1995). Average percent error was determined following Beamish and Fournier (1981).

Results

A total of 1589 anal fin samples were collected from swordfish (size range 52 to 275 cm OFL) caught in the waters off eastern Australia by the fishery (Fig. 1, Fig. 2). Samples were collected from all months although limited fishing during winter for swordfish meant fewer samples were collected during that time (Fig. 3).

A significant relationship between spine radius and fish length suggested that spines could be used to age swordfish (Fig. 4). Paired opaque and hyaline bands were observed in all fin spine sections although the visibility of some banding meant that not all spines could be used (Fig. 5). An annual cycle in the ratio of the last to the penultimate increment indicated that these bands were laid over a yearly cycle (Fig. 6). Marginal increments rose to a maximum in autumn and were at their lowest over winter and spring although there was a good deal of variation between months. When only sections were used that had a high confidence score (clear bands present) some of this variation disappeared showing a minimum value in August for females and in June for males and a maximum for both sexes in autumn (Fig. 6). This result was also supported by the more subjective interpretation of edge type that found hyaline edges mainly from May through to September in females and males. New opaque bands were present mainly in spring and were replaced by wide opaque bands over summer (Fig. 6). As a further test of the validity of using spine annuli for estimating age we also examined otoliths for daily increments in 1 (and one 2 year old) year old fish. Daily otoliths increment counts of these swordfish were significantly related to fish length and coincided to the position of age 1 fish in the age length relationship for those fish aged using fin spines (Fig. 8).

The relationship between two independent readings within CSIRO on the prepared spines showed an average percent error of 8.08% (Fig. 9). A further comparison was made between two readers from independent laboratories and although little can be drawn from such a small sample there is obvious differences in band interpretation that underline the potential for differences in resulting growth curves. Both these readings showed divergence although the completed reading of all samples fell within the limit of 10% suggested as reasonable.

A preliminary Von Bertalanffy growth curve was plotted using lower jaw fork length with parameters L inf, k and t0 of 323.2, -0.082 and 4.0 respectively for females and 249.2, -0.13 and 3.3 for males (Fig. 10). The curve fitted to the female data fell within previous estimates of swordfish growth. The male curve diverged beyond age 10 but was limited by the small number of older males in the sample (Fig. 11).

Discussion

There have been many studies of age and growth of swordfish with a wide variation in resulting parameters (see Ward and Elscott 2000 for summary). However, it is difficult to interpret whether these are the result of different life history and/or environmental pressures or simply to differences in reader interpretation. For example, the APE reported for the present study, although within acceptable bounds, was relatively high when compared to other studies of swordfish growth (e.g. APE ~5%, Sun et al 2002).

In the present study we found a seasonal trend in marginal increment width albeit with wide confidence intervals. Berkley and Houde (1983) also found a seasonal although not significant trend. Other studies appear to have had more success determining distinct seasonal variations in margin width with small confidence intervals (Tserpes and Tsimenides 1995, Sun et al 2002). The lack of clear differentiation in the present study may reflect the oceanography of the waters within which the eastern tuna and billfish fishery is located. The area of the fishery encompasses two distinct water masses – Tasman Sea waters to the south and those of the Coral Sea to the north – separated by the Tasman front. The East Australia Current feeds tropical origin water to the Tasman Sea, its magnitude depending on seasonal and interannual cycles such as the El Nino Southern Oscillation. Indirect evidence indicates that swordfish in the region may move between these water masses perhaps masking the potential for the occurrence of clearly defined bands in these fish (Young and Drake 2002). It may also be simply a reflection of the extended spawning period of swordfish in these waters. Small swordfish (<30 cm) are often observed in the stomach contents of Mahi mahi over summer and autumn when swordfish spawn (Personal observation). If swordfish leave the relatively warm waters of the spawning grounds only after a certain size is reached then those spawned at the start of the season would not have the same banding patterns as those spawned towards the end of the spawning season.

