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# Consideration of the robustness set of operating models for skipjack tuna in the WCPO

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**WCPFC-SC18-2022/MI-IP-12**

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# Contents

# Executive Summary

Development of the evaluation framework for WCPO skipjack has focussed on the characterisation of uncertainty for the reference set of operating models (OMs). The reference set comprises scenarios used for the initial testing of candidate management procedures (MPs). To assist in the final selection of a preferred MP, a second level of testing can, if necessary, be performed using the robustness set of OMs which comprises a reduced set of more extreme, though still plausible, scenarios.

The sources of uncertainty considered here represent only a subset of those initially proposed for the robustness set of OMs. Additional sources of uncertainty associated with movement rates, tag recaptures and biological responses to climate change have also been proposed. Whilst some initial work to investigate these factors has been undertaken, more work is required to better characterise these sources of uncertainty and to properly implement them in the evaluation framework. Options for the robustness set will continue to be developed as new information and new data become available.

Alternative scenarios for observation error in catch and effort; hyperstability in CPUE; and effort creep comprising the current set of OMs for the WCPO skipjack robustness set have been evaluated along with additional scenarios for alternative catches in archipelagic waters that are not subject to control by the MP. We investigate their impact on the performance of one candidate MP and determine their utility for identifying a best performing MP. Whilst some scenarios showed increased levels of impact in terms of stock status, total catches and effort controls, others showed little or no impact at all and may be considered for removal from the robustness set.

We invite SC18 to:

- provide advice on the removal of 30% CV observation error in catch and effort from the robustness set;
- consider any additional alternative plausible scenarios to be included in the robustness set;
- note that the scenarios for the robustness set will continue to be developed as new information becomes available.

# 1 Introduction

Before implementing a management procedure (MP) it should be tested to determine if it is likely to perform as desired. Testing MPs is conducted through a simulation modelling exercise (termed management strategy evaluation, MSE) in which the performance of the MP is evaluated under a range of simulated future scenarios.

The future scenarios represent alternative hypotheses about those aspects of the dynamics of the stock and the fishery for which our knowledge is uncertain and in particular the sources of uncertainty that can impact on management performance. Some sources of uncertainty will be more influential than others and not all of them will need to be considered. Importantly, the range of scenarios should encompass all plausible states of nature such that the inclusion of new data (when available) should reduce the range of uncertainty being considered and not increase it.

Each scenario is represented by an operating model (OM), and the full set of OMs is divided into two sets. The first is the reference set, comprising scenarios that represent the most plausible hypotheses of alternative stock and fishery dynamics. These form the primary basis for evaluating candidate MPs. The second is the robustness set, comprising more extreme scenarios that are considered less likely though still plausible. These are used to give a secondary indication of the performance of a reduced subset of management procedures that have been short-listed on the basis of their performance against the reference set.

An initial investigation of the potential scenarios to include in the robustness set (Scott et al., 2019a) considered options for effort creep, hyperstability in CPUE and outlined ongoing work to investigate alternative movement patterns. The robustness set of OMs continues to be the focus of ongoing work. Some desired elements of the robustness set relate to particularly challenging modelling issues (e.g. the prediction of impacts of climate change) that will require further research in the longer term.

In this paper we consider the current set of OMs that have been identified for the robustness set, including the initial options outlined in Scott et al. (2019a) as well as alternative assumptions for observation error in reported catch and effort and alternative catch assumptions for archipelagic waters that are not subject to control by the MP. We investigate their impact on the performance of one candidate MP and determine their utility for identifying a best performing MP.

# 2 WCPO skipjack operating models

Operating models for the WCPO skipjack reference and robustness sets are detailed in Table 1.

## 2.1 Robustness set scenarios

Currently just 3 scenarios are identified for the robustness set comprising more extreme settings for observation error on reported catch and effort (30% CV); hyperstability in CPUE (k=-0.9) and effort creep (3% p.a.).

### 2.1.1 Observation error in catch and effort

In the current skipjack MSE framework, variability in future catch and effort is included in the simulations via a user-specified coefficient of variation (CV) that applies to all fisheries in the model. A CV of 20% was determined from the OM conditioning process (Scott et al., 2018, 2020) and applied to the reference set of OMs. A higher value of 30% was proposed for the robustness set.

