Future Stock Projections of Oceanic Whitetip Sharks in the Western and Central Pacific Ocean

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Abstract

The updated stock assessment for oceanic whitetip shark presented to the 15th WCPFC Science Committee (Tremblay-Boyer et al., 2019) showed that the stock was overfished and undergoing overfishing, but it also highlighted a small reduction in stock depletion, with increases in recruitment and a reduction in fishing mortality relative to reference points under certain catch scenarios. However, since oceanic whitetip sharks are late-maturing and fishing mortality on juveniles is high, uncertainty remains as to the level of effectiveness of the non-retention measure active for the last 4 years of the assessment and the impacts of CMMs (CMM-2011-04 non-retention of the species, and CMM 2014-05 a ban on wire trace or shark lines) on the recovery timeline. The stock assessment characterized the uncertainty in the data and model parameters via a structural uncertainty grid in which multiple (648) combinations of data and parameter values were used to show the range of plausible uncertainty to the inputs. This study updates the projections of Rice et al. (2021) with contemporary estimates of mortality at longline retrieval, post-release mortality, catch reductions, and prohibitions of wire branchlines and shark lines. The study used the same representative subset of the structural uncertainty (108 runs) as in Rice et al. (2021) for projections. Future projections for the 2019 WCPO oceanic whitetip stock assessment are presented for five scenarios to assess the impacts of various potential management measures. Population projections illustrate a summary of spawning biomass in the latest time period (2031) relative to the equilibrium unfished spawning biomass ($SB_{2031}/SB_{F=0}$).

Recommendations from WCPFC SC17

- *SC17 recommends that the Project 101 be continued with the following modifications: Relevant CCMs should consider authorizing the release of their non-ROP*

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longline data (facilitated through SPC) for this study, specifically to provide more complete gear configurations by flag, or collaborating to conduct such an analysis for their flagged vessels, and allow analyses similar to Caneco et al. (2014) to estimate factors affecting shark catchability and condition on longline retrieval to be conducted using a more complete data set;

- *Conduct the Monte Carlo analyses with inputs on catchability, condition on longline retrieval and gear configurations by flag;*
- *Conduct updated projections with inputs on the impact of banning shark lines and wire leaders or both and estimates of the probability of post-release mortalities of silky and oceanic whitetip sharks (as based on Hutchinson et al. 2021 or other new information);*
- *Additionally, results of the analyses should be shared to CCMs that made contributions to those analyses for their review and comments in advance of SC18.*

Current state—For items 1 and 2, the Scientific Services Provider (SSP) was contacted to provide an update on ROP and non-ROP data for the 2010–2018 period. ROP data represent 3,250 additional sets for China, 1,507 additional sets for Chinese-Taipei, and 613 for Japan. These data can be provided to Project 101. There are very few non-ROP data from DWFN fleets. The Chinese-Taipei non-ROP data (4,439 sets) are from the PIC observer programs, thus not accessible by Chinese-Taipei under the WCPFC since they are non-ROP data and not included in ROP database. If Project 101 were to proceed with non-ROP data, the Project would need to request these data from the relevant PICs.
For item 3, this Working Paper represents updated projections representing several management options.

Item 4 has not been conducted as we seek advice from SC18 on the necessity to obtain additional ROP data and request non-ROP data from the PICs.

1 Introduction

Oceanic whitetip (OCS) sharks were first assessed in 2012 (Rice and Harley 2012), where the stock in the Western and Central Pacific Ocean (WCPO) was found to be overfished and that overfishing was occurring. Based in part on the 2012 assessment conservation and management measure (CMM) CMM2011-04 became active in 2013, enacting a no-retention measure for OCS for WCPFC Members, Cooperating Non-Members and Participating Territories (CCMs). Recently the OCS stock assessment was updated and presented to SC15 (Tremblay-Boyer et al 2019), which showed that the stock was overfished and undergoing overfishing, but also highlighted a small reduction in stock depletion, and positive trends in recruitment from 2013 to the terminal year and improvement with respect to fishing mortality (F-based) reference points under certain catch scenarios. However, since OCS are late-maturing and fishing mortality on juveniles is high (see Tremblay-Boyer et al. 2019, for details on the biology and recent mortality), any impacts on spawning stock that could be attributed to management intervention would not be captured in stock assessment results. Uncertainty remains as to the effectiveness of the non-retention measure active for the last years of the assessment (since implementation of CMM-2011-04) and the resulting timeline for recovery.

The WCPFC adopted CMM 2014-05 (superseded by 2019-04), whereby longline fisheries targeting tuna and billfish comply with either: 1) do not use or carry wire trace as branchlines or leaders; or 2) do not use branchlines running directly off the longline floats or drop lines, known as shark lines. Harley et al. (2015) conducted Monte Carlo simulation modeling for potential measures to reduce impacts to silky sharks (FAL) and OCS in the WCPO. The study considered: 1) banning of shark lines and removal of shallow hooks to reduce the initial inters actions with longline gear, 2) banning wire leaders to increase the ability of sharks to bite-off the leader, and 3) conversion of tuna hooks to circle hooks. Harley et al. (2015) concluded that either banning shark lines or wire traces (leaders) would not result in sufficient reductions in fishing mortality.

