COMMISSION
SIXTEENTH REGULAR SESSION
Port Moresby, Papua New Guinea
5 - 11 December 2019

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

WCPFC16-2019-24
15 November 2019

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 Scientific Committee (SC), the Northern Committee (NC) and the Technical and Compliance Committee (TCC) of relevance to the discussions on North Pacific striped marlin stock. It includes a brief summary of stock status and management advice, where detailed results of the 2019 stock assessment are in **Attachment 1**. The annexed information from NC15 at Portland meeting were extracted from the DRAFT NC15 Summary Report (https://www.wcpfc.int/node/43895), which is expected to be formalized and adopted by NC15 at its Special Session on 4 December 2019.

B. SCIENTIFIC COMMITTEE RECOMMENDATIONS

Stock status and management advice (Paragraphs 102 – 111, SC15 Outcomes Document)

a. Stock Status and trends

2. 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 t in 1975 to 6,000 t 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 76% 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:
>
> 1. There are no established reference points for WCNPO striped marlin;
> 2. 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.

3. SC15 noted that the assessment results are sensitive to the growth assumption and the ISC Billfish Working Group 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 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.

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

7. 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 persists 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%.

8. SC15 noted the following conservation advice from ISC:

> The status of the WCNPO striped marlin stock shows evidence of substantial depletion of spawning potential (SSB_{2017} 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:
> 1. 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);
> 2. 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[4] by 2022. This corresponds to a reduction of roughly 37% from the recent average yield of 2,151 t;
> 3. 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.

C. NORTHERN COMMITTEE RECOMMENDATIONS

(Paragraph 48, DRAFT NC15 Summary Report)

9. NC15 requested that the ISC provide advice on which future recruitment scenario is the most likely one 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.

D. TECHNICAL AND COMPLIANCE COMMITTEE RECOMMENDATIONS

10. TCC15 noted that there are presently nine quantitative limits where there are limited or no additional data presently available to WCPFC to verify the CCM's report on their implementation against the limit. [CMM 2005-03 02 (NP albacore), CMM 2006-04 01 (SW Striped Marlin), CMM 2009-03 01, 02 (Swordfish), CMM 2010-01 05 (NP striped marlin), CMM 2017-01 45, 47, 48 (Tropical tuna vessel limits), CMM 2017-01 51, CMM 2017-08 (Pacific Bluefin)]. TCC15 recommended that the Commission consider whether additional reporting or revised formulations of quantitative limits should be considered so that WCPFC has more ready access to data that can be used to verify a CCM's implementation of a quantitative limit. *(TCC15 draft summary report, para 125)*

Attachment 1

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
(Paragraphs 102 – 111, SC15 Outcomes Document)

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 $SPR_{2015-2017} = 17\%$ 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 76% 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:

11. There are no established reference points for WCNPO striped marlin;
12. 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 persists 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 (SSB_{2017} 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:
> 1. 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);
> 2. 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[4] by 2022. This corresponds to a reduction of roughly 37% from the recent average yield of 2,151 t;

3. 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.