A comparison of the results of evaluations for HCR1 for assumed levels of observation error in catch and effort of 20% and 30% (Figure 2) shows the range of future values for spawning potential depletion ($SB/SB_{F=0}$), total catches and the scalar resulting from the HCR in each management period. It shows no perceptible difference in results between the two assumptions with the two sets of results overlapping almost exactly. The increased level of observation error of 30% provides insufficient additional variability to further explore the dynamics of the MP and is therefore unlikely to be a useful component of the robustness set.

Although levels of observation error greater than 30% could be examined, they may not represent plausible future scenarios. Values of 20% and 30% were identified based on historical observations during the OM conditioning process (Scott et al., 2018, 2020). The plausibility of future values in excess of these levels should be considered before including them in the robustness set.

### 2.1.2 Model error in hyper-stability

For schooling species that form aggregations, such as tunas, there is the potential that, as the stock becomes depleted, catches and catch per unit effort (CPUE) remain high (Harley et al., 2001). This is known as hyperstability in CPUE and, if not taken into consideration, can impact on the performance of MPs.

The true level of hyperstability that operates in a fishery is very difficult to determine and the identification and selection of plausible scenarios is challenging. The ranges assumed in these evaluations span a broad range of possible levels, from zero hyperstability to very high levels that have almost flat CPUE across a wide range of stock abundance. Testing MPs against a wide range of alternative assumptions for hyperstability will ensure that, even though the true level of hyperstability is unknown, the MP should continue to perform acceptably well and is not expected to result in substantial stock decline.

Hyperstability in CPUE is implemented in the MSE framework through density dependent catchability in the MULTIFAN-CL model (Scott et al., 2015, 2019b; Davies et al., 2019) and is applied only to purse seine fisheries. In the reference set of OMs there are two levels of hyperstability assumed representing no hyperstability (k = 0) and moderate hyperstablility (k = -0.5). For the robustness set an additional, stronger level of hyperstability (k = -0.9) is set. At this stronger level of hyperstability, CPUE remains relatively constant across a broad range of stock abundance (Figure 1).

A comparison of the results of evaluations for HCR1 for the different hyperstability assumptions (Figure 3) shows only small changes in median estimates for future stock status, catches and the scalar value. However, larger differences are apparent in the overall range of values (i.e. the extent of the 95%ile range). For increased levels of hyperstability there is a greater chance of the stock falling below the limit reference point (Figure 3a) and a greater chance of effort being reduced to low levels (Figure 3c).

Hyperstability in CPUE is a density dependent effect. Consequently, the extent to which it affects the performance of the MP depends to a large extent on the amount of variation in stock abundance. MPs that maintain the stock at relatively constant and stable levels of abundance will be less impacted than MPs that result in large changes in stock abundance.

### 2.1.3 Implementation error in effort creep

Fishing operations can become progressively more efficient over time due to continual technological developments in fishing gear and fish finding technology as well as in fishing practices. This progressive increase in fishing effectiveness is referred to as effort creep and can be particularly problematic in effort managed fisheries where increasing efficiency of fishing vessels can reduce the effectiveness of effort limits that are designed to constrain fishing mortality. The potential for effort creep to impact on the performance of an MP should be taken into consideration when testing candidate MPs and, where appropriate, should be included in the evaluation framework.

Detecting the level of effort creep that is operating in a fishery can be difficult and numerous studies have been conducted in recent years to try to determine the level of effort creep in the tropical purse seine fishery (Tidd et al., 2015; Pilling and Brouwer, 2016; Muller et al., 2018; Vidal et al., 2021; Wichman and Vidal, 2021). Whilst no definitive value has been identified, a range of potential values have been suggested from 0% to 3% p.a. depending on the source of information used for the study. Based on these estimates, values of effort creep of 0% and 2% were included in the reference set of OMs and a value of 3% p.a. included in the robustness set.

Within the evaluations, effort creep is applied as a fixed annual increment (i.e. annual addition of 3% of the 2012 effort level) rather than as a rolling 3% of the previous year. Under this approach, effective effort in 2048 is around 90% higher than 2012 effort rather than around 140% higher under the rolling increment approach.

Of the sources of uncertainty considered here, effort creep has perhaps the greatest impact (Figure 4). For increasing levels of effort creep, future stock status is poorer and the potential for larger effort reductions increases. Catches remain high as a consequence of increased fishing efficiency. For the values of effort creep considered here, the stock remains above the LRP throughout the 30 year projection period.

