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An update on Australian otolith collection activities, direct ageing and length at age keys for the Australian surface fishery

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Table of Contents

Abstract
Australia continued to collect and archive otoliths from SBT caught by the Australian surface fishery, CSIRO tagging operations, and the recreational fishery during the 2010/11 fishing season. Age was also estimated for 100 SBT caught by the surface fishery in the 2009 10 fishing season. In 2010, the proportions at age of SBT caught in the Australian surface fishery were estimated for the 2001/02 to 2008/09 seasons using three methods - the standard age-length-key (ALK), the M&B method with known growth, and the M&B method with unknown growth. This has now been updated to include the 2009/10 season. The work highlights the need for further discussion within the CCSBT regarding the technical details of how the direct age data will be incorporated into the stock assessment model.

Introduction

Most stock assessments, including those for southern bluefin tuna (SBT), use age-based models to estimate stock abundance. Such models require estimates of the annual catch in numbers at age (catch-at-age) for each fishery as an input. For many fisheries, however, the only direct information available is the size distribution of the catch (catch-at-size) and total number caught. Although length provides some information on the age structure of the catch, since age and length are related, there is a need to convert catch-at-length into catch-at-age. Many simulation studies have shown that assessments based on direct age data are more reliable and more likely to give unbiased estimates of stock status than age-based assessments based on size data. Direct ageing from hard parts (otoliths) identifies different age groups among similarly sized fish and is generally considered a fundamental requirement of fisheries monitoring, particularly for long-lived species such as SBT.

From late 1999, otoliths were routinely sampled from SBT caught in the Australian purse seine (surface) fishery in the Great Australian Bight (GAB) via tuna farm mortalities, during CCSBT tagging operations in South Australia and Western Australia, opportunistically off the east coast of NSW, and the Indonesian longline fishery.

In 2003, CCSBT Extended Scientific Committee (ESC) agreed that all SBT fisheries should collect and analyse hardparts (otoliths) to characterise the age distribution of their catch from 2002. The most common way of using direct age data in assessments has been the construction of age-length-keys from which proportions at age in the catch can be estimated. Morton and Bravington (2003) developed more efficient parametric methods to estimate proportions-at-age for SBT and recommended between 100-200 otoliths from the surface fishery would be sufficient to provide acceptable levels of precision (CVs under 20%). Consequently, routine reading of at least 100 SBT otoliths collected from Australia's surface fishery starting in the 2001/02 fishing season. All direct age estimates were provided to the CCSBT during the data exchange process and the results were presented as working papers at the CCSBT SAG/ESC meetings. Additional otoliths collected each season provide a reserve which can be aged if we find that the CVs of the 100 are higher than 20%.

There is an explicit expectation that the CCSBT will move to direct age based methods in the SBT stock assessment rather than the current "cohort-slicing" approach which has recognised deficiencies. The only reason the CCSBT ESC has not moved to this approach is (a) the lack of a time series of samples (initiated in ~2002) and (b) a focus of resources on the Management Procedure development and evaluation.

The current paper provides an update on SBT otolith sampling in Australia for 2010/11, and age estimation of a subsample of otoliths from the 2009/10 fishing seasons to meet our CCSBT commitment. Updated estimates of proportion-at-age of the surface fishery are provided.

Methods

Otolith sampling in 2010/11

Surface fishery – farm sector

Developing an otolith sampling scheme from the surface fishery sector is challenging because of the farming (aquaculture) component. The challenge is that fish can grow significantly between their time of capture in the wild and the time when they are harvested after having been retained in farms during the grow out phase. It is also important to note that the period when fish for farming are captured corresponds to a season when juvenile SBT are growing rapidly. Thus, otoliths collected from fish at the time of harvest, at the completion of the grow-out phase, will not provide a reliable basis for developing age-length keys for the surface fishery. In response to these issues, Australia has developed a sampling program based on fish that die either during towing operations or during the first two weeks after fish are transferred from towing cage into farm cages.

The current protocol requires that all farm operators provide a sample of 10 fish that have died either in towing operations or within the first weeks after fish have been transferred to stationary farm cages. A company contracted to the Australian Fisheries Management Authority (AFMA), Protec Marine Pty Ltd, measures the length of each fish and extracts the otoliths from these mortalities. The otoliths and length data are sent to CSIRO for archiving. In the past, there have been between 25 and 40 tow cages a year, giving a total of ~200- 400 otoliths collected from this sector each season.

Tagging operations

CCSBT tagging operations have not been undertaken since the 2006-07 fishing season, and thus there was no opportunity to collect additional otoliths from fish smaller than those sampled from the surface fishery as has been done in previous seasons. SBT were, however, sampled during CSIRO acoustic tagging operations in Western Australia in the 2010/11 summer (n=42).

Recreational fishery:

The number of SBT caught by recreational fishers off Portland, Victoria, in late summer and autumn has been increasing in recent years. Otoliths were collected from a number of these fish by the Department of Primary Industry in Portland in May-June 2011. These otoliths have not been received yet.

