**COMMISSION**
**SEVENTEENTH REGULAR SESSION**
Electronic Meeting
8 – 15 December 2020

# REFERENCE DOCUMENT FOR THE REVIEW OF CMM 2010-01 (NORTH PACIFIC STRIPED MARLIN)

**WCPFC17-2020-19**
**25 November 2020**

**Paper prepared by the Secretariat**

## A. INTRODUCTION

1. The purpose of this paper is to provide a quick reference guide to the decision points of the Commission, recommendations of the Scientific Committee (SC) and the Northern Committee (NC) of relevance to the discussions on the North Pacific striped marlin stock. It includes issues from WCPFC16, SC15 recommendations, and NC15 requests to ISC and ISC20's responses to them.

## B. COMMISSION ISSUES AND DECISION POINTS

2. Highlights from WCPFC16 related to the North Pacific striped marlin stock status, management issues and decision points are extracted below from the WCPFC16 Summary Report, with their paragraph numbers:

> 20. FFA members highlighted their concerns on the status of certain stocks, with North Pacific striped marlin being the most critical, noting that management of these stocks must be a priority.
>
> 88. The United States introduced *Rebuilding Plan for North Pacific Striped Marlin* (WCPFC16-2019-DP12), the primary objective of which is to rebuild the stock to a specific level in a specific time, including a specific probability for achieving the objective.
>
> 435. The NC Chair stated that NC15 had discussed a consultative proposal for a rebuilding plan and requested that ISC provide advice on which future recruitment scenario might be the most likely over the near term. NC15 also requested the ISC to 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.
>
> 436 – 452. After lengthy discussions on the proposed rebuilding plan by the United States (Paragraphs 436 – 450, WCPFC16 Summary Report), the Chair noted the support among CCMs for a 2034 timeframe to reach the target, subject to further consideration in 2020, and the Commission adopted the *Interim Rebuilding Plan for North Pacific Striped Marlin*, which is in **Attachment A**.

## C. SCIENTIFIC COMMITTEE RECOMMENDATIONS

3. The last benchmark stock assessment for North Pacific striped marlin was conducted in 2019 by the ISC (SC15-SA-WP-09[1]), and the results were presented and discussed at SC15 (Paragraphs 344 – 359 of the SC15 Summary Report). As the SC16 virtual meeting did not cover issues related to North Pacific striped marlin, the stock status and management advice from SC15 (**Attachment B**) should be maintained, which is briefly summarized below.

### *a. Stock Status and trends*

4. 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/year during the 1975-1994 period with a range of 0.60 to 1.59/year, peaked at F=1.71/year in 2001, and declined sharply to F=0.64/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 $SSB_{MSY}$ ($SSB_{2015\text{-}2017} = 0.41SSB_{MSY}$).
- The current fishing mortality (average for ages 3-12 in 2015-2017) was 7% above $F_{MSY}$ ($F_{2015\text{-}2017} = 1.07F_{MSY}$).

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.

### *b. Management advice and implications*

5. 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.

6. SC15 recommends that WCPFC consider appropriate actions to ensure rebuilding this stock to the NC14 rebuilding target[2]. 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.

[1] https://www.wcpfc.int/node/42926

[2] (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.

7. 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:

a) 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 ($F_{1975\text{-}1977}$);
b) 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;
c) 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.

## D. NORTHERN COMMITTEE RECOMMENDATIONS

8. NC15 requested that the ISC Billfish Working Group (BILLWG) provide advice on which future recruitment scenario is the most likely one over the near term. NC15 also requested the BILLWG to 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. (Paragraph 48, NC15 Summary Report)

## E. PROVISION OF 2020 SCIENTIFIC INFORMATION FROM THE ISC

9. Through the ISC20 Plenary Report[3], ISC provided responses to the two questions in Paragraph 8 above as follows:

    1) The request to identify the most plausible recruitment scenario arose because the ISC's conservation information based on the 2019 striped marlin stock assessment identified different stock responses depending on the recruitment scenario used. The BILLWG reviewed the two recruitment scenarios and noted that there is a linearly decreasing trend in estimated recruitment with time (Figure 1). The BILLWG also noted that if the long-term recruitment scenario is used for future stock projections, then the observed long-term recruitment time series requires the assumption that there is no time trend. Based on this assessment, the BILLWG recommended that the short-term recruitment scenario was the most appropriate model to use for conducting stochastic stock projections for Western and Central North Pacific striped marlin.