For the analyses conducted here, we have assumed that effort creep applies only to purse seine fisheries. Recent studies (Hamer et al., 2022) suggest that effort creep in the tropical purse seine fishery has been at very low levels in recent years. In addition, recent studies suggest that effort creep may also apply, at relatively low levels, to pole and line fisheries (Matsubara et al., 2022). Further investigation will be required to determine the impact of effort creep in pole and line fisheries on the performance of the MPs.

### 2.1.4 Alternative assumptions for archipelagic water catches

Fisheries operating in archipelagic waters are managed through domestic arrangements and are not subject to control by the MP. Some countries are looking to develop their domestic fisheries and this may have implications for future catches within archipelagic waters. Therefore, some consideration of alternative future catches of domestic fisheries should be taken when testing candidate MPs.

For the purposes of this exercise we have considered three alternative scenarios for future catches from archipelagic waters of 100% (the base assumption of the evaluations), 125% and 150% of 2012 catches. We have assumed that these catch increases occur for all fisheries in archipelagic waters from the first year of the evaluation period and apply for the full 30 year time series of the evaluations. These alternative catches have been selected to investigate the sensitivity of the MP to increased catches in archipelagic waters rather than to represent expected catches for those fisheries.

The results (Figure 5) show the increased catches have little or no impact on stock status and future catches, but there is increased potential for greater effort reductions throughout the evaluation period.

## 3 Discussion

The robustness set should comprise a more extreme, though still plausible, set of scenarios that can be used to select a best performing MP from a shortlist of preferred options initially identified using the reference set. Due to time restrictions, the analyses presented here have been conducted on only a single MP and a comparison of the performance of different MPs under the robustness set was not possible. It is apparent, however, that increased levels of observation error in catch and effort are unlikely to provide sufficient information to enable further selection of MPs and the omission of this source of uncertainty from the robustness set is recommended.

The sources of uncertainty considered here represent only a subset of those initially proposed for the robustness set of OMs. Additional sources of uncertainty associated with movement rates, tag recaptures and biological responses to climate change have also been proposed. Whilst some initial work to investigate these factors has been undertaken, more work is required to better characterise these sources of uncertainty and to properly implement them in the evaluation framework. Options for the robustness set will continue to be developed as new information and new data become available. In this regard we note, in particular, recent studies on growth (Macdonald et al., 2022) and on the determination of tag mixing (Scutt Phillips et al., 2022) for WCPO skipjack and on estimates of effort creep in pole and line fisheries (Matsubara et al., 2022). Discussions during the SPC pre-assessment workshop (Hamer, 2022) regarding the development of operating models for MSE frameworks noted that it was not possible to fully account for all scenarios at this stage and that the development of OMs and the full characterisation of uncertainty, in particular for the robustness set, would be an ongoing process.

## 4 Conclusions

Scenarios comprising the current set of OMs for the WCPO skipjack robustness set have been evaluated along with additional scenarios for alternative catches in archipelagic waters. Whist some scenarios showed increased levels of impact in terms of stock status, total catches and effort controls, others showed little or no impact at all and may be considered for removal from the robustness set.

We invite SC18 to:

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- consider any additional alternative plausible scenarios to be included in the robustness set;
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## Acknowledgments

We gratefully acknowledge funding for this work from the New Zealand Ministry of Foreign Affairs and Trade (MFAT) funded project "Pacific Tuna Management Strategy Evaluation". In addition we thank both the Center for High Throughput Computing (CHTC UW-Madison) and the New Zealand eScience Infrastructure (NeSI) for generously providing access to their computing resources.

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Table 1: Skipjack OM uncertainty grid (reference set, 96 model scenarios). ‡ denotes those scenarios for which a dedicated fit of MULTIFAN-CL is required. Settings for the robustness set shown in bold

| **Axis** | **Levels** | | **Options** | | |
|---|---|---|---|---|---|
| | Reference | Robustness | **0** | **1** | **2** |
| **Process Uncertainty** | | | | | |
| Recruitment variability | 2 | | 1982-2018 | 2005-2018 | |
| **Observation Uncertainty** | | | | | |
| Catch and effort | 1 | **1** | 20% | **30%** | |
| Size composition (ESS) | 1 | | estimated | | |
| Tag recaptures | 1 | | status quo | | |
| **Model Uncertainty** | | | | | |
| Steepness ‡ | 3 | | 0.8 | 0.65 | 0.95 |
| Mixing period (qtr) ‡ | 2 | | 1 | 2 | |
| Growth ‡ | 2 | | | low | high |
| Movement | 1 | | estimated | | |
| Hyperstability in CPUE (k) ‡ | 2 | **1** | 0 | -0.5 | **-0.9** |
| **Implementation Uncertainty** | | | | | |
| Effort creep | 2 | **1** | 0% | 2% | **3%** |

