A FRAMEWORK FOR PROMOTING DIALOGUE ON PARAMETERIZING A HARVEST CONTROL RULE WITH LIMIT AND TARGET REFERENCE POINTS FOR NORTH ATLANTIC ALBACORE

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SUMMARY

A framework for promoting dialogue between SCRS and the Commission is proposed for advancing the application of a Harvest Control Rules consistent with the Commission's decision making framework for development and application of conservation and management measures. A provisional example is provided for northern Albacore, although the methods could be more broadly applied across the range of stocks for which quantitative stock assessments have been conducted and Kobe 2 Strategy matrices provided.

RÉSUMÉ

Un cadre visant à encourager le dialogue entre le SCRS et la Commission est proposé en vue de faire avancer l'application des normes de contrôle de la ponction conformément au cadre de prise de décision de la Commission pour le développement et l'application des mesures de conservation et de gestion. Un exemple est fourni à titre provisoire pour le germon du Nord, bien que les méthodes puissent être plus largement appliquées à une gamme de stocks pour lesquels des évaluations quantitatives des stocks ont été réalisées et des matrices de stratégie de Kobe 2 ont été fournies.

RESUMEN

Se propone un marco para propiciar el diálogo entre el SCRS y la Comisión para avanzar en la aplicación de normas de control de la captura de un modo coherente con el marco de toma de decisiones de la Comisión para el desarrollo y aplicación de las medidas de conservación y ordenación. Se presenta un ejemplo provisional para el atún blanco del norte, aunque los métodos podrían aplicarse más ampliamente a la gama de stocks para los que se han realizado evaluaciones de stock cuantitativas y para los que se han proporcionado matrices de estrategia de Kobe.

KEYWORDS

Albacore, northern stock, Harvest Control Rule, Precautionary Approach

Introduction

In line with the Kobe discussions and a "Best Practice" identified by several groups (e.g. DeBruyn *et.al.* 2011, Lodge *et.al.* 2008) and consistent with prior SCRS advice (see, SCRS 2011, for example) the Commission has embraced the application of a precautionary decision framework for development and application of conservation and management measures. This framework is specified in the Recommendation by ICCAT on the principles of decision making for ICCAT conservation and management measures [Rec. 11-13], in which the guiding principles for adoption of management measures, based on scientific stock status evaluations and which considers uncertainties in those evaluations, have been agreed. Paraphrasing, these guiding principles, outlined in **Figure 1**, are:

1. For stocks in the green quadrant of the Kobe plot, management measures shall be designed to result in a **high probability** of maintaining the stock within this quadrant.

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2. For stocks that are in the upper right yellow quadrant of the Kobe plot, the Commission shall immediately adopt management measures designed to result in a **high probability** of ending overfishing in **as short a period as possible**.
3. For stocks in the red quadrant of the Kobe plot, the Commission shall immediately adopt management measures, designed to result in a **high probability** of ending overfishing in **as short a period as possible** and the Commission shall adopt a plan to rebuild these stocks, and
4. For stocks in the lower left yellow quadrant of the Kobe plot, the Commission shall adopt management measures designed to rebuild these stocks in **as short a period as possible**.

In combination, these guiding principles provide a basis for design of Harvest Control Rules (HCRs) and SCRS has recommended a generic HCR framework (SCRS 2011, see **Figure 1**), upon which stock-specific robustness testing can and will be conducted. Indeed, SCRS has initiated work on conduct of Management Strategy Evaluations (MSE) for several species in support of identifying HCRs that are robust to a large range of scientific uncertainties (*e.g.* SCRS/2013/33) and consistent with the above principles.

It is useful to recognize that identification of HCRs that are robust to uncertainty and consistent with the principles agreed is a functional responsibility of SCRS, but that the specific parameterization of the decision framework elements identified in bold, above, are policy selections that require further choice by the Commission. That is to say, in order to identify a specific HCR parameterization to apply to a given stock, a dialogue between SCRS and the Commission is required in order to identify these specific policy elements on a stock-by-stock basis. This dialogue needs to focus on the critical policy elements of the decision framework which relate to defining the terms "high probability" and "as short a period as possible", noted in bold text above. The objective of this paper is to provide a framework for initiating this dialogue using an example case loosely based on northern Atlantic Albacore as an example and to offer some guidance from other arenas that deal with similar policy decision points.

How High is "High Probability"?

This question posed relates to how sure the Commission wishes to be in achieving the goals laid out in the decision framework [Rec. 11-13]. In recent ICCAT management measures, focus has been on probabilities of 50% or greater for achieving stock size consistent with the Convention Objectives over different time-frames, depending on the stocks in question (*e.g.*, achieving B_{MSY}, with at least 60% probability in a period of 15 years for eastern BFT; maintaining B_{MSY}, with greater than 50% probability for North Atlantic swordfish). In most situations a 'flip of the coin' probability (success as likely as failure) would not be considered high probability. In statistical hypothesis testing, one convention often applied is 95% probability (5% chance of rejecting a true hypothesis), mainly to gain confidence that the effect being tested is extremely likely not to be accepted as significant due to random chance.

