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STOCK ASSESSMENT DIAGNOSTICS FOR NORTH ATLANTIC SWORDFISH

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SUMMARY

Catch and catch per unit effort are used to fit a biomass dynamic stock assessment model. A variety of diagnostics are then used to check for violations of model assumptions and to explore the information in the data. Potential problems are identified and ways to overcome or avoid them discussed.

RÉSUMÉ

La capture et la capture par unité d'effort sont utilisées pour ajuster un modèle d'évaluation des stocks dynamique de la biomasse. Divers diagnostics sont ensuite utilisés afin de détecter le non-respect des postulats du modèle et d'explorer les informations dans les données. Les problèmes potentiels sont identifiés et les façons de les surmonter sont discutées.

RESUMEN

La captura y la captura por unidad de esfuerzo se usan para ajustar un modelo de evaluación de stock de dinámica de biomasa. A continuación se utilizan diferentes diagnósticos para comprobar infracciones de los supuestos del modelo y explorar información en los datos. Se identifican posibles problemas y se discuten formas de superarlos o evitarlos.

KEYWORDS

Swordfish, ASPIC, Assessment, Biomass Dynamic, Diagnostics, North Atlantic, Likelihood Profiles, Surplus Production

1. Introduction

A range of stock assessment models are used by the SCRS, from biomass dynamic models using catch and effort data with only a few parameters to statistical catch-at-size models with potentially 1000s of parameters. Despite these differences the methods are being used for the same purpose i.e. to estimate population parameters from fisheries dependent data. Therefore the Stock Assessment Methods Working Group (WGSAM) recommended that a common framework be developed to help ensure some consistency across assessment packages when decisions are being made about model choices. A common set of diagnostics that can be used for different stock assessment models were proposed in SCRS2013-36. Here we apply those diagnostics to the North Atlantic swordfish biomass dynamic assessment using ASPIC Prager (1992). The intention is to not provide strict guidelines but to look at some methods that can be used for a range of stock assessment models that use indices of abundance such as Catch per Unit Effort (CPUE) for fitting.

2. Materials and methods

A Stock Production Model Incorporating Covariates (ASPIC) is a non-equilibrium implementation of a biomass dynamic model based on surplus production model. ASPIC uses time series of indices of abundance and catch biomass to estimate stock status and uses bootstrapping to construct sampling distribution for a statistic of interest, e.g. stock status, the biomass that would provide the maximum sustainable yield (B_{MSY} and MSY). The model was fit to five time series of catch and catch per unit of effort (CPUE) fisheries data covering 15 distinct fishing fleets. The main assumptions of ASPIC are that population dynamics are surplus production function e.g. Pella and Tomlinson (1969). Where biomass of a stock next year (B_{t+1}) as the sum of the biomass this year B_t less the catch (C_t) plus the surplus production (P_t) where (r) is the intrinsic rate of increase, (K) the carry capacity (p) the shape of the surplus production function. If $p < 1$ then the curve is skewed to the left.

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The dynamics i.e. productivity and reference points and the response of the stock to perturbations, are determined by r and the shape of the production function p; if p = 1 then MSY is found halfway between 0 and K, as p increases MSY shifts to the right.

It is also assumed that catches and catch per unit effort (CPUE) are from a single homogeneous stock and that the CPUE represent stock trends in abundance. If there are zero or negative correlations between the indices, then this means that a basic assumption of ASPIC is violated, either because factors other than stock abundance are determining catch rates or that the indices are fishing different stock components.

3. Results

A single index of abundance was used, that had been created by combining all fleets using a GLM (SCRS2013/xxx). The combined index as estimated in 2009 (red) and 2013 (blue) are plotted in **Figure 1** for the entire series and from 1980. The error bars are the 10th and 90th confidence intervals. The index is replotted in **Figure 2** since the large values in early part of the series means the recent trends are obscured.

4. Crossvalidation

Gelman and Hill [2007] observed that when learning about a method it is convenient to predict outcomes that have already occurred, i.e. so the predictions can be compared to reality. Therefore to evaluate the performance of the 2009 ASPIC to provide advice in the Kobe framework we conduct a cross validation. We do this by taking the 2009 assessment then project the stock using the reported catches up to 2011 and compare the results to the current assessment.

5. Results

The assessment results, estimated time series of harvest rate and biomass, along with the reported catch are plotted in **Figure 3**. The main change in the assessment inputs has been in the index, catch has been updated for the recent years.

Three assessment runs are shown i.e. using the i) 2009 index, ii) 2013 index and iii) a retrospective analysis where the 2013 index was truncated to end in 2008. There is a big difference in stock assessment estimates; using the 2013 index results in stock biomass halving and harvest rate doubling. Since stock parameters, i.e. population growth rate (r) and virgin biomass (K) and reference points also changed the relative values are similar. However, if the assessment in 2009 had been conducted using the 2013 combined index the scientific advice would have been that the stock had not recovered.

Figure 4 presents the results of the cross validation, where the assessment from 2009 was projected to 2011 for the reported catches and compared to the current assessment.

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Figure 5 shows the profile for B0, showing that there is no information on the initial state of the stock in the data.

