Catch at age of Southern bluefin tuna in the New Zealand longline fishery, 2001-2004

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Prepared for the CCSBT SAG/SC meetings in Taipei, Taiwan 28 August to 8 September

Executive Summary

This report provides details of the length-frequency data, ageing methods, age-composition data and precision-of-age estimates of southern bluefin tuna collected between 2001 and 2004 from vessels fishing in New Zealand fisheries waters. It was prepared by the Central Ageing Facility (CAF) to meet the reporting requirements for the 2004 New Zealand Ministry Fisheries project (IFA2004-03)

A total of 3954 otolith pairs sampled during 2001 to 2004 from the New Zealand fishing grounds were supplied to, and subsequently registered, at the CAF. A sub-sample of 200 otoliths from each sampling year was selected and prepared according to CAF ageing protocols. Protocols outlined in the Direct Age Estimation Workshop of the CCSBT report (2002) formed the basis of the ageing estimation protocols used for this project. Otoliths were read blind a second time and an acceptable level of precision was attained.

Significant differences existing between years were evident in the age frequency and length frequency distribution. The modal age increased from 5 to 8 for 2001 to 2004 and age classes 3 to 5 were not represented in 2004 sample. The modal length of samples also increased from 130 to 150 cm from 2001 to 2004. Low numbers of younger age classes were observed and were most evident for the 2004 sample.

The von Bertalanffy growth equation derived from this project was consistent with the von Bertalanffy parameters derived from age estimates in the CCSBT database. However, the mean length at age of the 2001 to 2004 samples when compared to the CCSBT data, indicated that the age estimates in this project were consistently younger by one year. On analysis one reason for this bias may be due to a misclassification of the edge margin of either the 2001-04 New Zealand or the CCSBT data. The subsequent decision to either include or not include the increment forming on otolith margin would influence the final estimate. If direct age estimates from different sources are to be compared, a better understanding of the issues of timing of increment formation and birthdate assignment need to be addressed.

Introduction

Southern bluefin tuna are managed by the Commission for the Conservation for Southern bluefin tuna. During the 9th Meeting of the Scientific Committee held in Cheju, Republic of Korea, in September 2004, the following statement was made in relation to the status of the stock:

"The assessments and indicators presented at the 2004 SAG agree that there was at least one year of markedly low recruitment amongst the 1999-2001 year-classes. These support the recruitment concerns outlined in the 2003 SAG report. Moreover the lack of small fish in the longline fisheries and other indicators raised concern that there may have been several years of markedly lower recruitment among those year classes. There are also some concerns regarding possible reductions in spawning stock size."

Further to this, the following recommendations were made with respect to scientific research to be undertaken:

"Between CCSBT 2004 and SAG/SC 2005 assure the maximum possible monitoring of recruitment trends through analysis of length frequency, tag returns, and retention and targeting patterns in the longline fisheries; tagging, aerial surveys acoustic estimates of juveniles in Australia waters; and direct ageing from otoliths from all fisheries."

These recommendations were subsequently endorsed by CCSBT and in Attachment 10 of the report of the Extended Commission it is noted that otoliths should be read for the year 2002, with other years if possible.

The output from this project will be estimates of age from selected individuals sampled from years 2001–2004 from vessels working in the New Zealand fisheries in the format recommended by the 9th Scientific Committee, i.e. Year, Month, Latitude, Longitude, Length, Otolith ID, Age estimate, and Comments.

Material and Methods

Collection of Samples

Scientific observers aboard New Zealand domestic vessels and foreign vessels chartered to fish in New Zealand waters routinely obtained length estimates and collected otoliths from Southern bluefin tuna. The otoliths were contained in marked envelopes. Data sheets detailing the fish length, date of capture, area of capture and sex for each sample accompanied the samples.

Table 1. Numbers of Southern bluefin tuna otoliths collected each year from vessels working in New Zealand waters by calendar year and month.

Calendar year	April	May	June	July	Total
2001	106	367	304		777
2002	114	636	449		1199
2003	212	436	190		838
2004	282	490	345	23	1140

Sub-sampling of otoliths

To obtain an adequate sample for determination of catch at age, Morton and Bravington (2003) concluded that 100-200 per year is sufficient for the Australian surface fishery, 200 for the Japanese longline fishery, and 500 for the Indonesian fishery. Based on this, 200 otolith per year were randomly sampled from the collections for the years 2001 to 2004.

Random numbers were assigned to data from each sampling year and were sorted from lowest too highest. The lowest 200 random numbers were selected and the corresponding otoliths were used for the ageing sub-sample. The length frequency of the sub-samples was compared to the length frequency of the total samples, for each sampling year, to ensure that the sub-sample was a representative sample. All samples were registered at the CAF and allocated a unique identification number.

Ageing Methods

Otolith mass

Otolith weight is a useful diagnostic tool in assessing potential errors in age estimates and for examining patterns of otolith growth. Otolith weight tends to have a strong relationship with fish size and age. In long-lived species, the relationship of otolith weight against estimated age would therefore show an increased slope if the ages have been underestimated. Such underestimation has often occurred for species when whole otoliths have been used, instead of sectioned otoliths. Also a large variation about the relationship may indicate a lack of precision in the estimates.

Otolith preparation

Otoliths were prepared using the CAF thin sectioning technique. One otolith from each pair was embedded, mounted and sectioned following CAF procedures (Morison *et al.* 1998). Otoliths were initially placed into a thin layer of clear polyester casting resin poured on to the base of a silicon mould and left to partially cure. Otoliths were arranged in two rows of five. Resin blocks were labelled and coated with another layer of resin. Blocks were then oven cured at 55° C for 24 hours.

Otolith sections were cut using a Gemmasta™ lapidary saw fitted with a diamond-impregnated blade. From each otolith, up to five transverse sections were taken (approximately 350 µm in thickness) to ensure the primordium of each otolith was included. Sections were cleaned using alcohol and stored in vials. For identification, each vial contained a sample identification label consisting of batch and fish number.

A small amount of resin was poured on to a glass slide (50 x 75 mm). Otolith sections were immersed in the resin and the identification label placed at the top of the slide. Once the resin had semi-cured, further resin was applied to the preparations and cover-slipped. Slides were oven cured at 30° C for a minimum of 3 hours before reading.

Reading protocol

Counts and measurements

To ensure that age estimates were consistent with previously aged southern bluefin tuna, the reader re-read otoliths sections from a calibration set of previously aged (agreed age) otoliths collected from the Indonesian and Australian surface fisheries. Sufficient samples were aged until the level of agreement was at or below an acceptable level (Morison *et al.* 1998).

Sections were examined under transmitted light using a Leitz Wild M3C binocular microscope at 10 to 16x magnification. Higher magnification was sometimes required for the examination of the fine growth increments near the otolith edge from larger, presumably older fish. Opaque (dark) increments were counted along a transect from the primordium to the terminal edge on the ventral arm adjacent to the sulcus (Figure 1). The distance between the otolith margin and the last increment (edge type) was classified as either wide or narrow.

A customised image analysis system has been developed by the Central Ageing Facility to view the sections, count marked increments, and measure their positions relative to the primordium. A frame grabber installed in a personal computer captures an image from a video camera mounted on the dissecting/compound microscope, and displays it on the computer monitor. Using the screen cursor, a transect is drawn on the otolith image from the primordium to the edge of the section. The positions of increments along this transect, and of the otolith edge, are then marked with the cursor. The customised image analysis system then records the number of increments marked, and the distances from the primordium to each increment and to the edge of the otolith. All ageing data, including a subjective measure of the sample's readability (Table 2) was recorded in a Microsoft Excel file linked to the image analysis software. In addition to the measurements an image of each otolith section was taken at the magnification used for ageing.

