REVIEW OF RESEARCH ON FUTURE PROJECTIONS AND POTENTIAL MITIGATION MEASURES TO REDUCE FISHING RELATED MORTALITY ON OCEANIC WHITETIP SHARKS.

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SUMMARY

Pelagic sharks, including oceanic whitetips and silky sharks, face significant threats due to fishing-related mortality. This paper provides a review of research aimed at identifying effective mitigation measures to reduce mortality rates among these vulnerable species. As a study species, oceanic whitetip sharks in the Western and Central Pacific Ocean are used to assess the efficacy of existing conservation and management measures and investigate potential strategies to enhance conservation efforts.

The study reviews two previous papers Rice et al. (2021) and Bigelow et al (2022) which highlight the inadequacy of previous bans on shark lines or wire traces alone in mitigating fishing-related mortality. Despite initial attempts to address the issue, these measures have fallen short of achieving desired outcomes. Through an analysis of available data and insights, we conclude that a combination of bans on both shark lines and wire traces holds the greatest promise for reducing mortality rates to sustainable levels.

KEYWORDS
Oceanic Whitetip Sharks, pelagic longlines, mortality

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Introduction

This study provides an overview or research conducted on oceanic whitetip sharks ())CS) in the Western and Central Pacific Ocean. 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. This assessment used a structural uncertainty grid to explore the potential states of nature with respect to historical catch, natural mortality, steepness and other uncertainties. All of the runs showed that OCS was overfished and that overfishing was occurring.

Based in part on the 2012 assessment, as well as work on influence of four gear factors (leader type, hook type, “shark” lines and bait type) on shark catch rates in WCPO tuna longline fisheries (Bromhead et al. 2013) 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).

The WCPFC adopted CMM 2014-05 (superseded by 2019-04), whereby longline fisheries targeting tuna and billfish comply with either: 1) do not use or carry wire trace as branchlines or leaders; or 2) do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.

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 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 (CMM-2011-04 non-retention of the species, and CMM 2014-05 a ban on wiretrace or sharklines) and the impact of the CMM on the timeline for recovery. In parallel, Hutchinson and Bigelow (2019) presented new results quantifying post-release mortality for oceanic whitetip shark that were not available at the time the 2019 stock assessment was completed. The stock assessment characterized the uncertainty in the data and model parameters via a structural uncertainty grid where multiple (648) combinations of data and parameter values were used to show the range of plausible uncertainty to the inputs.

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 study used a representative subset of the structural uncertainty in the assessment (108 runs) based on the updated post-release mortality values. Future projections for the 2019 WCPO oceanic whitetip stock assessment were completed to assess the impacts of recent conservation and management measures future fishing mortality on recovery timelines, using updated estimates of post-release mortality.

This study demonstrated the effect of a range of post assessment (2017 and on) catch trends on the estimates of population growth rate. Population projections are carried forward to estimate the mean time and probability of the population reaching thresholds of 50%, 25%, and 12.5% of current (2016) biomass levels. This study was updated in 2022 (Bigelow et al. 2022) with contemporary estimates of mortality at longline retrieval, post-release mortality, catch reductions and prohibitions of wire branchlines and shark lines.

1. Methods

The Rice et al. (2021) and Bigelow et al (2022) studies used the same methods and considered the same five future catch scenarios and the following assumptions;.

1. 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),
2. 2019 Assessment values projected with zero future catches,
3. 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,
4. 2019 Assessment values projected with a 10% average annual percent reduction from 2016 for three 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,
5. 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).

2. Results and conclusions

The order of models with rebound potential from optimistic to pessimistic was:
1) Zero future catches (mean SB2031/SBF=0, 0.165),
2) Prohibit wire leaders and shark lines ((mean SB2031/SBF=0, 0.118),
3) 10% reduction in catch (mean SB2031/SBF=0, 0.098),
4) 2016 with PRM (mean SB2031/SBF=0, 0.070) and
5) 2016 (mean SB2031/SBF=0, 0.015)
The forecast with projecting the 2016 catch forward was the only model that had a mean SB2031/SBF=0 in 2031 (0.015) less than in 2016 (0.039)

An analysis of annual longline effort (2016-2020) for the WCPF Convention Area from 20°N to 20°S to evaluate if there have been longline effort reductions, showed that 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 that 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.

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Figures

(Figures 1-7 are Bigelow et al (2022), and Figures 8-13 from Rice et al. (2021))

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.

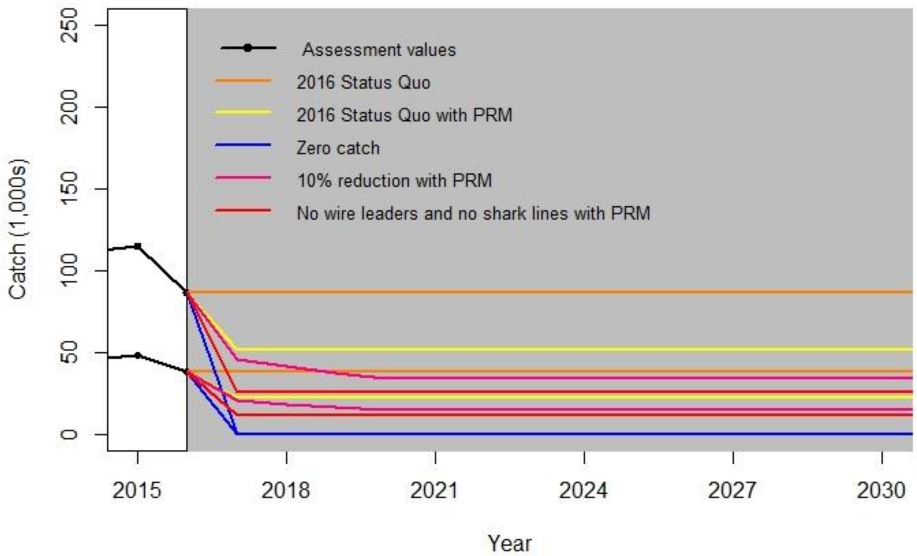

Figure 2. A close-up comparison of the projected catch values during the forecast period (shaded portion of the graph).