To check the fits the estimated parameters (MSY and K) were profiled for the residual sum of squares for a range of values, **Figures 6, 7 and 8**

Figure 9 shows Kobe phase plots for the three assessment runs, i.e. for 2009 index, 2013 index and for a retrospective analysis where the 2013 index was truncated to end in 2008

The observed values are plotted against the fitted values in **Figure 10**. ASPIC assumes that an index is proportional to the stock so the points should fall around the y = x line. However, the points fall below the y = x line at low stock size and above it at large stock sizes, i.e. the index is not consistent with stock estimates.

5.1 Residuals

Inspection of residuals allows a check for violation of models assumptions, e.g. patterns. Therefore the residuals are plotted against year in **Figure 11**, a lowess smoother is also fitted to help identify patterns. ASPIC assumes residuals are normally distributed and that there is no autocorrelation between them, these assumptions are evaluated in **Figures 12 and 13**. The Q-Q plots in **Figure 12** compare a sample of data on the vertical axis to a statistical population on the horizontal axis, in this case a normal distribution. If the points follow a strongly nonlinear pattern this will suggest that the data are not distributed as a standard normal i.e. X N(0; 1). Any systematic departure from a straight line may indicate skewness or over or under dispersion. For example in the panel showing the Taiwanese longline suggests that the negative residuals are much greater in magnitude than expected. It is also assumed that variance does not vary with the mean, this assumption is evaluated in **Figure 14** where the residuals are plotted against the fitted values.

Violation of the assumptions about the may result in biased estimates of estimated parameters, reference points and stock trends. In addition variance estimates obtained from bootstrapping assume that residuals are Independently and Identically Distributed (i.i.d.).

6. Discussion and conclusions

This paper presents some diagnostics for CPUE time series. The software is available as an R package (diags). Although the results are from ASPIC, the same plots can be generated for any stock assessment methods that uses fits to CPUE series for calibration. The paper was not intended to be used as a check list but an example of what to look at, how to do it, potential problems, consequences and how to overcome, but even better to avoid them, i.e. the intention is not to provide strict guidelines but to look at some methods that can be used for a range of stock assessment models that use indices of abundance such as Catch per Unit Effort (CPUE) for fitting.

It was seen that the biggest difference between the 2009 and 2013 assessment was due to the change in the CPUE series used.

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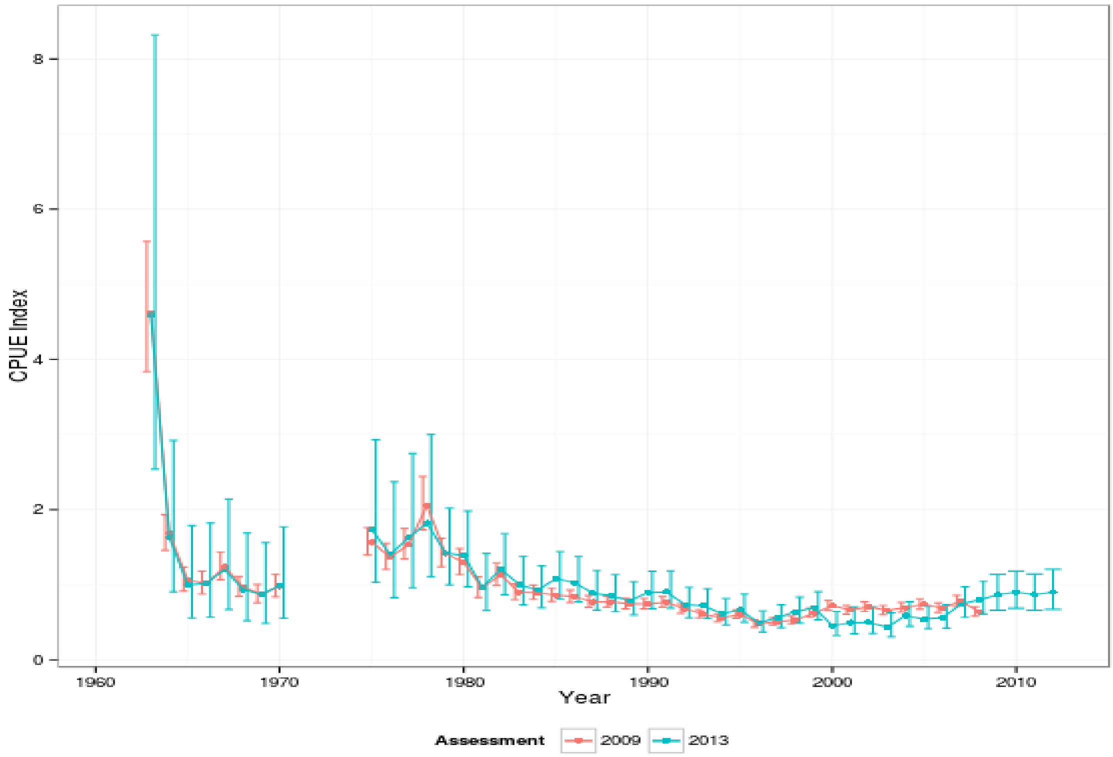

Figure 1. Combined index of abundance as estimated in 2009 (red) and 2013 (blue), error bars are the 10th and 90th Confidence Intervals.