Unfortunately, our scientific ability to fully characterize uncertainty in stock status is limited by many factors, including the amount and quality of available data for monitoring stock status and deviations from the modeled process for approximating fishery and fish population dynamics. One consequence of this is that we have less confidence that the extreme tails of the uncertainty distributions estimated are accurate representations of the actual chance of failure (see, for instance, Gavaris *et.al.* 2000). While scientific efforts are underway to advance the modeling and estimation methods for more fully quantifying uncertainty in assessments, current best practice involves providing advice on the basis of that uncertainty which can be quantified.

Several examples from outside ICCAT, based on fisheries management and on climate change science, are summarized below to provide additional guidance on addressing this policy question. In the context of work undertaken by the Intergovernmental Panel on Climate Change (IPCC), standard terms to define levels of confidence related to uncertainties in forecasts made by the IPCC have been developed. The terminology is shown in **Table 1**.

Another example where this issue is taken on is held within the Canadian Sustainable Fisheries decision making framework (see http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/fish-ren-peche/sff-cpd/precaution-eng.htm), which makes use of risk of decline categorizations shown in **Table 2**.

Still another example comes from the scoring system applied by the Marine Stewardship Council (MSC, available at: http://www.msc.org) for purposes of certifications. The MSC system equates "high probability" at somewhat different levels depending on the situation and context in which scoring is being made. This implies the possibility for some scope in applying different definitions depending on each of the 4 decision framework elements in [Rec. 11-13]. The MSC probability categorization scheme is summarized in **Table 3**.

In these categorization schemes, the term "high probability", "high confidence", or "highly likely" would roughly correspond to probability levels of 70% or greater and most certainly correspond to levels above a flip of the coin. It is noteworthy that a 'flip of the coin' (*i.e.* ~50%) probability is more typically taken for target levels while limits such as F_{MSY} in the decision framework [Rec. 11-13] are to be avoided with "high probability" which could correspond to levels substantially above 50%. A probability categorization scheme taken on by the Commission would be useful in eliciting parameters for HCRs to apply to ALB or other stocks and which should be discussed with the Commission.

How Long is "As Short As Possible"?

As indicated, another policy choice needed for parameterizing an HCR for north Atlantic albacore or other stocks is addressing the issues about time-frame for achieving the goals set out in the decision framework of [Rec. 11-13]. There are 2 distinct elements in this: one that relates to fishing mortality rate and the other to stock biomass levels.

The first (F) can have a near instantaneous change due to management intervention, while the second (B) depends on the life-history characteristics of the stock in question as well as the relative status of biomass and the Commission's weighing of the trade-offs related to tolerable risks of failure in achieving goals over what period of time to achieve them. In paraphrasing the ICCAT decision framework [Rec. 11-13], an important phrase was left out of the elements listed above related to time-frames, which is "as short a period as possible, taking into account, inter alia, the biology of the stock and SCRS advice." This underlined phrase inherently acknowledges the second element noted, that change in relative stock status depends on the underlying stock productivity as well as the distance the stock is from its target level. At best, the time required for a stock to grow to a level consistent with the Convention Objectives and the Commission's acceptable tolerance for failure, is the minimum time for rebuilding in the absence of fishing (referred to as T_{min}).

A summary of rebuilding time frames applied for fisheries around the world appears in a recent MSC Consultation Document (http://www.msc.org/about-us/consultations/previous-consultations/archived-msc-consultations-1/rebuilding-timeframes-for-depleted-stocks). A range of options are described, including those used in the US, Australia, and New Zealand. In the US, rebuilding time frames are required to be within 10 years, unless the biological capacity of the stock in question makes it impossible for that to occur, in which case the maximum rebuilding time frame is the time required to rebuild to B_{MSY} in the absence of fishing (*i.e. Tmin*) plus 1 mean generation (*G*, the average age of a reproductively mature animal in an unexploited population). In Australia, rebuilding time-frames permitted (rebuilding to $1.2B_{MSY}$) are the minimum of *G* + 10 years or 3*G*, although reportedly most Australian stock rebuilding strategies aim to rebuild stocks within the *G* + 10 years time-frame. In New Zealand, stock rebuilding within a specified time-frame is required when stocks fall below either $.5B_{MSY}$ or $.2B_0$, whichever is greater, in which case rebuilding time (to target B) should occur between *Tmin* and 2*Tmin*, with a 70% probability that the target has been achieved.

ICCAT has established rebuilding time-frames for several stocks, including north Atlantic swordfish, northern albacore and eastern and western Bluefin. These time-frames range from 10-20 years, depending on the relative stock condition, life history characteristics of the stocks and a number of other concerns. These, however, pre-date the decision framework [Rec. 11-13] adopted in 2011 and the constant catch harvest strategies generally applied to promote rebuilding largely imply an HCR that is not consistent with the decision framework regarding F management.