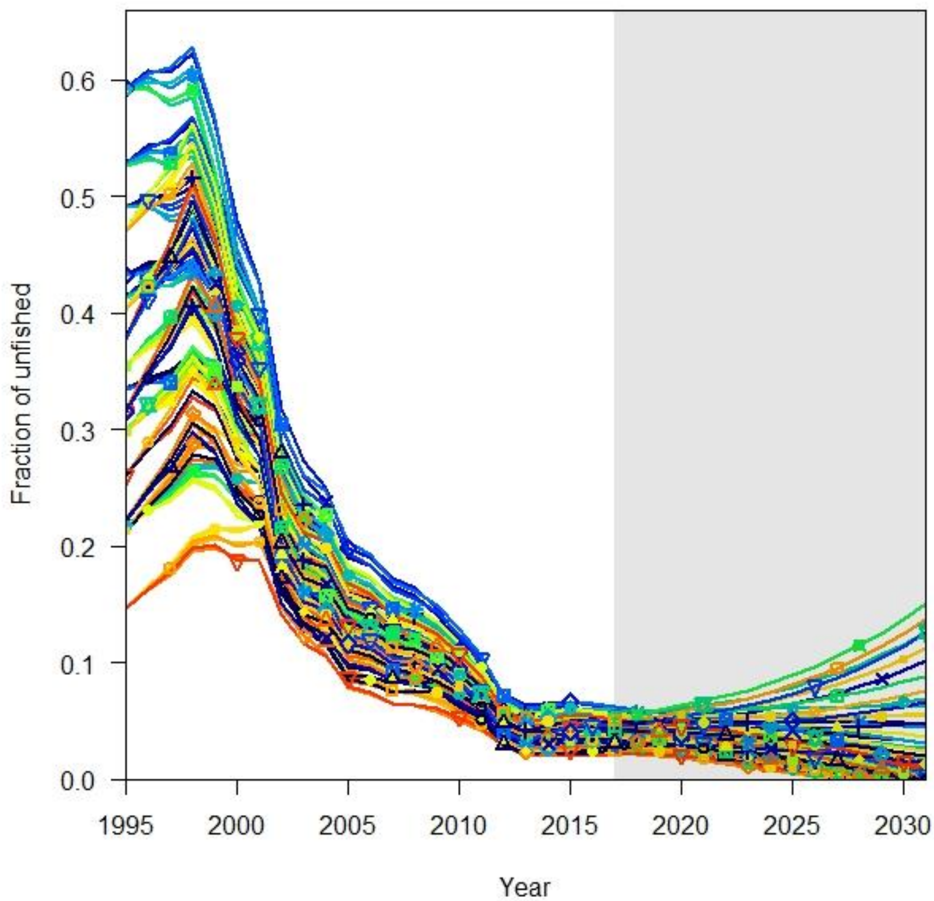

Figure 3. Projected biomass depletion under the 2016 status quo catch.

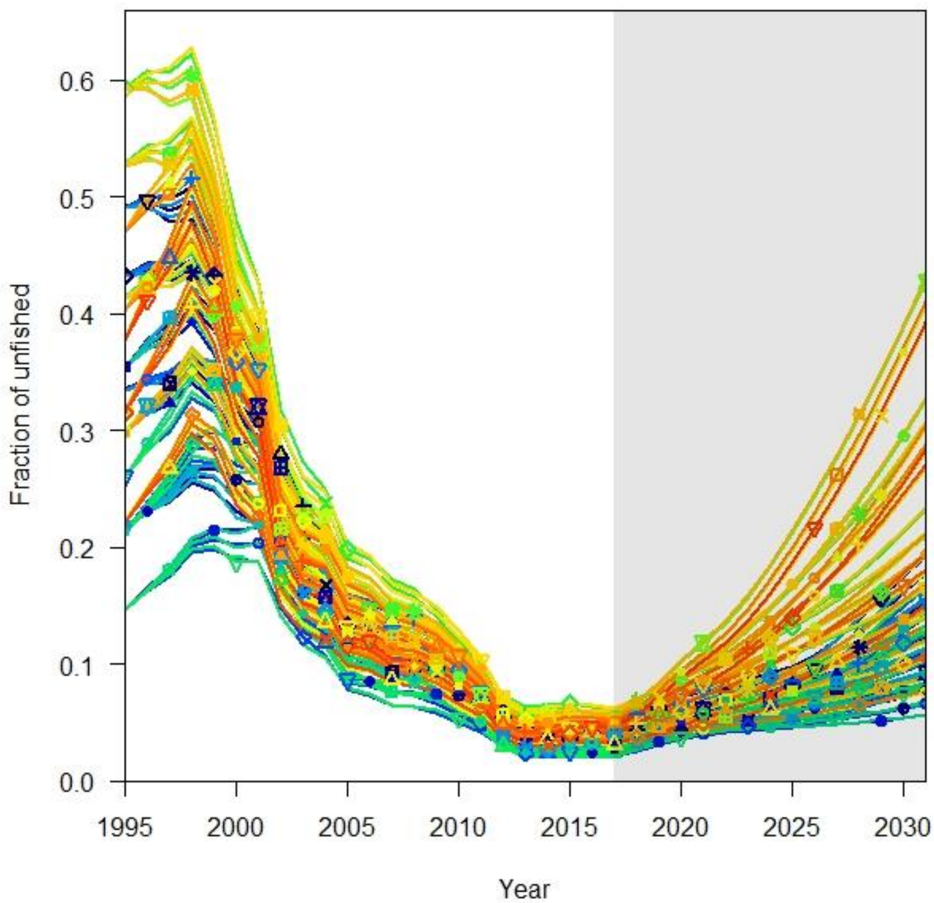

Figure 4. Projected biomass depletion with zero catch in 2017-2031, colors represent different runs.