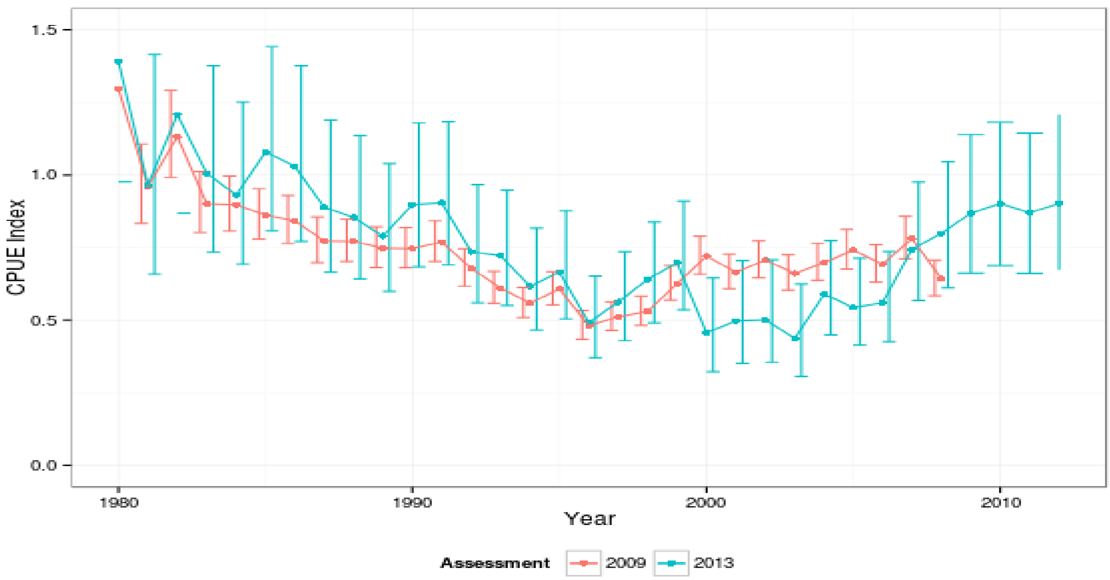

Figure 2. Combined index of abundance from 1980 onwards as estimated in 2009 (red) and 2013 (blue), error bars are the 10th and 90th Confidence Intervals

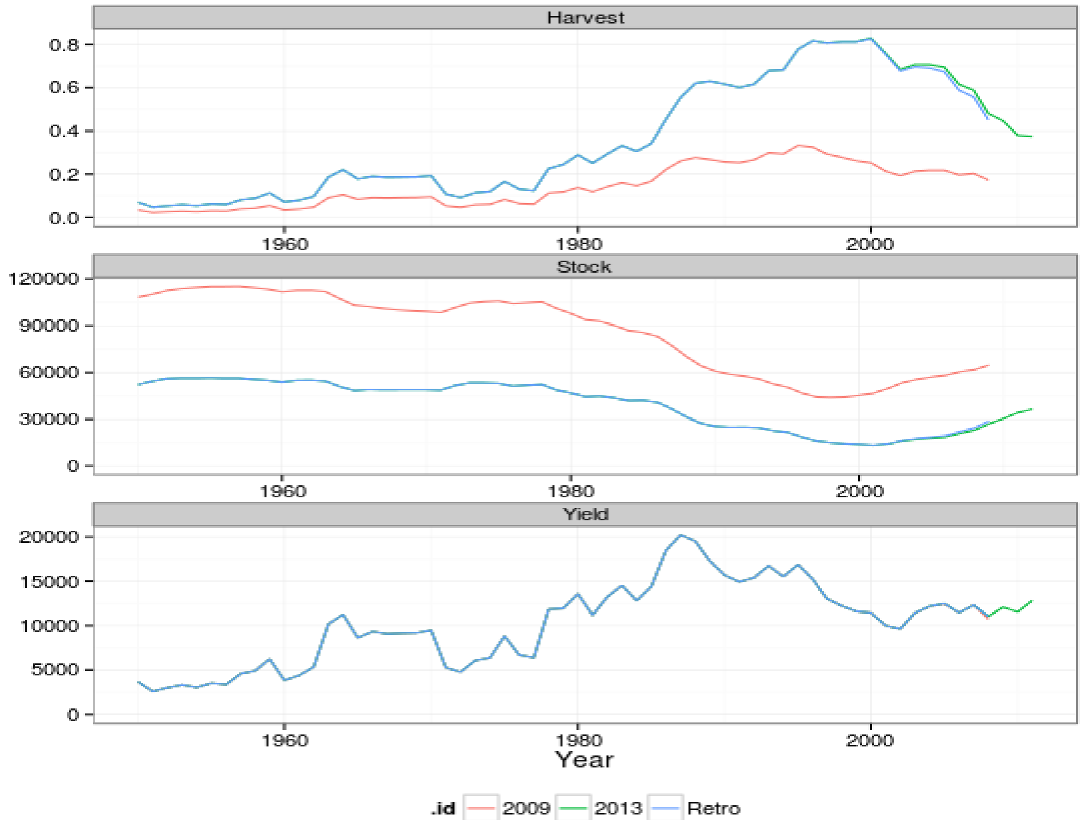

Figure 3. Historic time series of harvest rate, stock biomass and yield for the three assessment runs, i.e. for 2009 index, 2013 index and for a retrospective analysis where the 2013 index was truncated to end in 2008.

