CATCH-AT-SIZE AND AGE ANALYSES FOR ATLANTIC BLUEFIN

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SUMMARY

This document presents an analysis of the length frequency data (i.e. catch-at-size, CAS) and catch-at-age (CAA) used in the 2014 Eastern Atlantic and Mediterranean bluefin assessment. Two methods are used, i.e. Powell-Wetherall plots to explore changes in Z based on CAS and catch curve analysis using CAA to evaluate changes in selection patterns.

RÉSUMÉ

Ce document présente une analyse des données de fréquences de tailles (p.ex. prise par taille, CAS) et de prise par âge (CAA) utilisées dans l'évaluation du thon rouge de l'Atlantique Est et de la Méditerranée. Deux méthodes sont utilisées : des diagrammes de Powell-Wetherall visant à explorer les changements de Z sur la base de la CAS et une analyse de la courbe de capture utilisant la CAA afin d'évaluer les changements de schémas de sélection.

RESUMEN

Este documento presenta un análisis de los datos de frecuencia de tallas (es decir, la captura por talla, CAS) y la captura por edad (CAA) utilizada en la evaluación de atún rojo del Atlántico oriental y Mediterráneo. Se han utilizado dos métodos, diagramas de Powell-Wetherall para explorar los cambios en Z basándose en la CAS y un análisis de la curva de captura utilizando la CAA para evaluar cambios en los patrones de selección.

KEYWORDS

Bluefin, Catch-at-age, Catch-at-size, Catch curve analysis, Stock assessment

Introduction

This document presents an analysis of the length frequency data (i.e. catch-at-size, CAS) and catch-at-age used in the 2014 Eastern Atlantic and Mediterranean bluefin assessment. Two methods are used, Powell-Wetherall plots to explore changes in Z based on CAS and catch curve analysis using CAA to evaluate changes in selection patterns.

Material and Methods

The main method used to assess the Atlantic bluefin stock is Adapt-VPA. Key assumptions are that natural mortality (M) and CAA are known without error, the stock is homogeneous (i.e. there is no sub-stock structure), and there is no immigration or emigration. In addition for the method to work well fishing mortality (F) should be higher than M. VPA is based upon following the catches and recreating the age structure along a cohort, therefore the plus group which group several cohorts together has to be treated separately from other ages.

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Adapt-VPA uses CAA data to reconstruct cohorts and Catch Per Unit Effort (CPUE) as a proxy for stock abundance to calibrate the VPA, The main parameters estimated are the selection pattern in the last (i.e. terminal) year in the CAA matrix and the ratio between F in the last true age and the plusgroup. A difficulty is that ADAPT estimates of F are most uncertain at the end of the time series, i.e. the most recent cohorts, so that the selectivity patterns were based on F estimates that took place a few years ago.

Length-based methods are valuable methods for stock assessment, these can either be complex integrated stock assessment methods like Multifan-CL or simple methods with few assumptions. Cotter *et al*., (2004) in a review of stock assessment methods recommended the use of simple methods due to their visual appeal, simple statistical basis, minimal assumptions and the ease with which estimates can be derived from different data sets. A criticism of simple methods is that they do not estimate absolute stock numbers or fishing mortality but neither do other methods unless M is accurately known, as is seldom true.

Simple methods are also useful for validating data sets prior to their use in more complex methods as they can be used to identify anomalous results and are easier to understand.

Material

The CAA and CAS data are those used in the update assessment for the Adapt-VPA analysis.

Methods

Beverton and Holt (1956) developed a method to estimate population parameters such as total mortality (Z) from length data e.g.

$$Z = K\frac{L_\infty - \overline{L}}{\overline{L} - L'} \tag{1}$$

Based on this equation Powell (1979) developed a method, extended by Wetherall *et al*. (1987), to estimate growth and mortality parameters. This assumes that the right hand tail of a length frequency distribution was determined by the asymptotic length L and the ratio between Z and the growth rate K. The Beverton and Holt methods assumes good estimates for K and L_∞, while the Powell-Wetherall method only requires an estimate of K, since L_∞ is estimated by the method as well as Z/K.These method therefore provide estimates for each distribution of Z/K, if K is unknown and Z if K is known.

As well as assuming that growth follows the von Bertalanffy growth function, it is also assumed that the population is in a steady state with constant exponential mortality, no changes in selection pattern of the fishery and constant recruitment. In the Powell-Wetherall method L' can take any value between the smallest and largest sizes. Equation 1 then provides a series of estimates of Z. Plotting equation 2 provides an estimate of L_∞ and Z/K. If K is known then it also provides an estimate of Z.

$$\overline{L} - L' = a + bL' \tag{2}$$

$$b = \frac{-K}{Z + K} \tag{3}$$

$$a = -bL_\infty \tag{4}$$

$$L_\infty = -a/b \tag{5}$$

$$Z/K = \frac{-1 - b}{b} \tag{6}$$

Catch curve analysis

Catch curve can be fitted to an actual or a “synthetic” cohort which uses catch data from a single year or a few years (Ssentongo and P. Larkin. 1973).

If p_a denotes the fraction of the total catch corresponding to age a then a linear regression of p_a can be fitted over a range of ages $[\alpha, \beta]$. As for the year-class curve analysis, the slope of the regression can be used to estimate the total mortality (Z), but we here applied for estimating selectivity. In theory, the ages that are not fully selected do not follow a linear to age a, then a linear regression on p_a over a

Selectivities can be thus estimated from the ratio of observed to predicted catch proportions: then re-scaled so that the maximum is 1.

In other words, the selectivity is maximal (equal to 1) when there is no difference between the observed and expected curves and it becomes smaller as the difference between both curves increases.

Results

The CAS data from the 1990s onwards are plotted in **Figure 1**, in 2012 and 2013 there has been a shift to a larger mean size. The Powell-Whetherall plots are shown in **Figure 2** and the estimates of Z in **Figure 3**. The latter show the estimates from each year (points with hatched line) and a smoother (blue continuous line). There appears to have been a decline in Z in the 2000s.

The CAA **Figure 4** were generated from the CAS by age slicing. **Figure 5** shows the estimated ages for a mode at age 15 with a mean size of 241cm and a CV of 5%, the distribution is skewed to the right since the slope of the growth curve decreases as fish grow. This means that there is a positive bias in the mean age of the fish and that F estimates from age slicing will be negatively biased. Which in turn means that selectivity and F-at-age may not actually decrease in the older ages.