A Northern ALB Example

Under the HCRs consistent with the ICCAT decision framework in [Rec. 11-13], the intended management impacts on fishing mortality rate are those which result in rapid change in F to levels $<F_{MSY}$, with "high probability". Of the examples considered by SCRS/2013/33, those which limited inter-annual change in either TAC or F of no more than 10% showed behavior inconsistent with the decision framework in [Rec. 11-13] regarding F management. The so-called "At-once" and "Multi-annual" formulations showed F behaviors consistent with the decision framework. While there may be other formulations that are consistent with the

decision framework in [Rec. 11-13], an application of an example "At-once" parameterized HCR for a north-Atlantic ALB-like stock is provided below, with an eye toward eliciting more precise definitions of "high probability" and "as short as possible". The form of the HCR applied is as previously recommended by SCRS and as shown in **Figure 2** with a range of parameter values. The Limit, Target, and Threshold reference points were varied in order to evaluate their effects on estimated probability of success in the decision framework over time.

The example used here is based on an ASPIC Schaefer model assessment of provisional catch-effort data resembling that of northern Albacore, although any assessment model formulation (or combination across models) could be used. In this example, the Albacore-like stock is characterized as in **Table 4**. In this case, 501 bootstrap iterations of the model fit were used to quantify uncertainty in the outcomes needed for stochastic projections as has been the practice in SCRS for many stock status evaluations. Other methods for quantifying uncertainty could also be applied, if they were judged appropriate to do so.

Future stock condition was then projected for a range of candidate Target F, Biomass threshold, and Biomass limit levels (aka *Resan* levels, **Table 5**) to permit estimating the projected probability of F<Fmsy and B>Bmsy across time from several relative biomass starting points. Expected yield trajectories were also calculated to permit examining risk-reward trade-offs.

The outcomes from these simulations are described below and some methods for presenting the results in ways that could help guide better definition of the policy decision points noted above are provided.

Providing Management Advice in the K2SM Formulation.

The Commission requests that management advice be presented in the Kobe II Strategy Matrix (K2SM) framework. In ICCAT, this advice is presented in a formulation that provides estimates of probability of being in the 'Green' quadrant of the Kobe Plot for given levels of constant catch across time. This form of decision table is useful for the Commission, but it implies an HCR that is not necessarily consistent with [Rec. 11-13] management of F. The implied HCR for a constant catch projection is slowly reducing F with growing biomass, often resulting in $F>F_{MSY}$ for considerable periods. The generic HCR recommended by SCRS and used herein is consistent with the intent of the decision framework of [Rec. 11-13] and specifies increases in F (up to a point) with growing biomass and aims to keep $F<F_{MSY}$ with "high probability". A K2SM formulated for different FTarget levels resulting from the example used herein is shown in **Table 6**, considering a starting point of $\sim.8B_{MSY}$ for projections. In this case, an additional column and sub-table could be added to provide information on the catch/probability/time-frame tradeoffs. These projections made were from a starting biomass at or above the BThreshold value used ($\sim.8B_{MSY}$ for this example and hence in the flat region of the HCR), but the construct for cases with other starting points would be the same. To guide selection of an appropriate FTarget level to meet the Commission's "high probability" in "as short as possible" time frame, **Figures 3** and **4** are suggested complements to the HCR K2SM.

As has been noted by others, the pay-out in terms of cumulative catch across time, is typically higher for constant F harvest strategies (since catch increases with increasing stock size) compared to constant catch harvest strategies designed to achieve the same probability of success, although they sometimes require larger up-front costs in terms of effort reduction. Although not shown here, the constant F strategies projected resulted in, on average, 20% higher cumulative catch expectations over the time frame applied, than did constant catch scenarios which achieved an equivalent probability of success in the terminal year of the projections.

A useful point to consider when entering into dialogue with the Commission is the relative status for the stock under question. In the example used here, current status implied little influence of Blimit or BThreshold HCR values among *Resan* levels on outcomes, since the starting point for projection was at or above the BThreshold value used. In cases like the example used, discussion could focus on FTargets to avoid the more complicated and non-linear relationship amongst all the parameters of an HCR, especially considering the objective of the decision framework is "to get green and be happy", with "high probability".

Trade-offs between HCR parameters

In the case examined above, the influence of BThreshold and Blimit on the probability outcomes is minor since the starting point for these projections is generally above the BThreshold applied and the F's used permitted growth in the stock. As noted, however, starting point along the HCR can make a difference and the sensitivity of probability outcomes were subsequently examined by using several different relative biomass starting points in combination with the HCR parameters reflected in **Table 5** (the *Resan* levels). Probability outcomes are governed by the rate at which F reduces with declining biomass in combination with the stock's productivity level. The smaller the range between Blimit and BThreshold, the higher the rate of change in F with changing biomass within that region. Likewise, higher FTargets for a given BLimit and BThreshold pair, the steeper the slope of change in F with changing biomass in that region. **Figure 5** illustrates the point.

The interaction of BLimit, BThreshold, and FTarget combinations for 3 relative biomass starting points (~.2B_{MSY}, ~.5B_{MSY}, and ~.8B_{MSY}) for the example stock are shown in **Figure 6**.

