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# Updated estimates of growth rates for juvenile SBT using tag-recapture and otolith direct ageing data up to 2005

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## Abstract

The most recent analysis of growth for southern bluefin tuna (SBT) was conducted in 2001-2002, integrating growth information from three data sources to provide comprehensive estimates of mean length-at-age (as well as variance in length-at-age) for each of the past four decades (1960s, 1970s, 1980s and 1990s). Since then, additional data pertaining to growth of juvenile SBT during the late 1990s and early 2000s has been collected from tag-recapture studies and from otolith sampling in the Australian surface fishery. Preliminary analyses of these data have been conducted and suggest that growth of juveniles has remained similar in recent years as it was in the early 1990s, and if anything has perhaps increased marginally.


## Introduction

The last comprehensive analysis of growth for southern bluefin tuna (SBT) was conducted in 2001-2002 (Polacheck et al. 2003). The analysis incorporated growth information from the following three sources:

1. Release length, recapture length and time at liberty data from conventional tagging experiments conducted since the early 1960s. The last year of tag releases available for analysis was 1997 as part of Recruitment Monitoring Program (RMP), and the last year of recaptures was 2001.
2. Historic length-frequency data from the Australian surface fishery. No length-frequency data were included after 1989 due to selectivity issues arising from changes in the nature of the fishery.
3. Otolith direct ageing data from samples collected in various components of the fishery from the late 1980s to 1998, and in the Indonesian spawning ground fishery from 1998 to 2000.

The results of this study confirmed previous findings that cohorts from the 1980s grew substantially faster at young ages than cohorts from the 1960s.The results also suggested that the 1970s was a period of transition, and that growth of fish up to about age four was faster in the 1990s than in the 1980s. However, the data available for cohorts born in the 1990s were limited, so conclusions about the 1990s were uncertain. Since the time of the Polacheck et al. (2003) analysis, additional information pertaining to the growth of juvenile SBT in the 1990s and early 2000s has been accumulated, namely:

1. Additional release and recapture length and time at liberty data from
   - recaptures occurring in 2001 to present corresponding to tags released in previous tagging experiments up to 1997, as referred to above;
   - recaptures occurring in 2001 to present corresponding to tags released as part of the RMP in years 2001 and 2002, plus a few opportunistic releases in 2004.
   - recaptures occurring in 2002 to present corresponding to tags released as part of the CCSBT Scientific Research Program (SRP) in 2002 to present.
2. Otolith direct ageing data from juveniles caught in the Australian surface fishery in seasons 2002 to 2004.

In this paper we describe these new data and present preliminary results on growth from their analysis.

## Methods and Results

### *Otolith direct ageing data*

Otoliths for age determination were selected from samples collected from SBT caught in the Australian surface fishery in the GAB in the 2002, 2003 and 2004 fishing seasons. These otoliths were then sent to the Central Ageing Facility (CAF) in Victoria for age estimation. Details of the otolith sampling, the selection of otoliths for ageing, and the age estimation procedure are given in Basson et al. (2005). A summary of the sample sizes and age estimates per season are given in Table 1.

Table 1. Summary of direct ageing data from otoliths collected in the Australian surface fishery in seasons 2002 to 2004.

| Season | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Total |
|---|---|---|---|---|---|---|---|---|---|
| 2002 | 0 | 7 | 42 | 53 | 16 | 4 | 2 | 0 | 124 |
| 2003 | 2 | 10 | 34 | 34 | 25 | 10 | 3 | 4 | 122 |
| 2004 | 28 | 35 | 35 | 36 | 22 | 13 | 2 | 0 | 171 |
| Total | 30 | 52 | 111 | 123 | 63 | 27 | 7 | 4 | 417 |

To investigate whether juvenile growth has changed over time, we group fish according the decade in which they were born, and then compare the length at age data for fish born in different decades. For the data in Table 1, birth years (i.e. seasons) range from 1995 to 2003; thus, we group fish born between 1995 and 1999 inclusive, and fish born between 2000 and 2003 inclusive. We compare these data with length at age data from previous otolith studies for fish born in the 1980s and 1990s (i.e., the data used in the growth study of Polacheck et al. 2003). All of the new data are from otoliths collected in the South Australian surface fishery; therefore, we only include data from otoliths collected in South Australia from the previous data as well in order for them to be comparable[1]. Also, the previous 1990s data set only contains fish born between 1990 and 1994. We chose not to group the old 1990s data with the new 1990s data, but rather to leave it separated so that we can compare early 1990s with late 1990s growth (and also check for any systematic differences in the two data sets that may suggest differences in factors other than growth, such as sampling procedures, ageing methods, etc).

