# Evaluation of Management Advice for North Atlantic Albacore; Linking MULTIFAN-CL and FLR.

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SUMMARY

Projections based upon MULTIFAN-CL population estimates were performed using the estimated parameters and their corresponding variance covariance matrix using FLR. Although MULTIFAN-CL projections are based upon fisheries operating seasonally differences with the annual projections were small compared to the levels of uncertainty modelled.

KEYWORDS

Advice, Albacore, FLR, projections, MULTIFAN-CL,

## 2. Introduction

The 2009 assessment of North Atlantic albacore was conducted using Multifan-CL. Stock projections and advice on TACs was then made using FLR (Fisheries Library for R, http://www.flr-project.org Kell et al. 2007). A benefit of using FLR is that it is designed to conduct Management Strategy Evaluation (MSE) and can be used to evaluate alternative measures with respect to a range of management objectives, regulations and stock assessment methods under a variety of assumptions about resource and fishery dynamics (Fromentin and Kell, 2007, Tserpes et al. 2009). Therefore as well as providing traditional advice based upon stock assessment, management regulations can also be evaluated formally, given the uncertainty inherent in the system being managed, to determine the extent to which they achieve the goals for which they were designed (Punt, 2006).

At the first global summit of Tuna RFMOs (Kobe, Japan, January 2007) it was recommended to standardise the presentation of stock assessments and to base management decisions upon scientific advice and the application of the precautionary approach. To help in standardisation, it was agreed that stock assessment results across all five tuna RFMOs should be presented in the "four quadrant, red-yellow-green" format now referred to as the Kobe Plot. Since, this graphical aid has been widely embraced as a practical and user-friendly method for presenting stock status information especially if accompanied by a "strategy matrix" for managers that lays out options for meeting management targets, including if necessary, ending overfishing or rebuilding overfished stocks.

Therefore in this paper we evaluate TAC options in the form of Kobe plots and plots and tables derived from them. We do this to present precautionary advice based on uncertainty and estimates of risk for North Atlantic albacore but also to help inform the discussion on the development of standardisation of such advice and appropriate generic software for species groups.

## 3. Material and methods

### 3.2. Parameters

During the species group time did not allow stochastic projections to be conducted. Instead, the group made projections based on the base case (run 4B) for two sets of assumptions: i) predicting future recruitment (2008-2020) deterministically from the estimated Beverton-Holt relationship (Beverton and Holt, 1957); ii) assuming constant recruitment at the same level predicted for 2008 from the Beverton-Holt relationship (8689423 recruits).

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The stock and recruitment relationship was a Beverton and Holt with steepness (Francis and Shotton, R., 1997) constrained to be 0.9.

Estimates of population and fishery parameters from MULTIFAN-CL were use to build the simulation model, biological parameters i.e. weight, natural mortality and proportion mature-at-age are shown in **Figure 1** and were assumed not to vary across years. Selection patterns by year and age are shown in **Figures 2 and 3**, in the former selection patterns are presented by decade, it can be seen that the main change has been due to changing catchability of juveniles. **Figure 3** shows that while there has been variability in selectivity there does not appear to be a recent trend.

Differences were seen between the Excel projections based upon the average "at-age"·parameters and those conducted by Multifan-CL. This is because weights-at-age used in the Excel projections were those at the beginning of the year while the catch biomass in MULTIFAN-CL is calculated from the weight-at-the times of the fisheries, this resulted in higher predicted Fs in the Excel projections compared to those made with MULTIFAN-CL for the same catch level. Therefore in this paper catch weight-at-age were assumed to be the weight halfway through the year.

### 3.3. Uncertainty

Uncertainty was included in the historic time series forms by performing a Monte Carlo simulation based upon the CV of the estimated recruitment deviation (i.e. residual) in each year. While in the future projections uncertainty was modeled by i) deviations in future recruitment around the stock recruitment relationship by randomly sampling with replacement from historic recruitment deviations and ii) randomly sampling with replacement from the selection patterns from the most recent five years.

### 3.4. Methods

The MULTIFAN-CL stock assessment was used to construct a simulation model on the basis of the age-structured equation:

$$N_{a,t} = N_{a-1,,t-1}\, e^{-Z{a-1,t-1}}$$

where $N_{a,t}$ is the number of fish of age $a$ at time $t$, and $Z_{a,t}$ is the total mortality from age $a$–1 to age $a$. $Z_{a,t} = M_a + F_{a,t}$, where $M_a$ is the natural mortality at age $a$ and $F_{a,t}$ is the fishing mortality at age $a$ in year $t$.

The open source R statistical environment is available from cran.r-project.org, while the code, data and this manuscript are all available as part of a google project at http://code.google.com/p/mse4mfcl/. The project can be accessed by non members who may check out read-only working copies or by project members to allow committing changes, see http://code.google.com/p/glmscrs/source/checkout for more details. The project is managed using subversion and under windows TottoiseSVN provides an easy to use user interface; see http://code.google.com/p/mseflr/wiki/UsingTortoiseSVN for a guide on how to use tortoise. Routines in R to read, manipulate, write, analyze, and plot the MFCL input and output files are available at http://code.google.com/p/r4mfcl/ which is based on original work by Pierre Kleiber of the US National Marine Fisheries Service, and Adam Langley and John Hampton of the SPC.

### *3 Management options*

Projections assumed a catch of 30,200 t in 2008 and 2009. Thereafter, catches ranging from 20,000 tonnes to 36,000 tonnes were projected as done at the species group.

