



**COMMISSION
EIGHTEENTH REGULAR SESSION
Electronic Meeting
1 – 7 December 2021**

**REFERENCE DOCUMENT FOR NORTH PACIFIC STRIPED MARLIN FOR THE REVIEW
OF CMM 2010-01**

**WCPFC18-2021-22
9 November 2021**

Paper prepared by the Secretariat

A. INTRODUCTION

1. The purpose of this paper is to provide a quick reference guide to the recommendations of the Commission, ISC and SC in support of discussions for the review of CMM 2010-01 (CMM for North Pacific Striped Marlin). The Commission is anticipated to review the CMM and to update the rebuilding plan as needed.

B. COMMISSION ISSUES AND DECISION POINTS

2. In 2010, WCPFC7 adopted a CMM for North Pacific Striped Marlin (CMM 2010-01, **Attachment A**). In 2019, WCPFC16 adopted the Interim Rebuilding Plan for North Pacific Striped Marlin (**Attachment B**).

3. In 2020, WCPFC17 reviewed a proposal [WCPFC17-2020-DP08 Consultative Draft Proposal on Conservation and Management Measure for North Pacific Striped Marlin](#), and the Commission requested the ISC to provide responses on the following three issues:

250. *The Commission requested the ISC to:*

- i. examine differences between ISC stock assessment catch estimates by CCM and WCPFC catch estimates, and work with the Scientific Services Provider to provide an assessment of the shortcomings;*
- ii. provide explanation why the striped marlin stock decreased and the fishing mortality increased after a drastic decrease in fishing effort by high seas driftnet fisheries in the early 1990s; and*
- iii. develop a roadmap to address the issues identified in the latest stock assessment by ISC.*

C. INTERNATIONAL SCIENTIFIC COMMITTEE FOR TUNA AND TUNA-LIKE SPECIES IN THE NORTH PACIFIC OCEAN ([SC17-GN-IP-03 ISC21 Plenary Report](#), pages 22 - 23)

4. WCPFC17 requested that the ISC address the three issues arising from the most recent WCNPO MLS stock assessment. The BILLWG recommended responses are summarized for each of these requests below. More detail is provided in [SC17-SA-IP-16 \(Report of the Billfish WG Workshop\)](#):

- 1) *Examine differences between ISC stock assessment catch estimates by CCM and WCPFC catch estimates, and work with the Scientific Services Provider to provide an assessment of the shortcomings.*

The BILLWG, which includes members from the Scientific Services Provider, SPC, discussed this question at a workshop in early 2021 in the context of a retrospective review of the quality of Japanese catch statistics ([Working Paper ISC/21/BILLWG-01/05](#)). The differences in catch estimates between the ISC stock assessment and the WCPFC occurs for longline fisheries that record the catch in numbers. These differences in catch estimates are due to the different methods used to convert numbers to biomass for the WCPFC catch estimates and for the stock assessment, whether it is SS or MFCL model. The WCPFC catch estimates conversion is based on the product of the number of fish caught and average weight of the individuals caught on a trip or within the reporting strata. The stock assessment estimates catch as product of the numbers caught, the fishery selectivity function, and the weight-at-age of individuals. When conducting a stock assessment, it is important to account for potential conversion error by using the catch in the original recorded units, which for longline fisheries is numbers. The BILLWG noted that in the early part of the longline catch time series prior to 2000, the WCPFC catch estimates did not include Japanese longline training vessel catches. The inclusion of these catches after 2000 resulted in similar trends and catches although small differences remain. Based on these observations, the BILLWG concluded that WCPFC Japanese longline fishery statistics and the output from SS are similar.

- 2) *Explain why the striped marlin stock decreased and the fishing mortality increased after a drastic decrease in fishing effort by high seas driftnet fisheries in the early 1990s.*

The BILLWG identified three potential contributing factors: (1) The model assumes that selectivity for Japanese driftnet catches in the 1975-1993 period is the same selectivity as in the Japanese coastal driftnet fishery from 1994 to 2017, although there are no size data available from 1975-1993. The coastal driftnet fishery targets large adult MLS, which means that the model is assuming the majority of the catch from 1975 to 1993 also is large adult fish. In 1994, the majority of the catch is from CCM longline fleets, which caught predominately juvenile MLS. This assumed shift from catching large adults to small juveniles would result in an increase in fishing mortality even if the overall catch decreased; (2) The CPUE time series has a break in 1993 to 1994, which could be driving a shift in the model results due to a lack of continuity; and (3) the Japanese logbook data also change their reporting requirements in 1993 to 1994, which could contribute to the shift in fishing mortality, however not all CCMs agreed that this would drive the change in fishing mortality.

The WG noted that excluding data prior to 1994 in the MLS assessment was explored in the 2019 assessment meeting. The WG compared two models that started in 1994. A sensitivity run fixing the initial equilibrium catch (run 22, MLS SAR, ISC19, Figure 3 a) showed no difference relative to the base-case model results. In contrast, estimating the initial equilibrium catch (Model 2 in the Carvalho, et al. 2019, Figure 3 b) resulted in the same trend but produced different estimates of initial population size. It was noted that SSB0 is strongly associated with the initial equilibrium catch. However, the WG did not have strong information to justify setting the initial catch (5,000mt). **Based on this discussion, the WG agreed to estimate the initial equilibrium catch in the stock assessment model, and agreed that differences due to starting year were likely driven by the uncertainty in catches before 1993.**

- 3) *Develop a roadmap to address the issues identified in the latest stock assessment by ISC.*

The BILLWG recommends revising its work plan to assess WCNPO MLS in 2022 and postpone the WCNPO SWO assessment to 2023 to address the concerns identified by the questions above and by the WG in its WCNPO MLS stock assessment report ([ISC/19/ANNEX/11](#)). For example, there were concerns about providing a rebuilding plan in 2021 and then reassessing the stock in 2022. However, the proposed revised workplan would permit updating of the rebuilding plan after the stock assessment in 2022.

D. SCIENTIFIC COMMITTEE RECOMMENDATIONS

5. The last benchmark stock assessment for North Pacific striped marlin was conducted in 2019 by the ISC ([SC15-SA-WP-09 Stock Assessment Report for Striped Marlin \(*Kajikia audax*\) in the Western and Central North Pacific Ocean through 2017](#)), and the results were presented and discussed at SC15 (Paragraphs 344 – 359 of the SC15 Summary Report). Next benchmark stock assessment for North Pacific striped marlin will be completed in 2022.

6. As the SC16 and SC17 virtual meeting did not cover issues related to the North Pacific striped marlin stock, the stock status and management advice from SC15 (**Attachment C**) should be maintained, which is briefly summarized below.

Stock Status and trends

7. SC15 noted the following stock status from ISC:

Biomass (age 1 and older) for the Western and Central North Pacific Ocean (WCNPO) striped marlin stock decreased from 17,000 mt in 1975 to 6,000 mt in 2017.

