SOME BENCHMARKS DIAGNOSTICS

Laurie Kell[1]

SUMMARY

The SCRS presents stock assessment results to the Commission using the Kobe advice framework where estimates of stock status and probabilities of meeting management targets are reported relative to MSY *benchmarks. For advice based on Virtual Population Analysis (VPA) reference points are calculated after the historical stock assessment. In this document some diagnostics are presented that may help in making choices about derivation of these benchmarks*

RÉSUMÉ

Le SCRS présente à la Commission les résultats de l'évaluation des stocks en utilisant le cadre d'avis de Kobe où les estimations de l'état des stocks et les probabilités de réalisation des objectifs de gestion sont déclarées par rapport aux paramètres de la PME. Pour les avis basés sur l'analyse de population virtuelle (VPA), des points sont calculés après l'évaluation des stocks historique. Dans ce document, certains diagnostics sont présentés, lesquels pourraient aider à faire des choix sur la dérivation de ces paramètres.

RESUMEN

El SCRS presenta los resultados de la evaluación de stock a la Comisión utilizando el marco de asesoramiento de Kobe, en el que las estimaciones de la situación del stock y las probabilidades de cumplir los objetivos de ordenación se presentan en relación a los elementos de referencia del RMS. Para el asesoramiento basado en análisis de población virtual (VPA), los puntos de referencia se calculan después de la evaluación histórica del stock. En este documento se presentan algunos diagnósticos que podrían ayudar a la hora de hacer elecciones sobre la derivación de estos elementos de referencia.

KEYWORDS

Kobe framework, Reference points, Virtual population analysis

Introduction

The SCRS presents stock assessment results to the Commission using the Kobe advice framework where estimates of stock status and probabilities of meeting management targets are reported relative to *MSY* benchmarks. For advice based on Virtual Population Analysis (VPA) reference points are calculated after the historical stock assessment. In this document some diagnostics are presented that may help in making choices about derivation of these benchmarks. See for a consideration of other sources of uncertainty.

Material and Methods

The data used are the results from a Virtual Population Analysis (VPA) for East Atlantic and Mediterranean bluefin tuna. As in the assessment values of mass, natural mortality and maturity-at-age are assumed not to vary by year. The selection pattern however does change due to targeting and management and is normally derived from the geometric mean of a recent period.

1. ICCAT Secretariat, C/Corazón de María, 8. 28002 Madrid, Spain; Laurie.Kell@iccat.int; Phone: +34 914 165 600 Fax: +34 914 152 612.

A plusgroup of 40 was assumed to allow the consequences of rebuilding the population structure to be evaluated; mass-at-age was calculated from the growth curve, all other aged based parameters for ages 10 to 40 assumed to be the same as the original plus group.

Methods

Aged based reference points are estimated using an age-structured equilibrium model, where SSB-per-recruit, yield-per-recruit and stock–recruitment analyses are combined, using fishing mortality (*F*), natural mortality (*M*), proportion mature (*Q*) and mass (*W*) -at-age with a stock–recruitment relationship.

SSB-per-recruit (S / R) is then given by

$$S/R = \sum_{a=r}^{n-1} e^{\sum_{i=r}^{a-1} -F_i - M_i} W_a Q_a + e^{\sum_{i=r}^{n-1} -F_n - M_n} \frac{W_n Q_n}{1 - e_{-F_n - M_n}} \qquad (1)$$

where *a* is age, *n* is the oldest age, and *r* the age at recruitment. The second term is the plus-group (i.e. the summation of all ages from the last age to infinity).

Similarly for yield per recruit (Y / R)

$$Y/R = \sum_{a=r}^{n-1} e^{\sum_{i=r}^{a-1} -F_i - M_i} W_a \frac{F_a}{F_a + M_a} \left(1 - e^{-F_i - M_i}\right) + e^{\sum_{i=r}^{n-1} -F_n - M_n} W_n \frac{F_n}{F_n + M_n} \qquad (2)$$

The stock recruitment relationship is reparameterised so that recruitment *R* is a function of S / R allowing *S* to be derived from F.

Stock Recruit Relationship

A Shepherd Stock Recruit Relationship (SRR; Shepherd, 1988) was used i.e.

$$R = \frac{\alpha\ S}{[1 + (S/K)^{\beta}]}$$

where

α is the slope at the origin and is a measure of the maximum recruitment per unit spawning stock biomass. This can only occur at low stock sizes where density-dependent effects do affect recruitment

K is the stock size where the transition from density-independent to density-dependent processes occurs. If the stock falls below *K* then any stability afforded by density-dependent effects decreases and chances of stock collapse increase.

β is an indication of the density-dependent effects. If β <1 density-dependent effects are minimal, β = 1 then density-dependent effects exactly compensate for increases in stock size and if β > 1 there are very high density-dependent effects at high stock sizes.

The cross correlation between *S* and *R* allows the relationship between recruitment and SSB to be evaluated. For example if there is a monotonic relationship of *R* with *B*, i.e. a Beverton and Holt or Cushing stock recruitment relationship then there will be a significant correlation equal to the age at recruitment. However if stock biomass is driven by recruitment as a result of fluctuations in the environment then there will be negative lags at corresponding to the mature ages.

Evidence for regime shifts are explored using a a sequential t-test algorithm (STARS, Rodionov, 2004).

Bootstrap Bias

The bootstrap is used routinely to estimate the variance in stock assessment outputs, e.g. in the Kobe Phase Plot which are then carried through into stock projections in the Kobe Strategy Matrix. However uncertainty analysis is not just about evaluating probabilities but about identifying, violation of model assumptions, highly correlated or ill-defined parameters and lack of model convergence. For example the bootstrap can sometimes find a new global optimum, resulting in an improved model fit to the data. The bootstrap also allows bias to be estimated. If the difference is large then this may indicate a problem with the assessment requiring further analyses.

Results

In this section we first present the estimated quantities from the VPA, best fit and the bootstrap. The relationship between SSB and recruitment is then examined and the consequences for the expected dynamics based on equilibrium assumptions explored. Finally we look at some population metrics that could serve as indicators and validation of analytical assessments.

Bootstrap estimates

Time series of recruits and spawning stock biomass estimated by the VPA best fit and the Bootstrap are shown in **Figure 1**; the corresponding bootstrap estimates of bias are shown in **Figures 2 and 3**. The geometric means of fishing mortality-at-age of 2012 and 2013 are shown in **Figure 4** and the bias in **Figure 5**.

The bootstrap procedure resampled the residuals from the fits to the catch per unit effort (CPUE).

Stock Recruit

The cross correlations between recruitment and SSB are shown in **Figure 6**. Negative correlations are seen for all lags which could be explained by an increase in recruitment while SSB declines i.e. recruitment is increasing independently of SSB while SSB is declining due to increasing exploitation.

