SCIENTIFIC COMMITTEE
TWENTY-SECOND REGULAR SESSION
11-19 August 2026
Apia, Samoa (Hybrid)

STOCK ASSESSMENT REPORT FOR PACIFIC BLUE MARLIN (*MAKAIRA NIGRICANS*) THROUGH 2024

WCPFC-SC22-2026-SA-WP10
5 July 2026

ISC[1]

[1] International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean

ISC/26/ANNEX/09

ANNEX 09

26th Meeting of the
International Scientific Committee for Tuna
and Tuna-Like Species in the North Pacific Ocean
Taipei City, Chinese Taipei
22-29 June 2026

STOCK ASSESSMENT REPORT FOR PACIFIC BLUE MARLIN (*MAKAIRA NIGRICANS*) THROUGH 2024[1]

ISC Billfish Working Group

June 2026

[1] Prepared for the 26th Meeting of the International Scientific committee on Tuna and Tuna-like Species in the North Pacific Ocean (ISC) held June 22-29, 2026, in Taipei City, Chinese Taipei. Document should not be cited without permission of the authors.

Left Blank for Printing

Stock Assessment Report for Pacific Blue Marlin (*Makaira nigricans*) through 2024

ISC BILLFISH WORKING GROUP

05/29/2026

1.1 ABSTRACT

This report details the assessment of the Pacific blue marlin (*Makaira nigricans*) stock conducted in 2026 by the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) Billfish Working Group. The 2026 stock assessment consisted of applying a Stock Synthesis (SS3) model with the updated best-available life history parameters and catch estimates, abundance indices, and size composition data for 1971–2024. The results indicated population biomass (age 1 and older) of Pacific blue marlin declined from an initially fished level of 217,857 mt in 1971 to 183,150 mt in 1993, then 123,318 mt in 1999. Population biomass exhibited a steady further decline to average 102,490 mt in 2021–2023, with a terminal year increase to an estimated 127,300 mt in 2024. Estimated fishing mortality rate (F, expressed as exploitation rate of biomass) increased through the 1970s–1990s peaking at 0.23, then fluctuated around 0.20 before declining to 0.12 in 2023 and 0.14 in 2024. Fishing mortality rates have been below F_{MSY} (F_{MSY} = 0.26) for the entire assessment period. The recent (average for 2021–2023) female spawning stock biomass of 42,038 mt was greater than SSB_{MSY} (SSB_{MSY} =31,651 mt) and the recent *F* of 0.13 (average for 2021–2023) was 50% below F_{MSY}. The base model indicated under current conditions, the Pacific blue marlin stock was not overfished (>99% probability) and was not subject to overfishing (>99% probability) relative to MSY-based reference points.

2 EXECUTIVE SUMMARY: PACIFIC BLUE MARLIN (*MAKAIRA NIGRICANS*) STOCK ASSESSMENT

Stock Identification and Distribution: The Pacific blue marlin (*Makaira nigricans*) is assessed as a pan-Pacific stock caught primarily in tropical and sub-tropical waters (Figure S1). All available fishery data from ISC Members, the Inter-American Tropical Tuna Commission (IATTC), and the Western and Central Pacific Fisheries Commission (WCPFC) were used for this stock assessment. For modeling observations of catch-per-unit-effort (CPUE) and size composition data, it was assumed that there was instantaneous mixing of fish throughout the stock area on a quarterly basis.

Catches: Pacific blue marlin catches increased from 9,345 mt in the first year of the assessment (1971) to a maximum of 27,161 mt in 1995 (Figure S2). Catches were highly variable from 1996–2015, ranging from 18,287 to 27,073 mt and averaging about 22,150 mt. Since 2016, catches of Pacific blue marlin declined by almost half to less than 13,000 mt in 2023, and catch increased to an estimated 17,738 mt in 2024. Overall, longline gear has accounted for the vast majority of Pacific blue marlin catches (>80%) with Japanese fleets dominating the catch before 2000, and Chinese Taipei and other longline fleets dominating thereafter.

Data and Assessment: Catch and size composition data were compiled from ISC members (Japan, Chinese Taipei, and United States), other WCPFC members, and other IATTC members (Table S1). Standardized CPUE data used to measure trends in relative abundance were provided by Japan, Chinese Taipei, and U.S.. The size composition of Pacific blue marlin catches was included in the model for several fishing fleets, including data compiled from longline, driftnet, and purse seine gear. Life history parameters for sex-specific growth, longevity, and natural mortality were updated for this stock assessment. The value for the Beverton-Holt stock-recruitment steepness (*h*) in the base model was 0.87. An age-structured assessment model was fit to relative abundance indices (CPUE) and size composition data in the likelihood-based integrated statistical modeling framework Stock Synthesis (SS3). A large number of sensitivity analyses were conducted to evaluate the influence of the model specification and data streams on population biomass and fishing mortality trajectories. Model specifications and input parameters investigated in the sensitivity analyses included natural mortality, stock-recruitment steepness, growth, maturity, uncertainty in the input data (e.g., spatial definitions of CPUE indices, additional error added to input CPUE data, the first year of catch estimates, over- or under-estimation of catch, or the inclusion of size composition data in terms of either weight or length), and variations in model structure (e.g., fleet selectivity and catchability, initial catch and fishing mortality, and estimation of recruitment deviations from the stock-recruitment relationship).

