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A COMPARISON OF STATISTICAL AGE ESTIMATION AND AGE SLICING FOR ATLANTIC BLUEFIN TUNA (*Thunnus thynnus*).

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SUMMARY

Scientific management advice for Atlantic bluefin tuna is based upon Virtual Population Analysis (VPA), which requires as a main input estimates of catch-at-age (CAA). These are generated from catch-at-size (CAS) by age slicing assuming a deterministic growth model. An alternative is to use a statistically based approach, which assumes that the CAS is composed of a mixture of length frequency distributions.

KEYWORDS

Age slicing ,bluefin, catch curve, FLR, Mediterranean, statistical age estimation, Thunnus thynnus, year class curves.

1.Introduction

In this paper two methods, *age slicing* and *statistical age estimation,* for converting catch-at-size (CAS) into catch-at-age (CAA) are compared for East Atlantic and Mediterranean bluefin tuna. A separable VPA is then performed on the two sets of CAA. The intention is to investigate errors and biases in the basic CAS data and the CAA derived from it then to evaluate the consequences for stock assessment rather than to generate CAA for the assessment at this stage.

CAS are important inputs for many stock assessment methods. However, for use by methods such as Virtual Population Analysis (VPA) catch-at-size have first to be converted into catch-at-age (CAA). This is usually performed, prior to running an assessment, by age slicing where a deterministic growth model is used to divide the length frequency data into length bins corresponding to the length range of age classes. An alternative statistically based approach is to assume that the CAS is composed of a mixture of length frequency distributions and to estimate the parameters by the method of maximum likelihood. Alternatively models that do not require exact matches to CAA could be used

A benefit of age slicing is that it is a simple method requiring just a growth curve. However, if modes of the distribution overlap, e.g. due to measurement and or process error, some length classes may be assigned to the wrong age resulting in a bias in the CAA. In contrast statistical estimation assumes that there is overlap, allows more information to be used, the assumptions to be validated and for estimates of uncertainty to be derived. This is important since growth is a stochastic, not a deterministic, process, and the observed length distribution is also a function of the selectivity of the fisheries and the sampling regime. Using a statistical method also allows the checking of diagnostics and the estimation of uncertainty.

2.Material and Methods

The data used were East Atlantic and Mediterranean bluefin catch-at-size from the ICCAT database up to and including 2009 Growth was assumed to follow a Von Bertalanffy curve (Cort, 1991). All modelling was performed in R using FLR (www.flr-project.org, Kell et al. 2007) and statistical fitting of length distributions at age was performed using the mixdist package ((http://www.math.mcmaster.ca/peter/mix/mixdist.pdf))

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Age slicing predicts age from length using the inverse of the Von Bertalanffy growth curve i.e.

$$a = t_0 - \log(1 - l)/K$$

Permitting a length distribution to be transformed into an age distribution, using the inequality

$$l(a) \leq l < l(a+1)$$

Statistical fitting in contrast assumes that a length-frequency distribution is a weighted sum of k component densities i.e.

$$g(x|\pi, \mu, \sigma) = g(x|\pi_1, \mu_1, \sigma_1) + \ldots + g(x|\pi_k, \mu_k, \sigma_k)$$

Where the parameters are the mixing proportions (π) the means (μ) and standard deviations (σ) of the component distributions. Within the mixdist package components can be either normal, lognormal, gamma, exponential, Weibull, binomial, negative binomial or Poisson distributions.

When fitting mixing proportions to CAS three parameters have to be either fixed or estimated estimated per age group. Mixing proportions were estimated for all ages, however means and standard deviations were only estimates for the first five ages and the plus group. This was because for the other ages component distributions overlapped with no clear modes. The initial estimates for mixing proportions and means were taken from age slicing and σ was based on a CV of 10%.

3. Results

CAS are summarised by year and gear respectively in **figures 1 and 2**, and for long lines and bait boats, the two main fisheries used to provide catch per unit effort (CPUE), in **figures 3** and **4**.

