Update to the 2019 Western and Central North Pacific Ocean Striped Marlin Stock Assessment

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Abstract

An error was found in the 2019 western and central North Pacific Ocean (WCNPO) striped marlin (*Kajikia audax*) stock assessment catch data. The US Hawaii longline catch from years 2010–2017 included the entire North Pacific rather than just the western and central North Pacific area west of 150°W that was assessed. This document provides the results of the 2019 North Pacific striped marlin stock assessment with the corrected US Hawaii longline catch and a comparison with the original 2019 striped marlin assessment.

Changes to the 2019 striped marlin assessment

The 2019 WCNPO striped marlin assessment base-case model was only altered to adjust the US longline catch from 2010 to 2017, as detailed in WP XX. US longline catch was reduced by 13%, which accounts for about 2.5% of the total striped marlin catch. Differences between the 2019 assessment base-case and the 2021 assessment base-case catch time series are minimal (Figure 1). All other model settings, input data, and parameters remained unchanged, for details see the ISC Billfish Working Group stock assessment report. (ISC 2019).

Results and Discussion

A comparison between the original 2019 WCNPO striped marlin stock assessment and the 2021 corrected assessment indicates that reducing the US catch in 2010–2017 has minimal impacts on the stock assessment results. Spawning biomass is reduced slightly in 1975–1993 in the 2021 model (エラー！ 参照元が見つかりません。) and virgin spawning stock biomass is slightly lower in the 2021 model, although all estimates are well within the 95% confidence intervals.

Similarly, estimates of fishing mortality are slightly lower in the 1975–1993 time period (エラー！ 参照元が見つかりません。) but again well within the 95% confidence interval. Estimated recruitment is unchanged in the 2021 model (Figure 4). Fits to the CPUE indices are also unchanged in the 2021 model (Figure 5 through Figure 11). Comparing the stock status for the two models indicates that after 1976, the stock status for both models are almost the same (Figure 12). Notably, stock status in the final year of the model, 2017 is F/F_{MSY} = 1.33 and SSB/SSB_{MSY} = 0.34 for the 2021 model and F/F_{MSY} = 1.37 and SSB/SSB_{MSY} = 0.33 for the 2019 model. Both models indicate that the stock is likely overfished and that overfishing is likely to be occurring. The correction to the US Hawaii Longline catch in 2010 to 2017 has very little impact on the results of the base-case model for the 2019 WCNPO striped marlin assessment. It is recommended that the Executive Summary of the Stock Assessment Report be revised to say the following, noting that the projections text, tables, and figures would need to be updated to reflect the new base-case model, but the stock status and conservation advice would remain unchanged:

EXECUTIVE SUMMARY: WESTERN AND CENTRAL NORTH PACIFIC OCEAN STRIPED MARLIN STOCK ASSESSMENT

Stock Identification and Distribution

The western and central North Pacific Ocean (WCNPO) striped marlin (*Kajikia audax*) stock area consisted of waters of the North Pacific Ocean contained in the Western and Central Pacific Fisheries Commission management area bounded by the equator and 150°W. All available fishery data from this area were used for the stock assessment. For the purpose of modeling observations of CPUE and size composition data, it was assumed that there was an instantaneous mixing of fish throughout the stock area on a quarterly basis.

Catches

North Pacific striped marlin catches were high from the 1970s to the 1990s and has decreased to the present. The catch by Japanese fleets has decreased and catch from the US and Chinese Taipei has varied without trend, while the catch by other Western and Central Pacific Fisheries Commission (WCPFC) countries has increased (Figure S1). Overall, longline gear has accounted for the vast majority of western and central North Pacific striped marlin catches since the 1990s and the driftnet catch dominated from 1975 to 1993.

Data and Assessment

Catch and size composition data were collected from ISC countries (Japan, Chinese Taipei, and USA) and the WCPFC. Standardized catch-per-unit-effort data used to measure trends in relative abundance were provided by Japan, USA, and Chinese Taipei. The western and central North Pacific striped marlin stock was assessed using an age- and length-structured assessment Stock Synthesis model fit to time series of standardized CPUE and size composition data. The value for stock-recruitment steepness used for the base case model was $h = 0.87$. The assessment model was fit to relative abundance indices and size composition data in a likelihood-based statistical framework. Maximum likelihood estimates of model parameters, derived outputs, and their variances were used to characterize stock status and to develop stock projections. Several sensitivity analyses were conducted to evaluate the effects of changes in model parameters, including the natural mortality rate, the stock-recruitment steepness, the growth curve parameters, and the female age at 50% maturity, as well as uncertainty in the input data and model structure.

Status of Stock

Estimates of population biomass of the WCNPO striped marlin stock (*Kajikia audax*) 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 15,301 t, or 60% below unfished biomass during 1975–1993 and declined to 4,414 t, or 89% below unfished biomass in 2010. The minimum spawning stock biomass is estimated to be 577 t in 2011 (77% below SSB_{MSY}, the spawning stock biomass to produce MSY, Figure S2a). In 2017, SSB = 849 mt and SSB/SSB_{MSY} = 0.34. Fishing mortality on the stock (average F on ages 3–12) is currently around F_{MSY} (Figure S2b). It averaged roughly F = 0.69 during 2015–2017, or 13% above F_{MSY} and in 2017, F = 0.88 with a relative fishing mortality of F/F_{MSY} = 1.37. 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 currently SPR2015–2017 = 16% and is slightly below to the SPR required to produce MSY. Recruitment averaged about 254,000 age 0 recruits during 1994–2016, which was 36% below the 1975–2016 average. No target or limit reference points have been established for the WCNPO striped marlin stock under the auspices of the WCPFC. Despite the relative 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 juvenile fish, the biomass of the stock has remained below MSY. When the status of striped marlin is evaluated relative to MSY-based reference points, the 2017 spawning stock biomass of 849 mt is 67% below SSBMSY (2,534 t) and the 2015–2017 fishing mortality exceeds FMSY by 13%. Therefore, relative to MSY-based reference points, overfishing is occurring and the WCNPO striped marlin stock is overfished (Figure S3).

Table S 1. Reported catch (mt) used in the stock assessment along with annual estimates of population biomass (ages 1 and older, mt), female spawning biomass (mt), relative female spawning biomass (SSB/SSB_{MSY}), recruitment (thousands of age 0 fish), fishing mortality (average F, ages 3–12), relative fishing mortality (F/FMSY), and spawning potential ratio of western and central North Pacific striped marlin.

Year	2011	2012	2013	2014	2015	2016	2017	Mean[1]	Min[1]	Max[1]
Reported Catch	2,665	2,739	2,458	1,811	1,990	1,833	2,414	5,643	1,810	10,827
Population Biomass	5,518	5,861	4,693	5,847	5,426	5,428	5,492	12,216	4,414	22,316
Spawning Biomass	578	738	694	806	991	1,091	849	1,776	577	4,030
Relative Spawning Biomass	0.23	0.29	0.27	0.32	0.39	0.43	0.34	0.70	0.23	1.59
Recruitment (Age-0)	212,543	77,236	307,442	80,046	167,544	160,365	286,215	394,377	77,236	1,021,310
Fishing Mortality	1.17	1.15	0.89	0.65	0.66	0.53	0.88	1.06	0.53	1.72
Relative Fishing Mortality	1.89	1.47	1.07	1.08	0.88	1.45	1.34	1.73	0.88	2.82
Spawning Potential Ratio	9%	10%	11%	16%	17%	20%	13%	12%	20%	6%

[1]During 1975–2017.