To avoid the potential for biasing age estimates, all counts are initially made without knowledge of fish size, sex, or location. Such *a priori* data are sometimes used in ageing studies — but in developing CAF's ageing protocol over the last decade, experience has shown that these data can reduce the ability to detect variations in growth. Particularly when shifts in growth rates (both somatic and otolith mass) occur through mechanisms such as episodic, or strong recruitment. Once age estimates are completed, the ageing data are combined with such additional information for subsequent analyses.

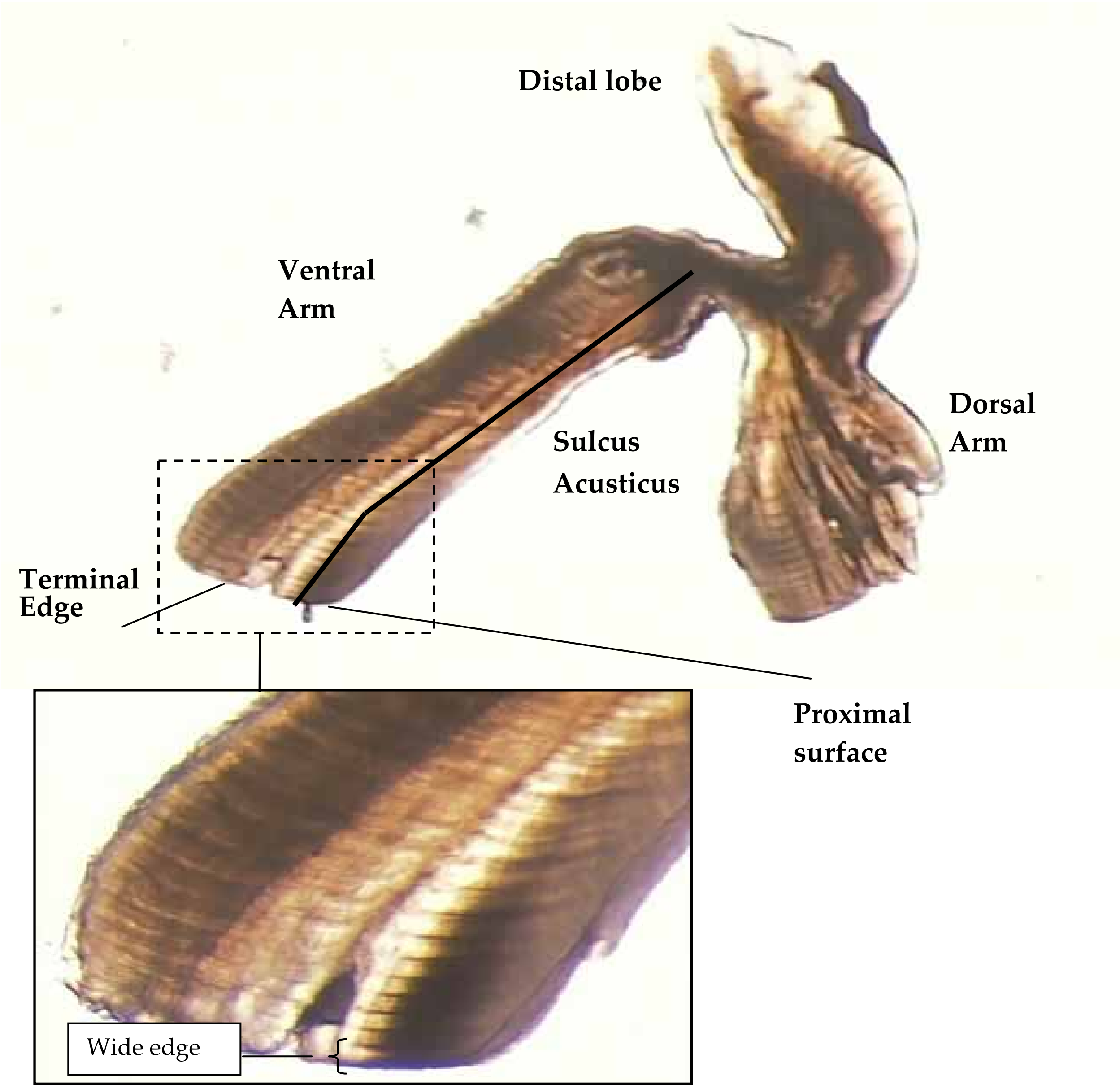

Figure 1. Southern bluefin tuna otolith section indicating ageing transect (black line) and edge analysis.

Table 2. Interpretation of readability scores.

Score	Interpretation
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 estimation
5	Excellent pattern - No doubt in age estimation

Birthday assignment/Age correction

In order for a final zone count to be converted to an age and an individual age to be classified into a year class, the following additional information is required:

- Theoretical birth date
- Date of capture
- Edge classification based on the distance from the last opaque increment to the terminal edge (proximal)

The theoretical birth date of SBT was defined as 1 January (CCSBT, 2002). Spawning is known to last from September to March, with peaks occurring near the beginning and end of that period. The timing and periodicity of opaque increment formation in whole otoliths are estimated to be in May-September ("winter") and the subsequent opaque zone during October-April ("summer"). In whole otoliths, the first translucent zone is formed in May-September ("winter") and the subsequent opaque zone during October-April ("summer") (Clear *et al*. in press). Translucent zones are narrower than opaque zones. However, the relationship between the zones seen in whole otoliths and those seen in thin sections has not been determined. Polacheck, et al. (2003) determined that the increments are forming during the middle of the year in sectioned otoliths.

Date of otolith sampling was between April and July. As date of collection is between 4 and 7 months after the assigned birthdate and 1-2 months before increment formation, increment counts were converted to estimates of age according to the following criteria:

If wide edge; age = increment count

If narrow edge; age = increment count – 1

The increments were counted and the edge was classified as wide or narrow. Increments were only counted near the margin (classified narrow edge) of the otolith if they were distinct from the margin, in that there was translucent material between the increment and terminal edge on both the ventral and dorsal margin of the otolith.

Quality Assurance / Quality Control

The CAF follows procedural quality assurance/quality control measures. To avoid potential bias, all counts were made without knowledge of fish size or otolith weight. Additional quality control measures include a qualitative index of readability, and a level of repeatibility of the estimated ages.

Repeated readings of the same otoliths provide a measure of intra-reader variability. They do not validate the assigned ages but provide an indication of the size of the error to be expected from a set of age estimates, due to variation in otolith interpretation. Beamish and Fournier (1987) developed an index of average percent error (IAPE), which has become a common method for quantifying this variation. The IAPE is calculated as:

$$IAPE = \frac{100}{N} \sum_{j=1}^{N} \left[\frac{1}{R} \sum_{i=1}^{R} \frac{|X_{ij} - X_j|}{X_j} \right]$$

where N is the number of fish aged, R is the number of times fish are aged, X_{ij} is the ith determination for the jth fish, and X_j is the average estimated age of the jth fish. The IAPE has the property that differences in age estimates for younger fish will contribute more to the final value than will the same absolute error for older fish (Anderson *et al.* 1992).