The rate of rebuilding a stock can achieve depends both on its life history characteristics and the relative depletion of the stock. As evidenced in the outcomes here, for cases with stocks close to target levels, rebuilding can take place in a much shorter time frame than can those that are more heavily depleted. The rate at which this can possibly occur is demonstrated by examining the F=0 trajectories for the different depletion levels. For the case of depletion to the lowest BLimit examined (.2B_{MSY} or 10% of unfished biomass) rebuilding to the 'Green' quadrant could take place by year 9 (50% model probability) whereas starting at ~.5B_{MSY} or ~.8B_{MSY} would take on the order of 4.5 or 1.5 years, respectively. Fishing during rebuilding obviously slows the rate at which it occurs, lengthening time-frames required to achieve a "high probability" outcome. In general, higher catches (cumulative), associate with lower probability outcomes, but this is not always the case, since the form of the HCR can influence the results. **Figure 7** provides a summary of the expected cumulative yield outcomes for HCR parameter combinations examined which provided relatively high probability to demonstrate the point. Parameter selection offering the highest expected cumulative catch and providing an acceptable level of 'high probability' within a rebuilding time-frame appropriate to the condition of the stock, could be an appropriate criterion to guide further dialogue with the Commission on defining a full range of parameters.

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Table 1. The standard terms used to define levels of confidence by the IPCC Uncertainty Guidance.

Confidence Terminology	Degree of confidence in being correct
Very high confidence	At least 9 out of 10 chance (90% probability)
High confidence	About 8 out of 10 chance (80% probability)
Medium confidence	About 5 out of 10 chance (50% probability)
Low confidence	About 2 out of 10 chance (20% probability)
Very low confidence	Less than 1 out of 10 chance (10% probability)

(see http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch1s1-6.html)

Table 2. Risk categorizations used within the Canadian Sustainable Fisheries Decision Making Framework.

Risk of decline[1]	**Risk category**
Less than 5%	Very low
5% - 25%	Low
25% - 50%	Moderate
~50%	Neutral
50%-75%	Moderately High
75%-95%	High
>95%	Very High

[1] Accounts for quantifiable risk only.

Table 3. Uncertainty categorizations used in MSC Certification scoring related to different Principles (P1 and P2) considered.

	Probability Category		
	Likely	Highly Likely	High degree of certainty
P1 (Sustainable Fish Stocks)	$\geq$70% prob	$\geq$80% prob	$\geq$95% prob
P2 (Minimizing Environmental Impact)	$\geq$60% prob	$\geq$70% prob	$\geq$80% prob

Table 4. Population parameters used in the example in this paper.

	MSY	B_{MSY}	K	F_{MSY}
median	40,100	310,000	620,000	0.13
mean	39,899	322,166	644,337	0.13
max	45,200	860,000	1,720,000	0.27
min	29,400	169,000	337,000	0.03

Table 5. Levels of candidate Target F, Biomass threshold, and Biomass limit levels used in this example (the *Resan* levels), corresponding to levels considered useful by SCRS.

FTarget:	$.5F_{MSY}$, $.75F_{MSY}$, $.8F_{MSY}$, $.85F_{MSY}$, $.9F_{MSY}$, $.95F_{MSY}$, F_{MSY}
BThreshold:	$.6B_{MSY}$, $.8B_{MSY}$, B_{MSY}
Blimit:	$.2B_{MSY}$, $.4B_{MSY}$

Table 6. Example K2SM formulated from the generic HCR recommended by SCRS parameterized with a Blimit of $.2B_{MSY}$ and BThreshold of $.8B_{MSY}$, with varying FTargets. The table entries represent indicated model probability levels. Additional information is provided on expected cumulative catch and expected annual catch under this projection.

