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Preliminary evaluation of catch-based harvest control rules for South Pacific albacore tuna

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Executive Summary

The objective of this paper is to provide further preliminary steps towards an operational HCR for south Pacific albacore tuna, specifically it aims to:

1. Assess the utility of assessing catch-based HCRs within the stochastic projection framework established within MULTIFAN-CL (MFCL) for other species.
2. Make suggestions on directions for further development of catch-based HCRs for South Pacific albacore, including several of the considerations and issues that the current preliminary analysis suggests will occur as the process is developed.

The approach for evaluating the candidate HCR follows closely from the methods described in detail by Scott et al. (2016a) which were similar to previous work on tunas by Kell et al. (2013). The analyses are based on the stock assessment models of SPA fitted by Harley et al. (2015a) and stochasic projections of the age-structured, multi-regional population are projected foward in time with fishery-specific catches for each run determined by the HCR.

The HCR was tuned to maintain the south Pacific albacore stock around the candidate target reference point submitted to WCPFC12 by FFA members of $45\%SB_{F=0}$. To provide an example of testing the robustness of the candidate HCR against alternative states of nature, the same HCR was applied to south Pacific albacore stock assessments that assumed two alternative values of natural mortality (M): 0.25 and 0.4 (M in the reference case model was 0.3).

The HCR was found to to be relatively robust to alternative states of nature when evaluated against the risk of the stock falling below the limit reference point. There was a small risk (2%) of the stock falling below the LRP at any time over the 30 years where the stock had the lower natural mortality rate, but no runs for the high natural mortality scenario breached $20\%SB_{F=0}$.

The approach presented here uses a model-based estimation method to inform the harvest control rule. The recent SPC technical workshop on MSE approaches for WCPO stocks noted that empirical methods, which could be based upon longline catch per unit effort, could be used for the estimation method for south Pacific albacore.

1 Introduction

Harvest control rules (HCRs) are an integral component of recognised best practice for managing exploited fish stocks (Punt et al., 2014). The accepted definition of HCRs is that they are pre-agreed rules that determine exploitation rates which are implemented in response to changes in estimated stock status, particularly with respect to well defined target and limit reference points (TRPs and LRPs, respectively). The objective of their use is to keep the stock close to the target reference point and to prevent the stock breaching the limit reference point with a high probability.

Recent years have seen gathering momentum towards the establishment of HCRs for tuna stocks in the western and central Pacific Ocean (WCPO) with several management objectives workshops held to progress the situation. The development of HCRs for WCPO stocks has also been specified within CMM 2014-06 and the associated work plan agreed by WCPFC12. The work plan schedules the development of harvest control rules for south Pacific albacore fisheries beginning in 2017.

Studies constructing and simulation testing candidate HCRs for WCPO tuna stocks have already begun, and development of rules for the skipjack tuna stock are perhaps the most advanced (Scott et al., 2016a). The current framework for assessing HCRs for this stocks is relatively simple, being similar to that of Kell et al. (2013), using stochastic projections from the most recent stock assessment to project stock status forwards in time with future effort levels that are determined from the HCR at specific management intervals.

As a result of of CMM 2014-06, there is interest in developing similar approaches for the south Pacific albacore (SPA) tuna stock. The most recent assessment of this stock was undertaken in 2015 (Harley et al., 2015b) and concluded that the stock has declined over time, particularly in recent years due to relatively high levels of longline fishing. Although it was estimated to be well above the limit reference point of $20\%SB_{F=0}$, biomass was estimated to be lower than proposed bio-economic-related target reference points indicating profitable stock levels (Pilling et al., 2015). This supports the significant concern about economic viability of many of the fleets targeting this stock that has been occurring for some time, and the situation is unlikely to improve without active management of the fishery (Harley et al., 2015b; Pilling et al., 2015).

Fishing for south Pacific albacore is almost entirely dominated by longline fishing in recent years (97% of catches; Pilling and Williams, 2016). Discussions of longline fisheries management within the WCPO have focussed upon catch limits (e.g. CMM 2015-01 for tropical longline fisheries), and a catch-based management system for the southern longline fishery has been put forward by FFA Members. This provides a contrast to skipjack, where the purse seine fishery is actively managed using effort-based measures.