Biological Reference Points

Biological reference points were computed for the base case model with Stock Synthesis (Table S2). The point estimate of maximum sustainable yield was MSY = 4,819 mt. The point estimate of the spawning biomass to produce MSY (adult female biomass) was SSBMSY = 2,534 mt. The point estimate of F_{MSY}, the fishing mortality rate to produce MSY (average fishing mortality on ages 3–12) was FMSY = 0.61 and the corresponding equilibrium value of spawning potential ratio at MSY was SPR_{MSY} = 18%.

Table S 2. 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 western and central North Pacific striped marlin, 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)	0.61
F_{2017} (age 3–12)	0.88
$F_{20\%SSB(F=0)}$	0.47
SSB_{MSY}	2,534 mt
SSB_{2017}	849 mt
$SSB_{20\%(F=0)}$	3,493 mt
MSY	4,819 mt
$C_{2015–2017}$	2,079 mt
SPR_{MSY}	18%
SPR_{2017}	13%
$SPR_{20\%SSB(F=0)}$	23%

Projections

[text in brackets to be revised pending completion of the projections]

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 western and central North Pacific Ocean. 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 the 14th Regular Session of the WCPFC Northern Committee were conducted. Two future recruitment scenarios were evaluated: (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-1 fish and the long-term recruitment mean was 306,989 age-1 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 5 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·SSB(F=0), (4) F_{High} at the highest 3-year average during 1975–2017, and (5) F_{Low} at F0.30%. For the F-based scenarios, fishing mortality in 2018–2019 was set to be F status quo (0.69) 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 7 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 (2079 mt) 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 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 S3 and Figure S4).

Conservation Advice

The WCNPO striped marlin stock has produced annual yields of around 2,200 mt per year since 2012, or about 40% of the MSY catch amount. Striped marlin stock status shows evidence of substantial depletion of spawning potential ($SSB_{Current}$ is 67% below SSB_{MSY}), however fishing mortality has fluctuated around F_{MSY} in the last 4 years. It was also noted that retrospective analyses show that the assessment model appears to underestimate spawning potential in recent years.

Special Comments

WG achieved a base-case model using best available data and biological information. However, the WG recognized has uncertainty in input catch data including drift gillnet and initial catch amounts, life history parameters including maturation and growth, and stock structure. The WG considered an extensive suite of model formulations and associated diagnostics for developing the base-case assessment model. Overall, we found issues with the base case model diagnostics and sensitivity runs that indicated some data conflicts exist (see Assessment Challenges and Sensitivity Analyses). To improve the stock assessment, the WG also recommends continuing model development work to reduce data conflicts and modeling uncertainties, and reevaluating and improving input assessment data. When developing a CMM to rebuild the resource, the WG recommends that these issues be recognized and carefully considered.

References

ISC Billfish Working Group. 2019. Annex 5: Report of the Billfish Working Group workshop. 14–21 January, 2019. Honolulu, HI, USA. http://isc.fra.go.jp/pdf/ISC19/ISC19_ANNEX05_Report_of_the_BILLFISH_Working_Group_Workshop_January2019.pdf

Ito R. 2019. U.S. commercial fisheries for marlins in the North Pacific Ocean. (ISC/19/BILLWG-1/1)

Walsh WA, Bigelow KA, and Ito RY. 2007. Corrected catch histories and logbook accuracy for billfishes (Istiophoridae) in the Hawaii-based longline fishery. NOAA Technical Memorandum NMFS-PIFSC-13, 49pp.

Tables and Figures

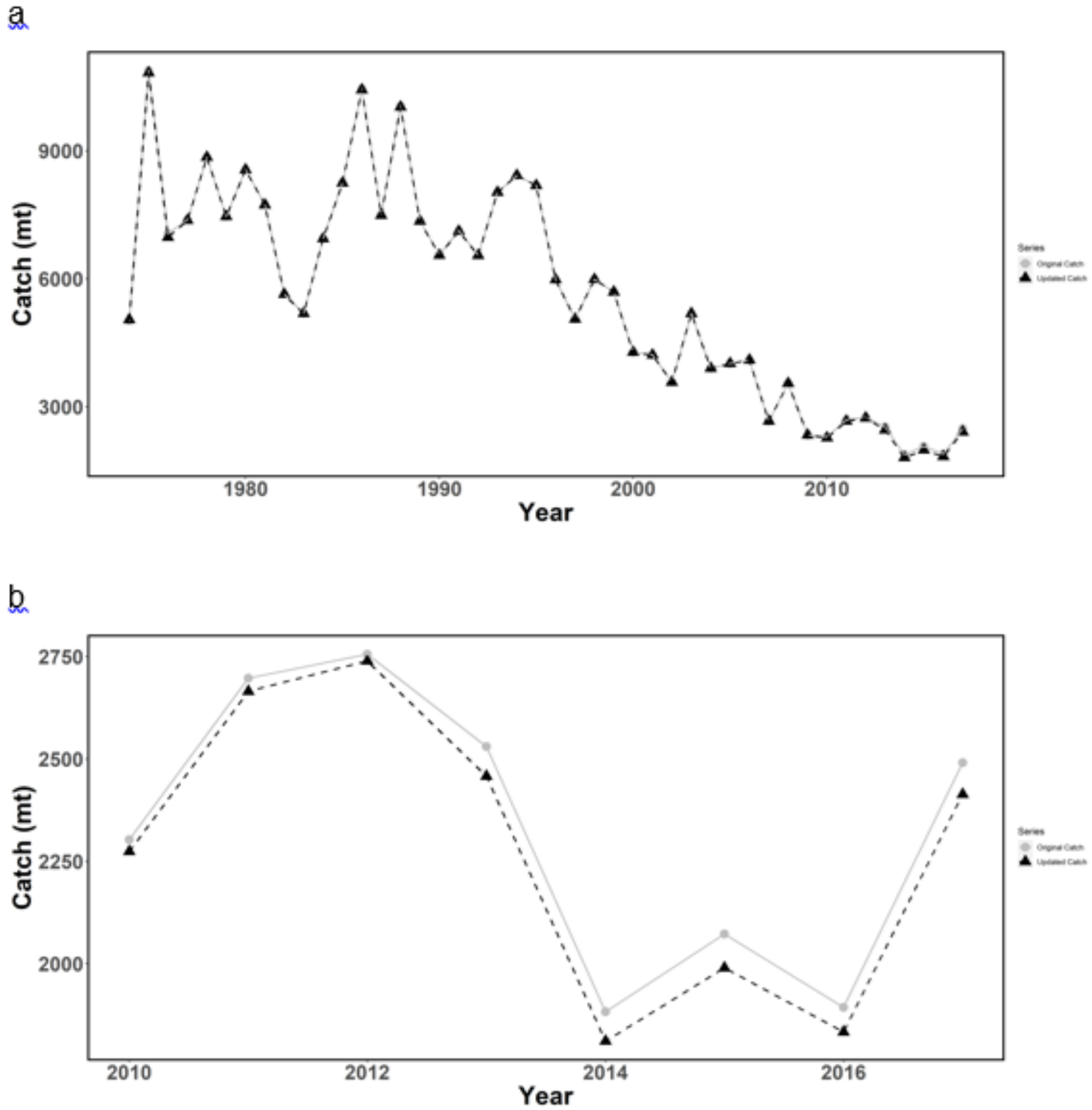

Figure 1. Time series of catch from the 2019 North Pacific striped marlin base-case assessment model (gray circles and solid line) and the 2021 NP MLS base-case assessment model (black triangles and dashed line) from 1975 to 2017 (panel a) and a detailed view of just 2010 to 2017 (panel b).