Marginal increment analysis is at best an indirect validation of timing of band formation. Daily increment counts of otoliths appear to be useful in only the first few years. The success of validation studies using marked tag and recapture techniques has enabled the refinement and reinterpretation of age and growth of southern bluefin tuna (Clear et al 1999). Although the lack of schooling in swordfish limits a similar approach the need for such a study is evident as, we suspect, continuation of studies such as this is likely to add to the perception that swordfish have a highly variable life history. An industry based tagging study is underway in Australian waters and ~400 fish have been tagged but as yet only four have been returned (Gunn and Williams 1999).

Acknowledgments: We thank the skippers and crew of longliners Scorpion, Sniper and Malibu for sea time. We are also grateful for the extra samples collected by AFMA observers and by a range of fishers working in the fishery. The Von Bertalanffy curves were fitted by Paige Everson (CSIRO)

References:

Beamish R. J.and Fournier, D. (1981) A method for comparing the precision of a set of age determinations. Can. J. Fish. Aquat. Sci. 38, 982 - 983

Berkeley, S. A. and Houde, E. D. (1983) Age determination of broadbill swordfish, Xiphias gladius, from the straits of Florida, using anal fin spine sections. U. S. Dep. Commer., NOAA Tech. Rep. NMFS 8, 137 – 143

Clear, N. and Davis, T. L. O. (2000) Developing techniques to estimate the age of bigeye tuna and broadbill swordfish off eastern Australia: a pilot project. FRDC Grant 98/113

Clear, N. P., Gunn, J. S., Rees, A. J. (1999) Direct validation of annual increments in the otoliths of juvenile southern bluefin tuna, Thunnus maccoyii, by means of a large-scale mark-recapture experiment with Strontium chloride. Fish. Bull. 98, 25-40

Gunn, J. and Williams, K. (1999) Determining the nature and extent of swordfish movement and migration in the eastern and western AFZ through an industry-based tagging program. AFMA

Pearson, D. E. (1995) Timing of hyaline-zone formation as related to sex, location, and year of capture in otoliths of the widow rockfish, Sebastes entomelas. Fish. Bull. 94, 190 - 197

Prince, E.D., Lee, D.W., and Berkeley, S.A. (1988) Use of marginal increment analysis to validate the anal spine method for ageing Atlantic swordfish and other alternatives for age determination. ICCAT Coll. Vol. Sci. Pap. 27: 194-201.

Sun, C., Wang, S. and Yeh, S. (2002) Age and growth of the swordfish (*Xiphias gladius*) in the waters around Taiwan determined from anal-fin rays. Fish. Bull. 100: 822-835.

Tserpes, G. & Tsimenides, N. (1995) Determination of age and growth of swordfish, Xiphias gladius L., 1758, in the eastern Mediterranean using anal-fin spines. Fish. Bull. 93: 594-602.

Ward, P. and Elscott, S. (2000) Broadbill swordfish: status of world fisheries. Bureau of Rural Sciences, Canberra

Young, J. W. and Drake, A. (2002) Reproductive dynamics of broadbill swordfish (Xiphias gladius) in the domestic longline fishery off eastern Australia. FRDC Grant 1999/108

Figure 1: Position of capture of swordfish sampled off Eastern Australia between 1999 and 2003