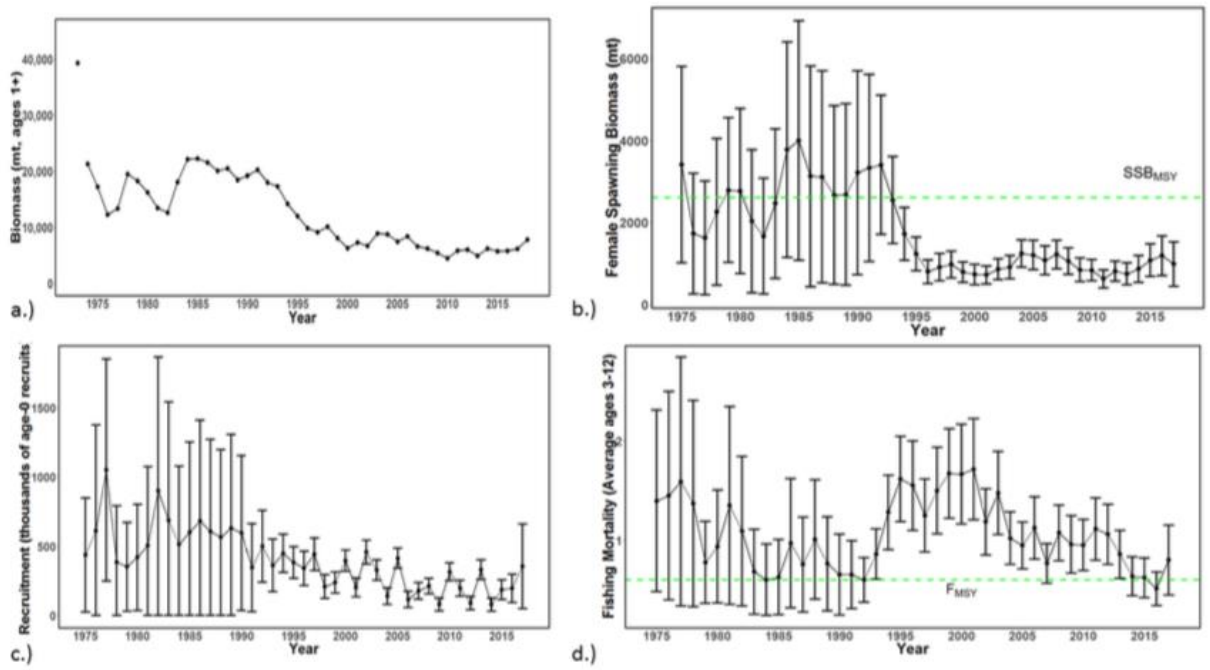

Figure NMLS-01. Time series of estimates of (a) population biomass (age 1+), (b) spawning biomass, (c) recruitment (age-0 fish), and (d) instantaneous fishing mortality (average for age 3-12, $year^{-1}$) for WCNPO striped marlin (derived from the 2019 stock assessment. The circles represent the maximum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