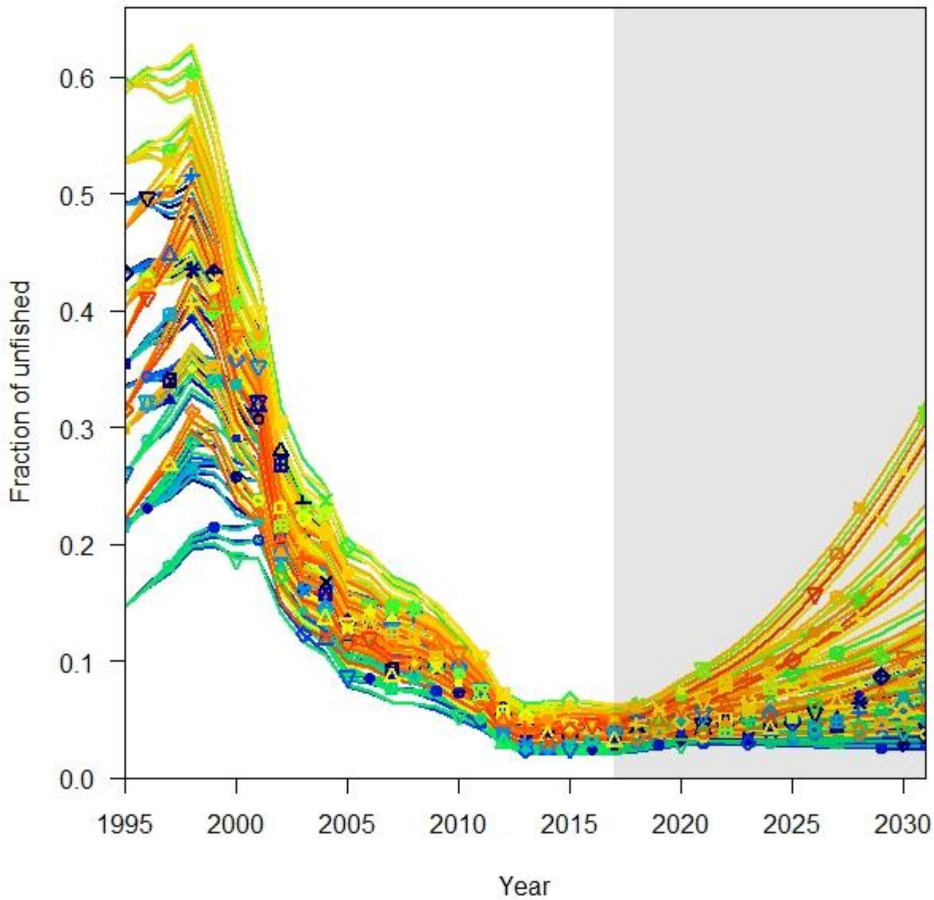

Figure 5. Projected biomass depletion with forecast at 2016 levels with updated mortality at retrieval and post-release mortality (PRM).

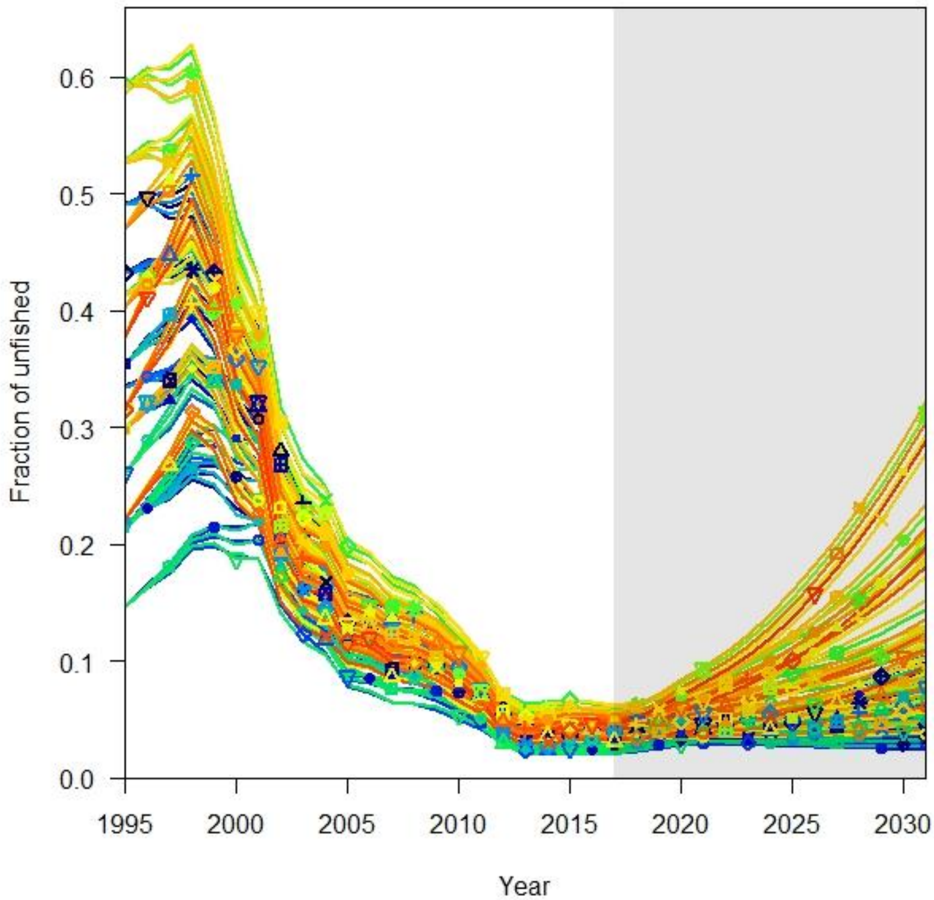

Figure 6. Projected biomass depletion with average annual 10% percent reduction in catch from 2016 for 2017 to 2020 with 2020 estimates carried forward to 2031 and updated mortality at retrieval and post-release mortality (PRM).