A Shepherd SRR was fitted to the S-R series, **Figures 7** and **8**, for β = 1 and 2 assuming compensatory and over compensatory dynamics respectively. These plots show the fits to the data and also diagnostics that allow model assumptions to be checked, i.e. that there is no systematic pattern in the residuals, that they are normally distributed, there is no autocorrelation and that the variance assumptions are correct.

The residuals are plotted by year in **Figures 9 and 10** along with rectangles showing the mean ± 1SD of the regimes detected by sequential t tests for regime shifts .

Equilibrium or Expected dynamics

Equilibrium curves for the two SRRs conditioned on the assumed biological values and estimated selectivity are shown in **Figures 11** The corresponding curves where the recruitment level is based on the sequential t tests are plotted in **Figures 12 and 13**.

Indicators

The proportion of plus group to total biomass as a function of F derived from the equilibrium analysis is plotted in **Figure 14**, the vertical lines indicate $F_{0.1}$ and F_{MSY} and the blue line the VPA estimates-

Mean size in the plus group as a function of F is plotted in **Figure 15**. The upper black line is the estimate from the equilibrium analysis and the lower the mass-at-age of age 10; again the vertical lines indicate $F_{0.1}$ and F_{MSY} and the blue line the VPA estimates.

Discussion

The mechanisms for productivity in this analysis are limited solely to the SRR as all other biological processes are assumed not to be stationary and density independent. Any discussion of productivity is therefore limited to the impact of the stock recruitment relationship.

MSY reference points are also a function of the selection pattern, which is also a tool for management.

The parameters of the Shepherd SRR parameters and their effect on the dynamics are

α

Recruitment per unit Spawner Reproductive Potential (SRP). F_{MSY}, r and F_{crash} will change does B_{MSY} change? is SSB a good proxy for SRP anyway?

K

stock size where density-dependence kicks in. Need to keep stock above K so what is an appropriate B_{lim} and F_{lim}

β

density-dependent v. density-independent effects (Vert-pre *et al.* 2013) recruitment a function of population size that productivity shifts irregularly between regimes unrelated to abundance production is related to abundance but there are irregular changes in the relationship production is random from year to year.

The non stationarity for biological reference points depend upon the mechanism through factors such as the environment act on recruitment, i.e. on juvenile survival or carrying capacity. However, it is highly unlikely to be able to distinguish between these processes with stock assessment data sets alone.

Conclusions

The bootstrap should not just be considered a way of estimating uncertainty for Kobe Phase Plots and Strategy Matrices, but a diagnostic method in its own right. Where bias exists causes should be identified and the consequences of not correcting for bias evaluated.

The Kobe advice framework requires assumptions to be made about the future productivity of stocks which is mainly based on past dynamics. However, what plausibility and hence weight should be assigned to dynamics from different periods and under different assumptions when as in this case and as shown in recent reviews considerable uncertainty exists about recruitment dynamics?

The answer partly depends on the assumptions about the factors affecting the dynamics, e.g. does climate change mean that future dynamics are unlikely to be the same as in the past. Or as pointed out ecosystem variability can involve a variety of climate to ecosystem transfer functions which can convert the red noise of the physical system to redder (lower frequency) noise of the biological response. However, these can also convert climatic red noise to more abrupt and discontinuous biological shifts.

The use of Management Strategy Evaluation (MSE) to develop management that is robust to changes in recruitment processes and climate and environmental uncertainty is widely being accepted as the way forward, see for a bluefin example.

References

S. N. Rodionov. A sequential algorithm for testing climate regime shifts. Geophysical Research Letters, 31(9), 2004.

J. Shepherd. A versatile new stock-recruitment relationship for fisheries, and the construction of sustainable yield curves. ICES Journal of Marine Science: Journal du Conseil, 40:67–75, 1982.

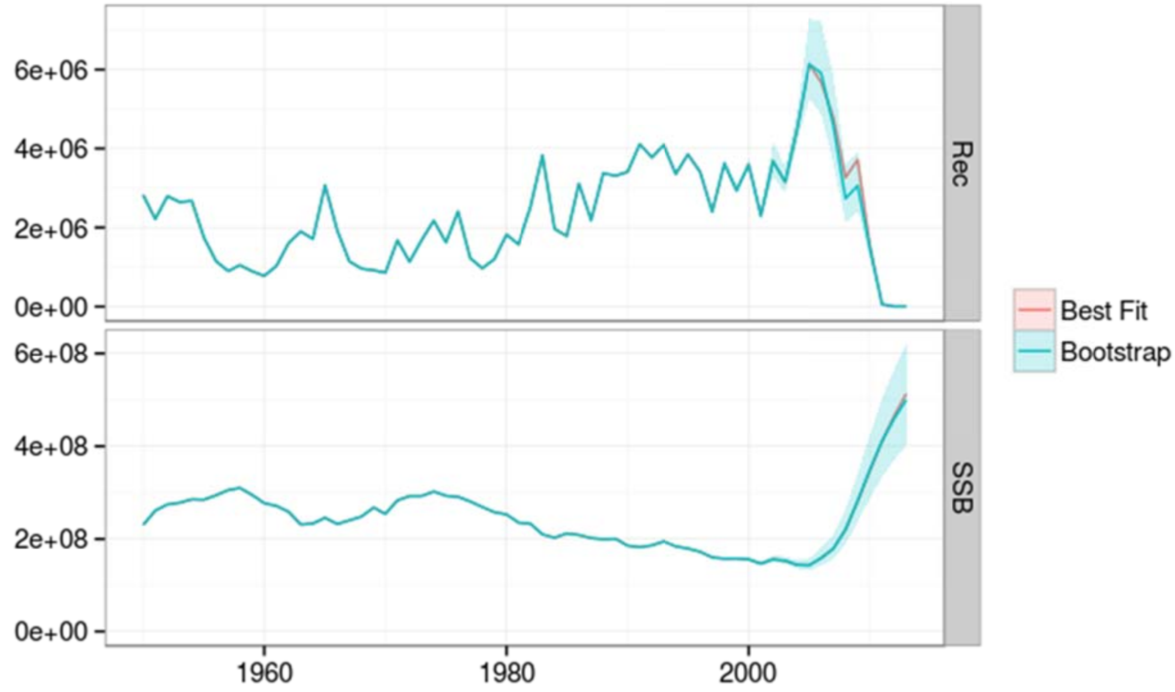

Figure 1. Time series of recruits and spawning stock biomass as estimated by VPA, these show the bootstrapped CIs and median blue and the values from the best fit to the original data.