[3] https://www.wcpfc.int/node/46858

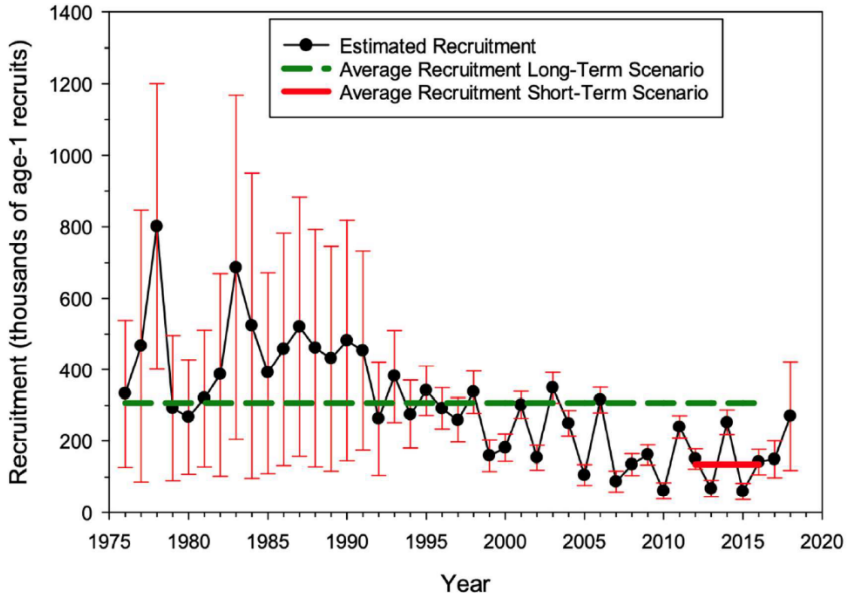



**Figure 1**. Estimated WCNPO MLS recruitment (black), average recruitment long-term scenario (green) and average short-term scenario (red) evaluated by the BILLWG in response to an NC15 request for advice on which scenario is more plausible.

2) Responding to the second request by NC15, the BILLWG noted that it is difficult to determine an explanation for the increase in fishing mortality on MLS when high seas driftnet effort decreased. A variety of factors could have affected the fishing mortality of MLS directly, but they are difficult to identify due to various uncertainties of the stock assessment model, at this time. The WG will attempt to address this issue in the next stock assessment.

**Attachment A**
(Attachment L, WCPFC16 Summary Report)

**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 $20\%SSB_{F=0}$, 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.

