Updated growth estimates for the 1990s and 2000s, and new age-length cut-points for the operating model and management procedures

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Abstract

A comprehensive analysis of growth for southern bluefin tuna (SBT) was conducted in 2001-02, integrating growth information from tagging data, length-frequency data and direct ageing data to provide estimates of mean length-at-age for each of four decades (1960s, 1970s, 1980s and 1990s) (Polacheck et al. 2003). The results showed that SBT growth increased over that time period. Since then, additional tagging data and direct ageing data pertaining to growth of SBT cohorts from the late 1990s and 2000s has been collected. Here we report on updated growth estimates for the 1990s, and preliminary estimates for the 2000s, using all data available at that time of analysis. The growth estimates for the 2000s are preliminary due to the lack of information on fish older than age 7, however, thus far they suggest growth has remained similar to that of fish born in the 1990s.

The growth estimates for the 1960s, 1970s and 1980s presented in Appendix 10 of Polacheck et al. (2003), and the updated growth estimates for the 1990s given in this report, have been used to calculate age-length cut-points. It was agreed at the 2010 CCSBT SC meeting that all of the historical length/size data would be re-aged using this new set of cut-points (referred to as "VBLK2010"), which replaces the previous cut-points agreed upon in 2001 ("SC2001").

Introduction

A comprehensive analysis of growth for southern bluefin tuna (SBT) was conducted in 2001-02 (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 the 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.

These data were used to estimate growth rates of SBT for each of the four decades from 1960 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 SBT cohorts from the 1990s and 2000s has been accumulated. The following additional data were available as of February 2010, when the analyses for the current report were conducted:

1. Release length, recapture length and time at liberty data from recaptures corresponding to:
    - conventional tags released as part of the RMP in 1990-1997 and 2001-2002, as well as a few opportunistic releases in 2003-2006;
    - conventional tags released as part of the CCSBT Scientific Research Program (SRP) in 2002-2007.
2. Otolith direct ageing data from:
    - juveniles caught in the Australian surface fishery in seasons 2002-2008;
    - adults caught on the Indonesian spawning grounds in 2001-2008.

In this paper we fit the growth models described in Polacheck et al. (2003) to the updated data for SBT to obtain updated estimates of growth for cohorts born in the 1990s, as well as preliminary estimates of growth for cohorts born in the 2000s.

Also, it was agreed at the 2010 CCSBT SC meeting that all of the historical length/size data would be re-aged using a new set of age-length cut-points. Here we document how the new cut-points, referred to as “VBLK2010”, were calculated. They replace the previous cut-points agreed upon in 2001, referred to as “SC2001”.

Methods

The VB log *k* growth model described in Appendix 4 of Polacheck et al. (2003) was fitted to growth data for SBT born in the 1990s and 2000s, respectively. SBT growth does not appear to follow the commonly used von Bertalanffy (VB) growth model; instead there appears to be a change in the growth process during the transitional period from juveniles to sub-adults. The VB log *k* model was developed to accommodate such a transition in growth.

The VB log *k* model uses six parameters to describe length, *l*, as a function of age, *a*:

(1)
$$l(a) = L_\infty \left[1 - e^{-k_2(a-a_0)} \left\{ \frac{1+e^{-\beta(a-a_0-\alpha)}}{1+e^{\alpha\beta}} \right\}^{-(k_2-k_1)/\beta} \right]$$

where a_0 is the theoretical age when a fish would have length zero; L_∞ is the asymptotic length; k_1 is the growth rate parameter for the first stage of growth; k_2 is the growth rate parameter for the second stage of growth; β is a parameter governing the rate of transition between k_1 and k_2; and α is a parameter determining the central age of transition. As age increases, this function makes a smooth transition (according to a logistic function) from a VB curve with growth rate parameter k_1 to a VB curve with growth rate parameter k_2. If k_1 equals k_2, the model reduces to the standard VB curve.

In addition to this basic model, a seasonal component was included in the model to reflect the fact that SBT growth, particularly as juveniles, appears to be substantially greater during the austral summer months than during the winter. Seasonality in growth can be modelled by replacing $a-a_0$ with $a-a_0+S(t)$ in (1), where $S(t)$ is an annually periodic function and t is the fractional time of year since January 1. We chose to model within-year growth with a sinusoidal function:

(2) $$S(t)=\frac{u}{2\pi}\sin\left(2\pi(t-w)\right)$$

where u is the amplitude and w controls the phase shift. Both parameters were estimated in the growth model, with u constrained to be between 0 and 1 to prevent negative growth and w constrained to be between –0.5 and 0.5 (any bounds with a span of one could have been chosen due to the periodicity of the function). In this formulation, the rate of growth is maximal at $t=w$ and diminishes symmetrically about w to a minimum at $t=w-0.5$ and $t=w+0.5$.

The direct ageing data used in fitting the 1990s and 2000s growth curves is summarized in Table 1 and Figure 1. The same screening criteria described in Appendix 3 of the Polacheck et al. (2003) were applied to the direct ageing data, with the exception that we include data from fish aged 12 and older caught on the spawning grounds, as opposed to aged 14 and older[1]. The only direct ageing data that pertains to cohorts from the 2000s comes from otoliths collected in the farms in the Great Australian Bight (GAB). Although otoliths have been collected from Indonesia in the 2000s, they are from adult fish that were born in previous decades.