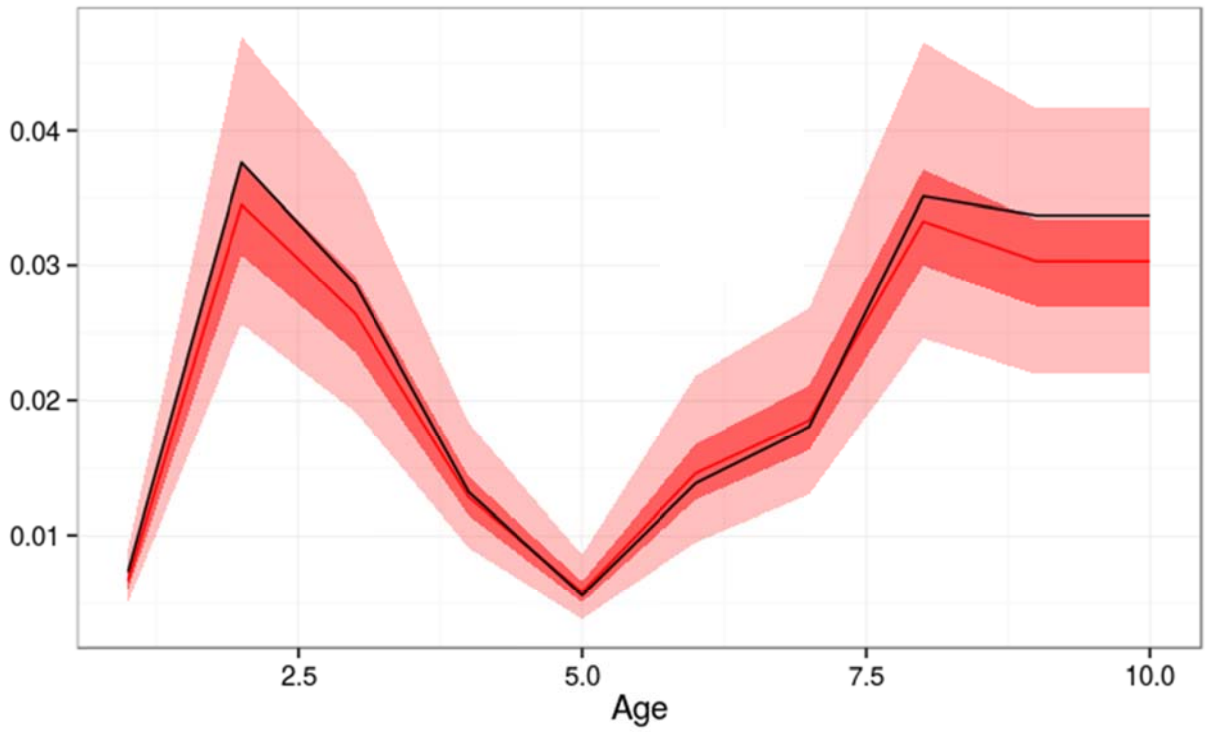

Figure 2. Geometric mean of fishing mortality-at-age of 2012 and 2013, red ribbon shows bootstrapped CIs and median, black like the estimates from the best fit to the actual data.

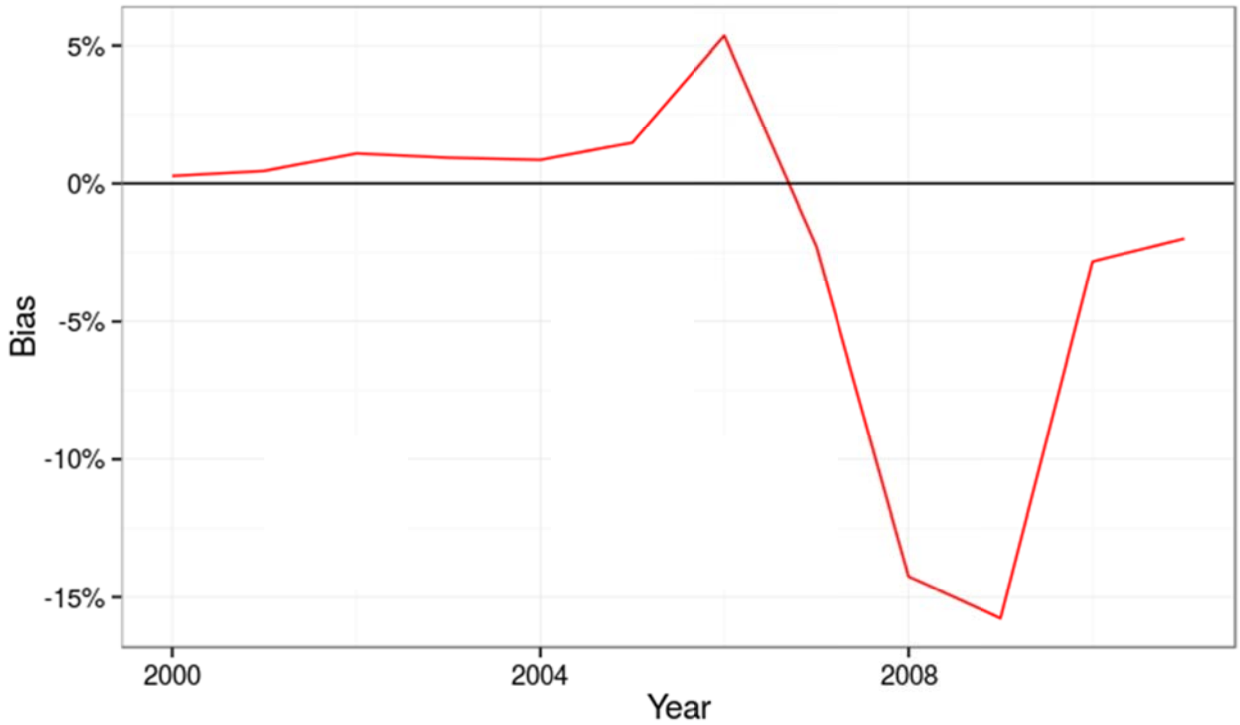

Figure 3. Bootstrap bias for recruit estimates.

