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EVALUATION OF MANAGEMENT ADVICE FOR NORTH ATLANTIC ALBACORE; LINKING MULTIFAN-CL AND FLR

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SUMMARY

Projections based upon Multifan-CL were performed 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. The most important effect was that B_{MSY} based reference points based on weights-at-age at the beginning of the year rather than weights at the time of the fishery can significantly underestimate catch biomass for a given fishing mortality. Therefore advice is based upon catch weights-at-age based upon weights-at-age in the stock in the middle of the year.

RÉSUMÉ

Des projections fondées sur Multifan-CL ont été réalisées en unilisant FFR. Buen que les projections Multifan-CL se fondent sur les pêcheries opérant de manière saisonnière, les différences avec les projections annuelles étaient réduites par rapport aux niveaux d'incertitude modelés. Cela a eu comme principal effet que les points de référence de B_{PME} fondés sur les poids par âge au début de l'année au lieu des poids au moment de la pêche peuvent considérablement sous-estimer la biomasse de capture pour une mortalité par pêche déterminée. Dès lors, l'avis se fonde sur les poids par âge de la capture qui sont obtenus à leur tour sur la base des poids par âge du stock en milieu d'année.

RESUMEN

Se realizaron proyecciones basándose en Multifan-CL y utilizando FLR. Aunque las proyecciones Multifan-CL se basan en pesquerías que operan estacionalmente, las diferencias con las proyecciones anuales fueron pequeñas en comparación con los niveles de incertidumbre modelados. El efecto más importante fue que los puntos de referencia basados en B_{RMS} utilizando el peso por edad al comienzo del año, en vez de en el peso en el momento de la pesca, pueden generar una importante subestimación de la biomasa de captura para una mortalidad por pesca determinada. Por tanto, el asesoramiento se centra en la utilización del peso de la captura por edad basado en el peso por edad en el stock a mediados del año.

KEYWORDS

Advice, Albacore, FLR, projections, Multifan-CL

1. 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,

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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.

2. Material and methods

2.1 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). 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 for calculation of the biological reference points and 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.

Equilibrium curves are commonly used to estimate reference points (Sissenwine and Shepherd, 1987) and are presented in **Figure 4** along with the reference points corresponding to F_{Max} F_{MSY}, $F_{0.1}$and $F_{30\%SPR}$. The black curve is calculated using catch weight-at-age at midyear and the red curve catch weights-at-age at the beginning of the year. The former were assumed by the original Excel projections and the reference points calculated by Multifan-CL.

2.2 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.

2.3 Methods

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

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

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.

2.4 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.

3. Results

The projections in FLR were validated by replicating the Excel and Multifan-CL projections. In the long-term when fishing at a constant catch there is a equilibrium point for the stock corresponding to a point on the yield/SSB curve and plotting the stock trajectories on these curves is therefore a check of the simulation model behaviour. In **Figure 5a** the deterministic Multifan-CL and in **Figure 5b** the medians of the stochastic FLR projections are plotted against their respective equilibrium curves. In **Figure 5a** there are equilibrium curves for each TAC level since in the Multifan-CL projections, which are by fishery and fishing period, the proportion of the TAC by fishery and fishing period is constant. This means that an increase in TAC causes a relative increase in fishing mortality in fisheries that occur later in the year, resulting in a change in the selection pattern. However, all trajectories converge on to the equilibrium curves confirming the agreement between the multi-fisheries projections and the annual dynamic model. In **Figure 5b** there is only one equilibrium, curve as there are no seasonal dynamics, and again the long-term projections converge on to the curve for the lower TAC levels. However for a TAC of 32000, 34000 and 36000 tonnes the stock collapse, this is because in the stochastic simulations periods of low recruitment will reduce productivity. Interestingly the simulations of a catch level of 32,000 tonnes is initially attracted to the upper equilibrium before being attracted to the lower equilibrium.

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 6a & b.** The same results are then presented in the form of Kobe plots in **Figures 7a & 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 50th 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 8a & 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 9**, green and red represent a 75% and 25% chance of being in the red Kobe quadrant.

4. Discussion

Although Multifan-CL projections are based upon fisheries operating seasonally differences between annual projections were small compared to the levels of uncertainty modelled. The most important effect was that the B_{MSY} based reference points originally used by the group were based upon beginning of the year weights-at-age rather than weights at the time of the fishery as used in the Multifan-CL projections. This can significantly underestimate catch biomass for a given fishing mortality.

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.