To establish confidence intervals to these estimates of precision, a bootstrap technique was applied on the individual error estimates between repeat readings, following methods described by Efron and Tibshirani (1993). Error estimates (each of the same size as the original sample) were randomly taken with replacement from the repeat readings, and a new IAPE calculated. This process was iterated five thousand times. The mean of these replicate IAPE is the mean bootstrap IAPE and the standard deviation is the standard error of the mean. The bootstrap procedure exaggerates any bias present in the original estimate, so it is necessary to correct for this by adding the difference between the original statistic and the bootstrap mean, to the original estimate. The bias-corrected bootstrapped IAPE is thus calculated as:

Bias-corrected IAPE = Original IAPE + (Original IAPE - Mean Bootstrap IAPE)

The 95% confidence interval was calculated as:

95 % C.I. = Bias-corrected IAPE ± (1.96 Standard deviation of Bootstrap IAPE)*

According to the protocols outlined in the Direct Age Estimation Report, the original reader performed a 100% sample re-read. The IAPE was calculated and an age-bias plot (Campana *et al.* 1995) was used to indicate any systematic bias in the repeated age estimates. Regression analysis and the distributions of the differences between repeat readings were also inspected as another indicator of ageing errors and bias.

Data analysis

Age estimates were combined with available biological data and otolith mass data. Length/age and otolith mass/age relationship scattergrams were produced. Length and age frequencies were provided for each sampling year. Mean lengths at each age were produced and compared to the mid point values interpolated by growth rate data (SC2001) in the CCSBT direct ageing database. Age-length-keys (ALK) were produced for years 2001–2004. The ALK's are not included in this report due to size restrictions.

Growth estimates

Von Bertalanffy growth curves were fitted to length-at-age data using the non-linear least squares method. The growth equations for male, female and combined sexes for southern bluefin tuna were determined.

$$L(t) = L_{\infty}(1 - e^{-k(t-t_0)})$$

where L_{∞} indicates the mean asymptotic fork length (mm), k represents the growth constant and to is the theoretical age at length zero.

The von Bertalanffy growth curve derived from this study was compared to the growth curve derived from previously aged southern bluefin tuna in the CCSBT database (CS2001).

Results

Ageing

The CAF has approximately 5 years of experience ageing southern bluefin tuna from the Australian and Indonesian fisheries. A description of the otolith morphology and increment pattern has been previously described (CCSBT 2002). The otolith morphology and structure of the samples supplied from New Zealand were similar to the Southern bluefin tuna otoliths routinely aged by the CAF. The edge margin was also similar to the Indonesian and Australian samples even though the date of capture was different (Appendix 1 and 2).

Ninety nine percent of the edge types were classified as wide. Newly formed increments could be seen on the otolith margin of some otoliths, particularly for those sampled during June and July (appendix 1). Even though opaque increments were forming on the margin there was insufficient translucent material between the increment and the margin for the edge to be classified as narrow.

Ageing precision

Of the 800 southern bluefin tuna samples that were aged, 10 received a readability score of 0 and were unable to be aged. Approximately 10% of the samples were considered unambiguous (readability 4), whereas 16.88% were considered open to multiple interpretations (readability 2). The modal readability was 3 (70.75%), which indicates that the interpretation of age for this species from otoliths is difficult and may be subject to some variation.

Table 3 Distribution of readability indices of southern bluefin tuna samples aged at the CAF.

Readability	Frequency	% Frequency
0	10	1.25
1	8	1.00
2	135	16.88
3	566	70.75
4	80	10.00
5	1	0.13

Repeat readings of the samples by the primary reader (intra-reader variability) produced an IAPE of 3.43%, which is indicative of a relatively high level of precision. The bias-corrected bootstrap IAPE was 3.46% with a lower 95% confidence interval of 3.05% and an upper 95% confidence interval of 4.38%. This is consistent with previous estimates of precision and is an acceptable level of agreement between readings for the CAF (Morison *et al.* 1998). The age bias plot (Figure 2) supports this level of agreement as the first and second age estimates were highly correlated. Regression parameters between the first age estimate and the difference between the two readings indicated a slight bias ($F_{1, 1000}$ = 20.51, p > 0.001, r^2 = 0.03, slope = 0.03 ± 0.01). The age difference table also shows this bias in the form of over-ageing samples for the 4-year-olds class when first and second age estimates are not in agreement (Table 1). The remaining age classes show no bias. The high level (54.6%) of age estimates in agreement further indicates an acceptable level of precision. This is slightly better than previously aged southern bluefin tuna from the CAF. (IAPE of 3.75% and an agreement of 34.3% between first and second readings were achieved).

The distributions of differences between first and second age estimates are shown in (Figure 3). The graph further highlights the consistency with which the ages were estimated as 38% of all secondary readings agreed with the first age estimate and 95% of the secondary readings were within +/– two years of the original estimate. When the first and second age estimates did not agree 20% were overaged and 27% were underaged by one year.

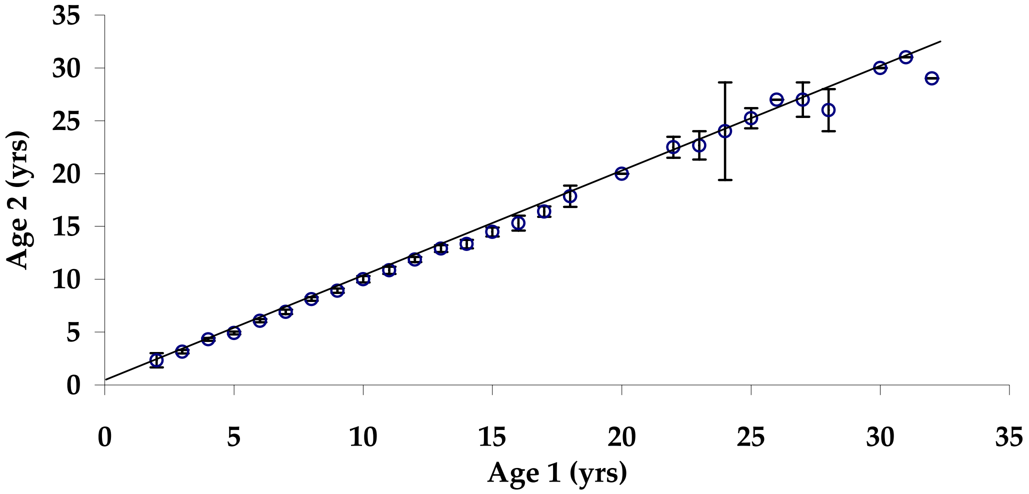

Figure 2. Age bias plot of first and second age estimates. Line represents equal agreement of age.

Table 4. Age difference table of first and second age estimates and percentage agreement.