- Estimated fishing mortality averaged $F=0.97/\text{year}$ during the 1975-1994 period with a range of 0.60 to 1.59/year, peaked at $F=1.71/\text{year}$ in 2001, and declined sharply to $F=0.64/\text{year}$ in the most recent years (2015-2017).
- Fishing mortality has fluctuated around F_{MSY} since 2013.
- Compared to MSY-based reference points, the current spawning biomass (average for 2015- 2017) was 59% below SSB_{MSY} ($\text{SSB}_{2015-2017} = 0.41\text{SSB}_{\text{MSY}}$).
- The current fishing mortality (average for ages 3-12 in 2015-2017) was 7% above F_{MSY} ($F_{2015-2017} = 1.07F_{\text{MSY}}$).

Based on these findings, the following information on the status of the WCNPO striped marlin stock is provided:

- a) There are no established reference points for WCNPO striped marlin;
- b) Results from the base case assessment model show that under current conditions the WCNPO striped marlin stock is overfished and is subject to overfishing relative to MSY-based reference points.

Management advice and implications

8. SC15 noted that:

- some CCMs expressed concerns that the WCNPO striped marlin stock was overfished and overfishing was occurring relative to MSY-based reference points;
- fishing mortality has generally remained above F_{MSY} since the introduction of CMM 2010-01 and the stock biomass continues to remain well below SB_{MSY} and the NC target; and

- this stock does not have agreed upon limit reference points and measures on catch limits and reductions in fishing mortality to allow rebuilding of this stock.

9. SC15 recommends the WCPFC consider appropriate actions to ensure rebuilding this stock to the NC14 rebuilding target¹.

10. SC15 noted the following conservation advice from ISC:

Though the WCNPO striped marlin stock shows substantial depletion ($SSB_{2017} = 38\%SSB_{MSY}$), fishing mortality has fluctuated around F_{MSY} during 2013-2017, and produced around 2,100 mt per year since 2012 (about 40%MSY) catch amount. However, most of the catch are likely immature fish.

Based on findings from projection, ISC provided the following conservation information:

- Under the long-term recruitment scenario, the stock has at least a 60% probability of rebuilding to $20\%SSB_{F=0}$ by 2022 for all harvest scenarios, except for the highest F scenario ($F_{1975-1977}$);
- Under the short-term recruitment scenario (2012-2016), catches must be reduced to 1,359 mt to achieve a 60% probability of rebuilding to $20\%SSB_{F=0} = 3,610$ mt by 2022.
 - This corresponds to a reduction of roughly 37% from the recent average yield of 2,151 mt;
- Under the long-term recruitment scenario, all projections with the constant catch scenarios would achieve the spawning biomass target by 2020 with probabilities of 61% to 73%.
 - Corresponding catch quotas ranging from 3,397 to 1,359 mt.

¹ (Paragraph 70 of the NC14 Summary Report) NC14 agreed to request ISC to conduct projections examining rebuilding scenarios for North Pacific striped marlin that cover a range of i) rebuilding targets ($20\%SSB_{F=0}$, F_{MSY} , and 0% to 50% reductions in increments of 10% from current catch limits); ii) timelines (10, 15 and 20 years) and iii) probabilities of each scenario to reach each target within different timelines.

**The Commission for the Conservation and Management of
Highly Migratory Fish Stocks in the Western and Central Pacific Ocean
SEVENTH REGULAR SESSION**

Honolulu, Hawaii, USA
6-10 December 2010

**CONSERVATION AND MANAGEMENT MEASURE FOR
NORTH PACIFIC STRIPED MARLIN**

Conservation and Management Measure 2010-01

The Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean:

Noting with concern that the best available scientific advice from the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) on the status of North Pacific Striped Marlin shows that the stock is subject to fishing mortality above levels that are sustainable in the long term;

Further noting the advice from the ISC that fishing mortality on the stock should be reduced from the 2003 levels;

Also noting that the Pacific Islands Forum Fisheries Agency (FFA) Members will be adopting a system of zone-based longline limits to replace the current system of flag-based arrangements within their Exclusive Economic Zones (EEZs);

Acknowledging the advice from the Scientific Committee that the information provided by the ISC does not support classification of North Pacific Striped Marlin as a “northern stock” under Annex 1 of the WCPFC Rules of Procedure;

Adopts, in accordance with Article 10 of the WCPF Convention:

1. This Measure shall apply in high seas and EEZs within the convention area north of the equator.
2. For the purposes of this measure, vessels operated under charter, lease or other similar mechanisms as an integral part of the domestic fleet of a coastal State, shall be considered to be vessels of the host State or Territory. Such charter, lease or other similar mechanism shall be conducted in a manner so as not to charter known IUU vessels.
3. Nothing in this measure shall prejudice the legitimate rights and obligations of Small Island Developing State Members and participating territories in the Convention Area seeking to develop their own domestic fisheries.
4. The total catch of North Pacific Striped Marlin will be subject to a phased reduction such that by 1 January 2013 the catch is [80%] of the levels caught in 2000 to 2003.
5. Each flag/chartering CCM with vessels fishing in the convention area north of the equator shall be subject to the following catch limits for North Pacific Striped Marlin for the years 2011 and beyond:
 - a. 2011 [10%] reduction of the highest catch between 2000 and 2003;
 - b. 2012 [15%] reduction of the highest catch between 2000 and 2003;

- c. 2013 and beyond: [20%] reduction of the highest catch between 2000 and 2003;
- 6. Each flag/chartering CCM shall decide on the management measures required to ensure that its flagged/chartered vessels operate under the catch limits specified in paragraph 5, noting that previous examples of such measures have included effort reductions, gear modification and spatial management.
- 7. By 30 April 2011, each flag/chartering CCM shall report to the Commission verifiable information regarding its catch of North Pacific Striped Marlin by its flagged/chartered vessels north of the equator.
- 8. Each year CCMs shall report in their Part 2 annual reports their implementation of this measure, including the measures applied to flagged/chartered vessels to reduce their catch and the total catch taken against the limits established under paragraphs 5 and 7.
- 9. This measure shall be amended in 2011 based on the revised stock assessment for north Pacific striped marlin.

**The Commission for the Conservation and Management of
Highly Migratory Fish Stocks in the Western and Central Pacific Ocean
COMMISSION
SIXTEENTH REGULAR SESSION
Port Moresby, Papua New Guinea
5 – 11 December 2019**

INTERIM REBUILDING PLAN FOR NORTH PACIFIC STRIPED MARLIN

The Western and Central Pacific Fisheries Commission (WCPFC):

Recognizing that the latest stock assessment of North Pacific striped marlin, completed by the International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean (ISC) in 2019, indicated that current spawning stock biomass is depleted ($SSB_{2018}/SSB_0 = 0.05$) and the average fishing mortality rate in 2015-2017 was greater than the fishing mortality rate associated with MSY ($F/F_{MSY} = 1.07$);

Adopts in accordance with Article 10 of the WPCF Convention, the following rebuilding plan for North Pacific striped marlin:

Rebuilding Objective

The interim rebuilding target for North Pacific striped marlin is $20\%SSBF=0$, to be reached by 2034, with at least 60% probability. This rebuilding objective will be subject to further consideration and decision at WCPFC17, taking into account any additional scientific advice.