The objective of this paper is to provide further preliminary steps towards an operational HCR for south Pacific albacore tuna, specifically it aims to:

1. Assess the utility of assessing catch-based HCRs within the stochastic projection framework

established within MULTIFAN-CL (MFCL) for other species.

2. Make suggestions on directions for further development of catch-based HCRs for South Pacific albacore, including several of the considerations and issues that the current preliminary analysis suggests will occur as the process is developed.

This paper is seen as a first step in encouraging progress with respect to some of the technical details of assessing and comparing candidate catch-based HCRs within the currently implemented framework utilised for species in the WCPO. We also note that technical discussions held during the SPC Technical Workshop on Management Strategy Evaluation (MSE; Scott et al., 2016b) are of direct relevance to this paper, and we briefly discuss the issues later in this paper.

2 Methods

2.1 General approach

The approach for evaluating the candidate HCR follows closely from the methods described in detail by Scott et al. (2016a) which were similar to previous work on tunas by Kell et al. (2013). The analyses are based on the stock assessment models of SPA fitted by Harley et al. (2015a) and stochasic projections of the age-structured, multi-regional population are projected foward in time with fishery-specific catches for each run determined by the HCR. Stochasticity enters the projections by way of random recruitments. Deviates from the stock recruitment relationship (SRR) estimated within the stock assessment for the time period over which the SRR was fitted were randomly sampled and applied to future recruitment estimates defined from the SRR based upon the adult biomass at that time. Further details of projection approach in MFCL are provided by Pilling et al. (2016).

Two hundred runs were projected from the reference case assessment model and two alternative models as a robustness trial. The projection period was 30 years from the terminal year of the stock assessment (2013), projections were carried out in 3-year management intervals, and catchability of each fishery was held constant at the 2013 values. At the conclusion of each interval the status of the stock was determined by examining the reference point $SB/SB_{F=0}$ (after propagating normally distributed random error with a CV of 10% around the model-calculated value to represent estimation uncertainty). $SB_{F=0}$ was calculated from the estimated unexploited adult biomass over the period 2003-2012. The allowable longline catch for the subsequent 3-year interval was then determined from the HCR, and the projections continued for another management interval. The process was repeated until the end of the full projection period. The proportional change in catch, as determined from the HCR, was applied as a single scaler to all fisheries rather than considering fishery-specific catch rules.

Catch for the troll fisheries are not considered within the HCR (they comprise a minor component of total catch, $< 5\%$, Pilling and Williams, 2016) and future catches were fixed at the observed values in the terminal year of the stock assessment (Harley et al., 2015a).

2.2 A preliminary candidate HCR

The HCR was tuned to maintain the south Pacific albacore stock around the candidate target reference point submitted to WCPFC12 by FFA members of $45\%SB_{F=0}$. Within this brief, the candidate HCR considered herein follows some general features commonly utilised in testing of HCRs for other stocks in the WCPO, and elsewhere.

Assuming a reduction in spawning biomass, the first inflection point in the HCR was set at a fisheries depletion level, $SB/SB_{F=0}$, of 0.4, five percentage points below the proposed TRP ($45\%SB_{F=0}$) to prevent the need to immediately react with active management in the case of short-term population fluctuations (to prevent treating the TRP as an LRP). The HCR then declines with decreasing stock status until the LRP of $20\%SB_{F=0}$ is breached. The residual catch allowed by the HCR below the LRP was set at the relatively arbitary level of 5% of the maximum allowed catch, to represent the fact that bycatch of albacore will continue to occur even if strong management is imposed on the fleets considered in the simulations (Figure 1).

Performance of the HCR was summarised by assessing several statistics including: the terminal estimate of spawning biomass after 30 years as a function of unfished biomass $SB/SB_{F=0}$, the proportion of simulations where $SB/SB_{F=0}$ dropped below $20\%SB_{F=0}$ over the projection time-period, the median terminal $SB/SB_{F=0}$ after 30 years, median quarterly catch over all simulations over the projection time-period, variability in catch between projection time-steps over all simulations, and the proportion of time-steps over all simulations where the population was estimated to be in three general states ($< 20\%SB_{F=0}$, $> 20\%SB_{F=0}$ and $< 45\%SB_{F=0}$, $> 45\%SB_{F=0}$).