Direct ageing for 2009/10

Otolith selection

Of the 230 otoliths collected from the Australian surface fishery last summer (the 2009/10 fishing season; see Farley et al., 2010), 100 were selected for age estimation. The number of otoliths selected was based on the work by Morton and Bravington (2003) who estimated that between 100-200 otoliths from the surface fishery would be sufficient to provide acceptable precision (CVs under 20%). Otoliths were selected based on size of fish (stratified sampling rather than random sampling) to obtain as many age estimates from length classes where sample sizes were small. All otoliths that had been collected from small and large fish were selected, as well as a fixed number of otoliths from each of the remaining 1 cm length classes (randomly selected within a class). This was the best way of obtaining as many age estimates from length classes where sample sizes were small, while providing enough estimates for each season.

Otoliths for ageing were not selected from SBT caught in Western Australia, Victoria or Tasmania as the growth rates of these fish may differ to those caught in South Australia, leading to potential bias in the age-length-keys and any subsequent estimation of the age distribution of the catch.

The selected otoliths were then weighed to the nearest 0.1mg if undamaged. Otolith weight was then compared to fork length to ensure that the capture data associated with each otolith was correct. Gunn et al. (2008) showed that the relationship between otolith weight and fork length was curvilinear (R2 = 0.903), and thus if any outliers were detected, they could be removed. Outlying data points were not found in the data.

Otolith preparation and reading protocols

Otoliths were prepared and read by ‘Fish Ageing Services Pty Ltd’ (FAS) in Victoria using the techniques described by Anon (2002). The SBT otolith reader at the FAS is the same reader from the ‘Central Ageing Facility’ (CAF) and has read SBT otoliths since 1998. To ensure that age estimates were consistent with previously aged SBT, the (primary) otolith reader re-read otoliths sections from a set of otoliths previously aged (agreed age) prior to reading new otoliths. Each otolith was then read once by the primary reader, and 33% were read by a secondary otolith reader (from CSIRO) who was trained in SBT otolith reading in 1996 and has read SBT otoliths routinely since that time. All readings were conducted without reference to the size of the fish, date of capture, otolith weight or to previous readings. An otolith reading confidence score is assigned to each otolith:

0. No pattern obvious
1. Pattern present – no meaning
2. Pattern present – unsure with age estimate
3. Good pattern present – slightly unsure in some areas
4. Good pattern – confident with age estimate
5. No doubt

The precision (consistency) of readings was assessed using coefficient of variation (CVs) (Chang, 1982; Campana et al., 1995):

$$CV_j = 100 * \frac{\sqrt{\sum_{i=1}^{R} \frac{(X_{ij} - X_j)^2}{R - 1}}}{X_j}$$

where x_{ij} is the $_i$th age of the $_j$th fish, and R is the number of times each fish was aged. The CV was averaged across all fish to determine the average precision within and between readers. Age bias plots were used to assess if there was bias in the age estimates from each reader.

A potential problem in assigning age for SBT is that the theoretical birth date is January 1 (middle of the spawning season; see CCSBT-ESC/0509/Info) and opaque increments are formed during winter (May and October) (Clear et al., 2000, Gunn et al., 2008). Using the number of increments as an estimate of age can be misleading if SBT are caught during the winter. However, SBT in the GAB are caught during summer (November to April), so there is less confusion about assigning an age from increment counts. For example, SBT with 2 increments in their otoliths were classed as 2 year-olds. Thus, SBT of the same age, caught in the same fishing season, were spawned in the same spawning season.

Age distribution of the surface fishery

As noted last year (Farley et al., 2010), the most common way of estimating proportions at age in a given year, using age-at-length samples and a length distribution sample in that same year, is via an age-length key (ALK). The length frequency data is multiplied by the proportion of fish in each age class at a given length to give numbers (or proportions) at age. In mathematical terms, the proportion of fish of age *a*, p_a, is estimated as follows:

$$\hat{p}_a = \sum_l \frac{N_l}{N} \frac{n_{al}}{n_l}$$

where N_l is the number of fish in the length sample of length *l*, n_{al} is the number of fish in the age-length sample of age *a* and length *l*, $N = \sum_l N_l$ and $n_l = \sum_a n_{al}$.

A drawback of the ALK method is that it makes no use of the information about likely age contained in the length frequency alone—thus it is inefficient, with variance up to 50% higher than necessary (Morton & Bravington 2003, Table 2). This is especially true for fisheries that catch young fish, such as the Australian SBT surface fishery, where length is quite informative about age. As an alternative to the ALK, Morton and Bravington (2003) developed a parametric method which makes more efficient use of the information in both the length frequency and the age data. The basis for the method is maximization of the following log-likelihood within each year:

$$\Lambda = \sum_l \left\{ N_l \log\left(\sum_a p_a p_{l|a} \right) + \sum_a n_{al} \log\left(p_a p_{l|a} \right) \right\}$$

where N_l, n_{al} and p_a are defined as above for the ALK, and $p_{l|a}$ is the probability that a fish of age *a* will have length *l*. Recall that the p_a's (the proportions at age) are what we are interested in estimating.

Here we assume $p_{l|a}$ follows a normal distribution with mean and variance that are either (a) known a priori, or (b) unknown and needing to be estimated together with the proportions at age. The former "known growth" approach is slightly more efficient if accurate estimates are available and if growth is consistent across cohorts; the latter "unknown growth" approach is robust to changes in growth and almost as efficient, so it is generally to be preferred.

Variances for the proportion at age estimates can be obtained from the Hessian using standard likelihood theory.