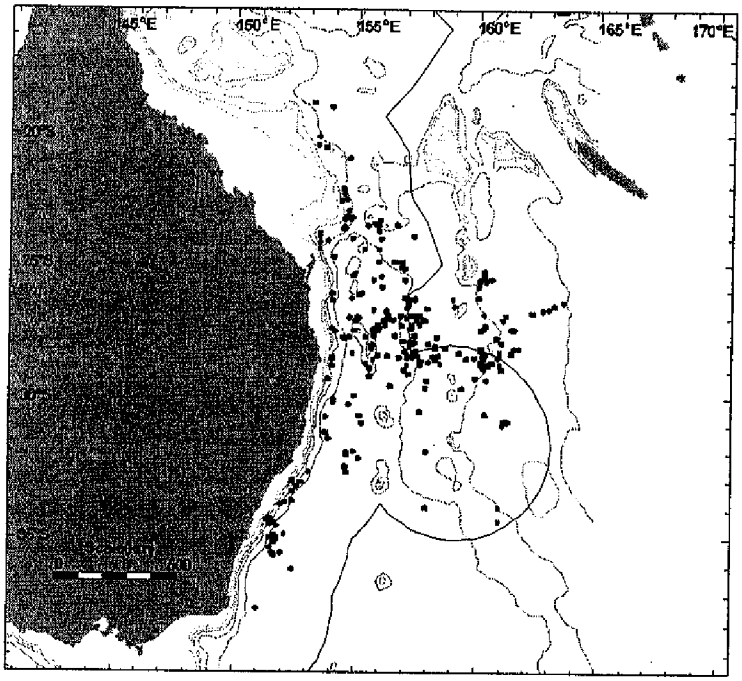
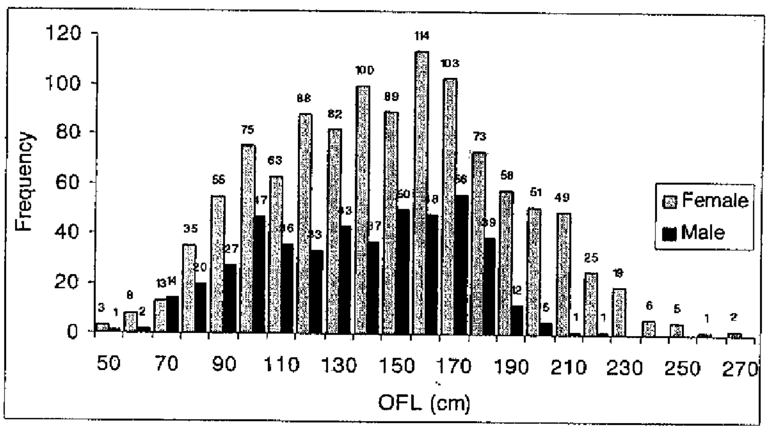


Figure 2: Length frequency distribution of swordfish sampled between 1999 and 2003 off eastern Australia