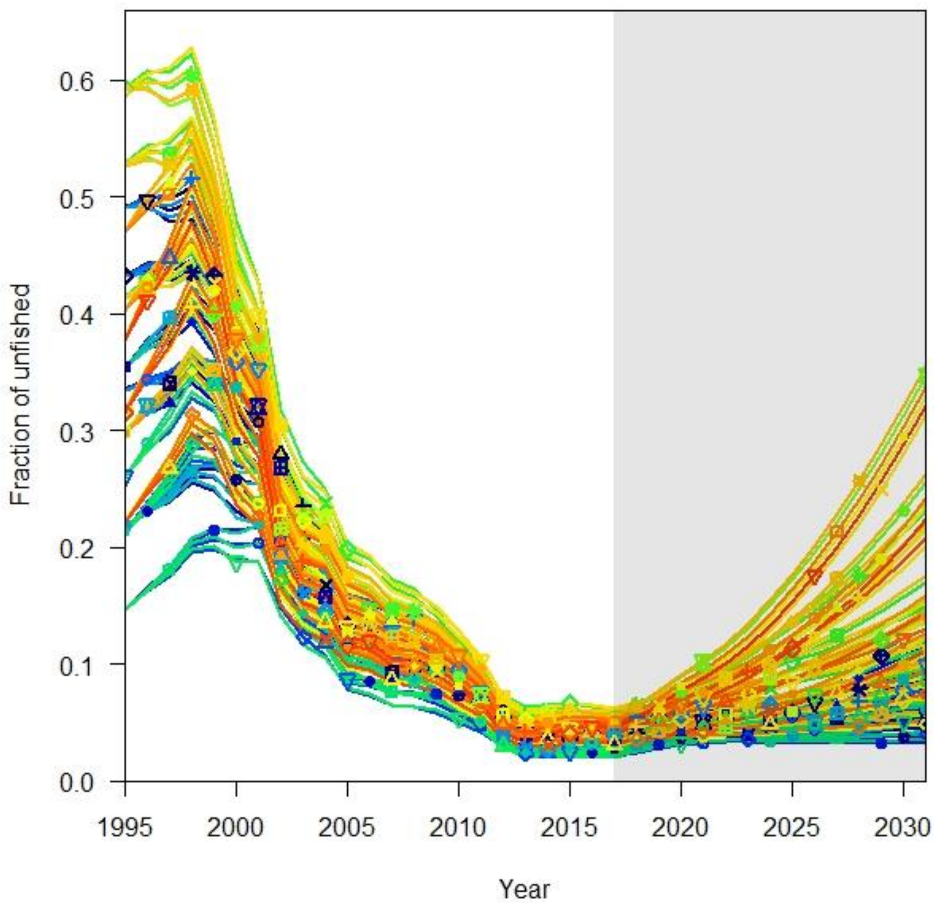

Figure 7. Projected biomass depletion with forecast at 2016 levels with updated mortality at retrieval, post-release mortality (PRM) and prohibition of wire branchlines and shark lines.