Last year, we applied the standard ALK method and the method of Morton and Bravington (hereafter referred to as the M&B method) to the age-length and length-frequency data from the Australian surface fishery in seasons 2001/02 through 2008/09 (Farley et al., 2010). Here we update the analysis to include data from the 2009/10 season. For the M&B method, we applied both the known and unknown growth approaches for comparison. In the known growth case, mean and standard deviation (SD) in length at age were assumed equal to the values in Table 1. These values were derived using the growth curve for the 2000s reported in Table 3 of Eveson (2011) and assuming the mid-point of the surface catches to be 1 February; the SDs include individual variation in growth, measurement error, and growth within the fishing season, taken as 1 December to 1 April (see Polacheck et al. 2002, p.44-48, for more information on calculating variance in expected length at age). In the unknown growth case, we found it was necessary to set lower and upper bounds on the mean length at age parameters, or else unrealistic estimates could be obtained for data-limited age classes (discussed in greater detail later). We chose fairly generous bounds equal to the mean length at age +/- 2 SDs taken from Table 1.

Table 1. Mean and standard deviation (SD) in length at age derived from the growth model for the 2000s.

Age	Mean	SD
1	55.0	5.7
2	81.9	6.3
3	102.6	6.8
4	114.7	7.3
5	124.8	7.8
6	133.4	8.2
7	140.7	8.5
8	146.8	8.8

Length samples are taken from the tow cages each year (generally 40 fish are sampled per cage), and the data scaled up by the number of fish in each tow cage to estimate the length frequency distribution of the entire catch. For the M&B method, it is important to estimate the "effective sample size"[1] of the length data in order to correctly weight the relative information of direct age data versus length data in the likelihood, and also to estimate variances correctly. This entails a re-scaling of the length frequencies derived from the scaled-up tow cage samples, as described in Basson et al. (2005). Specifically, if T is the number of tow cages in a particular season, c_i is the number of fish in tow cage i, m_i is the total number of fish sampled from tow cage i, and m_{il} is the number of fish of length l in the sample from tow cage i, then we estimate π_l, the frequency of fish of length l over all tow cages, to be

[1] The length samples taken from the tow cages do not constitute independent random draws from the entire catch (since the lengths of fish within a tow cage are not representative of the entire catch). The effective sample size refers to the sample size that leads to the equivalent variance as if the tow cage samples had in fact been independent random draws.

$$\hat{\pi}_l = \sum_i c_i^* \frac{m_{il}}{m_i}$$

where

$$m_i = \sum_l m_{il}$$

and

$$c_i^* = \frac{c_i}{\sum_{j=1}^{T} c_j}.$$

The variance of $\hat{\pi}_l$ is estimated by

$$\mathrm{V}[\hat{\pi}_l] = \sum_i \frac{c_i^{*2}}{m_i}$$

Finally, we estimate the effective sample size of fish of length *l* to be

$$\tilde{N}_l = \frac{\hat{\pi}_l}{\mathrm{V}[\hat{\pi}_l]}.$$

These are the numbers we used as the N_l's for both the ALK and M&B methods.[2]

For the ALK method, the age-at-length and length frequency data were binned into 5-cm length classes. Enough otoliths are available so that there are very few "missing rows" in the ALK for any year when 5-cm length bins are used; i.e., there are very few length bins for which the proportions-at-age cannot be calculated. For the M&B method, the data were binned into 1-cm length classes.

Results and Discussion

Otolith sampling in 2010/11

Surface fishery – farm sector

Otoliths were sampled from 180 SBT caught by the surface fishery in 2010/11 from fish between 79 and 145 cm fork length (Figure 1). The current sampling protocol does not provide either a fixed number of otoliths from each length class or representative samples of otoliths from all length classes in proportion to their abundance in the catch from the surface fishery. In previous seasons, this has often resulted in an apparent disproportionate number of large fish sampled compared to the size distribution of SBT from the surface fishery (based on CCSBT CatchAtLength data). This could be the result of selection biases by the fishermen in their choice of dead fish to retain for otolith sampling or it could be due to size related differences in towing and early farming related mortality rates. It is possible that the otoliths

[2] For the ALK method, which only makes use of the proportion of fish of a given length class and not the absolute numbers, it should not matter whether we use the scaled-up tow cage numbers or the re-scaled effective sample sizes, but for consistency we use the same numbers for all methods.

collected in the current season will not cover the full size range of farmed fish and the resulting age-length key will, therefore, have "missing rows" where there are no or very few age estimates for the smaller length classes.

