Age and growth of bigeye tuna (*Thunnus obesus*) in the eastern and western AFZ

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Abstract

Age, growth and maturity parameters were estimated for bigeye tuna (*Thunnus obesus*) caught in the Australian region, as part of a Fisheries Research and Development Corporation (FRDC) funded project The final report of this project is available as a PDF from CSIRO Marine Research (Report No. 2000/100, December 2003). A manuscript detailing the work will be sent to the journal *US Fishery Bulletin* later this year. The non-technical summary from the FRDC final report is provided below.

Non-technical summary

Little is known about the age and growth of bigeye tuna, yet it is one of the most valuable components of longline fisheries in the eastern and western Australian Fishing Zone. Accurate age estimates form the basis of calculations of natural mortality, age-at-maturity and longevity, all vital inputs to population stock assessments models. Stock assessments of bigeye in the Pacific Ocean currently use analysis of length frequency and tagging data to determine growth parameters. Estimating the age of large fish through modal progression of length frequency, however, is considered imprecise as size modes merge as fish grow. Similarly, estimates of growth using tag-return data are generally limited to small/young fish as most tagged fish are recaptured within a few years of release.

The project follows a previous FRDC funded study (Clear et al. 2000a) that developed techniques to validate estimates of annual age of bigeye tuna through a strontium chloride mark-recapture experiment in the Coral Sea. Clear et al. (2000a) were able to show that increments 2 to 8 visible in otoliths were deposited annually. The current study has been able to extend the validation of annual increment formation to the 9th increment (Objective 5). Evidence supporting the formation of annual increments was also obtained from analysis of otoliths from fish previously tagged (but not chemically marked) in the Coral Sea. Although fish were at liberty for a short time (0-3 years) the results confirmed that the number of opaque zones observed in otoliths after release from tagging was equal to or within the range expected for all fish. Analysis of strontium marked otoliths were also used to attempt to validate daily increment counts in larger (older) fish; generally above the size usually considered for daily age estimation as the increment are deposited so closely that they cannot be distinguished with confidence. All increment counts underestimated the days at liberty. This underestimate could be explained to some extent by an interruption in growth after tagging. However, the low confidence assigned to the counts from otoliths of the bigger fish analysed indicate using Sr-marked bigeye for validating daily age estimates has limited value for large fish.

To determine the length-at-age of bigeye in the both the western Pacific and eastern Indian Oceans, otoliths were sampled from over 2500 fish caught by Australian longline fisheries (78% from the Pacific Ocean and 22% from the Indian Ocean) between 1999 and 2002. We also estimated ages using otoliths from (1) the CSIRO hardparts archives collected by scientific observers onboard Japanese longliners between 1992 and 1997, and (2) bigeye caught in the Indonesian Indian Ocean longline fishery collected as part of a CSIRO-Indonesian RIMF catch-monitoring program between 2000 and 2002.

Annual age estimation of bigeye using otoliths is not straightforward. The proportion of otoliths that could not be read was high (32%) and only 50% of the otoliths examined were included in the final analyses. The high rejection rate was primarily due to difficulties interpreting the region of the otolith closest to the primordium, where the annual increments are broad and diffuse. Comparisons of assumed daily age estimates with annual increment counts, however, confirmed that the first 1-3 annual increments were being successfully identified in the otolith sections used in the final analysis. Unfortunately, neither marginal increment analysis nor edge type analysis provided conclusive evidence for the timing of annual increment formation in the otoliths, although winter seems the most likely based on our results. Knowledge of the difficulties encountered in estimating the age of bigeye tuna using sectioned otoliths will benefit further decisions on the practicability of routinely estimating the age of the catch using otolith increment counts.

A significant finding in the study was that the longevity of bigeye is greater than previously thought. The maximum age estimated with high confidence was 15 years for two females sampled in the Coral Sea and Indonesia. The oldest male sampled was 12 years old. A review of the literature revealed that 8-10 years was thought to be the maximum age for bigeye tuna. Given that we analysed no fish over 178 cm FL, and bigeye are known to reach at least 200 cm, it is possible that bigeye may live in excess of 15 years. The recent return of a tag from a bigeye at liberty for 12 years after being tagged as a 2 year old supports our maximum age estimates.

The growth curves fitted to lengths-at-age were significantly different between sexes for fish sampled in the Coral Sea and Western Australia only, with males being slightly larger at age than females (Objective 3). The absence of a statistical difference in mean length-at-age by sex at any of the sampling locations, however, indicates that sexual dimorphism in growth is relatively small in bigeye tuna. Growth rates varied to some extent between areas sampled, but differences were more noticeable between oceans (Objective 4). Estimates of the von Bertalanffy growth parameters indicate faster growth for fish caught in the western Pacific Ocean compared to the eastern Indian Ocean. Estimates of the theoretical maximum fish sizes were close to the observed maximum lengths, but were slightly larger for western Indian Ocean caught fish. Regional differences were also detected in otolith morphology. Otoliths sampled from the western Pacific Ocean were larger on average for the size of fish than those sampled from the eastern Indian Ocean. The differences in fish and otolith growth rates between oceans support the hypothesis of separate bigeye stocks in the Indian and Pacific Oceans.

The ages given in our study represent counts of opaque zones in otoliths, and do not take into account factors such as birth date, timing of opaque zone formation, or date of capture. Since the timing of opaque zone formation could not be precisely identified in our samples, and birth dates may vary substantially, the ages given may be biased by +/- 1 year. A comparison between our age estimates for small fish with those based on counts of daily increments (assumed to represent the "true" age) showed that our technique overestimates length-at-age for age classes 1+ to 3+ years. This type of bias is inherent in annual age estimation techniques as otolith growth after the formation of the last increments is not accounted for in the integer age estimated. This bias does not influence our comparisons of growth between areas or sexes, but must be acknowledged if the growth parameters are to be used for stock assessment purposes.

One of the key objectives of the project was to determine the age structure of bigeye catches by domestic longline fisheries in the eastern and western Australian Fishing Zone (AFZ) (Objective 1) using age-length keys applied to catch-at-length data for the fisheries. The results suggest both regional and inter-annual variation in the catch-at-age. Interpretation of the data, however, is difficult due to the short time series examined and the bias in age estimates in the younger age classes. Overall, however, young fish aged five or less dominated the catch in the AFZ. On the east coast, between 89 and 95% of the catch were age five or less and only 1-6% were age eight or older. On the west coast, the proportion of young fish in the catch was slightly lower than in the east (between 65-90%) and the proportion of old fish was higher (1-17%).

Size at maturity was determined for bigeye caught in the north-western Coral Sea using logistic curves (Objective 2). Length at 50% maturity was 102.4 cm in females and 86.6 cm in males. We estimated fish of these lengths to be 1.8 and 1.1 years old for females and males, respectively. However, using the composite growth curve developed by Hampton et al. (1998) based on daily age estimates and tagging data, fish of these lengths are estimated to be 2.4 and 1.7 years old for females and males respectively. These latter estimates are considered the most appropriate for stock assessment purposes.

The overall sex ratio of bigeye tuna was close to 1:1 in all areas except the Coral Sea where males were more abundant than females. We found that the dominance of males became more prominent as size increased in the Coral Sea, Qld/NSW and WA possibly as a result of sexual dimorphism in growth.

Overall, the knowledge and understanding gained during the project will advance the stock assessments for the species.