Rebuilding Strategy

Beginning in 2020, and based on the best scientific information available, members will develop measures to rebuild the stock in accordance with the rebuilding objective, with the aim of adopting revised conservation and management measures for North Pacific striped marlin at WCPFC17. Members should consider reduced catch limits and retention, release, and gear requirements, among other potential tools.

**The Commission for the Conservation and Management of
Highly Migratory Fish Stocks in the Western and Central Pacific Ocean
Scientific Committee
Fifteenth Regular Session
Pohnpei, Federated States of Micronesia
12 – 20 August 2019**

NORTH PACIFIC STRIPED MARLIN STOCK ASSESSMENT
(Refer to Paragraphs 344 – 359 of the SC15 Summary Report for the detailed discussions)

a. Stock Status and trends

1. SC15 noted that ISC provided the following conclusions on the stock status of Western and Central North Pacific striped marlin:

Estimates of population biomass of the Western and Central North Pacific Ocean (WCNPO) striped marlin fluctuated without trend between 1975 and 1993. The population decreased substantially in 1994 and fluctuated without trend until the present year. Population biomass (age-1 and older) averaged roughly 17,969 mt, or 54% below unfished biomass during the 1975-1993 period and declined to 4,508 mt, or 89% below unfished biomass by 2008. The minimum spawning stock biomass was estimated to be 618 t in 2011 (76% below SSB_{MSY} , the spawning stock biomass to produce MSY, Figure NMLS-1a). In 2017, $SSB = 981$ t and $SSB/SSB_{MSY} = 0.38$. Fishing mortality on the stock (average F on ages 3-12) has been around F_{MSY} since 2014 (Figure NMLS-1b). It averaged roughly 0.64 yr^{-1} during 2015-2017, or 7% above F_{MSY} and in 2017, $F=0.80 \text{ yr}^{-1}$ with a relative fishing mortality of $F/F_{MSY} = 1.33$ (Table NMLS-02). Fishing mortality has been above F_{MSY} in every year except 1984, 1992, and 2016. The predicted value of the spawning potential ratio (SPR, the predicted spawning output at current F as a fraction of unfished spawning output) is estimated to be $SPR_{2015-2017} = 17\%$ and is approximately equal to the SPR required to produce MSY. Recruitment averaged about 263,000 age-0 recruits between 1994 and 2017, which was 34% below the 1975-2017 average. No target or limit reference points have been established for the WCNPO striped marlin stock under the auspices of the WCPFC. Despite the relatively large L_{50}/L_{inf} ratio for WCNPO striped marlin, the stock is expected to be highly productive due to its rapid growth and high resilience to reductions in spawning potential. Recent recruitments have been lower than expected and have been below the long-term trend since 2005. Although fishing mortality has decreased since 2000, due to the prolonged low recruitment and landings of immature fish, the biomass of the stock has remained below MSY. When the status of WCNPO striped marlin is evaluated relative to MSY-based reference points, the 2017 spawning stock biomass of 981 mt is 62% below SSB_{MSY} (2,604 t) and the 2015-2017 fishing mortality exceeds F_{MSY} by 7%. Therefore, relative to MSY-based reference points, overfishing is occurring and the WCNPO striped marlin stock is overfished (Figure NMLS-02).

Biological reference points were computed for the base case model with Stock Synthesis (Table NMLS-01 and Table NMLS-02). The point estimate of maximum sustainable yield (MSY) was 4,946 t. The point estimate of the spawning biomass to produce MSY (adult female biomass, SSB_{MSY}) was 2,604 t. The point estimate of F_{MSY} , the fishing mortality rate to produce MSY (average fishing mortality on ages 3 – 12) was 0.60 and the corresponding equilibrium value of spawning potential ratio at MSY was $SPR_{MSY} = 18\%$.

Stock projections for WCNPO striped marlin were conducted using the age-structured projection model software AGEPRO. Stochastic projections were conducted using results from the base case model to evaluate the probable impacts of alternative fishing intensities or constant catch quotas on future spawning stock biomass and yield for striped marlin in the WCNPO. For fishing mortality projections, a standard set of F-based projections were conducted. For catch quota projections, the set of rebuilding projection analyses requested by NC14 were conducted. Two future recruitment scenarios were evaluated (Figure 3 and Figure 4): (1) a short-term recruitment scenario based on resampling the empirical cumulative distribution function of recruitment observed during 2012-2016 and (2) a long-term recruitment scenario based on resampling the empirical cumulative distribution function of recruitment observed during 1975- 2016. The short-term recruitment scenario had an average recruitment of 134,020 age-0 fish and the long-term recruitment mean was 306,989 age-0 fish. The stochastic projections employed model estimates of the multi-fleet, multi-season, size- and age-selectivity, and structural complexity in the assessment model to produce consistent results. Fishing mortality-based projections started in 2018 and continued through 2037 under five levels of fishing mortality and the two recruitment scenarios. The five fishing mortality stock projection scenarios were: 1) F status quo (average F during 2015-2017), 2) F_{MSY} , 3) F at $0.2 \cdot SSB_0$, 4) F_{High} at the highest 3-year average during 1975-2017, and 5) F_{Low} at $F_{30\%}$. For the F-based scenarios, fishing mortality in 2018-2019 was set to be F status quo (0.64) and fishing mortality during 2020-2037 was set to the projected level of F. Catch-based projections also ran from 2018 to 2037 and included seven levels of constant catch for the long-term recruitment scenario and 10 levels of catch for the short-term recruitment scenario. For the catch-based scenarios, catch biomass in 2018-2019 was set to be the status quo catch during 2015-2017 (2,151 t) and annual catches during 2020-2037 were set to the projected catch quota. The ten constant catch stock projection scenarios were: 1) Quota based upon WCPFC CMM10-01, 2) 90% of the quota, 3) 80% of the quota, 4) 70% of the quota, 5) 60% of the quota, 6) 50% of the quota, 7) 40% of the quota, 8) 30% of the quota, 9) 20% of the quota, and 10) 10% of the quota. Results show the projected female spawning stock biomasses and the catch biomasses under each of the scenarios (Table NMLS-03, Figure NMLS-03 and Figure NMLS-04).

2. SC15 noted the following stock status from ISC:

Biomass (age 1 and older) for the WCNPO striped marlin stock decreased from 17,000 t in 1975 to 6,000 t in 2017. Estimated fishing mortality averaged $F=0.97 \text{ yr}^{-1}$ during the 1975-1994 period with a range of 0.60 to 1.59 yr^{-1} , peaked at $F=1.71 \text{ year}^{-1}$ in 2001, and declined sharply to $F=0.64 \text{ yr}^{-1}$ in the most recent years (2015-2017). Fishing mortality has fluctuated around F_{MSY} since 2013. Compared to MSY-based reference points, the current spawning biomass (average for 2015- 2017) was 59% below SSB_{MSY} and the current fishing mortality (average for ages 3 – 12 in 2015-2017) was 7% above F_{MSY} .