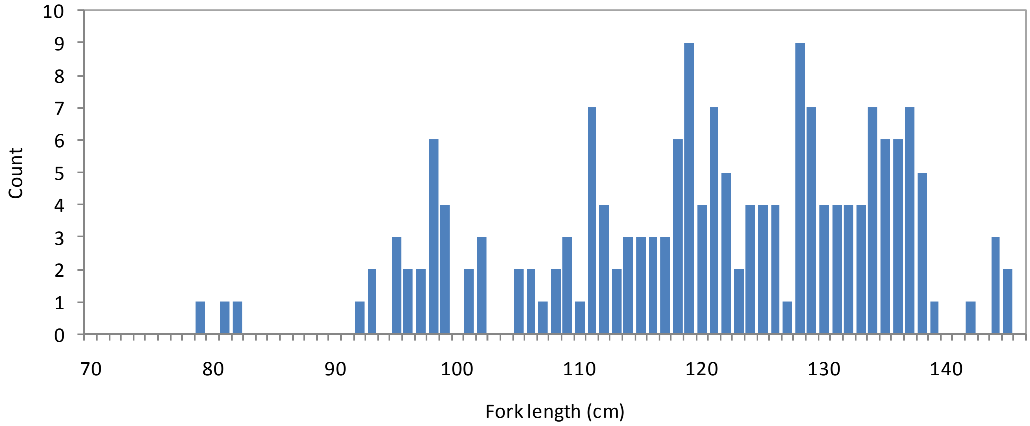

Figure 1. Length frequency of SBT with otoliths sampled from the Australian surface fishery in the 2010/11 fishing season.

Age estimates for 2009/10

A final age estimate was given to 98 SBT ranging in size from 81 to 135 cm FL (Figure 2). The CV between readings by the primary reader was 4.83%. When successive readings of otoliths differed (n=24), they were only by ±1, indicating a good level of precision. A confidence score of 3-5 was assigned to 86% of otoliths. The CV between readings by the primary and secondary reader was 7.88%, and when readings differed, they were only by ±1. A bias was not detected in the age estimates between readers. The low levels of error suggest consistent interpretation of age in blind tests.

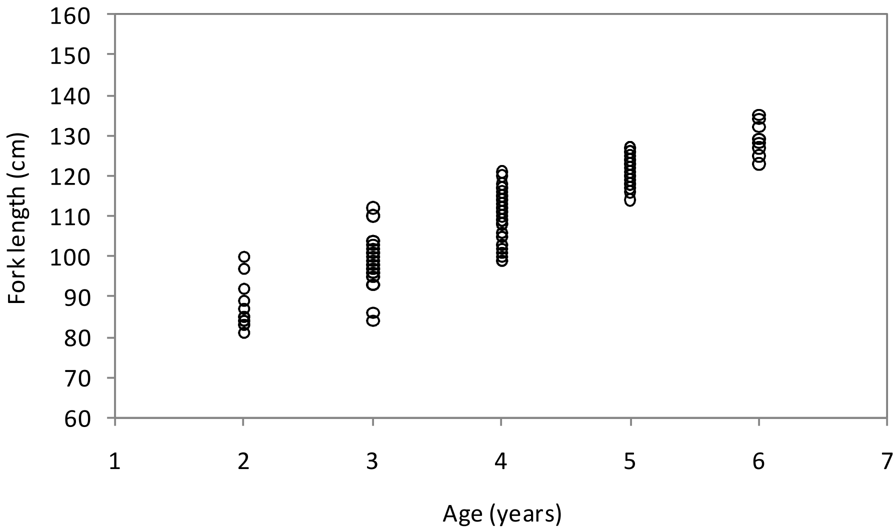

Figure 2. Length at age for SBT caught in the Australian surface fishery in the 2009/10 fishing season (n=98).

Age distribution of the surface fishery 2001/02 to 2009/10

The proportions at age estimated from the standard ALK method, the M&B method with known growth, and the M&B method with unknown growth are given in Table 2, Table 3 and Table 4. For easier comparison, the results are also plotted in Figure 3. The results for seasons 2001/02 to 2008/09 are the same as those presented last year (Farley et al., 2010). For most seasons, there is reasonably good agreement between the various methods, but for a few seasons, including 2009/10, the estimated proportions at ages 2-4 are considerably different. The M&B results differ significantly from the standard ALK results in seasons where the age-length data and length-frequency data suggest different proportions of fish in each age class, since the M&B method takes the length-frequency data into account whereas the ALK method uses only the age-length data.

The M&B method with unknown growth produces estimates that fit the length data very closely for all seasons (Figure 4). In comparison, the M&B method with known growth does not fit the length data nearly so well (Figure 5). This is to be expected since the unknown growth method estimates the mean (Table 5) and SD (Table 6 6) in length at age based on the data, and these estimates can be quite different than those derived from the growth model (Table 1).

The growth model for the 2000s was estimated based on age-length data and tag-recapture data for fish born in the 2000s. It does not include the length-frequency data due to concerns about size-selective fishing (Polacheck et al. 2002, Appendix 3), and is not specific to fish in the GAB nor to seasons. Provided that the length-frequency data are representative of fish caught in the surface fishery, and given our goal of estimating proportions at age in the *catches* (not in the *population*), the M&B estimator with unknown growth should be more accurate.

The relatively small numbers of otoliths for fish of age 1 and older than age 4, as well as the low proportion of fish corresponding to these age classes in the length-frequency data, can lead to difficulties in estimating mean length for these ages. Without constraints, it is hard to estimate ‘sensible’ mean lengths at age for these age classes. Even with the generous bound constraints that we imposed, some estimates still hit the bounds (Table 5). Since the proportion at age estimates are so close to 0 for these age classes, the consequences of incorrectly estimating their mean length should be small. Of some concern, however, are the mean length estimates for age 4 fish, which are often estimated to be very close to the mean length for age 3 (Figure 4). It is possible to impose tighter bounds on the mean length at age parameters, but doing so simply results in the age 4 estimates falling on the lower bound, so it is not a very satisfactory solution. A possibility for future consideration is to incorporate a prior distribution on the mean length at age parameters—this would provide an intermediate approach to the known and unknown growth methods currently available.