Bigelow and Carvalho (2021a) provided an update to the Harley et al. (2015) estimates using a FAL and OCS process model and subsequent Monte Carlo simulations. From both studies, banning both wire and shark lines resulted in similar reductions in fishing mortality, ~30% for FAL and ~40% for OCS. However, the contributions to reducing fishing mortality were different between studies due to the mitigation of banning shark lines and branchline wire leaders.

Rice et al. (2021) completed OCS population projections for 2017-2031 using Stock Synthesis (Methot and Wetzel 2013) that used a 15-year projection window under the assumption that is enough to capture the ongoing change of stock status following management measures given that estimates of the generation time for OCS are between 5 and 8 years and the timeline would allow estimates to approach an equilibrium state.

The projection horizon should allow the work to quantify the expected timeline for recovery for this stock, and could also inform short- to medium-term recovery plans. As with many shark stock assessments there is substantial uncertainty regarding historical catches due to underreporting and historical non-reporting of non-target species. The 2019 assessment (Tremblay-Boyer et al. 2019) considered uncertainty in six components via a structural uncertainty grid in which every combination of the values is run: 1) catch, 2) natural mortality, 3) historical fishing mortality (initial depletion), 4) recruitment via steepness, 5) recruitment deviations and 6) growth and maturity. The Rice et al. (2021) projections used five uncertainty scenarios representing an uncertainty grid of 108 runs compared to 648 runs in the assessment.

The current projections (2017−2031) use an identical uncertainty grid (108 runs) as Rice et al. (2021). A range of future catch scenarios was considered to represent potential catch reductions, incorporating updated mortality at longline retrieval (Bigelow and Carvalho 2021b) and post-release mortality (PRM) estimates (Hutchinson et al. 2021) and reducing fishing mortality due to banning shark lines and branchline wire leaders (Bigelow and Carvalho 2021a) to illustrate the effect of potential CMMs. The OCS projections rely on the assumption that the 2019 stock assessment adequately represents a suite of plausible population dynamics for OCS in the WCPO. In particular, the study assumes that future changes in recruitment do not compromise the quality of the projections, which is reasonable given the low fecundity inherent to OCS.

2 Methods

Future projections based on the 2019 WCPO oceanic whitetip stock assessment were carried out using the Stock Synthesis (V3.30.19.00) forecast module. The forecast period was implemented with the same model configurations from the 2019 OCS stock assessment (Tremblay-Boyer et al. 2019).

Representative Runs from the 2019 Assessment

The 2019 assessment used a structural uncertainty approach to explore the alternative states of nature that are plausible for the biology and catch history given the available information. The results along the axes of uncertainty were weighted to given an overall prediction of the stock status and related uncertainty. The axes of uncertainty contained 648 runs:

- 6 levels of catch,
- 3 for natural mortality,
- 3 for the initial F (fishing mortality prior to the start of the model),
- 3 levels for steepness,
- 2 for the recruitment deviations and
- 2 levels for growth and fecundity.

Catch estimates from 1995 to 2016 were used in the assessment model for OCS. The full assessment considered two different catch trajectories that were estimated with three different levels of PRM (for a total of six catch scenarios). The catch scenarios used in the assessment were estimated using a Bayesian model (Tremblay and Neubauer 2019) and were based on a high (90th quantile) estimate and median (50th quantile) estimate. Both scenarios considered three levels of PRM, a 100% mortality on all catches independently of discard status, a 25% mortality on discards and a 25% mortality on individuals released alive (total discard mortality of 43.75% =0.25+0.25*0.75), and a 25% mortality on discards (0% mortality on live release). For details regarding the catch estimation and implementation of the PRM, scenarios please see (Tremblay and Neubauer 2019, and Tremblay-Boyer et al 2019).

The study uses projections (2017−2031) identical to the Rice et al. (2021) uncertainty grid of 108 runs:

- 2 levels of catch 90th quantile (high) and 50th quantile (median),
- 3 for natural mortality,
- 3 for the initial F (fishing mortality prior to the start of the model),
- 3 levels for steepness and
- 2 levels for growth and fecundity.

Recent studies of OCS mortality have been carried out by the National Marine Fisheries Service Pacific Islands Fisheries Science Center. OCS mortality at longline retrieval averaged 19.2% (95% CI, 13.1%–27.3%, Bigelow and Carvalho 2021b). Estimates of PRM were available from a large electronic tagging study on 5 species (blue, bigeye thresher, oceanic whitetip, shortfin mako, and silky sharks) of pelagic sharks in the Hawaii deep-set and American Samoa longline fisheries in the central Pacific Ocean (Hutchinson et al. 2022). The study illustrated post-release survival rates at 1, 30, 60, 180, and 360 days. Results indicated high survival for 1 to 60 days if the sharks are in good condition at release, the branchline is cut to release them from the gear, and trailing gear is minimized. A 60-day time period was considered as the most appropriate of the five time points. Two estimates were used to characterize OCS probability of PRM with the following: 1) wire leaders and leaving ~10 m of trailing gear on a released shark, and 2) monofilament leaders and removing all trailing gear (0 m) on a released shark. The median PRM after 60 days for wire leaders and leaving ~10 m of trailing gear on a released shark is 8% and 3% for monofilament leaders with removing all trailing gear (0 m) on a released shark (Hutchinson et al. 2022, Table 8).