Table 2: Fishery groupings for the WCPO skipjack MSE framework, showing the management metric (catch or effort) and the extent to which they are controlled by the management procedure. Settings considered for the robustness set are also shown for hyperstability in CPUE ($k$), effort creep (% p.a.) and increased catches in archipelagic waters relative to 2012 levels.

| **Name** | **Region** | **Metric** | **MP Control** | **Hyperstability** | | | **Effort creep** | | | **AW catches** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P-ALL-1 | 1 | catch | full | | | | | | | | | |
| S-ALL-1 | 1 | effort | full | 0 | -0.5 | -0.9 | 0% | 2% | 3% | | | |
| L-ALL-1 | 1 | catch | none | | | | | | | | | |
| P-ALL-2 | 2 | catch | full | | | | | | | | | |
| S-ALL-2 | 2 | effort | full | 0 | -0.5 | -0.9 | 0% | 2% | 3% | | | |
| L-ALL-2 | 2 | catch | none | | | | | | | | | |
| P-ALL-3 | 3 | catch | full | | | | | | | | | |
| S-ALL-3 | 3 | effort | full | 0 | -0.5 | -0.9 | 0% | 2% | 3% | | | |
| L-ALL-3 | 3 | catch | none | | | | | | | | | |
| Z-PH-5 | 5 | catch | full | | | | | | | | | |
| Z-ID-5 | 5 | catch | none (AW) | | | | | | | 100% | 125% | 150% |
| S-ID.PH-5 | 5 | effort | partial (AW) | 0 | -0.5 | -0.9 | 0% | 2% | 3% | 100% | 125% | 150% |
| P-ALL-5 | 5 | catch | partial (AW) | | | | | | | 100% | 125% | 150% |
| SA-DW-5 | 5 | effort | full | 0 | -0.5 | -0.9 | 0% | 2% | 3% | | | |
| SU-DW-5 | 5 | effort | full | 0 | -0.5 | -0.9 | 0% | 2% | 3% | | | |
| Z-VN-5 | 5 | catch | full | | | | | | | | | |
| L-ALL-5 | 5 | catch | none | | | | | | | | | |
| P-ALL-6 | 6 | catch | full | | | | | | | | | |
| SA-ALL-6 | 6 | effort | partial (AW) | 0 | -0.5 | -0.9 | 0% | 2% | 3% | 100% | 125% | 150% |
| SU-ALL-6 | 6 | effort | partial (AW) | 0 | -0.5 | -0.9 | 0% | 2% | 3% | 100% | 125% | 150% |
| L-ALL-6 | 6 | catch | none | | | | | | | | | |
| P-ALL-4 | 4 | catch | full | | | | | | | | | |
| L-ALL-4 | 4 | catch | none | | | | | | | | | |
| P-ALL-7 | 7 | catch | full | | | | | | | | | |
| SA-ALL-7 | 7 | effort | full | 0 | -0.5 | -0.9 | 0% | 2% | 3% | | | |
| SU-ALL-7 | 7 | effort | full | 0 | -0.5 | -0.9 | 0% | 2% | 3% | | | |
| L-ALL-7 | 7 | catch | none | | | | | | | | | |
| P-ALL-8 | 8 | catch | full | | | | | | | | | |
| SA-ALL-8 | 8 | effort | full | 0 | -0.5 | -0.9 | 0% | 2% | 3% | | | |
| SU-ALL-8 | 8 | effort | full | 0 | -0.5 | -0.9 | 0% | 2% | 3% | | | |
| L-ALL-8 | 8 | catch | none | | | | | | | | | |