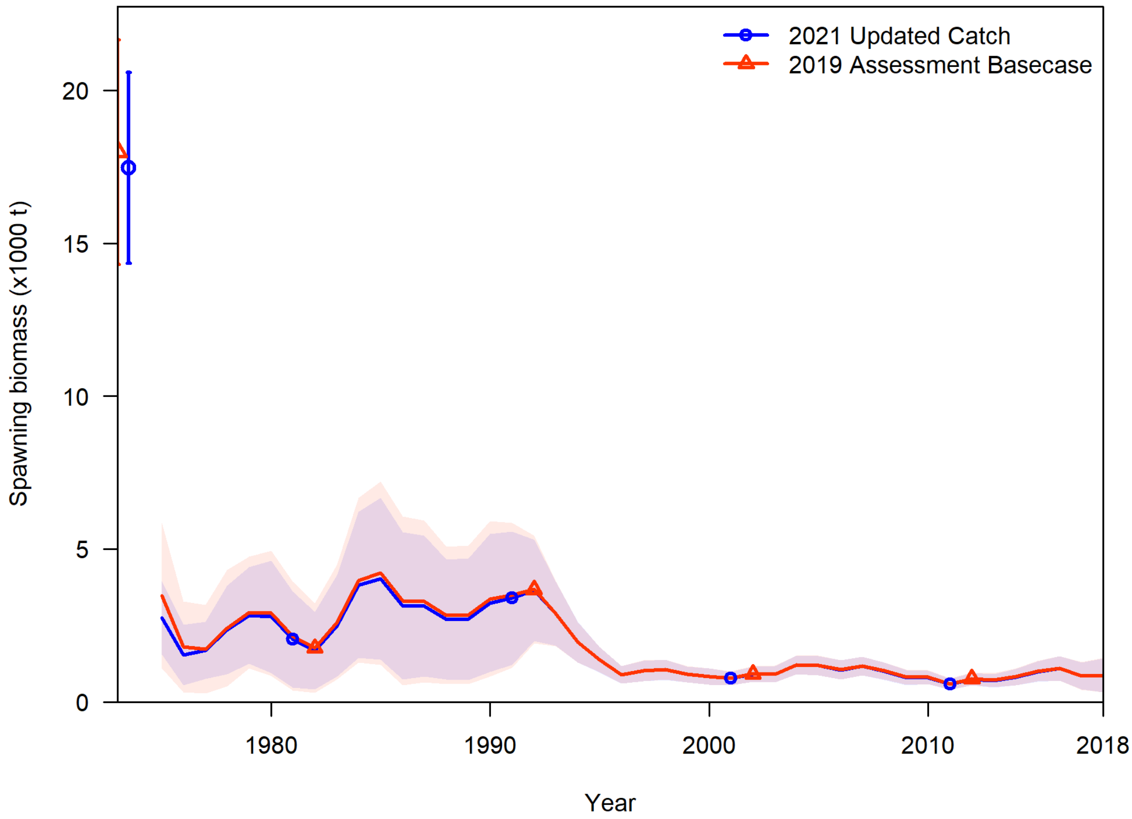

Figure 2. Comparison of 2019 striped marlin base-case assessment estimate of spawning stock biomass (red) with the 2021 correction assessment spawning stock biomass estimate (blue). First data points indicate virgin spawning stock biomass and shading indicates 95% confidence intervals.

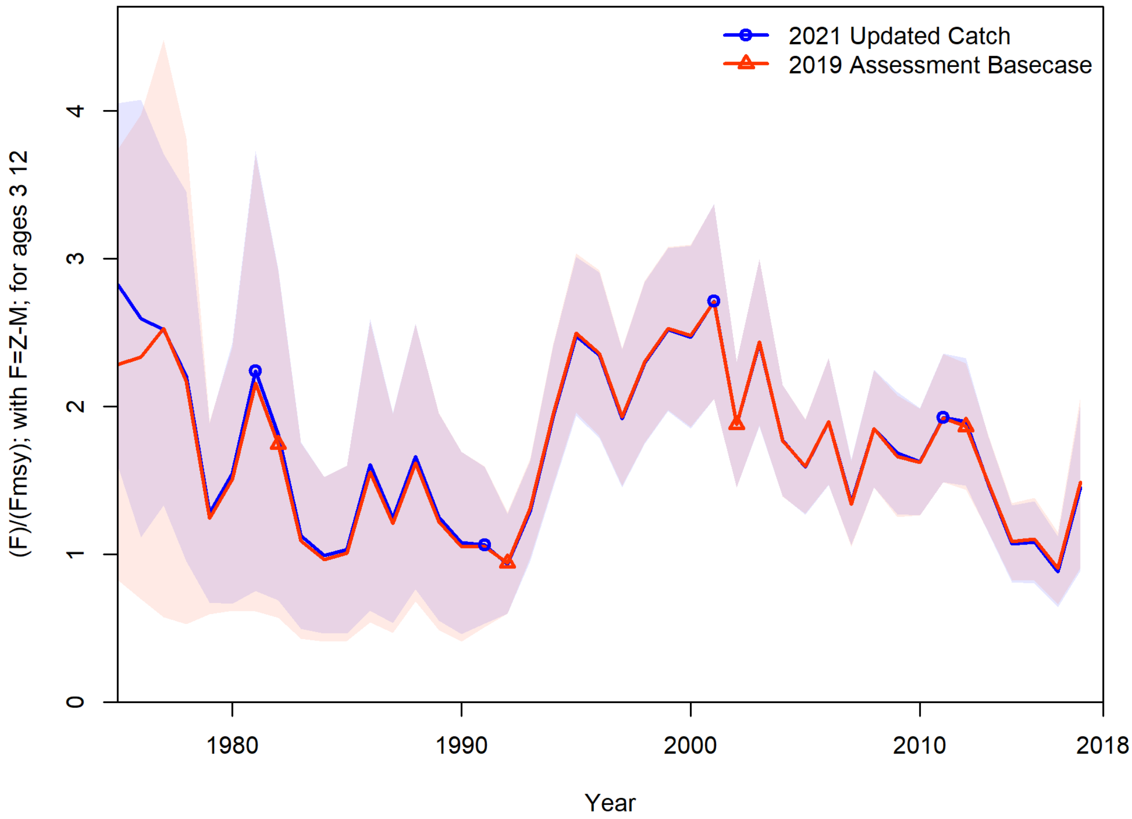

Figure 3. Comparison of 2019 striped marlin base-case assessment estimate of fishing mortality (red) with the 2021 correction assessment fishing mortality estimate (blue). Shading indicates 95% confidence intervals.