Figure 1 compares the length at age data from the 1980s, early 1990s, late 1990s, and (early) 2000s. The distribution of lengths at age appear similar at ages 1 and 2 in all time periods; however, there is some suggestion that lengths have increased at ages 3 and 4 from the 1980s to present. Using simple two-sided t-tests with a significance level of 0.02, we found that there was a statistically significant change in the mean length at age between the 1980s and early 1990s and between the early and late 1990s for fish of age 3 (but not between the late 1990s and 2000s), and between the late 1990s and 2000s for fish of age 4 (data are

[1] In the previous direct ageing data we found that one-year old fish caught off of Western Australia are approximately 10 cm smaller on average than the one-year old fish caught in the Great Australian Bight during the same month; the historic length-frequency and tag-recapture data also support this finding (Polacheck et al. 2003). This is most likely due to differences in spawning times (with the WA fish having been spawned later in the season and thus being younger). The difference appears to be negligible by age 2.

insufficient to make any other meaningful comparisons at age 4). We did not find any significant differences (at level 0.02) at ages 1 and 2.

### *Tag-recapture data*

The change in fork length of a fish between the time it was released and the time it was recaptured provides information about individual growth that can be used collectively to model the growth of the population. We compare data from recent conventional tagging studies with data from past studies to investigate whether growth rates of SBT have changed in recent years. The data we consider are all tag releases since 1990 (i.e., all RMP and SRP releases), and the corresponding recaptures up to May 2005. As with the otolith data, we group fish into decades (either 1990s or 2000s), but this time according to release year instead of birth year. Because the majority of SBT are tagged between the ages of 1 and 3, this is similar to using birth year, but does not require us knowing or estimating the age of an individual at release.

Prior to analysing the data we applied the same screening process as in Polacheck et al. (2003), with one exception. There were 2855 farm recaptures and 3323 wild recaptures corresponding to the 1990s' releases; whereas there were 1971 farm recaptures and only 101 wild recaptures corresponding to the 2000s' releases. Past and current investigations have found no difference in growth in terms of fork length between wild fish and farm fish; however, in previous growth analyses we took the cautious approach and excluded farm recaptured fish. There were sufficient wild recaptures for the 1990s' releases that this was not a problem. For the 2000s' releases, the wild recaptures are far fewer and analyses based only on these data would be highly uncertain. Thus, we have chosen to include the farm recaptures in the data summaries and analyses presented in this paper.

Before fitting growth models to the data, we did some exploratory data analyses. Figure 2 shows the distribution of release lengths broken down by decade of release: a) using releases corresponding to recaptured fish only; b) using all releases. Interestingly, the distributions are very similar for the 1990s, but for the 2000s the recaptured fish do not appear to be representative of the released fish. In particular, there is an absence of small releases (<60 cm) and a disproportionately large number of large releases (>85 cm) in the recaptured fish.

Figure 3 shows the average growth rate, calculated as centimetres growth per day at liberty, for fish of similar lengths and relatively similar times at liberty. This figure is analogous to Figure 2 in Appendix 3 of Polacheck et al. (2003), except we have updated the 1990s points to include new data and we have added points for the 2000s. Also, we only show points for which at least 20 observations were used to calculate the average growth rate. As previously documented, average growth rates increased between the 1960s and 1980s; the updated data suggest that average growth rates have remained quite similar in the 1990s and 2000s as in the 1980s, although there has perhaps been a small increase in the 2000s relative to the 1990s.

We fit a seasonal von Bertalanffy growth curve with a logistic growth rate parameter $k$ (VB log $k$) to the 1990s and 2000s tag-recapture data. Details of the model and its parameters can be found in Appendix 9 of Polacheck et al. (2003), and details of the estimation method used to fit the model is given in Appendices 4 and 9 of Polacheck et al. (2003). The estimated parameter values are given in Table 2. Note that there is no information available in these data sets on old fish that are approaching their maximum length, so we fixed the asymptotic length parameter to be 185 cm (this value is based on data from the spawning grounds as well as previous growth analyses). Results in Polacheck et al. (2003) found that the asymptotic length parameter was similar for fish in the 1970-1990s.

