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# Increased growth rates of juvenile SBT in recent years (1990s to present)

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## Abstract

This paper presents updated estimates of juvenile growth rates in recent years, using direct ageing and tag-recapture data available up to the end of April 2006. The results reinforce the findings presented last year in CCSBT-ESC/0509/32 (Eveson et al. 2005)— that juvenile growth has not declined, and in fact appears to have increased, between the early 1990s and early 2000s.


## Introduction

In CCSBT-ESC/0509/32 (Eveson et al. 2005), we presented estimates of growth rates for juvenile SBT using tag-recapture and otolith direct ageing data available as of April 2005. The results suggested that growth of juvenile SBT had been similar in the early 2000s as in the 1990s, and there was some evidence that the average length-at-age of fish aged 2 to 4 had increased slightly between the 1990s and 2000s. Since the time of that analysis, additional data pertaining to growth of juvenile SBT during the late 1990s and early 2000s has been collected. In particular, otoliths have been collected and aged from juvenile SBT caught in the GAB surface fishery in the 2005 season, plus additional tag releases and recaptures have occurred as part of the CCSBT conventional tagging program. In the current paper, we update the juvenile growth estimates for the late 1990s and early 2000s presented in Eveson et al. (2005) using these additional data. We also present annual estimates of juvenile growth in recent years to look for any evidence of finer-scale changes.

## Methods and Results

### *Otolith direct ageing data*

Using the same procedure as for the 2002-2004 fishing seasons, otoliths were selected for age determination from samples collected from SBT caught in the GAB surface fishery in the 2005 season, and then sent to the Central Ageing Facility (CAF) in Victoria for age estimation. Details of the otolith sampling, the selection of otoliths for aging, and the age estimation procedure are given in Basson et al. (2005) and Farley (2006). A summary of the GAB otolith data (sample sizes and age estimates) by fishing season are given in Table 1.

Table 1. Summary of direct aging data from otoliths collected in the Australian surface fishery in fishing seasons 2002 to 2005.

| | Age Estimate | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Season | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Total |
| 2002 | 0 | 7 | 42 | 53 | 16 | 4 | 2 | 0 | 0 | 0 | 124 |
| 2003 | 2 | 10 | 34 | 34 | 25 | 10 | 3 | 4 | 0 | 0 | 122 |
| 2004 | 28 | 35 | 35 | 36 | 22 | 13 | 2 | 0 | 0 | 0 | 171 |
| 2005 | 18 | 27 | 27 | 19 | 17 | 9 | 20 | 12 | 2 | 1 | 152 |
| Total | 48 | 79 | 138 | 142 | 80 | 36 | 27 | 16 | 2 | 1 | 569 |

Figure 1a shows the average length at age of SBT by cohort (aggregated over 5-year periods) and by catch season. The plot includes the direct aging data summarised in Table 1, which correspond to cohorts 1995 to 2004, as well as historical direct aging data from fish caught in the GAB during seasons 1991 to 1995, which correspond to cohorts 1990 to 1994. Although close to 1500 otoliths were collected from the surface fishery in 1996 to 2001 inclusively, none of these have been aged. As such, there are no data on age 1 or 2 fish born in the late 1990s for which we can make comparisons. However, of the comparisons that can be made, the most noticeable difference is that the average length of age 4 fish has increased for cohorts from the early 1990s through the early 2000s. This can also be seen in the age 4 length estimates calculated by catch season (Figure 1b – note that only data from Table 1 are included in this plot). The estimates by catch season also show a positive trend in the average length of age 5 fish over the past several seasons (cohorts 1997 to 2000), and a negative trend in the average length of age 2 fish (cohorts 2000 to 2003).

The limitations of the data must be considered before drawing conclusions from these results. In particular, the otoliths used in this study have been collected from mortalities in the South Australian tuna farms in Port Lincoln and from incidental mortalities during CCSBT tagging operations in the GAB (Basson et al. 2005; Farley 2006), and the size of these fish may not be representative of the general population. Subsequent selection of otoliths for aging was based on size of fish, with all otoliths from the smallest and largest fish in a season being selected, and a fixed number of otoliths (either 10 or 20) being chosen from each of the remaining 5 cm length classes (Basson et al. 2005; Farley 2006). While this sampling procedure was chosen to allow for the best estimation of the age-length key, it could potentially bias the length at age estimates presented here. Finally, the months during which most otoliths were collected varied between seasons (Table 2). Because fish grow substantially between December and April, average length at age estimates made in years when most sampling occurred early in the season are not directly comparable with those made in years when most sampling occurred late in the season.