2.3 Robustness testing

To provide an example of testing the robustness of the candidate HCR against alternative states of nature, the same HCR was applied to south Pacific albacore stock assessments that assumed two alternative values of natural mortality (M): 0.25 and 0.4 (M in the reference case model was 0.3). This modelled the situation where the stock was less, or more productive than assumed in the reference case assessment. In the 2015 stock assessment, stock status and other model output was particularly sensitive to this uncertainty (Harley et al., 2015a).

3 Results

3.1 Reference case model projections

From the simulated projections, spawning biomass was predicted to initially decline moderately for all runs in the initial years of the simulation period under recent catch levels (Figure 2). The decline of the reference point $SB/SB_{F=0}$ then activated management intervention in all cases with a drop in catch and a positive response in biomass with all runs increasing towards $45\%SB_{F=0}$ over the next management inteval. For the rest of the simulation period the pattern was largely similar with runs showing a range of dynamics from some runs producing very favourable stock status ($SB/SB_{F=0} >> 0.45$) which allowed higher catches that reduced the biomass back towards $45\%SB_{F=0}$, to others where stock status declined to the point where the HCR reduced catches by a significant amount to bring the population back towards $45\%SB_{F=0}$. Overall the HCR was very successful in maintaining $SB/SB_{F=0}$ relatively close to $45\%SB_{F=0}$, with few runs closely approaching $20\%SB_{F=0}$ and no runs breaching it.

The distribution of the catches showed a somewhat bimodal pattern (Figures 2 and 3). The majority of catches were at or close to the maximum allowed by the HCR, with a second mode at approximately 70% of the maximum catch, and a small proportion of catches of less than 50% of maximum allowable catch.

The median terminal $SB/SB_{F=0}$ after 30 years, over all simulations, was 0.46, which was predictably close to $45\%SB_{F=0}$ due to the tuning of the HCR performance.

3.2 Robustness testing

The HCR was found to to be relatively robust to alternative states of nature when evaluated against the risk of the stock falling below the limit reference point. There was a small risk (2%) of the stock falling below the LRP at any time over the 30 years where the stock had the lower natural mortality rate, but no runs for the high natural mortality scenario breached $20\%SB_{F=0}$. These low and high natural mortality scenarios also produced more and less favourable outcomes for most of the other performance indicators, respectively; median terminal stock status ($SB/SB_{F=0}$) was 0.38 and 0.62 (Figures 4 and 5), median catch was 35,800 and 45,300mt, and there was considerably more and less between time-step variation in catch for the high and low mortality scenarios compared to the reference case model, respectively (Figure 3).

4 Discussion

This paper presents preliminary steps in the development of harvest control rules for south Pacific albacore. It represents a proof of concept, demonstrating that HCRs for WCPO tuna stocks can be based upon catch, as well as effort.We note that in the absence of an agreed target reference point for south Pacific albacore, the example HCR was tuned to maintain the albacore stock around a level of 45%SBF=0. Following agreement of a TRP, HCRs can be re-tuned where necessary to maintain the stock on average around any specified level.

A small suite of performance statistics were examined within the preliminary work. These focussed upon the stock status relative to the TRP, the level of annual catch achieved, and the inter-annual change in catches defined under the HCR. As noted within Scott (2016), these are a sub-set of potential performance statistics that could be examined for this stock and the southern longline fishery. Expansion of the performance statistics to monitor catch rates and evaluate the potential profitability of fleets is a logical extension to this work.

Similarly, we note that only a small range of alternative states of nature have been considered in this preliminary analysis and that future studies will need to take greater account of the full range of uncertainty. In particular we note that these evaluations assume that the catch specified by the HCR is perfectly implemented and therefore take no account of potential outcome error.