Table 2. Parameter estimates from fitting the seasonal VB log k growth model to the southern bluefin tuna tagging data from the 1990s and 2000s. [2]

| | $\mu_\infty$ | $\sigma_\infty$ | $k_1$ | $k_2$ | $\alpha$ | $\beta$ | $u$ | $w$ | $\mu_{\log A}$ | $\sigma_{\log A}$ | $\sigma_s$ | $\sigma_f$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990s | 185 | 9.22 | 0.26 | 0.16 | 2.41 | 13.01 | 0.43 | 0.27 | 0.69 | 0.31 | 2.08 | 2.11 |
| 2000s | 185 | 12.24 | 0.72 | 0.15 | 0.87 | 6.39 | 1.00 | 0.38 | 0.10 | 0.22 | -- | 2.55 |

The fitted curves are compared in Figure 4, using the assumption that the mean length for an age 2 fish is 79 cm in both decades[3]. The curves are only plotted over the range for which there are data.

The model results suggest that fish between ages 2 and 5 are slightly larger on average in the 2000s than in the 1990s. Furthermore, the results for the 2000s suggest that growth of small/young fish (less than 80 cm/ age 2) was very rapid; however, it is important to keep in mind that there is not much information on such small/young fish in the 2000s tag-recapture data. The model also estimates a strong seasonal component to growth in the 2000s, with growth being very rapid during the summer months and almost zero during the winter.

## Discussion

Preliminary analyses of the most recent growth data suggest that growth of juvenile SBT is similar in the 2000s as in the 1990s, although it has perhaps increased marginally. In particular, there is some evidence in the direct ageing data as well as in the tag-recapture data that the average length-at-age of fish aged 2 to 4 is slightly greater in the 2000s than in the 1990s.

Limitations in the data for the 2000s should, however, be recognized. Otolith direct ageing data are only available for juvenile fish caught in the Great Australian Bight in seasons 2002 to 2004. Although a large number of tags have been releases as part of the SRP in seasons 2002 to present, the times at liberty for fish that have been recaptured to date are obviously relatively short. As more recapture data with longer times at liberty become available, estimates of growth for the 2000s will be much improved.

It is also worth noting that the most recent data on growth for the 1990s is consistent with the previous data used in the Polacheck et al. (2003) analysis. For example, the fitted VB log *k* growth curve for the 1990s presented in this paper is almost identical to the fitted curve for the 1990s presented in Appendix 10 of Polacheck et al. (2003).

[2] Note that the measurement error component of the model is estimated separately for scientist- versus fishermen-measured fish for the 1990s but not for the 2000s because of insufficient scientist-measured recapture lengths in the latter data set.

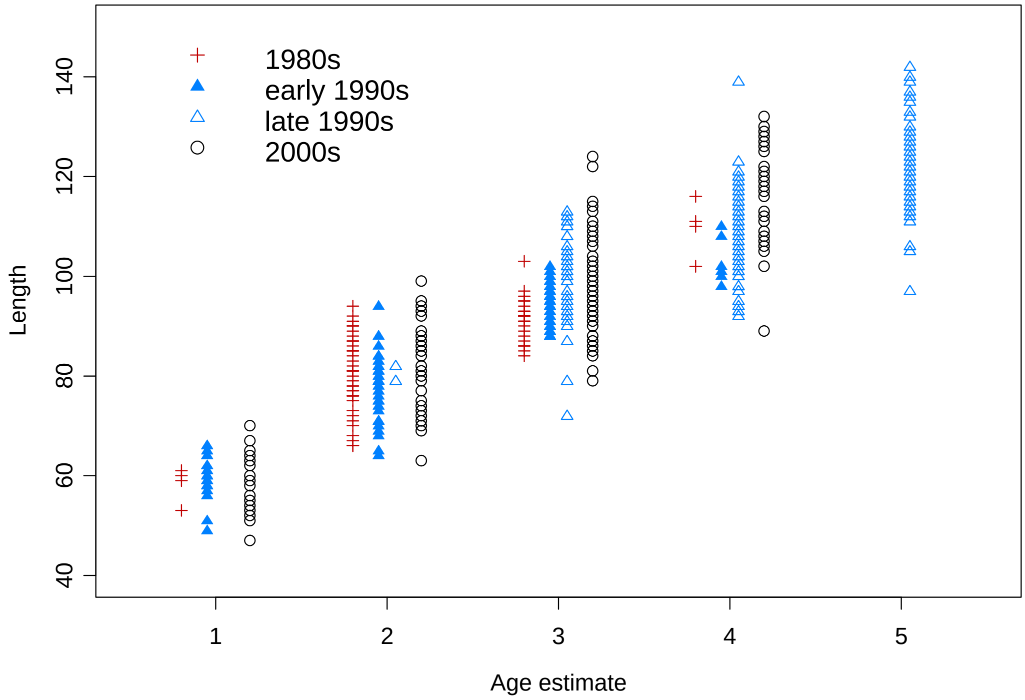
[3] One of the problems with using tag-recapture data for modelling growth is that information is available on change in length over time, not on actual length at age. In order to achieve the latter, we must fix the length of a fish at a particular age. We calculated the average release length for all fish released in the 1990s and 2000s, respectively, that were estimated to be age 2, where age was estimated from length using the method currently used by the CCSBT, and we found it to be 79 cm in both decades.