Based on these findings, the following information on the status of the WCNPO striped marlin stock is provided:

- a) **There are no established reference points for WCNPO striped marlin;**
- b) **Results from the base case assessment model show that under current conditions the WCNPO striped marlin stock is overfished and is subject to overfishing relative to MSY-based reference points (Table NMLS-01, Table NMLS-02, and Figure NMLS-01).**

3. SC15 noted that the assessment results are sensitive to the growth assumption and the ISC billfish working group (hereafter, WG) chair noted that the WG will attempt to revise the growth curve at the next stock assessment.

4. SC15 also highlighted the sharp decline in the stock biomass in the mid-1990s and recommends that ISC further investigate the reasons for this decline.

b. Management advice and implications

5. SC15 noted that some CCMs expressed concerns that based on the new assessment the WCNPO striped marlin stock was overfished and overfishing was occurring relative to MSY-based reference points.

6. SC15 noted that while fishing mortality has declined since 2000 fishing mortality has generally remained above F_{MSY} since the introduction of CMM 2010-01 and the stock biomass continues to remain well below SB_{MSY} and the NC target, while noting that the assessment model overestimate biomass in the terminal years. This is despite the phased reduction of the total catch to 80% of the levels caught in 2000-2003 as prescribed in the CMM. SC15 recommends that WCPFC16 note that further reduction in catch will be required to rebuild the stock to MSY levels and the NC target.

7. SC15 also noted that this stock does not have agreed upon limit reference points and measures on catch limits and reductions in fishing mortality to allow rebuilding of this stock.

8. SC15 recommends that WCPFC16 consider identifying appropriate limit reference points for WCNPO striped marlin.

9. SC15 recommends the WCPFC consider appropriate actions to ensure rebuilding this stock to the NC14 rebuilding target. SC15 noted that if lower than average recruitments persist over the near future the probability of rebuilding the stock would be low, noting that there has been a long-term decline in recruitment since the 1990s. Under the F_{MSY} scenario with short-term recruitment assumptions, the probability of achieving 20% SB_0 in 2027 is <0.5%.

10. SC15 noted the following conservation advice from ISC:

The status of the WCNPO striped marlin stock shows evidence of substantial depletion of spawning potential (SSB₂₀₁₇ is 62% below SSB_{MSY}), however fishing mortality has fluctuated around F_{MSY} in the last four years. The WCNPO striped marlin stock has produced average annual yields of around 2,100 t per year since 2012, or about 40% of the MSY catch amount. However, the majority of the catch are likely immature fish. All of the projections show an increasing trend in spawning stock biomass during the 2018-2020 period, with the exception of the high F scenario under the short-term recruitment scenario. This increasing trend in SSB is due to the 2017 year class, which is estimated from the stock-recruitment curve and is more than twice as large as recent average recruitment.

Based on these findings, the following conservation information is provided:

- a) Projection results under the long-term recruitment scenario show that the stock has at least a 60% probability of rebuilding to 20% SSB_0 , the rebuilding target specified by NC14, by 2022 for all harvest scenarios, with the exception of the highest F scenario (Average F 1975-1977);
- b) However, if the stock continues to experience recruitment consistent with the short-term recruitment scenario (2012-2016), catches must be reduced to 60% of the WCPFC catch quota from CMM 2010-01 (3,397 t) to 1,359 t in order to achieve a 60% probability of rebuilding to 20% SSB_0 =3,610 t by 2022. This corresponds to a reduction of roughly 37% from the recent average yield of 2,151 t;

- c) For the constant catch projection scenarios that were tested, it was notable that all of the projections under the long-term recruitment scenario would be expected to achieve the spawning biomass target by 2020 with probabilities ranging from 61% to 73% and corresponding catch quotas ranging from 3,397 to 1,359 t (Table NMLS-03).**

It was also noted that retrospective analyses show that the assessment model appears to overestimate spawning potential in recent years, which may mean the projection results are ecologically optimistic.

Special Comments

The WG achieved a base-case model using the best available data and biological information. However, the WG recognized uncertainty in some assessment inputs including drift gillnet catches and initial catch amounts, life history parameters such as maturation and growth, and stock structure.

Overall, the base case model diagnostics and sensitivity runs show that there are some conflicts in the data (ISC/19/ANNEX/11). When developing a conservation and management measure to rebuild the resource, it is recommended that these issues be recognized and carefully considered, because they affect the perceived stock status and the probabilities and time frame for rebuilding of the WCNPO striped marlin stock.

Research Needs

To improve the stock assessment, the WG recommends continuing model development work, to reduce data conflicts and modeling uncertainties, and reevaluating and improving input assessment data.

Existing genetic studies suggest regional spawning subgroups of striped marlin throughout the entire Pacific. More research is needed to improve upon knowledge of regional stock structure and regional mixing for incorporation into the stock assessment.

Table NMLS-01. Reported catch (t) used in the stock assessment along with annual estimates of population biomass (age-1 and older, t), female spawning biomass (t), relative female spawning biomass (SSB/SSB_{MSY}), recruitment (thousands of age-0 fish), fishing mortality (average F, ages-3 – 12), relative fishing mortality (F/F_{MSY}), and spawning potential ratio of WCNPO striped marlin.

Year	2011	2012	2013	2014	2015	2016	2017 ²	Mean ¹	Min ¹	Max ¹
Reported Catch	2,690	2,757	2,534	1,879	2,072	1,892	2,487	5,643	1,879	10,862
Population Biomass	5,874	6,057	4,937	6,241	5,745	5,832	6,196	12,153	4,509	22,303
Spawning Biomass	618	809	743	864	1,073	1,185	981	1,765	618	3,999
Relative Spawning Biomass	0.24	0.31	0.29	0.33	0.41	0.46	0.38	0.68	0.24	1.54
Recruitment (age 0)	196,590	87,956	330,550	77,274	185,438	195,069	354,391	396,218	77,274	1,049,460
Fishing Mortality	1.11	1.06	0.86	0.63	0.62	0.51	0.80	1.06	0.51	1.71
Relative Fishing Mortality	1.85	1.76	1.42	1.05	1.03	0.85	1.33	1.76	0.85	2.85
Spawning Potential Ratio	9%	11%	11%	16%	17%	20%	14%	12%	20%	6%

¹ During 1975-2017

² Recruitment in 2017 is estimated from the stock recruitment curve.

Table NMLS-02. Estimates of biological reference points along with estimates of fishing mortality (F), spawning stock biomass (SSB), recent average yield (C), and spawning potential ratio (SPR) of WCNPO MLS, derived from the base case model assessment model, where “MSY” indicates reference points based on maximum sustainable yield.

Reference Point	Estimate
F_{MSY} (age 3-12)	0.60
F_{2017} (age 3-12)	0.80
$F_{20\%SSB(F=0)}$	0.47
SSB_{MSY}	2,604 t
SSB_{2017}	981 t
$20\%SSB_0$	3,610 t
MSY	4,946 t
$C_{2015-2017}$	2,151 t
SPR_{MSY}	18%
SPR_{2017}	14%
$SPR_{20\%SSB(F=0)}$	23%

Table NMLS-03. Projected median values of WCNPO striped marlin spawning stock biomass (SSB, t), catch (t), and probability of reaching 20%SSB₀ under five constant fishing mortality rate (F) and ten constant catch scenarios during 2018-2037. For scenarios which have a 60% probability of reaching the target of 20%SSB_{F=0}, the year in which this occurs is provided; NA indicates projections that did not meet this criterion. Note that 20%SSB_{F=0} is 3,610 t and SSB_{MSY} is 2,604 t.