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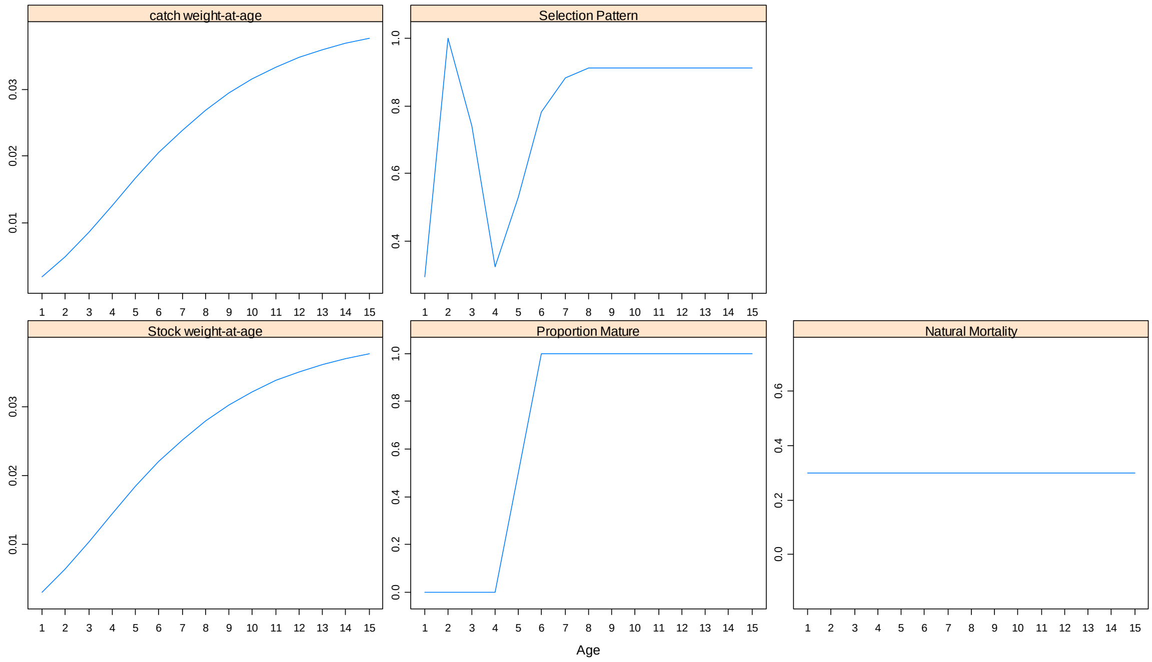

Figure 1. Biological parameters, catch weight, natural mortality and proportion mature-at-age.

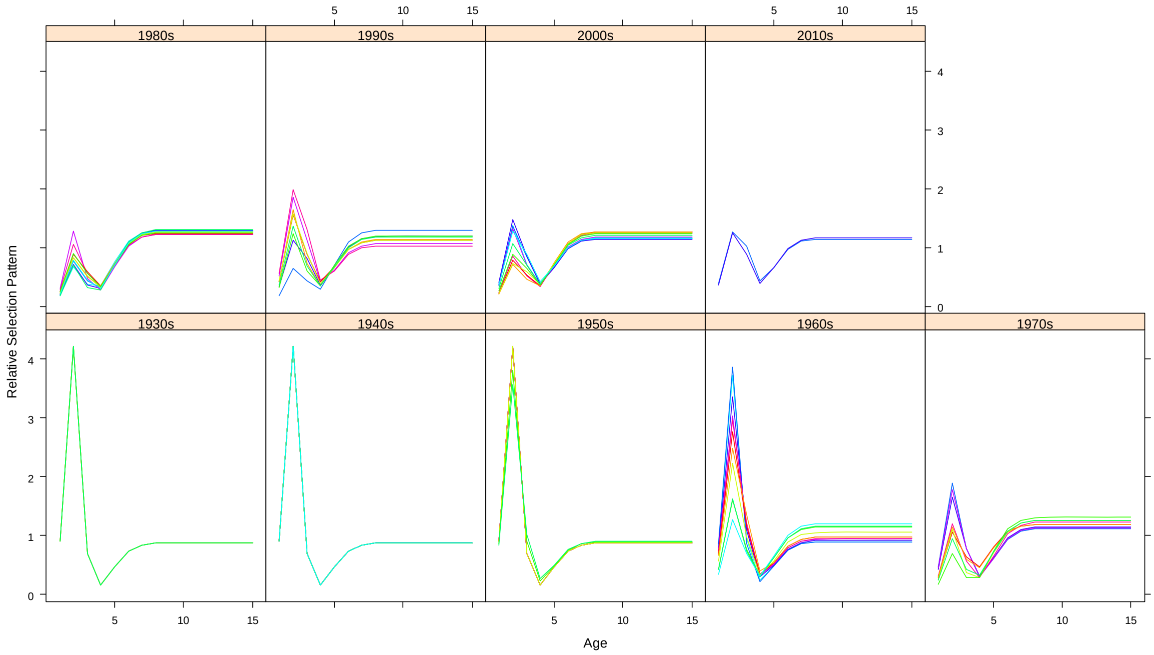

Figure 2. Selection pattern-at.age, panels by decade.