Figure 6 plots the standardised residuals of the proportion of numbers-at-age per year. It would be expected to be able to follow cohorts, i.e. a strong cohort recruiting to the fishing would be shown as a black row of dots moving diagonally from left to right. For example it should be possible to follow a strong 2003 year-class (starting in 2004 at age 1) across the ages used in the VPA (i.e. 1 to 9). However, although this year class can be followed up to age 4 the 2002 year-class appears strong in 2004 and the 2004 in 2005. While after age 4 all year-class appear to be strong.

Synthetic catch curves constructed by lustrum (5 years) are presented in **Figure 7** and the corresponding selection patterns in **Figure 8**. These confirm the shift away from catches of juveniles towards older mature fish.

Next selection patterns are compared by the most recent lustrums for the main gear area interactions. These were chosen by calculating the cumulative catch in numbers over the last two lustrums by gear and area interaction summing up from the interaction in order of catch, **Figure 9**.

The catch curves and selection patterns were then calculated for the gear areas which account for 80% of the catch, **Figure 9** and **Figure 10**.

The selection pattern for the **BB** and **ATE** interaction suggests that there is a recent targeting of larger fish. The BB fishery is traditionally for juveniles therefore as a check we plot the CSA in **Figure 11**. This shows that in 2013 there were a lot of large fish reported.

Figure 12 shows how age slicing potentially biases the CAA, this shows the “mis-aging” of for a mode of age 10 with a mean size of 241cm and a CV of 5%.

Virtual population analysis

Virtual population Analysis is used to convert the CAA into numbers and fishing mortality-at-age conditioned on the last/terminal age in a cohort. The terminal age is either from the most recent year or the oldest age in a cohort. In these example the terminal age F was based on an Adapt VPA, while the terminal age F is calculated from assumed ratio between the F in the last true age and that in the plusgroup.

Since the plus group includes a range of age classes from different cohorts the mean size of an individual in the plus group will vary as F and cohort vary, **Figure 13** therefore evaluates how the average mass of an individual in the plus group has varied.

In the last assessment the ratio of F in the last true age and the plus group was fixed not estimated, **Figure 14**. The ratio can be investigated by comparing the estimates from the catch curve analysis **Figure 15**. This also shows a sequential t-test to identify any temporal patterns in the F ratio.

The F ratio from 2012, a null hypotheses (H_0) of F ratio=1 and the time series seen in **Figure 14** were used to condition the VPA. The VPA are compared in **Figure 16** and the results summarised in **Figure 17**.

Figure 17 summarises time series of recruits, SSB, F_{apex} the maximum F-at-age, the age at which F_{apex} occurs, F at age 9 F_9, F in the plus group F_{10+}, plus group F ratio and the proportion of biomass in the plus group.

Discussion

The analysis showed that F has decreased and that there has been a reduction in F on juveniles and a shift towards mature individuals. It appears that the CAA matrix is unable to track cohorts, probably due to age slicing underestimated both the proportion of younger fish in the catch and uncertainty in the catch-at-age estimates. Numbers-at-age of a strong year class, especially at younger ages when it is more numerous, will be underestimated by slicing and uncertainty in proportions of older ages, where there will be considerable overlap in lengths-at-age, will be large.

The assumed ratio between F in the last true age and plus group has a big impact on the VPA results.

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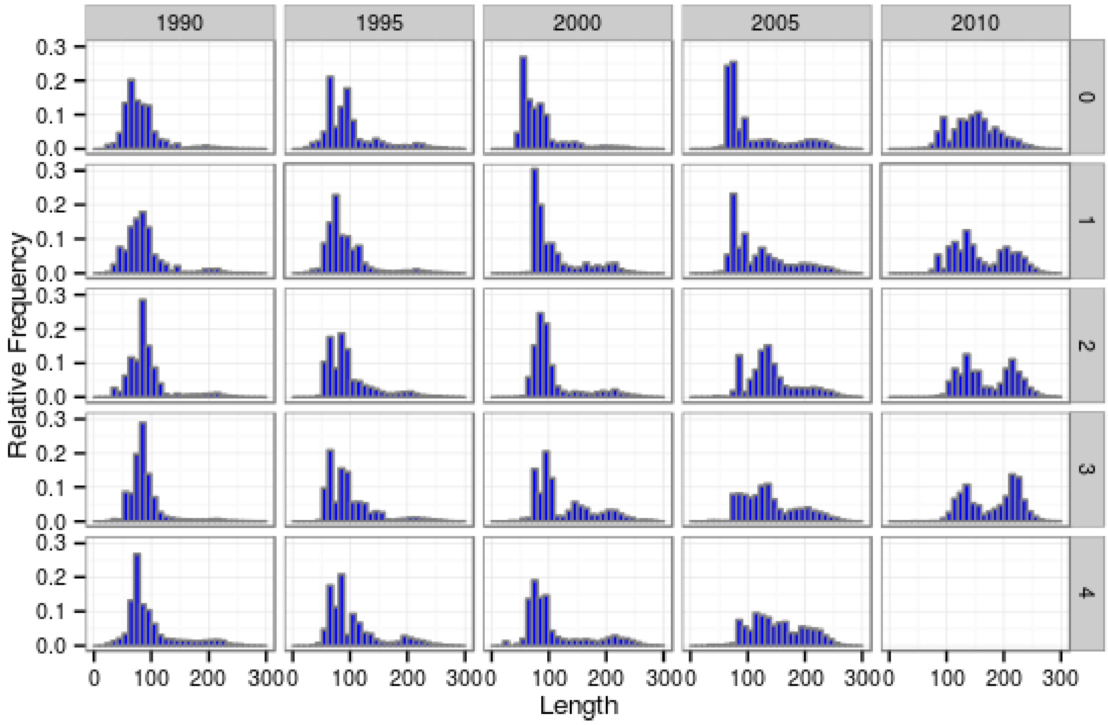

Figure 1. Catch length-at-age.