Post-assessment Catch Estimation for OCS

The study considered five future catch scenarios and the following assumptions (Tables 1 and 2).

- 2019 Assessment values projected, with an assumption of 25% mortality at longline retrieval and a 25% mortality on individuals released alive (total discard mortality of 43.75% =0.25+0.25*0.75),
- 2019 Assessment values projected with zero future catches,
- 2019 Assessment values updated with mortality at longline retrieval (19.2%) and PRM (8%) assuming wire leaders and leaving ~10 m of trailing gear on a released shark,
- 2019 Assessment values projected with a 10% average annual percent reduction from 2016 for 3 years (2017−2020). The catch in 2020 is 72.9% of 2016. The catch was set constant at the 2020 estimated values for 2021 through 2031. The catches were further reduced with mortality at longline retrieval (19.2%) and PRM (8%) assuming wire leaders and leaving ~10 m of trailing gear on a released shark, and
- 2019 Assessment values projected, with an assumption of reducing mortality by 41.2% by banning shark lines and branchline wire leaders. The catches were further reduced with mortality at longline retrieval (19.2%) and PRM (3%) assuming monofilament leaders and leaving ~0 m of trailing gear on a released shark.

The assessment and post-assessment catch estimation is illustrated in Figure 1 and a finer scale post-assessment catch estimation is illustrated in Figure 2. These catch levels are also consistent with catch trajectories of oceanic whitetip sharks through 2018 as estimated by Peatman and Nicol (2020; SC16-ST-IP-11).

3 Results

The population is projected to increase at a moderate pace over the projection period (Table 3, Figures 3−7). The summary of spawning biomass in the latest time period (2031) relative to the equilibrium unfished spawning biomass ($SB_{2031}/SB_{F=0}$) from the population projections (Table 3) illustrates that four of the five scenarios had higher projected spawning biomass in 2031 relative to 2016.

The order of models with rebound potential from optimistic to pessimistic was as follows:

1) Zero future catches (mean $SB_{2031}/SB_{F=0}$, 0.165),
2) Prohibit wire leaders and shark lines ((mean $SB_{2031}/SB_{F=0}$, 0.118),
3) 10% reduction in catch (mean $SB_{2031}/SB_{F=0}$, 0.098),
4) 2016 with PRM (mean $SB_{2031}/SB_{F=0}$, 0.070) and
5) 2016 (mean $SB_{2031}/SB_{F=0}$, 0.015)

The forecast with projecting the 2016 catch forward was the only model that had a mean $SB_{2031}/SB_{F=0}$ in 2031 (0.015) less than in 2016 (0.039).

The SSP provided annual longline effort (2016-2020) for the WCPF Convention Area from 20°N to 20°S to evaluate if there has been longline effort reductions, whereby OCS catch is assumed to be proportional. Longline effort was 681 million hooks in 2016, 768 million in 2017, 770 million in 2018, 666 million in 2019 and 604 million in 2020. Years 2019 and 2020 represent effort reductions from 2017 to 2018; however none of the reductions would be similar to the Post Assessment Catch Estimation for OCS assumed in the model with 10% reduction in catch.

The reaction of the model to the structural assumptions was similar to results of Rice et al. (2021). Models with higher natural mortality or steepness result in a population that is more readily able to rebound from a depleted status. The growth curve parameterization in the assessment considered values by two different studies (Joung et al. 2016 and Seki et al. 1998), with the results based on the Seki parameterization showing a greater ability to rebound under all catch scenarios.

4 Acknowledgements

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5 Recommendations

Project 101 analyzed observer data on gear configurations by flag for 110,154 longline sets to estimate factors affecting shark catchability and condition on longline retrieval. There are ~5,370 additional ROP sets and ~4,439 additional non-ROP sets that could be included in the analysis, although the additional ~10% of sets may not alter results on gear configuration nor catchability. SC18 can provide advice on if Project 101 should be continued.

Analyses have been conducted on the effects of converting from wire to monofilament leaders on catch rates of target, incidental, and bycatch species in deep-set longline fisheries (WCPFC-SC18-2022/EB-IP-18. Project 101 projected the effects of a 10% decrease in overall catch. Additional research could consider the effort reduction levels that would be needed to achieve these catch reductions and the impacts that would occur for the target species of bigeye and yellowfin tuna.

6 References

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7 Tables

Table 1. Assumptions for mortality, post-release mortality (PRM) and catch reduction for the five projection scenarios considered.