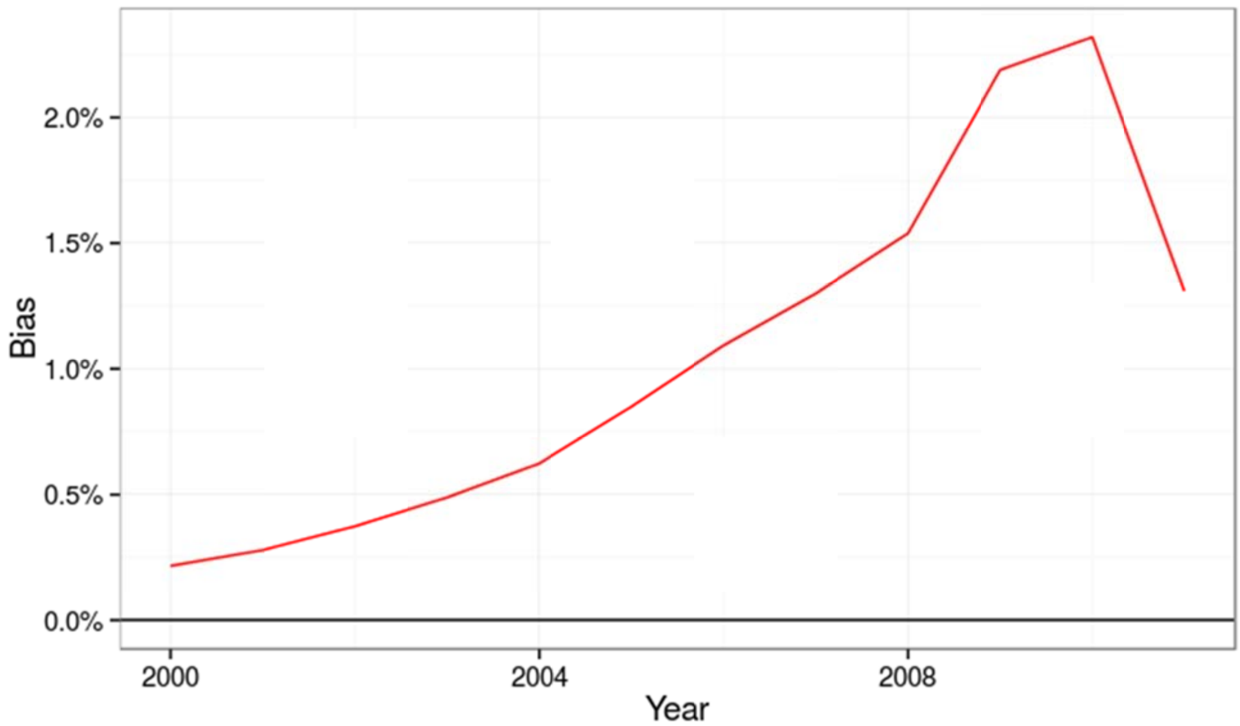

Figure 4. Bootstrap bias for SSB estimates.

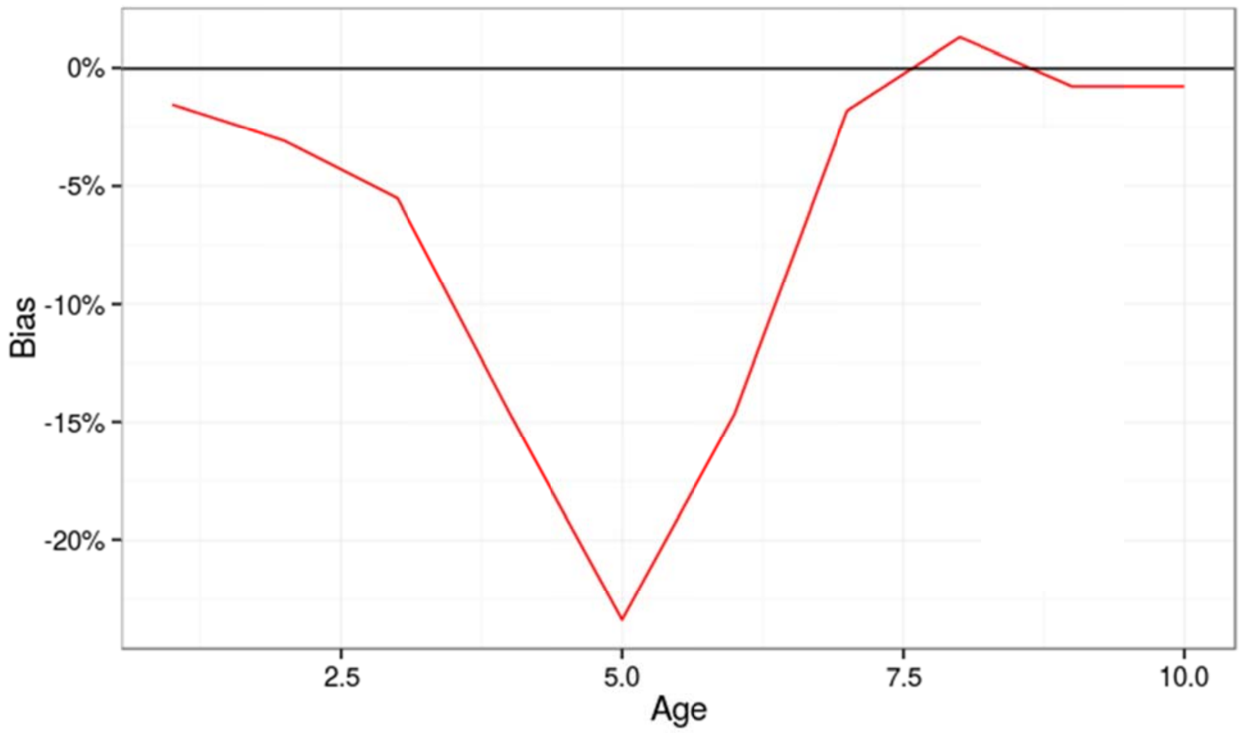

Figure 5. Bootstrap bias for fishing mortality-at-age.

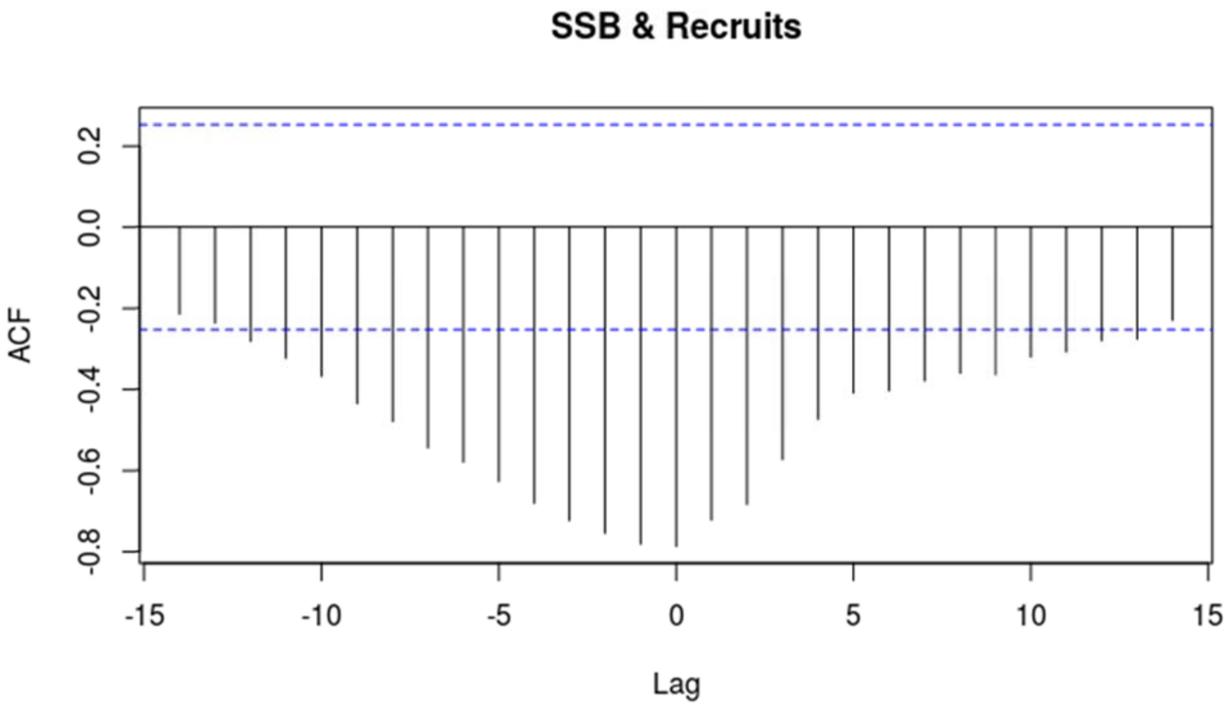

Figure 6. Cross correlations between recruitment and SSB.