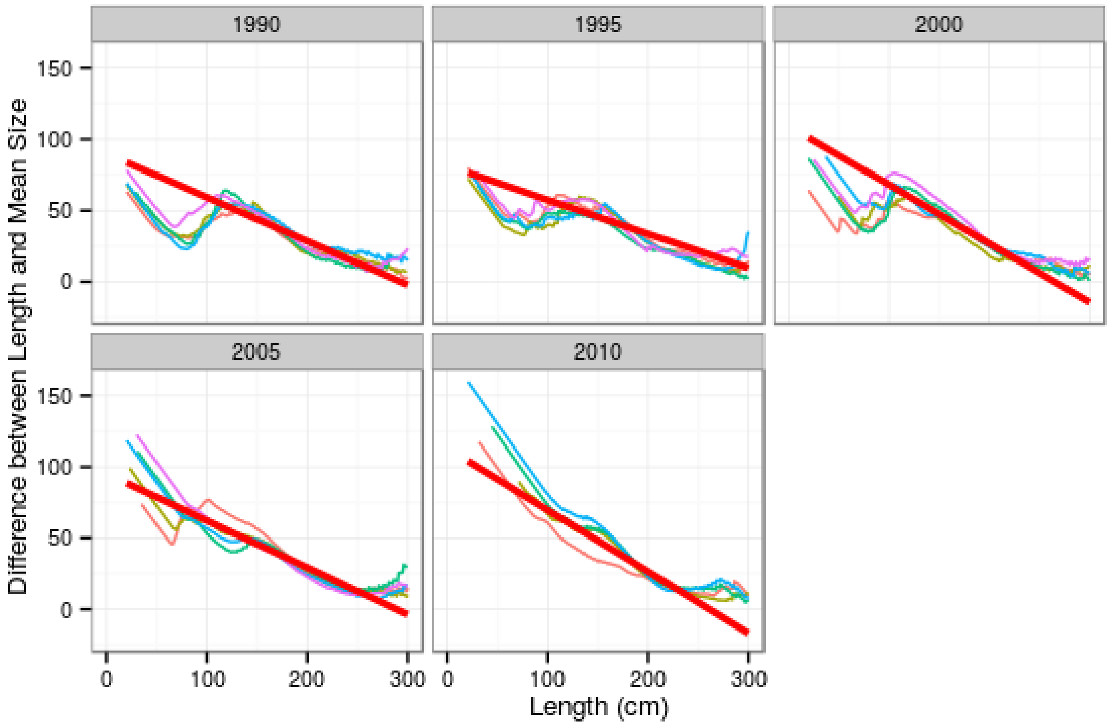

Figure 2. Powell-Whetherall plots.

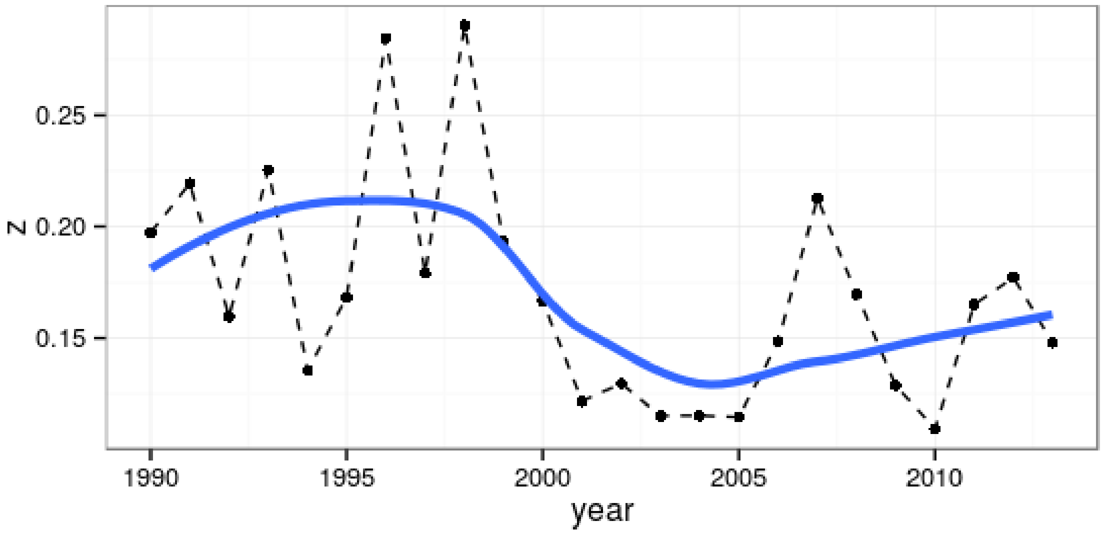

Figure 3. Estimates of Z derived from the Powell-Wetherall plots; showing the estimates from each year (points with hatched line) and a smoother (blue continuous line).

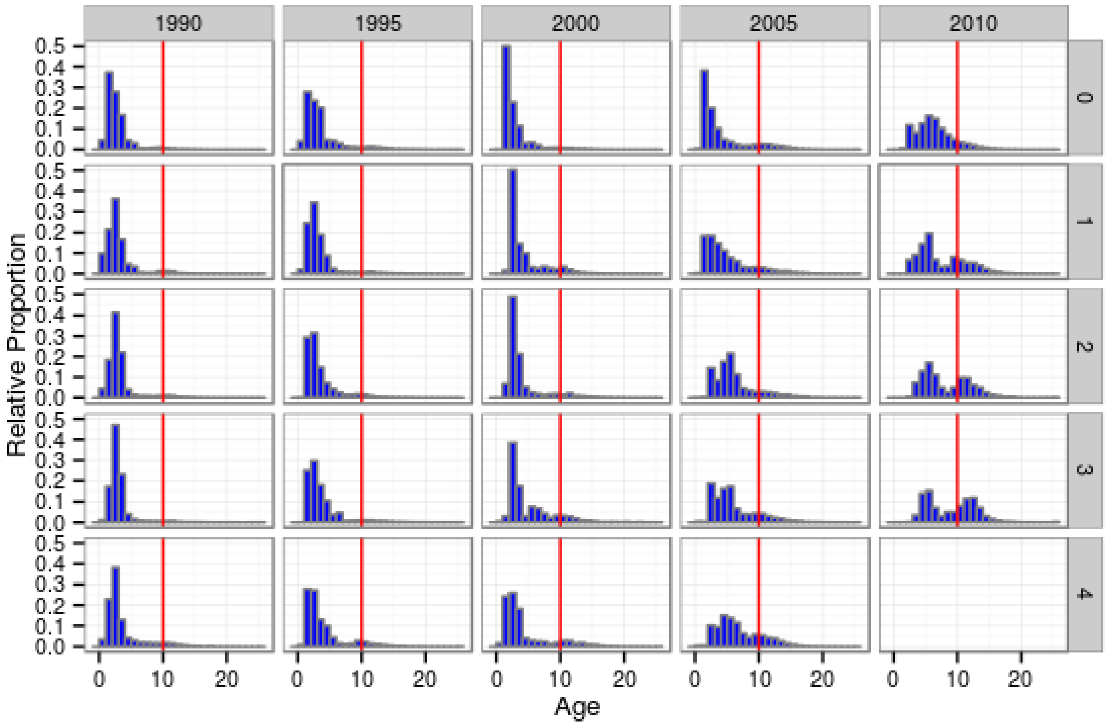

Figure 4. Catch numbers-at-age.