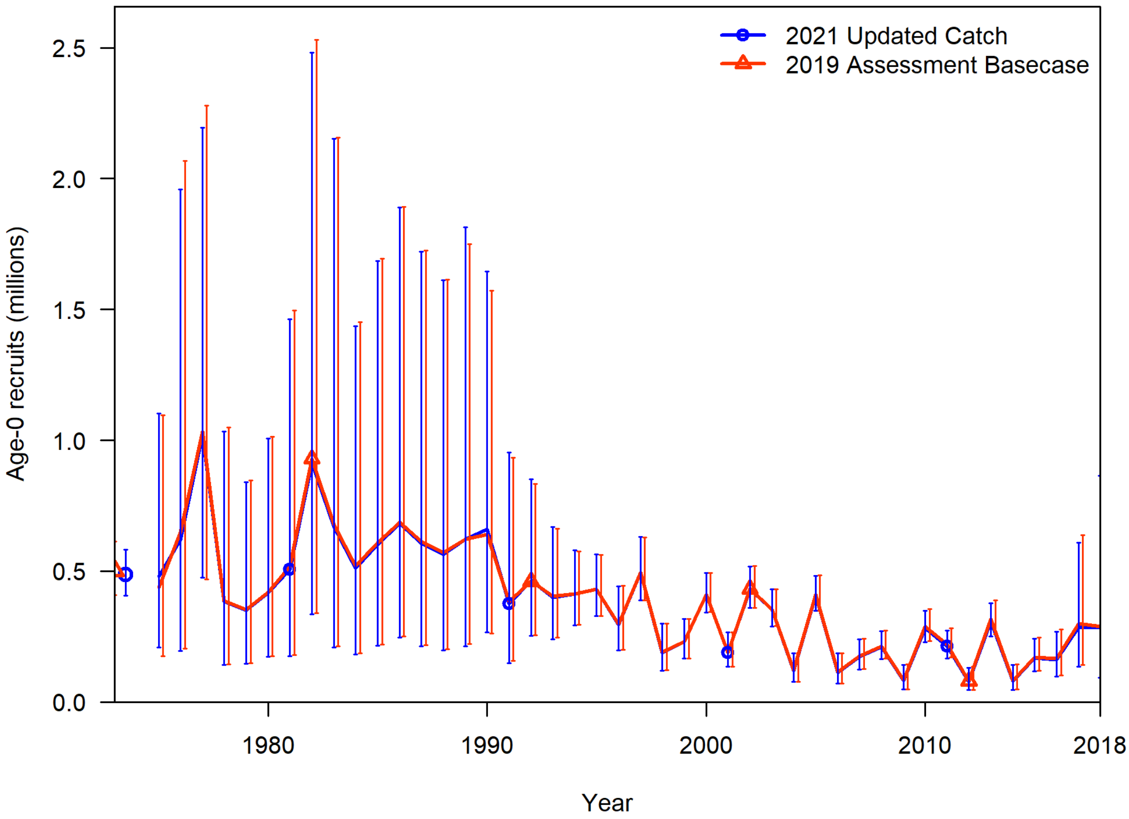

Figure 4. Comparison of 2019 striped marlin base-case assessment estimate of recruitment in 1,000s of age-0 fish (red) with the 2021 correction assessment recruitment estimate (blue) with 95% confidence intervals, the first data point represents virgin recruitment.

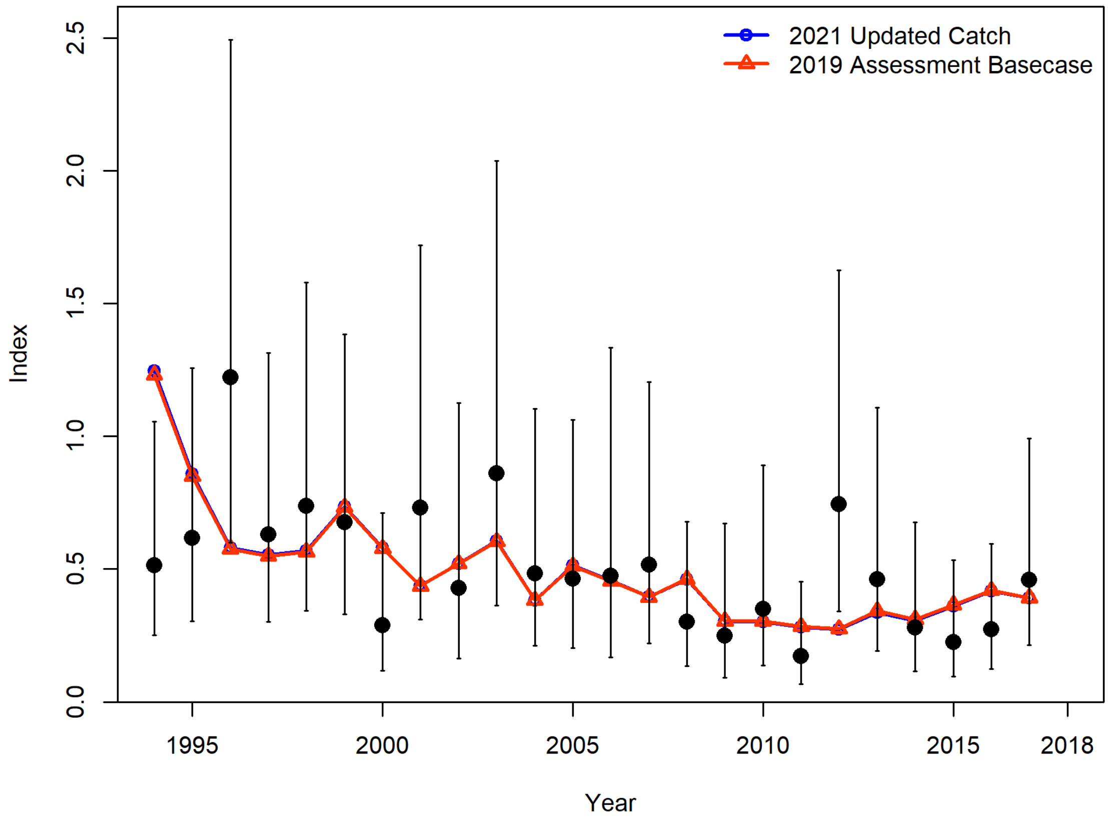

Figure 5. Fit to the CPUE of Fleet S1, Japanese Longline Q1A1 Late, in the 2019 striped marlin base-case assessment model (red) and the 2021 correction assessment model (blue).

