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SENSITIVITY OF THE KOBE II STRATEGY MATRIX TO LIFE HISTORY ASSUMPTIONS

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SUMMARY

The adoption of the Precautionary Approach (FAO, 1996) requires a formal consideration of uncertainty, for example in the quality of the available data and knowledge of the stocks and fisheries. The Kobe II Strategy Matrix (K2SM) is an important tool for communicating between stakeholders for the Tuna RFMOs. It assists the decision-making process by allowing a consideration of the different levels of risk. However substantial uncertainties still remain in stock assessments. Therefore it is important to develop research activities to help better quantify the uncertainty and understand how this uncertainty is reflected in the risk assessment inherent in the K2SM. In this study we show to simulated stock dynamics based on life history theory to evaluate the impact of uncertainty about biological processes on the K2SM.

RESUME

L'adoption de l'approche de précaution (FAO, 1996) nécessite un examen formel de l'incertitude, telle que l'incertitude entourant la qualité des données disponibles et les connaissances des stocks et des pêcheries. La matrice de stratégie de Kobe II (K2SM) constitue un outil important de communication entre les parties intéressées dans le cadre des ORGP thonières. Elle vient appuyer le processus de prise de décision, car elle permet d'examiner les différents niveaux de risque. Toutefois, des incertitudes importantes demeurent dans les évaluations de stock. Il est dès lors important de développer des travaux de recherche afin de contribuer à mieux quantifier l'incertitude et de comprendre comment cette incertitude est intégrée dans l'évaluation des risques inhérente à la K2SM. Dans cette étude, nous avons simulé la dynamique des stocks sur la base de la théorie du cycle vital afin d'évaluer l'impact de l'incertitude entourant les processus biologiques sur la K2SM.

RESUMEN

La adopción del enfoque precautorio (FAO, 1996) requiere una consideración formal de la incertidumbre, por ejemplo en la calidad de los datos disponibles y en los conocimientos de las pesquerías y de los stocks. La matriz de estrategia de Kobe II (K2SM) es una herramienta importante para que se comuniquen las partes interesadas en el marco de las OROP de túnidos. La K2SM ayuda en el proceso de toma de decisiones, ya que permite considerar diferentes niveles de riesgo. Sin embargo, siguen existiendo importantes incertidumbres en las evaluaciones de stock. Por lo tanto, es importante desarrollar actividades de investigación que ayuden a cuantificar mejor la incertidumbre y a comprender el modo en que dicha incertidumbre se integra en la evaluación de riesgo inherente a la K2SM. En este estudio se muestra la simulación de dinámica del stock basándose en la teoría del ciclo vital para evaluar el impacto de la incertidumbre sobre los procesos biológicos en la K2SM.

KEYWORDS

Data-poor, FLR, life history relationships, reference points

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1. Introduction

The SCRS provides scientific advice in the form of the Kobe II Strategy matrix (K2SM), which summaries the probabilities of SSB > BMSY and F < FMSY for different levels of catch (or other management options) across multiple years. This requires stock assessment working groups to provide probabilistic statements on management outcomes. To be consistent with the Precautionary Approach (Garcia, 1996) requires a formal consideration of uncertainty. Therefore, the Commission has recommended that along with the K2SM a statement is included describing the uncertainty associated with stock estimates and projections. This should also include a characterisation of the robustness of modeling approaches used and assumptions made.

Traditionally, stock assessments consider mainly uncertainty in observations and process such as recruitment. However, uncertainty about the actual dynamics (i.e. model uncertainty) can have a larger impact on achieving management objectives (Punt, 2008). Therefore in this study we evaluate the relative importance of uncertainties in growth, maturity, natural mortality and the stock recruitment relationship on the K2SM. We do this by conducting stochastic projections for different levels of recruitment variability and CVs for estimates of stock status for several assumptions about stock dynamics, i.e. growth, natural mortality, the stock recruitment relationship and age at maturity. This allows us to evaluate the relative importance of the different sources of uncertainty on management advice, and the robustness of advice to uncertainty about the dynamics.