---

**Attachment B**
(Paragraphs 350 – 359, SC15 Summary Report)

**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 deceased 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 $yr^{-1}$ with a relative fishing mortality of $F/F_{MSY} = 1.33$ (Table NMLS-02). Fishing mortality has been above FMSY 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 $SPR_{2015\text{-}2017} = 17\%$ 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 L50/Linf 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 $yr^{-1}$ during the 1975-1994 period with a range of 0.60 to 1.59 $yr^{-1}$, peaked at F=1.71 $year^{-1}$ in 2001, and declined sharply to F=0.64 $yr^{-1}$ 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 SSBMSY), 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 |
| $C_{2015\text{-}2017}$ | 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 |
|---|---|---|---|---|---|---|---|---|
| **Scenario 1: $F_{status\ quo}$; Long-Term Recruitment** | | | | | | | | |
| 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 |
| **Scenario 2: $F_{status\ quo}$; Short-Term Recruitment** | | | | | | | | |
| 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 |
| **Scenario 3: FMSY; Long-Term Recruitment** | | | | | | | | |
| 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 |
| **Scenario 4: FMSY; Short-Term Recruitment** | | | | | | | | |
| 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 |
| **Scenario 5: F $20\%SSB_{F=0}$; Long-Term Recruitment** | | | | | | | | |
| 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 |
| **Scenario 6: F $20\%SSB_{F=0}$; Short-Term Recruitment** | | | | | | | | |
| 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 |
| **Scenario 7: Highest F (Average F 1975-1977); Long-Term Recruitment** | | | | | | | | |
| 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 |
| **Scenario 8: Highest F (Average F 1975-1977); Short-Term Recruitment** | | | | | | | | |
| 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 |
| **Scenario 9: Low F ($F_{30\%}$); Long-Term Recruitment** | | | | | | | | |
| 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 |
| **Scenario 10: Low F ($F_{30\%}$); Short-Term Recruitment** | | | | | | | | |
| 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 |
| **Scenario 11: Current Quota; Long-Term Recruitment** | | | | | | | | |
| 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 |
| **Scenario 12: Current Quota; Short-Term Recruitment** | | | | | | | | |
| 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 |
| **Scenario 13: 10% Reduction; Long-Term Recruitment** | | | | | | | | |
| 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 |
| **Scenario 14: 10% Reduction; Short-Term Recruitment** | | | | | | | | |
| 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 |
| **Scenario 15: 20% Reduction; Long-Term Recruitment** | | | | | | | | |
| 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 |
| **Scenario 16: 20% Reduction; Short-Term Recruitment** | | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|---|
| **Scenario 17: 30% Reduction; Long-Term Recruitment** | | | | | | | | |
| 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 |
| **Scenario 18: 30% Reduction; Short-Term Recruitment** | | | | | | | | |
| 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 |
| **Scenario 19: 40% Reduction; Long-Term Recruitment** | | | | | | | | |
| 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 |
| **Scenario 20: 40% Reduction; Short-Term Recruitment** | | | | | | | | |
| 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 |
| **Scenario 21: 50% Reduction; Long-Term Recruitment** | | | | | | | | |
| 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 |
| **Scenario 22: 50% Reduction; Short-Term Recruitment** | | | | | | | | |
| 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 |
| **Scenario 23: 60% Reduction; Long-Term Recruitment** | | | | | | | | |
| 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 |
| **Scenario 24: 60% Reduction; Short-Term Recruitment** | | | | | | | | |
| 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* |
| **Scenario 25: 70% Reduction; Short-Term Recruitment** | | | | | | | | |
| 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.