	Age																													%	+/-1	+/-2
Diff (Age1-Age2)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	24	25	26	27	28	29	30	31	N	Agreed	year	years
-6																																	
-5																																	
-4										1																1				2			
-3								1				3			1															5			
-2					1		3	2	2	2	1	1		2		1	2		1			2					1			21			
-1		1	3	18	13	22	13	20	9	11	8	9	5	2	2	1		1				1		2	1					142			
0	2	18	39	46	62	37	41	36	21	20	32	23	14	9	7	2	2		1		3	1	1		2			1	1	421	54%	91%	97%
1		1	19	20	19	12	12	17	6	5	7	8	10	4	3	2				1	2	1			1					150			
2			1	4	1	3	2	2	4	3	5	2	1		1								1							30			
3							2	1	1		1	4											1				1			11			
4									1										1											2			
5																																	
6																																	
N	2	20	62	88	96	74	73	79	44	42	54	50	30	17	14	6	4	1	3	1	5	5	3	2	4	1	2	1	1	784			

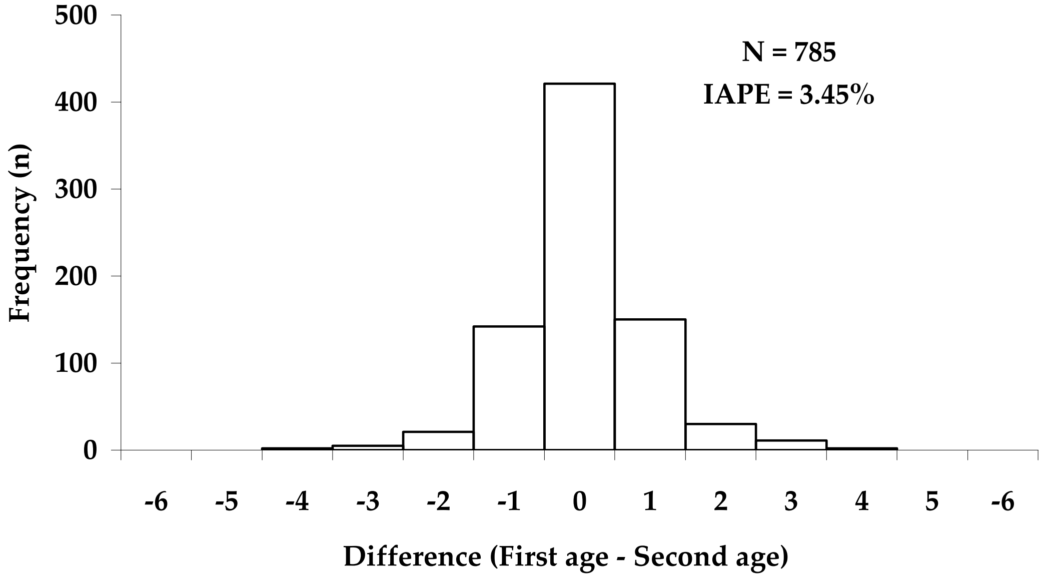

Figure 3. Age distribution of first age estimate against second age estimate.

Growth

The otolith mass-age relationship is essentially curve-linear over the range of ages, showing a marked decrease in otolith mass growth rate after approximately seven years of age (Figure 4). Mean otolith mass-at-age for 1996–2001 data also shows a similar relationship to the current data.

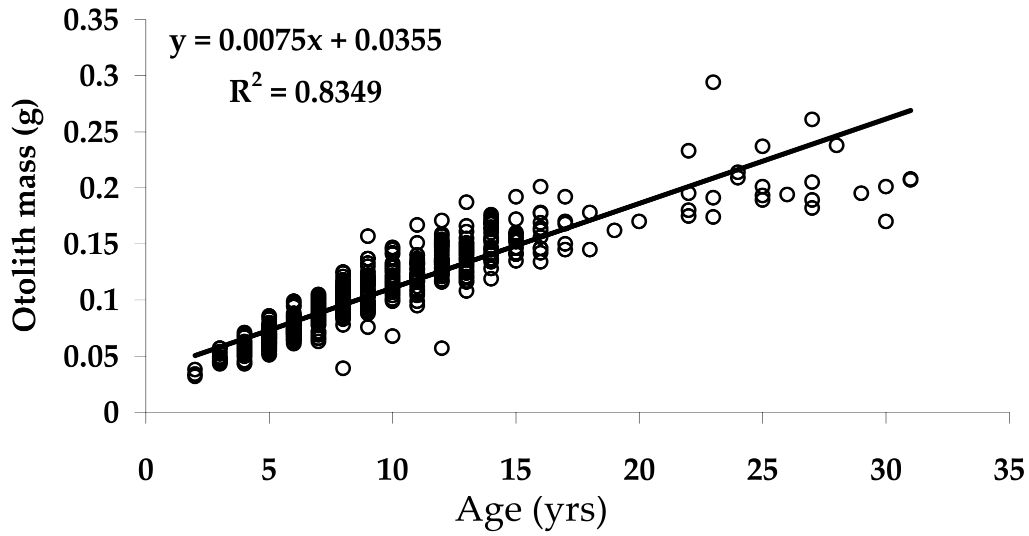

Figure 4. Comparison of otolith-mass at-age for southern bluefin tuna sampled from 2001– 2004.

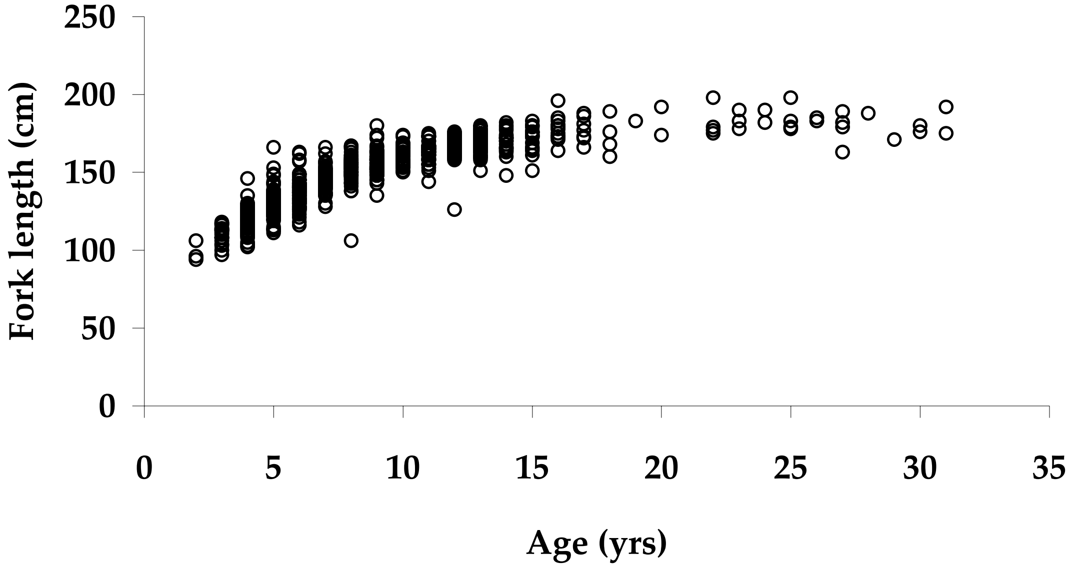

Figure 5. Age length relationship for southern bluefin tuna sampled from 2001–2004

Significant differences between years were evident in the age frequency distributions. The distributions for years 2001-2004 show marked a decrease in younger age classes over time (Figure 6). The ages ranged from 2 to 29 years in 2001, 2 to 28 years in 2003, 4 to 27 in 2003 and 4 to 30 in 2004. Age estimates showed a modal age distribution of 5 in 2001, 6 in 2002, 6 in 2003 and 8 years in 2004. Thirty five percent of age estimates were less than 6 years in 2001, 27.5 % were less than 6 years in 2002, 17.5% were less than 6 years in for 2003 and 2.5% were less than 6 years in 2004.

The length–frequency indicates a difference in size between 2001 and 2004 (Figure 7). Fork length ranged from 89 to 193 cm in 2001, 104 to 199 cm in 2002, 119 to 199 cm in 2003 and 134 to 193 cm in 2004. Thirty six percent of samples were less than 130 cm in 2001, 27% were less than 130 cm in 2002, 13% were less than 130 in2003 and no samples were under 130 cm in 2004.