We do this for an example based on life history relationships (Gislason et al. 2008 b,a), using the approach described in SCRS/2012/034.

2. Material and Methods

Life history relationships are used to parameterise 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. We consider five scenarios:

- Default based on the life history relationships and a value of $L\infty$ equal to 175 with a steepness equal to 0.9.
- Growth: Growth model changed from von Bertalanffy to the Gascuel growth model.
- Natural Mortality In the default life history model it is assumed that M varies by age, in this scenario
- M is set as 0.1 at all ages.
- Maturity fish mature at a younger age, i.e.,
  Steepness: The steepness of the stock recruitment relationship is 0.75, i.e., recruitment is reduced at low values of S and MSY.

The simulated stock that was initially above B_{MSY} and fishing mortality below F_{MSY}. Fishing mortality was then increased linearly for a period of twenty years until the SSB was 50% of B_{MSY}.Projections with process error in recruitment were performed for a range of TACs.

All modelling was carried out using FLR (Kell, et al. 2007) which can be used to build simulation models representing alternative hypotheses about stock and fishery dynamics. This allows a higher level of complexity and knowledge than used by stock assessment models and to explicitly include a greater range of uncertainty.

3. Results

Natural mortality, proportion mature and mass-at-age for the five scenarios are shown in **Figure 1**. These relationships where then used to simulate the equilibrium dynamics of stocks based on different hypotheses about the biology. A comparison of the equilibrium (expected) yield values as a function of SSB and as a function of fishing mortality for the five scenarios can be made by inspecting **Figures 2 and 3**, respectively. MSY reference points are indicated. From **Figure 2** it can be seen that assuming M varies by age has a large effect on productivity, increasing both MSY and B_{MSY}. The next biggest effect is seen for growth, i.e., using the Gascuel growth curve. Reducing steepness from 0.9 to 0.75 and increasing the age at first maturity reduces MSY but increases B_{MSY}. Inspection of **Figure 3** allows a similar analysis to be conducted with respect to fishing mortality; F_{MSY} increases for all scenarios except steepness. F_{crash}, the fishing mortality that would drive the stock to extinction can be inferred from the point where the right hand limb of the curve crosses the x-axis. The steepness and growth scenarios result in a reduction in F_{crash}, i.e., the stock is more vulnerable to overfishing.

Population growth rates by scenario are plotted in **Figure 4**, changing the M assumptions results in the greatest increase in population growth rate followed by growth, then maturity. Steepness is the only scenario where growth rate is reduced.

ICCAT management advice, in common with other tuna Regional Fisheries Management Organisations (tRFMOs), is presented as a Kobe Strategy Matrix or K2SM, a decision table that shows the probabilities of achieving a management objective for different options (e.g. catch or effort levels) over various time frames. For example, in the case of a recovery plan, where the stock is currently overfished, the objective is to recover the stock to a level that will support MSY in the long term.

Figure 5 shows phase plots by scenarios for the simulated stocks. These plot SSB against fishing mortality scaled by the MSY benchmarks; the red zone corresponds to overfishing and overfished and green to a stock that is currently greater than $_{BMSY}$ and is being fished at a level below F_{MSY}. The stocks were then gradually overfished until SSB fell below B_{MSY}. A TAC well below MSY was then implemented. This results in the stock trajectories following an anti-clockwise path, being initially in the green zone then entering the red zone before returning to the green when the TAC is reduced. The trajectories vary by scenario since the productivity and the growth rates vary too.