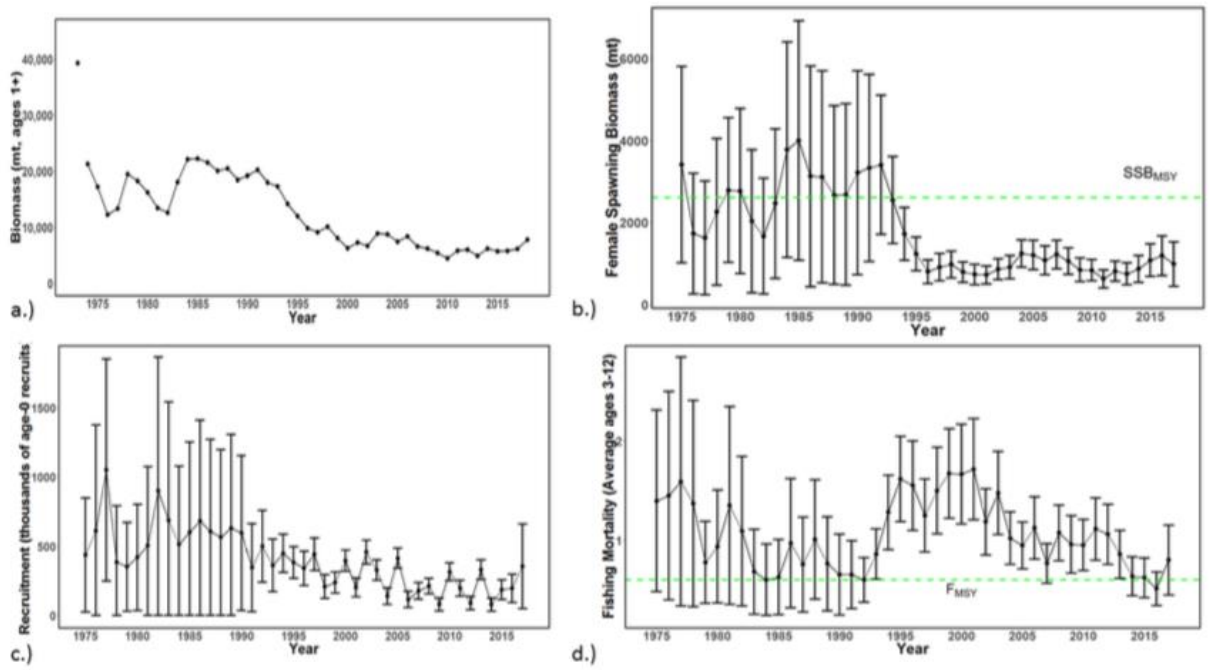



**Figure NMLS-01.** Time series of estimates of (a) population biomass (age 1+), (b) spawning biomass, (c) recruitment (age-0 fish), and (d) instantaneous fishing mortality (average for age 3-12, $year^{-1}$) for WCNPO striped marlin (derived from the 2019 stock assessment. The circles represent the 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 $F_{MSY}$.