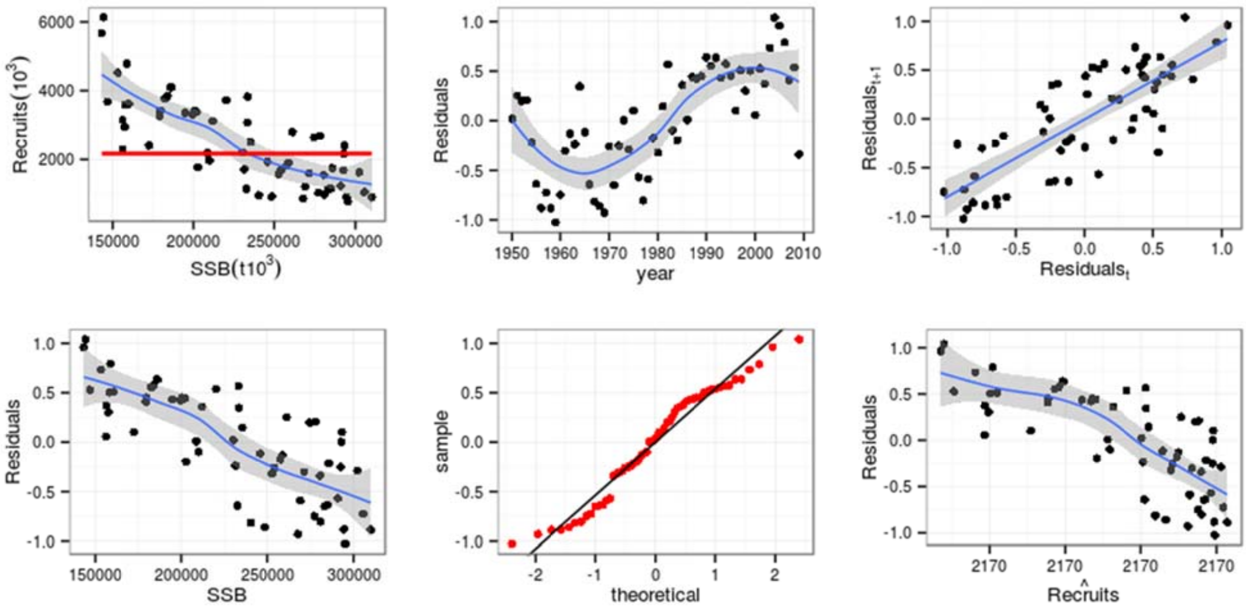

Figure 7. Shepherd Stock Recruitment Relationship (SRR) with beta=1 (i.e. Beverton and Holt like functional form) with diagnostics.

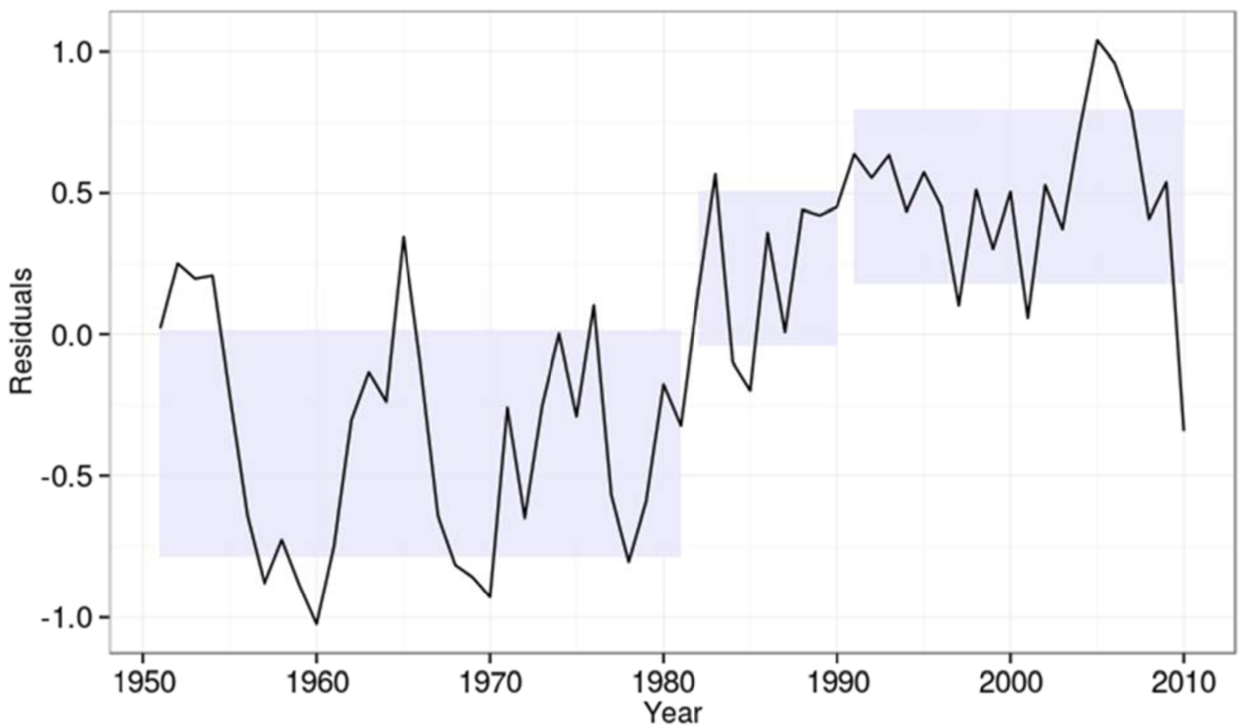

Figure 8. Residuals from the SRR fit with beta =1, the rectangles show the estimates of mean and 1 SD.