Length frequency data and the corresponding ages are presented in **figure 5** for 1987 as an example and then in **figure 6** for all years. Observed length frequency distributions are plotted in blue, the expected length mid way through the year are indicated by the vertical lines, the modes of the fitted length distributions-at-age are plotted in red and the fitted mixture distribution in green. In general the fitted distribution shows good agreement with the observations, particularly for age 0 through to 3; subsequently the modes become more difficult to distinguish.

The relative proportions at age are compared in **figure 7**, the statistical age slicing results in a higher proportion of catches occurring at younger ages (i.e. 0,1 and 2) and also a reduced proportion of catch in the plus group.

The weights-at-age estimated by the two approaches are plotted in **figure 8**.

In order to evaluate the effect on fishing mortality and stock size a seperable VPA was conducted, the estimates of fishing mortality by decade and trends in mean F and SSB are plotted in **(figures 9, 10 and 11)** .

Coefficients of variation for catch proportion-at-age from the statistical age estimate are presented in **table 1**.

4.Discussion

Where there is overlap in length-at-age, CAA derived from slicing may underestimate the numbers-at-age of the more numerous age classes. This may means that estimates of fishing mortality and year class strength are biased when using VPA based methods. However, this does not necessarily mean that the results from VPA are not useful for management and only statistical catch-at-age based methods should be used, since they may still be able to indicate trends within the stock and fishery. Management Strategy Evaluation (MSE) can be used to evaluate the robustness of VPA based management advice where there is such uncertainty.

An advantage of using statistical catch-at-age estimation is that estimates of uncertainty in proportions at age can be derived. In the context of VPA this may indicate at what age a plus group should be set and also deterioration in the quality of data, for example if uncertainty has increased recently.

5.References

CORT, J. L. 1991. Age and growth of the bluefin tuna *Thunnus thynnus* (L.) of the Northeast Atlantic. Collect. Vol. Sci. Pap, ICCAT,35: 213-230.

Kell, L.T., Mosqueira, I., Grosjean, P., et al. (2007) FLR: an open-source framework for the evaluation and development of management strategies. ICES Journal of Marine Science 64:640-646.