## References

Basson, M., Peel, S., and Farley, J. 2005. Estimates of proportions at age in the Australian surface fishery catch from otolith ageing and size frequency data. CCSBT-SC/0509/19.

Polacheck, T., Laslett, G.M., and Eveson, J.P. 2003. An integrated analysis of the growth rates of southern bluefin tuna for use in estimating the catch at age matrix in the stock assessment. Final Report. FRDC Project 1999/104. ISBN 1 876996 38 2.

Figure 1. Fork length (cm) versus age, as estimated from otoliths, for fish born in different time periods. The top graph shows the raw length data; the bottom graph shows the mean length ± one standard deviation. Only data from fish caught in the Great Australian Bight are included.



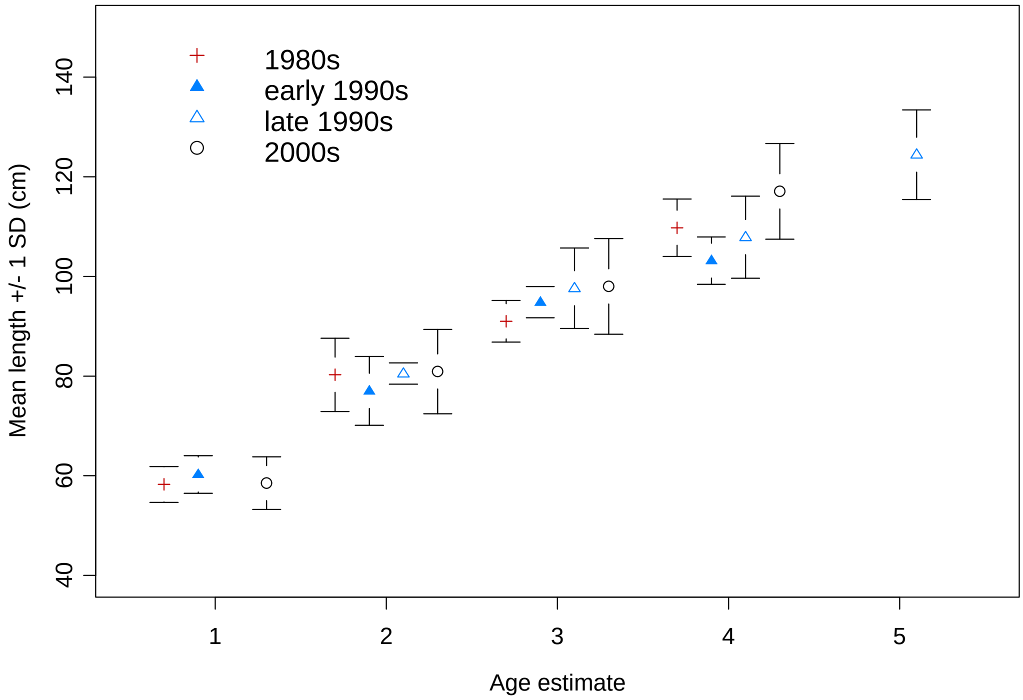
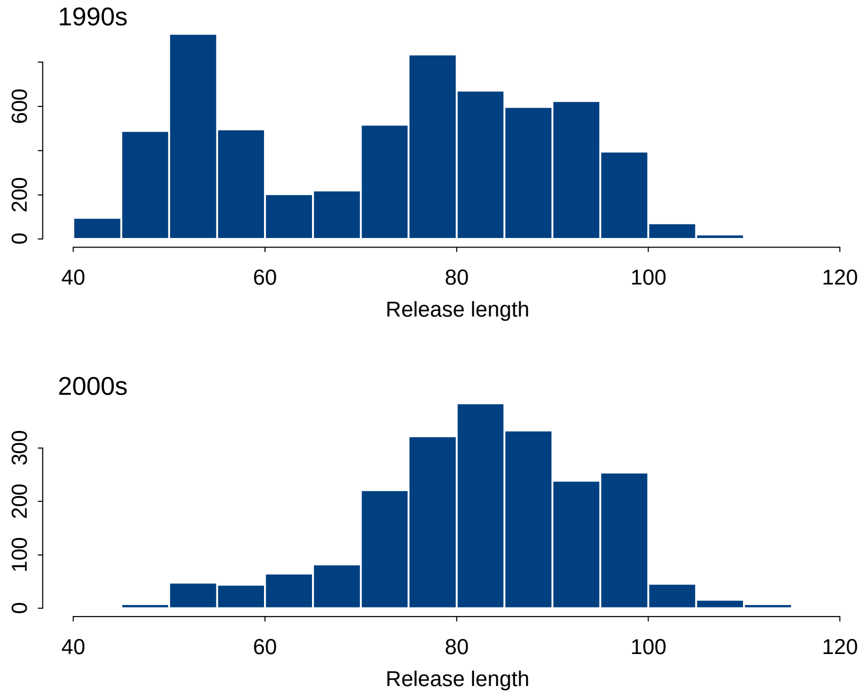