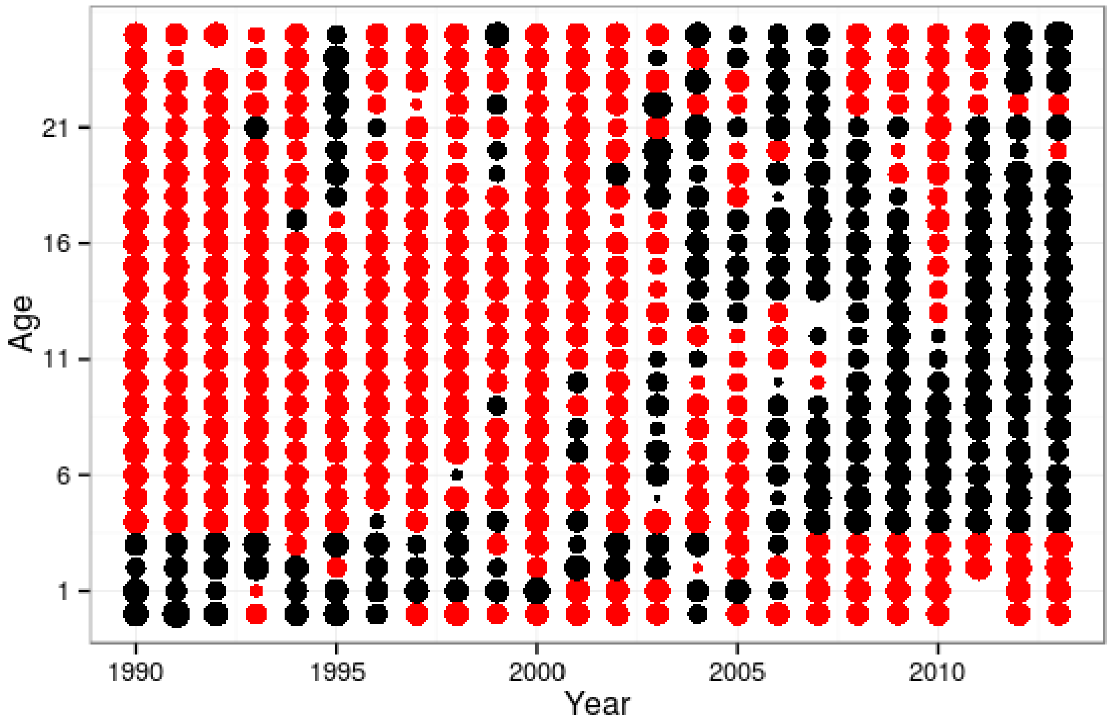

Figure 5. Standardised residuals of the proportion of numbers-at-age.

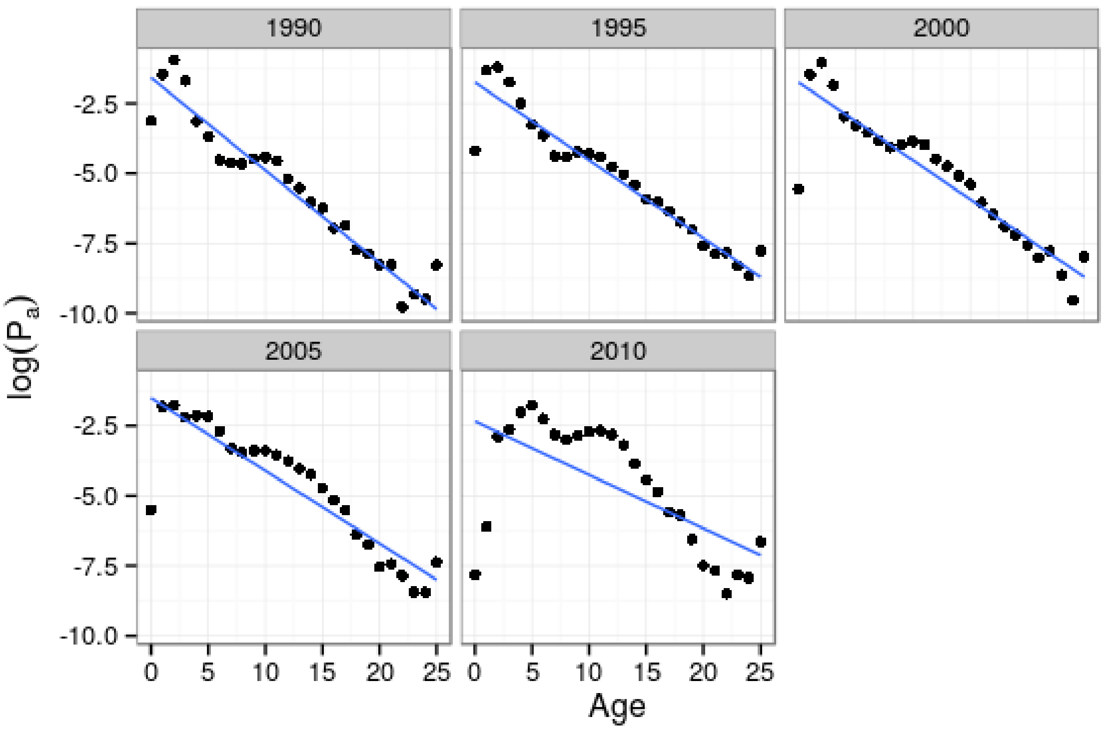

Figure 6. Catch curves by lustrum.