Figures

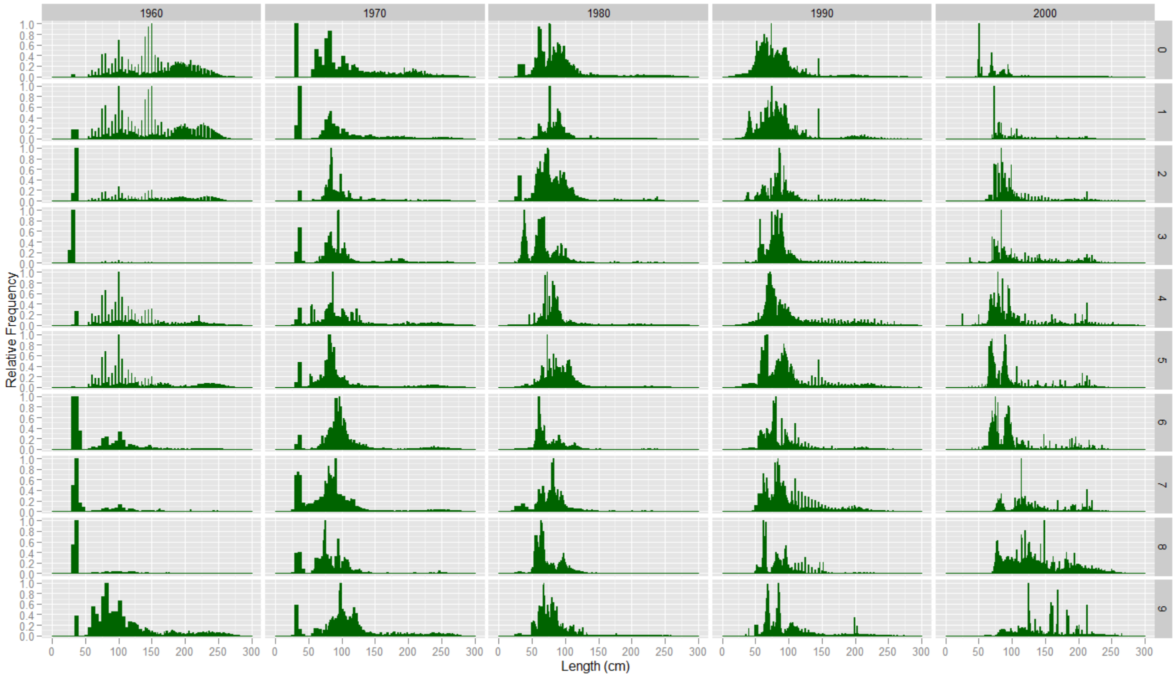

Figure 1. Length frequency distributions by decade (column) and year (row).

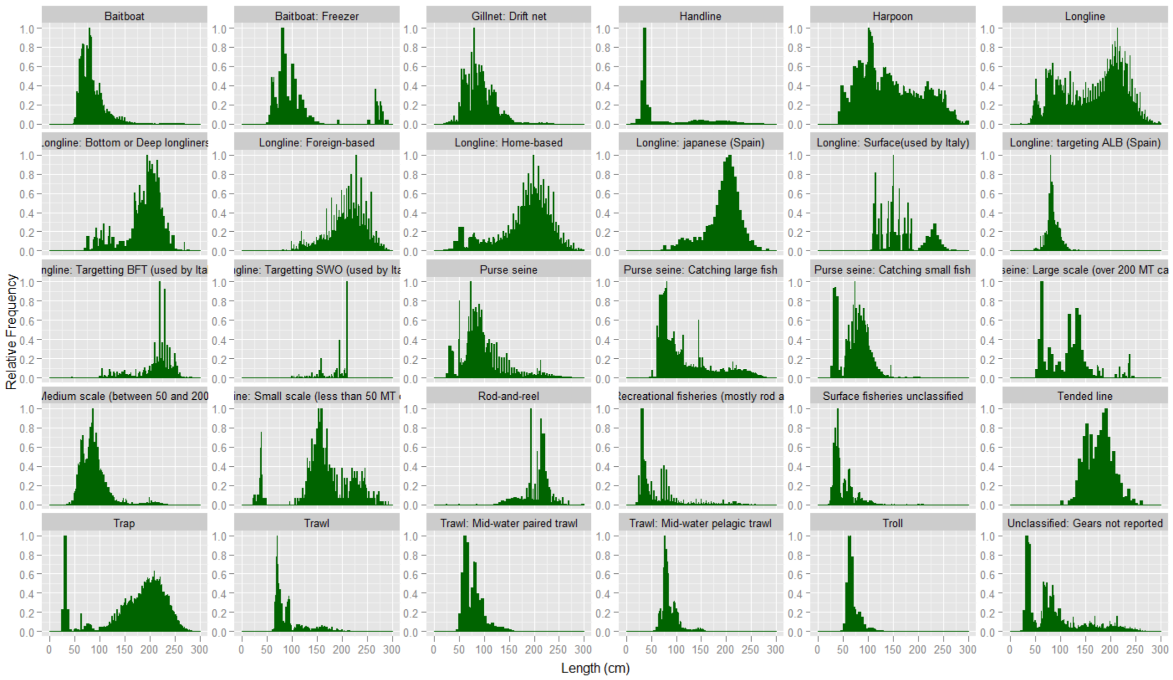

Figure 2. Length frequency distributions by gear.