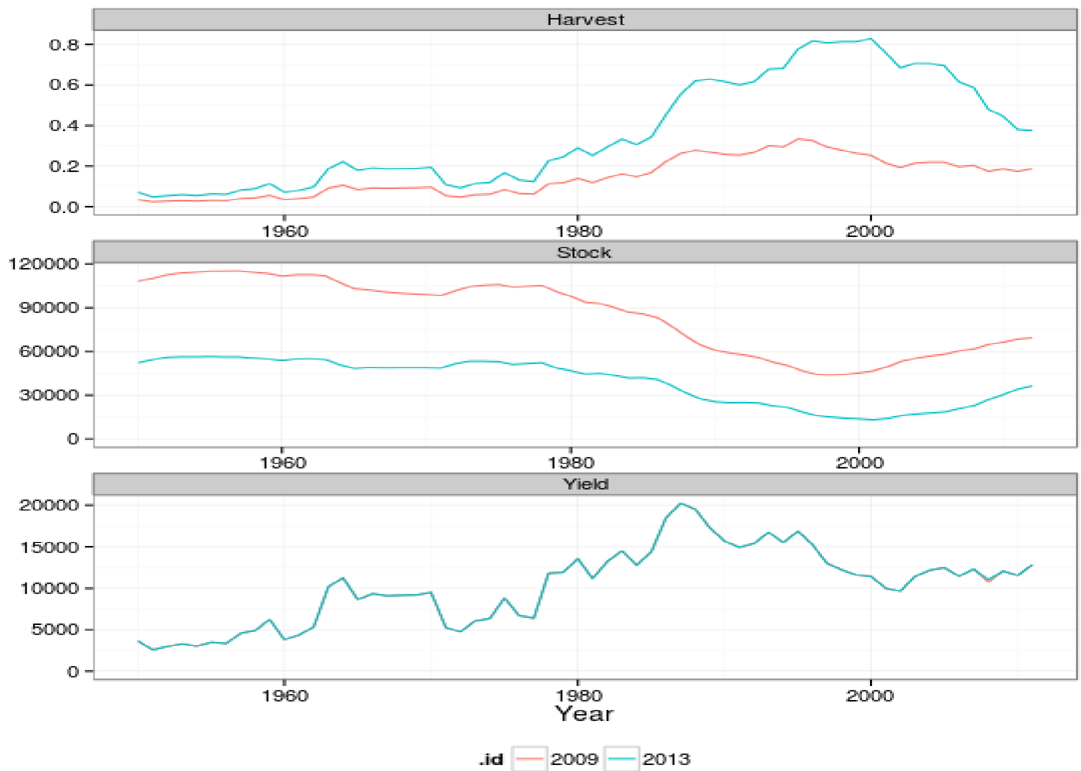

Figure 4. Crossvalidation, i.e. projection of the 2009 assessment using reported catches; time series of harvest rate, stock biomass and yield.

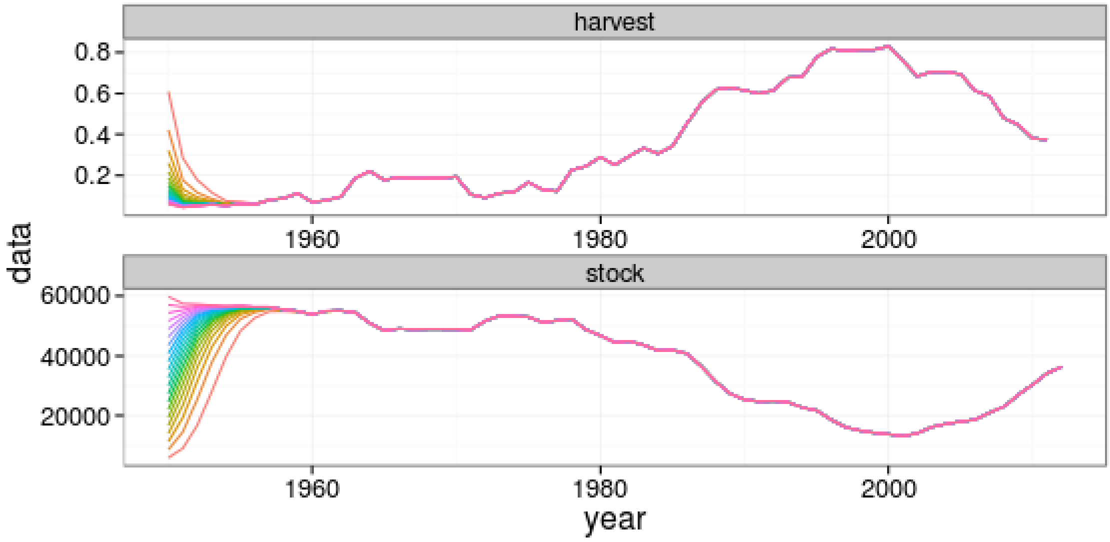

Figure 5. Time series of harvest rate and stock biomass for different values of B_0.