Table 2. Proportion of aged otoliths by fishing season coming from each month of collection.

| Season | Nov | Dec | Jan | Feb | Mar | Apr |
|---|---|---|---|---|---|---|
| 2002 | 0.44 | 0.36 | 0.04 | 0.02 | 0.00 | 0.14 |
| 2003 | 0.41 | 0.25 | 0.20 | 0.08 | 0.00 | 0.06 |
| 2004 | 0.22 | 0.28 | 0.13 | 0.02 | 0.01 | 0.34 |
| 2005 | 0.36 | 0.22 | 0.09 | 0.00 | 0.00 | 0.33 |

### *Tag-recapture data*

The change in length of a tagged fish between the time it was released and the time it was recaptured provides information about its growth. In Eveson et al. (2005), we compared growth estimates derived from recent conventional tagging data with estimates from past data to investigate whether growth of juvenile SBT had changed in recent years. In our analysis, we used all tag releases since 1990 (i.e. all RMP and SRP releases) and their corresponding recaptures up to May 2005. Here, we update the analysis to include any releases and recaptures that occurred between May 2005 and the end of April 2006.

We applied the same screening process to this new data as we used in Eveson et al. (2005) (a detailed description of which can be found in Polacheck et al. 2003). As in Eveson et al. (2005), we included farm recaptures in the analysis presented here because there are not enough wild recaptures in recent years to allow for meaningful estimates if only wild recaptures are used. We do not expect this to bias our results because past and current investigations have found no significant differences in growth in terms of fork length between wild fish and farm fish (e.g. Figure 2).

Figure 3

Figure 3 compares the average growth rate, calculated as centimetres growth per day, between fish released in the 1990s and those released in the 2000s. Comparisons are made for fish of similar release lengths and relatively similar times at liberty—this is necessary since growth slows as fish get larger/older. We only plot points for which at least 20 observations were used in calculating the average. The updated estimates support the finding in Eveson et al. (2005) that there has been a small increase in juvenile growth rates in the 2000s relative to the 1990s. Note that this comparison pertains more to the early 1990s because no releases occurred in 1998 or 1999.

If we assume that SBT grow according to a von Bertalanffy (VB) curve, then another way of quantifying growth, which is independent of release length and time at liberty, is to calculate the VB growth rate parameter *k*. By fixing the asymptotic length parameter $L_\infty$ to be 185 cm for all fish[1], we could calculate a *k* value for each fish using its change in length and time at liberty. Figure 4 compares the average *k* values by season of release, using only fish with release lengths greater than 80 cm. The reason for excluding small fish is that we know from previous studies (Hearn and Polacheck 2003; Polacheck et al. 2003) that SBT growth is best described by a two-stage VB model in which very small/young SBT grow according to a VB model with a larger *k* value than older fish. These studies have found that the transition between growth stages occurs between ages 2 and 3, at roughly 80 cm. Thus, the *k* values for fish with release lengths greater than 80 cm should be comparable because these fish should have been in their second stage of growth for their entire time at liberty. We see from Figure 4 that average *k* values increased during the 1990s and have perhaps continued to increase slightly in the 2000s (unfortunately the data are lacking for release seasons 1998 to 2001 inclusively).

Note that for comparison, Figure 4 also shows the average *k* values calculated using all release lengths. As expected, the averages increase because they now include *k*'s for fish that experienced the early, rapid stage of growth for at least part of their time at liberty. Interestingly, however, the difference between the averages calculated with and without fish less than 80 cm is quite large for the early 1990s but becomes much smaller after 1995. While this could be explained by a greater percentage of fish having release lengths less than 80 cm in the early 1990s, this does not appear to be the case (Table 3). Instead, it suggests that growth rates during the two stages have been more similar after 1995. This would be consistent with age 3 and 4 fish growing faster in the late 1990s and early 2000s than in the early 1990s (some evidence of which was seen in Eveson et al. 2005 and in the current paper); however, this is still rather speculative at this stage.