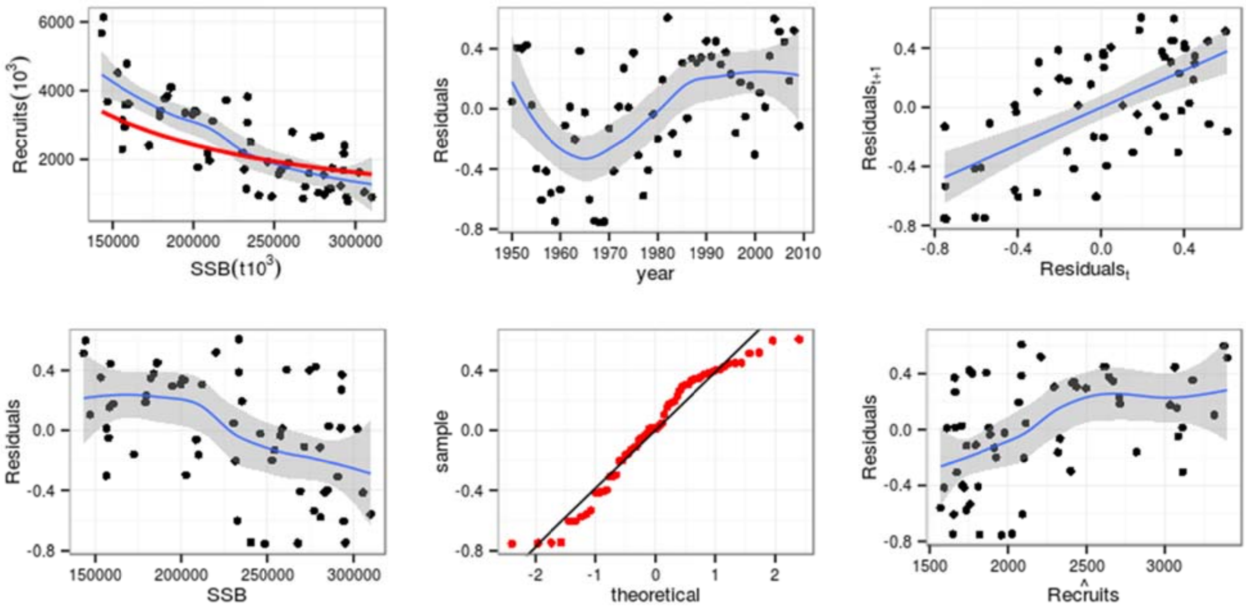

Figure 9. Shepherd Stock Recruitment Relationship (SRR) with beta=2 (i.e. Ricker like functional form) with diagnostics.

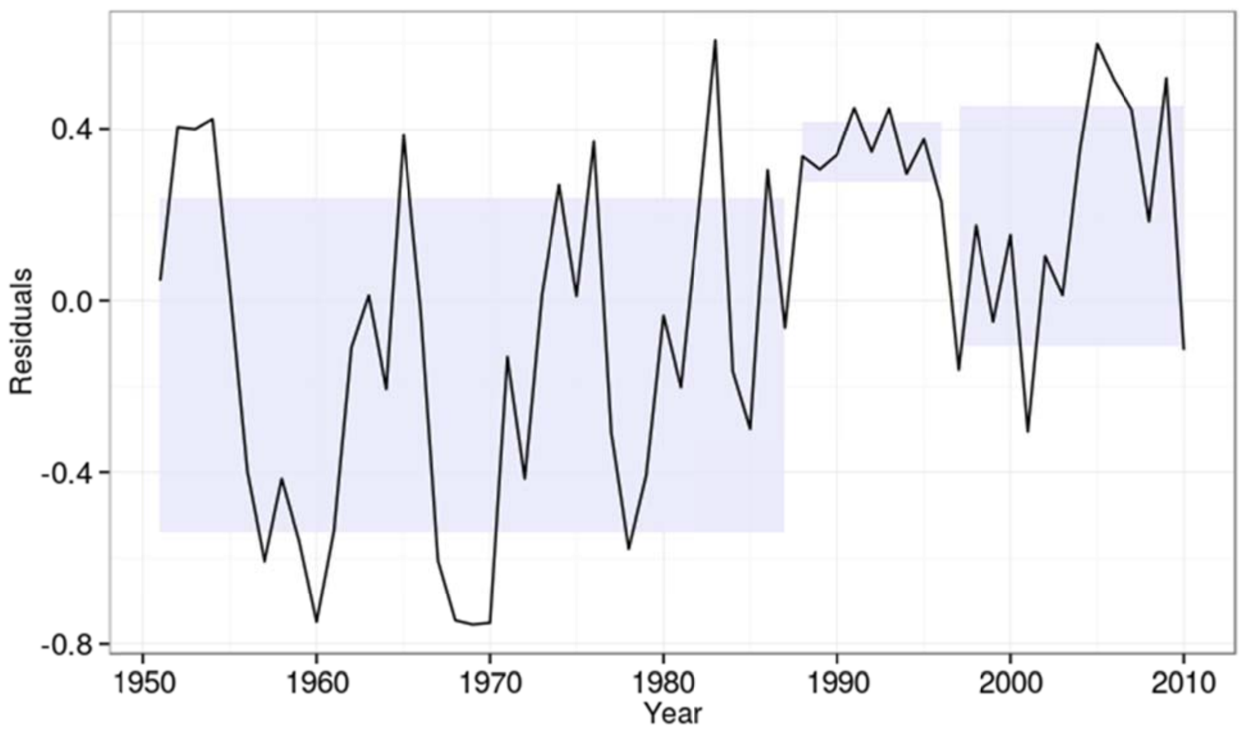

Figure 10. Residuals from the SRR fit with beta=2, the rectangles show the estimates of mean and 1 SD.