The comparison between the midpoint values from the CCSBT age data (SC2001) and the mean length-at-age for the 2001-04 data indicate a bias. The midpoint values of the CCSBT derived data were consistent with the length-at-age of the previous 2001-04 age. Results indicate that the age estimates provided by the CAF are consistently younger by 1 year. The mean length-at-age for the 2001-04 age estimates, 2001-2004 estimates plus 1 year and the midpoint values for the CCSBT data (SC2001) are shown in Appendix 1. The age frequency distribution of CAF age + 1 are shown in Appendix 2. Age–length keys for each sampling year were produced, however were not included in this report due to size restrictions.

Parameters of von Bertalanffy growth curves derived from the 2001-2004 age data (combined sampling years), CAF age data + 1 year, and the CCSBT data (SC2001) are presented in Table 5. The mean asymptotic length (L_∞) and growth constant (K) are similar. There were few young fish in the 2001-2004 samples and therefore the growth trajectory tends towards higher asymptotic lengths, more negative t_o values and reduced curvature coefficients (*k*). The distribution of size–age data fitted around the von Bertalanffy growth curve can be seen in Figure 8.

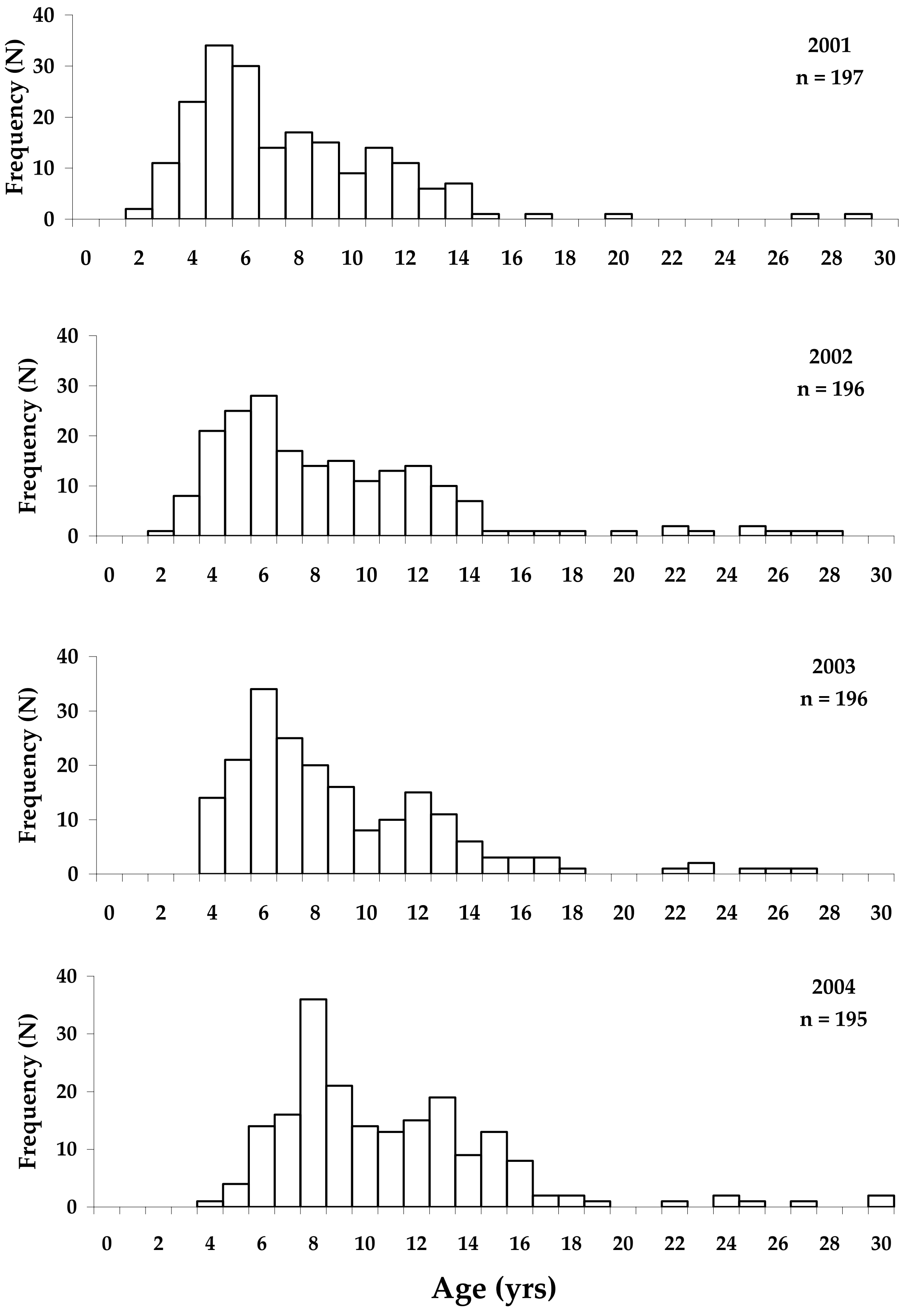

Figure 6. Age frequency distribution of southern bluefin tuna sampled from 2001-2004.