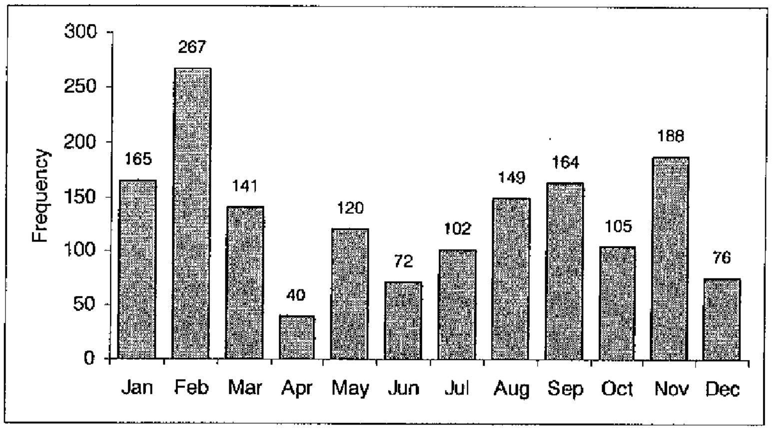


Figure 3: Distribution of samples collected off eastern Australia by month

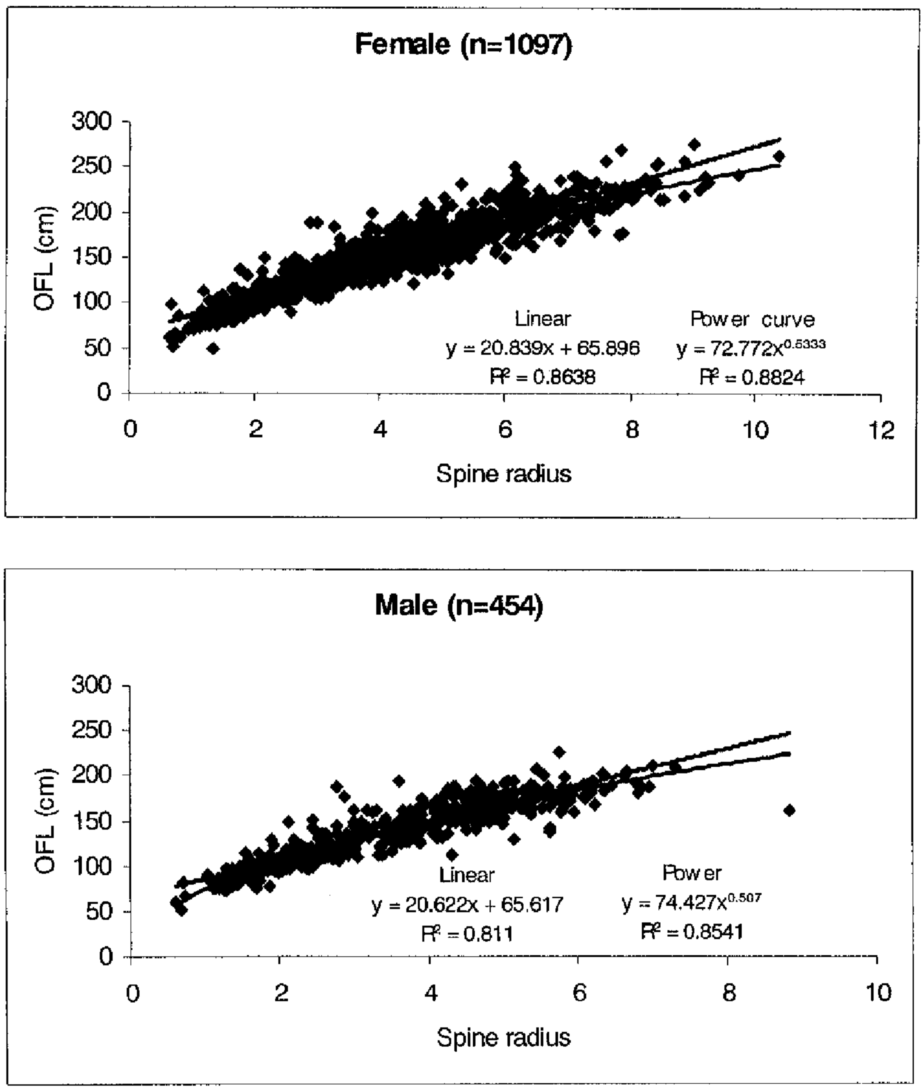


Figure 4: Relationship between spine radius and fish length by sex

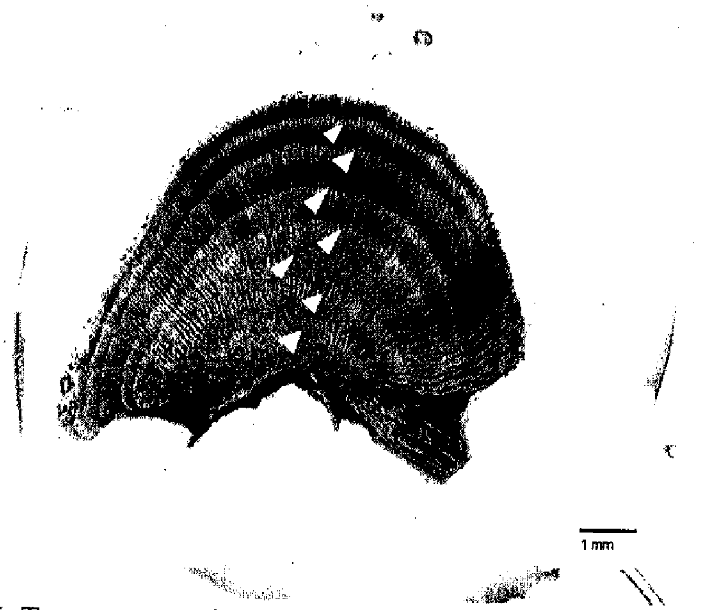


Figure 5: Transverse section of the second anal fin spine of a broadbill swordfish with seven annuli