Year	2018	2019	2020	2021	2022	2027	2037	Year when target achieved with 60% probability
<u>Scenario 1: F_{status quo}; Long-Term Recruitment</u>								
SSB	1931.3	2605.3	3591	4288.3	4639.4	4893.4	4884.4	
Catch	2229.8	3089.8	3911.6	4412.8	4644.9	4797.2	4790.9	
Probability of reaching 20% SSB	0%	4%	44%	70%	79%	84%	84%	2021
<u>Scenario 2: F_{status quo}; Short-Term Recruitment</u>								
SSB	1932.4	2556.5	3080	2786.9	2422.3	2071.4	2072.1	
Catch	2224.6	2827	2871.7	2535.9	2260.7	2029.6	2030.4	
Probability of reaching 20% SSB	0%	4%	21%	9%	2%	<0.5%	<0.5%	NA
<u>Scenario 3: F_{MSY}; Long-Term Recruitment</u>								
SSB	1935.1	2611.8	3650.5	4444	4860.6	5158.9	5203.5	
Catch	2228.1	3092.7	3705.2	4241.6	4498.9	4666.4	4711.5	
Probability of reaching 20% SSB	0%	4%	47%	75%	83%	89%	89%	2021
<u>Scenario 4: F_{MSY}; Short-Term Recruitment</u>								
SSB	1932.9	2557.7	3126.3	2895.5	2552.2	2207	2197	
Catch	2230.8	2829.6	2724.6	2450.7	2209.9	1994.1	1984.9	
Probability of reaching 20% SSB	0%	4%	23%	12%	4%	<0.5%	<0.5%	NA
<u>Scenario 5: F 20%SSB_{F=0}; Long-Term Recruitment</u>								
SSB	1933.7	2611.9	3813.4	4943.7	5631	6358.1	6348.5	
Catch	2227.6	3091.3	2996.4	3588.7	3933.2	4271.7	4266.7	
Probability of reaching 20% SSB	0%	4%	55%	85%	93%	97%	98%	2021
<u>Scenario 6: F 20%SSB_{F=0}; Short-Term Recruitment</u>								
SSB	1934	2560.5	3276.3	3274.8	3030.2	2697	2690.2	
Catch	2224.9	2828.8	2211.6	2115.4	1969.7	1809.1	1804.7	
Probability of reaching 20% SSB	0%	4%	29%	28%	17%	6%	7%	NA
<u>Scenario 7: Highest F (Average F 1975-1977); Long-Term Recruitment</u>								
SSB	1932.8	2611.8	2739.8	2299.1	2102	2028.4	2036.2	
Catch	2226.4	3088.5	7520.7	6557.5	6184.4	6058	6084.1	

Table NMLS-03. (Continued)

Year	2018	2019	2020	2021	2022	2027	2037	Year when target achieved with 60% probability
Probability of reaching 20% SSB	0%	4%	9%	4%	2%	1%	1%	NA
<u>Scenario 8: Highest F (Average F 1975-1977); Short-Term Recruitment</u>								
SSB	1933.5	2559.4	2289.2	1330.7	968.3	858.7	859.2	
Catch	2225.9	2827.6	5362.9	3399.3	2751.6	2564.6	2570.9	
Probability of reaching 20% SSB	0%	3%	2%	<0.5%	0%	0%	0%	NA
<u>Scenario 9: Low F (F_{30%}); Long-Term Recruitment</u>								
SSB	1933.6	2612.5	4009.5	5603.2	6742.4	8287.5	8353	
Catch	2228.6	3093.5	2117.6	2693.6	3075	3558.2	3577.8	
Probability of reaching 20% SSB	0%	4%	63%	93%	98%	>99.5%	>99.5%	2020
<u>Scenario 10: Low F (F_{30%}); Short-Term Recruitment</u>								
SSB	1932.5	2555.6	3453.8	3788.4	3747.4	3537.4	3525.3	
Catch	2228.4	2832	1572.9	1623.8	1589	1515.8	1511.6	
Probability of reaching 20% SSB	0%	4%	37%	54%	54%	44%	42%	NA
<u>Scenario 11: Current Quota; Long-Term Recruitment</u>								
SSB	1946.7	2823	4141.1	5220.9	6074.7	8147.5	8715.3	
Catch	2150.6	2150.6	3396.8	3396.7	3396.3	3396.1	3396.8	
Probability of reaching 20% SSB	<0.5%	17%	61%	76%	83%	93%	95%	2020
<u>Scenario 12: Current Quota; Short-Term Recruitment</u>								
SSB	1948.8	2737.1	3279.8	2592.9	1781.9	524.2	436.7	
Catch	2150.6	2150.6	3393.7	3377.1	3319.7	2954.7	2903	
Probability of reaching 20% SSB	<0.5%	15%	36%	20%	7%	<0.5%	<0.5%	NA
<u>Scenario 13: 10% Reduction; Long-Term Recruitment</u>								
SSB	1947.9	2826.1	4225.3	5467.3	6492.5	9096.5	9798.7	
Catch	2150.6	2150.6	3057.1	3057.1	3056.8	3057.1	3057.1	
Probability of reaching 20% SSB	<0.5%	17%	63%	81%	87%	96%	97%	2020
<u>Scenario 14: 10% Reduction; Short-Term Recruitment</u>								
SSB	1948.6	2738	3390.9	2886.8	2162.9	763	587	
Catch	2150.6	2150.6	3054.6	3052.8	3032.5	2846.7	2780.1	
Probability of reaching 20% SSB	<0.5%	15%	40%	26%	12%	<0.5%	<0.5%	NA
<u>Scenario 15: 20% Reduction; Long-Term Recruitment</u>								
SSB	1949.9	2829.1	4317.7	5750.4	6954.1	9928.4	10806.2	
Catch	2150.6	2150.6	2717.4	2717.4	2717.4	2717.4	2717.4	
Probability of reaching 20% SSB	<0.5%	18%	65%	84%	90%	98%	99%	2020
<u>Scenario 16: 20% Reduction; Short-Term Recruitment</u>								
SSB	1949.3	2739.2	3495.1	3176.4	2570.8	1175.5	883.3	
Catch	2150.6	2150.6	2716.8	2714.3	2710.8	2648.8	2610.7	
Probability of reaching 20% SSB	<0.5%	15%	43%	34%	19%	1%	<0.5%	NA

Table NMLS-03. (Continued)