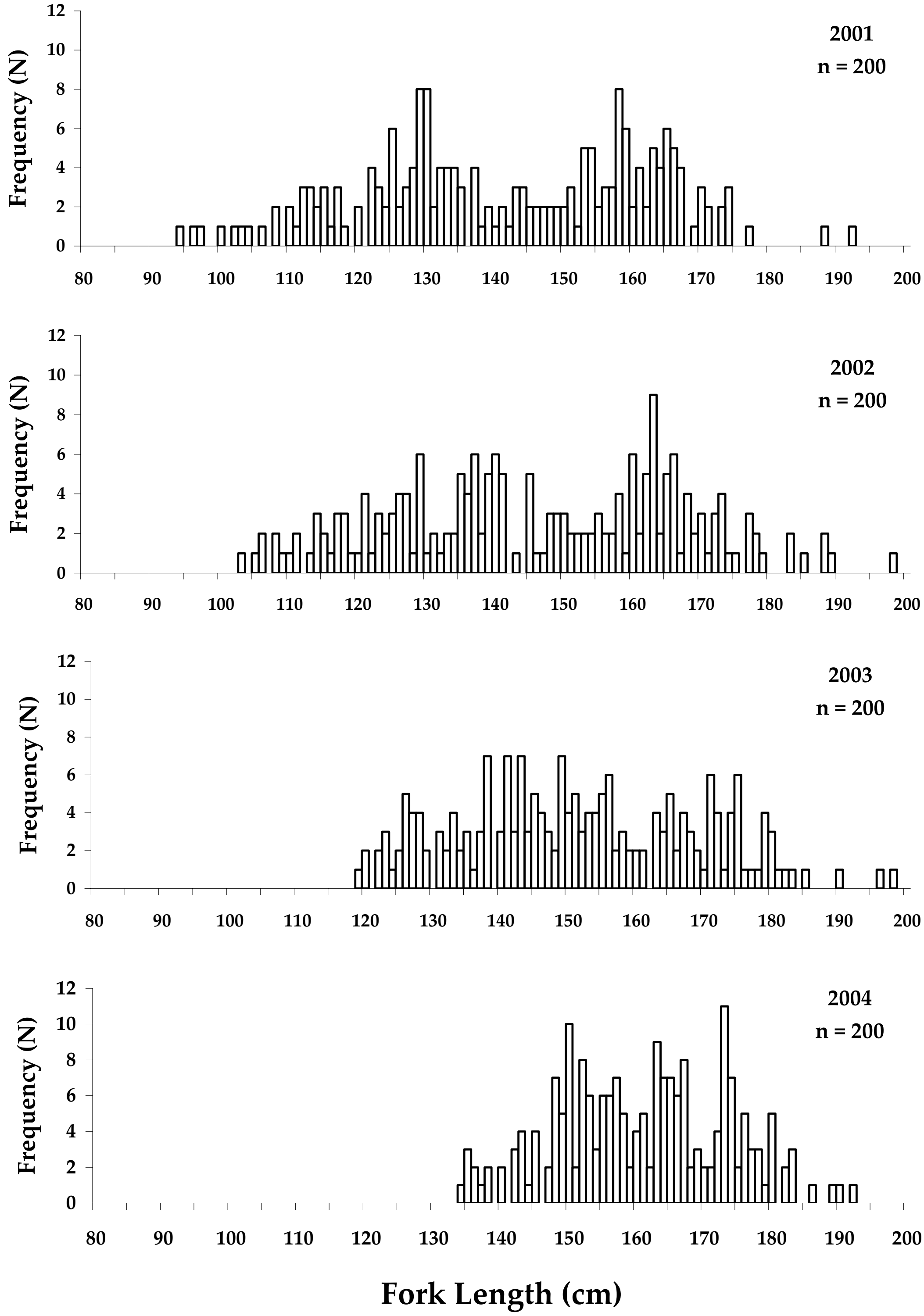

Figure 7. Length frequency distributions for southern bluefin tuna sampled from 2001-2004

Table 5. 2001-04 Age, 2001-04 Age + 1 and CCSBT data (SC2001) von Bertalanffy growth curve parameters for southern bluefin tuna.

Source	L∞	K	to
2001-04 Age	183.5	0.16	-2.52
CCSBT (SC2001)	184.9	0.18	0.18
2001-04 Age + 1	183.5	0.16	-1.52

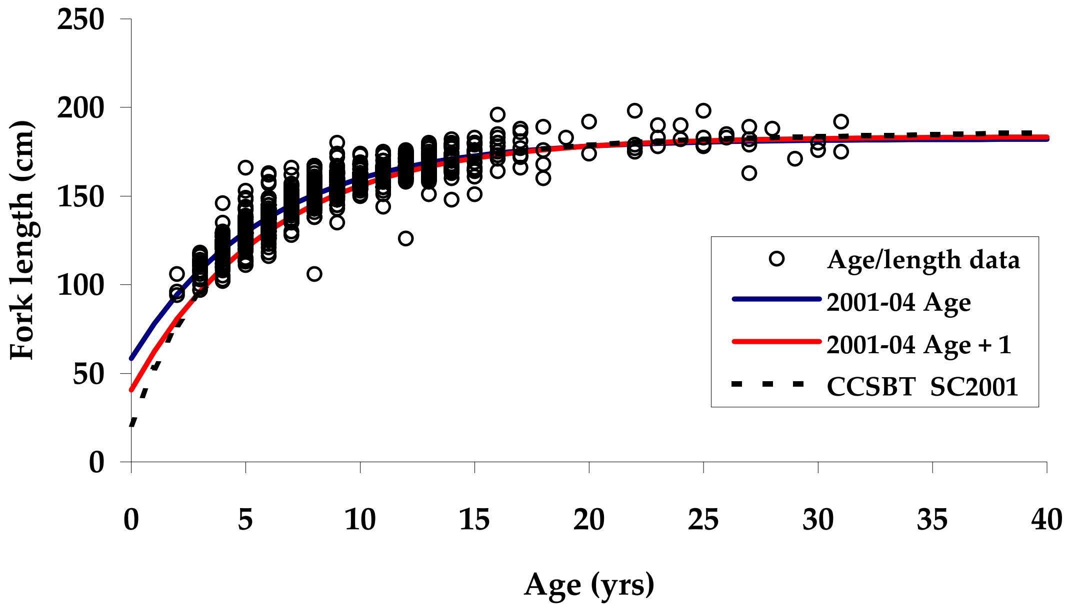

Figure 8. Length at age data for southern bluefin tuna samples with von Bertalanffy growth curve for all data

Discussion

Sufficient samples were aged from years 2001-2004 to determine the catch at age for samples collected from the New Zealand longline fishery. Ages were estimated from counting opaque growth increments on thin-sectioned otoliths. Protocols used for the age estimation followed the criteria outlined in the Direct Age Estimation Workshop of the CCSBT report (2002). The proportion of unreadable otoliths (1.25%) was considered satisfactory for this study and consistent with the levels normally experienced for the samples of southern bluefin tuna aged routinely at the CAF. The levels of precision presented in the results were considered high, indicating that even though southern bluefin tuna otoliths may be subject to variation, the ages presented in this report are repeatable to a high level of precision.

The data presented on the catch at age data indicate poor recruitment of younger age classes (3-5) over time and a significant increase in the modal age and length of the catch from 2001 to 2004. Only 2.5 % of the samples in 2004 were less than 6 years of age, in comparison to 2001 in which 27.5 % were classified as 5 years or younger. No data is presented on the comparison of growth rate differences between 2001-2004.

While the precision was high, the age estimates presented in this report when compared to the mid point values of mean length at age (SC2001) from the Indonesian and Australian surface fishery indicated a systematic bias of one year. While systematic biases can generally be better explained than random errors they can be more problematic to the assessment of a fishery. Systematic biases can greatly influence growth rates, estimates of productivity and mortality estimates and also result in the masking of strong year-classes. The failure to assess and correct the bias may lead to implications in the efficient management of the fishery.

The systematic misinterpretation of the first increment or subsequent increments cannot be dismissed as the cause of the systematic bias exhibited between the two sets of age data. However it seems unlikely, since the age reader calibrated their reading interpretation with the reference set of previously "agreed" aged samples from the Indonesian fishing grounds. The variation in length at age could be a function of the comparison of data from different times of the year, ie New Zealand samples are larger for their age because they are caught later in the year. The investigation of differences in growth between areas and the influence of capture dates on the estimation of length at age is beyond the scope of the project.

It is more likely that the birthdate assignment and the possible misinterpretation of the edge can explain the bias and therefore miss allocation of the estimates into age classes. The ageing protocols followed in this project use a birthdate of 1st January. A theoretical birthdate ensures that ages would be assigned to the same spawning cohorts, regardless of the timing of increment formation. Assigning a birthdate is relatively straightforward if the spawning period, timing of increment formation and the date of capture are known.

Validation studies have been carried out to validate the periodicity of increment formation. Clear *et al.* (2000) through large-scale strontium mark and recapture experiments, validated that increments are formed each year for southern bluefin tuna aged from 1 to 6 years. Kalish *et al.* (1996) provided further evidence that increments in southern bluefin tunas otoliths are formed annually throughout life by a comparison of increment counts with age estimates derived from levels of bomb-radiocarbon in the early growth zones of otoliths. While these studies have established that counting increments on otoliths is a valid method for age determination for southern bluefin tuna, they have not focused on the timing of the increment formation. Polacheck *et al,* (2003) attempted to address this issue and found that increment formation occurs during the middle of the year – but appears to be variable among fish and can occur in where within a period of several months. It was noted however that data is lacking to resolve the timing issue further (e.g. to estimate the probability that the annual band has formed in a particular month within this period), (Polacheck, *pers comm*).

The assignment of an age estimate into an age class is a function of determining the increment count and estimating the edge type in relation to the date of collection and assigned birthdate, however classification of the edge type is often a difficult process. Correct interpretation of the edge influences ageing accuracy and bias at the yearly level, since the annulus on the structure collected just after the assigned birthday can be given a different age assignment than the same structure collected just before the birthday. (Campana, 2001).