Figure 6. Residual sum of squares profile for MSY the assessment using the 2013 index.

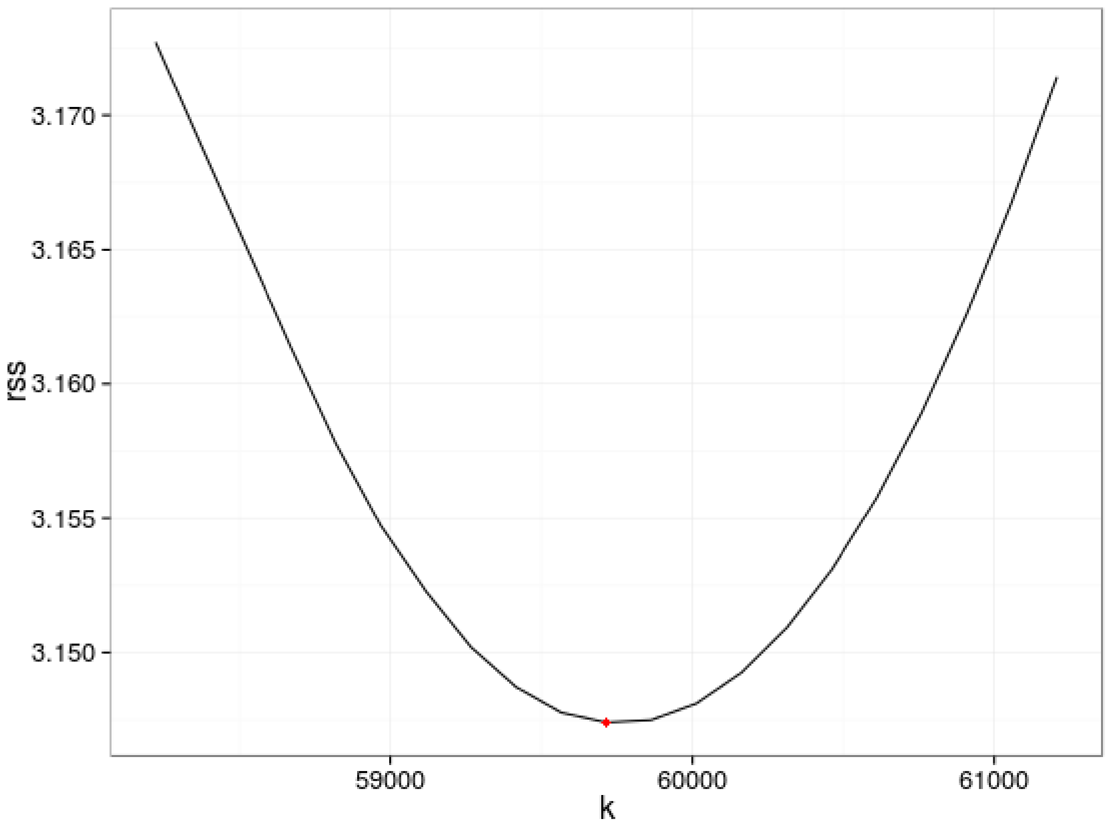

Figure 7. Residual sum of squares profile for K the assessment using the 2013 index.