The tag-recapture data used in fitting each of the growth curves is summarized in Table 2 and Figure 2. The same screening criteria described in Appendix 3 of the Polacheck et al. (2003) were applied to the tagging data, except that we included data from farm-recaptured fish. Even though there is no evidence that growth in terms of length differs between farm and wild recaptures, there were enough wild recaptures for the 1990s that Polacheck et al. (2003) erred on the side of caution and excluded farm fish. However, for the 2000s, there are not enough wild recaptures to give reliable estimates, so here we opted to include the farm fish in both decades to be consistent. We fit the VB log k growth model for the 1990s with and without the farm data and found that it made very little difference to the results.

Maximum likelihood methods were used to fit the growth model jointly to both sets of data. There is a likelihood component for the tag-recapture data and one for the direct age and length data, details of which can be found in Appendices 4 and 9 of Polacheck et al. (2003) (see also Laslett et al. 2002 and Eveson et al. 2004). Individual variability in growth is allowed for by modelling L_∞ as a random normal variable with mean μ_∞

[1] Farley et al. (2001) found evidence that the average size of fish below age 14 on the spawning ground is larger than the average size of fish of the same age found off the spawning ground (since larger fish mature earlier). Thus, in Polacheck et al. (2003), we only included fish of ages 14 and above caught on the spawning ground in order not to bias the growth results. However, we re-investigated the direct ageing data prior to fitting the updated growth models, and found that this size bias appears to disappear by age 12; thus, we chose to include fish of ages 12 and above in our analysis here.

and standard deviation σ_∞. In total, there are 14 parameters to be estimated, namely 6 parameters defining the mean VB log *k* growth curve (μ_∞, k_1, k_2, α, β, a_0), 2 parameters defining the seasonal component of growth (u, w), 2 parameters for the tag-recapture component defining the lognormal distribution used to model the unknown ages at release ($\mu_{\log A}$, $\sigma_{\log A}$), the variance parameter for asymptotic length (σ_∞^2), and 3 measurement error parameters (σ_s^2: the error variance for the tagging data when lengths were measured by scientists, which applies to all release lengths and some recapture lengths; σ_f^2: additional error variance for the tagging data when recapture lengths were measured by fishers; σ_γ^2: the error variance for the direct aging data).

Results and Discussion

Growth estimates

Parameter estimates from fitting the VB log *k* growth model to the updated 1990s data are given in Table 3. They are very similar to the previous estimates reported in Polacheck et al. (2003), which are also given in Table 3 for comparison. The addition of direct ageing data for older fish caught on the spawning grounds has led to a slightly smaller estimate in mean asymptotic length. Figure 3 shows the estimated mean growth curve overlaying the data. To plot the tagging data, we required an estimate of the age at release for each fish. We used the approximately conditionally unbiased estimators, $\tilde{A}_f$, described in Laslett et al. (2004).

Fitting the VB log *k* growth model to the 2000s data was problematic since the data are not sufficient to get reliable estimates of all parameters. For instance, there are no data on fish older than age 7, so we fixed the mean asymptotic length parameter μ_∞ at 181.5 cm (the estimate for the 1990s). The data does not contain much information on seasonal growth[2] either, and unrealistic estimates were obtained when the seasonal parameters were estimated freely (i.e., fastest growth was estimated to be in winter, simply because we have almost no data in the winter months). Thus, we also fixed the timing of fastest growth to be February 1st (i.e., w=0.16), but still allowed the "strength" of the seasonality to be estimated (i.e., u was estimated). Furthermore, the parameter β controls the speed at which the transition between the juvenile and sub-adult growth phases occurs. We have done simulations that show this parameter is poorly estimated (Laslett et al. 2002). To help achieve convergence for the 2000s, we fixed β at 30, which means an almost instant transition between the two growth phases, since this is the value estimated for the 1990s and most previous decades (see Table 4). The parameter estimates obtained based on the above constraints are given in Table 3, and the estimated mean growth curve is shown in Figure 4.

[2] Length-frequency data were only included in the growth models for the 1960s, 1970s and 1980s. These data are the most informative on within season growth (see Appendices 7 and 10 of Polacheck et al. 2003). The tag-recapture data contains some information; however, most recaptures in the 2000s came from the few months of the year when the farm fish are culled, so information in growth throughout the year is lacking.

Given the absence of data on mature fish, and the necessity to fix many of the model parameters, the results for the 2000s are considered very preliminary. However, based on these preliminary results, growth of fish born in the 2000s appears similar to growth of fish born in the 1990s.

Age-length cut-points

New age-length cut-points for ageing the historical length/size data were calculated using the decade-specific growth curves given in Table 4. The values for the 1960s, 1970s and 1980s were taken from Table 2 of Appendix 10 of Polacheck et al. (2003) (also Table 2 of Polacheck et al. 2004). The values for the 1990s were taken from the updated estimates provided in Table 3 of this report. We assumed that growth in the 1950s was the same as for the 1960s, and that growth in the 2000s was the same as growth in the 1990s (once more data are available for the 2000s on older fish, it should be possible to use a growth curve estimated specifically for the 2000s).

We use the decadal growth curves to calculate the expected length of a fish from each age class on July 1st of each year; this gives the lower and upper length cut-points for estimating the age of a fish caught on January 1st based on its length (i.e., the lower cut-points are the predicted lengths at age 6 months earlier). The cut-points get adjusted for fish caught later in the year using linear interpolation. The appropriate growth curve to use to calculate the cut-points depends on cohort not year, so when calculating the expected length of a 10-year-old fish on 1 July 1985, the appropriate growth curve to use is the one for the 1970s since this fish belongs to the 1975 cohort. Where cut-points change from one decadal growth curve to the next (i.e. cohorts starting in 1971, 1981, 1991), we smoothed the transition over two years using linear interpolation. This makes the difference between upper and lower cut-points for each age class more even during the transition times.

The new cut-points are provided in Appendix A.