The approach presented here uses a model-based estimation method to inform the harvest control rule. The recent SPC technical workshop on MSE approaches for WCPO stocks noted that empirical methods, which could be based upon longline catch per unit effort, could be used for the estimation method for south Pacific albacore. The reader is referred to that report (Scott et al., 2016b) for specific suggested developments in the albacore HCR. The work presented here provides an initial step in that process.

Acknowledgements

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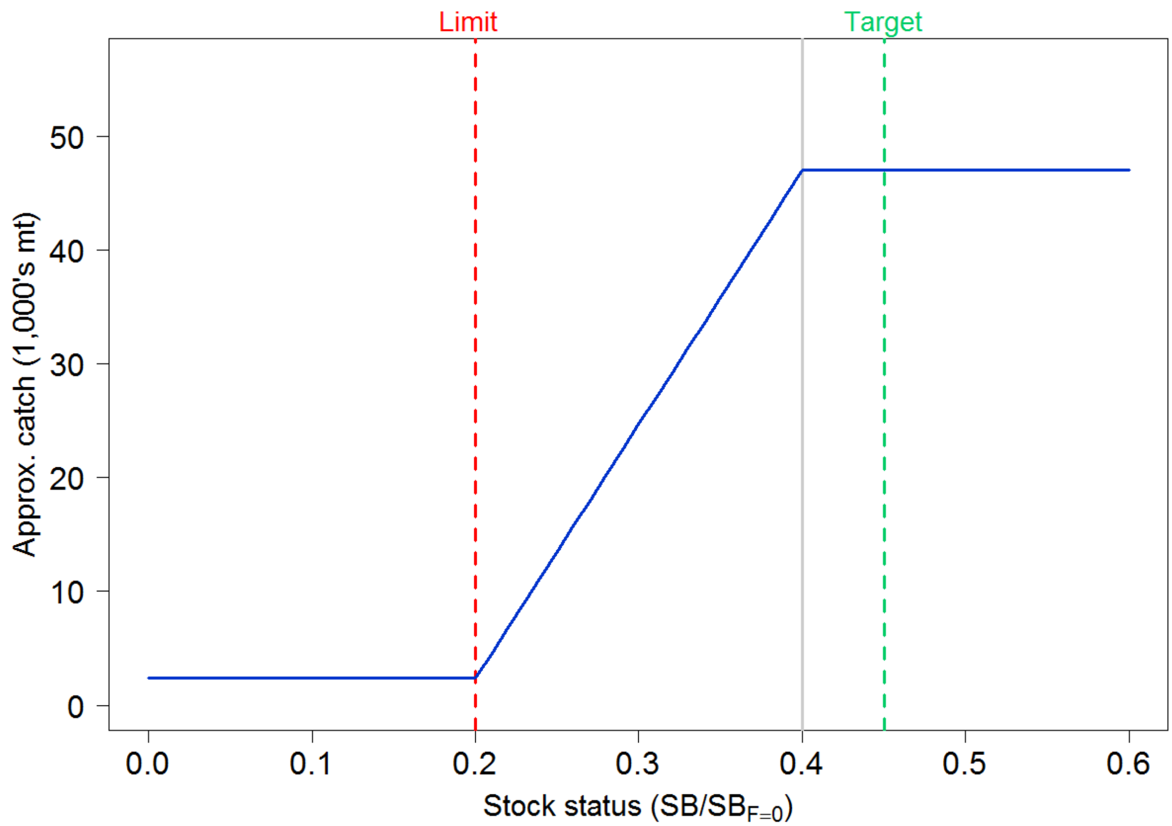

Figure 1: The candidate harvest control rule tested using stochasic projections of the south Pacific albacore stock.