Coefficients of variation (CVs) of the estimated proportions at age using the M&B method with unknown growth are provided in Table 7. They were calculated by dividing the square root of the Hessian-based variance estimates by the estimates. The CVs suggest the proportion at age estimates are precise for ages 2 and 3 (generally <10%), but less so for age 4 (ranging from 14% to 68%), and quite poor for ages 1 and >5 (many over 100%). This simply reflects the amount of data available for the different age classes.

We stress that the proportions at age derived as part of this project apply only to fish caught in the GAB in the surface fishery. They are unlikely to apply to the population of fish found in the GAB due to the size-selective nature of the surface fishery, and they are less likely to apply to the global population since data collected in the GAB are not representative of fish found in other regions (for example, age-1 fish found off Western Australia are smaller on average than age-1 fish found in the GAB at the same time, likely due to a later spawning event (Polacheck et al. 2002).

Table 2: Proportions at age for each fishing season estimated using the standard ALK method. (Four decimal places are shown to retain the small but non-zero proportions for ages 1 and >4).

Season	1	2	3	4	5	6	7	8
2001-2002	NA	0.0626	0.5130	0.3742	0.0457	0.0039	0.0006	NA
2002-2003	0.0013	0.0652	0.5726	0.3256	0.0350	0.0002	0.0001	0.0000
2003-2004	0.0000	0.3515	0.5817	0.0665	0.0003	0.0000	0.0000	NA
2004-2005	0.0000	0.2853	0.5448	0.1572	0.0122	0.0003	0.0001	0.0000
2005-2006	0.0000	0.4504	0.5448	0.0044	0.0002	0.0001	NA	NA
2006-2007	0.0024	0.3528	0.5440	0.1003	0.0004	0.0001	0.0000	NA
2007-2008	0.0000	0.2622	0.6716	0.0622	0.0035	0.0005	NA	NA
2008-2009	NA	0.3551	0.5257	0.1054	0.0053	0.0000	NA	NA
2009-2010	NA	0.2192	0.4973	0.2516	0.0179	0.0024	NA	NA

Table 3: Proportions at age for each fishing seasons estimated using the M&B method with known mean and variance in length at age.

Season	1	2	3	4	5	6	7	8
2001-2002	NA	0.0575	0.8812	0.0470	0.0108	0.0023	0.0012	NA
2002-2003	0.0013	0.1212	0.8333	0.0318	0.0091	0.0021	0.0005	0.0007
2003-2004	0.0048	0.3336	0.6394	0.0176	0.0036	0.0010	0.0001	NA
2004-2005	0.0343	0.4276	0.4628	0.0265	0.0145	0.0072	0.0167	0.0104
2005-2006	0.0014	0.3501	0.6379	0.0097	0.0008	0.0002	NA	NA
2006-2007	0.0022	0.5526	0.4238	0.0180	0.0026	0.0005	0.0002	NA
2007-2008	0.0006	0.2646	0.7098	0.0199	0.0041	0.0011	NA	NA
2008-2009	NA	0.3274	0.6380	0.0239	0.0088	0.0019	NA	NA
2009-2010	NA	0.1904	0.7337	0.0496	0.0178	0.0085	NA	NA

Table 4: Proportions at age for each fishing seasons estimated using the M&B method with unknown mean and variance in length at age.

Season	1	2	3	4	5	6	7	8
2001-2002	NA	0.0803	0.7093	0.1780	0.0279	0.0040	0.0006	NA
2002-2003	0.0008	0.1478	0.6195	0.2059	0.0256	0.0002	0.0001	0.0000
2003-2004	0.0004	0.3851	0.5648	0.0494	0.0003	0.0000	0.0000	NA
2004-2005	0.0000	0.5023	0.4527	0.0393	0.0053	0.0003	0.0000	0.0000
2005-2006	0.0000	0.3735	0.6251	0.0010	0.0002	0.0001	NA	NA
2006-2007	0.0000	0.3156	0.6348	0.0490	0.0005	0.0001	0.0000	NA
2007-2008	0.0000	0.2268	0.7259	0.0428	0.0041	0.0005	NA	NA
2008-2009	NA	0.2868	0.6213	0.0882	0.0036	0.0000	NA	NA
2009-2010	NA	0.2238	0.5759	0.1805	0.0179	0.0018	NA	NA

Table 5: The estimated mean length at age (in cm) for each fishing season using the M&B method with unknown mean and variance in length at age.

Season	1	2	3	4	5	6	7	8
2001-2002	NA	85.3	98.0	102.3	113.8	119.7	136.5	NA
2002-2003	66.4*	84.8	100.0	104.3	113.1	129.7	132.6	141.6
2003-2004	65.2	85.9	98.7	100.1#	109.2#	117.3#	135.5	NA
2004-2005	43.6#	84.2	99.8	104.3	111.4	119.0	137.6	137.4
2005-2006	66.4*	85.5	98.0	120.5	130.6	132.7	NA	NA
2006-2007	66.4*	83.9	93.8	105.7	129.5	130.4	142.0	NA
2007-2008	55.0	86.3	96.1	105.2	111.2	133.0	NA	NA
2008-2009	NA	85.2	96.5	107.1	117.3	125.5	NA	NA
2009-2010	NA	85.7	98.4	106.1	118.3	126.4	NA	NA

Estimate hit lower bound.
* Estimate hit upper bound.