Year	2018	2019	2020	2021	2022	2027	2037	Year when target achieved with 60% probability
<u>Scenario 17: 30% Reduction: Long-Term Recruitment</u>								
SSB	1947.6	2824.5	4381.5	5981.7	7356.2	10856.1	11783.5	
Catch	2150.6	2150.6	2377.8	2377.8	2377.8	2377.8	2377.8	
Probability of reaching 20% SSB	<0.5%	17%	67%	87%	94%	99%	>99.5%	2020
<u>Scenario 18: 30% Reduction: Short-Term Recruitment</u>								
SSB	1947.4	2733.8	3594	3479.2	3018.1	1736.6	1383.5	
Catch	2150.6	2150.6	2377.8	2377.1	2377.1	2365.6	2355.3	
Probability of reaching 20% SSB	<0.5%	15%	45%	42%	29%	5%	2%	NA
<u>Scenario 19: 40% Reduction: Long-Term Recruitment</u>								
SSB	1949.2	2831.8	4486.8	6295.8	7868.9	11749.2	12851.3	
Catch	2150.6	2150.6	2038.1	2038.1	2038.1	2038.1	2038.1	
Probability of reaching 20% SSB	<0.5%	18%	70%	90%	95%	>99.5%	>99.5%	2020
<u>Scenario 20: 40% Reduction: Short-Term Recruitment</u>								
SSB	1949.9	2737.3	3689.5	3756	3445.9	2444.2	2124.2	
Catch	2150.6	2150.6	2038.1	2038.1	2037.9	2037.6	2036.4	
Probability of reaching 20% SSB	<0.5%	15%	48%	49%	41%	16%	10%	NA
<u>Scenario 21: 50% Reduction: Long-Term Recruitment</u>								
SSB	1950.4	2829.7	4548.9	6512.1	8259.1	12654	13799.3	
Catch	2150.6	2150.6	1698.4	1698.4	1698.4	1698.4	1698.4	
Probability of reaching 20% SSB	<0.5%	17%	71%	92%	97%	>99.5%	>99.5%	2020
<u>Scenario 22: 50% Reduction: Short-Term Recruitment</u>								
SSB	1949.1	2737.4	3791.4	4065.7	3916.3	3214.4	3021.3	
Catch	2150.6	2150.6	1698.4	1698.4	1698.4	1698.4	1698.4	
Probability of reaching 20% SSB	<0.5%	15%	51%	57%	53%	35%	29%	NA
<u>Scenario 23: 60% Reduction: Long-Term Recruitment</u>								
SSB	1949.9	2829.1	4631.3	6798.1	8741.1	13605.2	14857.1	
Catch	2150.6	2150.6	1358.7	1358.7	1358.7	1358.7	1358.7	
Probability of reaching 20% SSB	<0.5%	18%	73%	94%	98%	>99.5%	>99.5%	2020
<u>Scenario 24: 60% Reduction: Short-Term Recruitment</u>								
SSB	1948.6	2737.7	3888.1	4364.3	4396.6	4110.1	3970.5	
Catch	2150.6	2150.6	1358.7	1358.7	1358.7	1358.7	1358.7	
Probability of reaching 20% SSB	<0.5%	15%	53%	65%	67%	63%	59%	2021*
<u>Scenario 25: 70% Reduction: Short-Term Recruitment</u>								
SSB	1948.7	2736.4	3979.8	4667.7	4886	4960.9	4977	
Catch	2150.6	2150.6	1019	1019	1019	1019	1019	
Probability of reaching 20% SSB	<0.5%	15%	56%	72%	78%	85%	86%	2021

Table NMLS-03. (Continued)

Year	2018	2019	2020	2021	2022	2027	2037	Year when target achieved with 60% probability
Scenario 26: 80% Reduction: Short-Term Recruitment								
SSB	1948.7	2736.2	4071.1	4971.3	5380.3	5909.1	5977.5	
Catch	2150.6	2150.6	679.4	679.4	679.4	679.4	679.4	
Probability of reaching 20% SSB	<0.5%	15%	58%	79%	88%	97%	97%	2021
Scenario 27: 90% Reduction: Short-Term Recruitment								
SSB	1950.6	2740.5	4170.3	5284.1	5881.7	6836.7	7009.4	
Catch	2150.6	2150.6	339.7	339.7	339.7	339.7	339.7	
Probability of reaching 20% SSB	<0.5%	15%	61%	85%	94%	>99.5%	>99.5%	2020

* This scenario has a 60% probability of being at or above 20%SSB_{F=0} in 2020 but drops slightly below 60% starting in 2035.

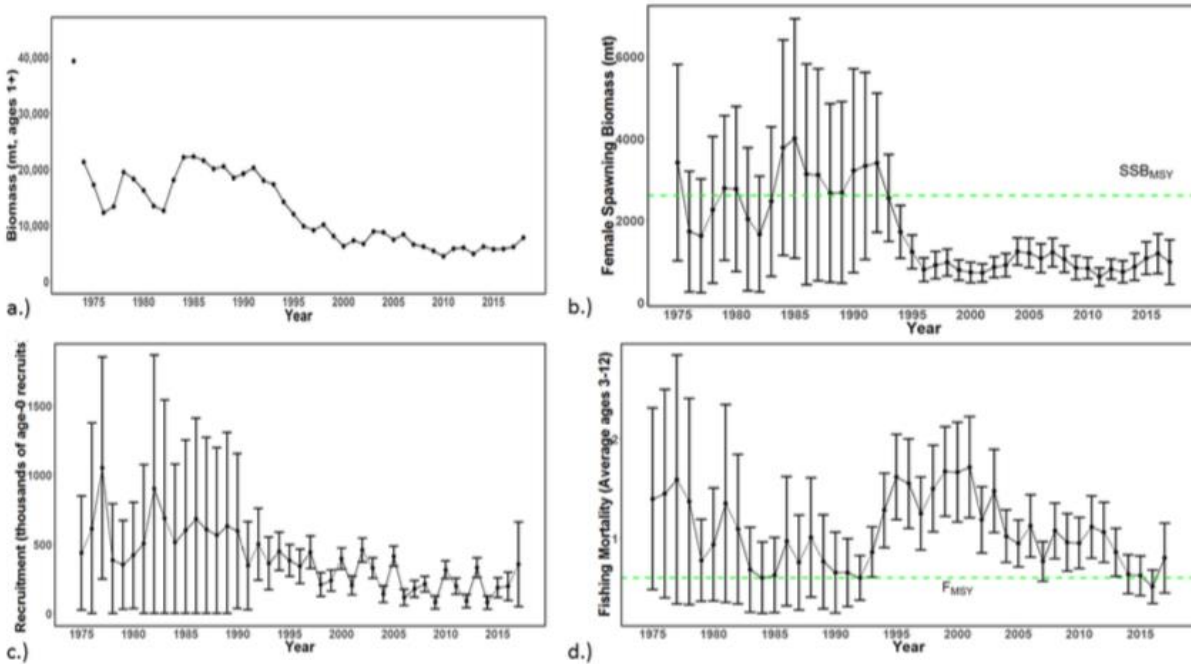


Figure NMLS-01. Time series of estimates of (a) population biomass (age 1+), (b) spawning biomass, (c) recruitment (age-0 fish), and (d) instantaneous fishing mortality (average for age 3-12, year⁻¹) for WCNPO striped marlin (derived from the 2019 stock assessment). The circles represent the maximum likelihood estimates by year for each quantity and the error bars represent the uncertainty of the estimates (95% confidence intervals), green dashed lines indicate SSB_{MSY} and F_{MSY}.