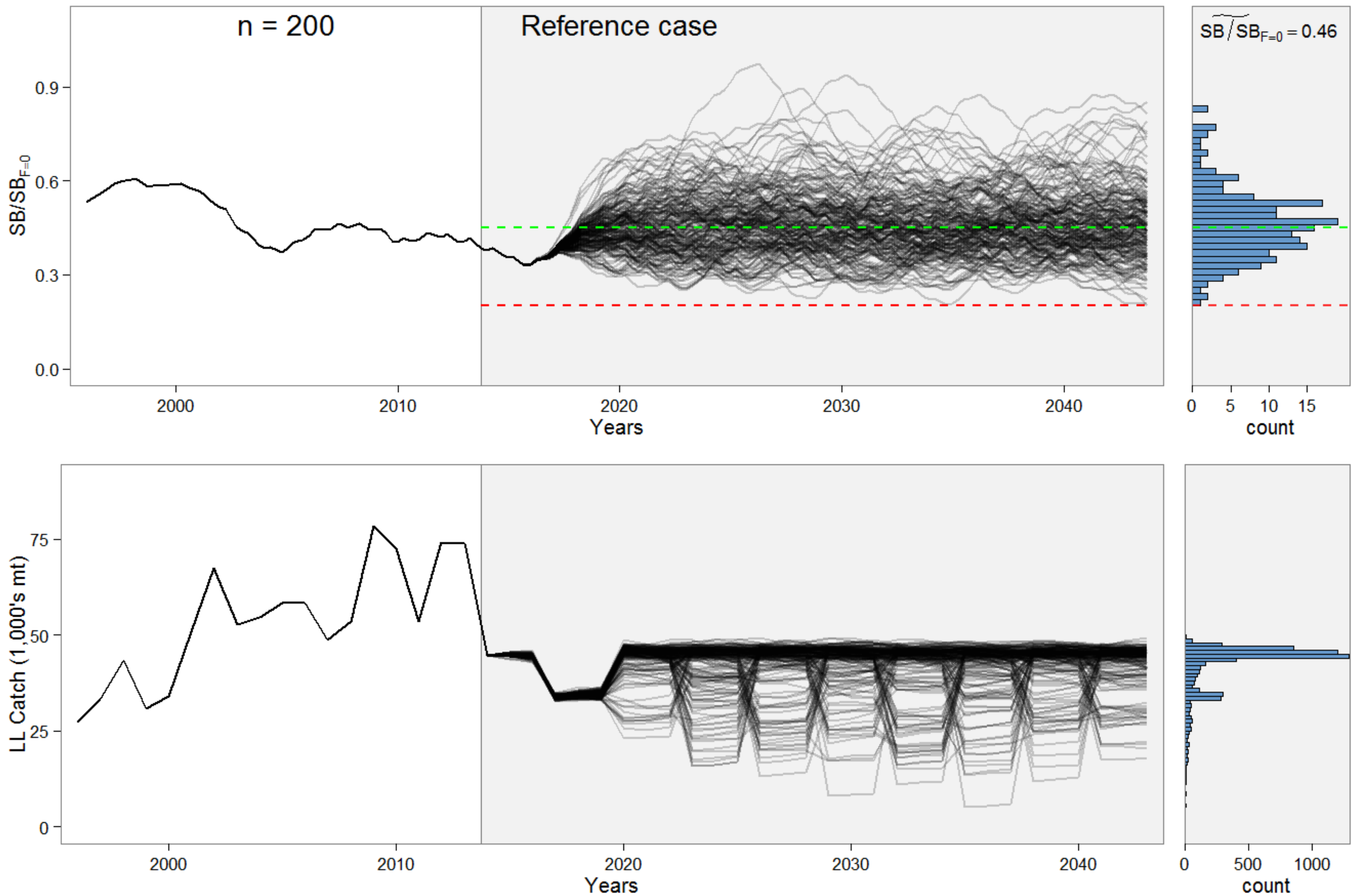

Figure 2: Reference Case. Results of evaluations of the HCR. The upper figure shows projected adult biomass relative to $SB_{F=0}$ from 200 stochastic projections, along with a histogram showing the frequency of $SB/SB_{F=0}$ over the 30 year projection period. The lower figure shows a similar plot for catch. Note that catch as determined from the HCR was fixed for each 3 year management period.