## 4. Results

The projections in FLR were validated by replicating the MULTIFAN-CL projections, these are presented in **Figure 4**; the thick coloured lines are the MULTIFAN-CL projections and the superimposed thin black line the corresponding FLR values. It can be seen that assuming catch-at-age corresponding to mid year values has little effect on the trajectories. There is a difference also due to the MULTIFAN-CL projections being made upon a fishery and seasonal basis in that selection pattern is then also a function of relative fishing mortality by fishery. However, differences in the projections are minor.

Stochastic time series of recruitment, SSB, yield and fishing mortality for each of the assumed future recruitment scenarios, TAC levels correspond to 20,000 tonnes to 36,000 tonnes in increments of 2000 tonnes are presented in, **Figure 5a & b;** thick lines correspond to medians and dashed lines to the inter-quartiles. The same results are then presented in the form of Kobe plots in **Figures 6a & b,** the axes correspond to fishing mortality relative to $F_{MSY}$ and SSB relative to $B_{MSY}$ The green quadrant corresponds to the stock being above $B_{MSY}$ and harvesting at less than $F_{MSY.}$ While the red quadrant to the stock being below $B_{MSY}$ and harvesting at greater than $F_{MSY}$ and the yellow quadrants to the stock being either below $B_{MSY}$ or harvesting at greater than $F_{MSY}$. The black line corresponds to the median of historical estimates, the grey to the median of projected estimates and the points to individual realisations at the end of the projection period (2020), white correspond to the $50^{th}$ bi-variate percentile. Individual panels correspond to the different TAC levels (20,000 tonnes starting in the top left hand panel then increasing TACs going left to right across columns).

The Kobe plots can then be used to show the probabilities of restoring the stock to be within management targets over time given the different management options in **Figures 7 & b**. The lines show the probability of being in each quadrant, again TAC levels increase from left to right, levels increase from left to right, top to bottom.

The performance of all the management options are summarised in **Figure 8**, green and red represent a 75% and 25% chance of being in the red Kobe quadrant.

## 5. Discussion

Stochastic projections were made in FLR in order to be able to generate probabilistic estimates based upon the Kobe plots, catch and fishing mortality-at-age were not readily available for use in FLR and therefore annual projections were made. Although MULTIFAN-CL projections are based upon fisheries operating seasonally differences between annual projections were small compared to the levels of uncertainty modelled. Stochastic projections to provide probabilistic advice on achieving the Commissions objectives (i.e. of ensuring the stock is above $B_{MSY}$ and exploitation is below $F_{MSY}$) were asked to be performed prior to the SCRS SG meeting; in addition these evaluated the projections made at the species group and the MULTIFAN-CL projections made subsequently. It was found that the weights-at-age in the catch assumed by the original Excel projections were those at start of the year and that since the main fisheries operate in quarters 1 and 2 this resulted in higher fishing mortality and lower SSB than those made in SCRS 122 and using MULTIFAN-CL; both of which gave similar results, with the exception that in the deterministic MULTIFAN-CL projections MSY, BMSY and FMSY reference points changed as catch and hence fishing mortality increased. MSY increasing as catch increased due to a change in the selection pattern due to the seasonal mix of fisheries with different selection patterns but constant catches.

The adoption of the precautionary approach requires a formal consideration of uncertainty (Kirkwood and Smith 1996, Rosenberg and Restrepo, 1994). A major challenge is how to use decision support tools such as MSE within a multi-stakeholder management environment to achieve effective implementation and monitoring consistent with principles of good governance.

## 6. References

Beverton, R.J.H., and Holt, S.J., 1957. On the dynamics of exploited fish populations. Fish. Investig. London Ser. 2. No. 19.

Francis, R.I.C.C. and Shotton, R., 1997. 'Risk' in fisheries management: a review. Can. J. Fish. Aquat. Sci. 54: 1699-1715.

Fromentin, J.M., Kell, L.T., 2007. Consequences of variations in carrying capacity or migration for the perception of Atlantic bluefin tuna population dynamics. Canadian Journal of Fisheries and Aquatic Science 67, 627-836.

Kell, L.T., Fromentin, J.M., 2007. Evaluation of the robustness of MSY-based management strategies to variations in carrying capacity or migration pattern of Atlantic bluefin tuna Canadian Journal of Fisheries and Aquatic Science 67, 837-847.

Kell, L.T., Mosqueira, I., Grosjean, P., Fromentin, J-M., Garcia, D., Hillary, R., Jardim, E., Mardle, S., Pastoors, M.A., Poos, J.J., Scott, F. and Scott. R.D., 2007. FLR: an open-source framework for the evaluation and development of management strategies. ICES Journal of Marine Science 64:640-646.

Kirkwood, G.P. and Smith, A.D.M., 1996. Assessing the precautionary nature of fishery management strategies. In Precautionary Approach to Fisheries, Part 2: Scientific Papers. FAO Fisheries Technical Paper 350/2: 141-158.

Punt, A. E. 2006. The FAO Precautionary Approach after almost 10 years: Have we progressed towards implementing simulation-tested feedback-control management systems for fisheries management? Natural Resource Modelling, 19: 441-–464.

Rosenberg, A.A. and Restrepo, V.R., 1994. Uncertainty and risk evaluation in stock assessment advice for U.S. marine fisheries. Can. J. Fish. Aquat. Sci. Vol. 51 (12), pp. 2715-2720.

Sissenwine, M.P and Shepherd, J.G. 1987. An alternative perspective on recruitment overfishing and biological reference points. Can. J. Fish. Aquat. Sci., 44: 913-918.