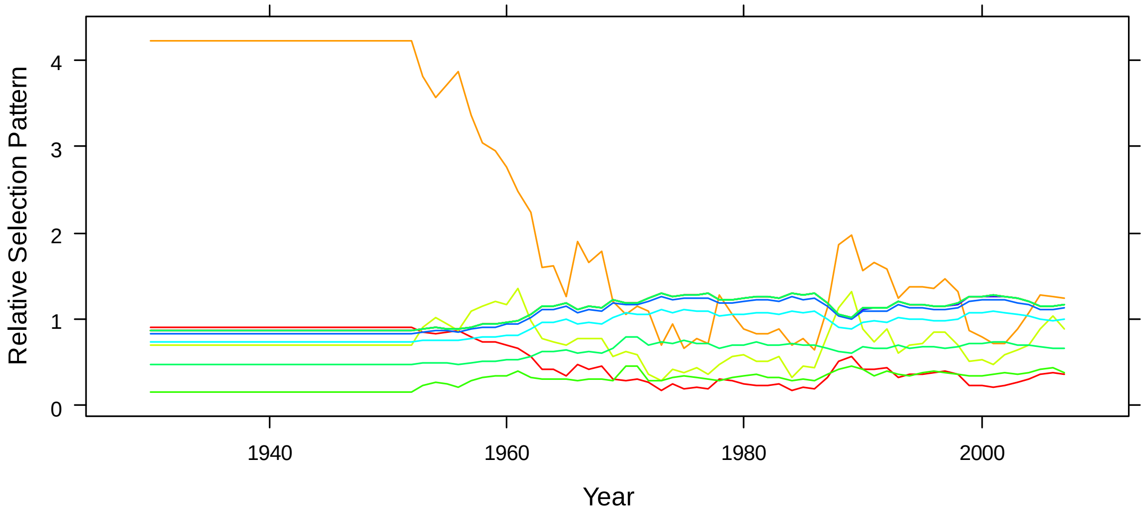

Figure 3. Selectivity-at-age by year.

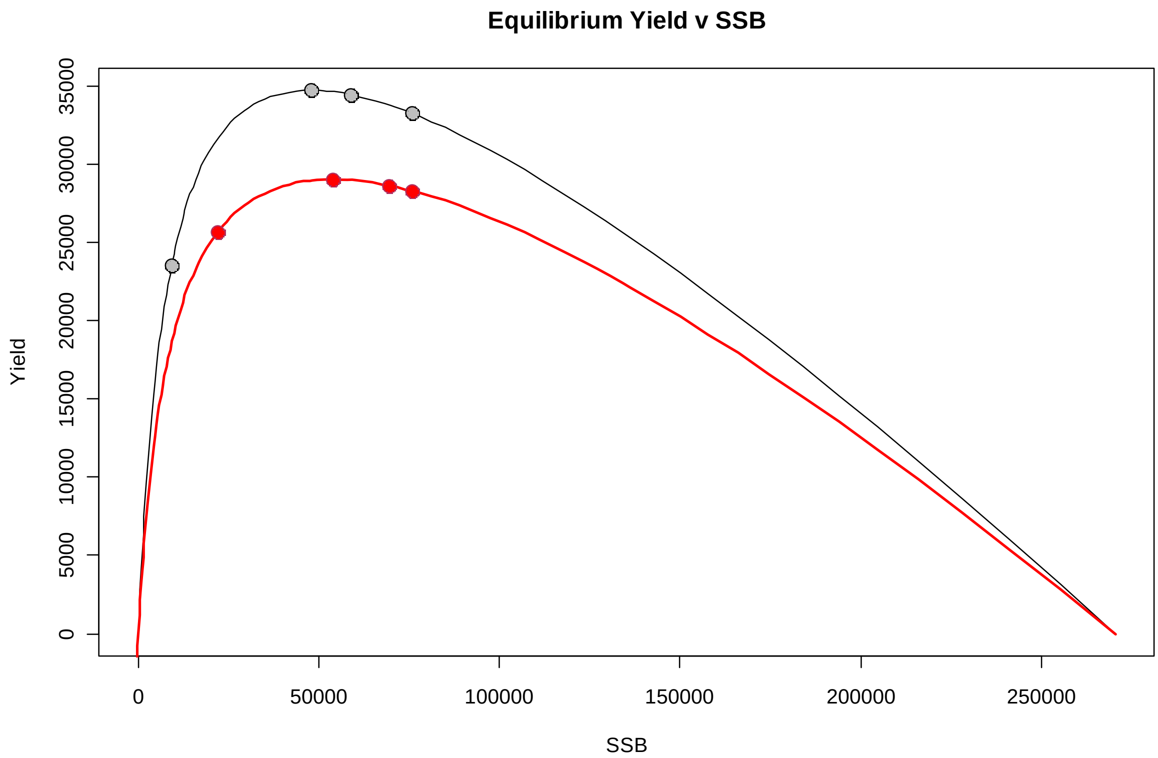

Figure 4. Equilibrium curves with reference points F_{MAX}, F_{MSY}, $F_{0.1}$ and $F_{30\%SPR0}$, for catch weights-at-age corresponding to start and mid-year (black and red respectively).