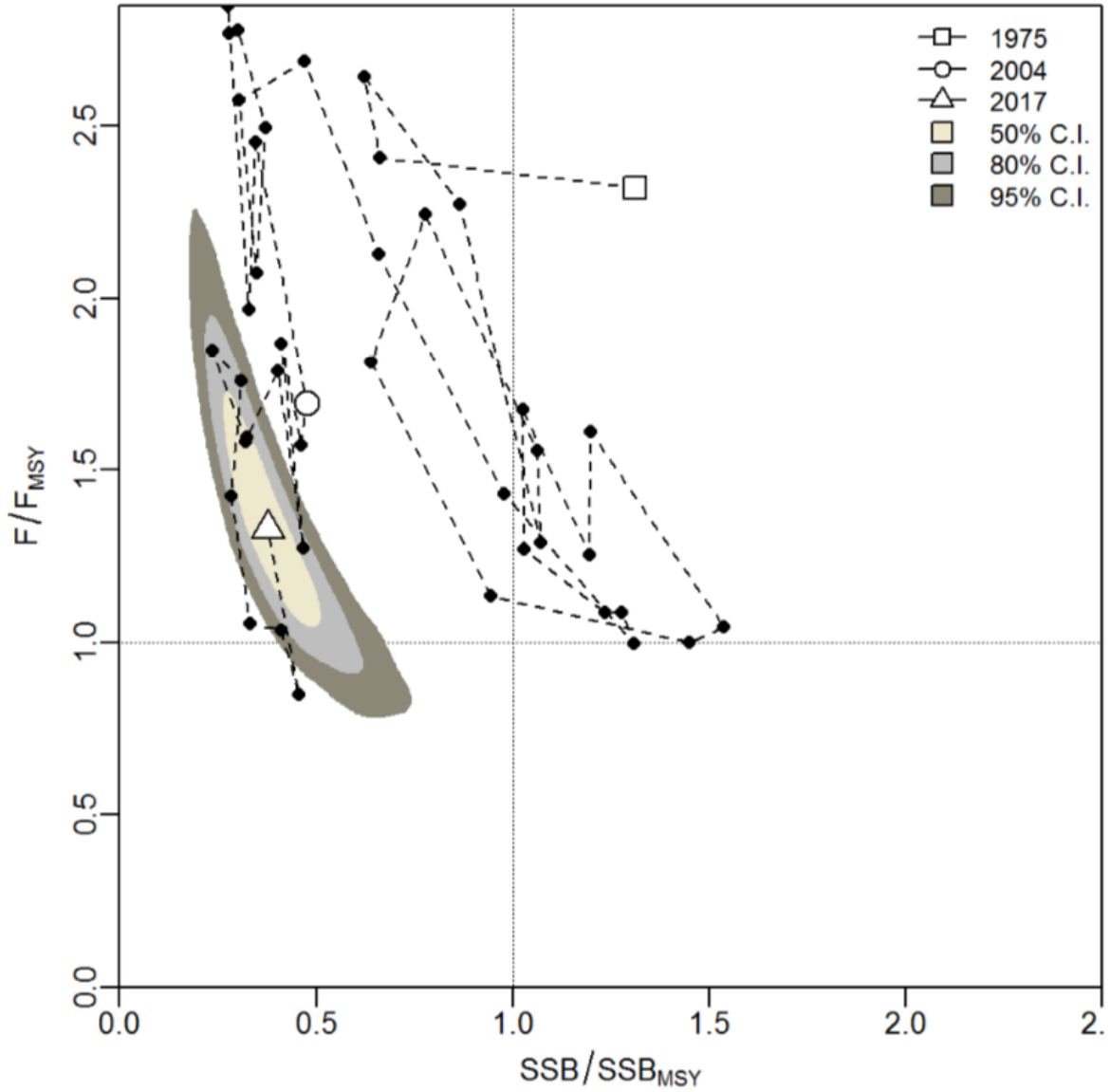
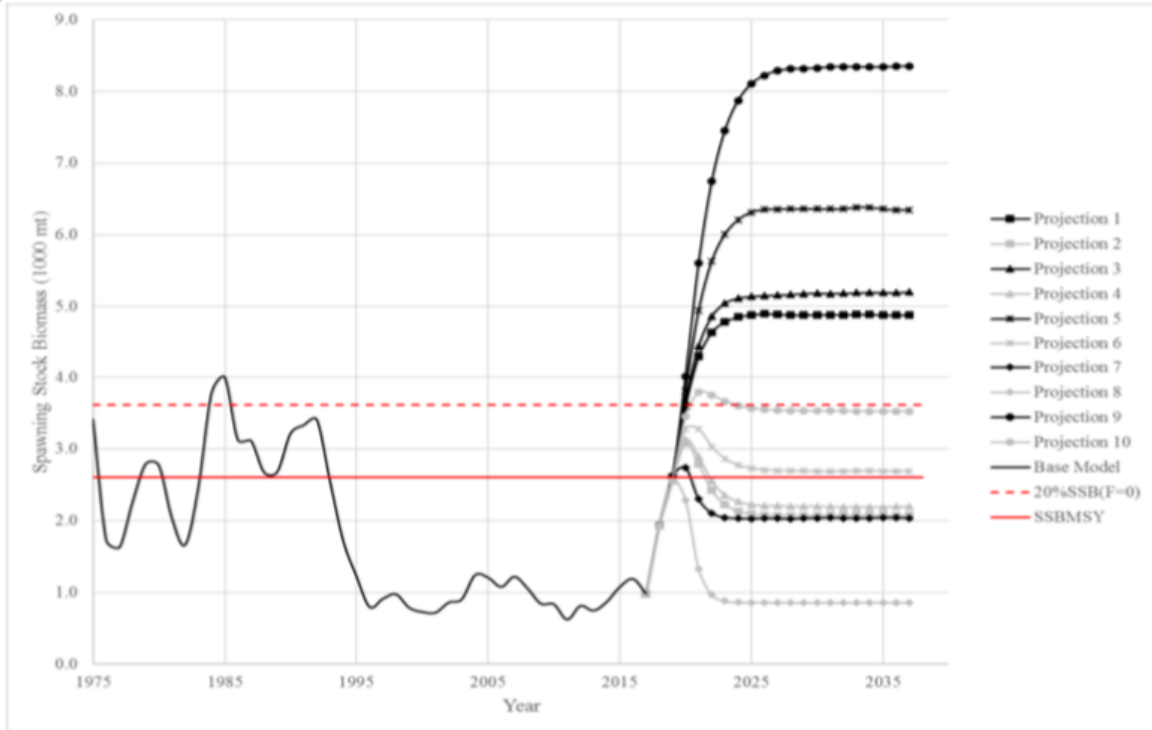


Figure NMLS-02. Kobe plot of the time series of estimates of relative fishing mortality (average of age 3-12) and relative spawning stock biomass of WCNPO striped marlin during 1975-2017. The white square denotes the first year (1975) of the assessment, the white circle denotes 2004, and the white triangle denotes the last year (2017) of the assessment.

a.)



b.)