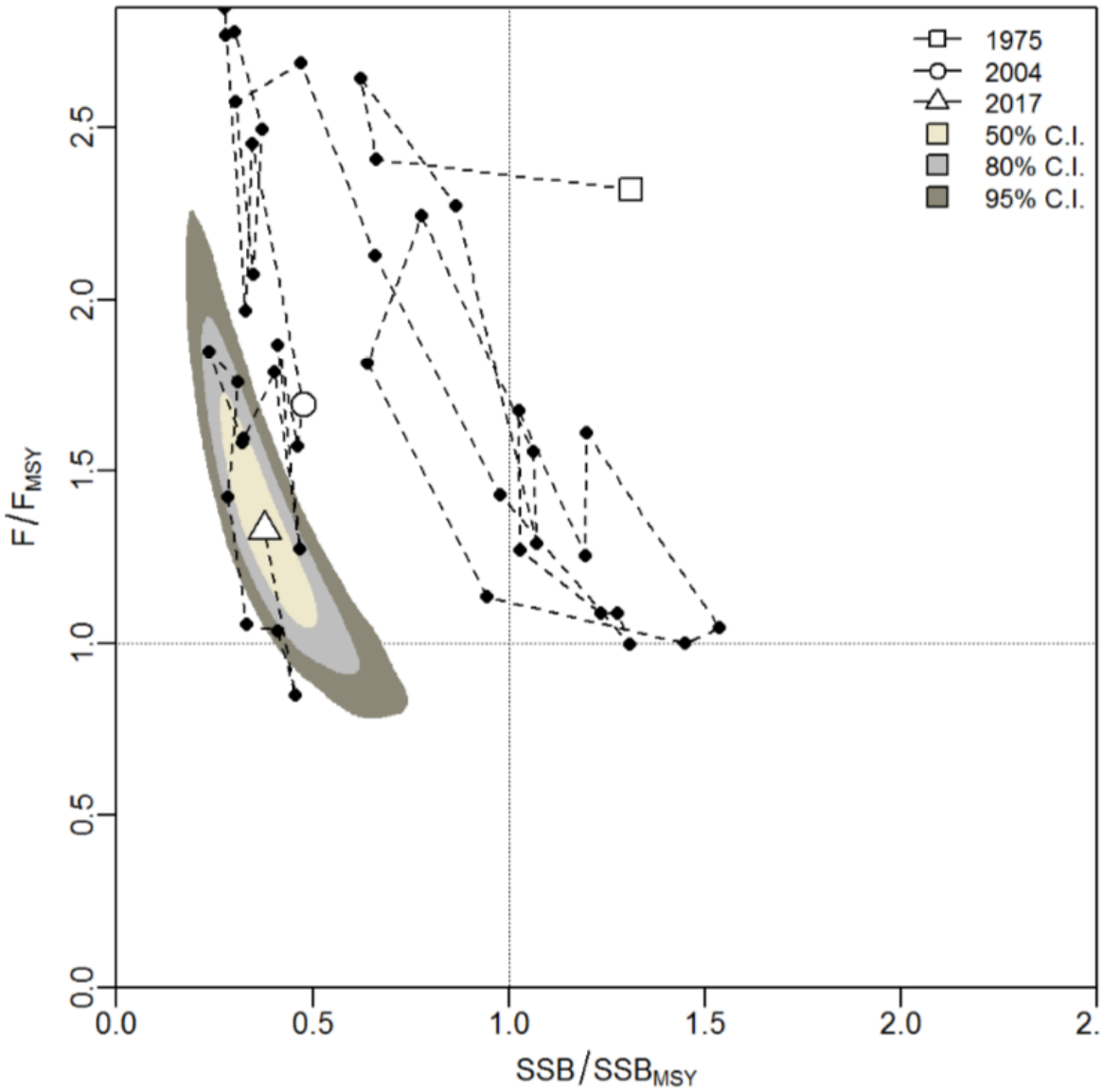



**Figure NMLS-02.** Kobe plot of the time series of estimates of relative fishing mortality (average of age 3-12) and relative spawning stock biomass of WCNPO striped marlin during 1975-2017. The white square denotes the first year (1975) of the assessment, the white circle denotes 2004, and the white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