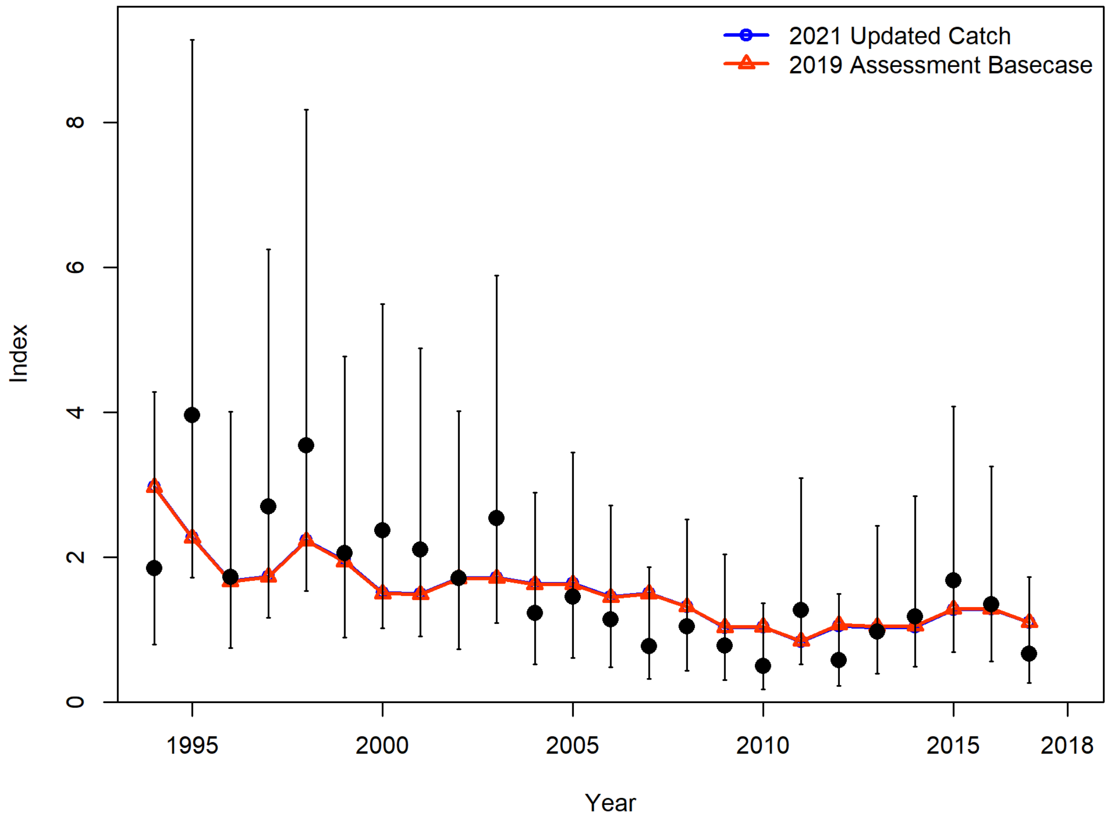

Figure 6. Fit to the CPUE of Fleet S2, Japanese Longline Q3A1 Late, in the 2019 striped marlin base-case assessment model (red) and the 2021 correction assessment model (blue).

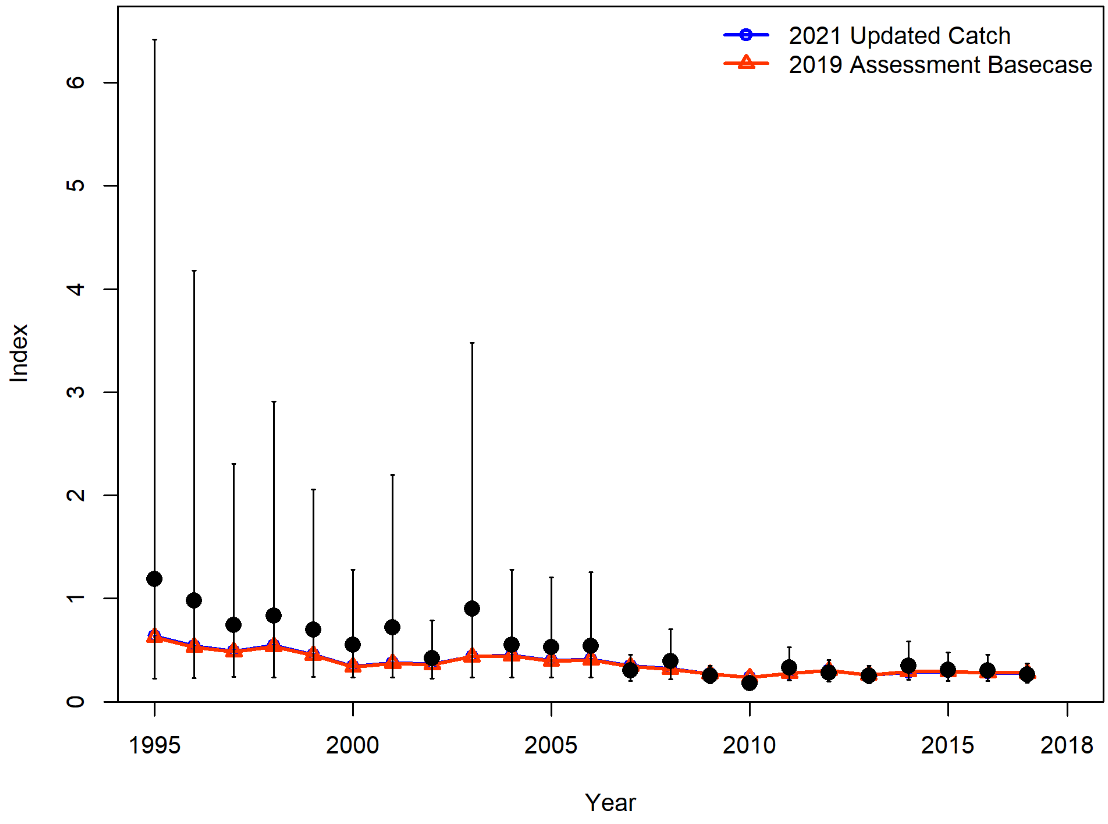

Figure 7. Fit to the CPUE of Fleet S3, US Longline, in the 2019 striped marlin base-case assessment model (red) and the 2021 correction assessment model (blue).

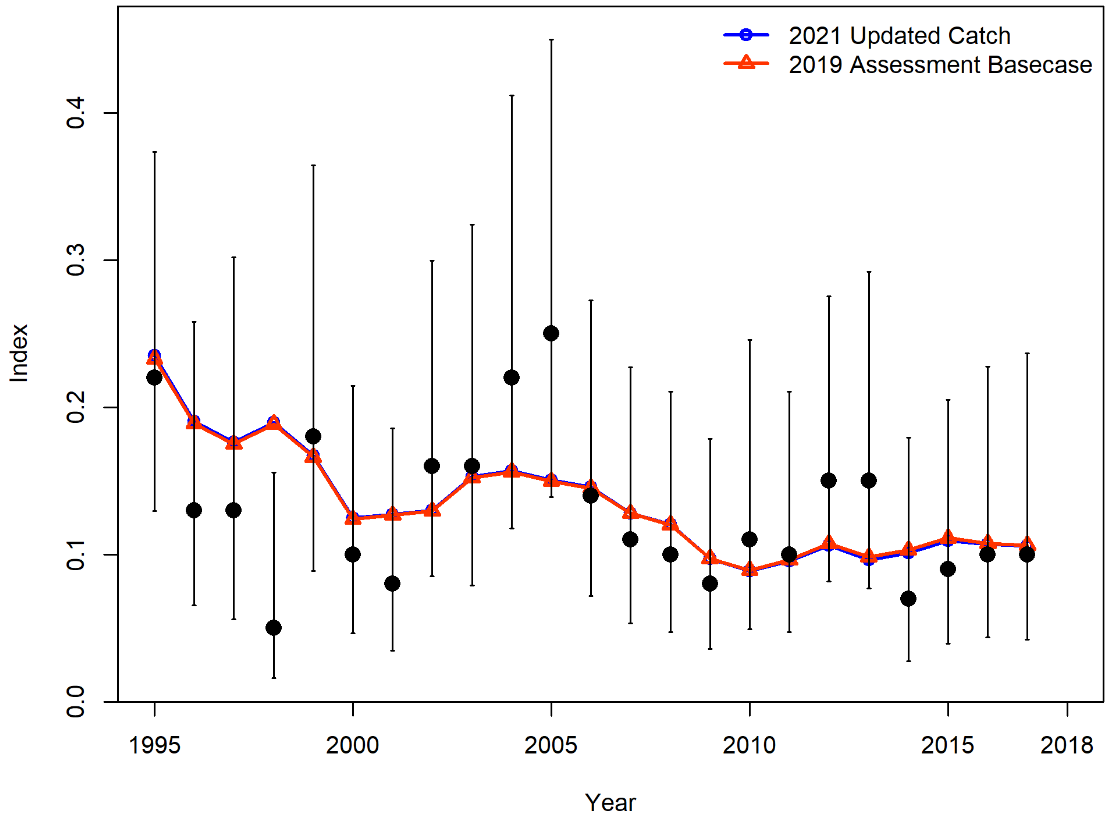

Figure 8. Fit to the CPUE of Fleet S4, Taiwanese Deepwater Longline, in the 2019 striped marlin base-case assessment model (red) and the 2021 correction assessment model (blue).