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Table 1. Number of direct age estimates used in estimating growth for the 1990s and 2000s, broken down by area of otolith collection. The numbers for a particular decade correspond to fish born in that decade.

Area	1990s	2000s
GAB	422	575
Tasmania	1	0
WA	86	0
South Africa	0	0
SE Indian Ocean	25	0
New Zealand	7	0
Indonesia	1115	0
Total	1656	575

Table 2. Number of wild and farm recaptures used in estimating growth for the 1990s and 2000s. The numbers for a particular decade correspond to fish tagged in that decade.

Place of recapture	1990s	2000s
Farm	2854	6915
Wild	3276	584
Total	6130	7499

Table 3: Maximum likelihood parameter estimates from fitting the integrated VB log *k* growth model with a seasonal component to the most recent data from the 1990s and 2000s. The previous estimates for the 1990s as reported in Polacheck et al. (2003) are given for comparison (1990s – old).

Decade	μ_∞	σ_∞	k_1	k_2	α	β	a_0	u	w	$\mu_{\log A}$	$\sigma_{\log A}$	σ_s	σ_f	σ_γ
1990s – old	184.9	8.7	0.25	0.16	2.5	12.4	-0.31	0.41	0.26	0.72	0.32	1.81	3.36	5.57
1990s	181.5	8.6	0.26	0.17	2.5	30.0*	-0.30	0.39	0.28	0.71	0.31	2.26	2.14	5.25
2000s	181.5^	9.8	0.24	0.17	3.5	30.0^	-0.46	0.14	0.16^	0.88	0.18	3.60	0.10*	7.63

* Estimate is equal to the upper or lower bound set for this parameter.

^ Parameter was fixed at this value.

Table 3: Parameters of the decade-specific VB log *k* growth models used to calculate the new age-length cut-points (referred to as VBLK2010). Note that 1950s growth is assumed to be the same as 1960s growth, and 2000s growth is assumed to be the same as 1990s growth. (σ_ε is the measurement error variance for the length-frequency component of the model, which is not included in the 1990s and 2000s growth models)

Decade	μ_∞	σ_∞	k_1	k_2	α	β	a_0	u	w	$\mu_{\log A}$	$\sigma_{\log A}$	σ_s	σ_f	σ_γ	σ_ε
1950s	187.8	7.0	0.14	0.15	5.5	30.0*	0.53	-0.07	1.19	0.16	2.40	1.49	-1.57	5.87	2.01
1960s	187.8	7.0	0.14	0.15	5.5	30.0*	0.53	-0.07	1.19	0.16	2.40	1.49	-1.57	5.87	2.01
1970s	184.3	7.9	0.15	0.19	5.7	30.0*	0.92	0.06	0.77	0.12	2.05	3.06	-1.28	0.00*	3.54
1980s	184.7	8.1	0.22	0.17	2.8	18.3	0.34	0.13	0.58	0.17	2.08	2.61	-0.43	4.57	4.30
1990s	181.5	8.6	0.26	0.17	2.5	30.0*	0.39	0.28	0.71	0.31	2.26	2.14	-0.30	5.25	–
2000s	181.5	8.6	0.26	0.17	2.5	30.0*	0.39	0.28	0.71	0.31	2.26	2.14	-0.30	5.25	–

* Estimate is equal to the upper or lower bound set for this parameter.

Figure 1. Otolith direct age and length data for fish born in the 1990s and 2000s. Only data used in fitting the growth models are included.