Table 6: The estimated standard deviation in length at age (in cm) for each fishing season using the M&B method with unknown mean and variance in length at age.

Season	1	2	3	4	5	6	7	8
2001-2002	NA	4.2	3.2	7.3	7.4	7.6	0.0	NA
2002-2003	4.4	4.5	4.8	6.9	6.6	4.6	2.2	2.1
2003-2004	3.5	5.3	3.9	5.7	5.3	6.2	4.9	NA
2004-2005	4.1	3.5	4.3	6.8	7.9	9.1	6.5	8.1
2005-2006	2.7	4.8	3.6	7.5	4.0	2.8	NA	NA
2006-2007	10.0*	3.7	4.1	6.8	2.9	3.3	0.1	NA
2007-2008	5.7	3.7	4.1	7.1	9.1	1.7	NA	NA
2008-2009	NA	3.3	3.8	5.0	3.6	2.3	NA	NA
2009-2010	NA	4.2	3.6	5.7	4.0	3.6	NA	NA

* Estimate hit upper bound.

Table 7: Coefficients of variation (CVs) of the estimated proportions at age for each fishing season using the M&B method with unknown mean and variance in length at age.

Season	1	2	3	4	5	6	7	8
2001-2002	NA	0.13	0.03	0.14	0.25	0.63	1.05	NA
2002-2003	1.05	0.10	0.06	0.18	0.39	0.93	1.11	2.49
2003-2004	0.99	0.05	0.04	0.23	0.68	0.00	0.00	NA
2004-2005	0.00	0.03	0.04	0.36	0.56	1.43	1.92	2.12
2005-2006	1.31	0.06	0.04	0.68	1.09	1.41	NA	NA
2006-2007	2.28	0.08	0.05	0.25	0.96	1.21	NA	NA
2007-2008	4.56	0.11	0.04	0.31	0.77	1.27	NA	NA
2008-2009	NA	0.07	0.04	0.18	0.53	1.60	NA	NA
2009-2010	NA	0.09	0.06	0.17	0.35	0.67	NA	NA