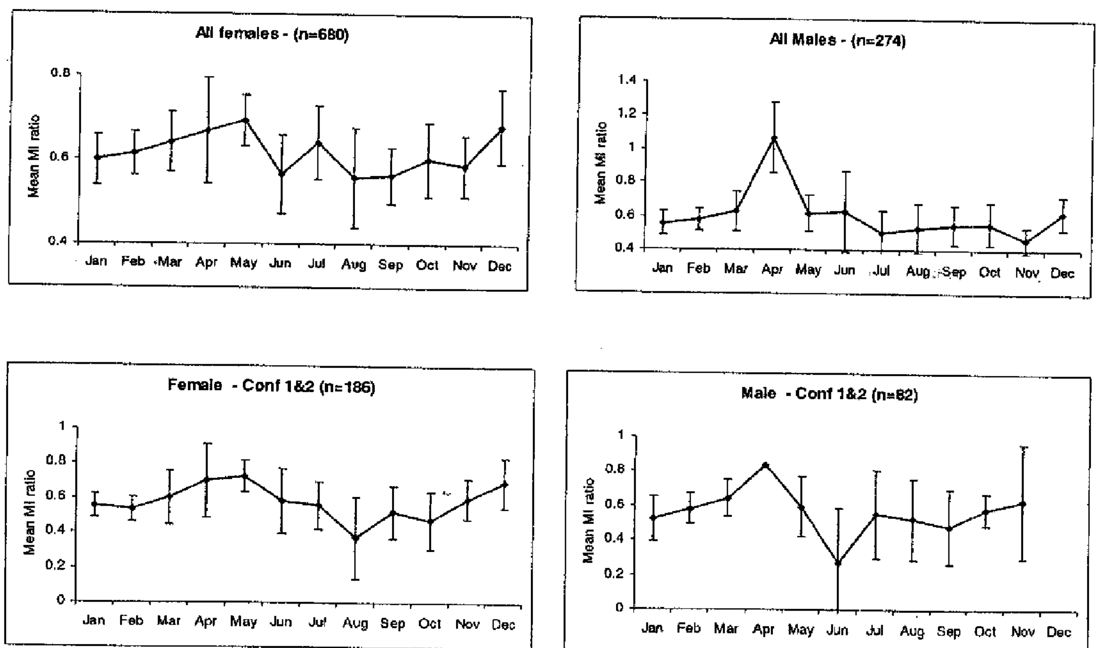


Figure 6: Mean (+-95%CI) marginal increments in relation to time of year for female and male swordfish, and replotted using spines with a high clarity (confidence score of 1 and 2)