Tserpes,G., Tzanatos,E., Peristeraki,P., Placenti,V. and Kell, L.T. 2009. A bio-economic evaluation of different management measures for the Mediterranean swordfish. Fisheries Research, Volume 96, Issues 2-3, March 2009, Pages 160-166

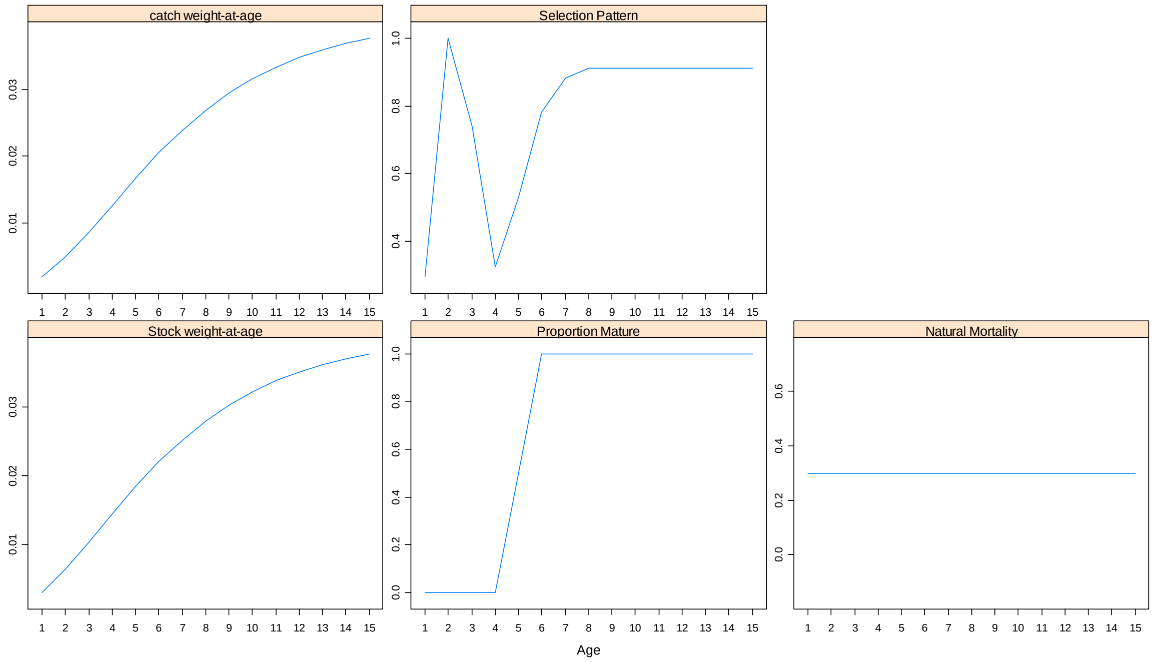


**Figure 1.** Biological parameters, catch weight, natural mortality and proportion mature-at-age.

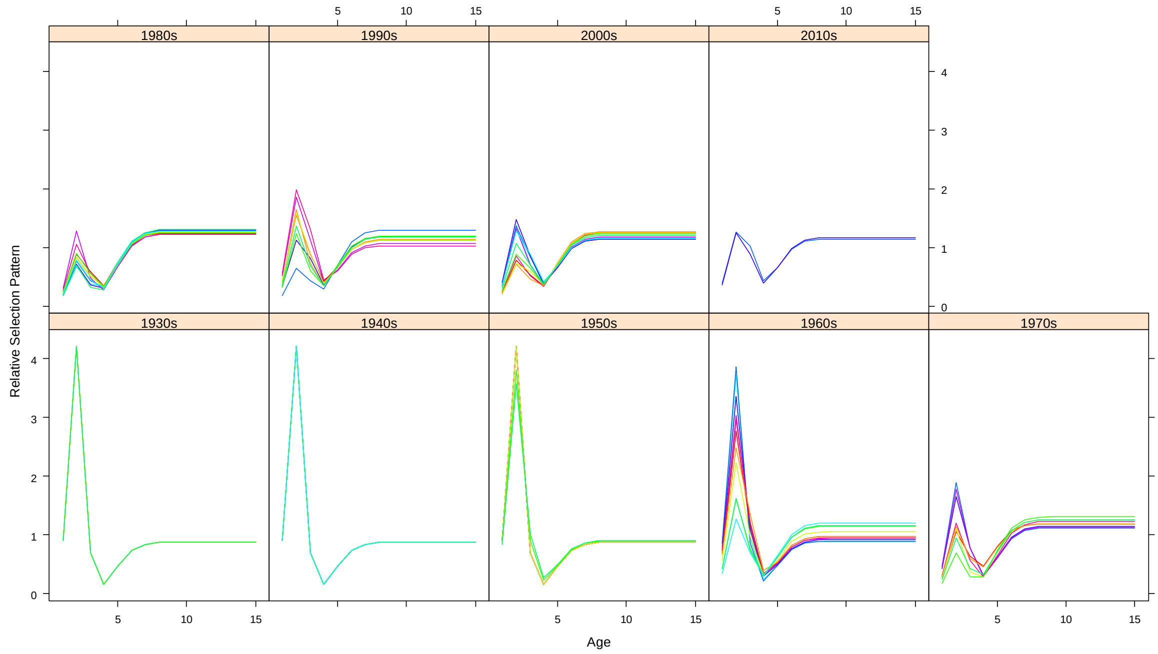