	Mortality at retrieval	**Post-release mortality**	**Released-alive individuals**	**Total mortality**	**Catch reduction**	**Scaler from year = 2016**
Forecast at 2016 (Rice et al. 2021)	0.25	0.25	0.75	0.438	1.000	1.000
No catch				0.000	1.000	0.000
Forecast at 2016 with updated M and PRM, assume PRM with wire	0.192	0.0812	0.808	0.258	1.000	0.589
Catch 10% reduction with updated M and PRM, assume PRM with wire	0.192	0.0812	0.808	0.258	0.900	0.530
Forecast at 2016 with updated M and PRM, and no wire and no shark lines.	0.192	0.0344	0.808	0.220	0.588	0.295

Table 2. Estimated catches (in 1000s of individuals) used in the assessment (High PRM 0.75, Median PRM 0.75) for the years 2012−2016, along with calculated values for 2017−2031 based on 1) forecast at 2016 levels (Rice et al. 2017); 2) zero catch in 2017−2031; 3) forecast at 2016 levels with updated mortality at retrieval and post-release mortality (PRM); 4) average annual 10% percent reduction in catch from 2016 for 2017 to 2020 with 2020 estimates carried forward to 2031 and updated mortality at retrieval and PRM; 5) forecast at 2016 levels with updated mortality at retrieval and PRM and prohibition of wire branchlines and shark lines.

Forecast at 2016 levels			Forecast at zero catch			Forecast at 2016 levels with updated M and PRM, assume PRM with wire			Forecast at 2016 levels with 10% reduction in catch and updated M and PRM, assume PRM with wire			Forecast at 2016 levels with updated mortality at retrieval and PRM and prohibition of wire branchlines and shark lines		
Year	High catch	Median catch	Year	High catch	Median catch	Year	High catch	Median catch	Year	High catch	Median catch	Year	High catch	Median catch
2012	233.0	112.4	2012	233.0	112.4	2012	233.0	112.4	2012	233.0	112.4	2012	233.0	112.4
2013	111.4	54.3	2013	111.4	54.3	2013	111.4	54.3	2013	111.4	54.3	2013	111.4	54.3
2014	111.2	45.6	2014	111.2	45.6	2014	111.2	45.6	2014	111.2	45.6	2014	111.2	45.6
2015	114.5	48.2	2015	114.5	48.2	2015	114.5	48.2	2015	114.5	48.2	2015	114.5	48.2
2016	86.8	38.1	2016	86.8	38.1	2016	86.8	38.1	2016	86.8	38.1	2016	86.8	38.1
2017	86.8	38.1	2017	0.0	0.0	2017	51.1	22.4	2017	46.0	20.2	2017	25.6	11.2
2018	86.8	38.1	2018	0.0	0.0	2018	51.1	22.4	2018	41.4	18.2	2018	25.6	11.2
2019	86.8	38.1	2019	0.0	0.0	2019	51.1	22.4	2019	37.3	16.4	2019	25.6	11.2
2020	86.8	38.1	2020	0.0	0.0	2020	51.1	22.4	2020	33.5	14.7	2020	25.6	11.2
2021	86.8	38.1	2021	0.0	0.0	2021	51.1	22.4	2021	33.5	14.7	2021	25.6	11.2
2022	86.8	38.1	2022	0.0	0.0	2022	51.1	22.4	2022	33.5	14.7	2022	25.6	11.2

Table 3. Summary of spawning biomass in the start of the time period (1995) and latest time period (2016) relative to the equilibrium unfished spawning biomass the 2019 assessment (Laura Tremblay-Boyer et al. 2019) and summary of spawning biomass in the latest time period (2031) relative to the equilibrium unfished spawning biomass (SB_{2031}/SBF=0) from the population projections.

Model	Mean	Median	Min	10%	90%	Max
2019 Assessment						
1995	0.355	0.354	0.147	0.341	0.370	0.593
2016	0.039	0.037	0.019	0.038	0.040	0.064
2031 values from projections						
2016 grid	0.015	<0.001	0.000	0.011	0.019	0.151
No catch	0.165	0.141	0.056	0.154	0.176	0.430
2016 + PRM	0.070	0.048	0.011	0.062	0.078	0.274
10% catch reduction	0.098	0.073	0.023	0.090	0.107	0.322
No wire and no shark lines	0.118	0.093	0.033	0.092	0.124	0.355