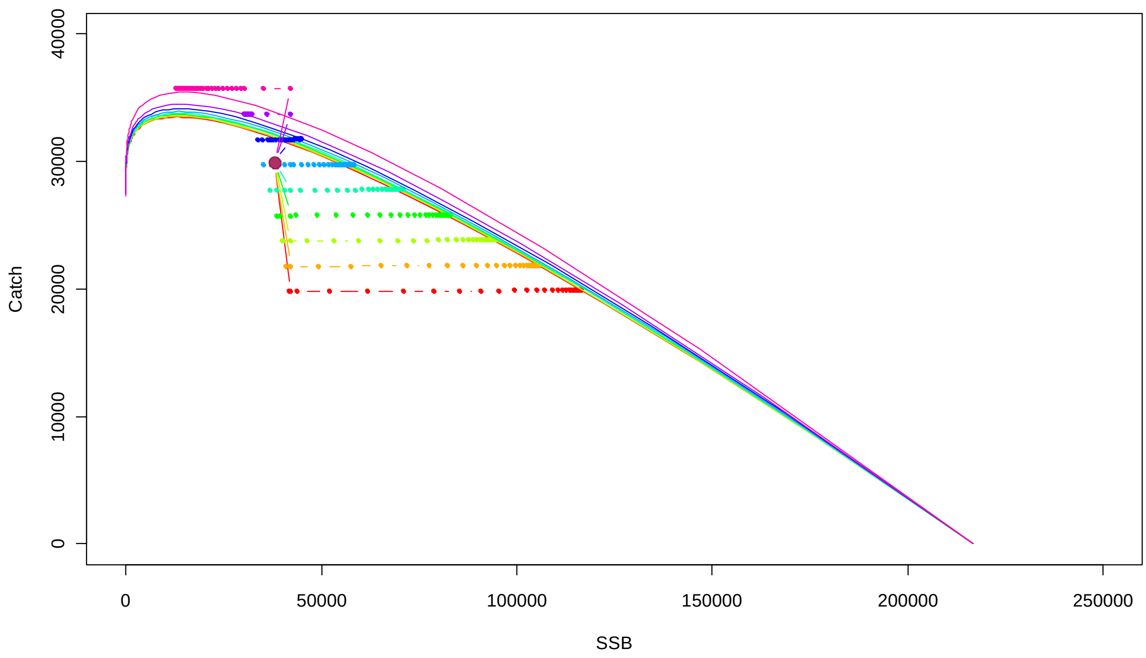

Figure 5a. Equilibrium curves with trajectories from Multifan-CL projections.

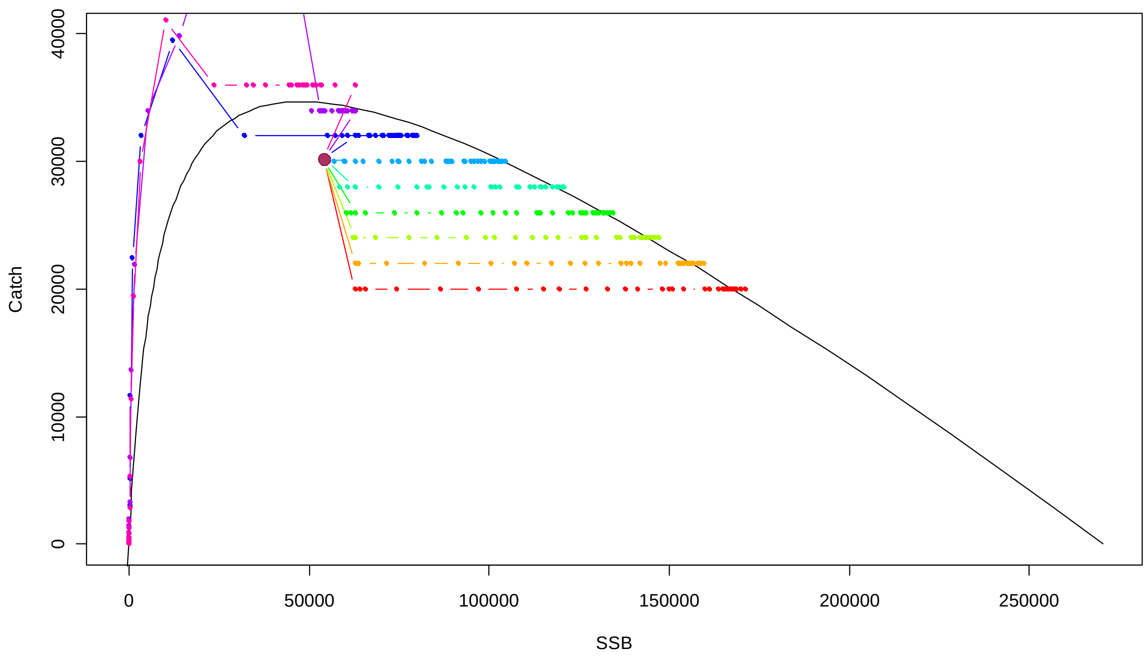

Figure 5b. Equilibrium curves with median trajectories from FLR projections.