Kobe II Strategy Matrices are shown in **Figure 6**. for different levels of process error (i.e., recruitment variability), estimation error (i.e. CV of current stock status) and scenario. The first row corresponds to the default scenario with zero estimation error; the columns correspond to the level of recruitment variability. As recruitment variability increases so does the probability of being in the green zone of **Figure 5** for a given TAC level. The second row again shows the default scenario with a recruitment CV of 20%, columns are for different levels of estimation error. As estimation error increases the probability of being in the green zone of **Figure 7** decreases, i.e., there is a positive benefit in reducing stock assessment uncertainty in estimates of current stock size. The final row contrast scenarios for a 20% CV in recruitment and no estimation error. As predicted by the estimates of population growth rate, M and Growth increase the probability of recovery for a given TAC whilst reducing steepness and an increase in the age at maturity decreases it.

4. Discussion

The Commission has recommended that a statement characterizing the robustness of methods applied to assess stock status and to develop the scientific advice must be included in SCRS assessment reports. This statement should focus on modeling approaches, assumptions and the reliability of long term projections period. SCRS/2012/036 explored the use of life history relationship for data poor and rich stock assessments and found that the biological processes and their parameters had a large effect of both the productivity of stocks and target and limit reference points. Therefore in this study we evaluated the sensitivity of the Kobe strategy II matrix to the assumed biology.

We simulated a generic stock based on a range of assumptions about natural mortality, growth and maturity. Large changes were seen in the productivity of the stock, the expected dynamics and reference points, depending on the assumed biological characteristics. In all cases B_{MSY} increased with respect to the base case, while F_{MSY} also increased expected when steepness decreased. M SY nearly doubling when M was age specific. The biggest effect was due to the assumed natural mortality followed by growth. Surprisingly steepness had less of an effect.

Important differences were seen in population growth rates, which will impact on advice based on the K2SM. We therefore conducted projections to generate K2SMs under a range of hypotheses about uncertainty. These simulations showed that while increasing variability in the expected recruitment improved recovery time for a given TAC (or will permit a higher TAC for the same management objective of a given probability of recover within a set time scale). While for increasing estimation error the opposite effect was seen. The biggest effect however was seen for the biological assumptions. M and growth have the biggest effect.

There is often inconsistency between stocks and within species, for example in some stock assessments natural mortality varies by age in other it is constant, our analysis showed that the assumptions about M are very important when providing advice. There is a need to develop ways of reducing uncertainty about the key biological processes and integrating such uncertainty into management advice.

This study was generic and did not consider any specific stock. However it did show the importance of the biology when providing scientific advice. The approach could be used on a case specific base to develop priors or weight for scenarios based on biological assumptions. Often stock assessment working groups conduct alternative runs when estimating the historical time series and parameters. These are mainly based on assumptions about selectivity and catch per unit effort. These are then used as the basis of the projections on which advice is based.

Weighting of hypotheses is likely to become an increasing concern of stock assessment working groups may be done using Bayesian methodology on the basis of the extent to which they are supported by the available data within a single model structure Or to use externally specified on either a continuum or more commonly a small number of representative values for each parameter. For different structural models (e.g., one-stock vs. two-stock hypotheses) it is most likely that externally specified weights will be required rather than likelihood-based weights.

An alternative approach is that of the IWC Scientific Committee (see IWC 2005 and Annex 5) which avoids quantification, and instead categorises hypotheses as of high, medium and low weight. In cases where there is no agreement, but a plausible case can be made by some for a high weight, a medium weight is assigned. (IWC 2005 and Annex 5) describes how such weights are incorporated in the decision process.

To avoid experts choices of weights being influenced by the management implications of an associated hypothesis, these weights should ideally be finalised on the basis of informed discussion concerning the hypotheses alone, conducted before any computations related to management. However, pragmatically, some flexibility on this point may be entertained in the interests of time for example to identify at an early stage that some hypotheses, although of appreciable plausibility, make little difference in terms of management implications when compared to corresponding default hypotheses, and hence need not be considered further.

5. Conclusions

Life History relationships result in that biological parameters being correlated, i.e. species that reach a large maximum size, growth more slowly, mature later and experience lower natural mortality. These relationships mean that from something that is easily observable such as size, parameters that are more difficult to observe such as M can be infer. Use of life history theory also allows the transfer of knowledge between species, stocks and populations.