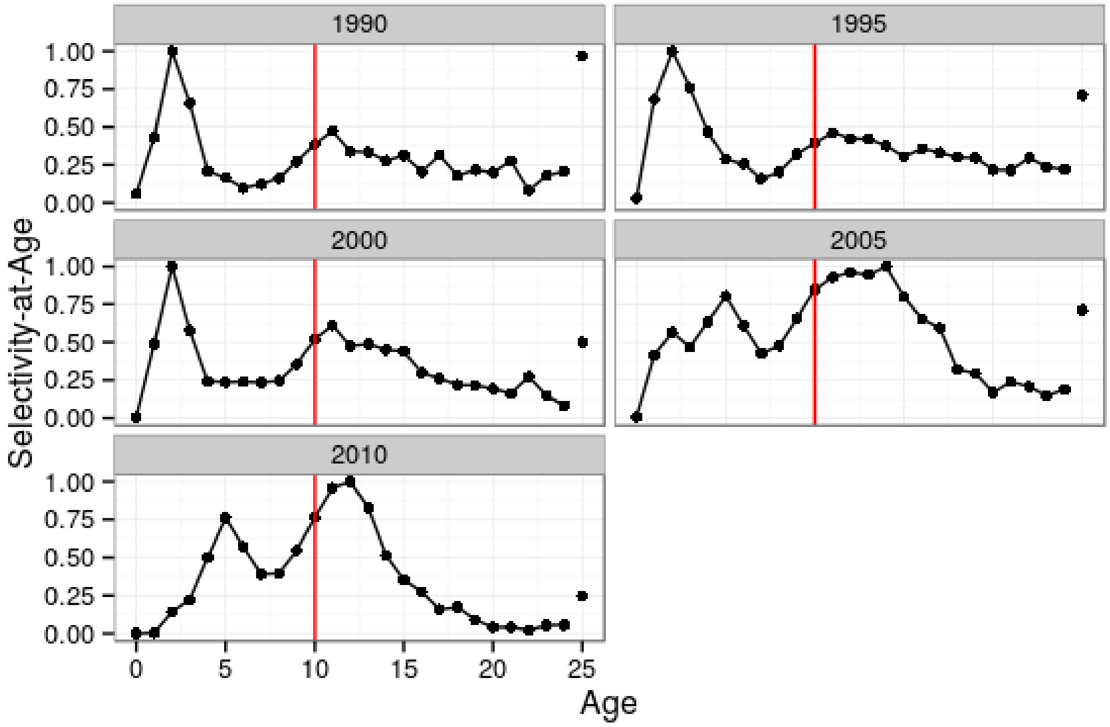

Figure 7. Selectivity by lustrum.

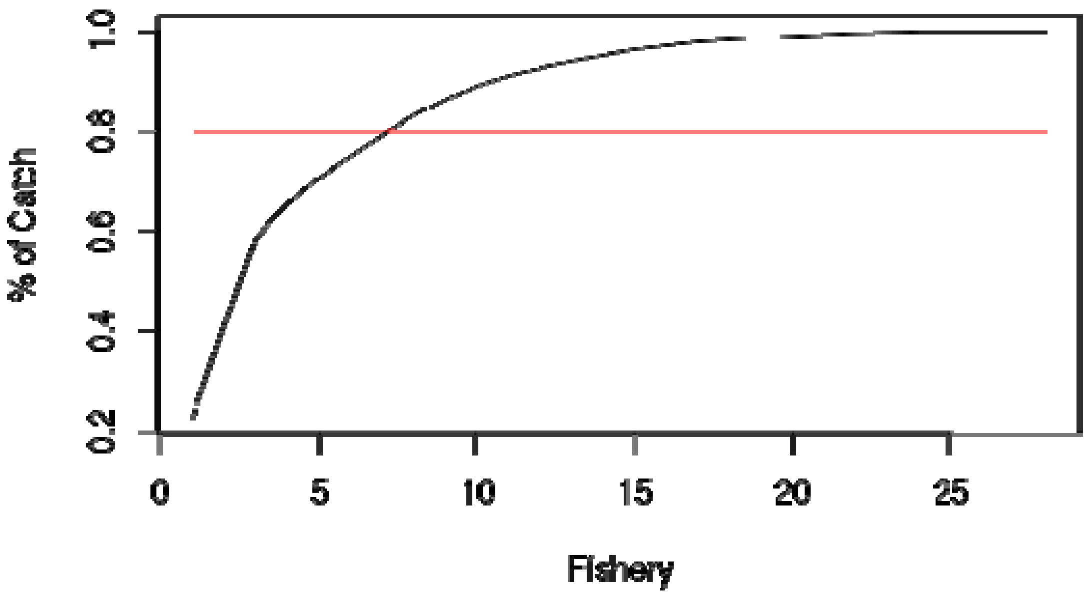

Figure 8. Cumulative catch by gear area interaction.

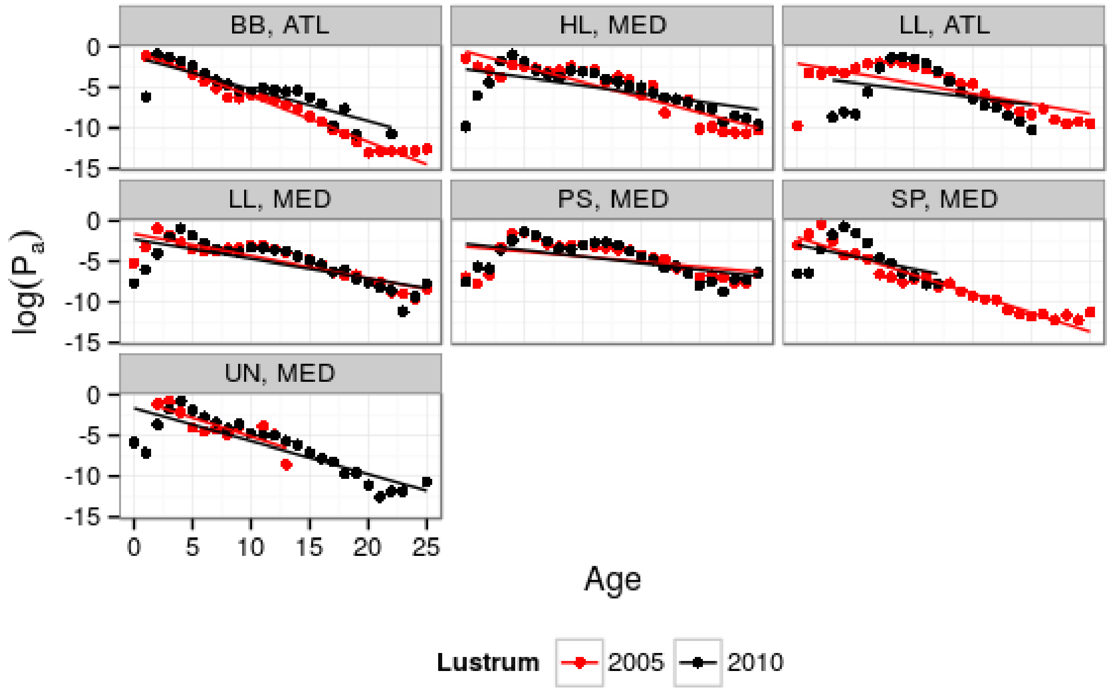

Figure 9. Catch curve by gear area interaction and lustrum.