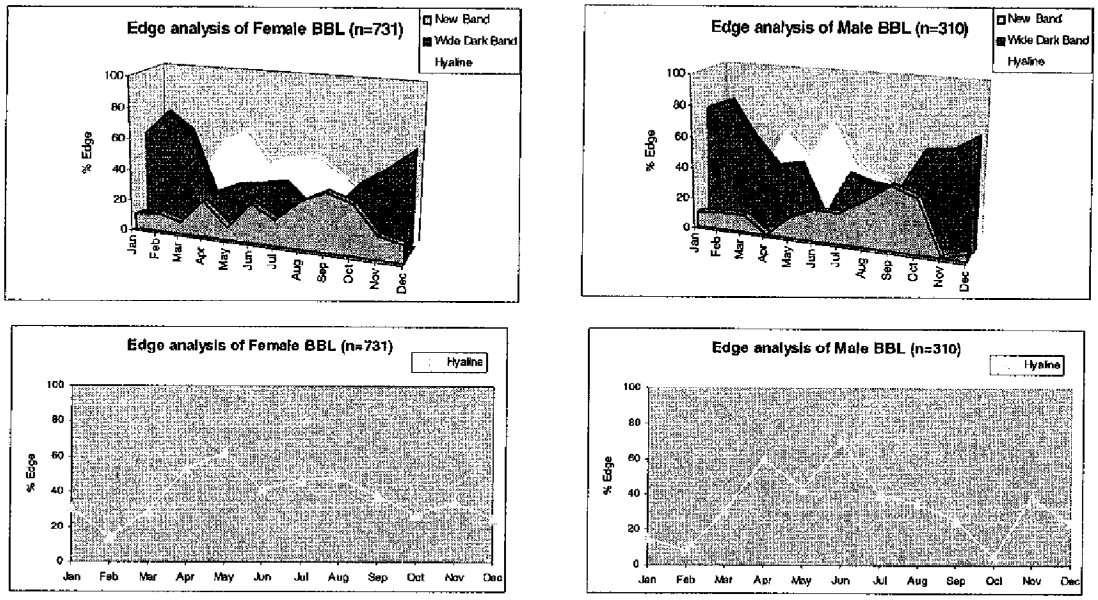


Figure 7: Subjective scoring of edge type in relation to