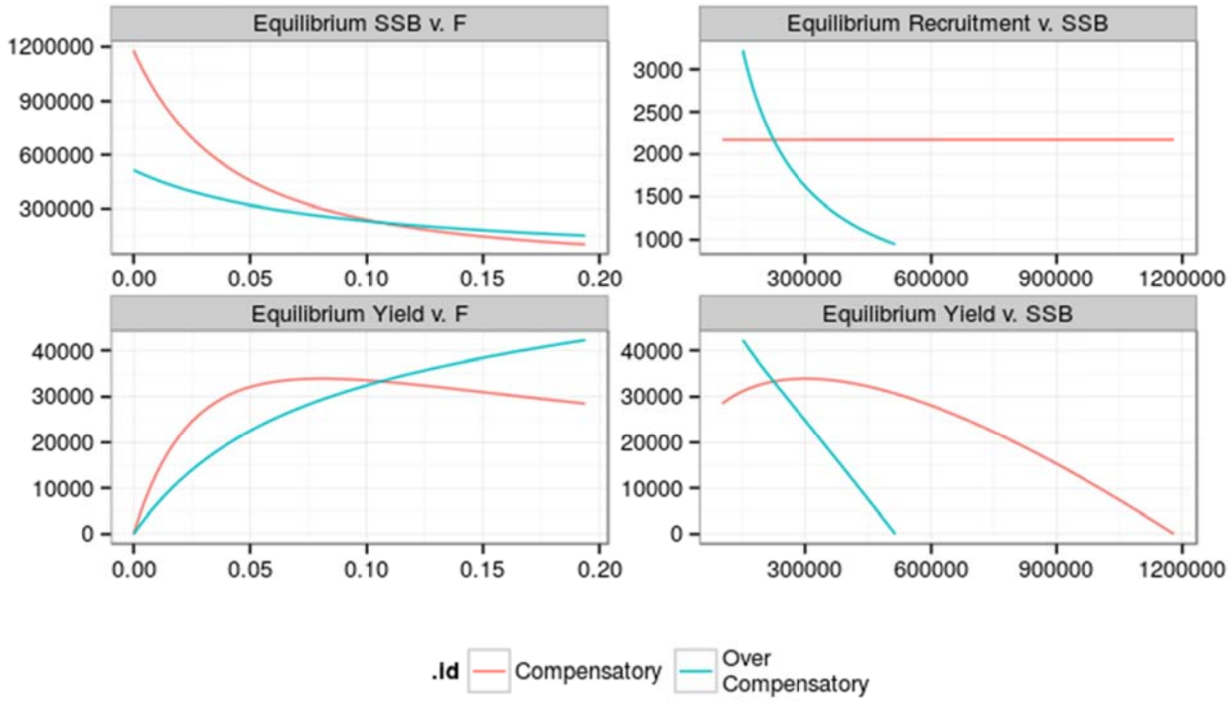

Figure 11. Equilibrium curves for the two SRRs, assumed biological values and estimated selectivity.

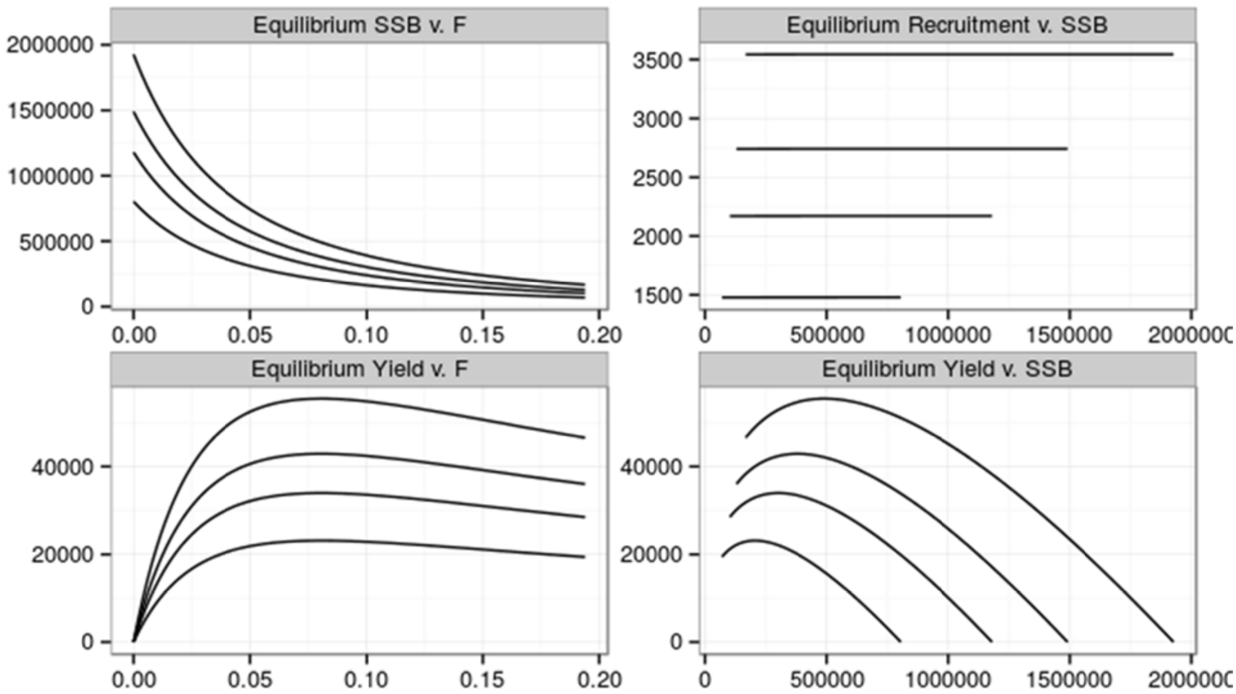

Figure 12. Equilibrium curves for the the Shepherd SRR with β=1, for the assumed biological values and estimated selectivity-at-age.

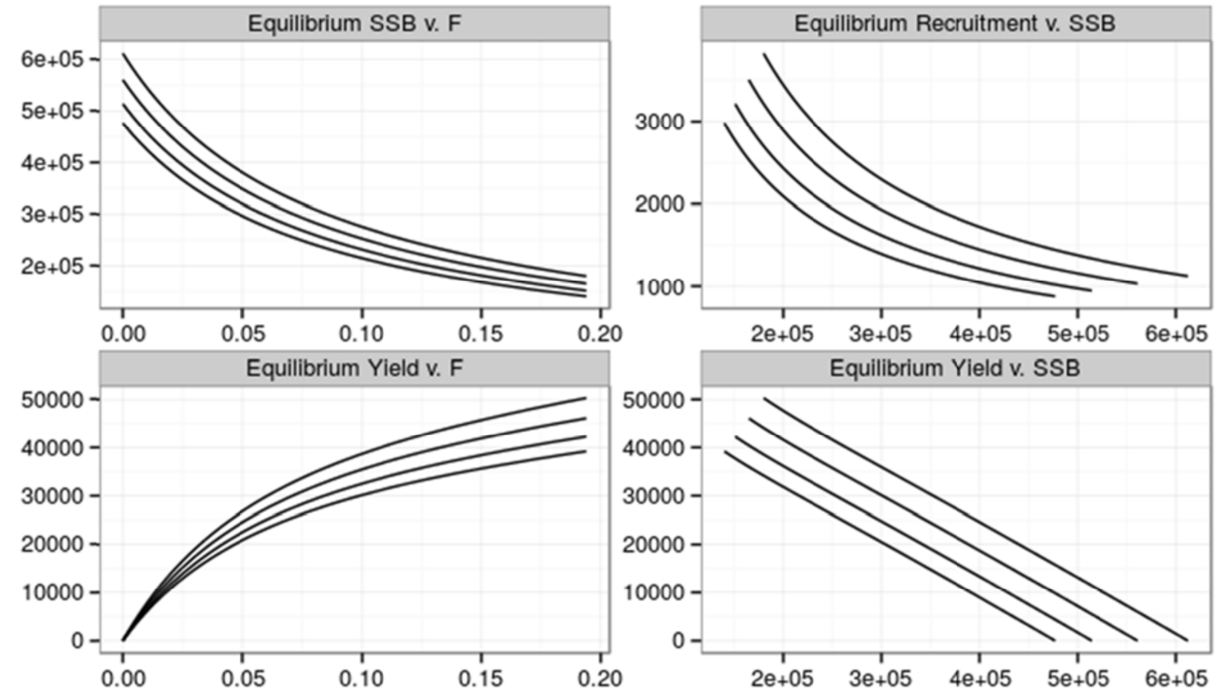

Figure 13. Equilibrium curves for the the Shepherd SRR with β=2, for the assumed biological values and estimated selectivity-at-age.