Status of the Stock: The base model indicated the Pacific blue marlin stock was likely not overfished and likely not subject to overfishing. Estimates of population biomass (age 1 and older) for the Pacific blue marlin stock declined from 183,150 mt in 1993 to 123,300 mt in 1999, with a steady further decline to average 102,490 mt in 2021–2023, and a terminal year increase to an estimated 127,300 mt in 2024 (Figure S3). Estimated fishing mortality rate (F, expressed as exploitation rate of biomass) increased through the 1970s–1990s, and fluctuated around 0.20 before declining to 0.12 in 2023 and 0.14 in 2024. Fishing mortality rates have been below F_{MSY} for the entire assessment period. The recent spawning stock biomass of 42,038 mt (average for 2021–2023) was greater than SSB_{MSY} (SSB_{MSY} = 31,651 mt) and the recent F of 0.13 (average for 2021–2023) was 50% below F_{MSY}. The base model indicated under current conditions the Pacific blue marlin stock was virtually certain to be not overfished (>99% probability) and was virtually certain to be not subject to overfishing (>99% probability) relative to MSY-based reference points (Figure S4).

Biological Reference Points: MSY-based biological reference points and a depletion-based reference point (20% of virgin population mature female biomass; denoted 20%SSB_0) were computed for the base model (Table S2). The point estimate of annual catch at F_{MSY} was 24,306 mt and at 20%SSB_0 was 24,119 mt. The point estimate of the female SSB to produce MSY (mature female biomass) was 31,651 mt. The point estimate of F_{MSY}, the fishing mortality rate to produce SSB_{MSY} was 0.26 (when F is calculated as exploitation rate of total biomass) or 0.22 (when F is calculated as average F for ages 1–10). $F_{20\%SSB0}$, the fishing mortality rate to maintain the population at 20%SSB_0 was 0.23 (F as exploitation rate of total biomass) or 0.20 (average F for ages 1–10). The corresponding equilibrium value of spawning potential ratio (SPR) at SSB_{MSY} was 19.6%; SPR corresponding to 20%SSB_0 was 23%.

Projections: Future projections for Pacific blue marlin were conducted using SS3, without incorporating recruitment deviations or applying a log-bias adjustment in the projections. Projections were reported as the median value from 100 bootstrapped input dataset model runs for each scenario. Projections started in 2025 and continued through 2034 under fishing mortality levels corresponding to four harvest scenarios: (1) $F_{High} = F_{2003}$, the highest fishing mortality rate estimated for the entire time series (1971–2024); (2) F_{MSY}; (3) $F_{Recent} = F_{(2021–2023)}$, corresponding to the average fishing intensity (SPR) over 2021–2023; and (4) $F_{30\%SPR}$, corresponding to SPR = 30%. The results show the projected female SSB and catch biomass under each of these scenarios (*Table S3*; *Figures S5*–S6). Under the F_{Recent} scenario, projected catches remained below 2024 levels for several years, then increased to about 80% of MSY by 2034, while biomass increased to well above SSB_{MSY}. In contrast, the F_{MSY} scenario showed increased catch to above the historical maximum, followed by a decline to MSY as biomass decreased. The remaining scenarios produced intermediate trajectories with catches initially increasing and later declining as stock biomass is reduced. The most stable catch trajectory was observed under $F_{30\%SPR}$, with projected annual catches remaining approximately constant at 23,000 mt.

Conservation information: The Pacific blue marlin stock has produced annual yields of 13,690–20,400 mt since 2019, or about 53–84% of MSY. This suggests the stock may be able to support somewhat higher yields. The stock status of Pacific blue marlin is positive, with no evidence of fishing mortality exceeding F_{MSY}, or substantial depletion of spawning potential or spawning stock biomass relative to MSY.

Special Comments: The lack of sex-specific size data for all but one fishing fleet, and the simplified treatment of the spatial structure of Pacific blue marlin fishing fleets and population dynamics remain as two important sources of uncertainty for improving future assessments.