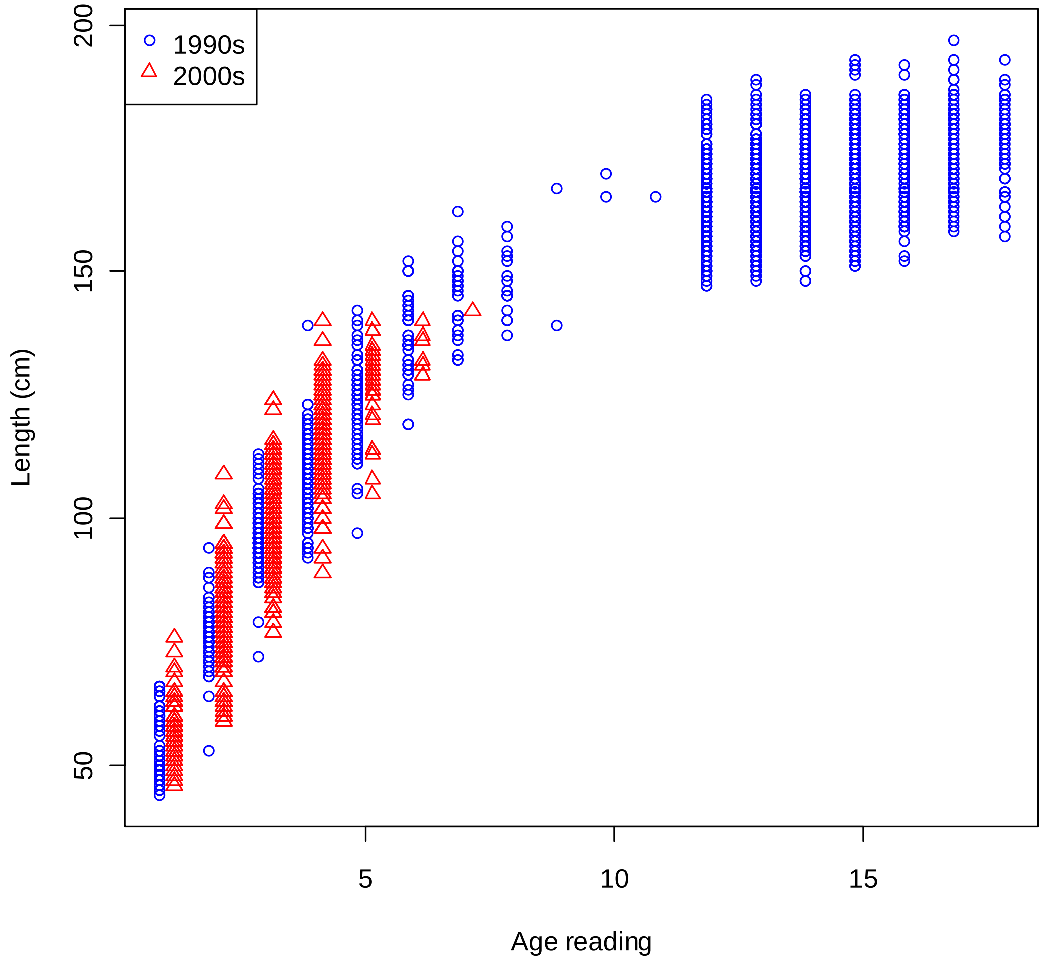


Figure 2. Change in length between release and recapture versus time at liberty for fish tagged in the 1990s and 2000s. Only data used in fitting the growth models is included.

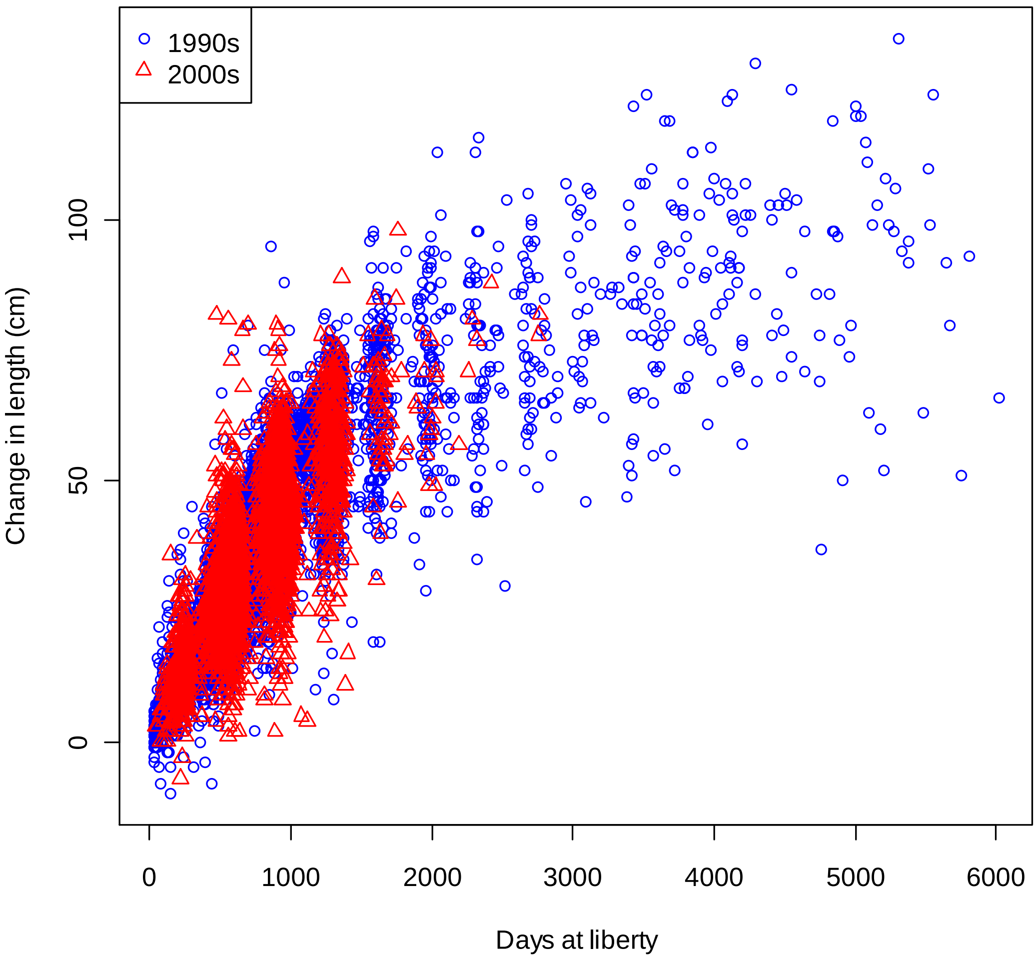


Figure 3. Mean growth curve estimated for the 1990s, overlaying the direct ageing (red triangles) and tag-recapture (blue circles) data. To plot the tagging data, we required an estimate of the age at release for each fish. We used the approximately conditionally unbiased estimators, $\tilde{A}_f$, described in Laslett et al. (2004).