K2SM Formulation for F-based control rules

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	
	P(B>Bmsy)										
.5Fmsy	0.50	0.68	0.78	0.86	0.89	0.94	0.95	0.97	0.98	0.99	
2011F	0.43	0.56	0.68	0.74	0.80	0.84	0.87	0.89	0.92	0.93	
.75Fmsy	0.40	0.51	0.59	0.68	0.72	0.76	0.80	0.82	0.84	0.86	
.8Fmsy	0.38	0.47	0.55	0.61	0.68	0.71	0.74	0.77	0.79	0.81	
.85Fmsy	0.35	0.43	0.50	0.55	0.60	0.65	0.69	0.71	0.72	0.74	
.9Fmsy	0.34	0.40	0.45	0.50	0.53	0.56	0.58	0.61	0.64	0.67	
.95Fmsy	0.32	0.36	0.40	0.43	0.46	0.49	0.51	0.53	0.53	0.55	
Fmsy	0.30	0.33	0.35	0.37	0.39	0.40	0.42	0.43	0.44	0.46	
	P(F<Fmsy)										
.5Fmsy	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
2011F	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	
.75Fmsy	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	
.8Fmsy	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	
.85Fmsy	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	
.9Fmsy	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	
.95Fmsy	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	
Fmsy	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	
	P(Green)										Cum Catch
.5Fmsy	0.50	0.68	0.78	0.86	0.89	0.94	0.95	0.97	0.98	0.99	266,790
2011F	0.43	0.56	0.68	0.74	0.80	0.84	0.87	0.89	0.92	0.93	328,670
.75Fmsy	0.40	0.51	0.59	0.68	0.72	0.76	0.80	0.82	0.84	0.86	356,770
.8Fmsy	0.38	0.47	0.55	0.61	0.68	0.71	0.74	0.77	0.79	0.81	371,480
.85Fmsy	0.35	0.43	0.50	0.55	0.60	0.65	0.69	0.71	0.72	0.74	385,650
.9Fmsy	0.34	0.40	0.45	0.50	0.53	0.56	0.58	0.61	0.64	0.67	398,730
.95Fmsy	0.32	0.36	0.40	0.43	0.46	0.49	0.51	0.53	0.53	0.55	410,960
Fmsy	0.30	0.33	0.35	0.37	0.39	0.40	0.42	0.43	0.44	0.46	422,470
	Expected Catch (t)										
.5Fmsy	19,180	20,500	21,720	22,840	23,860	24,770	25,570	26,260	26,870	27,390	
2011F	25,220	26,440	27,570	28,590	29,520	30,340	31,070	31,710	32,270	32,760	
.75Fmsy	28,340	29,420	30,420	31,310	32,120	32,840	33,470	34,030	34,530	34,960	
.8Fmsy	30,100	31,080	31,970	32,770	33,490	34,130	34,700	35,200	35,640	36,030	
.85Fmsy	31,900	32,750	33,510	34,200	34,820	35,370	35,850	36,290	36,670	37,000	
.9Fmsy	33,670	34,360	34,990	35,550	36,050	36,500	36,900	37,250	37,560	37,830	
.95Fmsy	35,420	35,940	36,420	36,840	37,210	37,550	37,850	38,110	38,340	38,550	
Fmsy	37,180	37,520	37,810	38,080	38,320	38,530	38,710	38,880	39,020	39,150	

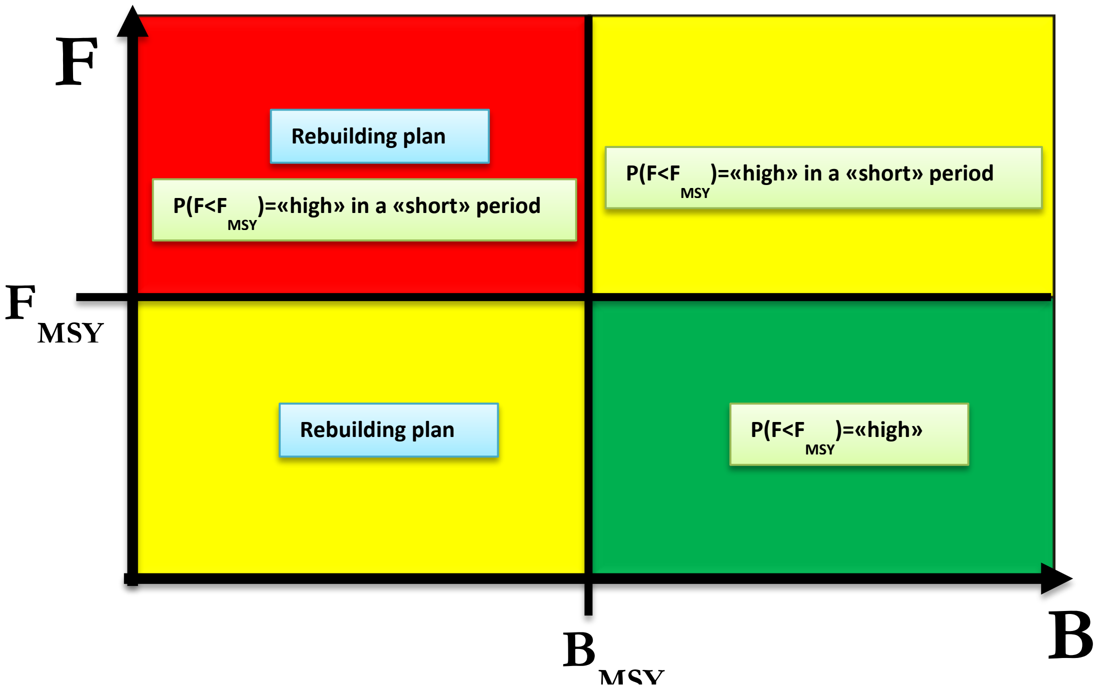


Figure 1. Schematic representation of the key elements of the Recommendation by ICCAT on the principles of decision making for ICCAT conservation and management measures [Rec. 11-13].