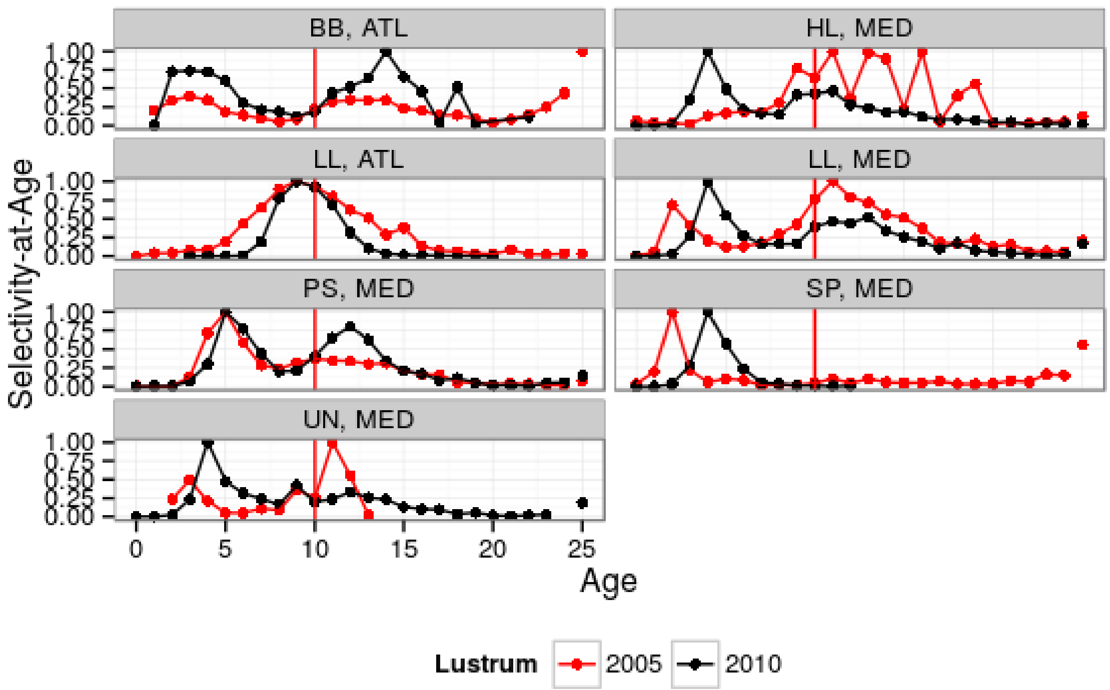

Figure 10. Selectivity by gear area interaction and lustrum.

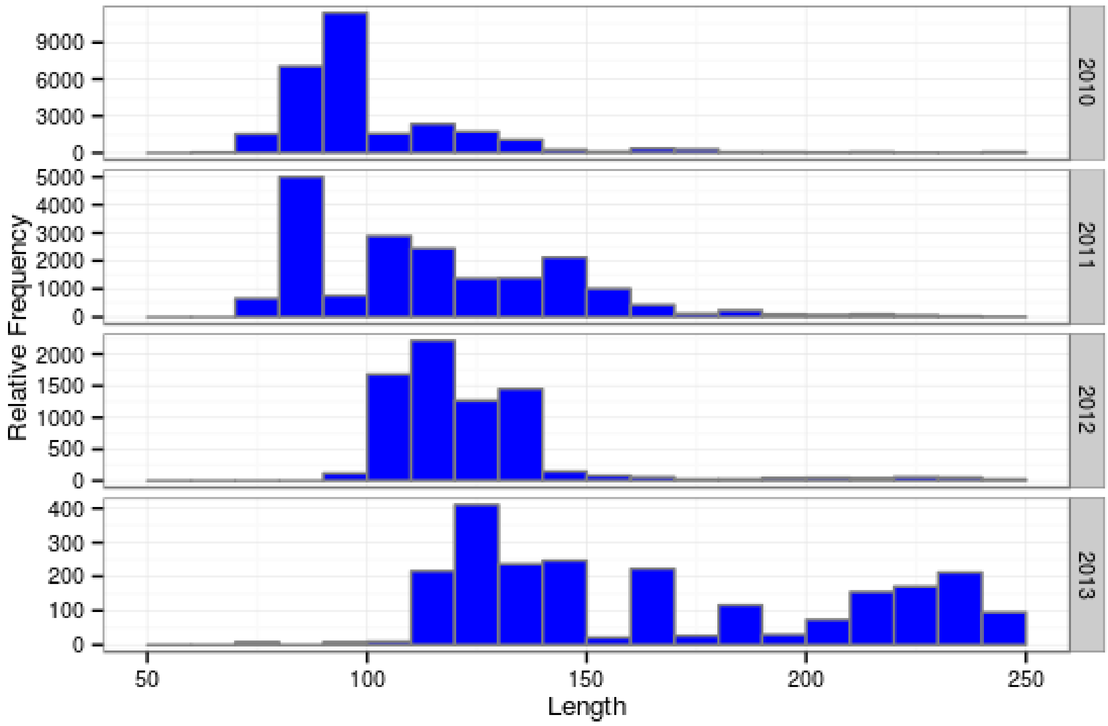

Figure 11. Catch-at-size for BB and ATE.

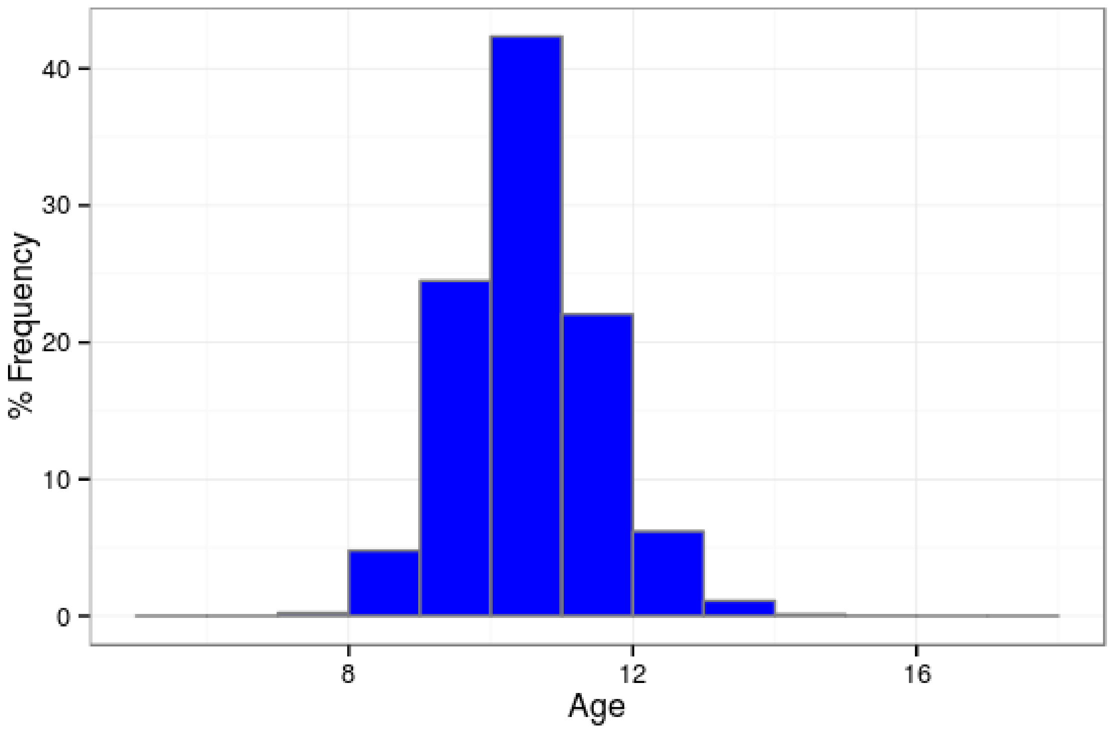

Figure 12. Estimated ages for a mode at age 10 with a mean size of 241cm and a CV of 5%.