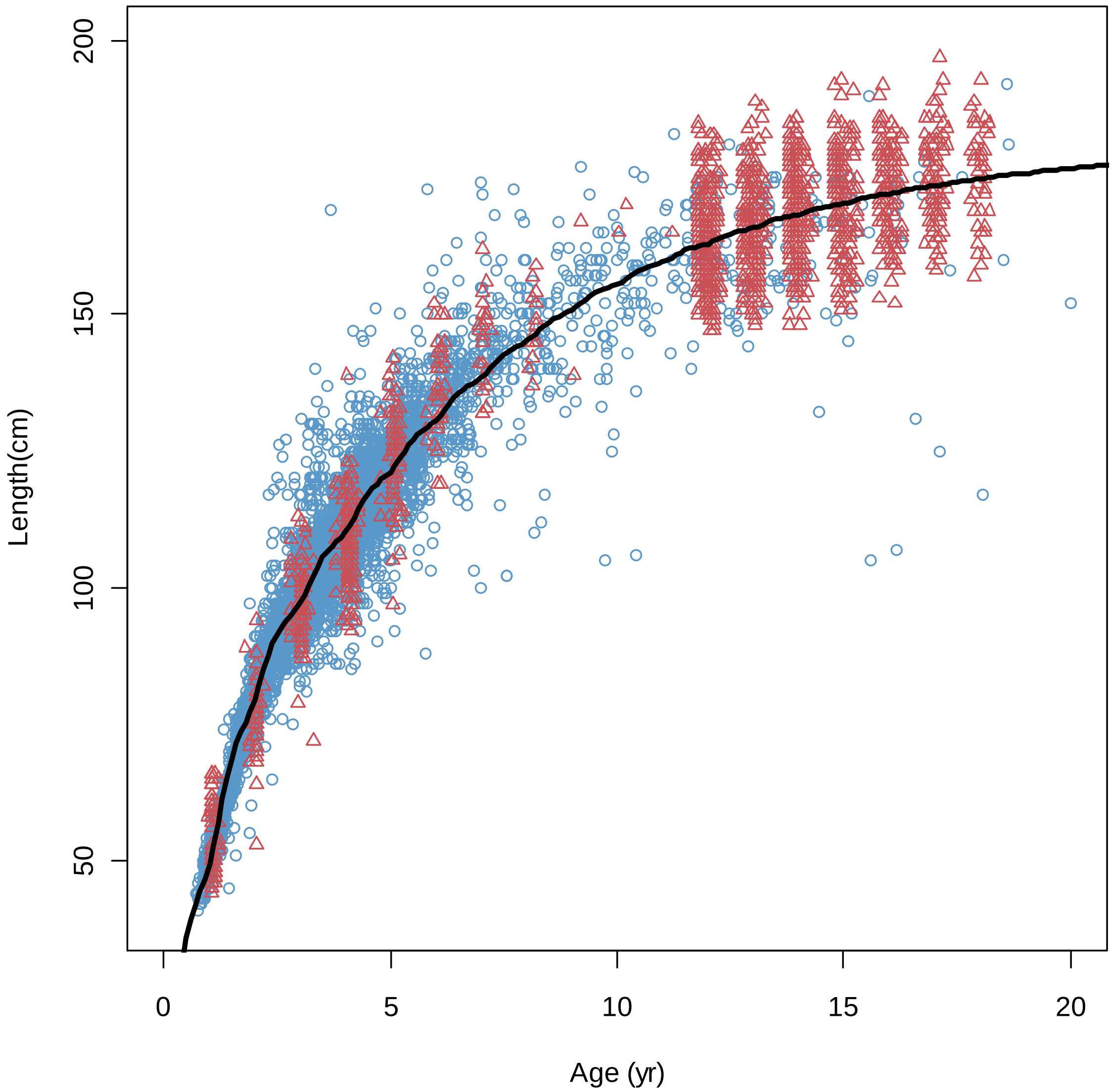
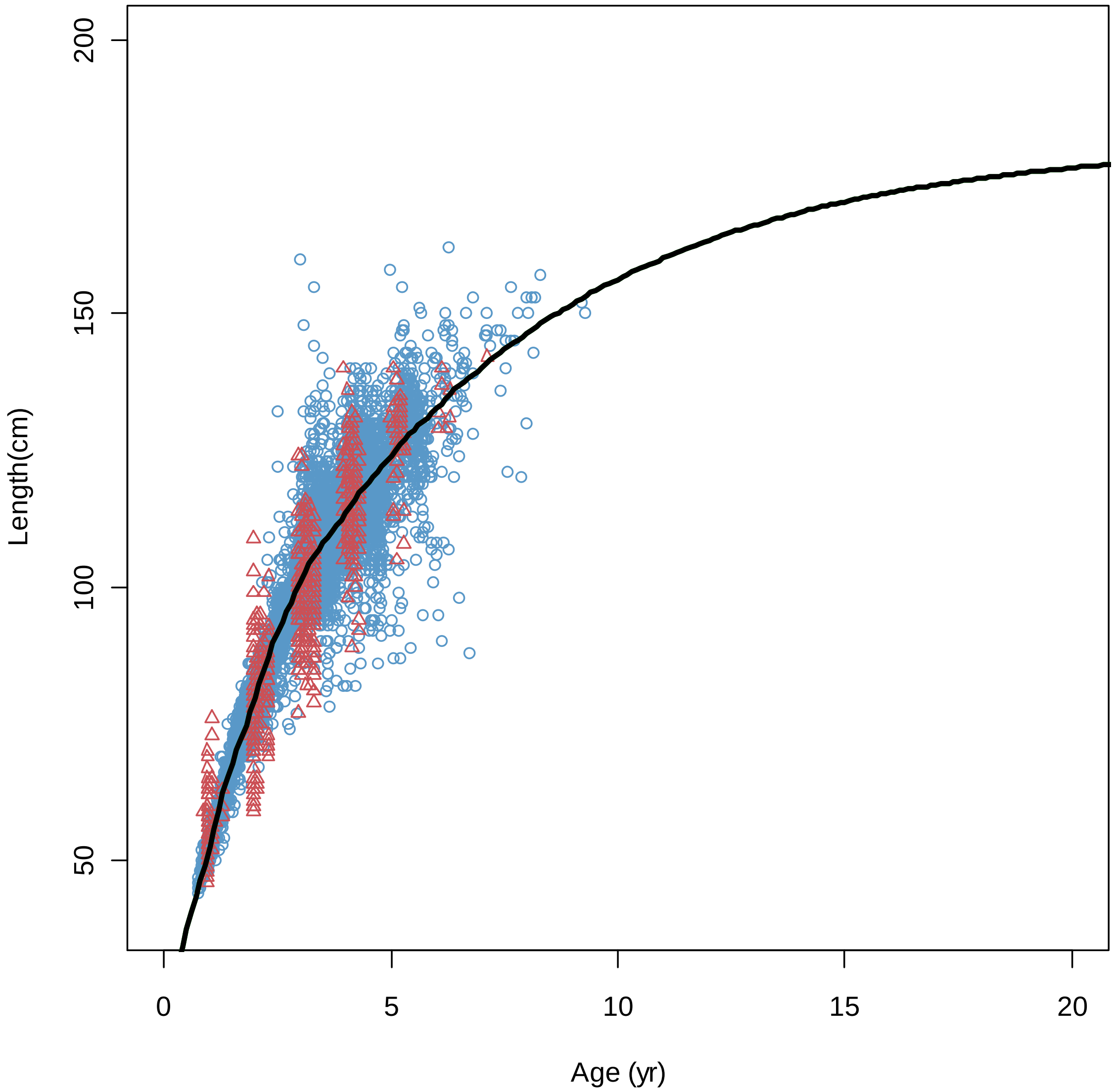