Table S1: Reported catch (mt and numbers) used in the stock assessment along with annual estimates of total catch (mt), population biomass (age-1 and older, mt), female spawning stock biomass (SSB, mt), relative female spawning stock biomass (SSB/SSB_{MSY}), recruitment (thousands of age-0 fish), fishing mortality rate (F as exploitation rate of total biomass), relative fishing mortality rate (F/F_{MSY}), and spawning potential ratio of Pacific blue marlin (Makaira nigricans).

Year	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**Mean[1]**	**Min[1]**	**Max[1]**
Estimated total Catch (mt)	20,407	16,827	13,692	14,336	12,958	17,738	18,967	9,345	27,161
Population Biomass	101,913	99,122	98,388	100,637	108,435	127,300	148,355	98,388	217,857
Spawning Stock Biomass	39,065	39,099	40,365	42,117	43,633	47,244	71,486	38,868	133,084
Relative Spawning Stock Biomass	1.23	1.24	1.28	1.33	1.38	1.49	2.22	1.23	4.03
Recruitment (age 0)	737	673	727	1,044	1,386	931	936	614	1,410
Fishing Mortality Rate	0.20	0.17	0.14	0.14	0.12	0.14	0.14	0.04	0.23
Relative Fishing Mortality Rate	0.78	0.66	0.54	0.55	0.46	0.54	0.55	0.20	0.90
Spawning Potential Ratio	0.26	0.30	0.37	0.36	0.41	0.37	0.39	0.21	0.70

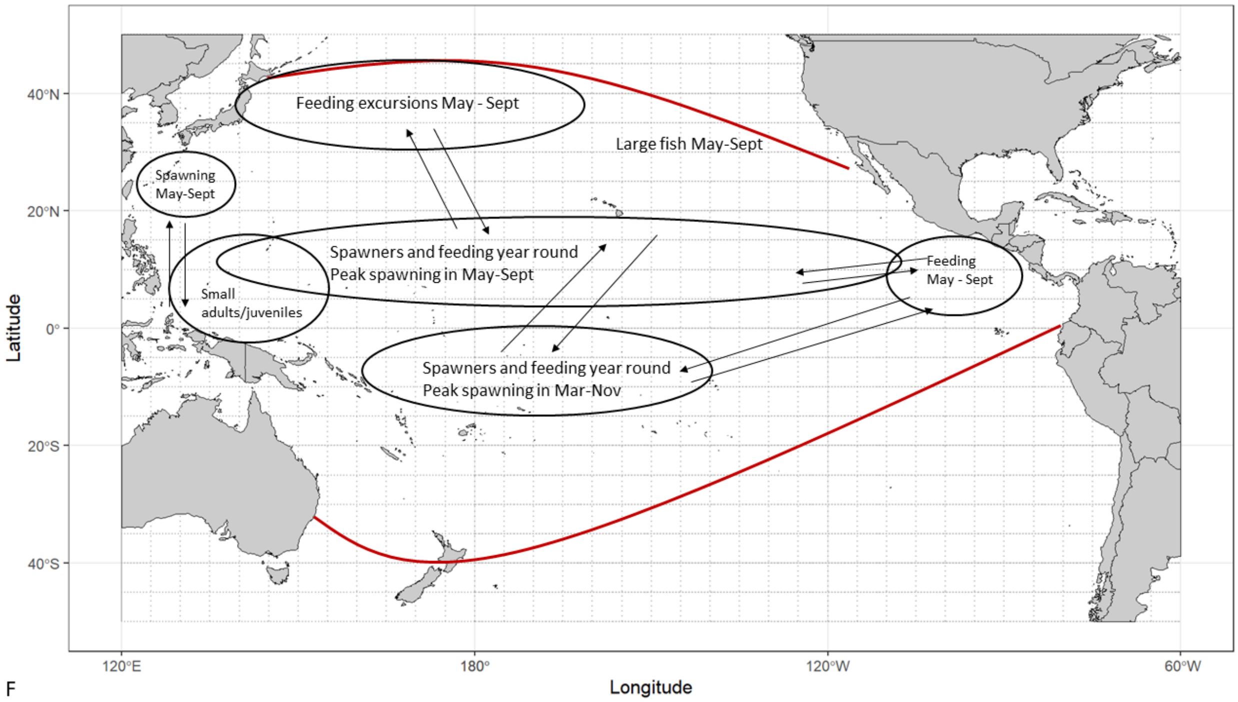
[1] During 1971–2024

Table S2. Estimated biological reference points derived from the base model for Pacific blue marlin (Makaira nigricans) where F is the fishing mortality rate, expressed as exploitation rate of biomass or instantaneous annual F of ages 1–10. SPR is annual spawning potential ratio, SSB is spawning stock biomass (mature female biomass), SSB_0 is virgin unfished SSB, and MSY is maximum sustainable yield.