8 Figures

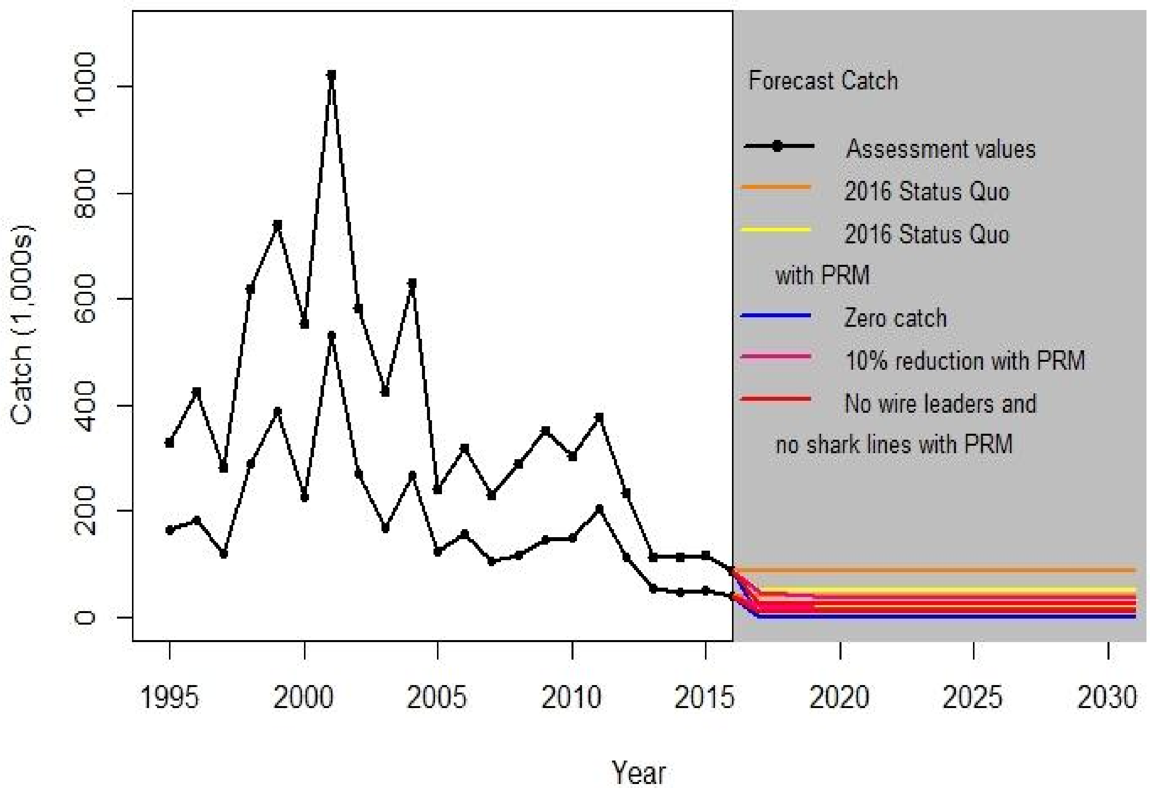

Figure 1. Assessment catch values (dotted line) under the High Catch PRM 0.75 (upper line) and Median Catch PRM 0.75 scenarios with forecast catch under 2016 catch, 2016 catch with updated post-release mortality, zero catch, 10% reduction in catch and prohibition of wire leaders and shark lines.

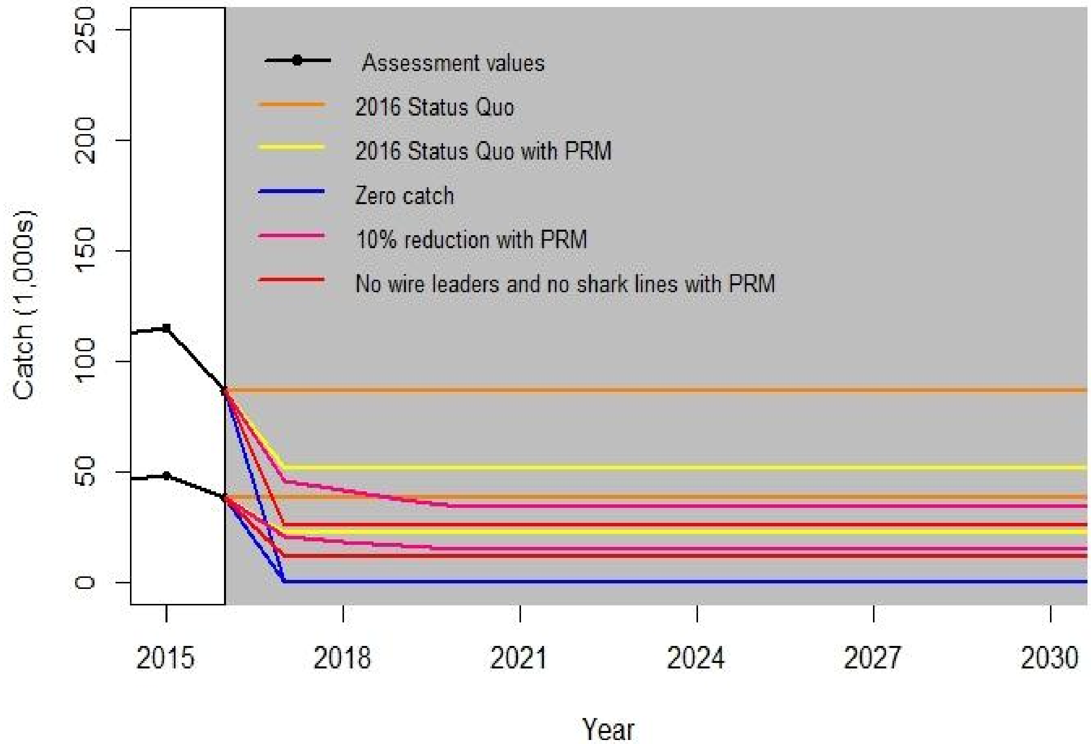

Figure 2. A close-up comparison of the projected catch values during the forecast period (shaded portion of the graph).