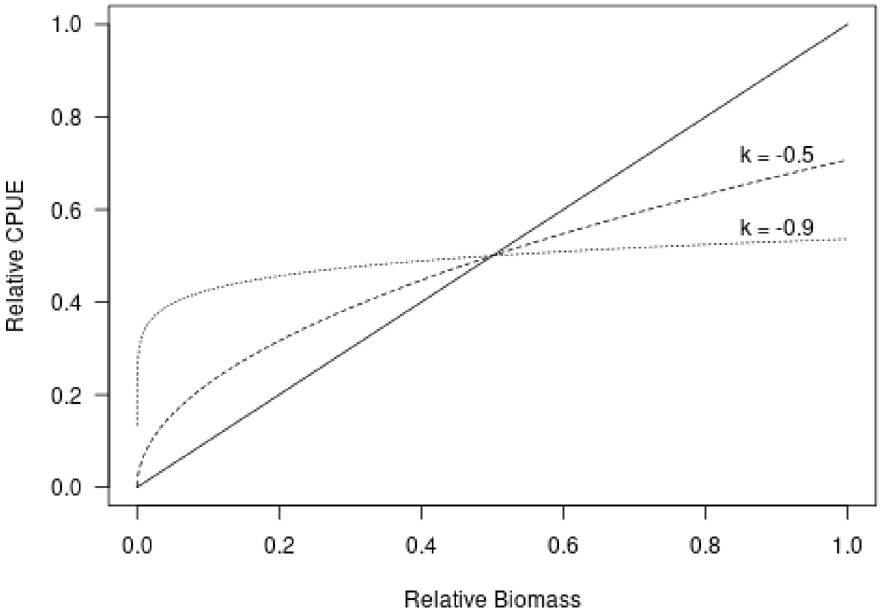
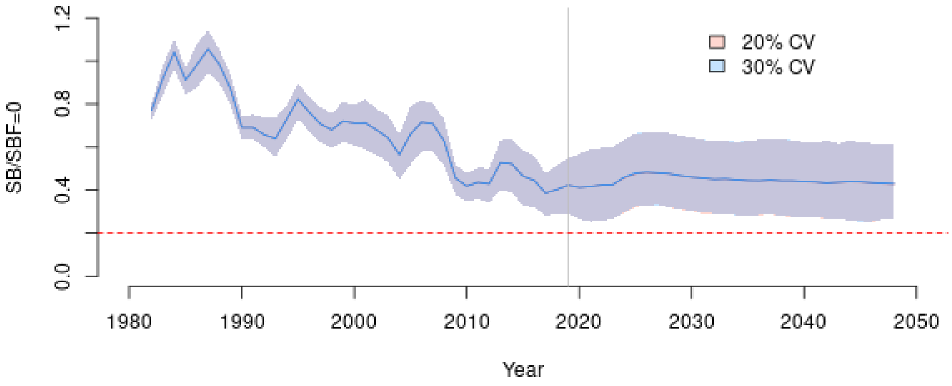
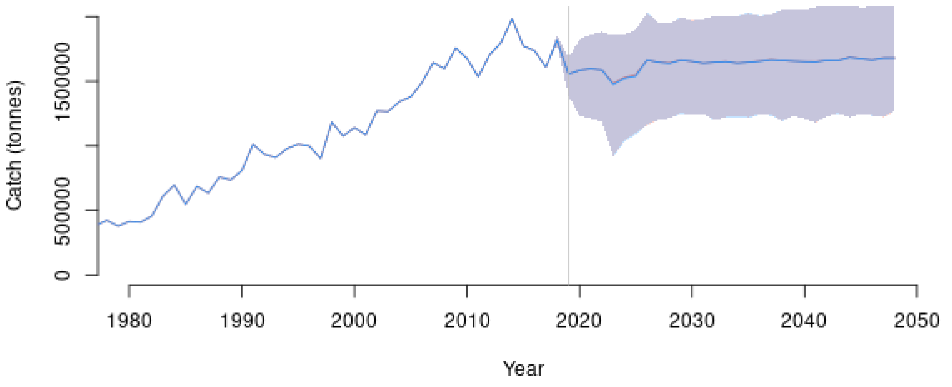