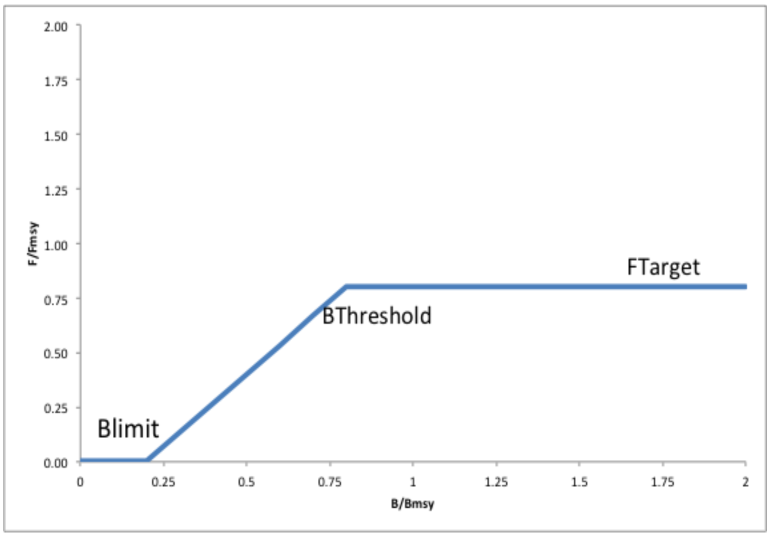


Figure 2. Generic form of the HCR recommended by SCRS (SCRS, 2011). Blimit is the limit biomass reference point, BThreshold is the biomass point at which increasingly strict management actions should be taken as biomass decreases and Ftarget, the target fishing mortality rate to be applied such that it is lower than F_{MSY} with 'high probability'.

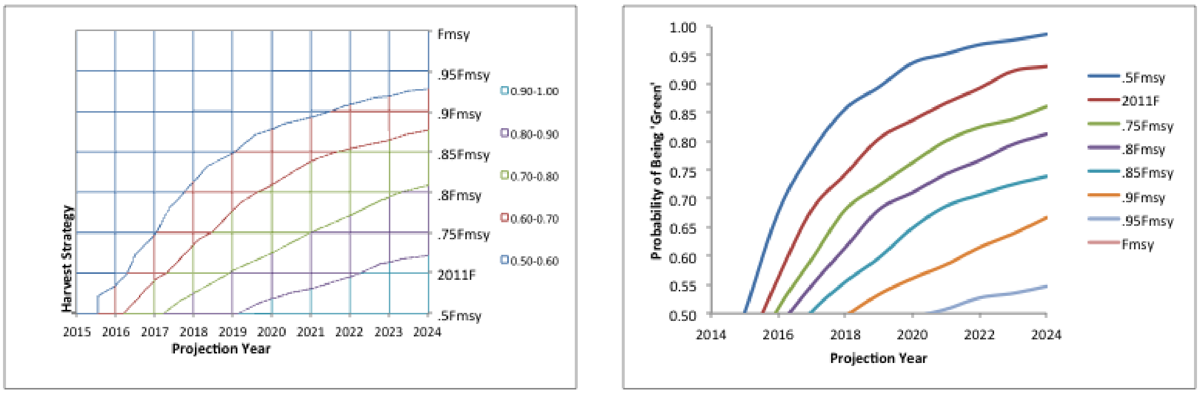


Figure 3. Model probability isopleths (left) and model probability trajectories (right) related to Ftarget levels indicated for the projections in Table 4 across time.

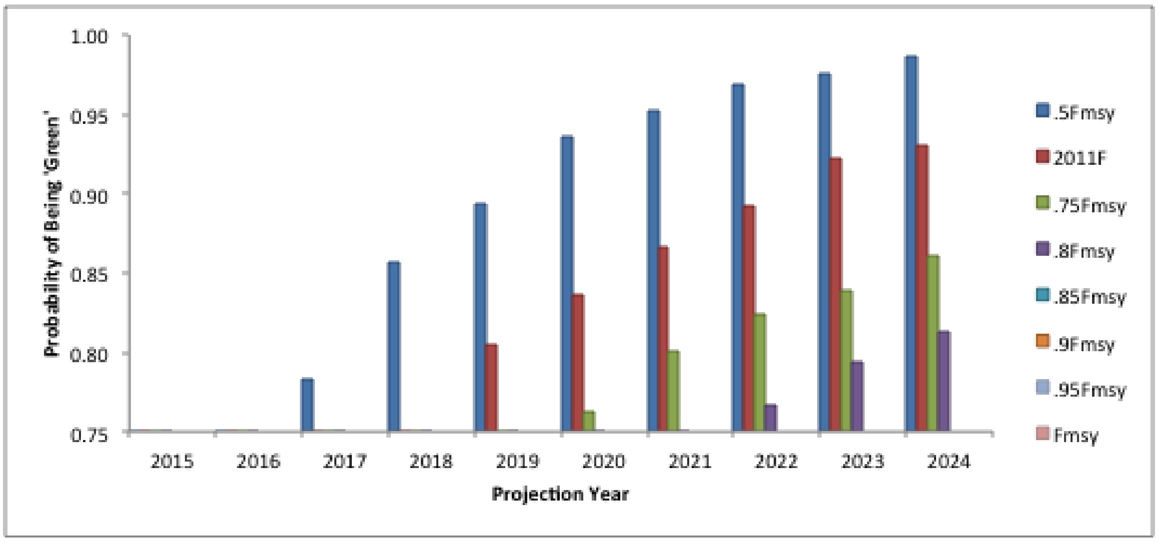


Figure 4. Focusing on the time-trends in probability of being 'Green' to levels that might be considered 'high', such as characterized in Tables 1 , 2 and 3, could help focus discussion about meeting the Commission's standards.