**Figure 2.** Selection pattern-at.age, panels by decade.

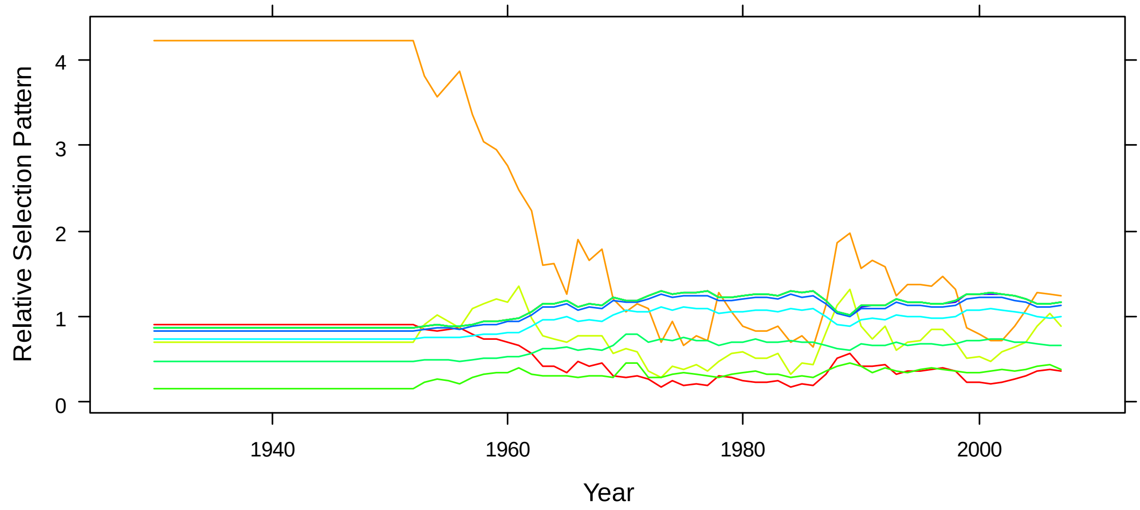


**Figure 3.** Selectivity-at-age by year.

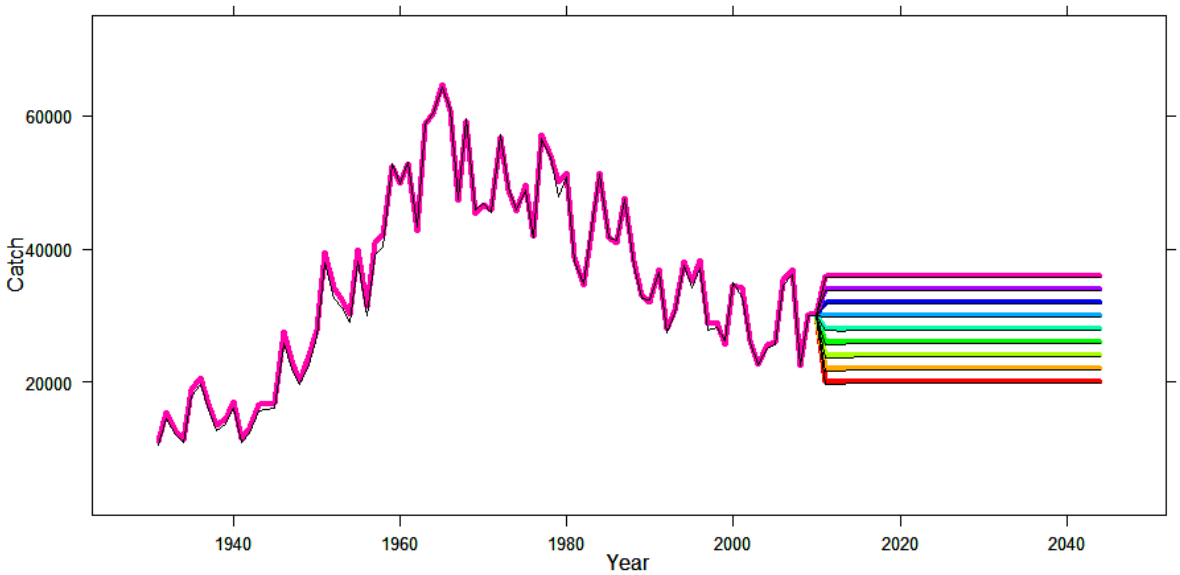


**Figure 4. D**eterministic projections assuming constant recruitment, lines correspond to TAC levels (20000, 22000, 24000, 26000, 28000, 30000, 32000, 34000 and 36000); red through violet. Coloured lines correspond to MULTIFAN-CL and thin black line to FLR projections.