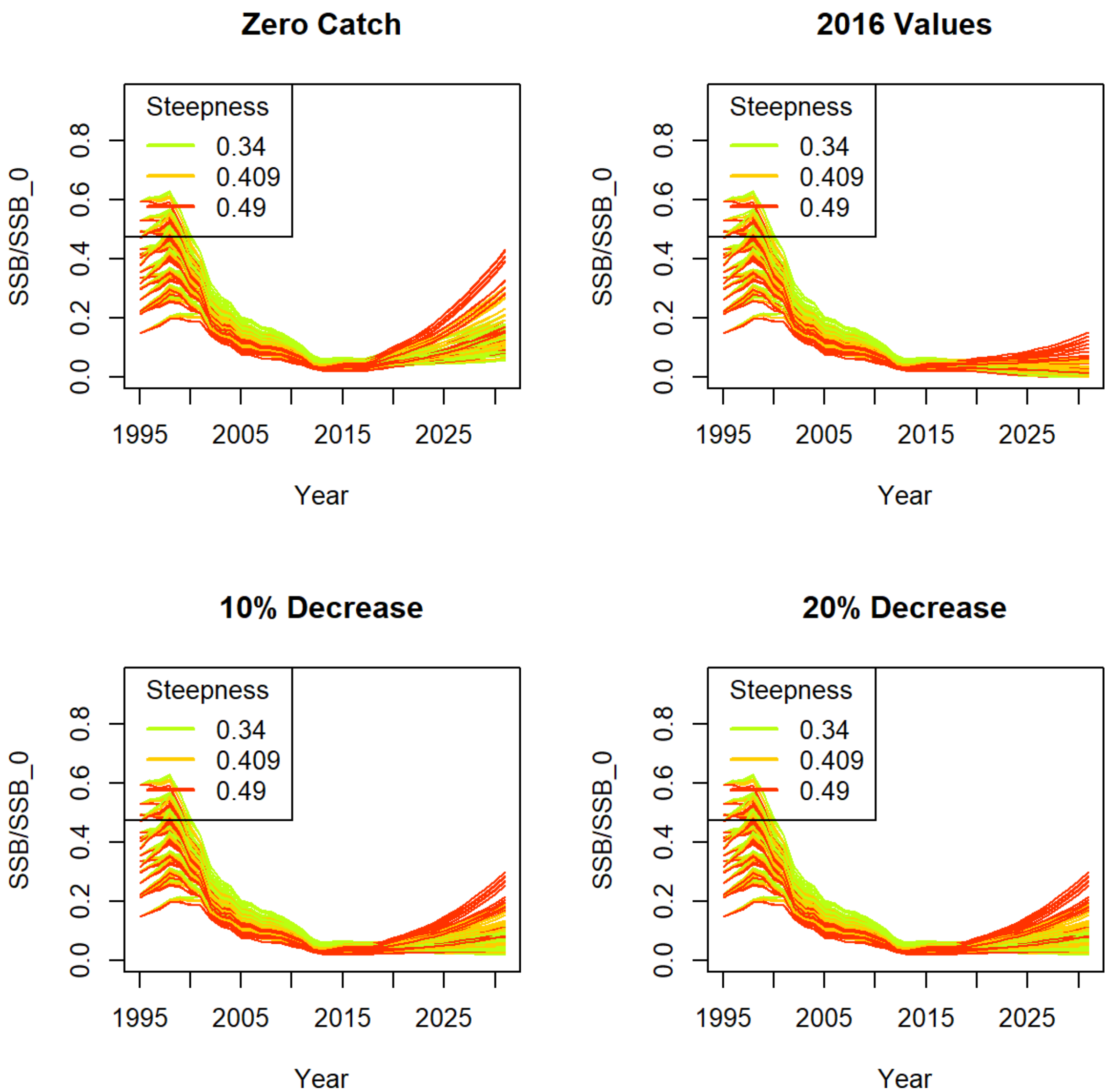

Figure 8. Projected biomass depletion under zero catch scenario, the 2016 status quo catch a 10% decline from 2016 and a 20% decline from 2016. Colors indicate steepness values assumed in the assessment as part of the structural uncertainty grid.

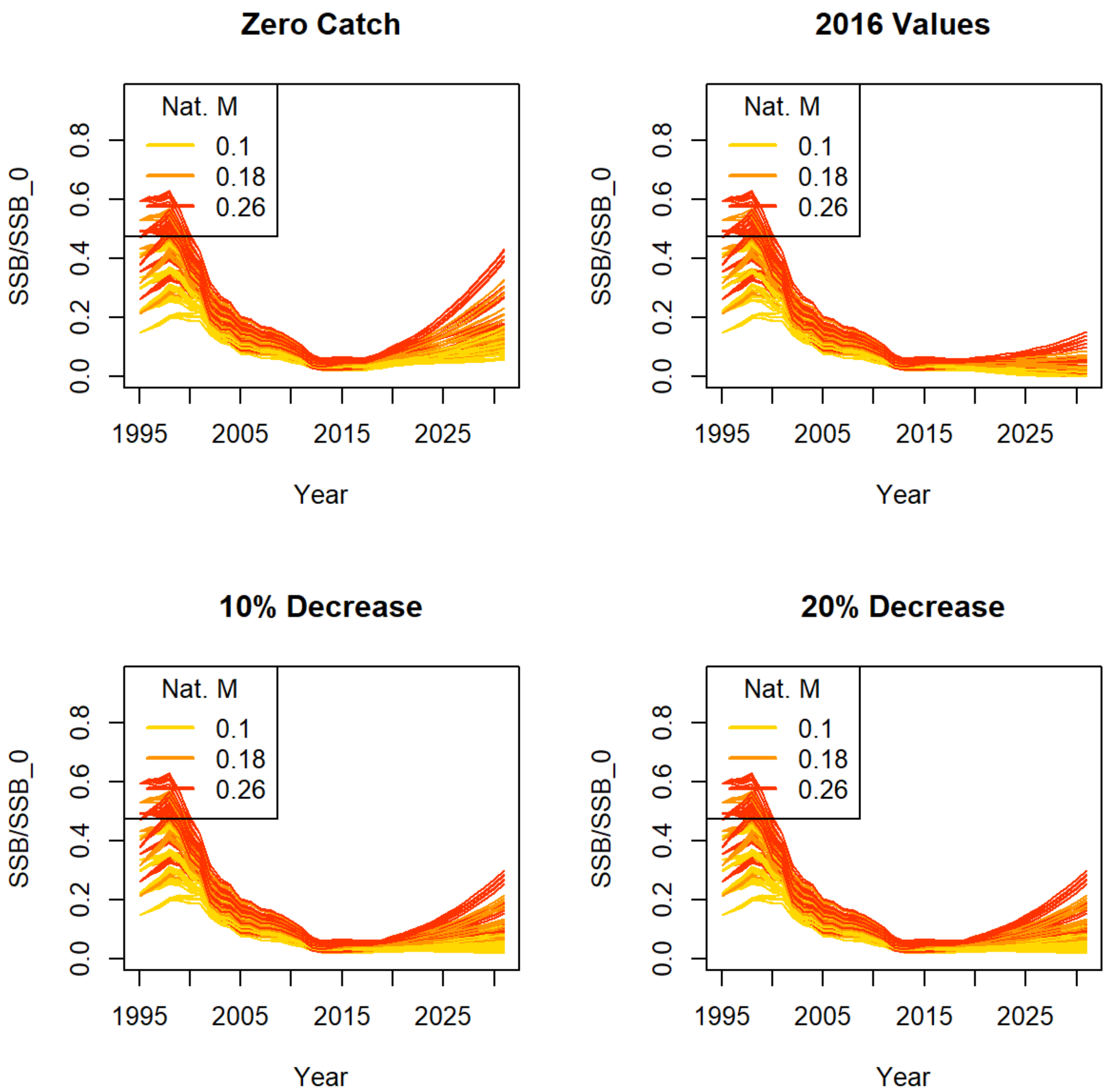

Figure 9. Projected biomass depletion under zero catch scenario, the 2016 status quo catch a 10% decline from 2016 and a 20% decline from 2016. Model runs are colored by the natural morality values