Reference Point	Estimate
F as exploitation(biomass)	
F_{MSY}	0.26
$F_{20\%SSB0}$	0.23
F_{2003}	0.23
$F_{2021–2023}$	0.13
Average F ages 1–10	
F_{MSY}	0.22
$F_{20\%SSB0}$	0.20
F_{2003}	0.20
$F_{2021–2023}$	0.11
Spawning Stock Biomass (SSB, mt)	
SSB_0	192,529
SSB_{MSY}	31,651
$20\%SSB_0$	38,506
SSB_{2003}	42,652
$SSB_{2021–2023}$	42,038
Catch (C, mt)	
C_{MSY}	24,306
$C_{20\%SSB0}$	24,119
C_{2003}	27,073
$C_{2021–2023}$	13,662
Spawning Potential Ratio (SPR)	
SPR_{MSY}	0.196
$SPR_{20\%SSB0}$	0.230
SPR_{2003}	0.209
$SPR_{2021–2023}$	0.381

Table S3: Projected median values of Pacific blue marlin (Makaira nigricans) spawning stock biomass (SSB, mt) and catch (mt) in 2025–2034 under 4 constant fishing mortality rate scenarios: (1) F_{High} = F_{2003}, which is the highest fishing mortality rate (F) estimated for the model time series; (2) F_{MSY}; (3) F_{Recent} = $F_{(2021–2023)}$ which is the F corresponding to the average fishing intensity (SPR) from 2021–2023; and (4) $F_{30\%SPR}$ which is the F corresponding to SPR = 30%.

Year	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Scenario 1: F_{High}										
SSB	53,390	50,126	47,384	45,292	43,642	42,530	41,649	40,950	40,418	39,970
Catch	28,998	27,390	26,414	25,647	25,233	24,833	24,506	24,263	24,129	24,001
Scenario 2: F_{MSY}										
SSB	51,646	46,467	42,614	40,069	38,360	37,143	36,262	35,680	35,140	34,765
Catch	32,992	30,396	28,563	27,326	26,518	25,875	25,437	25,110	24,899	24,705
Scenario 3: F_{Recent}										
SSB	56,574	60,297	62,837	65,475	67,469	69,089	70,349	71,131	71,741	72,218
Catch	16,158	16,873	17,505	18,102	18,566	18,930	19,147	19,293	19,408	19,514
Scenario 4: $F_{30\%SPR}$										
SSB	54,642	54,136	53,702	53,663	53,502	53,386	53,290	53,090	53,045	53,019
Catch	23,256	23,050	23,009	22,901	22,902	22,874	22,861	22,873	22,863	22,874



F

Figure S1. A diagram of the conceptual model developed by the ISC Billfish Working Group for female Pacific blue marlin (Makaira nigricans). Arrows show general exchange of fish, not directed movement. The red boundary represents approximate habitat range of Pacific blue marlin.