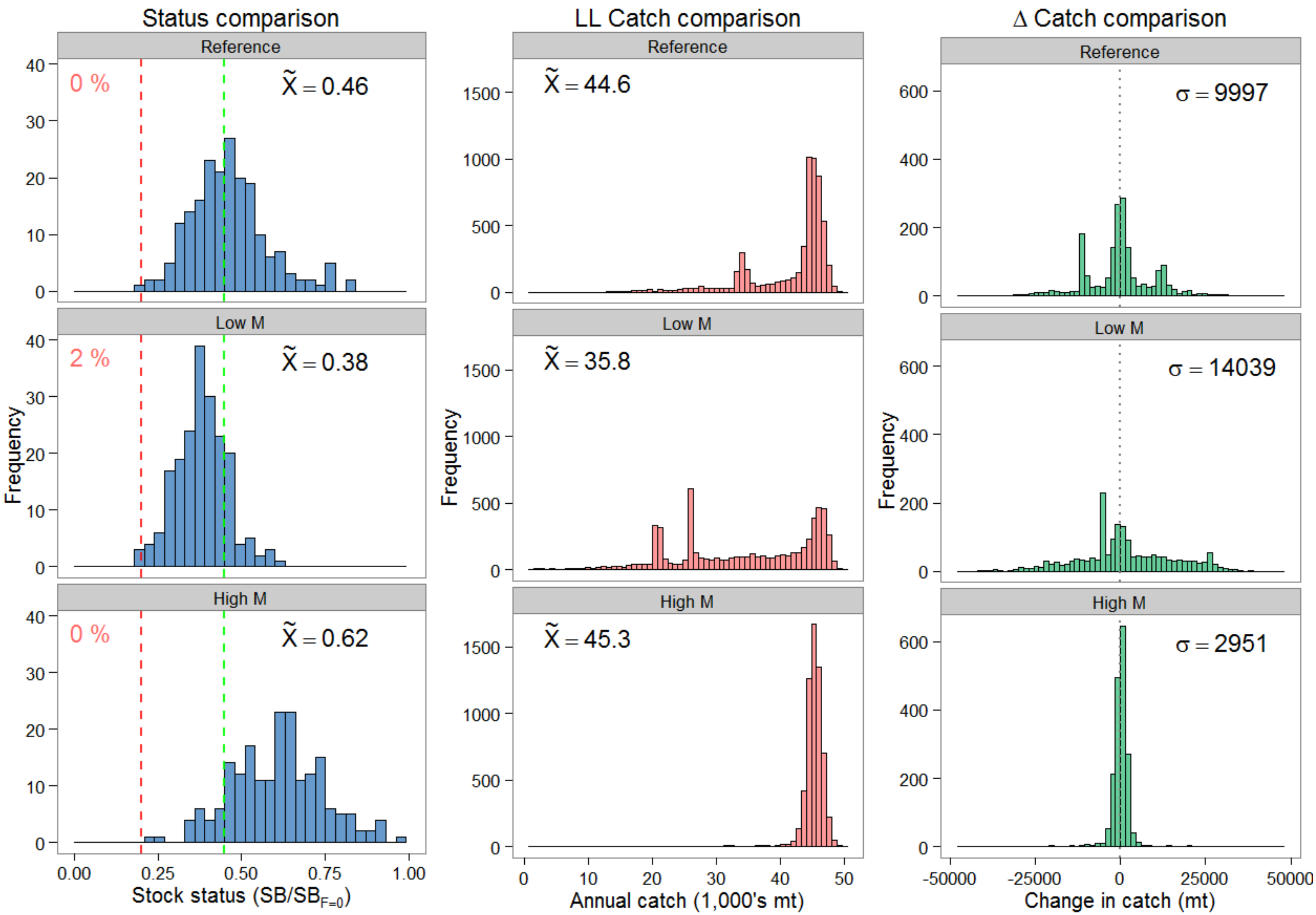

Figure 3: Summary output from the HCR evaluations: showing performance statistics (columns) for $SB/SB_{F=0}$, catch distribution and change in catch between management periods for each of the scenarios considered (rows) reference case, low M and high M.