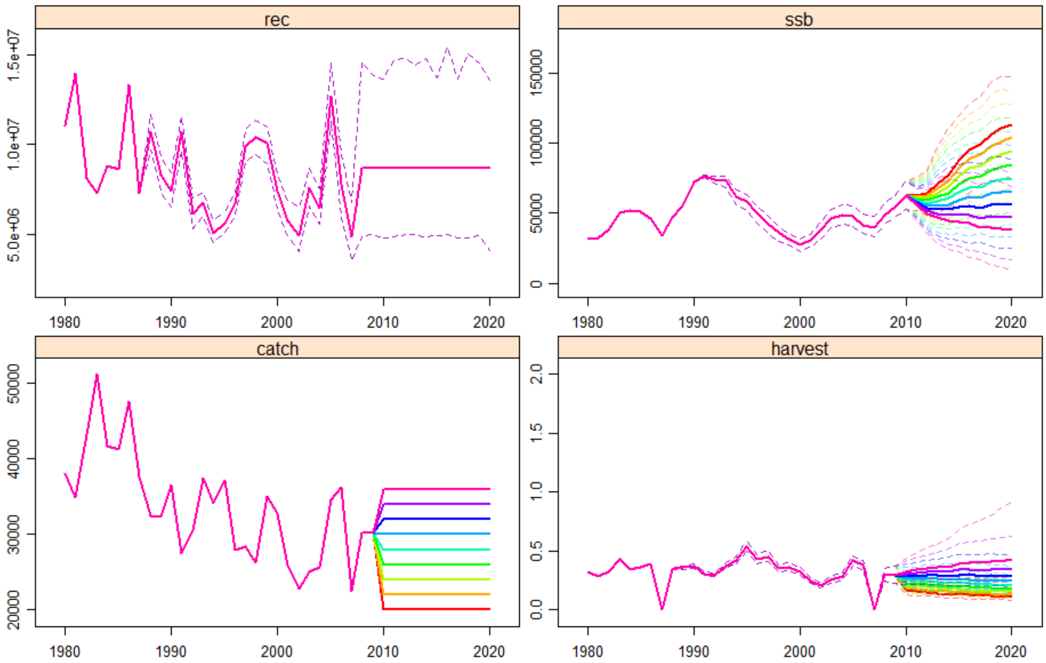


**Figure 5a.** Stochastic FLR projections assuming constant recruitment, lines correspond to TAC levels (20000, 22000, 24000, 26000, 28000, 30000, 32000, 34000 and 36000); red through violet. Thick lines correspond to median and thin lines to inter-quartiles.

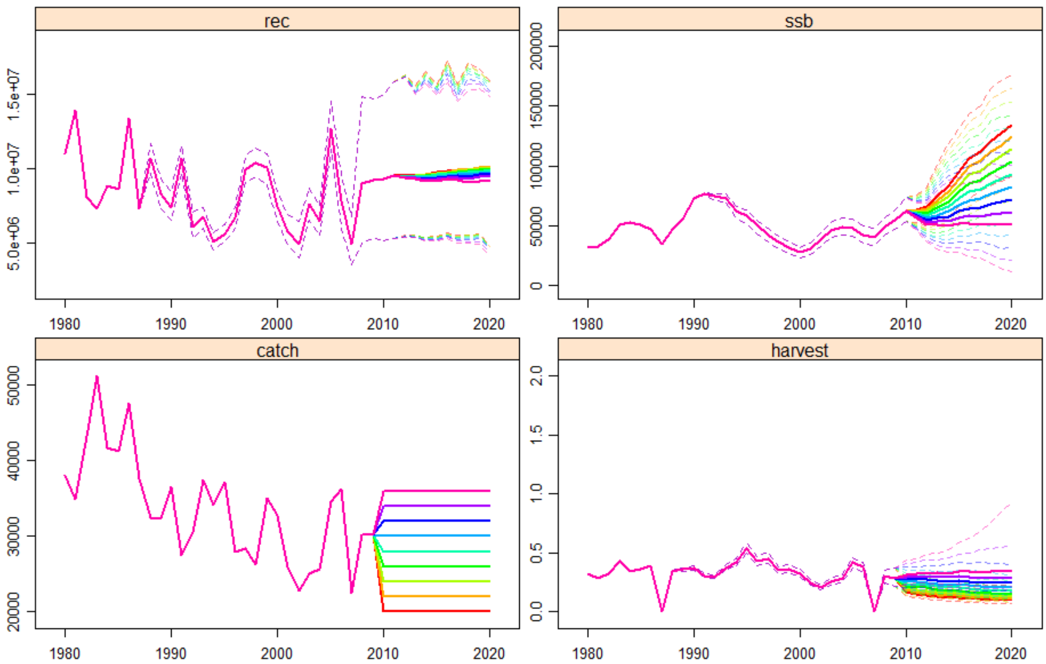


**Figure 5b.** Stochastic FLR projections assuming Beverton and Holt recruitment, lines correspond to TAC levels (20000, 22000, 24000, 26000, 28000, 30000, 32000, 34000 and 36000); red through violet. Thick lines correspond to median and thin lines to inter-quartiles.