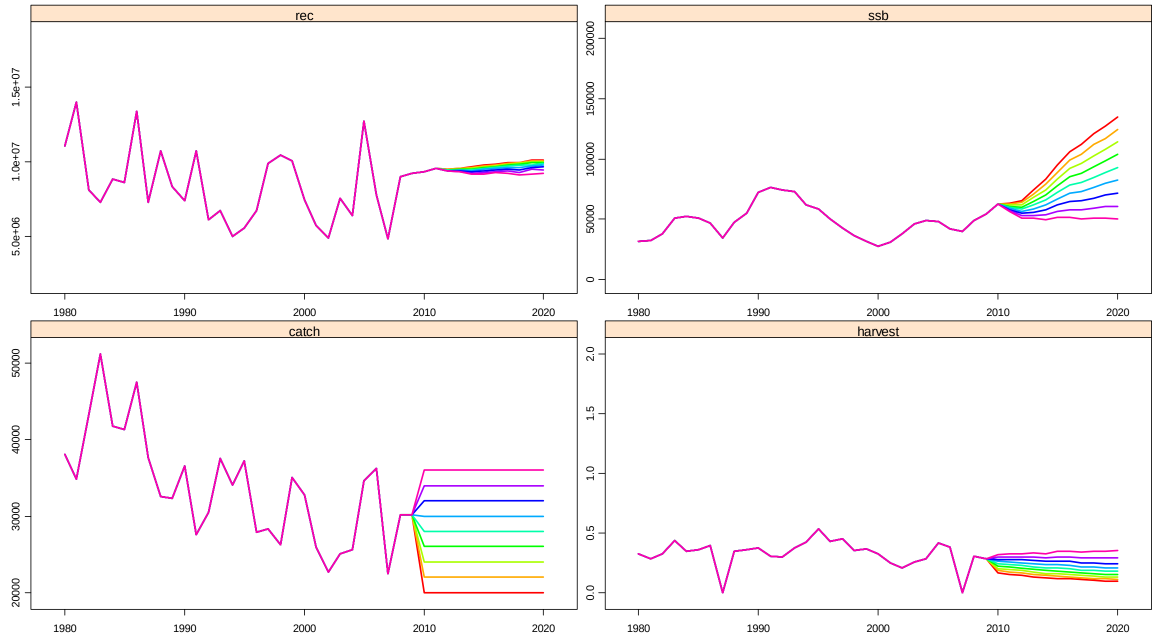

Figure 6a. Projections assuming a Beverton and Holt stock recruitment relationship, lines correspond to TAC levels 20000, 22000, 24000, 26000, 28000, 30000, 32000, 34000 and 36000; red through violet

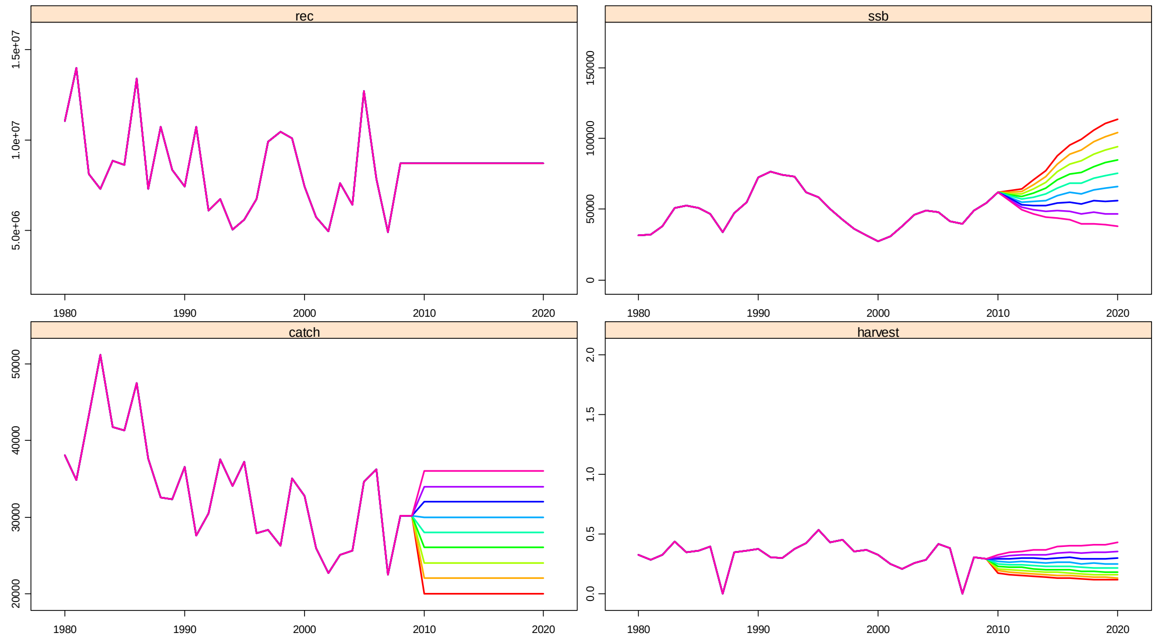

Figure 6b. Projections assuming a Beverton and Holt stock recruitment relationship with future recruitment at 2008 level, lines correspond to TAC levels 20000, 22000, 24000, 26000, 28000, 30000, 32000, 34000 and 36000; red through violet