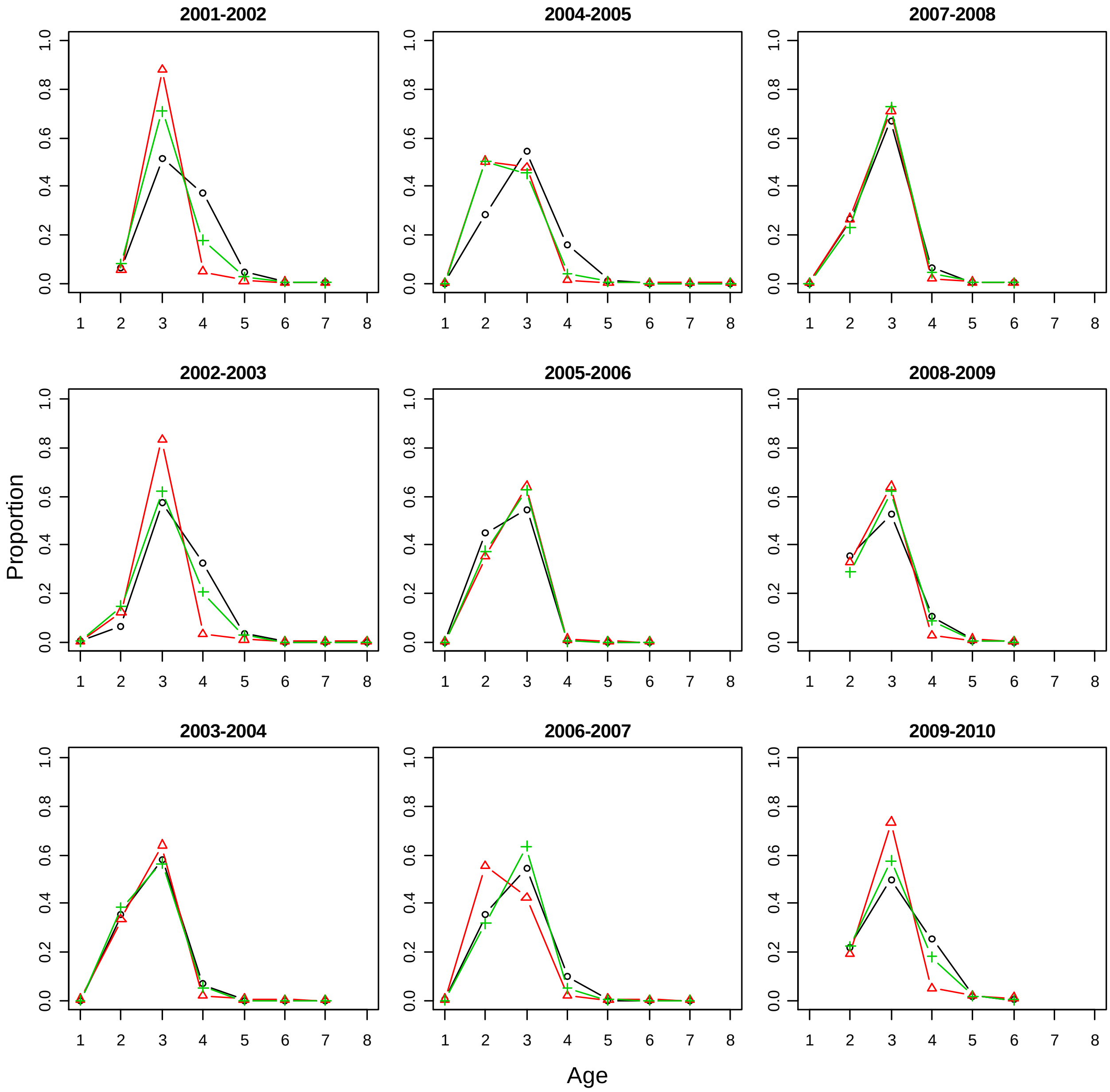

Figure 3. Estimated proportions of fish at age in each fishing season using i) the ALK method (black, open circles); ii) the M&B method with known growth (red, open triangles); iii) the M&B method with unknown growth (green, plus symbols).

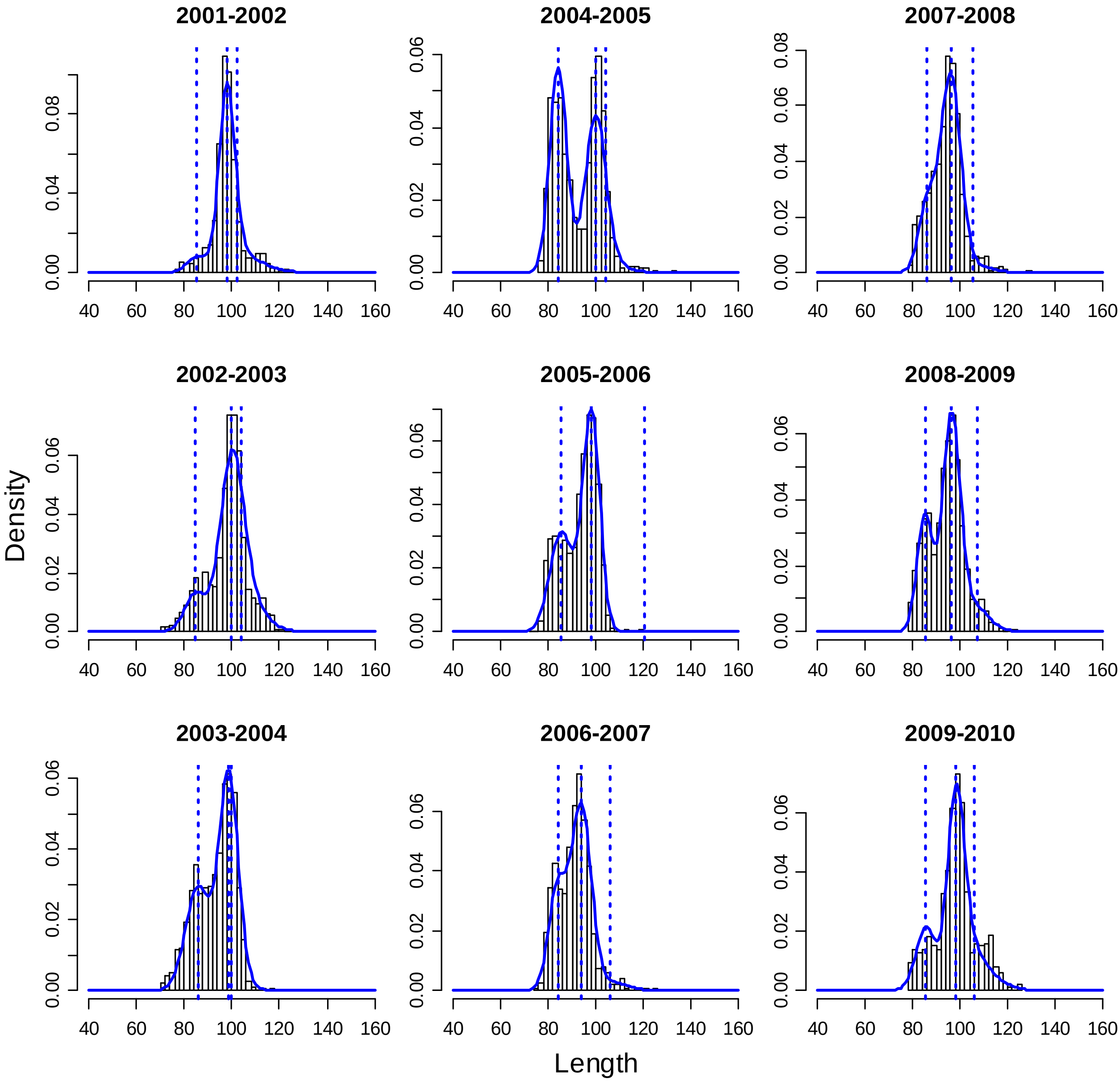

Figure 4. Length distribution of fish caught in the GAB in each fishing season, along with the estimated distribution and estimated mean lengths at age for ages 2-4 from the M&B method with unknown growth (solid blue curve and dashed blue vertical lines).