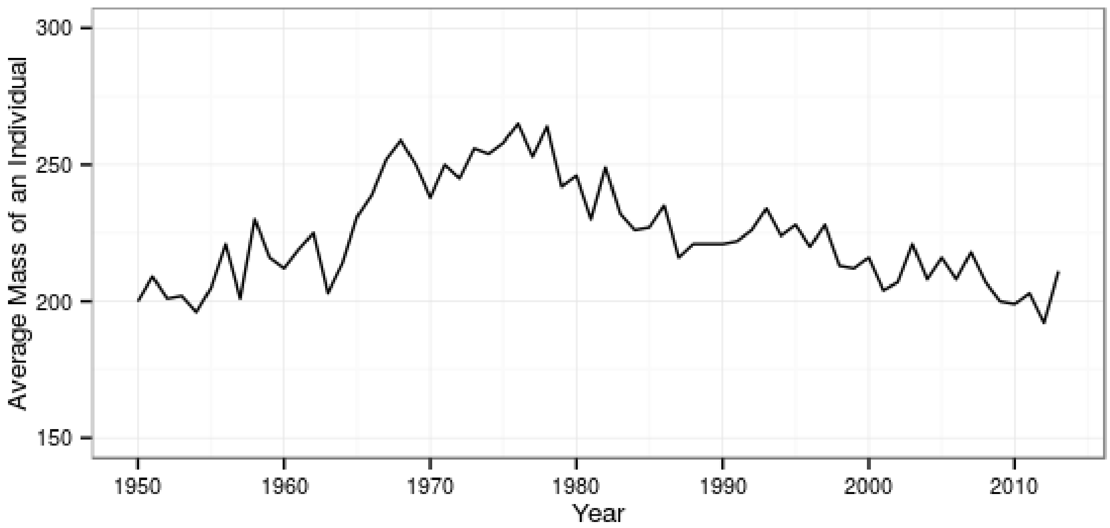

Figure 13. Average mass of an individual in the plus group.

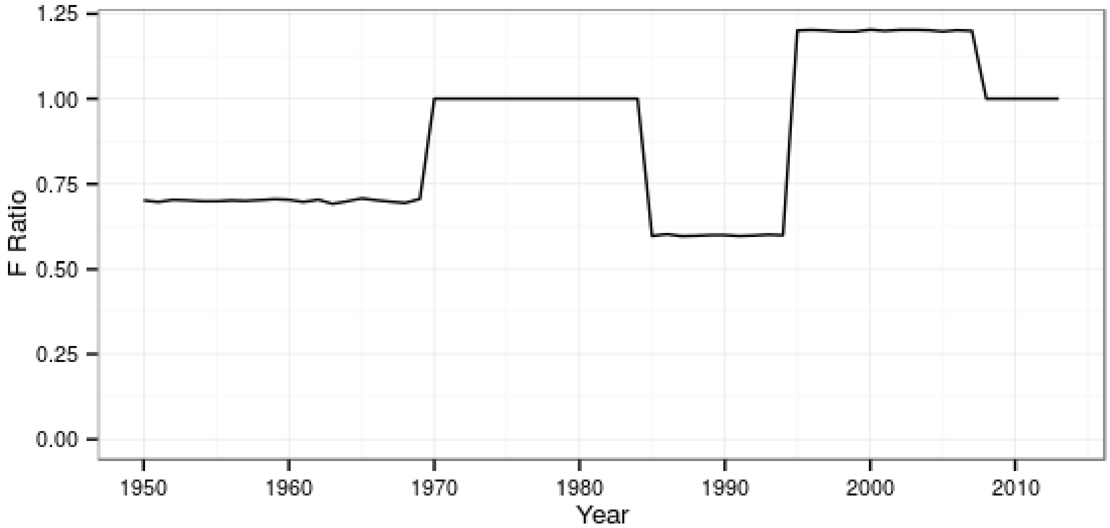

Figure 14. Assumed ratio between F in the last true age and the plus group/newline/newline.

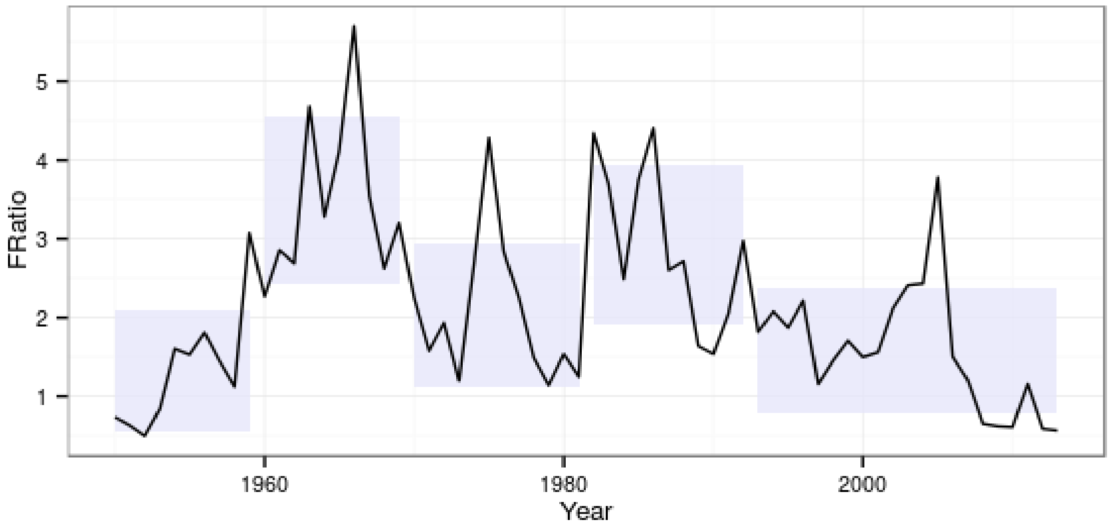

Figure 15. Ratio between F in the last true ages and the plus group with periods identified using a sequential t-test.