Tuna may differ in some of their life history relationships from other species. However, most of the published relationships are based on demersal and small pelagic species therefore it is important to collate data on tuna and other species (e.g., sharks, billfish and turtles) management by and of interest to ICCAT. Case studies can be conducted using life history relationships using the generic stock simulator to evaluate consistency of the advice based on stock assessment methods; e.g. reviews of M, maturity and growth in age based assessments and parameters such as the r intrinsic growth rate in biomass dynamic models.

Kobe 2 Strategy Matrices are important tools for communication of advice and uncertainty. Life history relationships are important to evaluate the robustness of advice based on the K2SM. Uncertainty in estimation, stock recruitment variability and biological assumptions were simulated and their effect on the K2SM evaluated. It was found that the biological assumptions had the biggest impact on advice.

Future work should include evaluation of life history relationships by a wide range of taxa and methods to proposing scenario and weighting them need to be developed.

6. References

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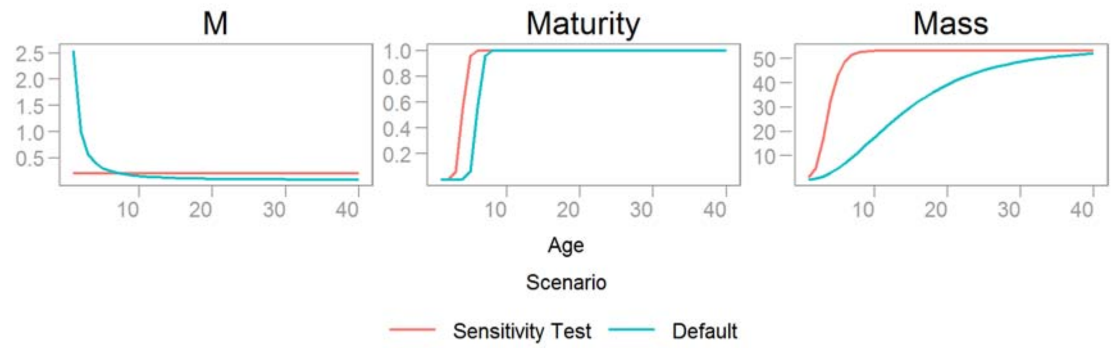

Figure 1. Natural mortality and proportion mature and mass-at-age from the five scenarios.

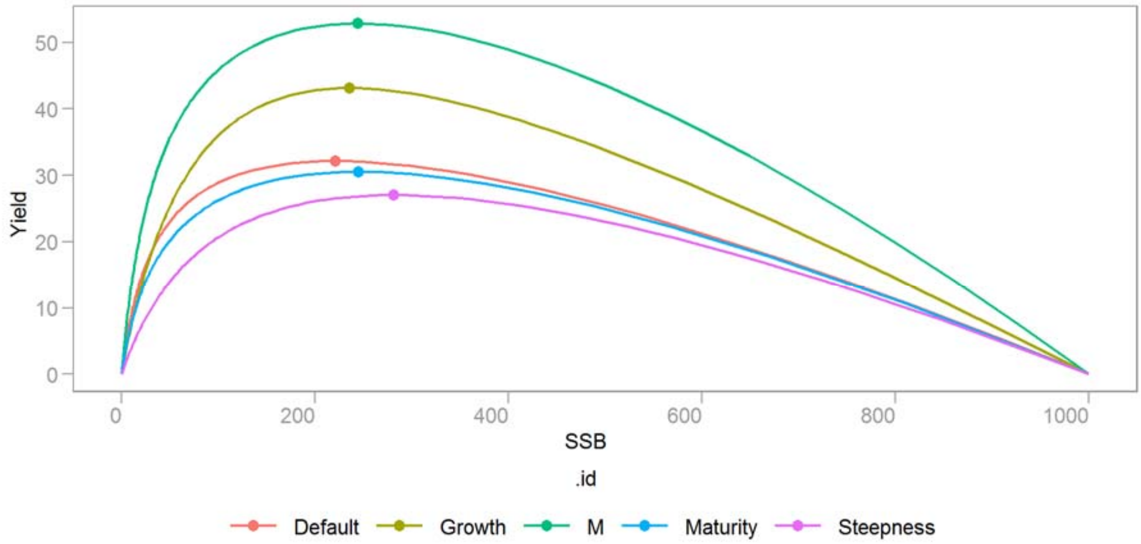

Figure 2. A comparison of the equilibrium or expected values of SSB and yield by scenario; points correspond to MSY.