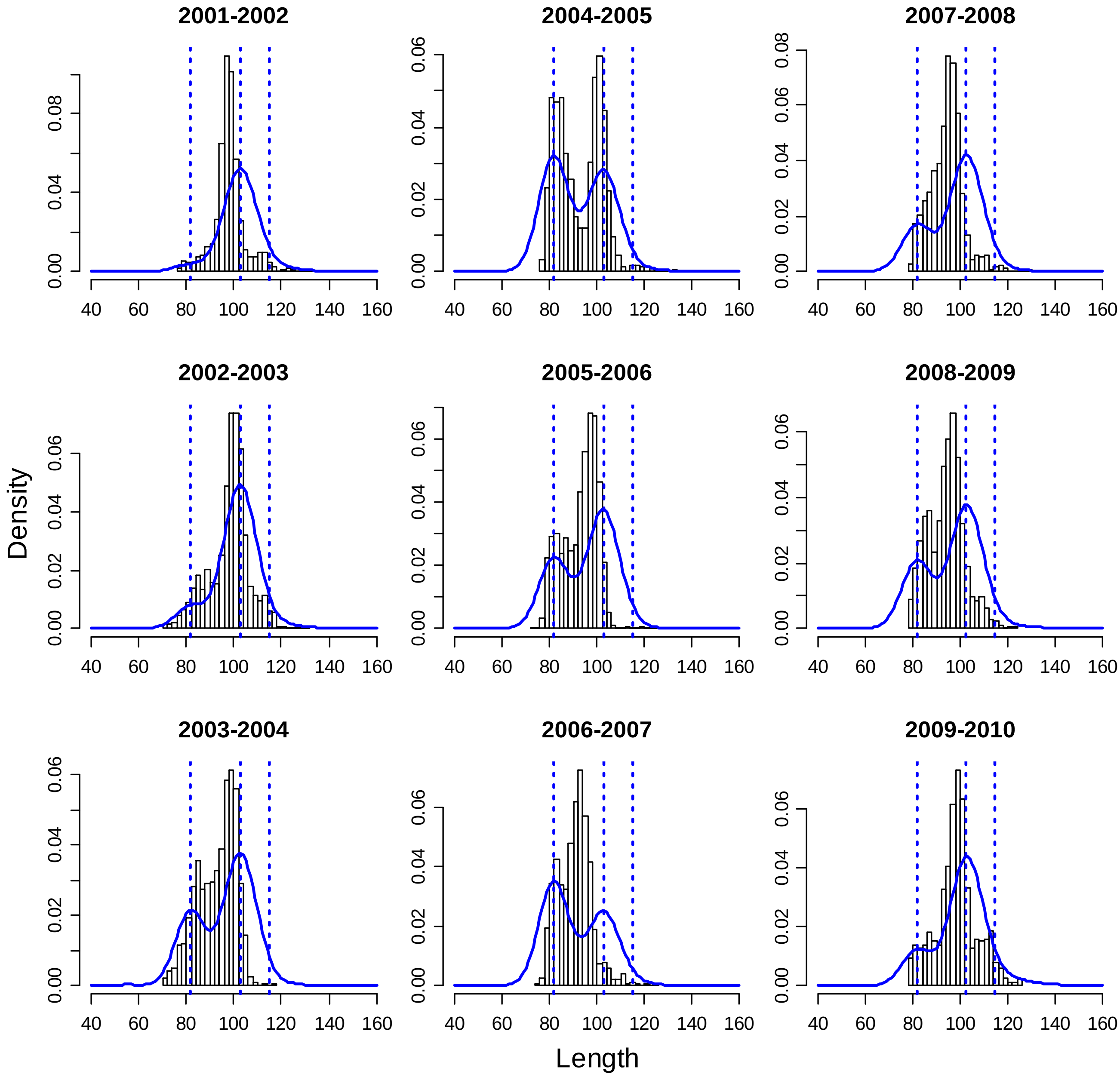

Figure 5. Length distribution of fish caught in the GAB in each fishing season, along with the estimated distribution and “known” mean lengths at age for ages 2-4 from the M&B method with known growth (solid blue curve and dashed blue vertical lines).

Conclusions

Australia continued to collect and archive otoliths from SBT caught in Australian waters during the 2010/11fishing season. Age was estimated for 98 SBT caught by the surface fishery in the 2009/10 fishing season from otoliths collected and archived last year. Using these data, we estimated proportions at age in the 2009/10 catch of the Australian surface fishery. At this stage we consider that the otolith sample sizes for age estimation (100 otoliths per fishing season) provide acceptably low CVs for ages 2 and 3 (generally <10%), but less so for age 4 (ranging from 14% to 68%), and quite poor for ages 1 and >5 (many over 100%). This simply reflects the amount of data available for the different age classes. Whether the high CVs for age classes other than 2 and 3 matters or not, can only be evaluated once the direct age data are used in the SBT operating/assessment model. If it is important, then there will be a need to re-evaluate the sampling design for otoliths including (a) number sampled per length class and (b) the number of otoliths that need to be read. The estimated numbers at age will also only be representative of the catch if the size frequency distribution is representative. The work highlights the need for further discussion within the CCSBT regarding the technical details of how the direct age data will be incorporated into the stock assessment model.

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