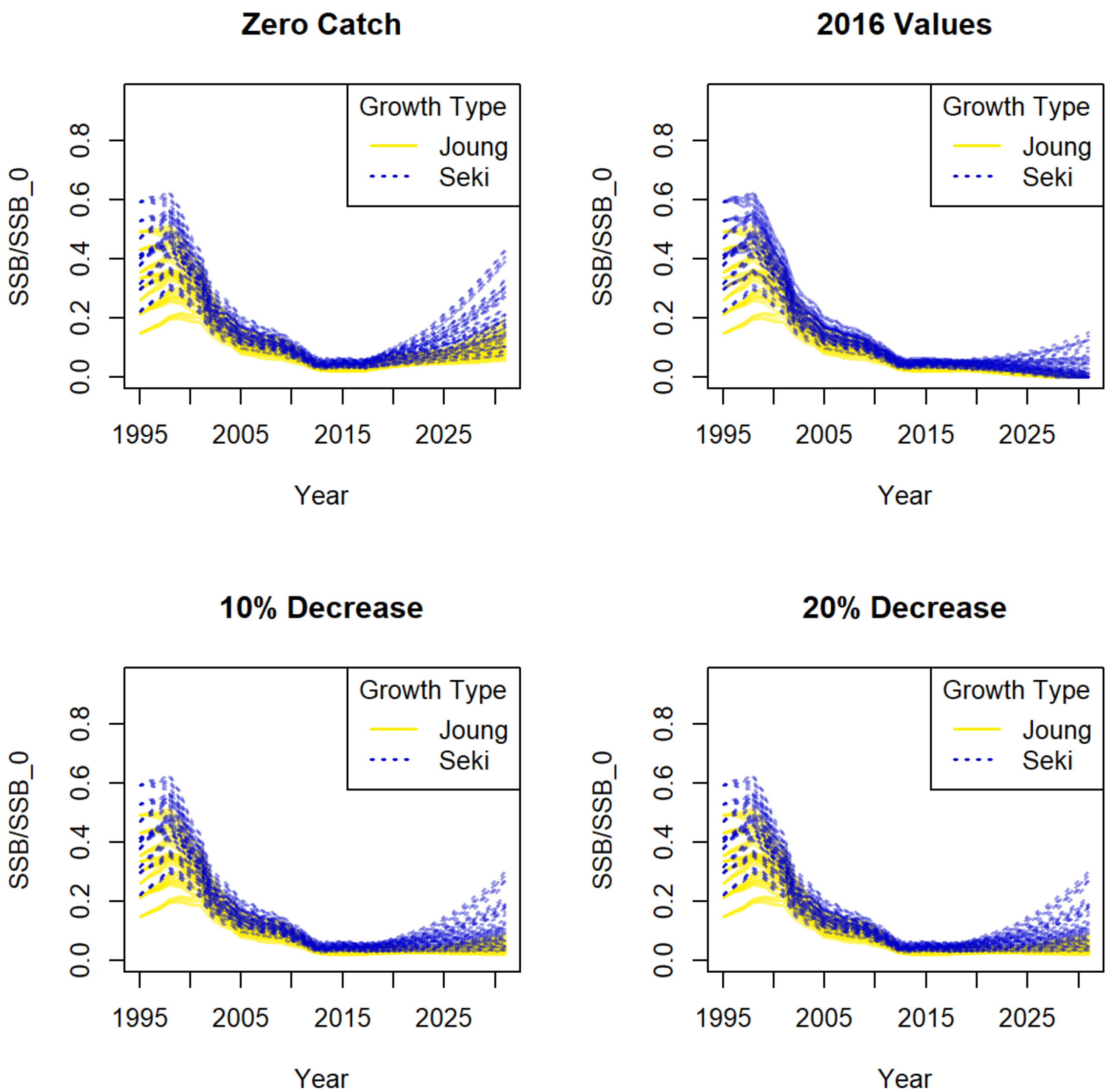

Figure 10. Projected biomass depletion under zero catch scenario, the 2016 status quo catch a 10% decline from 2016 and a 20% decline from 2016. Model runs are colored by the growth curve used.