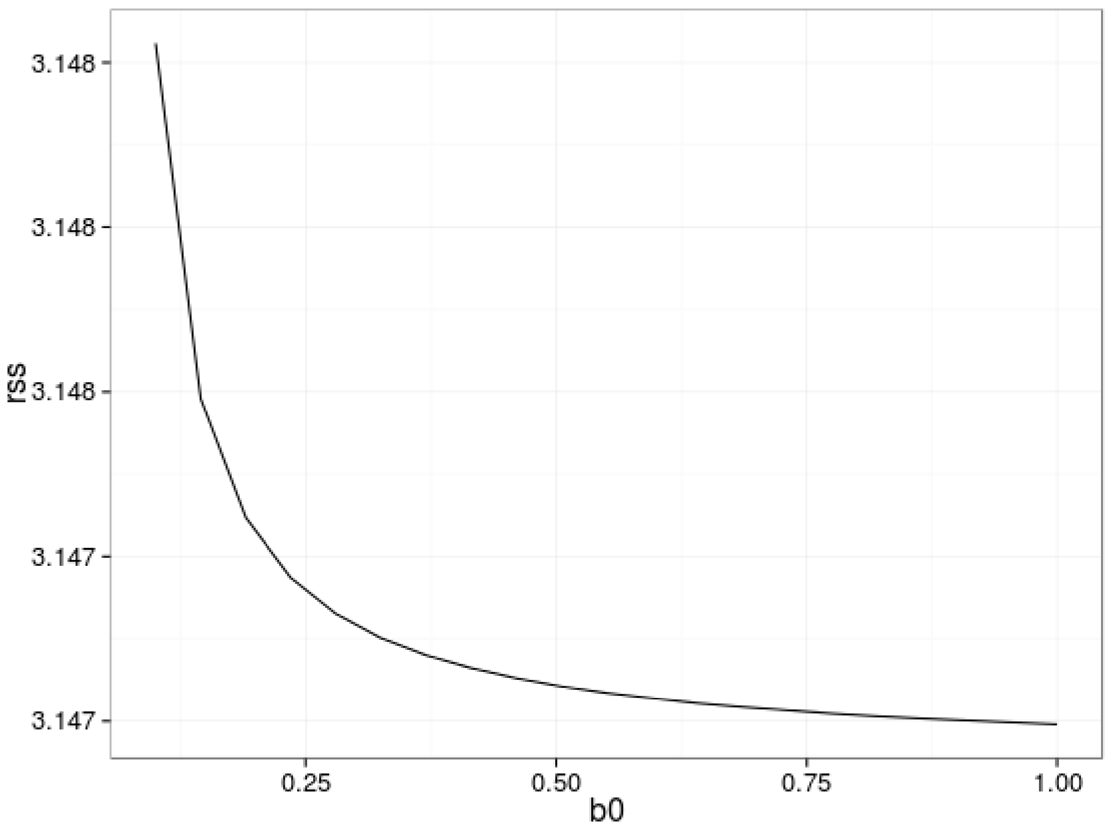

Figure 8. Residual sum of squares profile for B0 the assessment using the 2013 index.

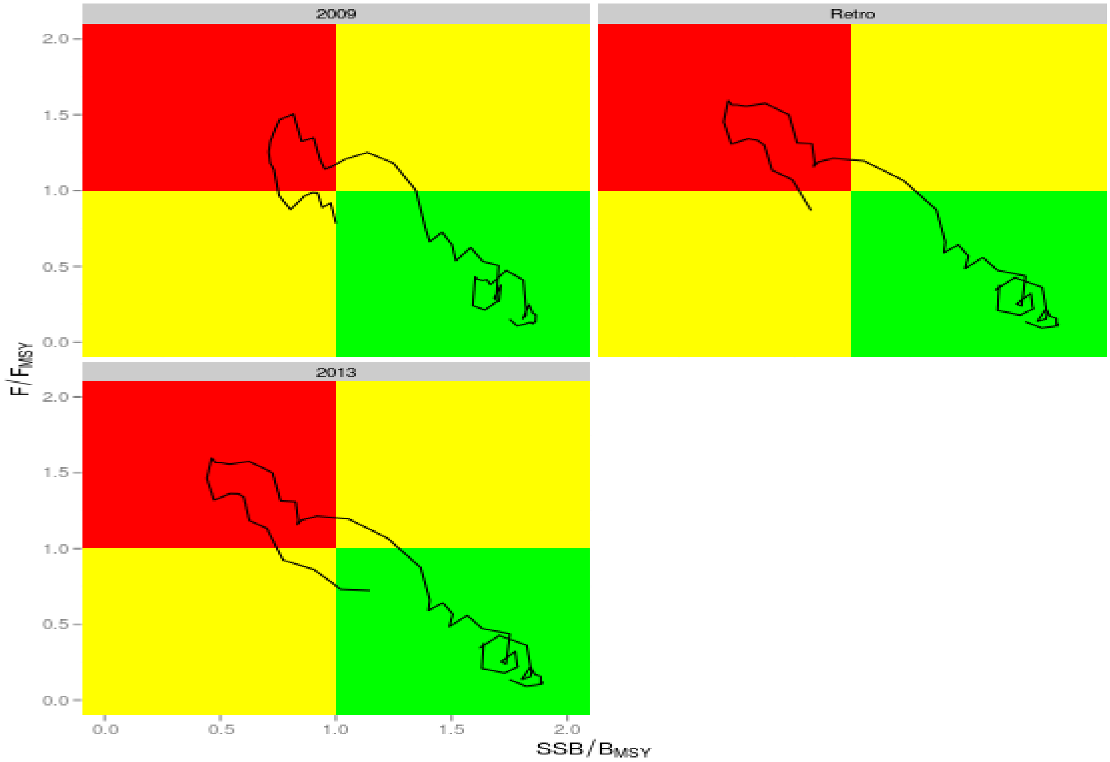

Figure 9. Kobe phase plot for the three assessment runs, i.e. for 2009 index, 2013 index and for a retrospective analysis where the 2013 index was truncated to end in 2008.