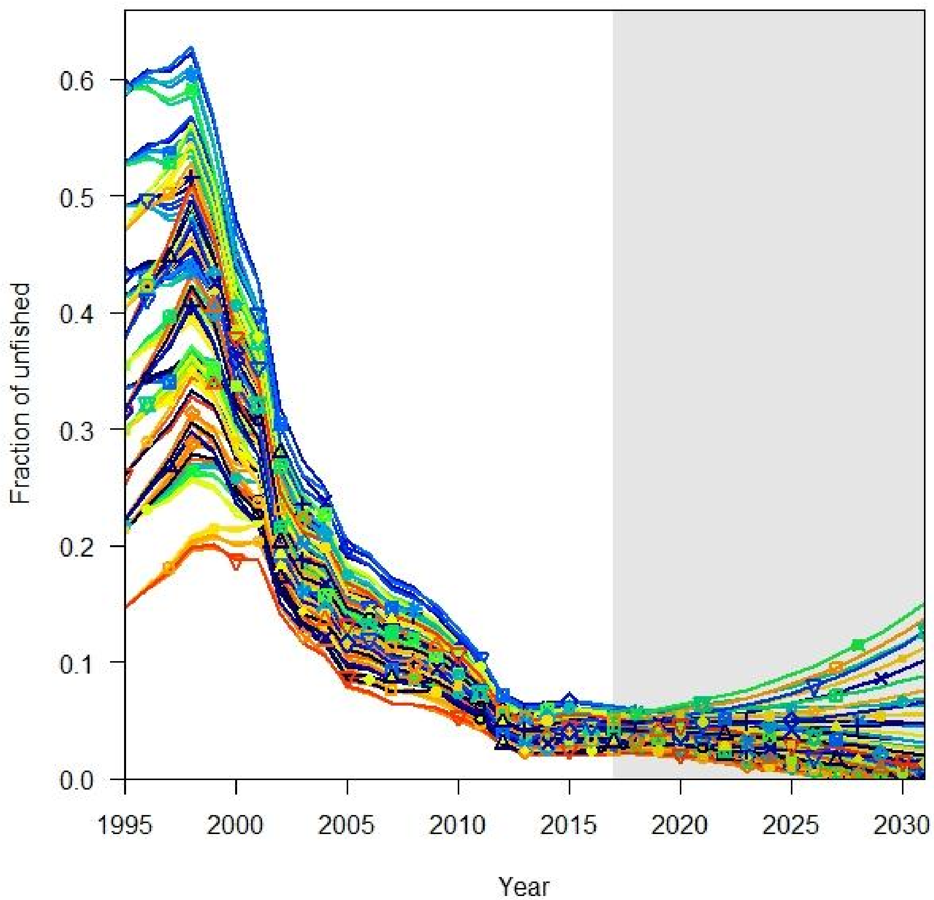

Figure 3. Projected biomass depletion under the 2016 status quo catch. Colors indicate individual runs.