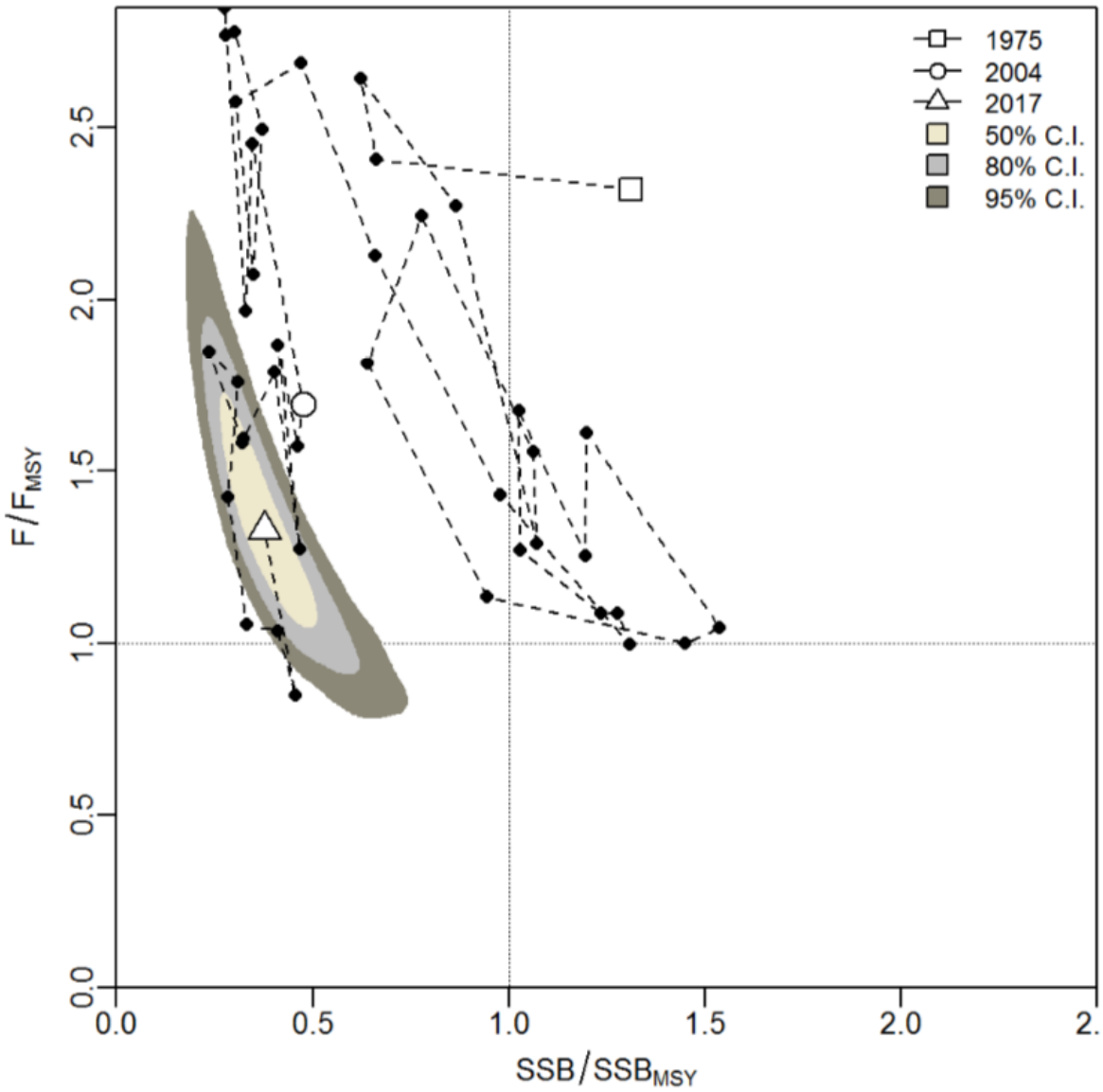

Figure NMLS-02. Kobe plot of the time series of estimates of relative fishing mortality (average of age 3-12) and relative spawning stock biomass of WCNPO striped marlin during 1975-2017. The white square denotes the first year (1975) of the assessment, the white circle denotes 2004, and the white triangle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

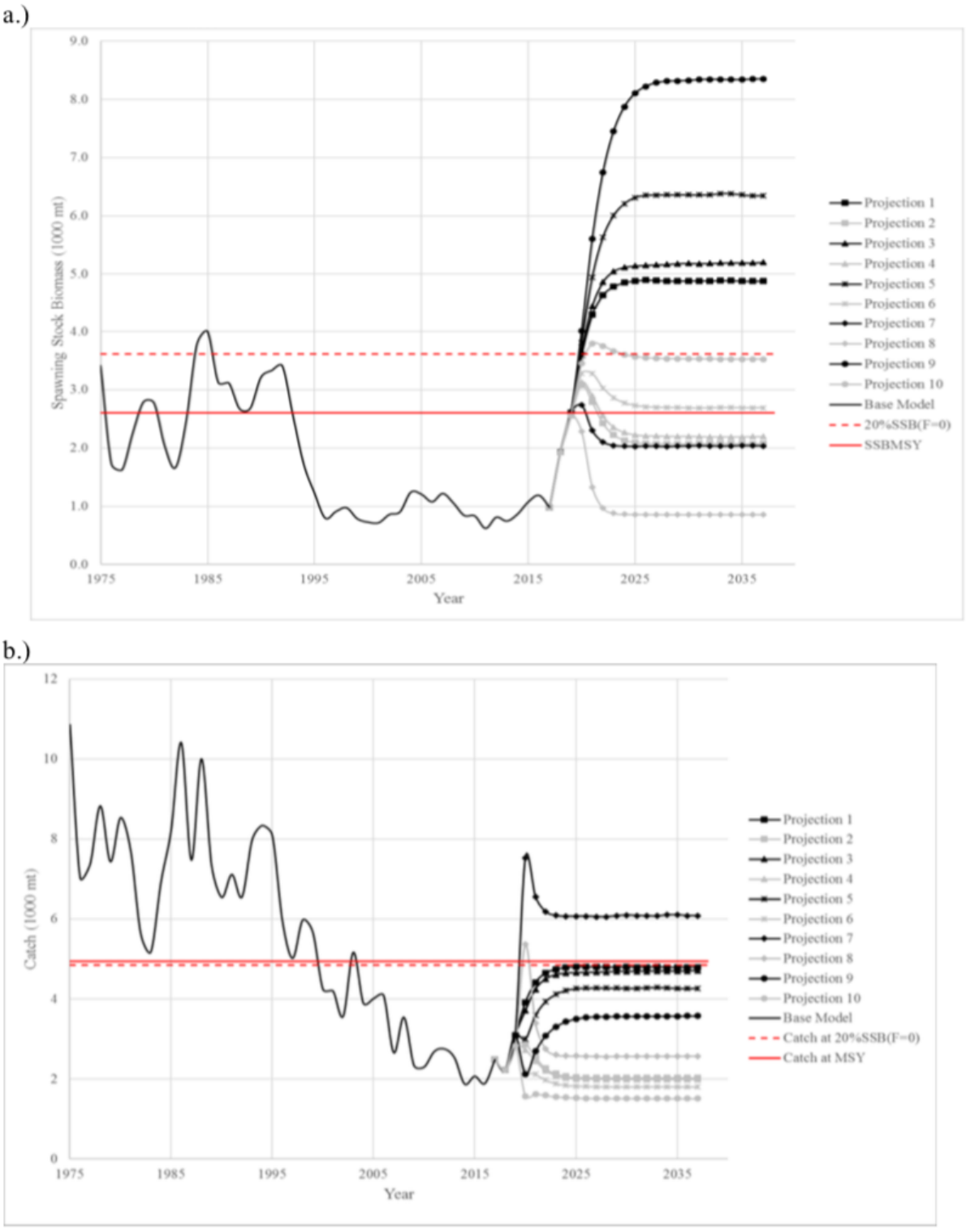

Figure NMLS-03. Historical and projected trajectories of spawning biomass and total catch from the WCNPO striped marlin base case model based upon F scenarios (projection 1-10): (a) projected spawning biomass and (b) projected catch.