In theory the assignment of samples collected either side of this increment formation (e.g. for surface or Indonesian catches) should be relatively straightforward and the assignment for mid-year catches (i.e. for most of the longline catches on feeding grounds) is more difficult. However the deposition of a zone may begin some time before it becomes visible at the terminal edge of the otolith. Therefore in southern bluefin tuna increments that are forming during May to September may not be visible until November or December. This would make the allocation of edge classification difficult even during the last and first quarter of the year.

The sampling dates for the otoliths collected in this project ranged between April to July. Of the 800 otoliths aged, 90% of the marginal state of the samples examined in this project were classified as wide. Increments were observed on the margin of some otoliths however as there was no translucent material between the increment and the margins most were classified as wide. An example of otolith sections from each month of collection between April – July can be seen in Appendix 3. Using the criteria outlined in the methods, the majority of age estimates do not need to be adjusted.

Otoliths examined from the Indonesian fishery (November to March) also exhibited a similar marginal state with an increment forming on the terminal edge of the otolith. Examples of the marginal state of sectioned otoliths from November and February are shown in Appendix 4. If an increment on the edge was counted for these samples and not for the 2001-04 New Zealand samples then this may account for the bias observed in this study. Alternatively if the criteria for the edge adjustment for the 2001-04 New Zealand samples was to be changes so that if the otolith margin is classified as wide then the age would be the increment count plus 1, the difference of one year would be accounted for. Without the knowledge of edge type the data sets cannot be directly compared and the bias can not be fully explained.

The above examples highlights the difficulty often exhibited when using birthdate adjustment to assign age estimates to age classes. This report has also outlined that it is very difficult to compare age data from different sources and different capture dates using the current methodologies. To allow the age estimates from different sources to be directly compared the edge type should accompany the increment count. Additional information such as increment measurements would also allow the source of bias and error to be determined.

Conclusions

Of the total 3954 otolith samples sent to the CAF for ageing, 800 samples were examined. Of these, 850 estimates of age were made. Seventy-nine percent of the aged estimates were considered to have a good pattern of increment formation and a confident estimate of age could be made. Repeated readings on 25% of the sample gave a IAPE less than 4 percent, indicating a high level of precision. The age frequency distributions showed a modal increase from 5 years in 2001 to 8 years in 2004. The length frequency also showed a modal increase over time. This indicates poor levels of recruitment in the fishery recruitment of younger age classes to the New Zealand southern bluefin tuna fishery.

Von Bertalanffy growth parameters were similar to previously aged samples. The mean length at age when compared to the mid length data for the Indonesian and Australian surface fishery held in the CCSBT database indicated a bias of 1 year. The bias may be due to several reasons including reading error, differences in length at age due to the timing of otolith collection and the conversion of age estimates into age classes using a Birthdate of 1st January. Since the estimates provided for in this project were calibrated against previously aged Indonesian samples, reading error was not thought to be the source of this bias. The timing of sample collection may influence the length at age. The effect of capture date could not be determined within the scope of this project. Bias caused by interpretation of the terminal edge and misclassification of the edge was also examined and could account for a difference of 1 year. At the time of reporting the difference could not be fully examined because no information on the direct age data from which the mid-point values (SC2001) data were derived were available.

It is recommended that a birthdate and protocols be established to allow age estimates to be assigned into the correct age cohort regardless of the fishery or time of year they were sampled. To allow the direct age estimates from different sources to be compared the edge classification must also accompany the increment count. Additional information such as increment measurements or images would also increase the ability to determine the source of potential error or bias with the estimates.

Acknowledgments

The author would like to thank the New Zealand Ministry Fisheries for funding this project (IFA2004/03). Thérèse Stokie and Joe Restall of the Central Ageing Facility for sample registration and preparation.