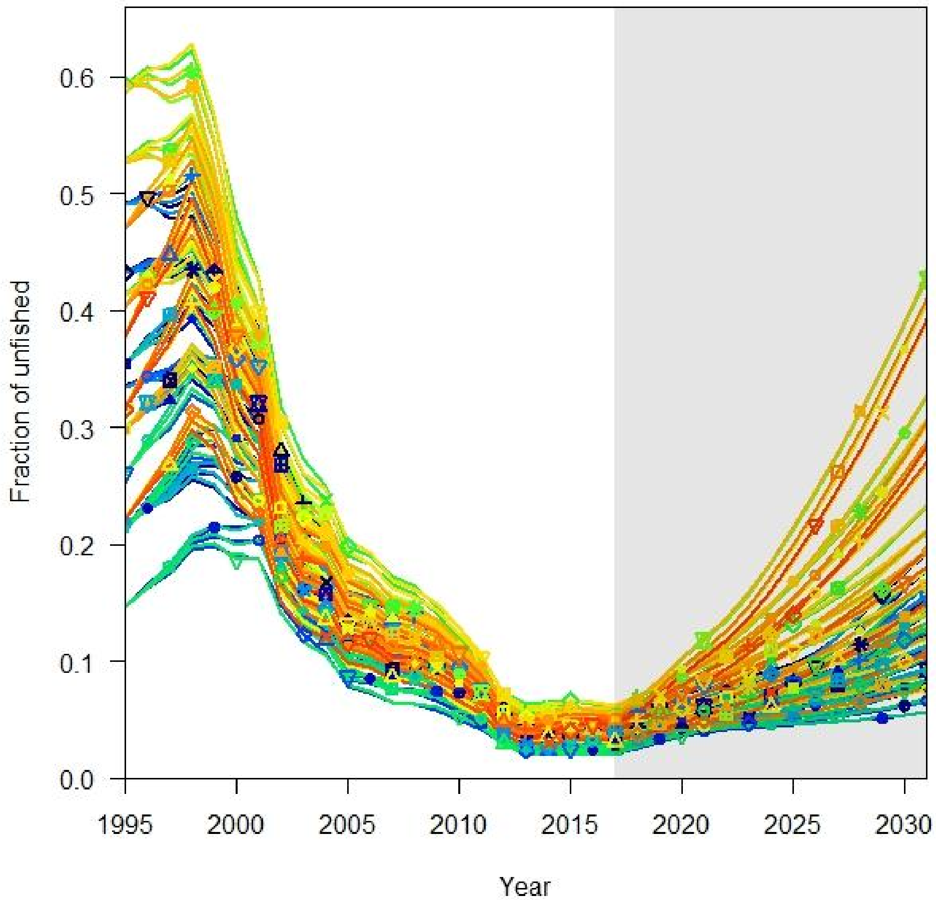

Figure 4. Projected biomass depletion with zero catch in 2017-2031. Colors indicate individual runs.

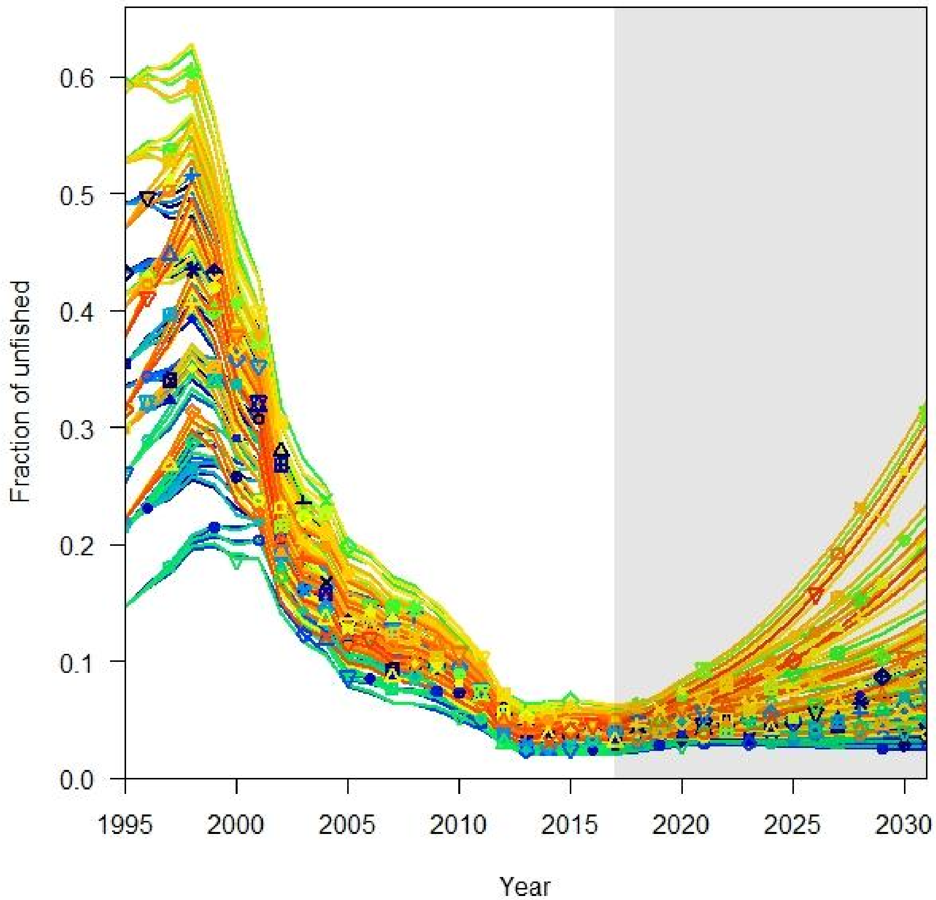

Figure 5. Projected biomass depletion with forecast at 2016 levels with updated mortality at retrieval and post-release mortality (PRM). Colors indicate individual runs.