Table 3. Proportion of releases by size category and release season for which release and recapture lengths are available.

| Release | Release Season | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| length | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 2001 | 2002 | 2003 | 2004 | 2005 |
| ≤ 80 cm | 0.63 | 0.53 | 0.55 | 0.70 | 0.71 | 0.41 | 0.45 | 0.97 | 0.80 | 0.36 | 0.48 | 0.44 |
| > 80 cm | 0.37 | 0.47 | 0.45 | 0.30 | 0.29 | 0.59 | 0.55 | 0.03 | 0.20 | 0.64 | 0.52 | 0.56 |

[1] This value was used in Eveson et al. (2005) and is based on data from the spawning grounds as well as from the growth analyses presented in Polacheck et al. (2003, 2004).

## Discussion

The updated growth estimates presented in this paper strongly suggest that growth of juvenile SBT (referring mainly to ages 2 to 4) has not declined and has more likely increased between the early 1990s and early 2000s. It would appear that this increase was greatest through the early 1990s and more moderate thereafter; however, limitations of the data make conjectures on the timing of increases fairly speculative. In particular, data from the late 1990s are lacking in both the otolith data and the tag-recapture data.

We reiterate the caution in Eveson et al. (2005) that the otolith direct aging data are only for juvenile fish caught in the GAB. If significant numbers of juvenile fish do not go into the GAB during the summer, then the growth results presented here may not pertain to the entire population. Furthermore, the recapture data corresponding to releases in the 2000s are still reasonably limited, both in numbers and in lengths of time at liberty. Growth estimates for the 2000s will become more reliable as more recaptures with longer times at liberty become available. Nevertheless, if the recent increases in growth rates are confirmed with additional data, they could have implications for the estimation of the age of the catch in the stock assessments. For example, a difference of 0.18 and 0.21 in *k*, as suggested by the results shown in Figure 4, would mean that a fish of length 80cm (~2 years old) would take ~5 years to grow to 150 cm in the 2000s compared to ~6 years in the early 1990s (i.e. an age 7 fish in the 2000s would be expected to be of a similar length to an age 8 fish from the early 1990s). While these differences are not as great as those detected between the 1960s and 1980s (Hearn and Polacheck 2003; Polacheck et al. 2004), they are still of sufficient magnitude that they could have implications for estimates of recent trends in the stock given the late age of maturity for SBT.

## References

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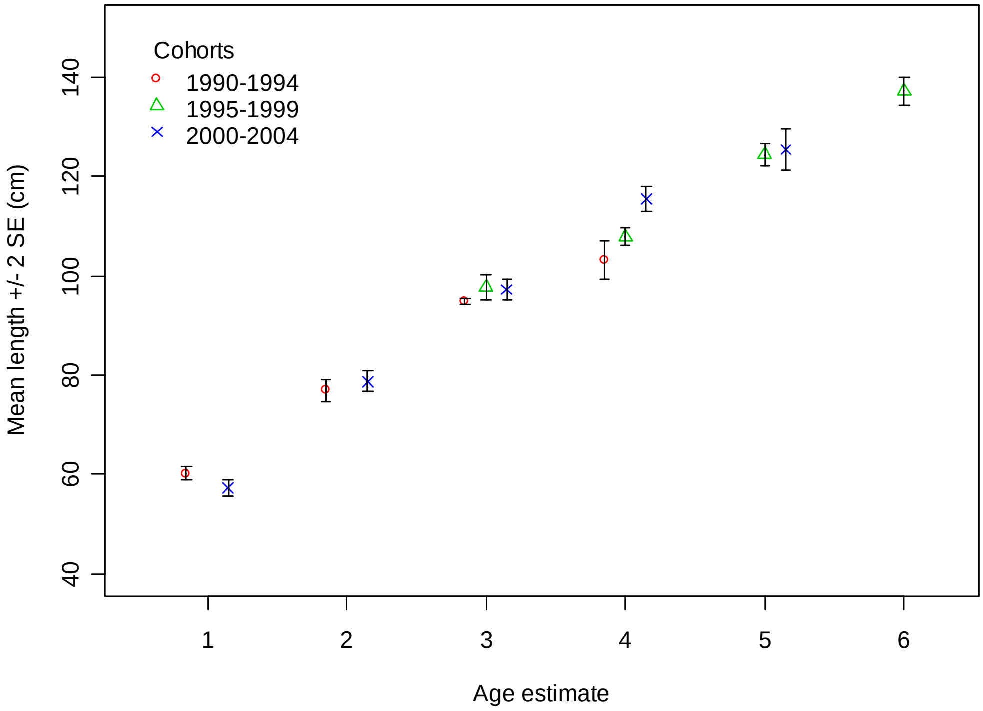
Polacheck, T. Eveson, J.P., and Laslett, G.M. 2004. Increase in growth rates of southern bluefin tuna (*Thunnus maccoyii*) over four decades:1960 to 2000. Can. J. Fish. Aquat. Sci. 61: 307-322.