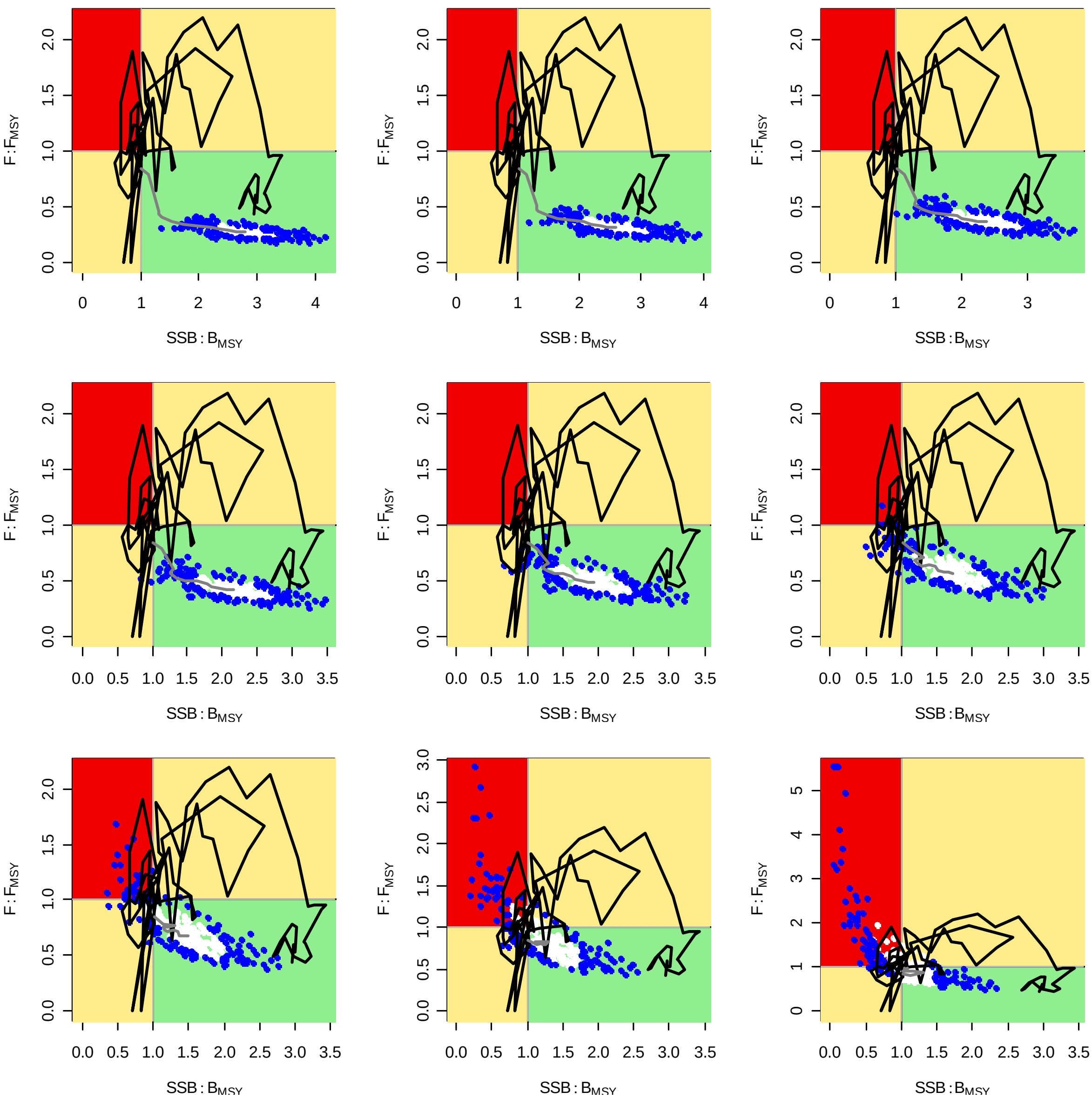

**Figure 6a.** "Kobe plots"; points show individual realisations in 2020 and lines the median stock trajectories for historic and projected periods (black and grey respectively). Quadrants are defined for the stock amd fishing mortality relative to $B_{MSY}$ and $F_{MSY}$; i.e. red SSB<$B_{MSY}$ and F>$F_{MSY}$, green red SSB≥$B_{MSY}$ and F≤$F_{MSY}$ yellow otherwise. Results are for scenarios 4b assuming a Beverton and Holt stock recruitment relationship; panels are for constant TAC levels (20,000 to 36,000 tonnes) from top left to bottom right.