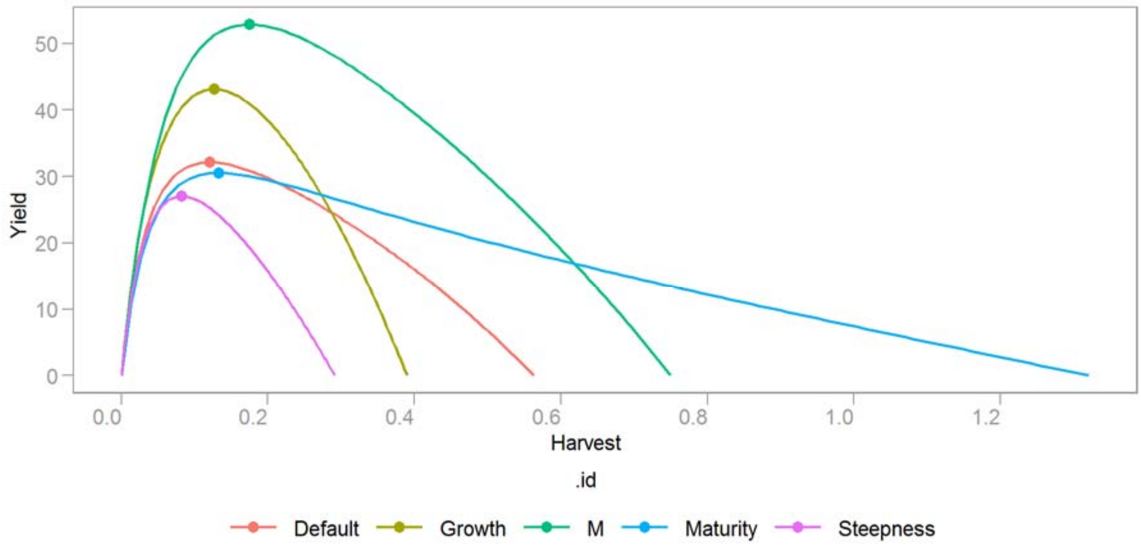

Figure 3. A comparison of the equilibrium or expected values of fishing mortality and yield by scenario; points correspond to MSY.