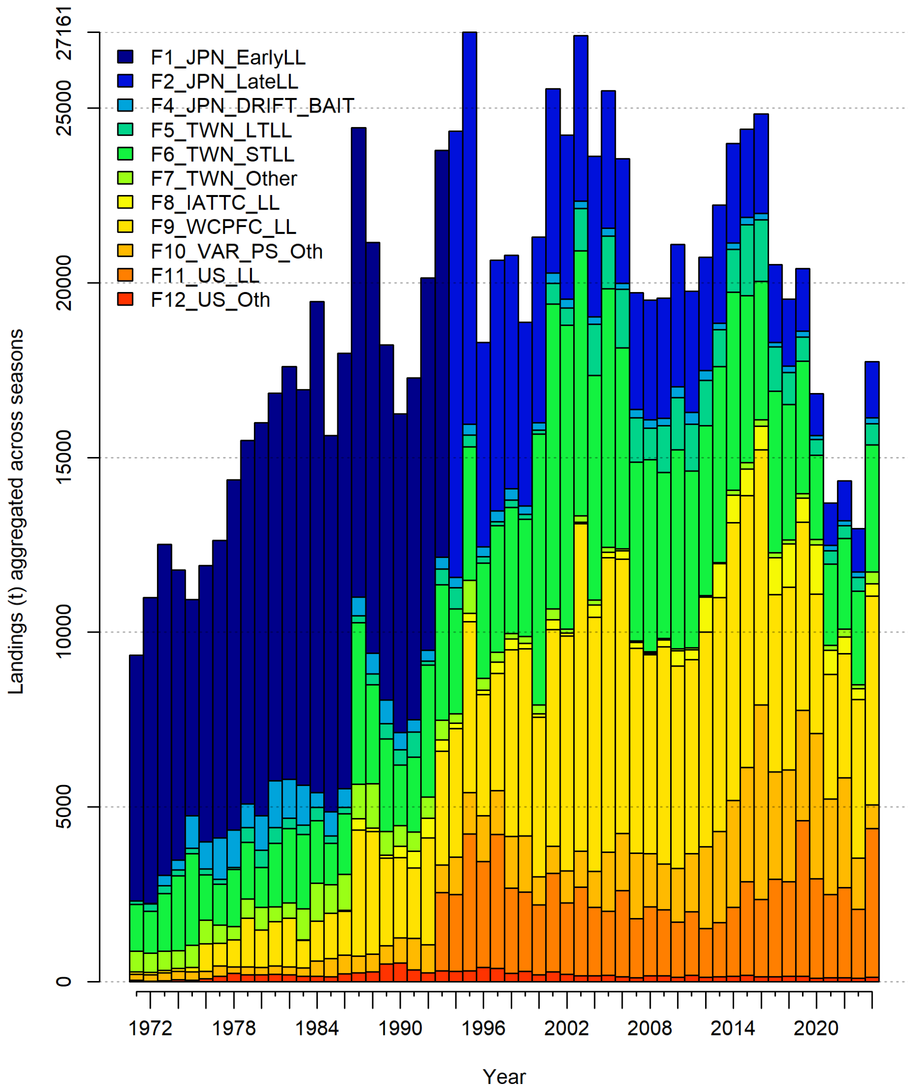


Figure S2. Total annual catch of Pacific blue marlin (Makaria nigricans) 1971–2024 by fleet in the 2026 stock assessment. See Table 1 in the stock assessment report for descriptions of each fishing fleet.