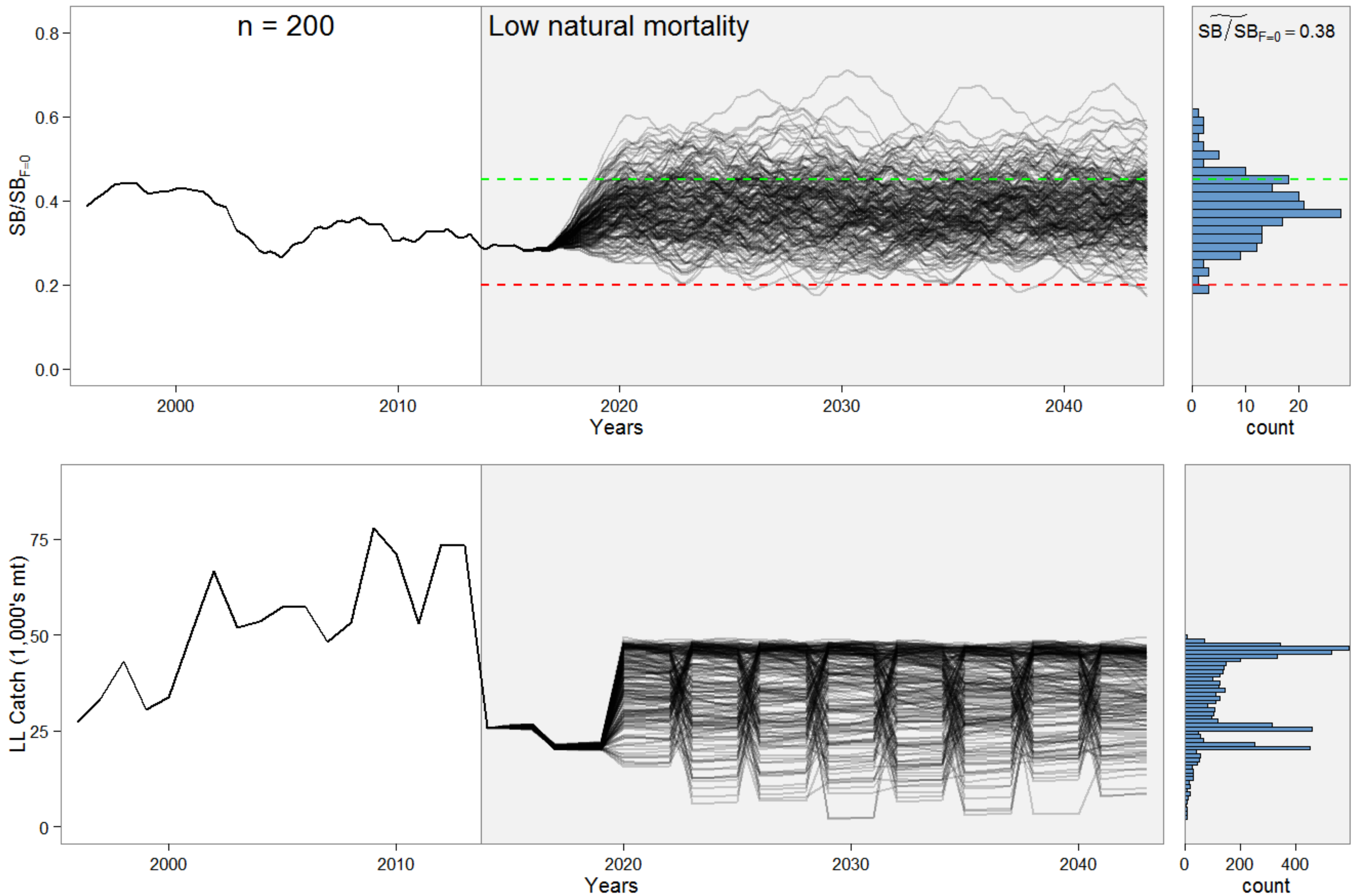

Figure 4: Low natural mortality. Results of evaluations of the HCR. The upper figure shows projected adult biomass relative to $SB_{F=0}$ from 200 stochastic projections, along with a histogram showing the frequency of $SB/SB_{F=0}$ over the 30 year projection period. The lower figure shows a similar plot for catch. Note that catch as determined from the HCR was fixed for each 3 year management period.