Figure 4. Preliminary mean growth curve estimated for the 2000s, overlaying the direct ageing (red triangles) and tag-recapture (blue circles) data. To plot the tagging data, we required an estimate of the age at release for each fish. We used the approximately conditionally unbiased estimators, $\tilde{A}_f$, described in Laslett et al. (2004).



Appendix A: VBLK2010 cut-points

Lower cut-point for age:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1950	46.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1951	46.3	64.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1952	46.3	64.7	80.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1953	46.3	64.7	80.6	94.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1954	46.3	64.7	80.6	94.6	107.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1955	46.3	64.7	80.6	94.6	107.2	118.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1956	46.3	64.7	80.6	94.6	107.2	118.6	128.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1957	46.3	64.7	80.6	94.6	107.2	118.6	128.3	136.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1958	46.3	64.7	80.6	94.6	107.2	118.6	128.3	136.7	143.9	0.0	0.0	0.0	0.0	0.0	0.0
1959	46.3	64.7	80.6	94.6	107.2	118.6	128.3	136.7	143.9	150.1	0.0	0.0	0.0	0.0	0.0
1960	46.3	64.7	80.6	94.6	107.2	118.6	128.3	136.7	143.9	150.1	155.4	0.0	0.0	0.0	0.0
1961	46.3	64.7	80.6	94.6	107.2	118.6	128.3	136.7	143.9	150.1	155.4	160.0	0.0	0.0	0.0
1962	46.3	64.7	80.6	94.6	107.2	118.6	128.3	136.7	143.9	150.1	155.4	160.0	163.9	0.0	0.0
1963	46.3	64.7	80.6	94.6	107.2	118.6	128.3	136.7	143.9	150.1	155.4	160.0	163.9	167.3	0.0
1964	46.3	64.7	80.6	94.6	107.2	118.6	128.3	136.7	143.9	150.1	155.4	160.0	163.9	167.3	170.2
1965	46.3	64.7	80.6	94.6	107.2	118.6	128.3	136.7	143.9	150.1	155.4	160.0	163.9	167.3	170.2
1966	46.3	64.7	80.6	94.6	107.2	118.6	128.3	136.7	143.9	150.1	155.4	160.0	163.9	167.3	170.2
1967	46.3	64.7	80.6	94.6	107.2	118.6	128.3	136.7	143.9	150.1	155.4	160.0	163.9	167.3	170.2
1968	46.3	64.7	80.6	94.6	107.2	118.6	128.3	136.7	143.9	150.1	155.4	160.0	163.9	167.3	170.2
1969	45.7	64.7	80.6	94.6	107.2	118.6	128.3	136.7	143.9	150.1	155.4	160.0	163.9	167.3	170.2
1970	45.1	64.5	80.6	94.6	107.2	118.6	128.3	136.7	143.9	150.1	155.4	160.0	163.9	167.3	170.2
1971	44.5	64.3	80.7	94.6	107.2	118.6	128.3	136.7	143.9	150.1	155.4	160.0	163.9	167.3	170.2
1972	44.5	64.1	80.8	94.8	107.2	118.6	128.3	136.7	143.9	150.1	155.4	160.0	163.9	167.3	170.2
1973	44.5	64.1	81.0	95.1	107.6	118.6	128.3	136.7	143.9	150.1	155.4	160.0	163.9	167.3	170.2
1974	44.5	64.1	81.0	95.4	108.0	119.5	128.3	136.7	143.9	150.1	155.4	160.0	163.9	167.3	170.2
1975	44.5	64.1	81.0	95.4	108.4	120.5	129.6	136.7	143.9	150.1	155.4	160.0	163.9	167.3	170.2
1976	44.5	64.1	81.0	95.4	108.4	121.5	131.0	138.2	143.9	150.1	155.4	160.0	163.9	167.3	170.2
1977	44.5	64.1	81.0	95.4	108.4	121.5	132.3	139.7	145.5	150.1	155.4	160.0	163.9	167.3	170.2
1978	44.5	64.1	81.0	95.4	108.4	121.5	132.3	141.2	147.1	151.7	155.4	160.0	163.9	167.3	170.2