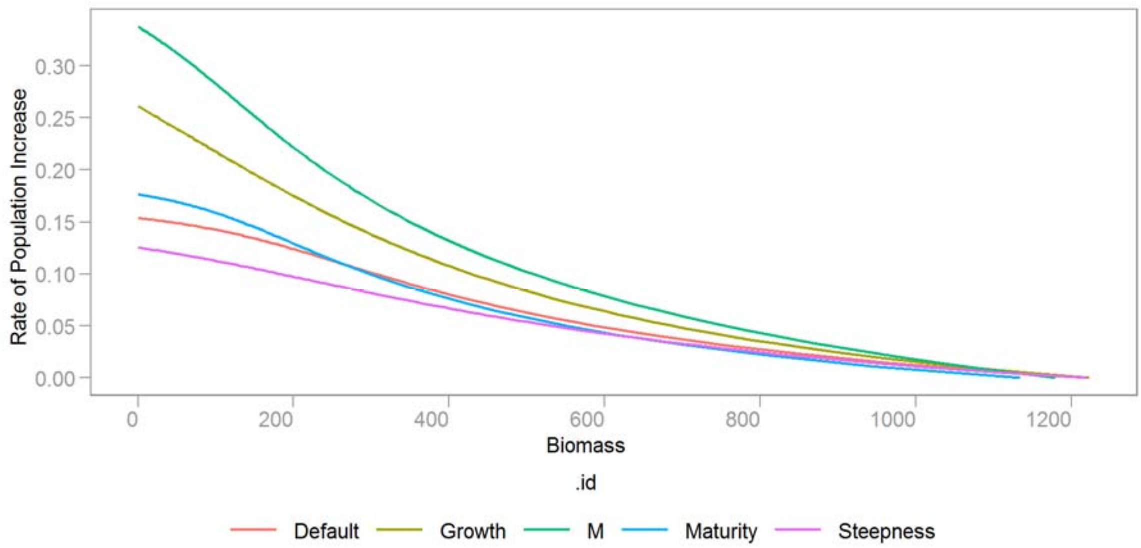

Figure 4. Population growth rate by scenario.