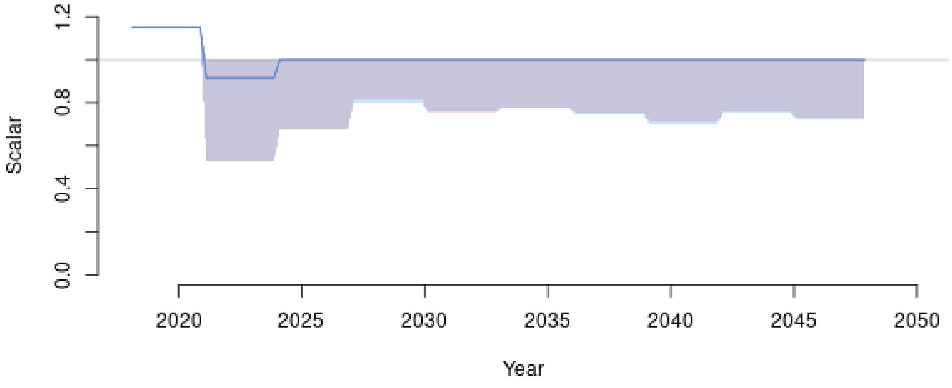
Figure 1: Illustration of the relationship between CPUE and stock abundance under different assumptions for hyperstability.



(a) depletion

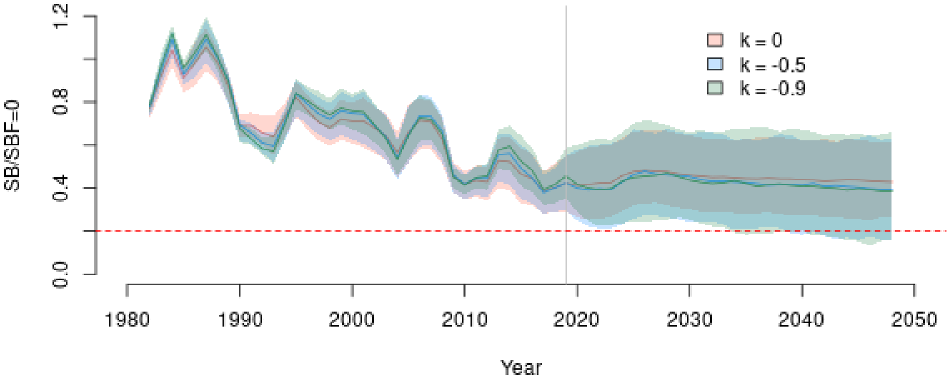


(b) catch

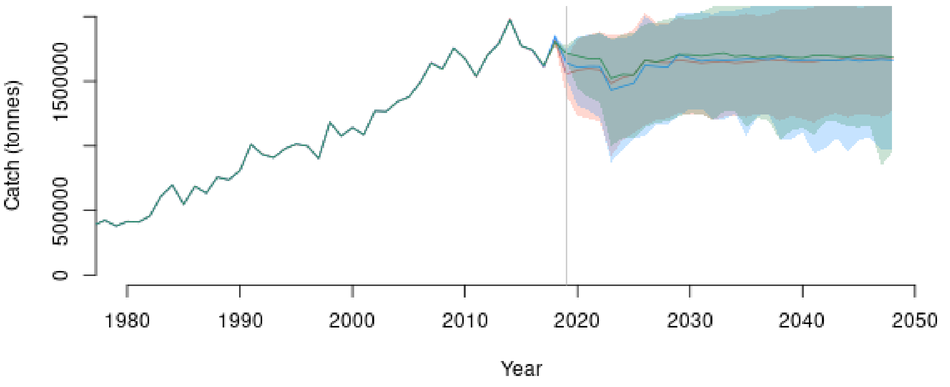


(c) scalar

Figure 2: Median and 95%ile ranges of spawning potential depletion ratio, total catch (all fisheries) and the catch-effort scalar determined from HCR1 under different assumptions for observation error in catch and effort (20% CV and 30% CV).