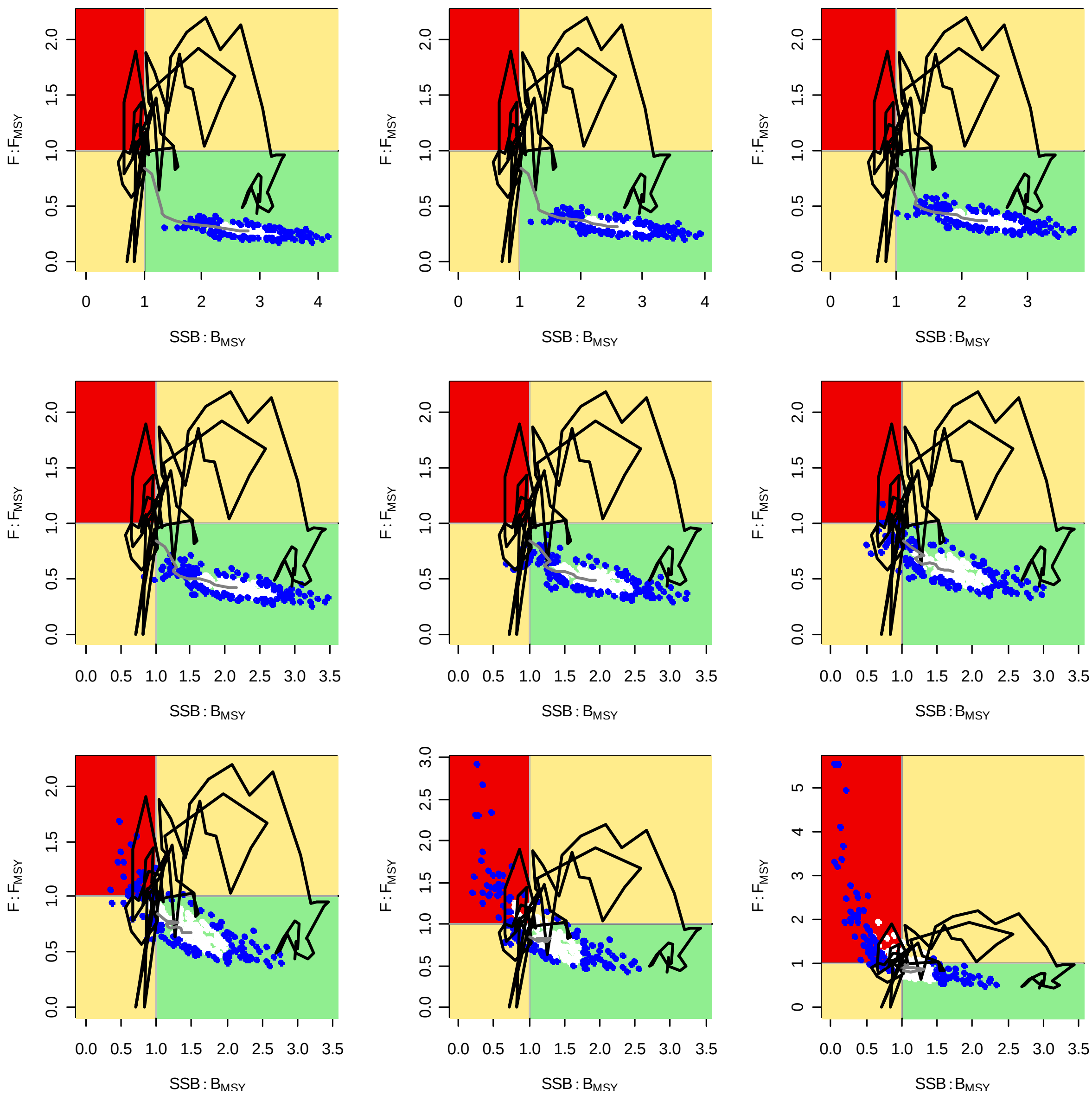

Figure 7a. "Kobe plots"; points show individual realisations in 2020 and lines the median stock trajectories for historic and projected periods (black and grey respectively). Quadrants are defined for the stock amd fishing mortality relative to B_{MSY} and F_{MSY}; i.e. red $SSB<B_{MSY}$ and $F>F_{MSY}$, green red $SSB\geq B_{MSY}$ and $F\leq F_{MSY}$ 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.