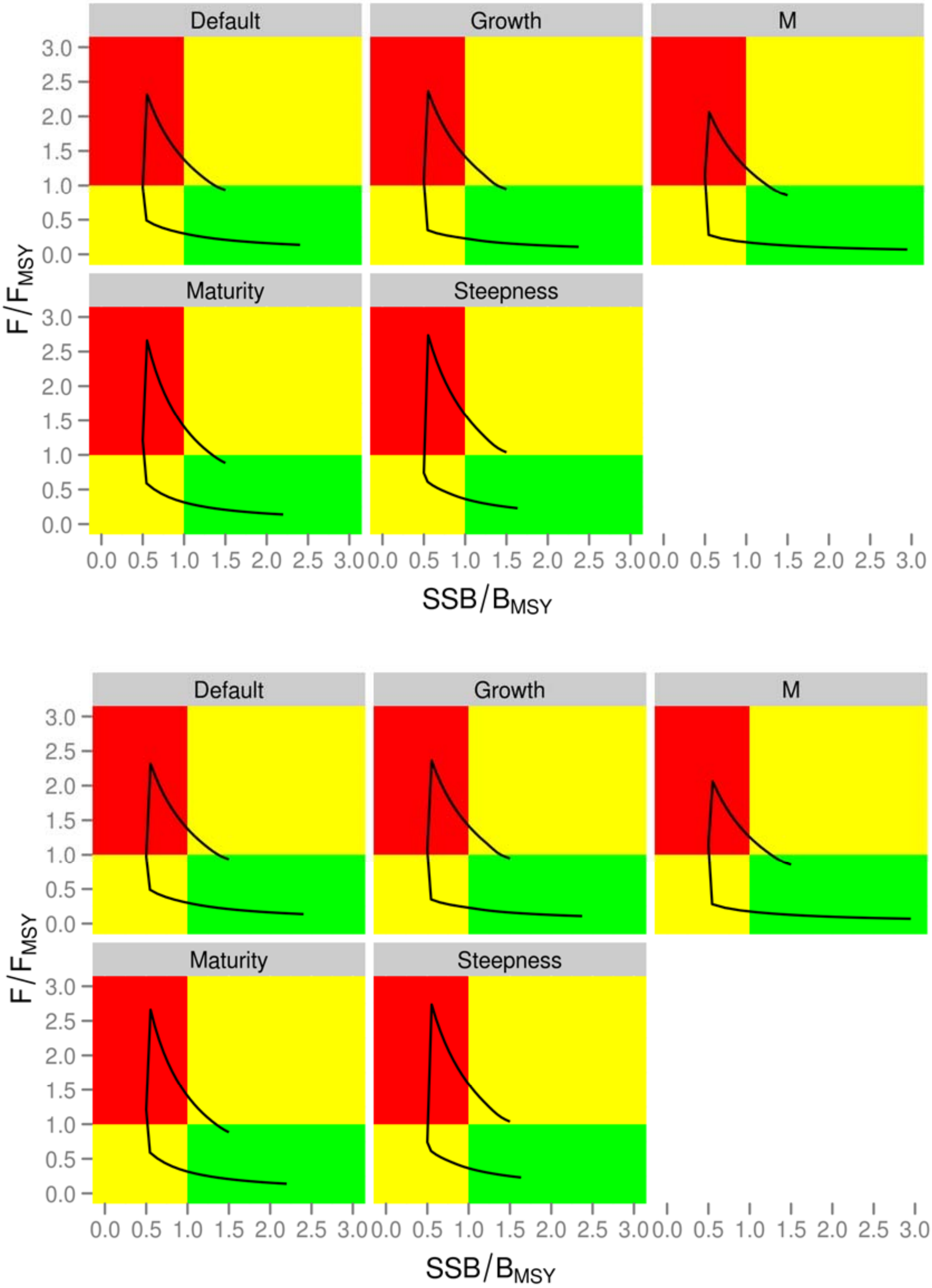

Figure 5. Phase plots by scenarios for the simulated stocks. These plot SB verses harvest rate scaled by MSY benchmarks; the red zone corresponds to overfishing and overfished and green to a stock that is currently greater than $_{BMSY}$ and is being fished at a level below F_{MSY}

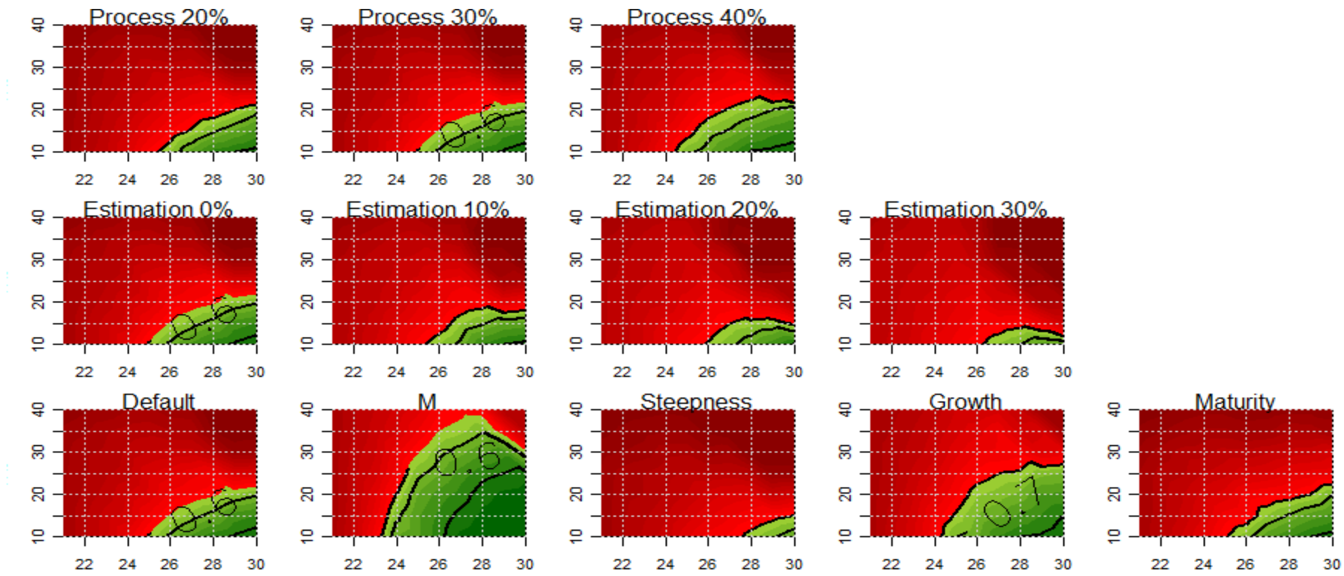

Figure 6. Kobe II Strategy Matrices by scenario; the contours are the probabilities of being in the green qradrant of the phase plot (i.e., not overfished or overfishing).