1979	41.7	64.1	81.0	95.4	108.4	121.5	132.3	141.2	148.7	153.2	156.9	160.0	163.9	167.3	170.2
1980	38.9	64.7	81.0	95.4	108.4	121.5	132.3	141.2	148.7	154.8	158.4	161.4	163.9	167.3	170.2
1981	36.0	65.3	83.6	95.4	108.4	121.5	132.3	141.2	148.7	154.8	159.9	162.7	165.1	167.3	170.2
1982	36.0	65.9	86.3	98.3	108.4	121.5	132.3	141.2	148.7	154.8	159.9	164.1	166.4	168.4	170.2
1983	36.0	65.9	89.0	101.1	111.1	121.5	132.3	141.2	148.7	154.8	159.9	164.1	167.6	169.4	171.1
1984	36.0	65.9	89.0	104.0	113.8	123.4	132.3	141.2	148.7	154.8	159.9	164.1	167.6	170.5	172.0
1985	36.0	65.9	89.0	104.0	116.6	125.3	133.6	141.2	148.7	154.8	159.9	164.1	167.6	170.5	172.8
1986	36.0	65.9	89.0	104.0	116.6	127.2	134.9	142.1	148.7	154.8	159.9	164.1	167.6	170.5	172.8
1987	36.0	65.9	89.0	104.0	116.6	127.2	136.2	142.9	149.2	154.8	159.9	164.1	167.6	170.5	172.8
1988	36.0	65.9	89.0	104.0	116.6	127.2	136.2	143.8	149.7	155.1	159.9	164.1	167.6	170.5	172.8
1989	36.0	65.9	89.0	104.0	116.6	127.2	136.2	143.8	150.2	155.3	160.0	164.1	167.6	170.5	172.8
1990	36.0	66.9	89.0	104.0	116.6	127.2	136.2	143.8	150.2	155.6	160.1	164.1	167.6	170.5	172.8
1991	35.9	67.9	89.9	104.0	116.6	127.2	136.2	143.8	150.2	155.6	160.1	164.0	167.5	170.5	172.8
1992	35.9	68.9	90.7	104.5	116.6	127.2	136.2	143.8	150.2	155.6	160.1	164.0	167.3	170.3	172.8
1993	35.9	68.9	91.6	105.0	116.8	127.2	136.2	143.8	150.2	155.6	160.1	164.0	167.2	170.1	172.6
1994	35.9	68.9	91.6	105.5	117.0	127.2	136.2	143.8	150.2	155.6	160.1	164.0	167.2	170.0	172.5
1995	35.9	68.9	91.6	105.5	117.3	127.2	136.0	143.8	150.2	155.6	160.1	164.0	167.2	170.0	172.3
1996	35.9	68.9	91.6	105.5	117.3	127.2	135.8	143.4	150.2	155.6	160.1	164.0	167.2	170.0	172.3
1997	35.9	68.9	91.6	105.5	117.3	127.2	135.6	143.1	149.7	155.6	160.1	164.0	167.2	170.0	172.3
1998	35.9	68.9	91.6	105.5	117.3	127.2	135.6	142.7	149.2	155.0	160.1	164.0	167.2	170.0	172.3
1999	35.9	68.9	91.6	105.5	117.3	127.2	135.6	142.7	148.7	154.4	159.4	164.0	167.2	170.0	172.3
2000	35.9	68.9	91.6	105.5	117.3	127.2	135.6	142.7	148.7	153.8	158.8	163.2	167.2	170.0	172.3
2001	35.9	68.9	91.6	105.5	117.3	127.2	135.6	142.7	148.7	153.8	158.1	162.4	166.4	170.0	172.3
2002	35.9	68.9	91.6	105.5	117.3	127.2	135.6	142.7	148.7	153.8	158.1	161.7	165.6	169.1	172.3
2003	35.9	68.9	91.6	105.5	117.3	127.2	135.6	142.7	148.7	153.8	158.1	161.7	164.7	168.2	171.3
2004	35.9	68.9	91.6	105.5	117.3	127.2	135.6	142.7	148.7	153.8	158.1	161.7	164.7	167.3	170.4
2005	35.9	68.9	91.6	105.5	117.3	127.2	135.6	142.7	148.7	153.8	158.1	161.7	164.7	167.3	169.5
2006	35.9	68.9	91.6	105.5	117.3	127.2	135.6	142.7	148.7	153.8	158.1	161.7	164.7	167.3	169.5
2007	35.9	68.9	91.6	105.5	117.3	127.2	135.6	142.7	148.7	153.8	158.1	161.7	164.7	167.3	169.5
2008	35.9	68.9	91.6	105.5	117.3	127.2	135.6	142.7	148.7	153.8	158.1	161.7	164.7	167.3	169.5
2009	35.9	68.9	91.6	105.5	117.3	127.2	135.6	142.7	148.7	153.8	158.1	161.7	164.7	167.3	169.5

Lower cut-point for age:	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1950	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1951	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1952	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1953	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1954	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1955	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1956	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1957	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1958	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1959	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1960	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1961	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1962	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1963	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1964	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1965	172.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1966	172.7	174.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1967	172.7	174.8	176.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1968	172.7	174.8	176.7	178.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1969	172.7	174.8	176.7	178.2	179.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1970	172.7	174.8	176.7	178.2	179.6	180.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1971	172.7	174.8	176.7	178.2	179.6	180.8	181.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1972	172.7	174.8	176.7	178.2	179.6	180.8	181.8	182.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1973	172.7	174.8	176.7	178.2	179.6	180.8	181.8	182.6	183.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1974	172.7	174.8	176.7	178.2	179.6	180.8	181.8	182.6	183.3	184.0	0.0	0.0	0.0	0.0	0.0	0.0
1975	172.7	174.8	176.7	178.2	179.6	180.8	181.8	182.6	183.3	184.0	184.5	0.0	0.0	0.0	0.0	0.0
1976	172.7	174.8	176.7	178.2	179.6	180.8	181.8	182.6	183.3	184.0	184.5	185.0	0.0	0.0	0.0	0.0
1977	172.7	174.8	176.7	178.2	179.6	180.8	181.8	182.6	183.3	184.0	184.5	185.0	185.4	0.0	0.0	0.0
1978	172.7	174.8	176.7	178.2	179.6	180.8	181.8	182.6	183.3	184.0	184.5	185.0	185.4	185.7	0.0	0.0