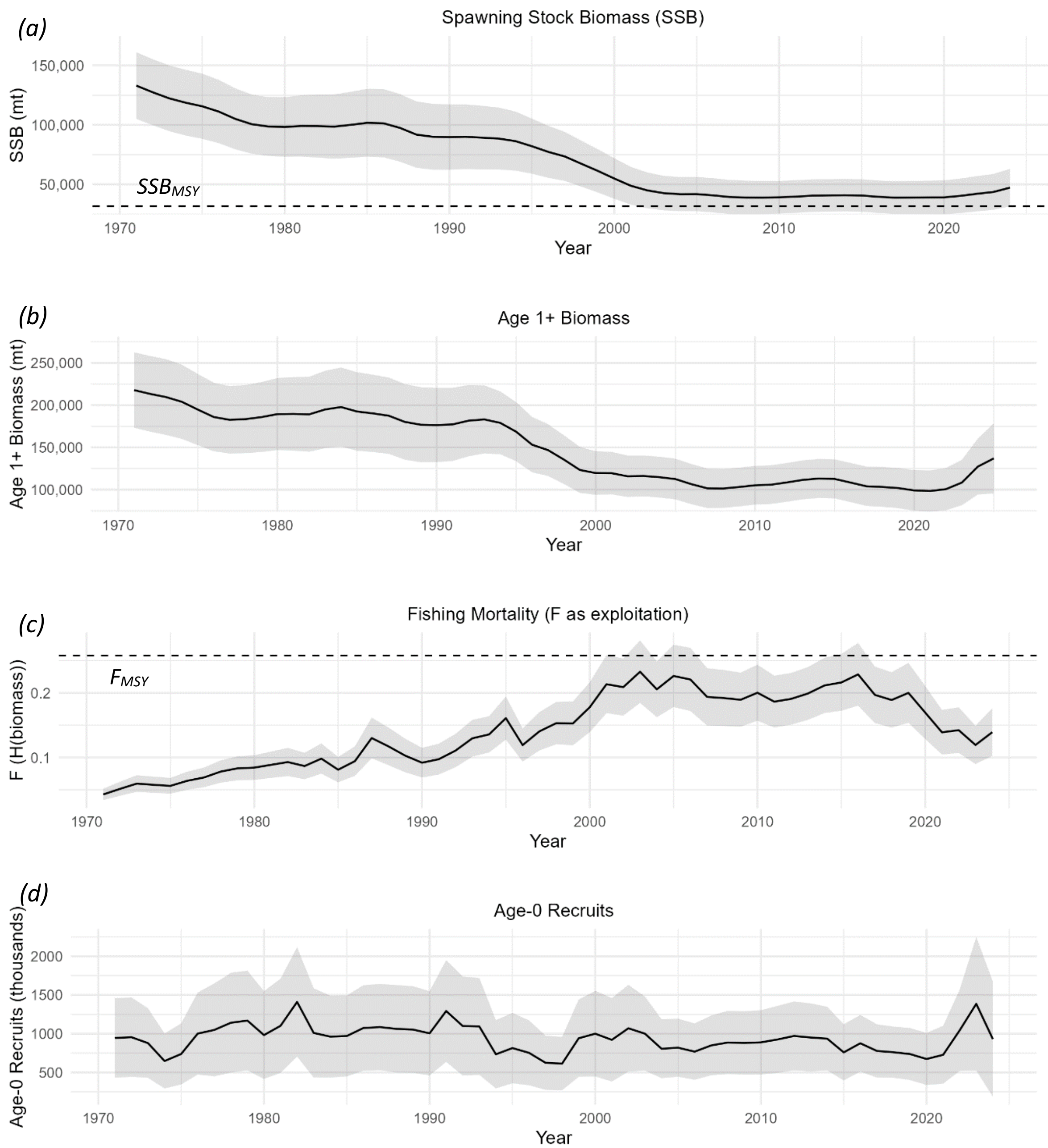


Figure S3. Annual estimates of (a) female spawning stock biomass, SSB; (b) population biomass (age 1+); (c) fishing mortality rate (F) as exploitation rate of biomass; and (d) recruitment (age-0 fish) for Pacific blue marlin (Makaria nigricans). The solid line represents the maximum likelihood estimates by year for each quantity, the shaded areas are 95% confidence intervals, and dashed lines indicate the static SSB_{MSY} and F_{MSY} reference points.

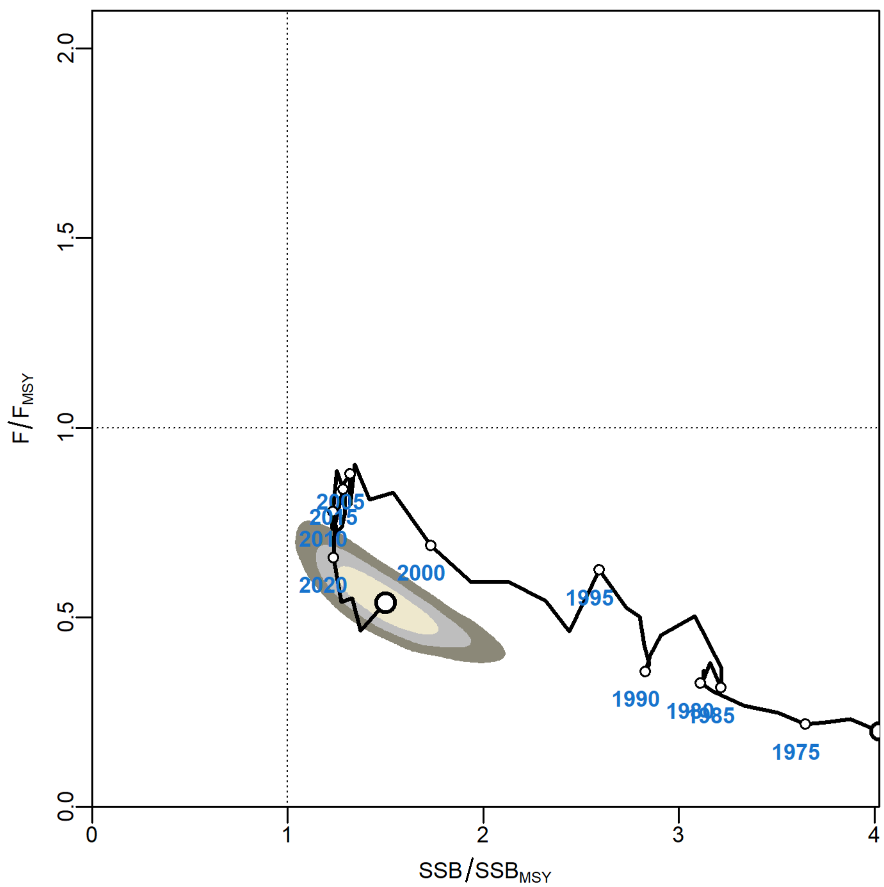


Figure S4: Kobe plot of the timeseries of estimates of mature female spawning stock biomass (SSB) and fishing mortality rate (as exploitation of biomass) relative to MSY values (SSB_{MSY} and F_{MSY}, respectively) of Pacific blue marlin (Makaira nigricans) during 1971–2024. The earliest white symbol indicates 1971, subsequent years are labeled in 5-year increments. Shading indicates 50% (innermost), 80%, and 95% confidence intervals of terminal year (2024) stock status.