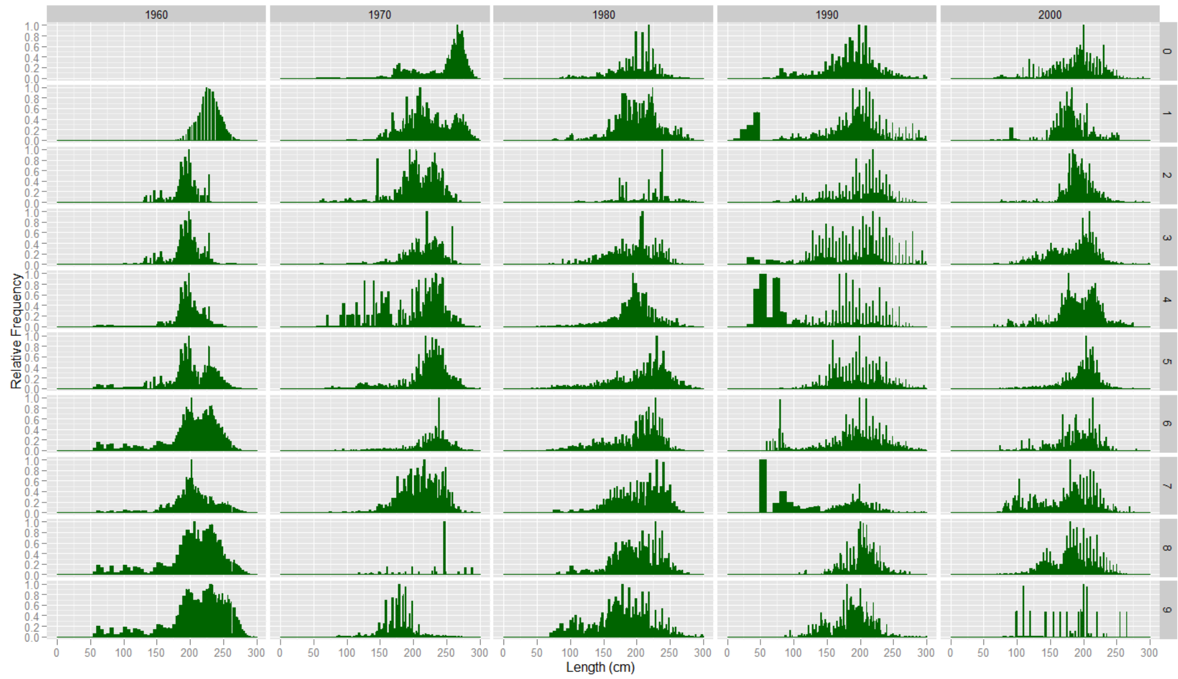

Figure 3. Long line length frequency distributions by decade (column) and year (row).