Figure 1. Mean fork length (cm) ± 2 standard errors versus age estimate from otoliths, broken down by: a) cohort (aggregated according to early 1990s, late 1990s and early 2000s); b) catch season. Only otolith data from fish caught in the Great Australian Bight are included. Means consisting of less than 5 observations are not shown.

a)




b)

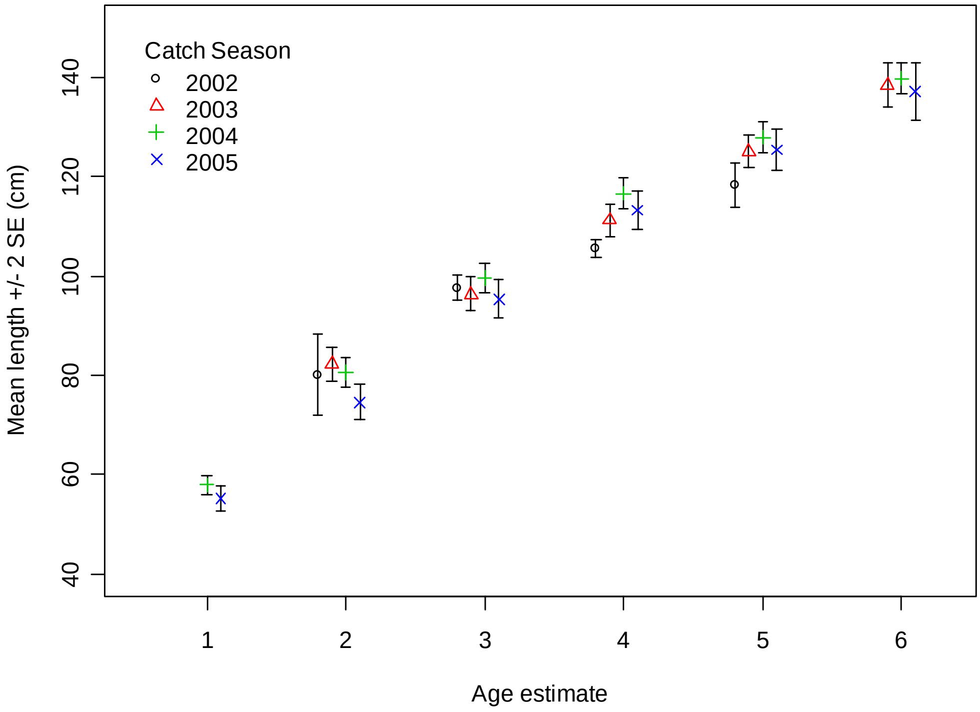


Figure 2. Mean growth rate of recaptured fish (calculated as centimetres growth per day at liberty) versus release length broken down by source of recapture (farm versus wild). Fish at liberty for similar time periods are plotted separately to make growth rates more comparable. Only points with data from at least 20 fish are included in the figure.