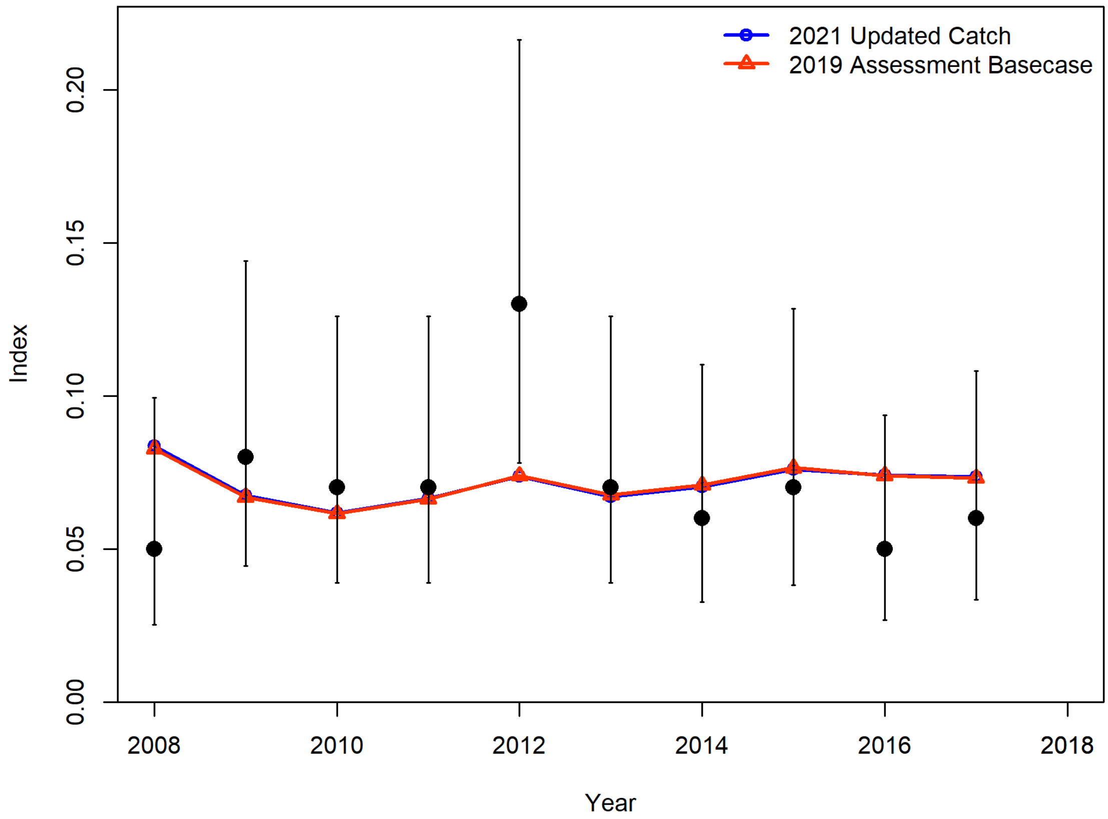

Figure 9. Fit to the CPUE of Fleet S5, Taiwanese Small-scale Tuna Longline, in the 2019 striped marlin base-case assessment model (red) and the 2021 correction assessment model (blue).

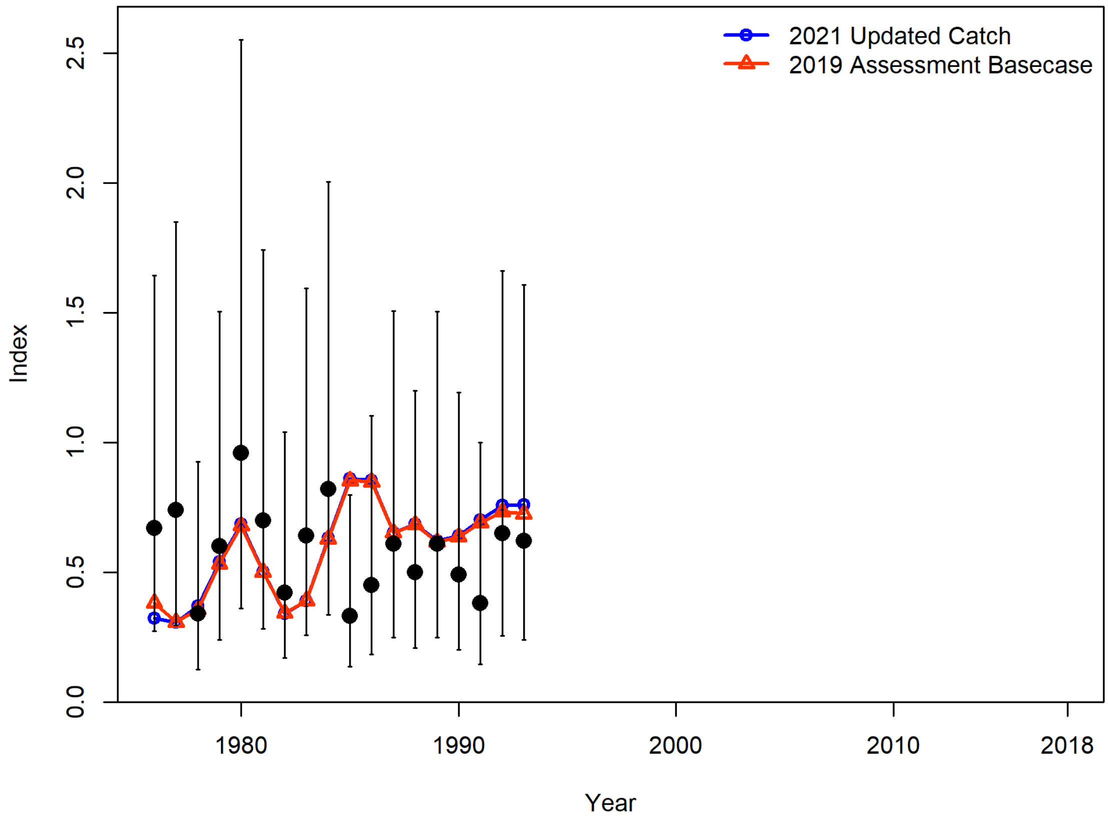

Figure 10. Fit to the CPUE of Fleet S6, Japanese Longline Q1A1 Early, in the 2019 striped marlin base-case assessment model (red) and the 2021 correction assessment model (blue).