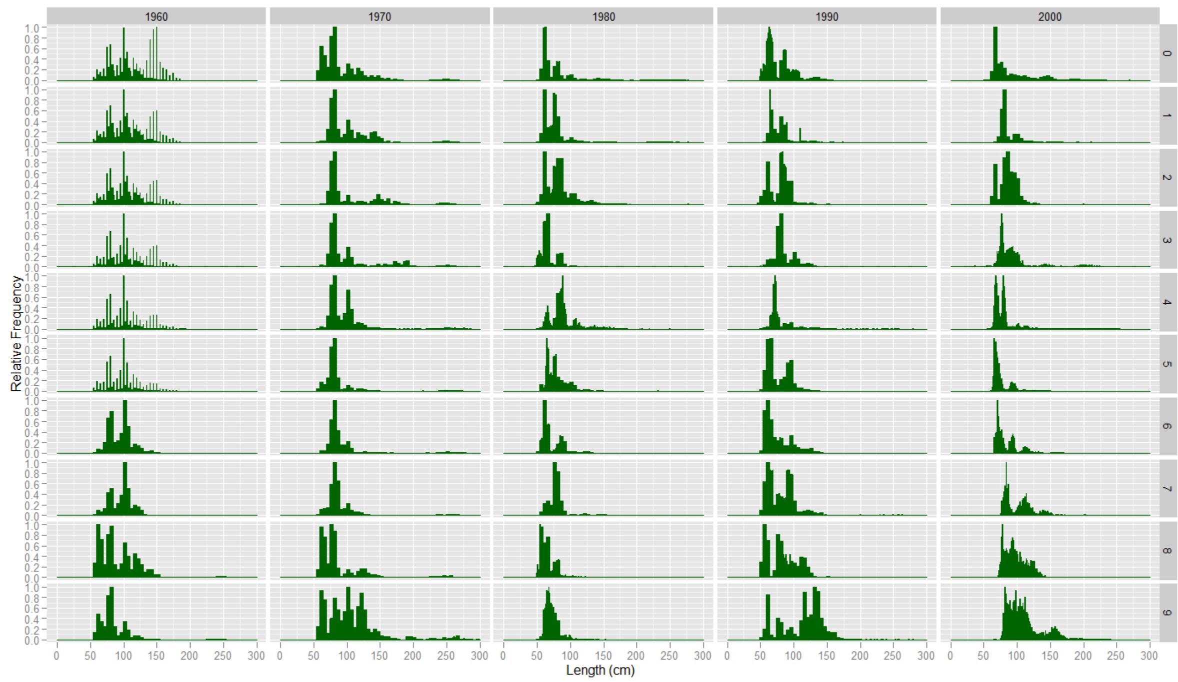

Figure 4. Bait boats length frequency distributions by decade (column) and year (row).