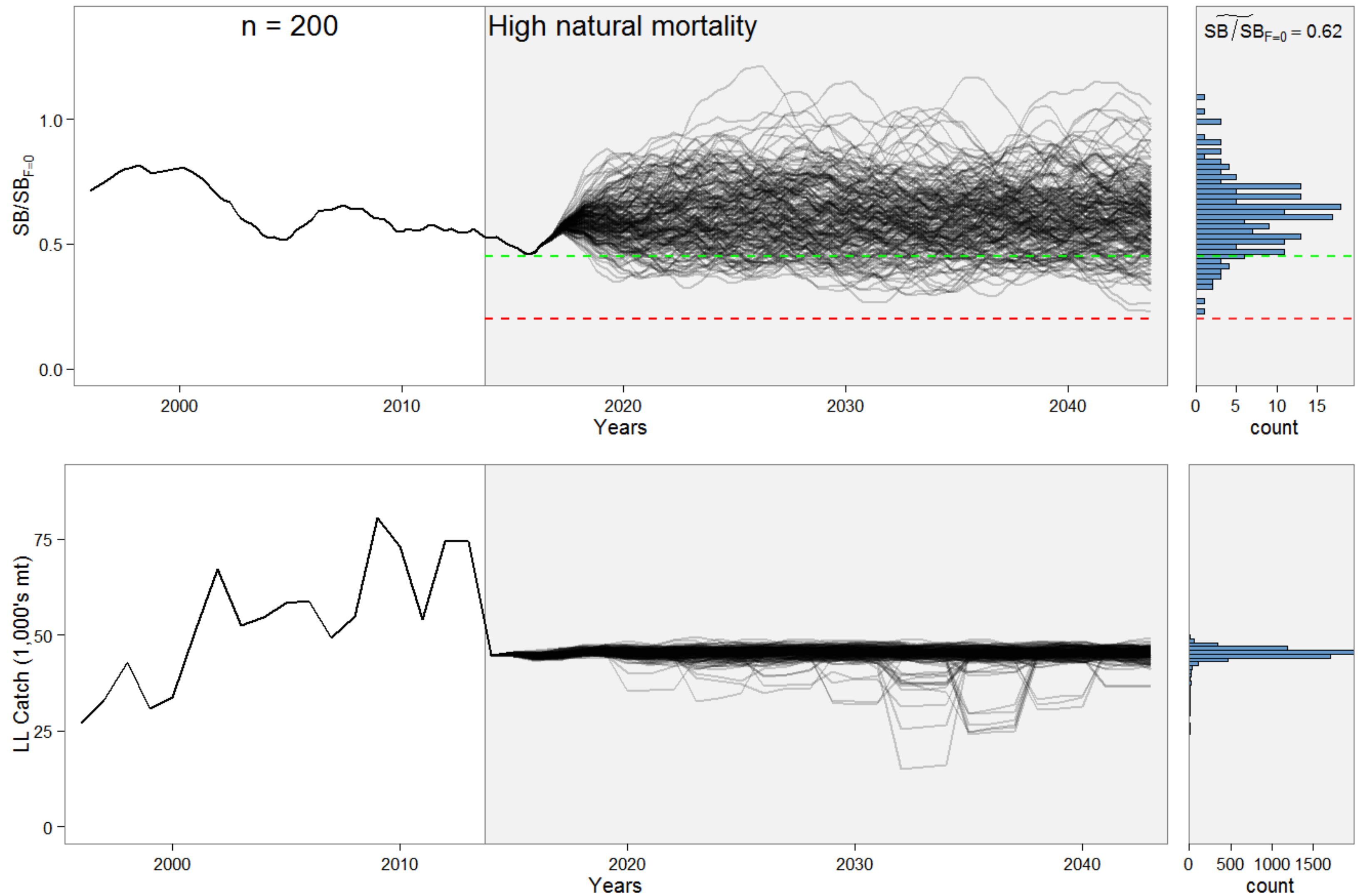

Figure 5: High natural mortality. Results of evaluations of the HCR. The upper figure shows projected adult biomass relative to $SB_{F=0}$ from 200 stochastic projections, along with a histogram showing the frequency of $SB/SB_{F=0}$ over the 30 year projection period. The lower figure shows a similar plot for catch. Note that catch as determined from the HCR was fixed for each 3 year management period.