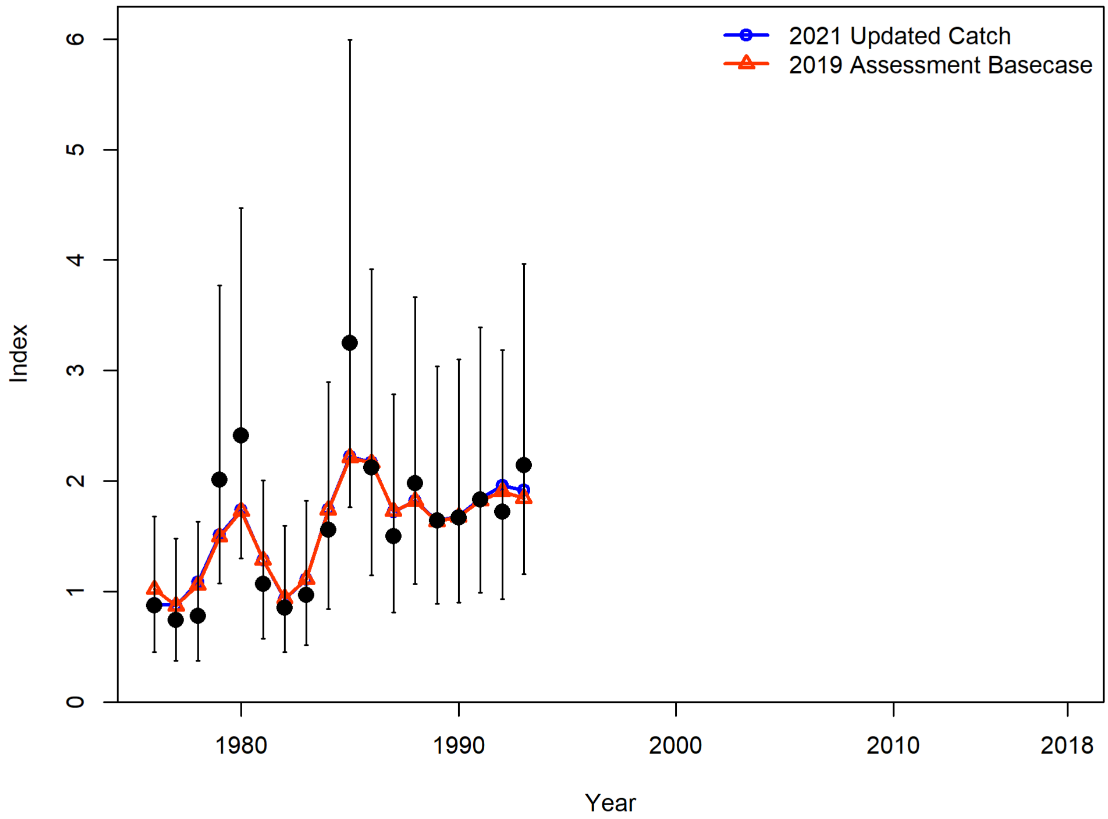

Figure 11. Fit to the CPUE of Fleet S1, Japanese Longline Q3A1 Early, in the 2019 striped marlin base-case assessment model (red) and the 2021 correction assessment model (blue).

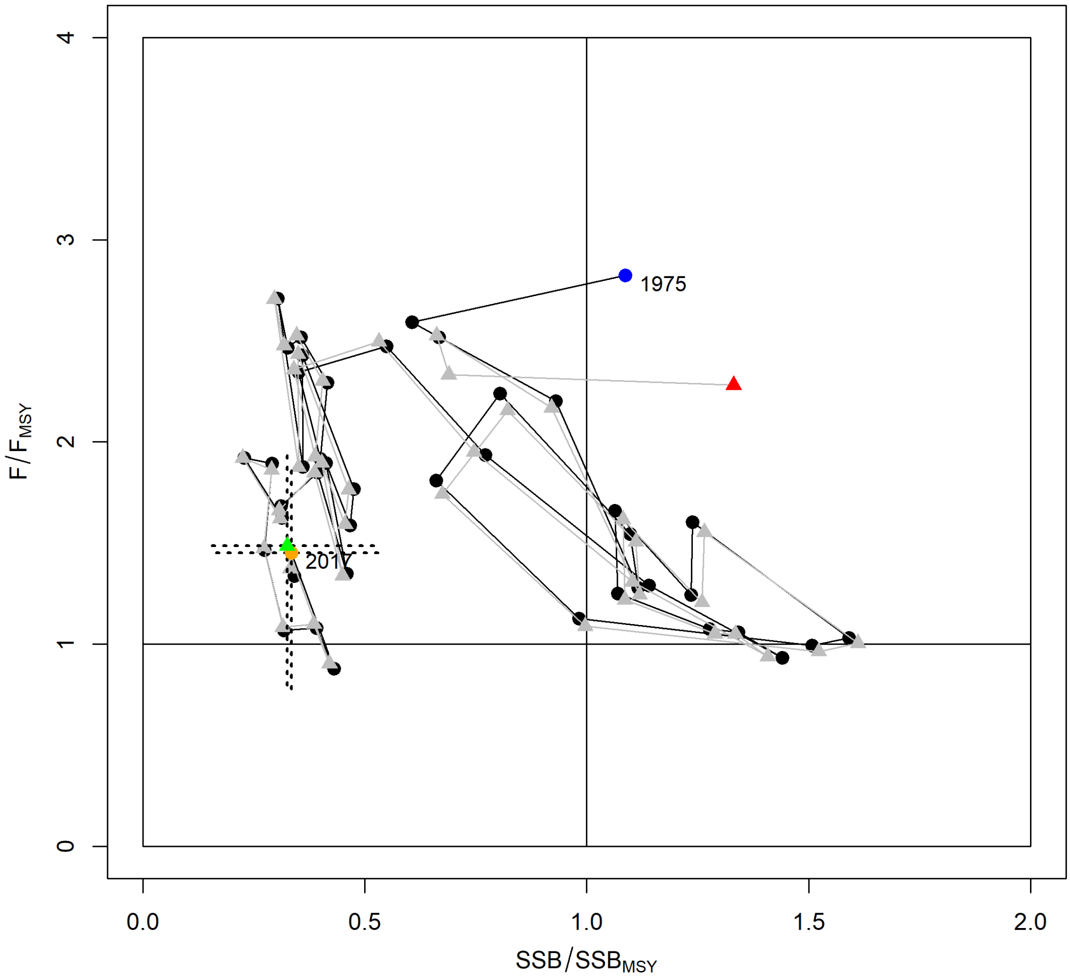

Figure 12. Kobe plot comparing the stock status from the 2019 MLS assessment base-case model (grey triangles) and the 2021 corrected catch MLS assessment base-case model (black circles). The year 1975 is indicated as the red triangle and blue circle for the 2019 and 2021 assessment models and 2017 is indicated with the green triangle and yellow circle for the 2019 and 2021 assessment models, respecitvely. Dashed lines indicate 95% confidence intervals for the 2017 endpoint.