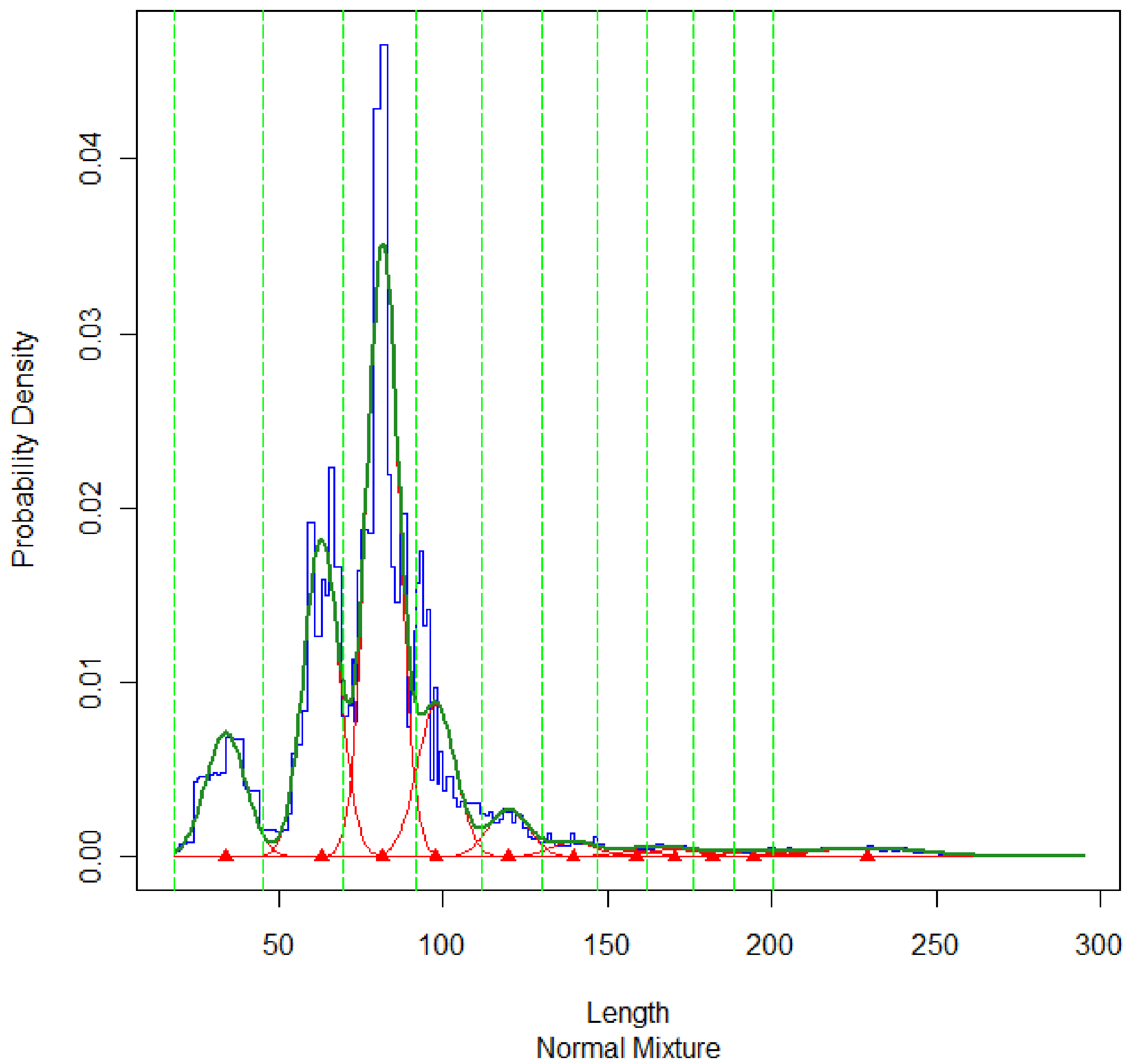

Figure 5. Length frequency distribution for 1987 partitioned by age; blue denotes observed length frequency, red the fitted distributions by age, green solid line the fitted length distribution and green vertical hatched lines length by age at midyear.

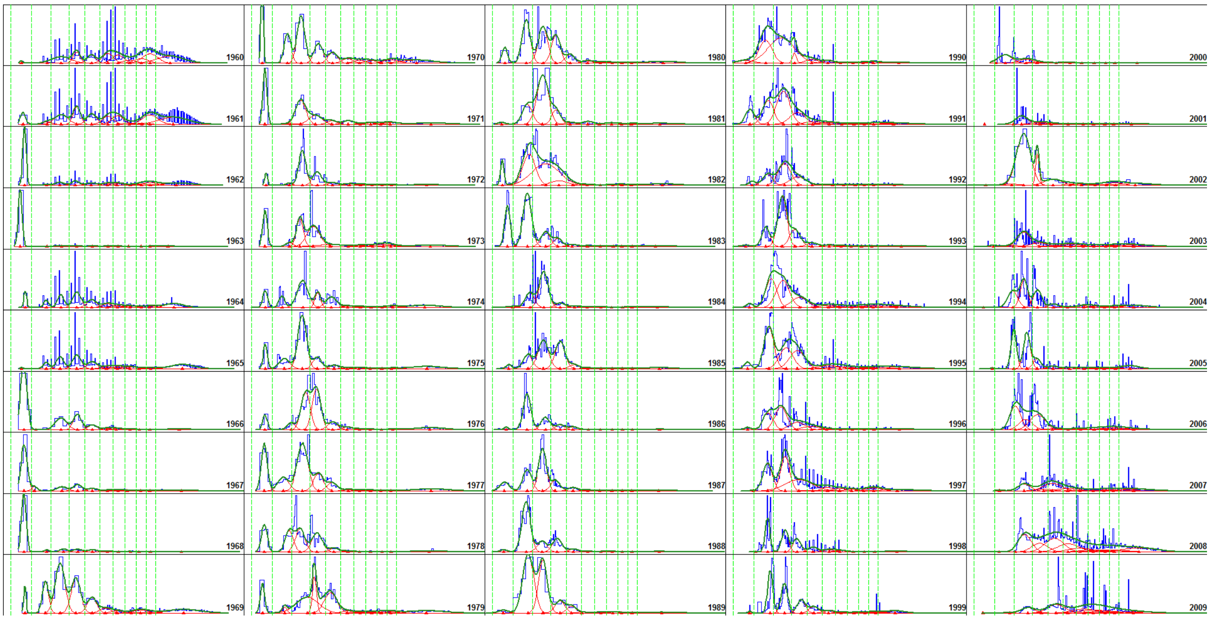

Figure 6. Length frequency distribution for all years partitioned by age; blue denotes observed length frequency, red the fitted distributions by age, green solid line the fitted length distribution and green vertical hatched lines length by age at midyear.