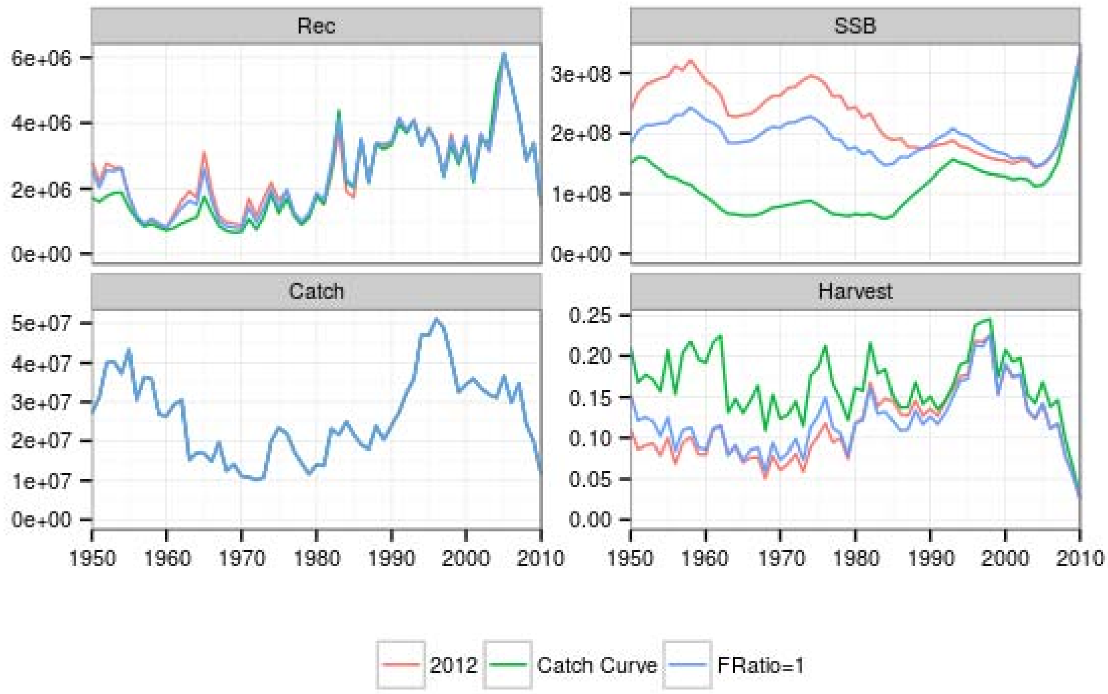

Figure 16. Comparison of VPAs with different Plus Group F Ratios. /newline/newline.

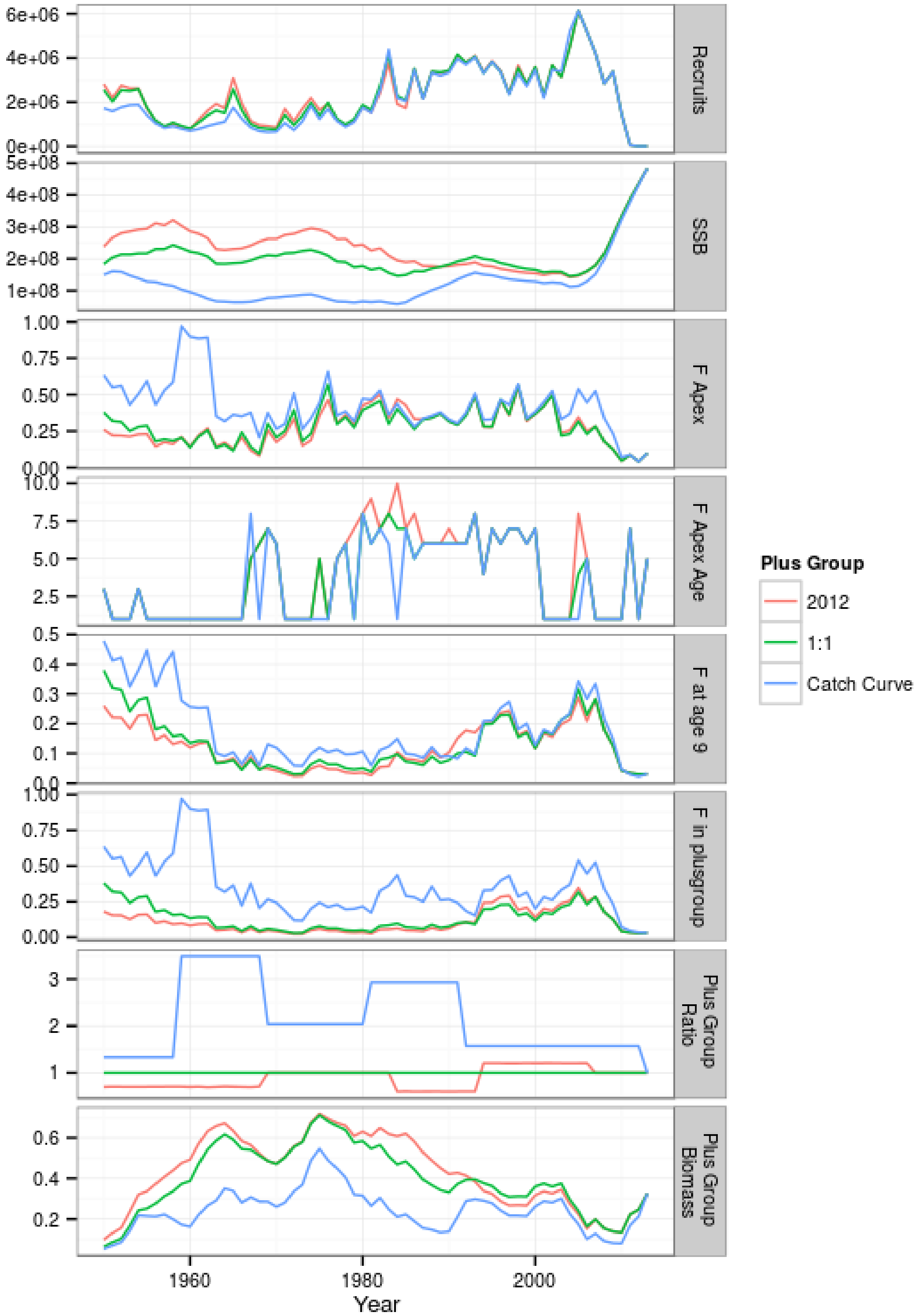

Figure 17. Comparison of affect of Plus Group F Ratios.