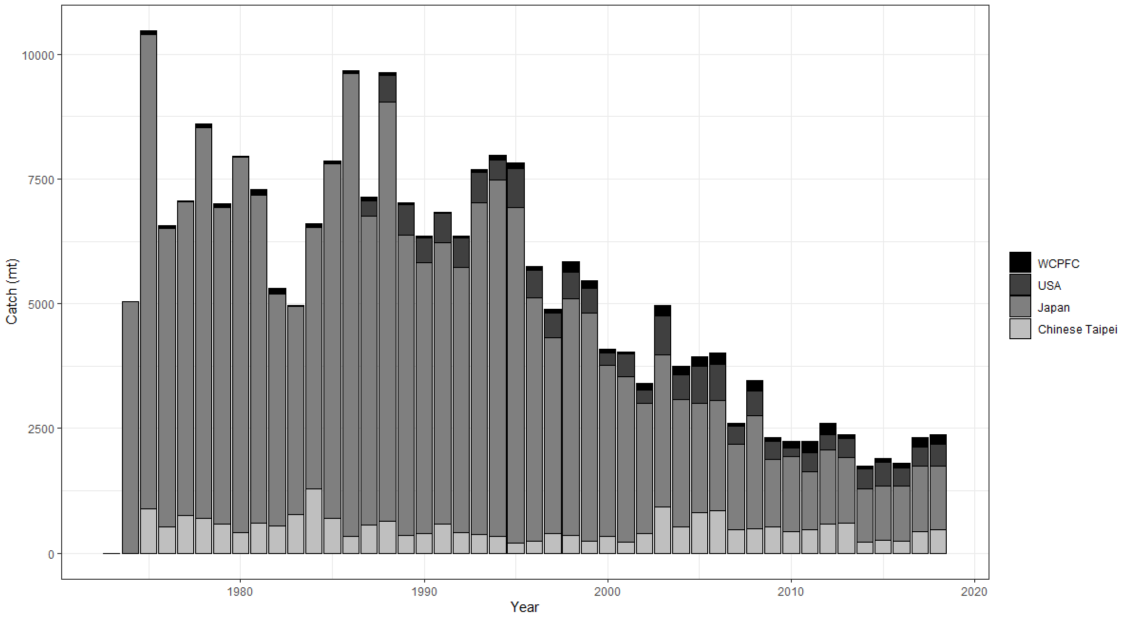

Figure S1. Annual catch biomass (mt) of western and central North Pacific striped marlin (Kajikia audax) by country for Japan, Chinese Taipei, the USA, and all other countries during 1975–2017.

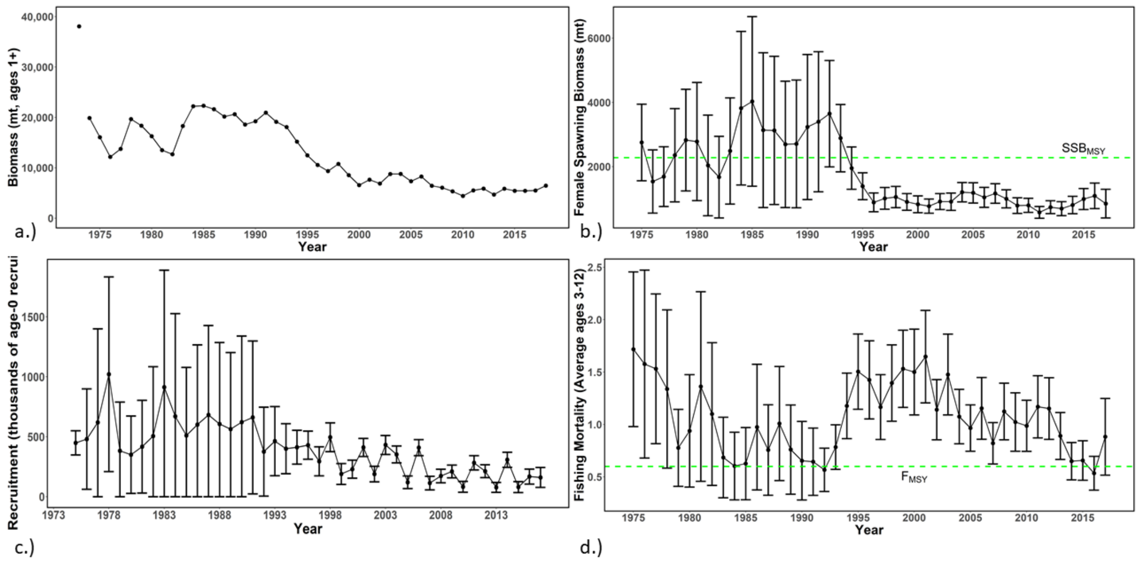

Figure S2. Time series of estimates of (a) population biomass (age 1+), (b) spawning biomass, (c) recruitment (age-0 fish), and (d) instantaneous fishing mortality (average for age 3–12, year 1) for Western and Central North Pacific striped marlin (*Kajikia audax*) derived from the 2019 stock assessment. 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}.

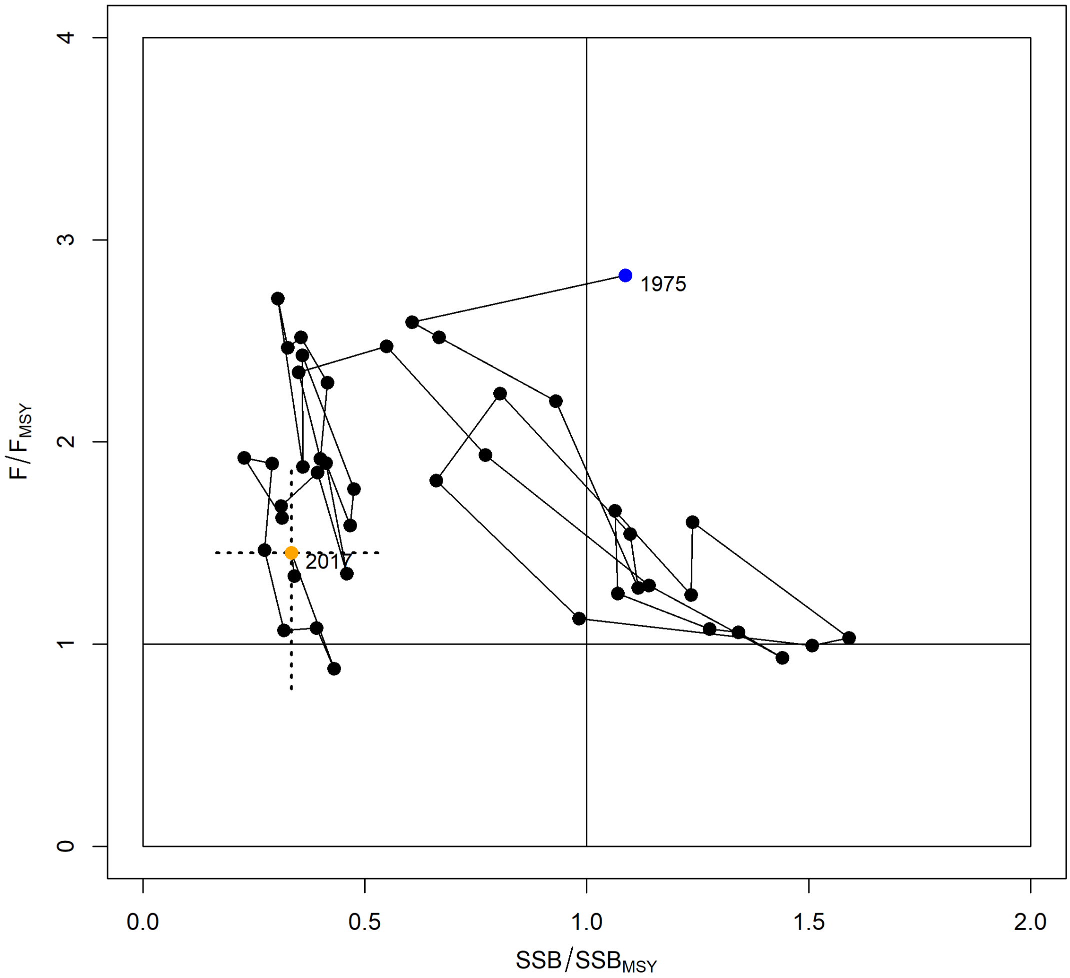

Figure S 3. Kobe plot of the time series of estimates of relative fishing mortality (average of age 3–12) and relative spawning stock biomass of western and central North Pacific striped marlin (*Kajikia audax*) during 1975–2017. The blue circle denotes the first (1975) year of the assessment, the orange circle denotes 2004, and the white triangle denotes the last (2017) year of the assessment, dashed lines indicate 95% confidence intervals.