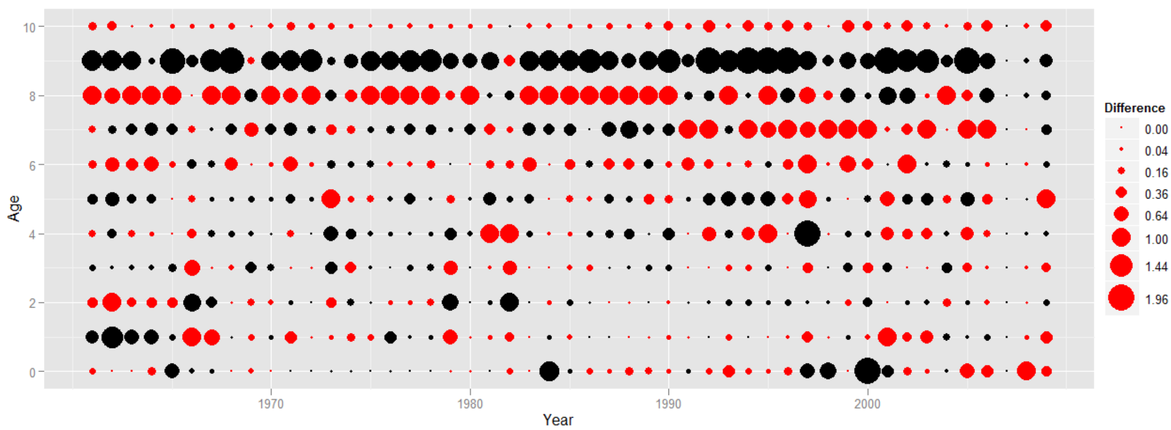

Figure 7. Comparison of catch-at-age obtained by age slicing and statistical estimation. Bubbles correspond to the relative difference in the statistical estimates (α) compared to those obtained by age slicing (β), i.e. (α-β)/β.