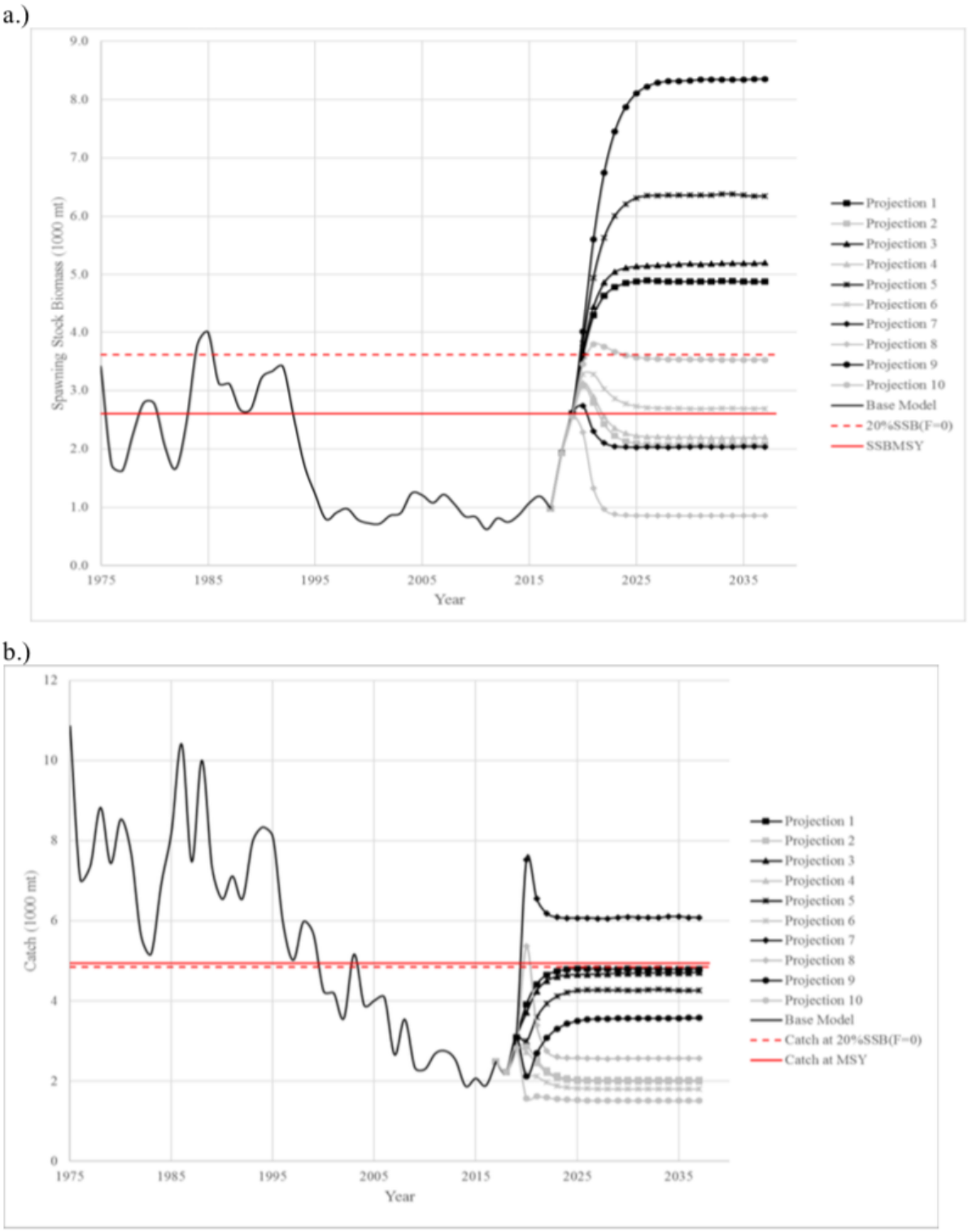
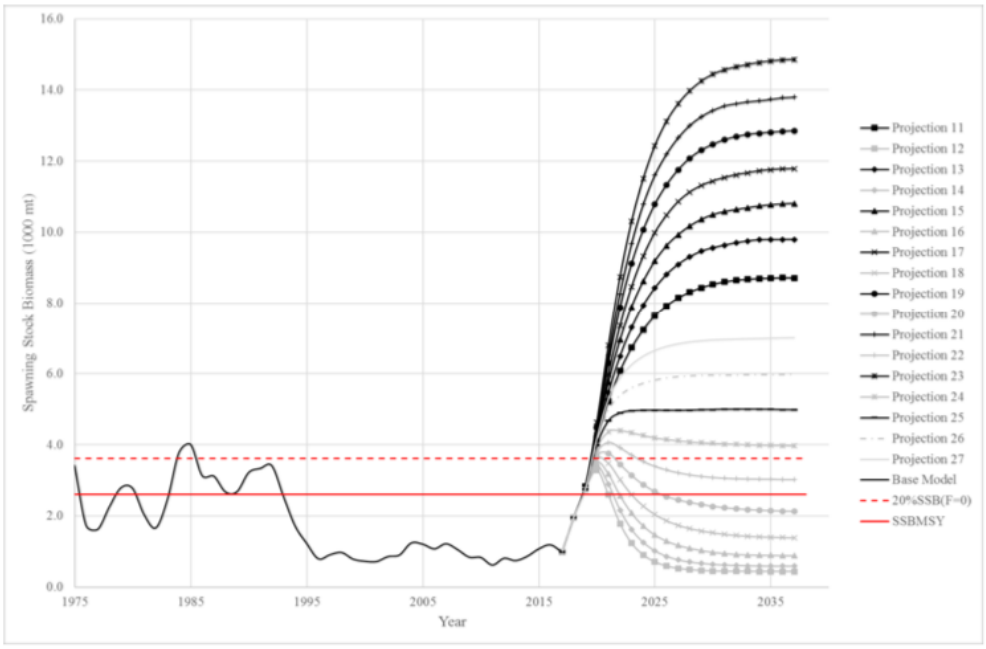



**Figure NMLS-03.** Historical and projected trajectories of spawning biomass and total catch from the WCNPO striped marlin base case model based upon F scenarios (projection 1-10): (a) projected spawning biomass and (b) projected catch.

a.)




b.)


**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.