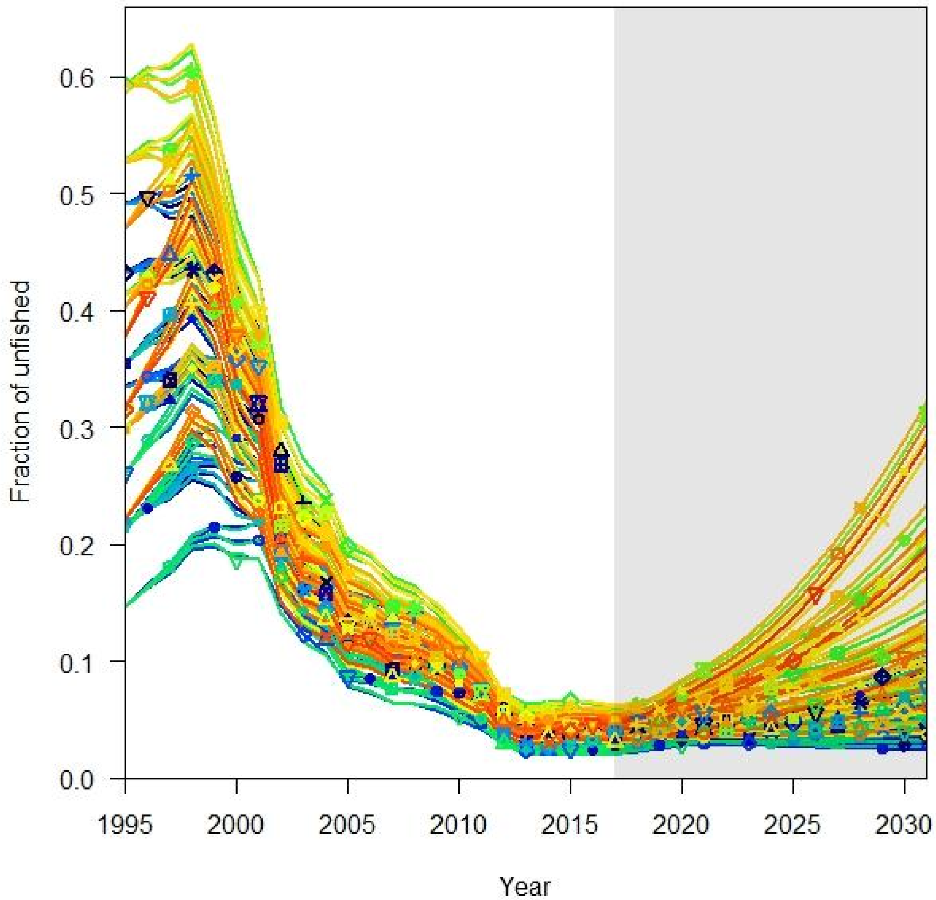

Figure 6. Projected biomass depletion with average annual 10% percent reduction in catch from 2016 for 2017 to 2020 with 2020 estimates carried forward to 2031 and updated mortality at retrieval and post-release mortality (PRM). Colors indicate individual runs.

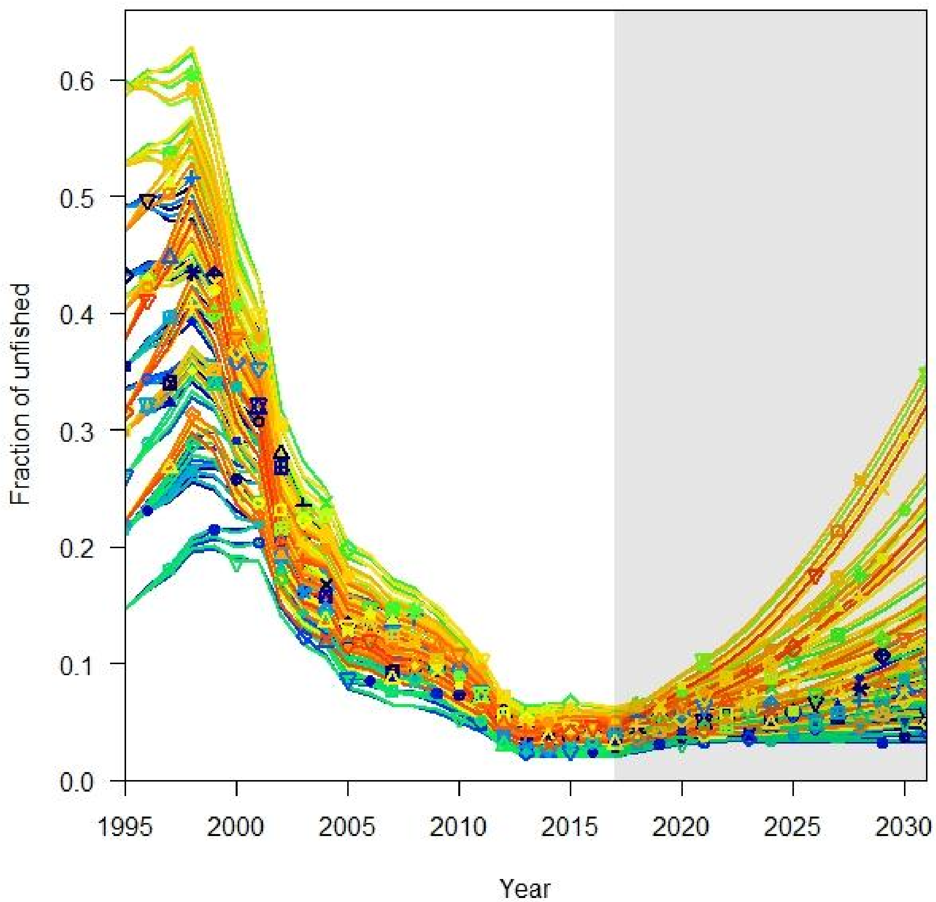

Figure 7. Projected biomass depletion with forecast at 2016 levels with updated mortality at retrieval, post-release mortality (PRM) and prohibition of wire branchlines and shark lines. Colors indicate individual runs.