time of year

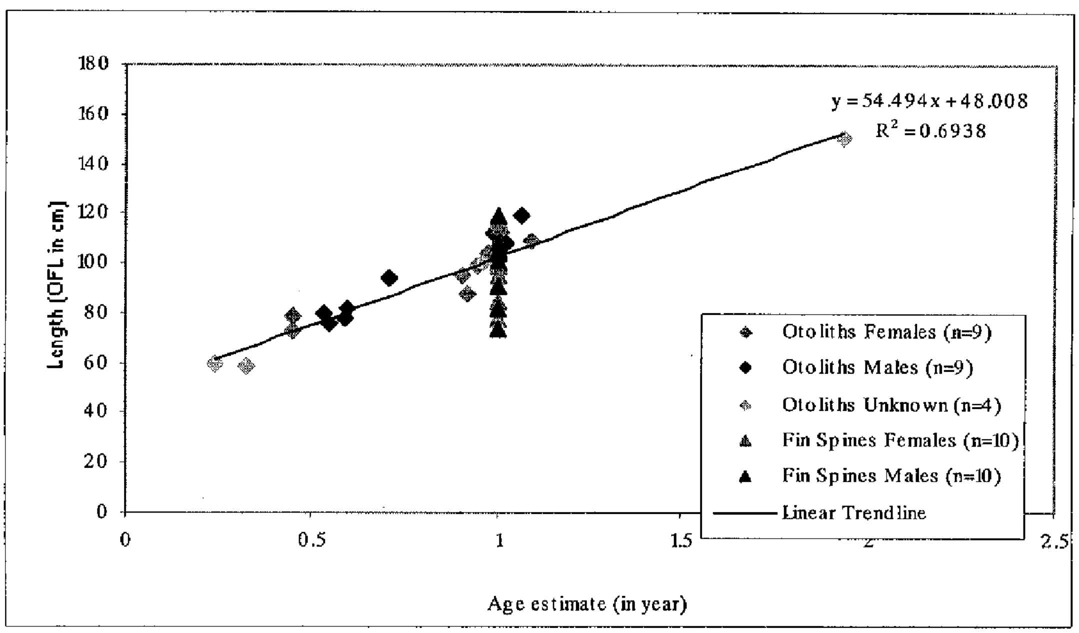
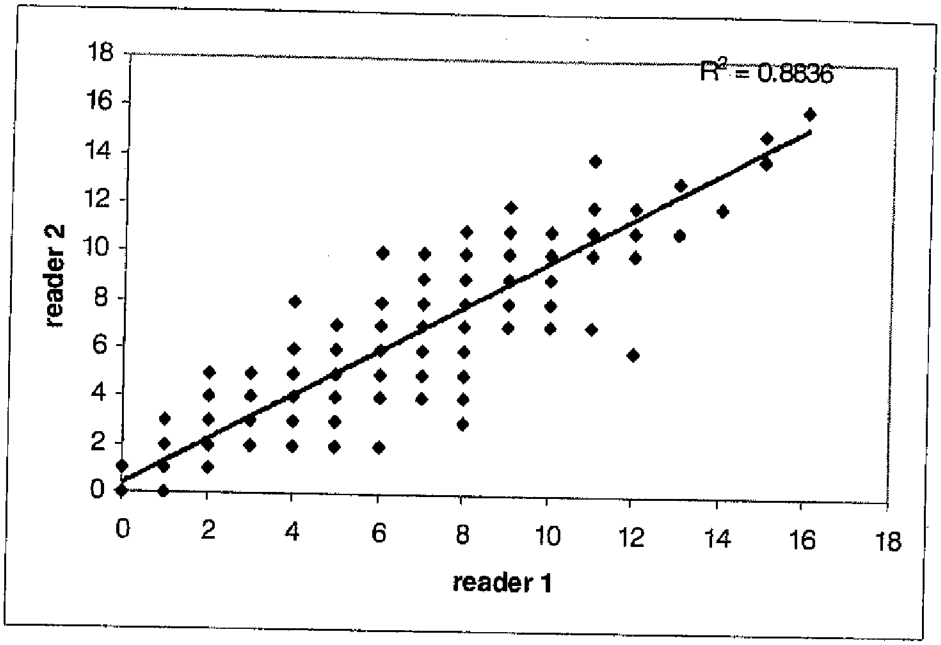