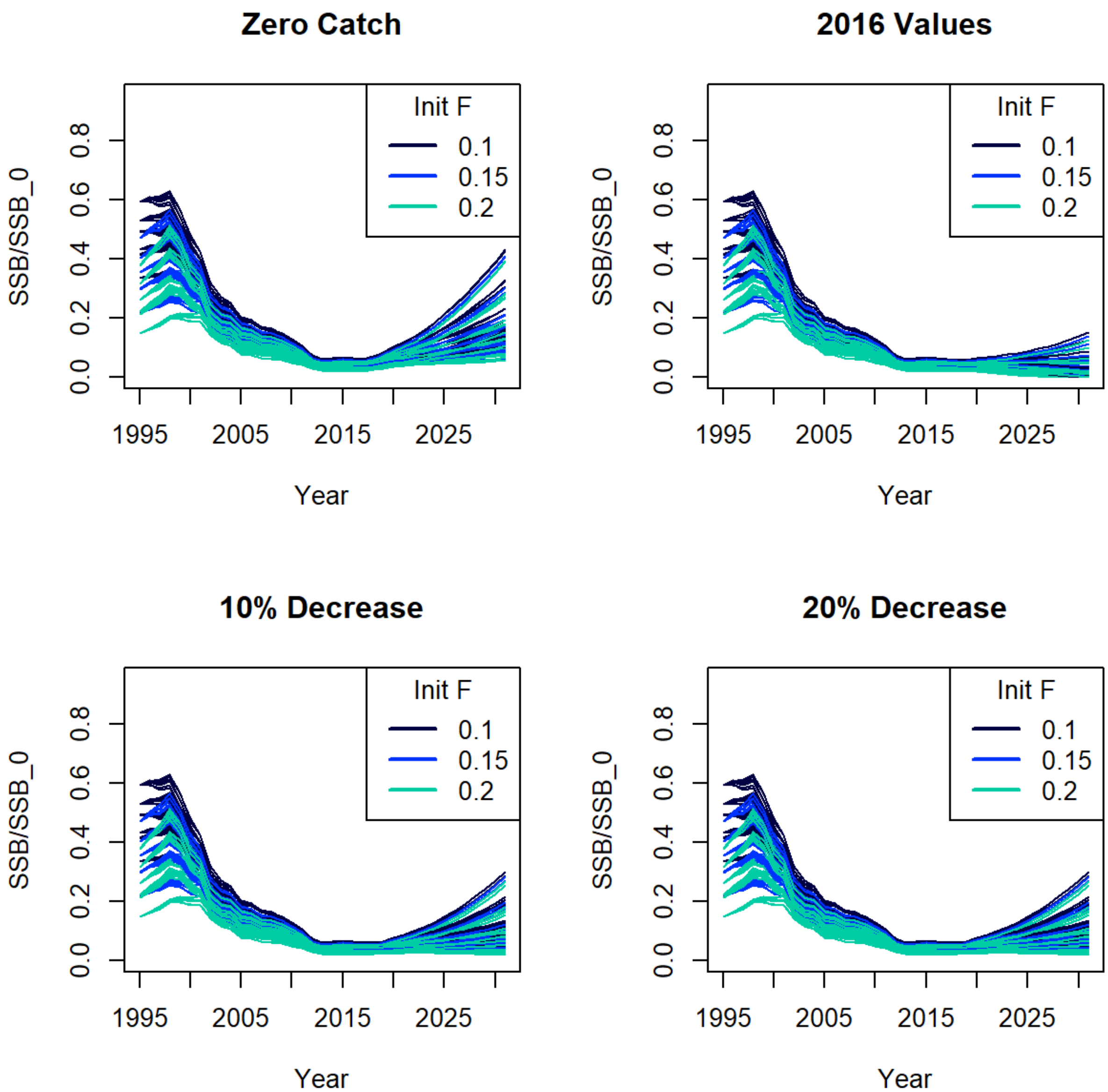

Figure 11. Projected biomass depletion under zero catch scenario, the 2016 status quo catch a 10% decline from 2016 and a 20% decline from 2016.Model runs are colored by the initial depletion used.

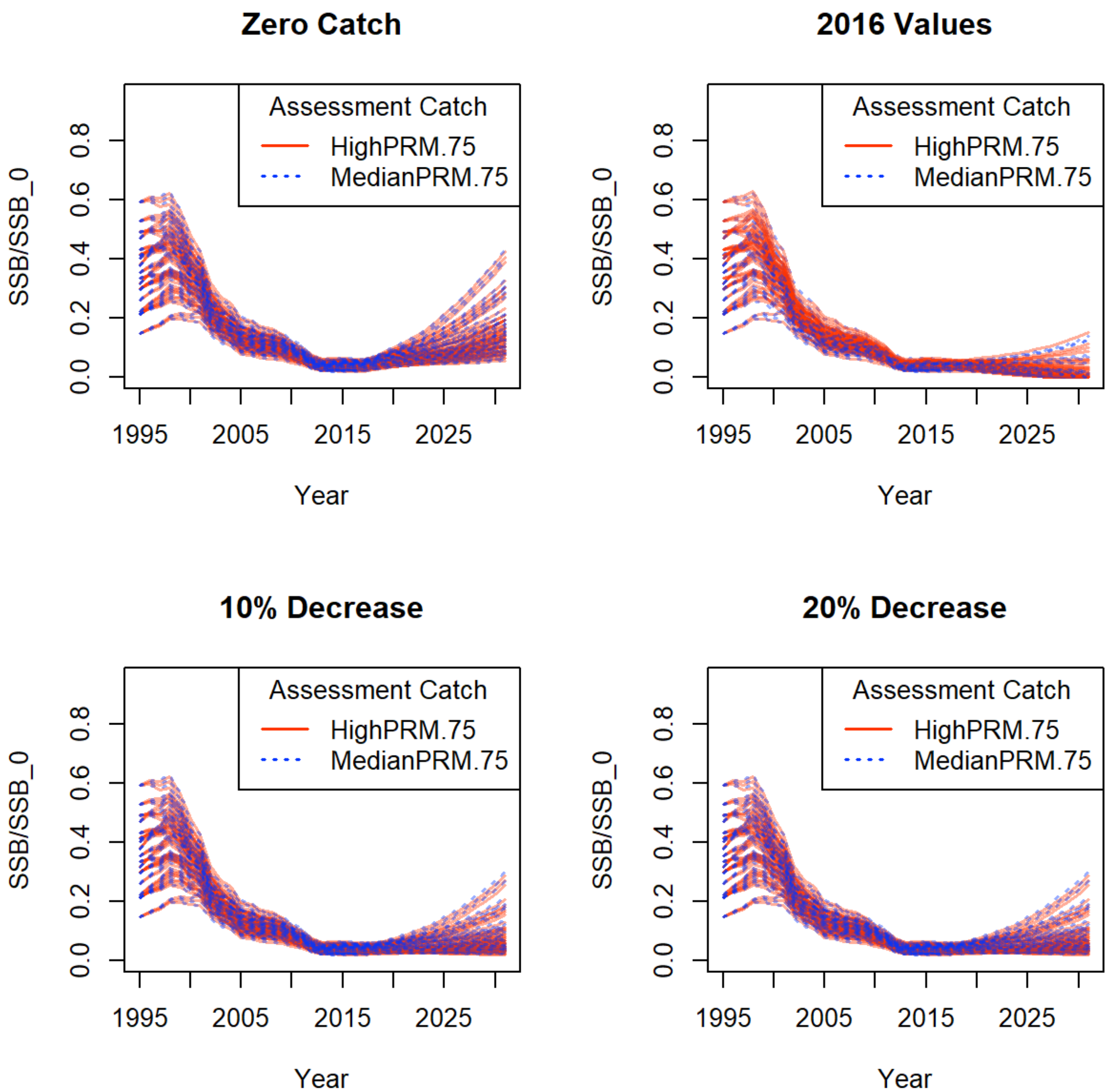

Figure 12. Projected biomass depletion under zero catch scenario, the 2016 status quo catch a 10% decline from 2016 and a 20% decline from 2016. Model runs are colored by the catch trajectory used.