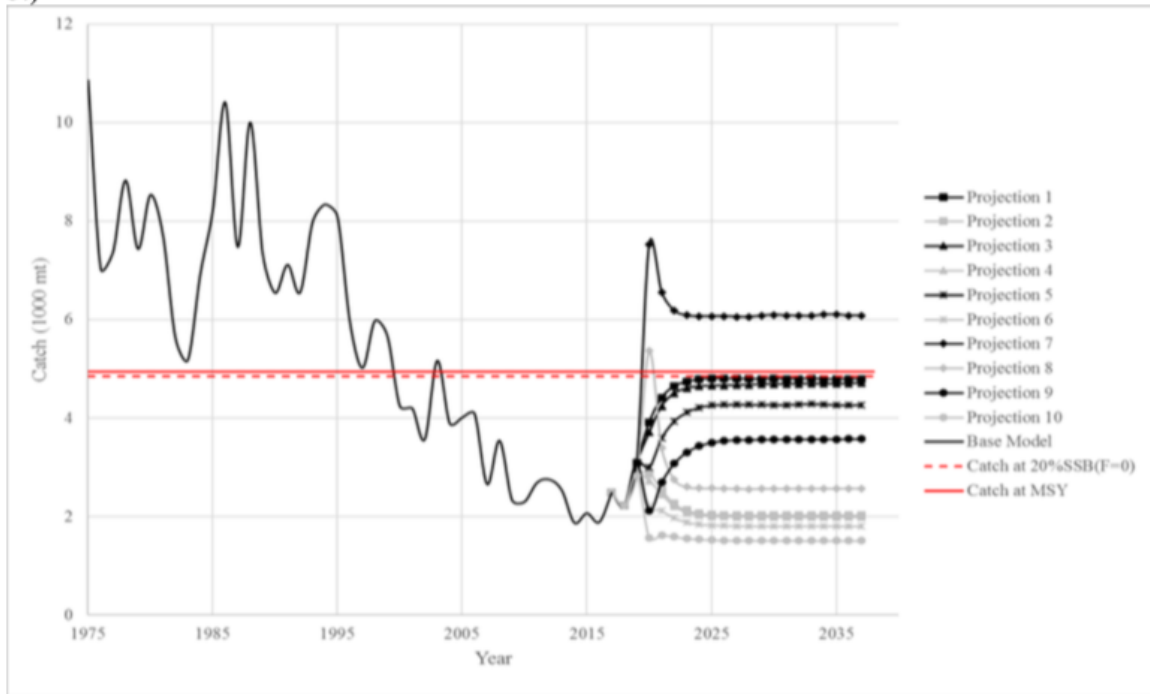


Figure NMLS-03. Historical and projected trajectories of spawning biomass and total catch from the WCNPO striped marlin base case model based upon F scenarios (projection 1-10): (a) projected spawning biomass and (b) projected catch.

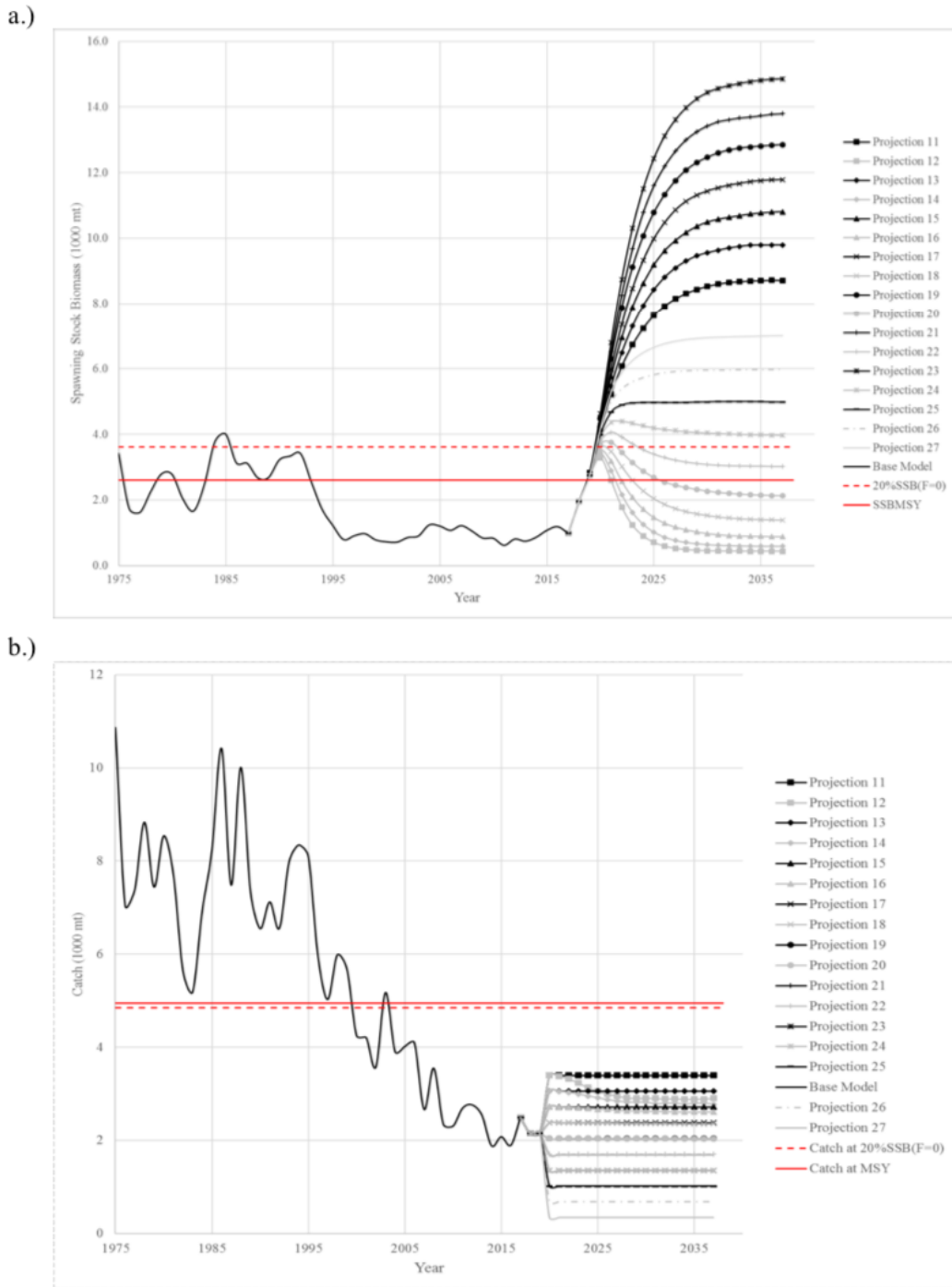


Figure NMLS-04. Historical and projected trajectories of spawning biomass and total catch from the WCNPO striped marlin base case model based upon constant catch scenarios (projections 11-15): (a) projected spawning biomass; and (b) projected catch.

Note on Figure NMLS-3 and Figure NMLS-4: Black lines are the long-term recruitment scenario results; grey lines show the short-term recruitment scenario results. The red dashed line shows the catch or spawning stock biomass at 20%SSB_{F=0} and the solid red line is the catch or spawning stock biomass at SSB_{MSY}. The list of projection scenarios can be found in Table NMLS-03.