Figure 8 Daily increment counts from otoliths in relation to fish length plotted with their respective annulus counts

Figure 9: Comparison of annulus counts of two independent readers. The average percentage error was ~8%



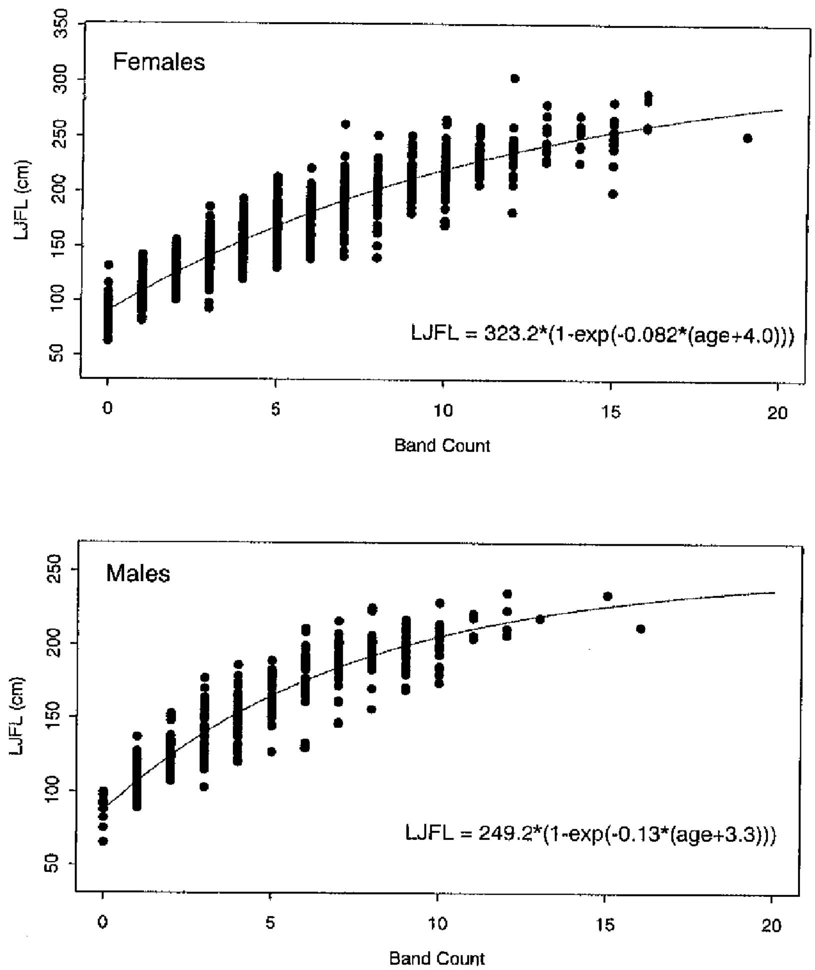


Figure 10: Preliminary Von Bertlanfy growth curve for eastern Australian Swordfish.

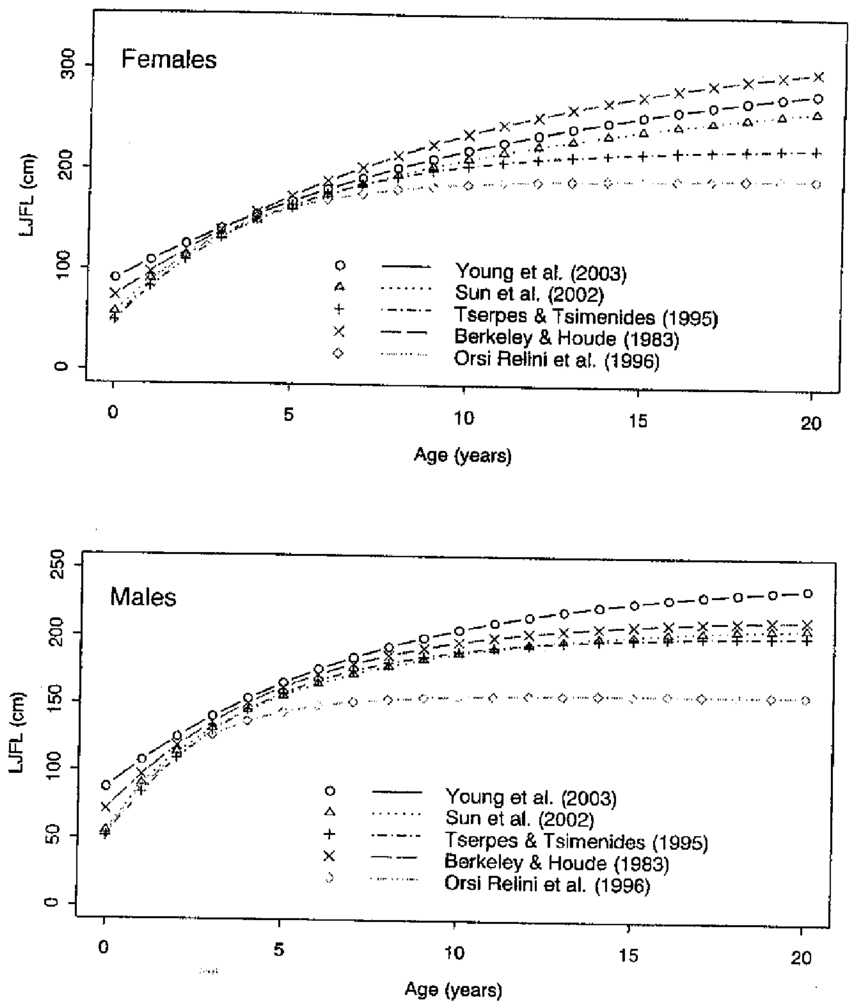


Figure 11: Comparison of growth curves between the present study and those of swordfish from Taiwan (Sun et al 2002), Atlantic Ocean (Berkley and Houde 1983) and the Mediterranean Sea (Orsi Relini et al 1996)