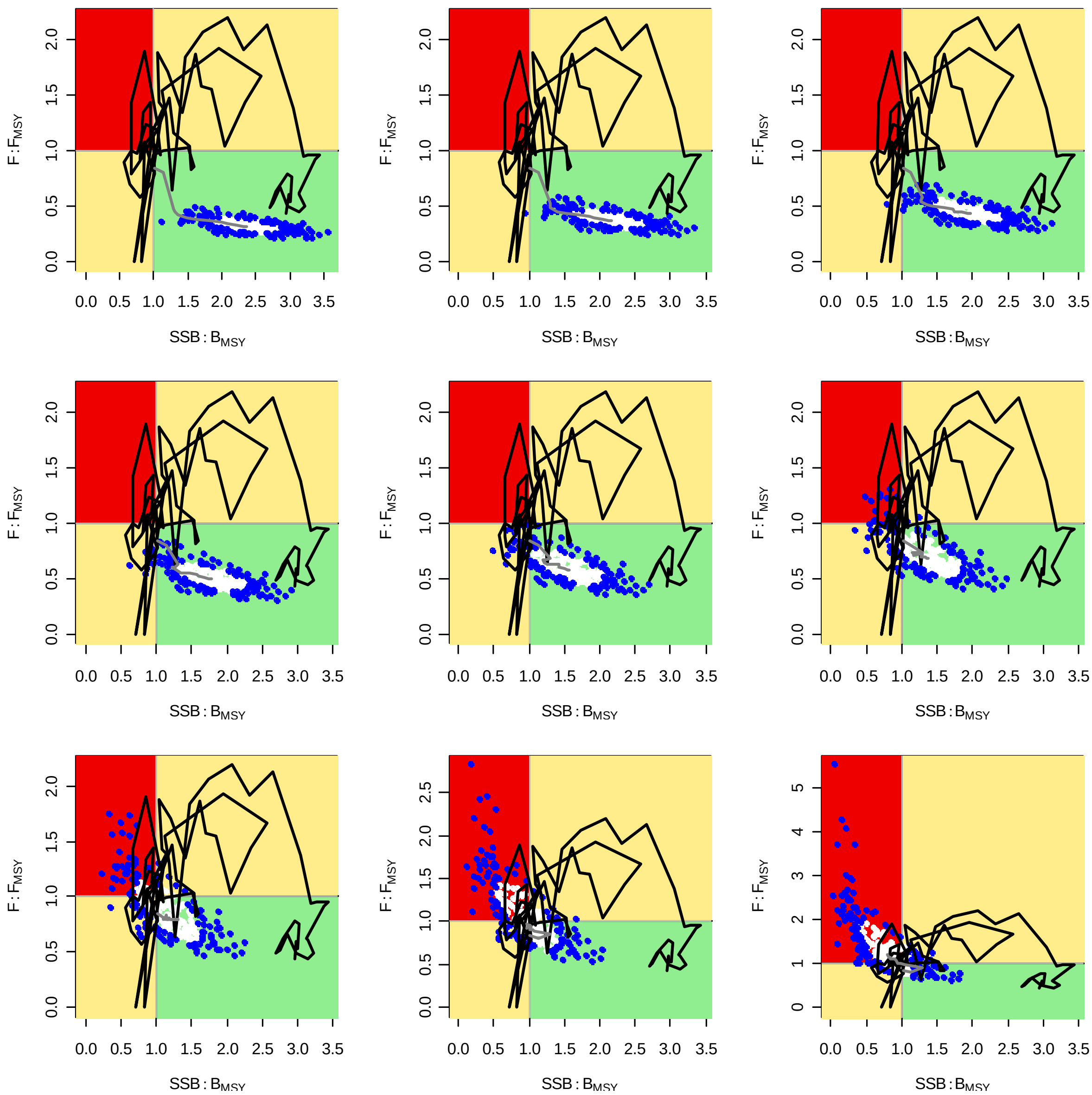

Figure 7b. "Kobe plots"; points show individual realisations in 2020 and lines the median stock trajectories for historic and projected periods (black and grey respectively). Quadrants are defined for the stock and fishing mortality relative to B_{MSY} and F_{MSY}; i.e. red SSB<B_{MSY} and F>F_{MSY}, 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.

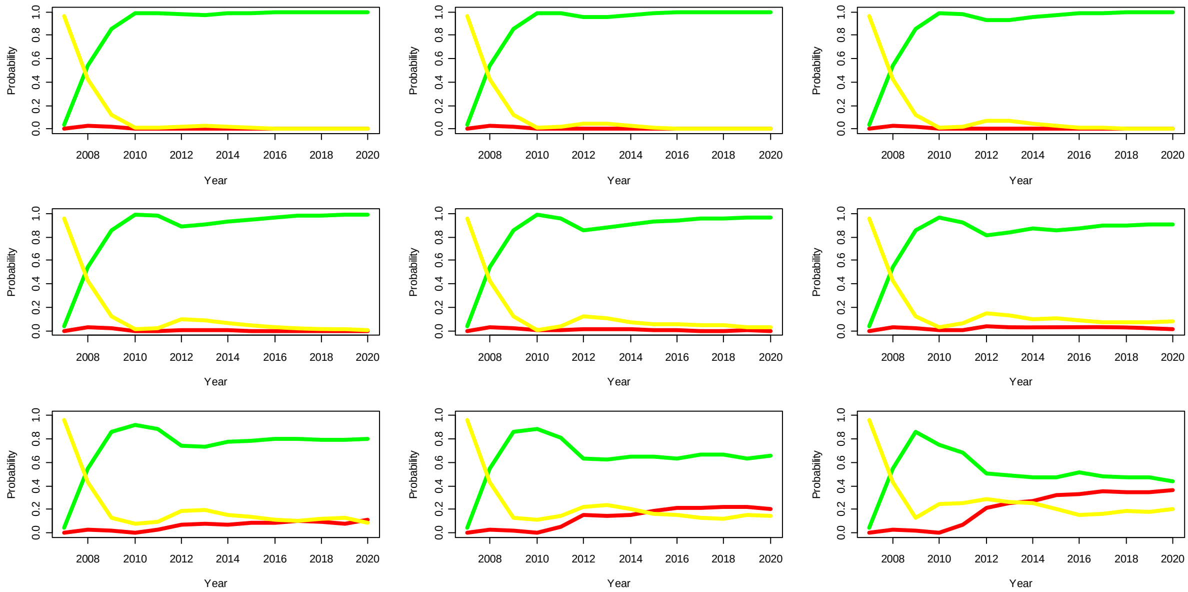

Figure 8a. Probability trends of north Atlantic swordfish under constant TACs levels for North Atlantic swordfish showing probability of being in one of the quadrants by year defined relative to B_{MSY} and F_{MSY}; red $SSB<B_{MSY}$ and $F>F_{MSY}$, green red $SSB \geq B_{MSY}$ and $F \leq F_{MSY}$ 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.