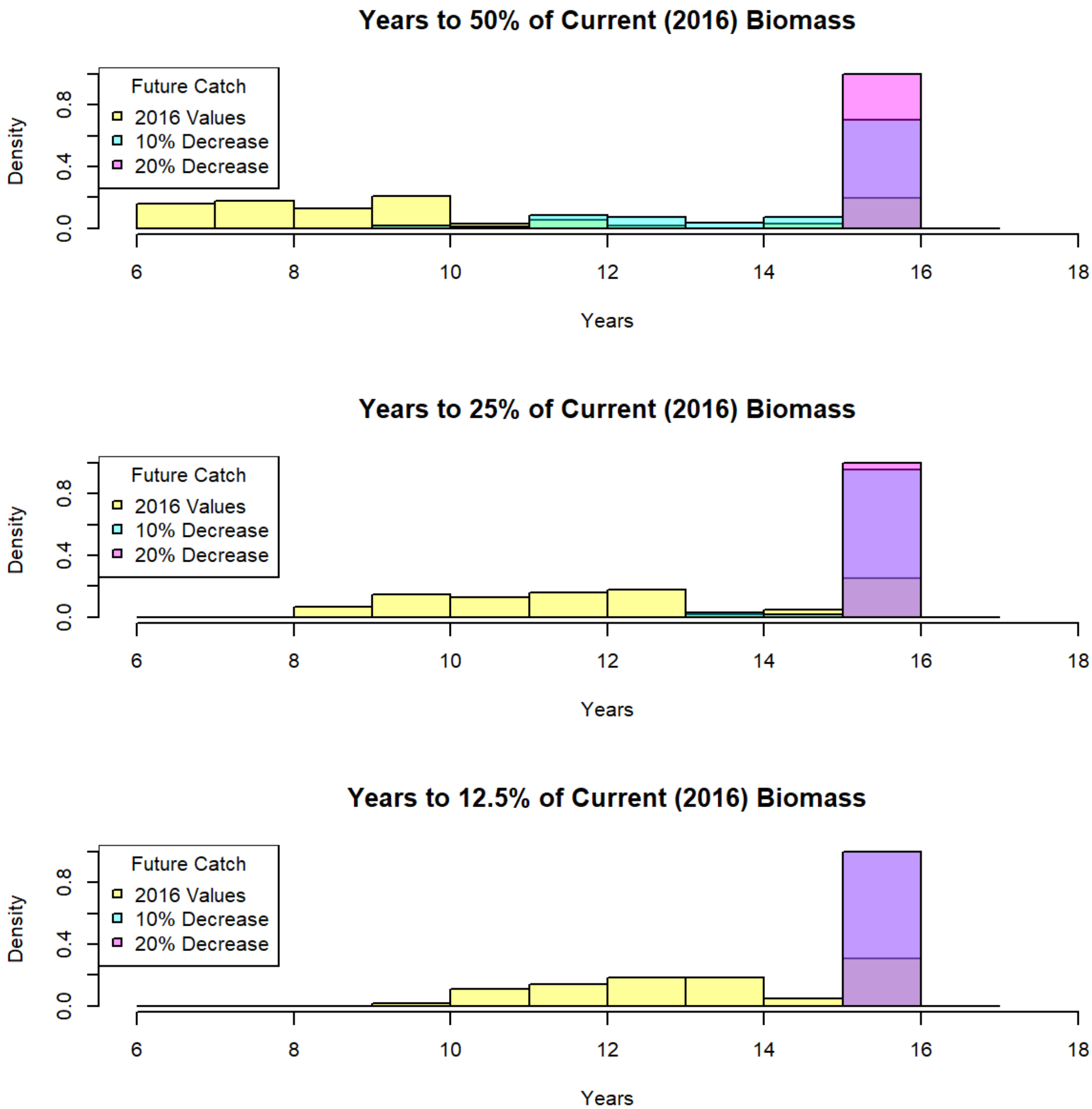

Figure 13. Time in years to biomass depletion to percentages of the 2016, (50%, 25% and 12.5%. Model runs are colored by the catch trajectory used.

Tables (From

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
Grid_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
Grid_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
Grid_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 1000's 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		
Year	High catch	Median catch		High catch	Median catch
2012	233.0	112.4	2012	233.0	112.4
2013	111.4	54.3	2013	111.4	54.3
2014	111.2	45.6	2014	111.2	45.6
2015	114.5	48.2	2015	114.5	48.2
2016	86.8	38.1	2016	86.8	38.1
2017	86.8	38.1	2017	0.0	0.0
2018	86.8	38.1	2018	0.0	0.0
2019	86.8	38.1	2019	0.0	0.0
2020	86.8	38.1	2020	0.0	0.0
2021	86.8	38.1	2021	0.0	0.0
2022	86.8	38.1	2022	0.0	0.0

Table 2 continued. Estimated catches (in 1000's 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 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	
Year	High catch	Median catch		High catch	Median catch
2012	233.0	112.4	2012	233.0	112.4
2013	111.4	54.3	2013	111.4	54.3
2014	111.2	45.6	2014	111.2	45.6
2015	114.5	48.2	2015	114.5	48.2
2016	86.8	38.1	2016	86.8	38.1
2017	51.1	22.4	2017	46.0	20.2
2018	51.1	22.4	2018	41.4	18.2
2019	51.1	22.4	2019	37.3	16.4
2020	51.1	22.4	2020	33.5	14.7
2021	51.1	22.4	2021	33.5	14.7
2022	51.1	22.4	2022	33.5	14.7

Table 2 continued. Estimated catches (in 1000's 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 with updated mortality at retrieval and PRM and prohibition of wire branchlines and shark lines		
Year	High catch	Median catch
2012	233.0	112.4
2013	111.4	54.3
2014	111.2	45.6
2015	114.5	48.2
2016	86.8	38.1
2017	25.6	11.2
2018	25.6	11.2
2019	25.6	11.2
2020	25.6	11.2
2021	25.6	11.2
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