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Appendix 1

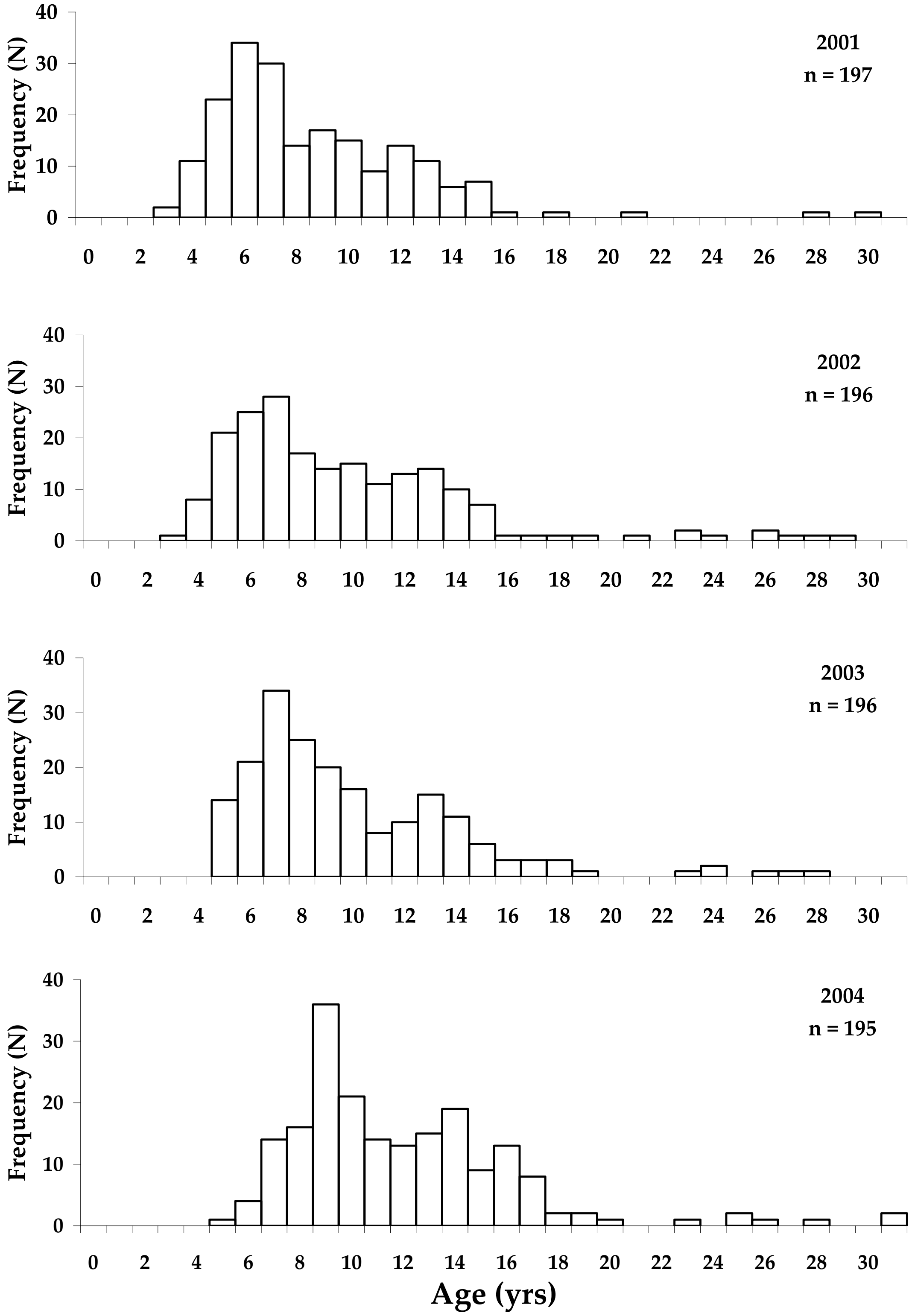
Mean length-at-age

Age	Data	CAFAge	CCSBT(SC2001)	CAFAge(Adjusted)
1			53.2	
2	Mean	98.7	77.5	
	SD	6.4		
	N	3.0		
3	Mean	109.9	95.7	98.7
	SD	5.9		6.4
	N	19.0		3.0
4	Mean	120.7	109.5	109.9
	SD	7.9		5.9
	N	59.0		19.0
5	Mean	130.4	121.0	120.9
	SD	8.8		7.9
	N	84.0		60.0
6	Mean	137.1	130.6	130.5
	SD	8.1		8.9
	N	106.0		84.0
7	Mean	145.7	138.7	137.1
	SD	6.7		8.1
	N	71.0		105.0
8	Mean	152.4	145.6	145.8
	SD	7.8		6.7
	N	86.0		72.0
9	Mean	156.4	151.4	152.5
	SD	7.2		7.9
	N	66.0		86.0
10	Mean	160.0	156.3	156.4
	SD	5.6		7.3
	N	42.0		65.0
11	Mean	163.3	160.4	160.0
	SD	6.3		5.6
	N	49.0		42.0
12	Mean	166.6	164.0	163.3
	SD	7.1		6.3
	N	55.0		49.0
13	Mean	168.9	167.0	166.6
	SD	6.5		7.1
	N	46.0		55.0
14	Mean	169.6	169.6	168.9
	SD	6.9		6.5
	N	29.0		46.0
15	Mean	171.8	171.7	169.6
	SD	7.9		6.9
	N	18.0		29.0
16	Mean	178.0	173.6	171.8
	SD	8.0		7.9
	N	12.0		18.0
17	Mean	177.6	175.2	178.0
	SD	7.9		8.0
	N	7.0		12.0
18	Mean	173.3	176.6	177.6
	SD	12.4		7.9
	N	4.0		7.0
19	Mean	183.0	177.8	173.3
	SD			12.4
	N	1.0		4.0
20	Mean	183.0	178.8	183.0
	SD	12.7		
	N	2.0		1.0

Age	Data	CAFAge	CCSBT(SC2001)	CAFAge(Adjusted)
22	Mean	182.3	179.6	183.0
	SD	10.6		12.7
	N	4.0		2.0
23	Mean	183.7		182.3
	SD	6.0		10.6
	N	3.0		4.0
24	Mean	186.0		183.7
	SD	5.7		6.0
	N	2.0		3.0
25	Mean	184.5		186.0
	SD	9.3		5.7
	N	4.0		2.0
26	Mean	184.0		184.5
	SD	1.4		9.3
	N	2.0		4.0
27	Mean	178.3		184.0
	SD	11.0		1.4
	N	4.0		2.0
28	Mean	188.0		178.3
	SD			11.0
	N	1.0		4.0
29	Mean	171.0		188.0
	SD			
	N	1.0		1.0
30	Mean	178.0		171.0
	SD	2.8		
	N	2.0		1.0
31	Mean	183.5		178.0
	SD	12.0		2.8
	N	2.0		2.0
32	Mean			183.5
	SD			12.0
	N			2.0

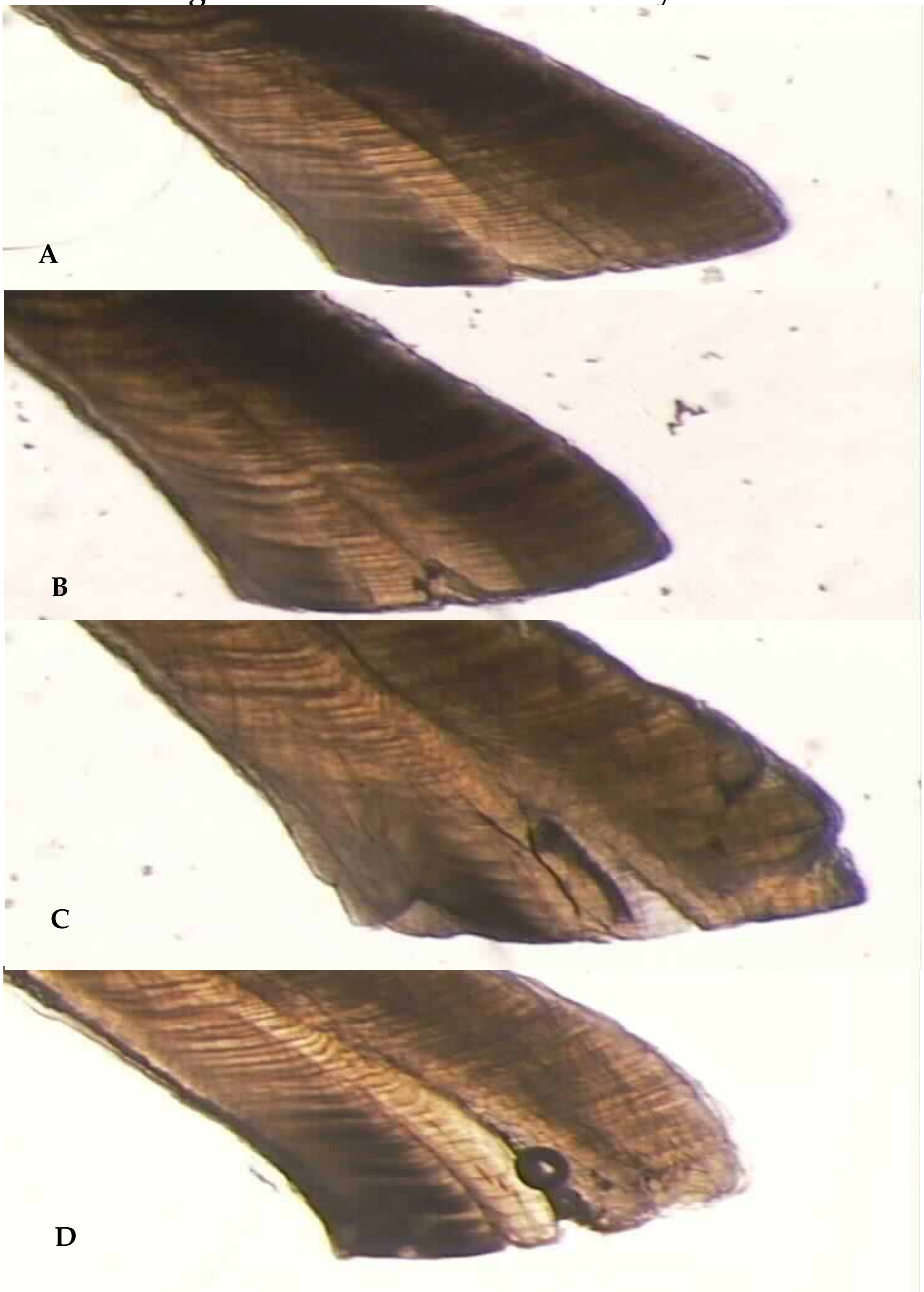
Appendix 2

Age composition (Adjusted age)



Appendix 3

Otolith Marginal State – New Zealand fishery



Appendix 3 – (A) April, (B) May, (C) June and (D) July

Appendix 4

Otolith Marginal State – Indonesian surface fishery

Appendix 3 – (A) November, (B) January.