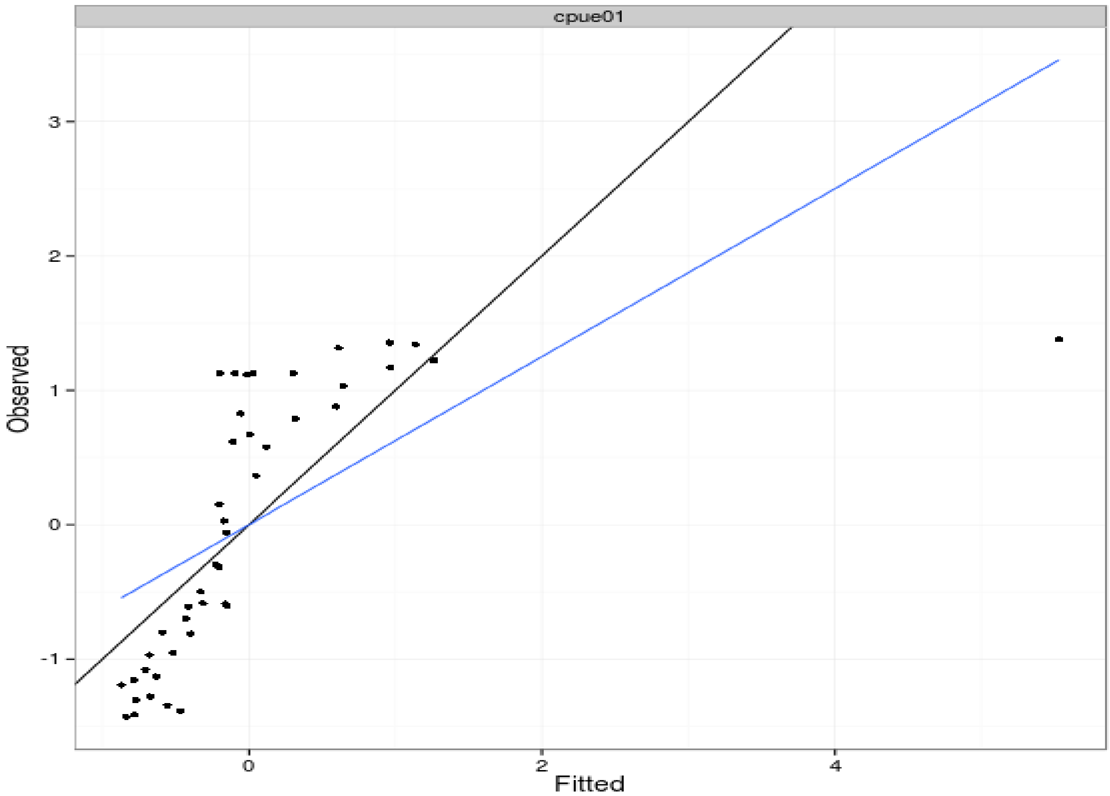

Figure 10. Observed CPUE verses fitted, blue line is a linear resgression fitted to points, black the y=x line.

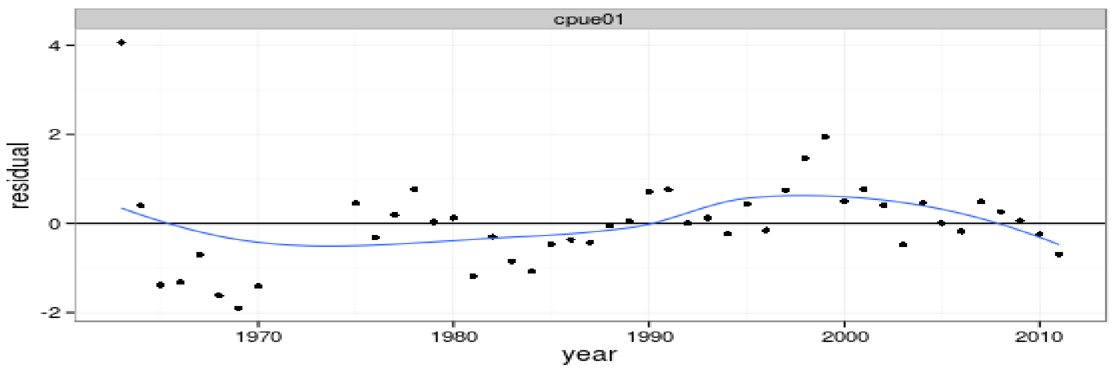

Figure 11. Residuals by year, with lowess smoother.

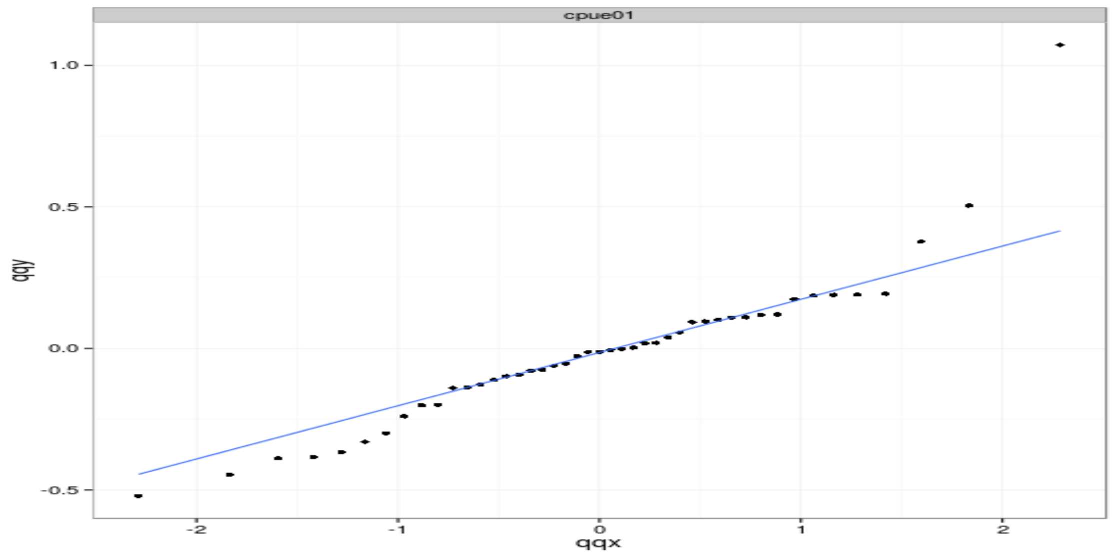

Figure 12. Quantile-quantile plot to compare residual distribution with the normal distribution.