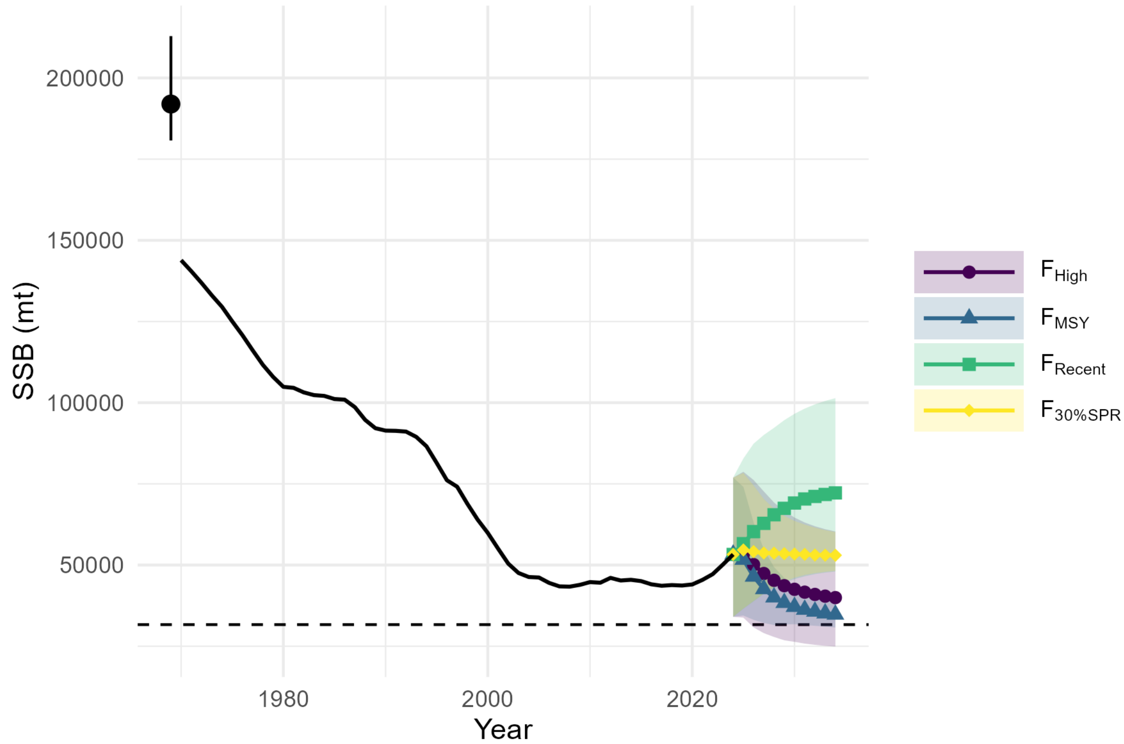


Figure S5. Historical and projected trajectories of mature female spawning stock biomass (SSB) from the Pacific blue marlin (Makaira nigricans) base model based on 4 constant fishing mortality rate (F) scenarios: (1) $F_{High} = F_{2003}$, which is the highest F estimated for the model time series; (2) F_{MSY}; (3) $F_{Recent} = F_{(2021–2023)}$ which is the F corresponding to the average fishing intensity (SPR) from 2021–2023; and (4) $F_{30\%SPR}$ which is the F corresponding to SPR = 30%. The solid lines and symbols are the median value of the 100 bootstrap model runs and the shaded ribbon is the 95% confidence interval. The dashed line indicates the spawning stock biomass at MSY.