Figure 2. Histograms of release lengths broken down by decade of release for a) for releases corresponding only to recaptured fish; b) for all releases.

a)




b)

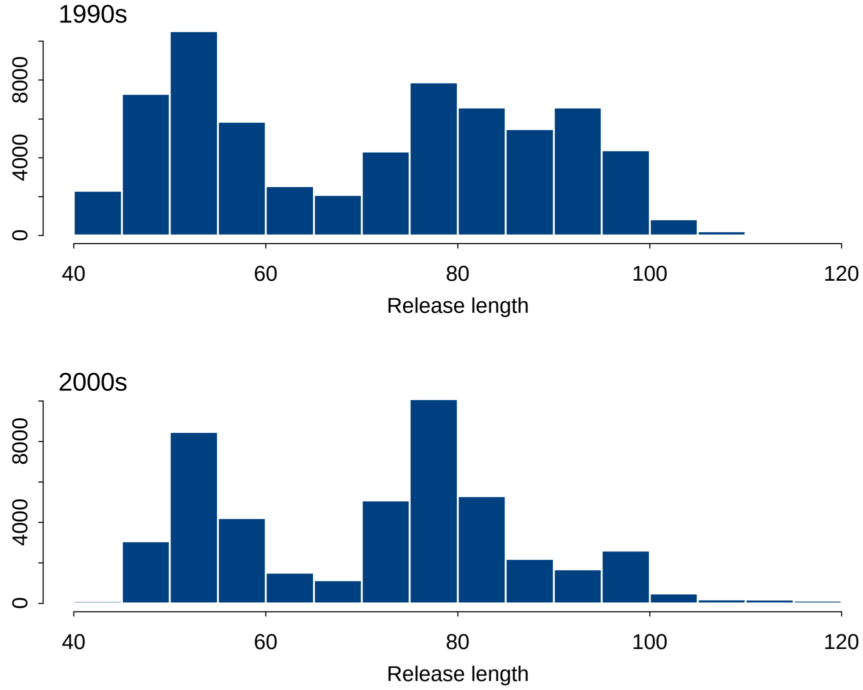


Figure 3. Mean growth rate of recaptured fish (calculated as centimetres growth per day at liberty) versus release length. Fish at liberty for similar time periods are plotted separately to make growth rates more comparable. Only points with data from at least 20 fish are included in the figure.