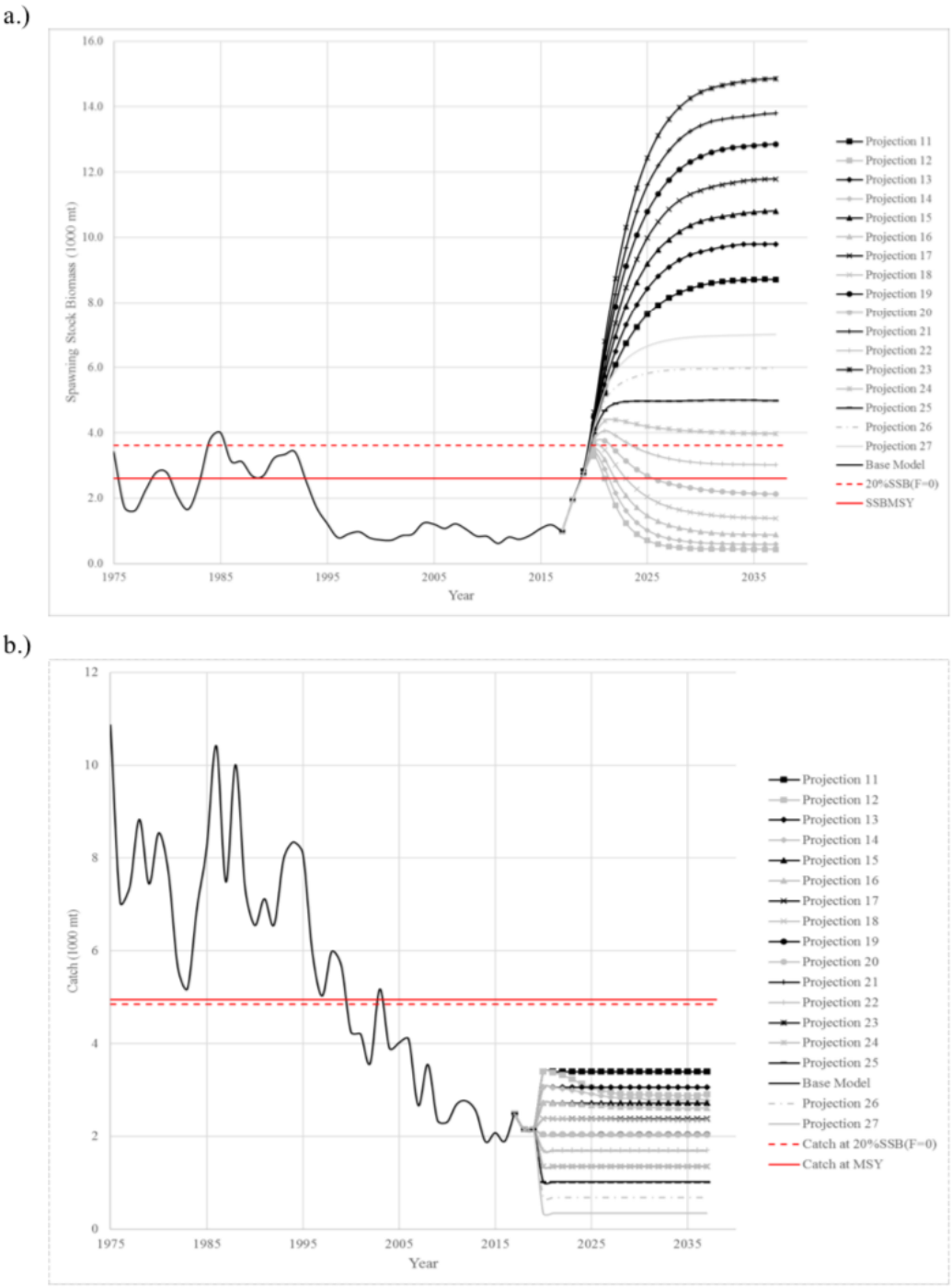

Figure NMLS-04. Historical and projected trajectories of spawning biomass and total catch from the WCNPO striped marlin base case model based upon constant catch scenarios (projections 11-15): (a) projected spawning biomass; and (b) projected catch.

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.