1979	172.7	174.8	176.7	178.2	179.6	180.8	181.8	182.6	183.3	184.0	184.5	185.0	185.4	185.7	186.0	0.0
1980	172.7	174.8	176.7	178.2	179.6	180.8	181.8	182.6	183.3	184.0	184.5	185.0	185.4	185.7	186.0	186.3
1981	172.7	174.8	176.7	178.2	179.6	180.8	181.8	182.6	183.3	184.0	184.5	185.0	185.4	185.7	186.0	186.3
1982	172.7	174.8	176.7	178.2	179.6	180.8	181.8	182.6	183.3	184.0	184.5	185.0	185.4	185.7	186.0	186.3
1983	172.7	174.8	176.7	178.2	179.6	180.8	181.8	182.6	183.3	184.0	184.5	185.0	185.4	185.7	186.0	186.3
1984	173.4	174.8	176.7	178.2	179.6	180.8	181.8	182.6	183.3	184.0	184.5	185.0	185.4	185.7	186.0	186.3
1985	174.1	175.4	176.7	178.2	179.6	180.8	181.8	182.6	183.3	184.0	184.5	185.0	185.4	185.7	186.0	186.3
1986	174.8	175.9	177.0	178.2	179.6	180.8	181.8	182.6	183.3	184.0	184.5	185.0	185.4	185.7	186.0	186.3
1987	174.8	176.5	177.4	178.5	179.6	180.8	181.8	182.6	183.3	184.0	184.5	185.0	185.4	185.7	186.0	186.3
1988	174.8	176.5	177.8	178.7	179.7	180.8	181.8	182.6	183.3	184.0	184.5	185.0	185.4	185.7	186.0	186.3
1989	174.8	176.5	177.8	178.9	179.8	180.7	181.8	182.6	183.3	184.0	184.5	185.0	185.4	185.7	186.0	186.3
1990	174.8	176.5	177.8	178.9	179.9	180.7	181.6	182.6	183.3	184.0	184.5	185.0	185.4	185.7	186.0	186.3
1991	174.8	176.5	177.8	178.9	179.9	180.6	181.4	182.3	183.3	184.0	184.5	185.0	185.4	185.7	186.0	186.3
1992	174.8	176.5	177.8	178.9	179.9	180.6	181.3	182.1	183.0	184.0	184.5	185.0	185.4	185.7	186.0	186.3
1993	174.8	176.5	177.8	178.9	179.9	180.6	181.3	181.8	182.6	183.5	184.5	185.0	185.4	185.7	186.0	186.3
1994	174.6	176.5	177.8	178.9	179.9	180.6	181.3	181.8	182.2	183.0	184.0	185.0	185.4	185.7	186.0	186.3
1995	174.4	176.2	177.8	178.9	179.9	180.6	181.3	181.8	182.2	182.6	183.4	184.4	185.4	185.7	186.0	186.3
1996	174.2	176.0	177.6	178.9	179.9	180.6	181.3	181.8	182.2	182.6	182.9	183.7	184.7	185.7	186.0	186.3
1997	174.2	175.8	177.4	178.7	179.9	180.6	181.3	181.8	182.2	182.6	182.9	183.1	184.0	185.0	186.0	186.3
1998	174.2	175.8	177.2	178.6	179.7	180.6	181.3	181.8	182.2	182.6	182.9	183.1	183.3	184.2	185.2	186.3
1999	174.2	175.8	177.2	178.4	179.5	180.5	181.3	181.8	182.2	182.6	182.9	183.1	183.3	183.5	184.4	185.4
2000	174.2	175.8	177.2	178.4	179.4	180.3	181.1	181.8	182.2	182.6	182.9	183.1	183.3	183.5	183.6	184.6
2001	174.2	175.8	177.2	178.4	179.4	180.2	181.0	181.7	182.2	182.6	182.9	183.1	183.3	183.5	183.6	183.8
2002	174.2	175.8	177.2	178.4	179.4	180.2	180.9	181.6	182.1	182.6	182.9	183.1	183.3	183.5	183.6	183.8
2003	174.2	175.8	177.2	178.4	179.4	180.2	180.9	181.5	182.1	182.5	182.9	183.1	183.3	183.5	183.6	183.8
2004	173.3	175.8	177.2	178.4	179.4	180.2	180.9	181.5	182.0	182.5	182.8	183.1	183.3	183.5	183.6	183.8
2005	172.3	174.9	177.2	178.4	179.4	180.2	180.9	181.5	182.0	182.4	182.8	183.1	183.3	183.5	183.6	183.8
2006	171.4	173.9	176.2	178.4	179.4	180.2	180.9	181.5	182.0	182.4	182.8	183.1	183.3	183.5	183.6	183.8
2007	171.4	172.9	175.3	177.4	179.4	180.2	180.9	181.5	182.0	182.4	182.8	183.1	183.3	183.5	183.6	183.8
2008	171.4	172.9	174.3	176.4	178.4	180.2	180.9	181.5	182.0	182.4	182.8	183.1	183.3	183.5	183.7	183.8
2009	171.4	172.9	174.3	175.4	177.4	179.2	180.9	181.5	182.0	182.4	182.8	183.1	183.3	183.6	183.7	183.8