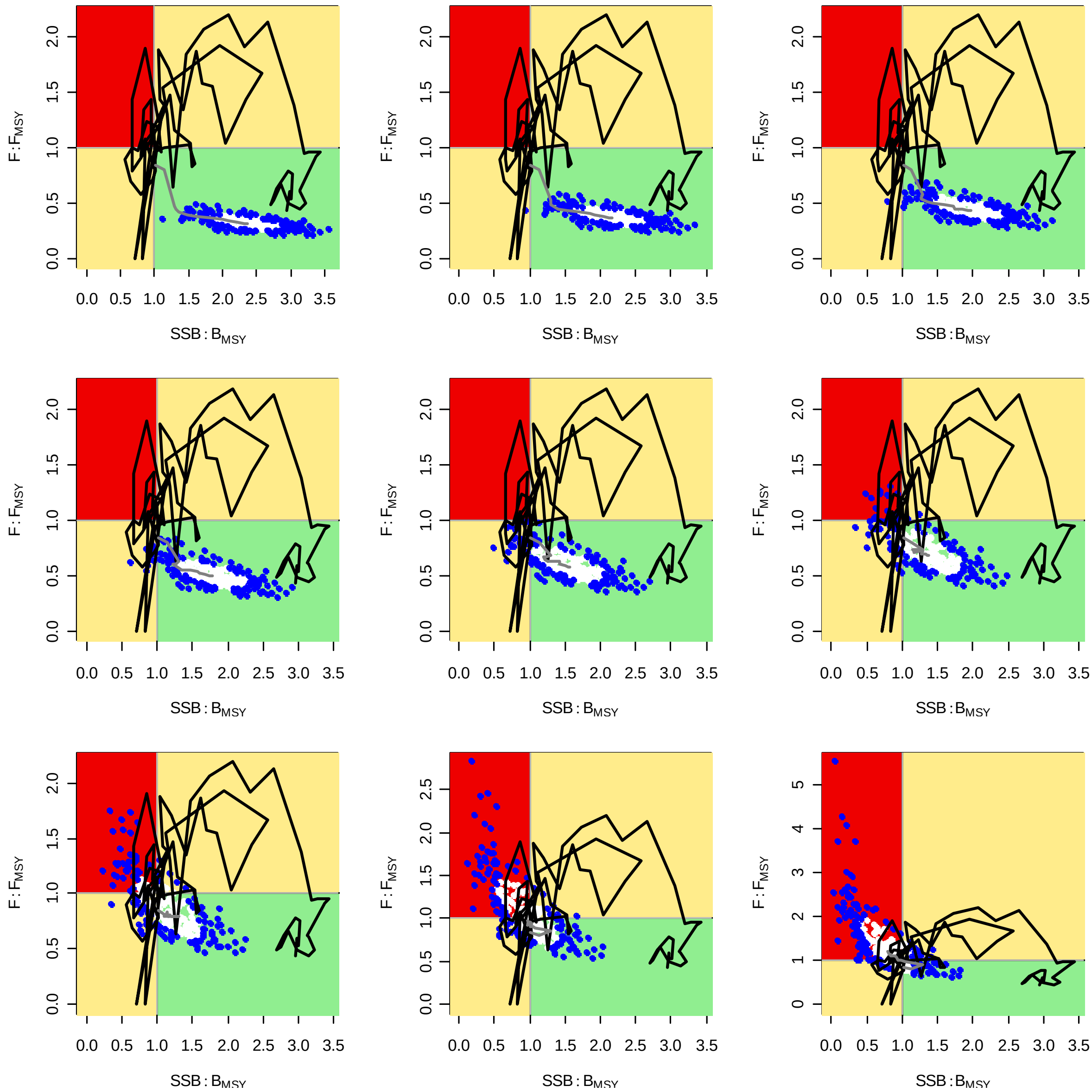


**Figure 6b.** "Kobe plots"; points show individual realisations in 2020 and lines the median stock trajectories for historic and projected periods (black and grey respectively). Quadrants are defined for the stock amd fishing mortality relative to $B_{MSY}$ and $F_{MSY}$; i.e. red SSB<$B_{MSY}$ and F>$F_{MSY}$, green red SSB≥$B_{MSY}$ and F≤$F_{MSY}$ yellow otherwise. Results are for scenarios 4b assuming constant recruitment at the 2008 level as predicted by a Beverton and Holt stock recruitment relationship; panels are for constant TAC levels (20,000 to 36,000 tonnes) from top left to bottom right.

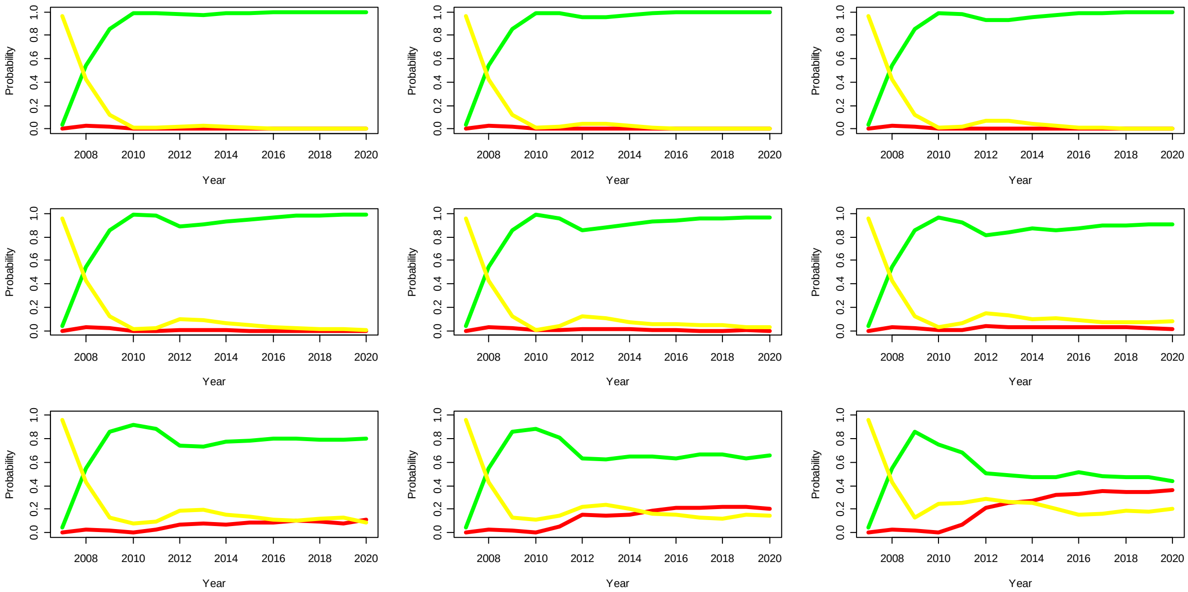


**Figure 7a.** Probability trends of north Atlantic swordfish under constant TACs levels showing probability of being in one of the quadrants by year defined relative to $B_{MSY}$ and $F_{MSY}$; red SSB<$B_{MSY}$ and F>$F_{MSY}$, green red SSB≥$B_{MSY}$ and F≤$F_{MSY}$ yellow otherwise. . Results are for scenarios 4b assuming a Beverton and Holt stock recruitment relationship; panels are for constant TAC levels (20,000 to 36,000 tonnes) from top left to bottom right.