(a) depletion



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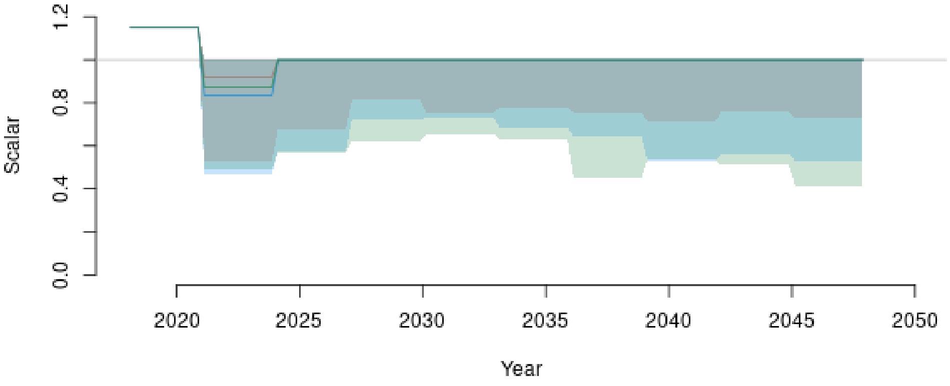
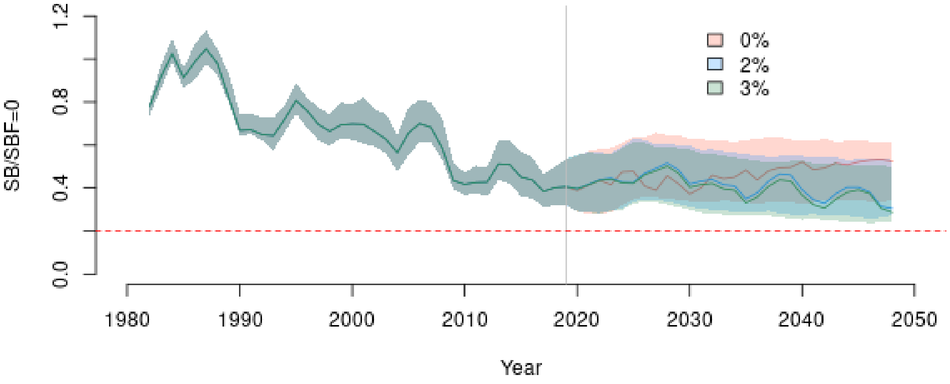
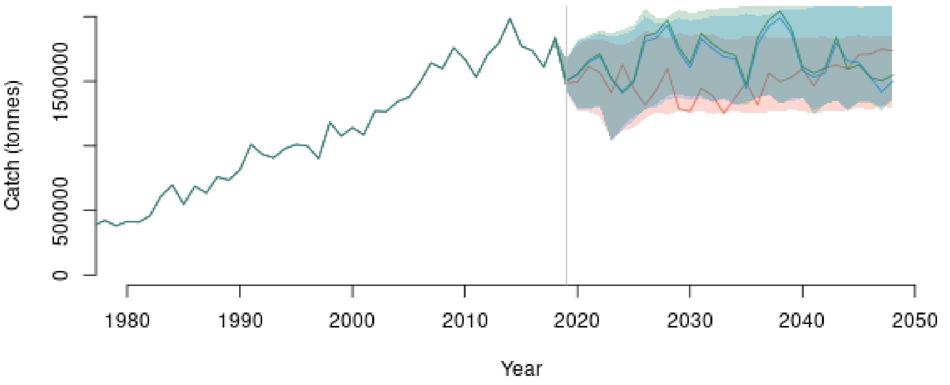


(c) scalar

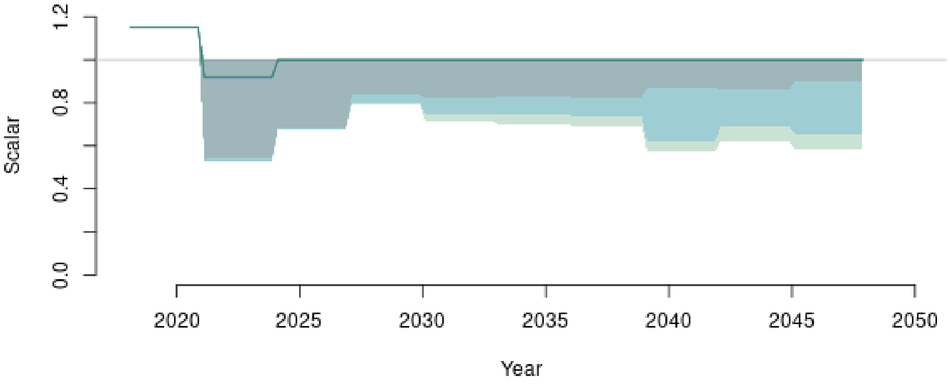
Figure 3: Median and 95%ile ranges of spawning potential depletion ratio, total catch (all fisheries) and the catch-effort scalar determined from HCR1 under different assumptions for hyperstability in purse seine fisheries (k=0, k=-0.5 and k=-0.9).