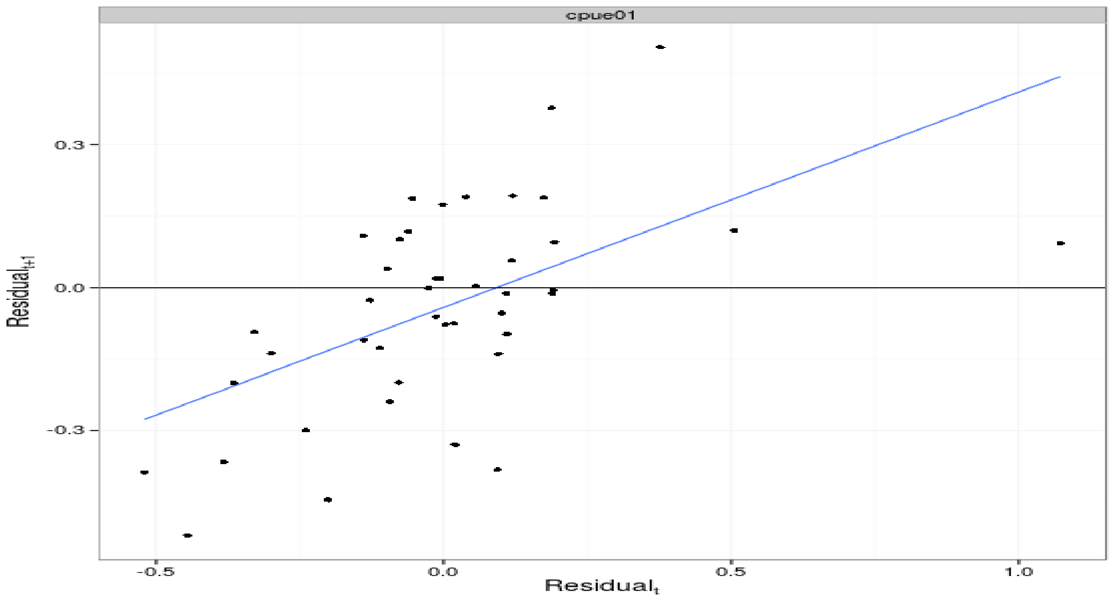

Figure 13. Plot of autocorrelation, i.e. residualt+1 verses residualt.

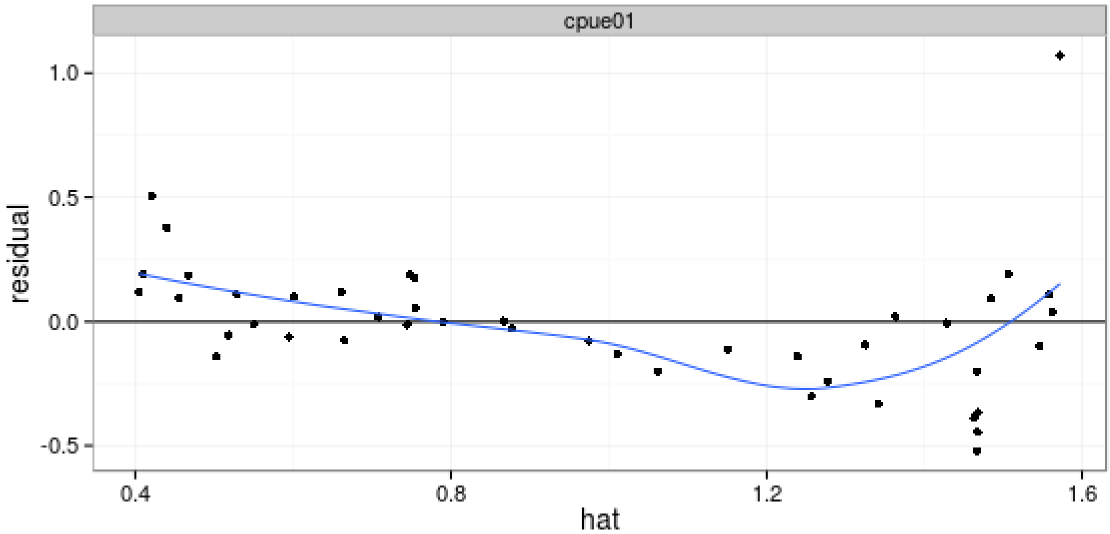

Figure 14. Plot of residuals against fitted value, to check variance relationship.