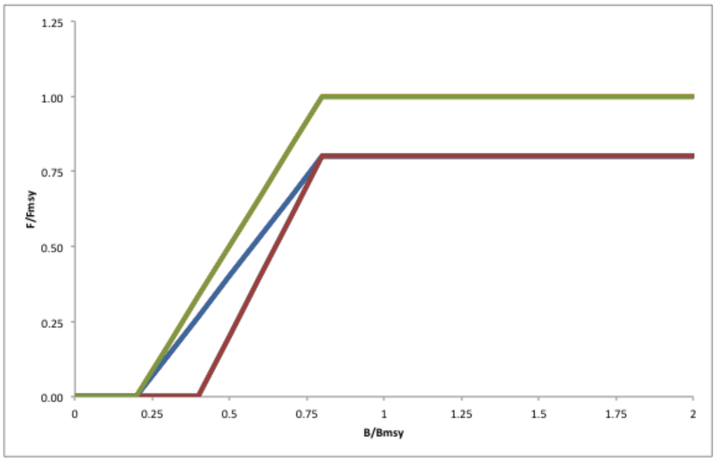


Figure 5. Changes in HCR parameters (Blimit, BThreshold, FTarget) imply different rates and rate of change in F with changing biomass, which imposes different model probability of success outcomes across time. The green line has Blimit at $0.2B_{MSY}$ and BThreshold at $.8B_{MSY}$ with an FTarget of F_{MSY}; the red line: BLimit $0.4B_{MSY}$, BThreshold, $.8B_{MSY}$, FTarget $.8F_{MSY}$; and blue line: BLimit $.2B_{MSY}$, BThreshold $.8B_{MSY}$, FTarget $.8F_{MSY}$.