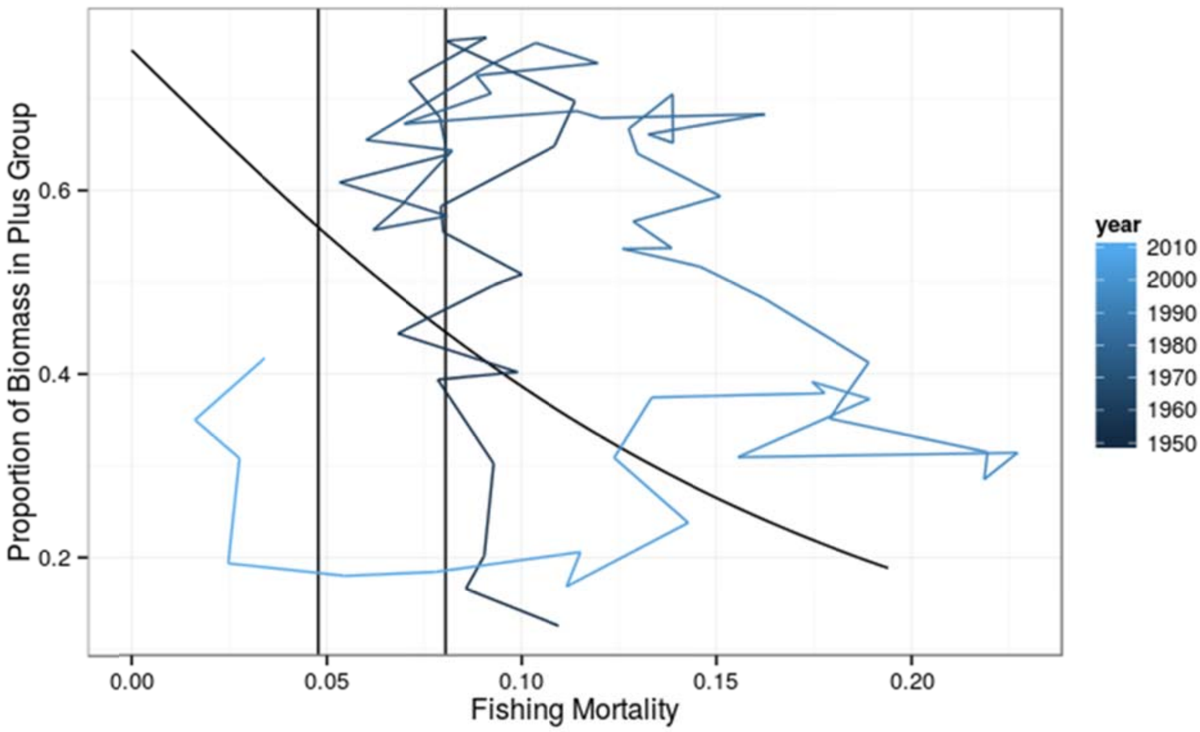

Figure 14. Proportion of biomass in the plus group as a function of F, the black line is the estimate from the equilibrium analysis, the vertical lines indicate $F_{0.1}$ and F_{MSY} and the blue line the estimated values from the VPA.

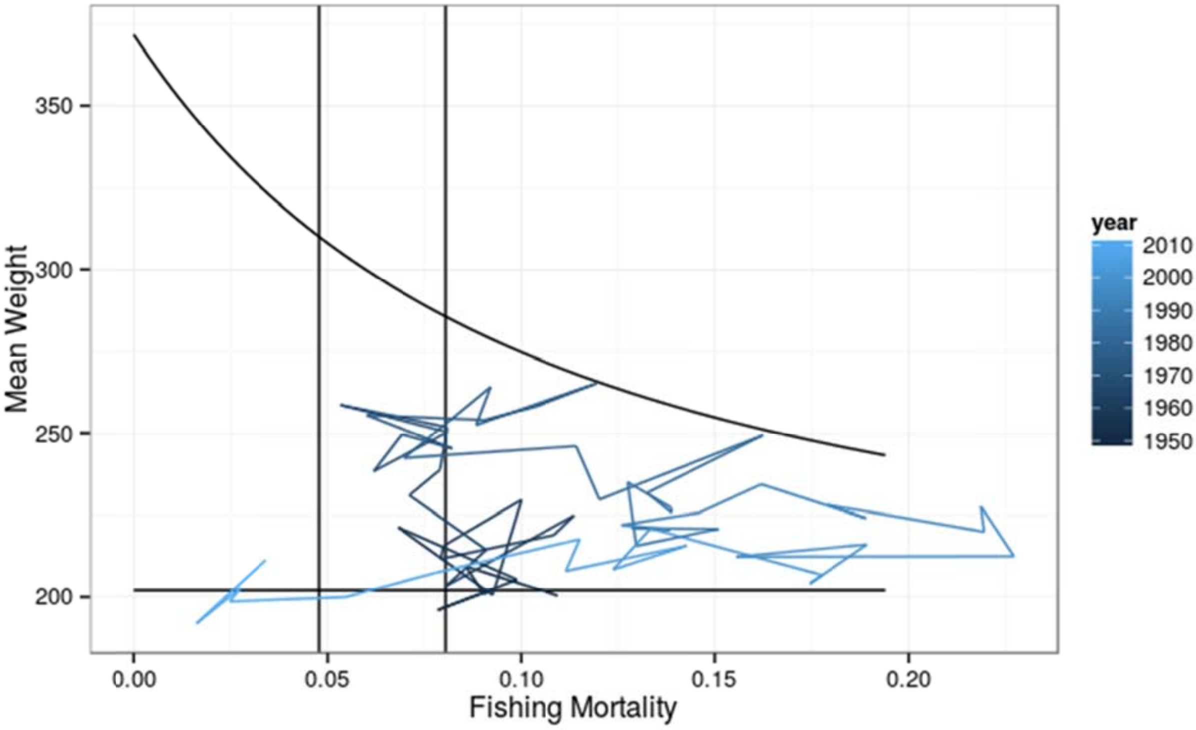

Figure 15. Mean size in the plus group as a function of F, the black line is the estimate from the equilibrium analysis, the vertical lines indicate $F_{0.1}$ and F_{MSY} and the blue line the estimated values from the VPA.