(a) depletion

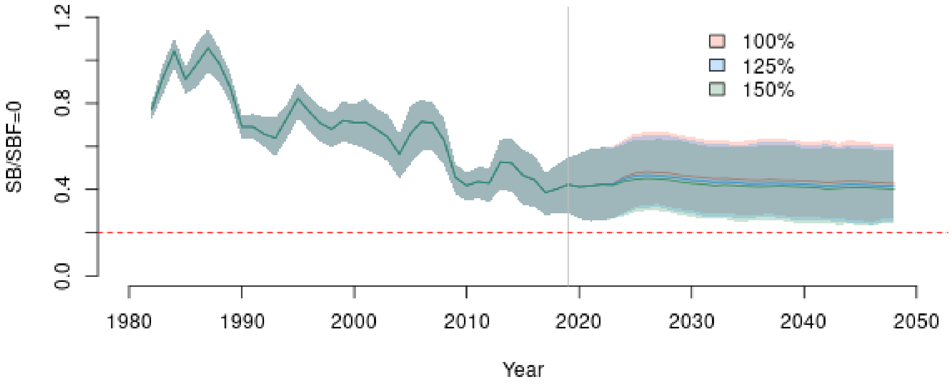


(b) catch

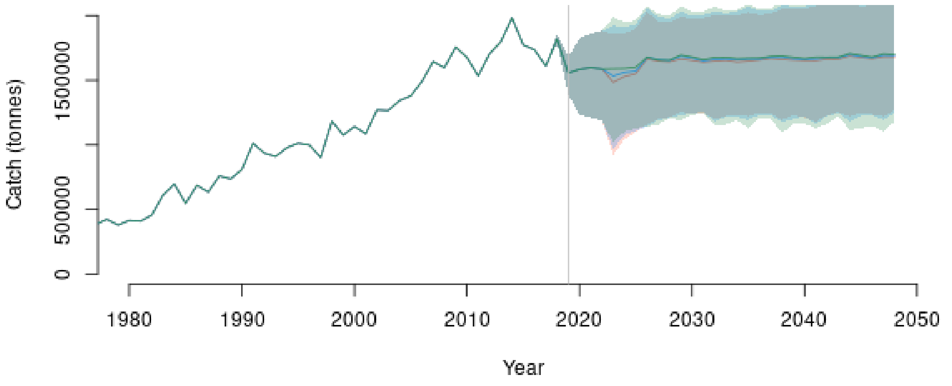


(c) scalar

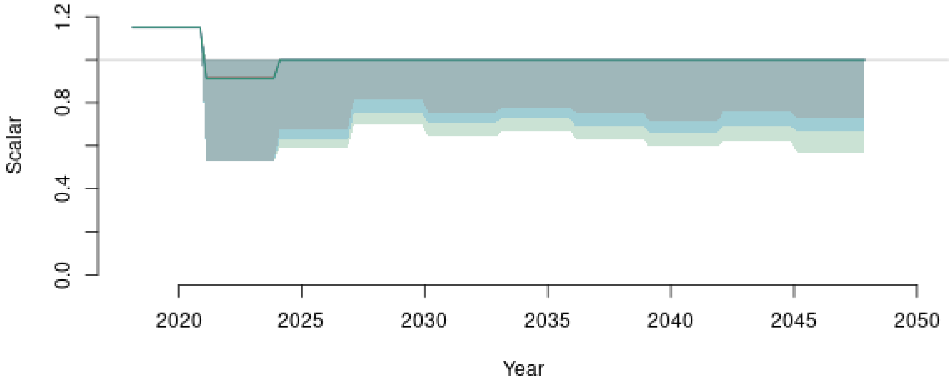
Figure 4: Median and 95%ile ranges of spawning potential depletion ratio, total catch (all fisheries) and the catch-effort scalar determined from HCR1 under different assumptions for effort creep in purse seine fisheries (0%, 2% and 3% p.a.).



(a) depletion



(b) catch



(c) scalar

Figure 5: Median and 95%ile ranges of spawning potential depletion ratio, total catch (all fisheries) and the catch-effort scalar determined from HCR1 under different assumptions for catches in archipelagic waters (2012, 125% of 2012 and 150% of 2012).