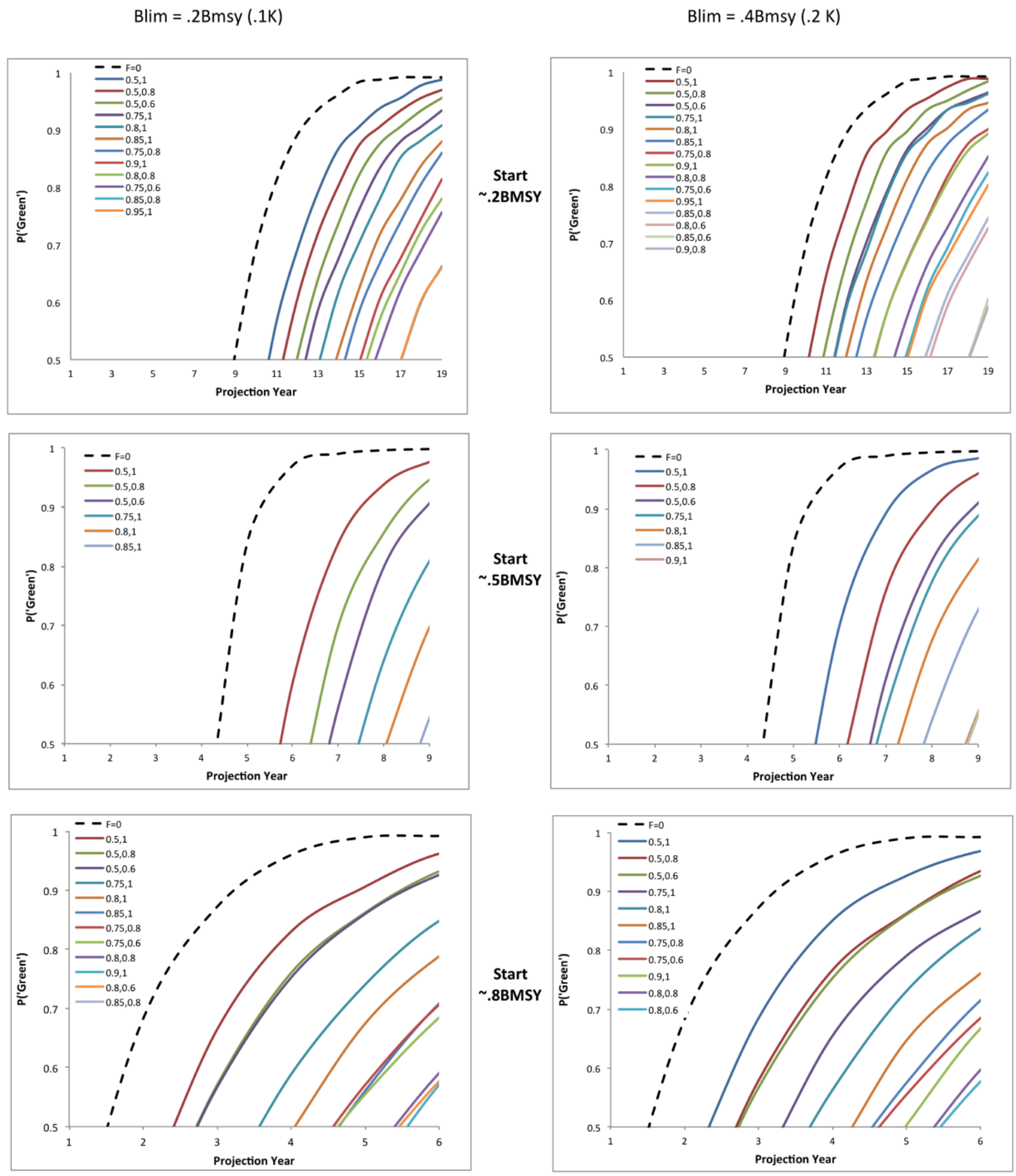
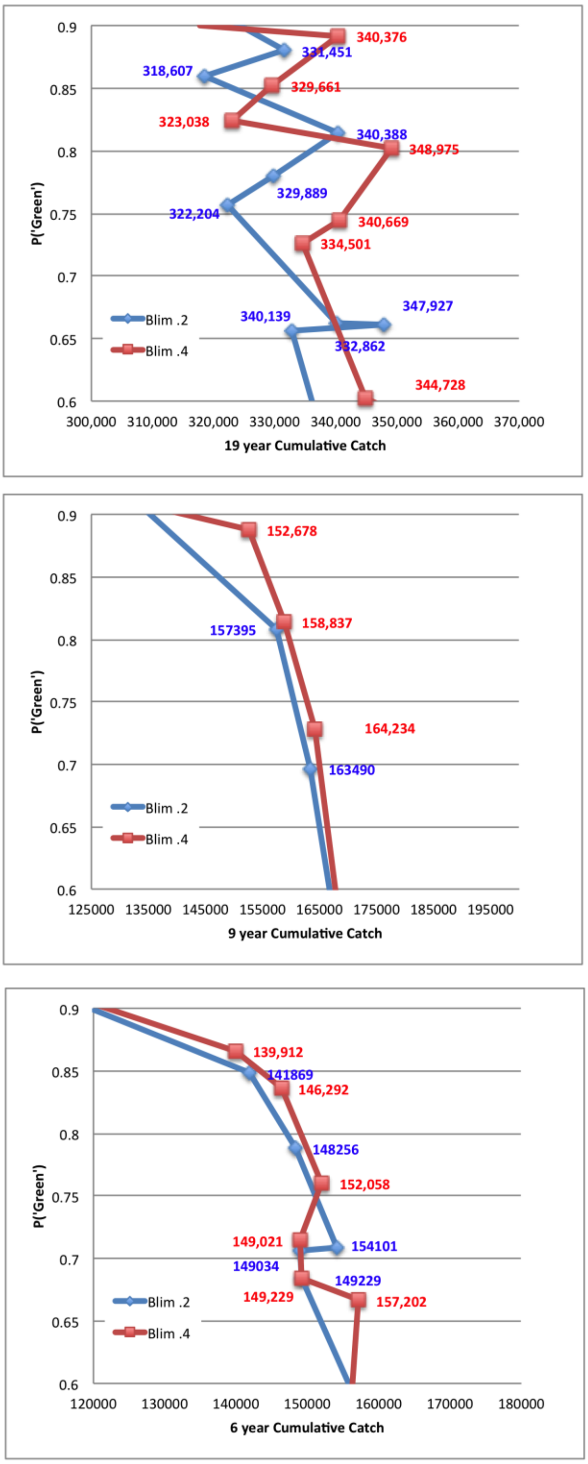


Figure 6. Model probability trajectories over time given different combinations of Blimit (columns), FTarget, BThreshold (coded as e.g. .5, 1 to represent .5F_{MSY} FTarget with B_{MSY} BThreshold), for three levels of starting relative biomass. In all cases, the F=0 trajectory demonstrates biological feasibility (*Tmin*). Only outcomes with at least 50% probability of being in the 'Green' quadrant of the Kobe plot are shown. A time-frame of 19 years (1 Generation time + 10y) is shown for the case of starting at 10% of unfished biomass (.2B_{MSY}). A time-frame of 9 years (1 Generation time) is shown for the case of starting at 50% of B_{MSY} and a time frame of 6 years (.67 Generation time) is shown for the case of starting at 80% of B_{MSY}.



Start ~.2

Start ~.5

Start ~.8

Figure 7. Expected cumulative catch levels and associated model P('Green') outcomes based on different HCR parameter combinations considering the relative biomass starting positions indicated for relatively high probabilities over the time frames indicated.