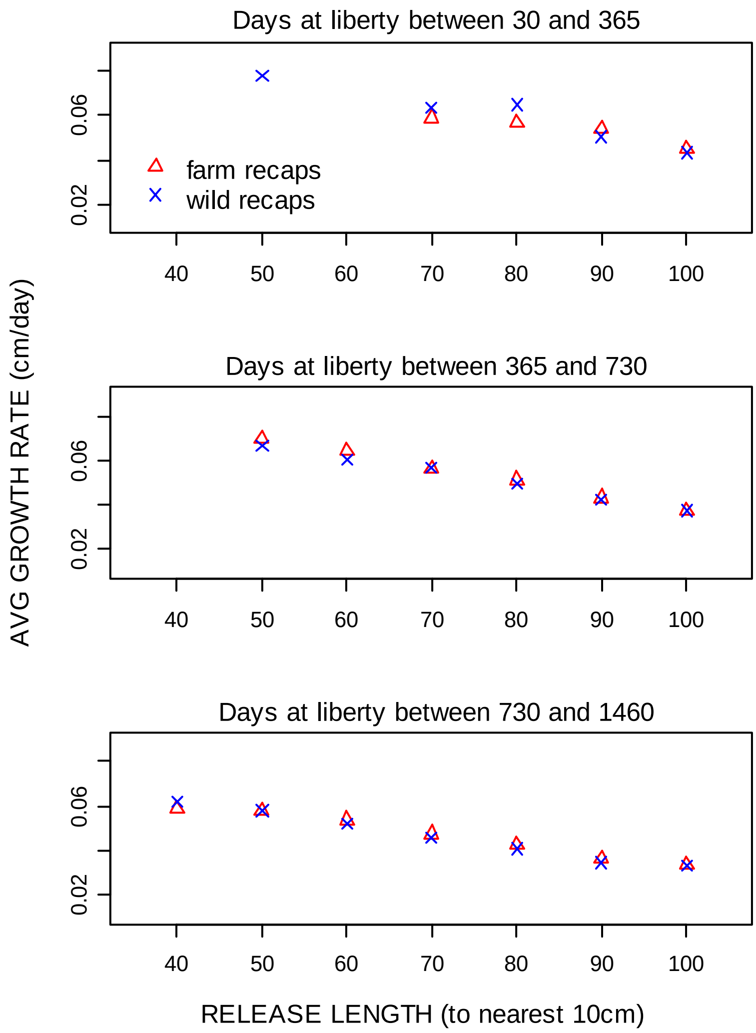


Figure 3. Mean growth rate of recaptured fish (calculated as centimetres growth per day at liberty) versus release length broken down by decade of release (1990s versus 2000s). Fish at liberty for similar time periods are plotted separately to make growth rates more comparable. Only points with data from at least 20 fish are included in the figure.

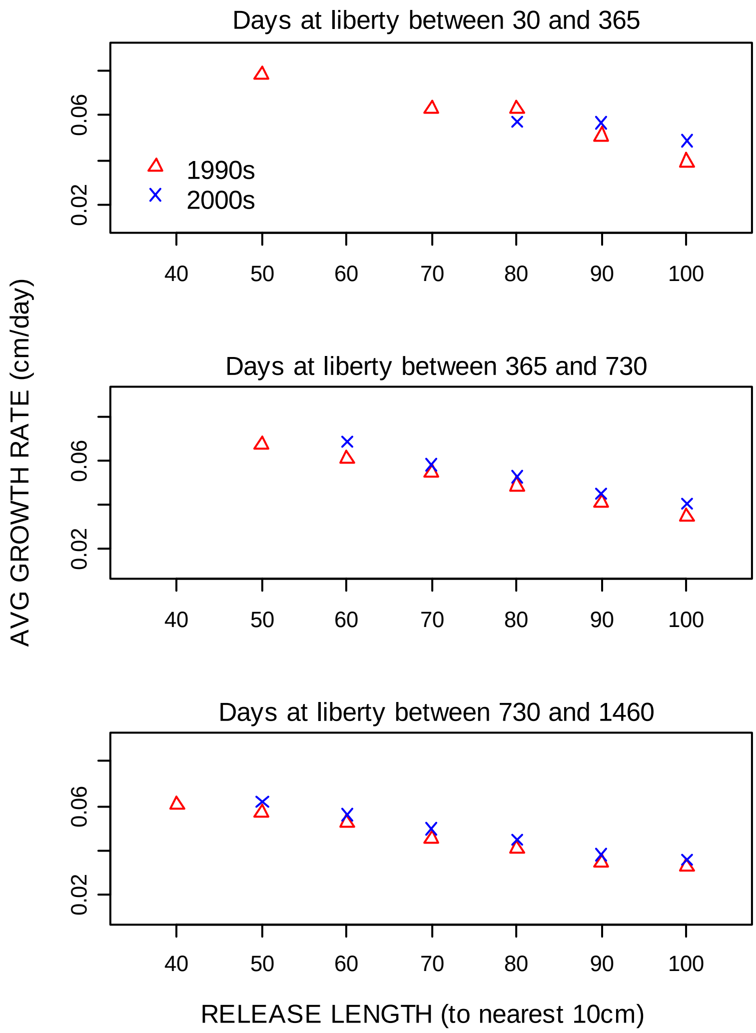


Figure 4. Mean von Bertalanffy growth rate parameter (*k*) for recaptured fish (calculated assuming $L_\infty$ = 185 cm) versus release season. Only fish at liberty for over 30 days are included in the averages, and only averages calculated using more than 5 observations are shown.