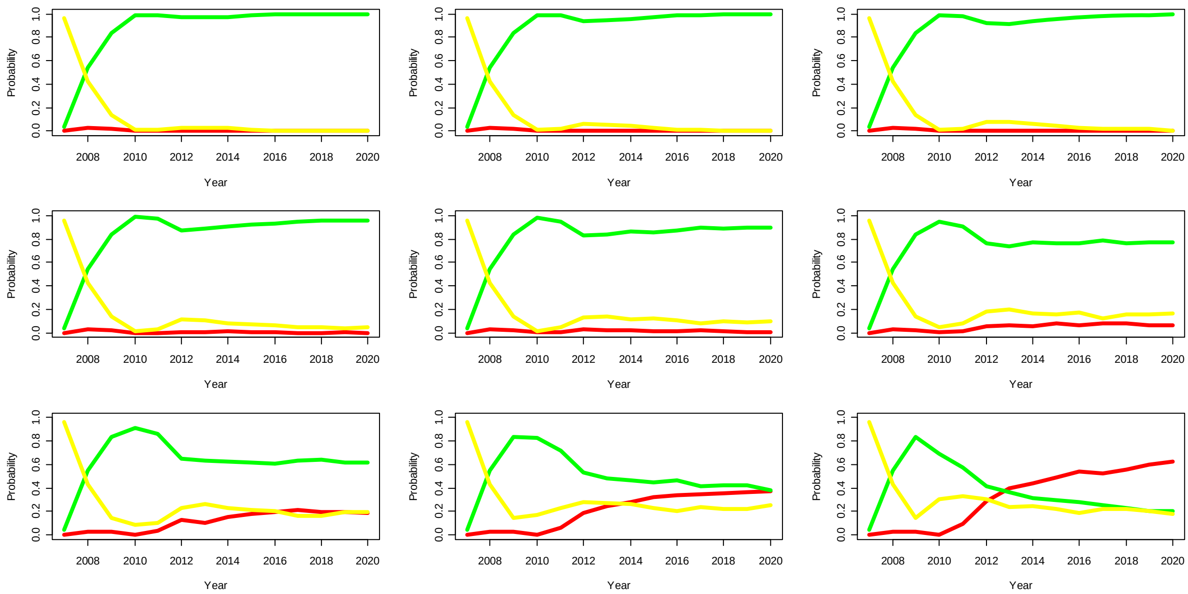

Figure 8b. Probability trends of north Atlantic swordfish under constant TACs levels for North Atlantic swordfish showing probability of being in one of the quadrants by year defined relative to B_{MSY} and F_{MSY}; red $SSB<B_{MSY}$ and $F>F_{MSY}$, green red $SSB \geq B_{MSY}$ and $F \leq F_{MSY}$ 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.

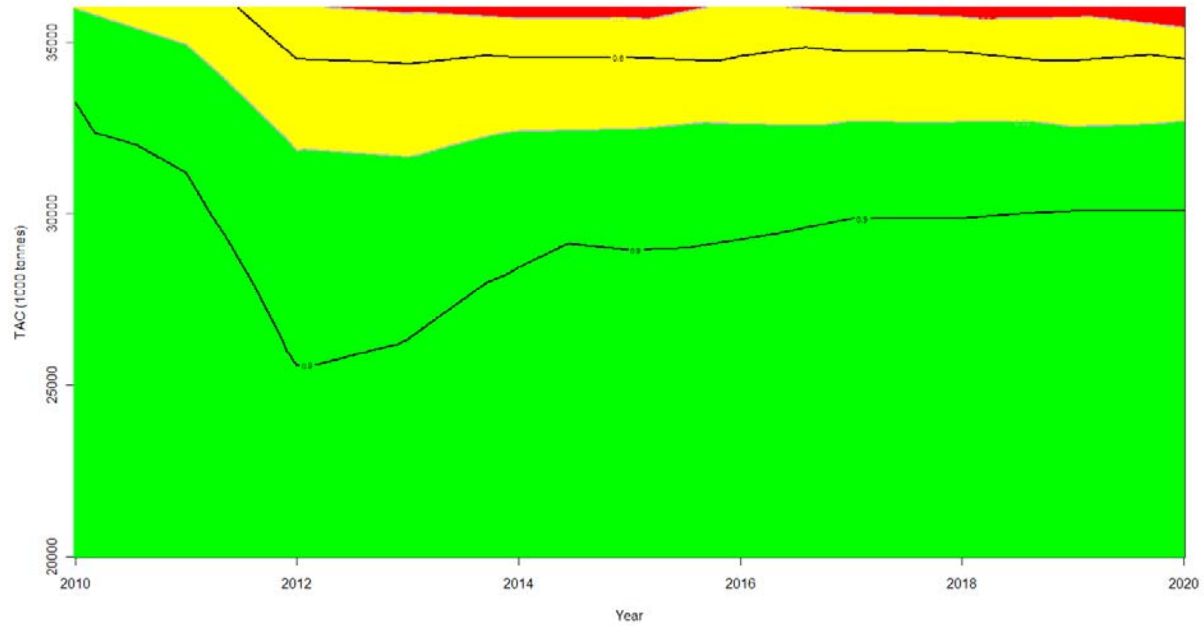

Figure 9. Advice plot, green, yellow and red correspond to the probabilities (≥75%, ≥50% & <75$, <25% respectively) of being in the Kobe quadrant corresponding to SSB≥B_{MSY} and F≤F_{MSY} by year for each of the TAC levels, integrated over both stock recruitment assumptions.