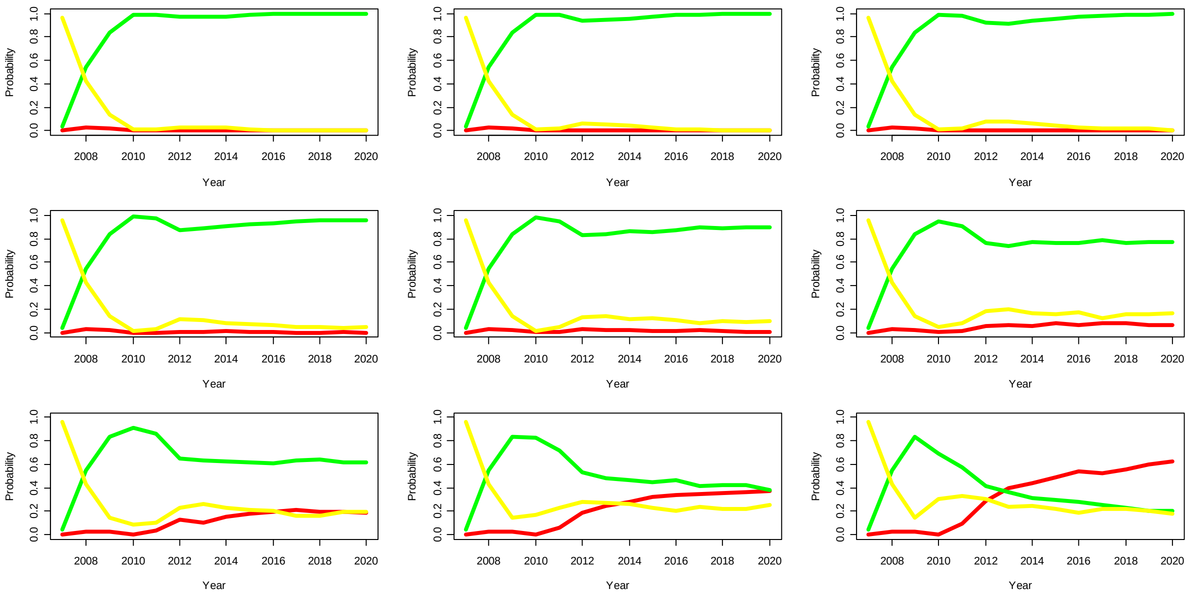


**Figure 7b.** Probability trends of north Atlantic swordfish under constant TACs levelsshowing probability of being in one of the quadrants by year defined relative to $B_{MSY}$ and $F_{MSY}$; red SSB<$B_{MSY}$ and F>$F_{MSY}$, green red SSB≥$B_{MSY}$ and F≤$F_{MSY}$ yellow otherwise. . Results are for scenarios 4b assuming constant recruitment at the 2008 level as predicted by a Beverton and Holt stock recruitment relationship; panels are for constant TAC levels (20,000 to 36,000 tonnes) from top left to bottom right.

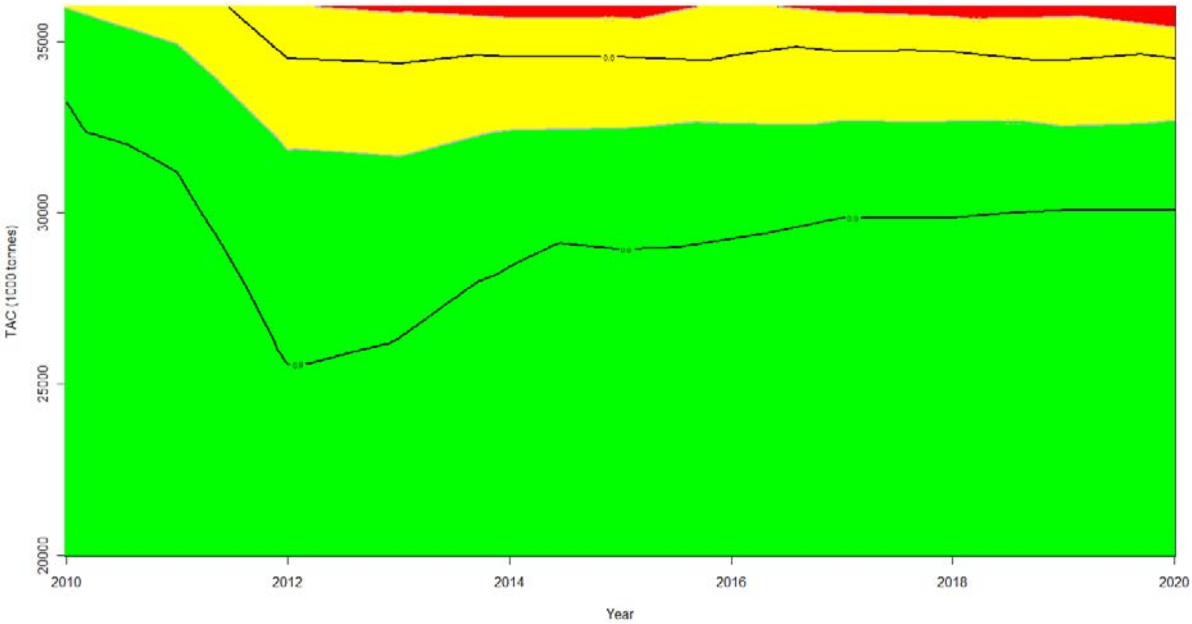


**Figure 8.** Advice plot, green, yellow and red correspond to the probabilities (≥75%, ≥50% & <75$, <25% respectively) of being in the Kobe quadrant corresponding to SSB≥$B_{MSY}$ and F≤$F_{MSY}$ by year for each of the TAC levels, integrated over both stock recruitment assumptions;