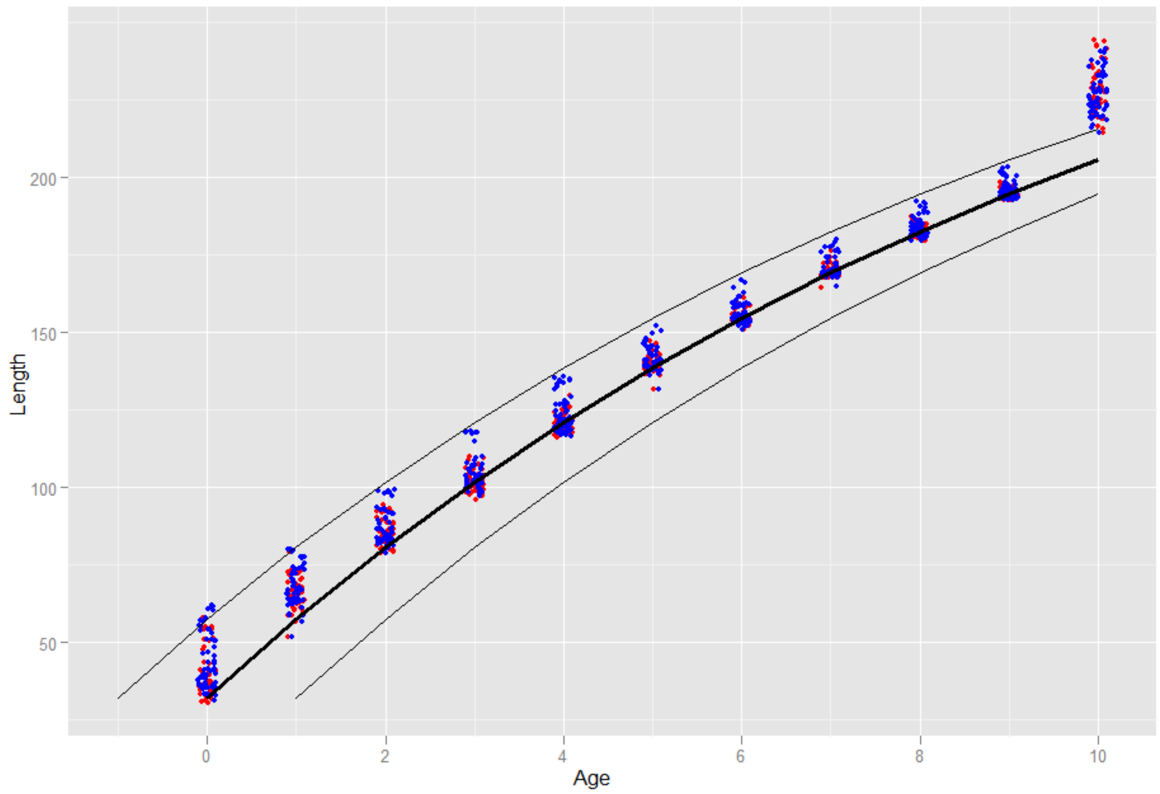

Figure 8. Comparison of growth curve and weight-at-age estimates from age slicing (blue) and statistical estimation (red); thin lines represent weight at age ± 0.5.

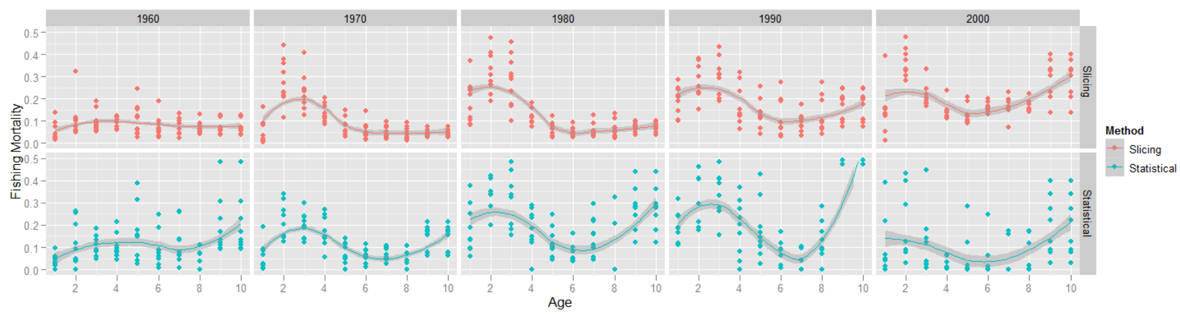

Figure 9. Fishing mortality by age and decade estimates from separable VPA, for age slicing and statistical age estimation

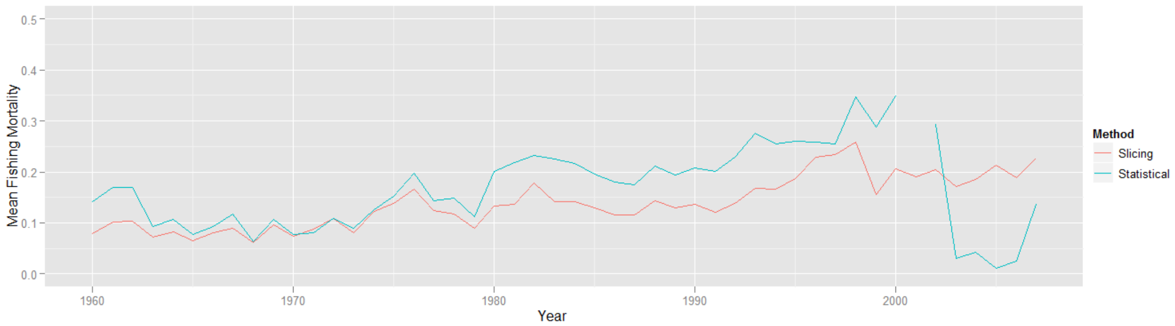

Figure 10. Mean fishing mortality estimates from separable VPA, for age slicing and statistical age estimation

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Table 1. Coefficient of variation in proportion of catch-at-age from statistical age estimation.

	Decade				
Age	60´s	70´s	80´s	90´s	00´s
0	1%	0%	1%	1%	231%
1	1%	9%	0%	0%	96%
2	242%	1%	0%	1%	0%
3	2%	1%	1%	2%	1%
4	1%	2%	2%	25%	2%
5	2%	2%	2%	2%	31306%
6	5%	3%	6%	19%	10973%
7	3%	3%	17%	581812%	403072200%
8	6097369%	459370%	924614%	474214%	2469%
9	3%	3%	11%	4%	5%
10	1%	1%	2%	1%	1%