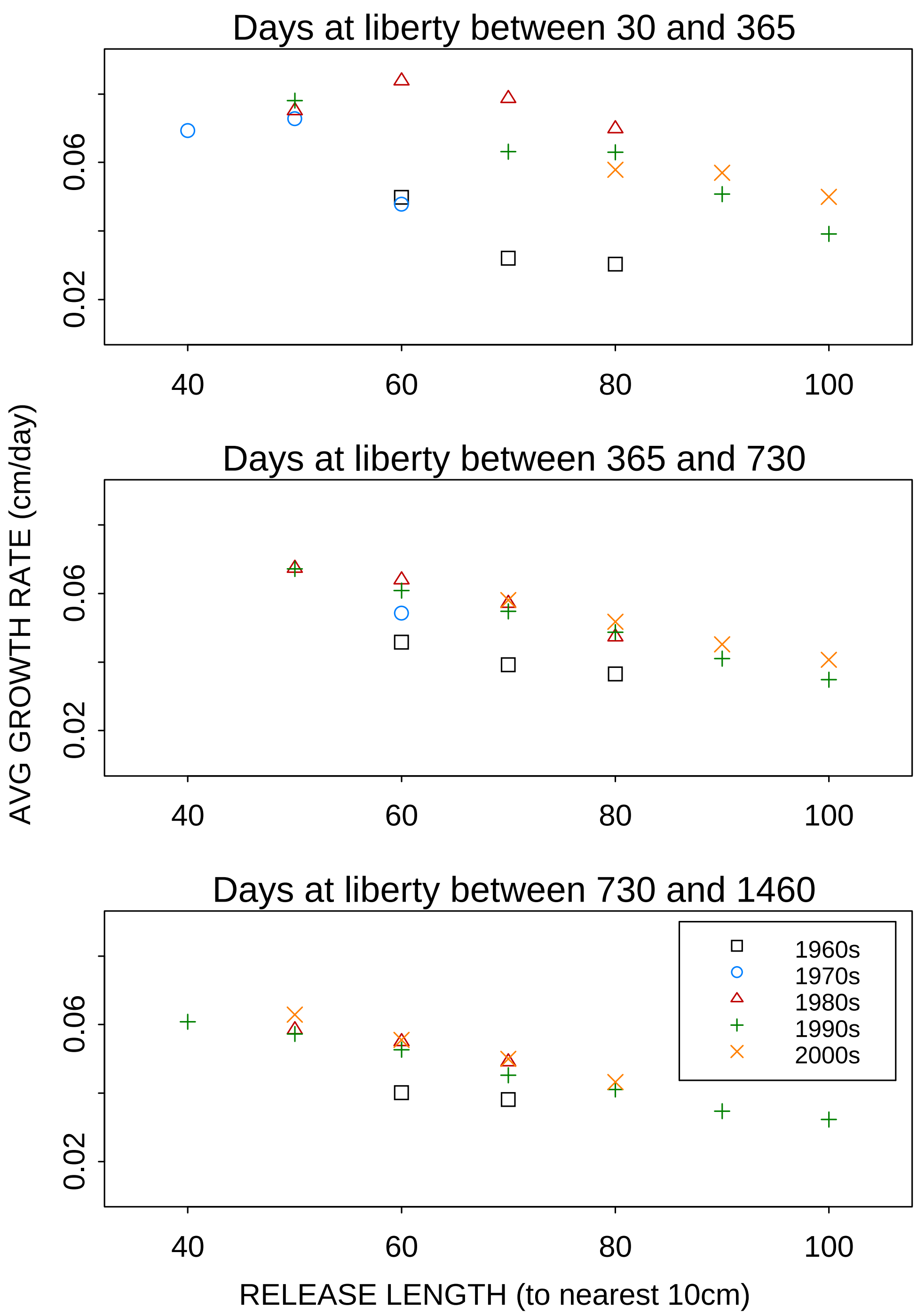


Figure 4. Fitted VB log *k* growth curves for the 1990s and 2000s tag-recapture data with asymptotic length parameter fixed at 185cm in both curves (based on data from the spawning grounds and previous analyses). Both curves are plotted using the assumption that age 2 fish have length 79cm, and they are only plotted over the range for which there are data.