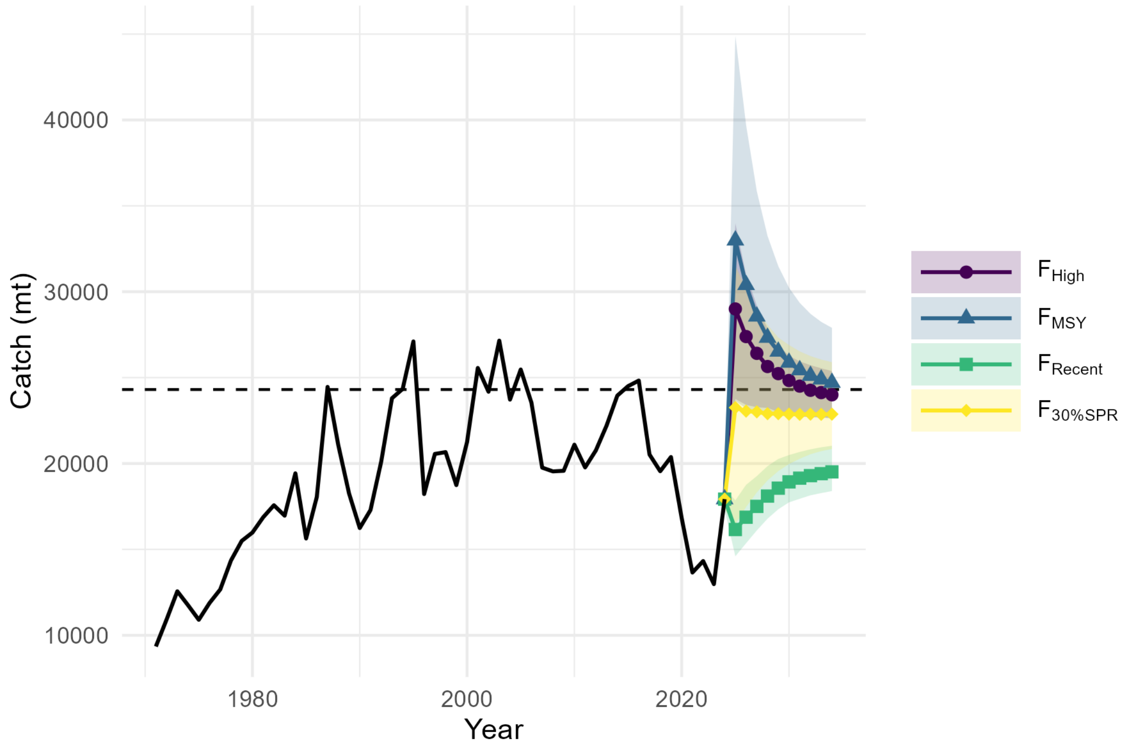


Figure S6. Historical and projected trajectories of catch from the Pacific blue marlin base (Makaira nigricans) case model based on 4 constant fishing mortality rate (F) scenarios: (1) F_{High} = F_{2003}, which is the highest F estimated for the model time series; (2) F_{MSY}; (3) F_{Recent} = $F_{(2021–2023)}$ which is the F corresponding to the average fishing intensity (SPR) from 2021–2023; and (4) $F_{30\%SPR}$ which is the F corresponding to SPR = 30%. The solid lines and symbols are the median value of the 100 bootstrap model runs and the shaded ribbon is the 95% confidence interval. The dashed line indicates MSY.

3 2026 Pacific Blue Marlin Assessment

3.1 Introduction

The International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) Billfish Working Group (BILLWG) completed a benchmark stock assessment of Indo-Pacific blue marlin (*Makaira nigricans*). Data were compiled from ISC Members, other Western and Central Pacific Fisheries Commission (WCPFC) members, and other Inter-American Tropical Tuna Commission (IATTC) members. The BILLWG held a hybrid data preparatory meeting in Yokohama, Japan in January 2026 to review and compile information on stock structure, life history parameters, and fishery data (ISC 2026a). Biological parameters, including sex-specific growth and natural mortality, were agreed to by the BILLWG at the data preparatory meeting, where a new growth curve was presented (Chang et al. 2025). The BILLWG convened a 6 day stock assessment meeting in Honolulu, Hawai'i, April 28 to May 4, 2026 to finalize the base case stock assessment model and review model diagnostics (ISC 2026b). This report describes the 2026 stock assessment for the Pacific blue marlin stock which is an age-structured integrated-assessment model using the modeling platform Stock Synthesis version 3.30.24. (SS3; Methot and Wetzel 2013). This stock assessment integrates the best available scientific information including recently published improved estimates of sex-specific growth and natural mortality, and up-to-date catch, catch-per-unit-effort (CPUE), and size composition data from 1971–2024.

3.2 Materials and Methods

3.2.1 *Spatial and Temporal Specification*

The Indo-Pacific blue marlin (Pacific blue marlin or BUM) is assessed as a single Pacific-wide stock. Generally, Pacific blue marlin are found in the warm tropical waters of the Pacific Ocean and are known to make long distance movements for feeding and spawning over relatively short periods of time, potentially moving east and west across the Pacific Ocean and crossing the equator (Su et al. 2011; Carlisle et al. 2016). The BILLWG drafted a conceptual model which details the seasonal and ontogenetic movements of Pacific blue marlin (ISC 2026a). Size and sex- composition data generally indicate larger individuals and more females are encountered by fisheries in the eastern and more poleward areas of the Pacific Ocean, whereas smaller individuals, which include mature males and juveniles, are more encountered by fishing fleets in the western and equatorial areas (Figure 1 Figure 2).

Three types of data were used in this stock assessment: fishery-specific catches, relative abundance indices (catch per unit effort, CPUE), and size (length or weight) composition. The stock was assumed to be in a fished condition at the start of the assessment model in 1971. There are limited data to estimate catches going back to 1950 when the stock is generally believed to be at essentially unfished levels. Given the rapid growth of BUM and the diverse seasonal nature of Members' fisheries, the model was run using a quarterly timestep.

3.2.2 *Definition of Fisheries*

Seventeen different fleets are available for inclusion in the base case model: 11 catch time series, 6 CPUE indices, 5 fleets with length composition data, and 1 fleet with weight composition data. The fleet names, numbers, descriptions, and data available are detailed in Table 1**Error! Reference source not found.** and are shown graphically in Figure 3. The acronyms in the fleet names and used throughout this working paper are: ISC Members: JPN, Japan; TWN, Chinese Taipei; US, United States; IATTC, Inter-American Tropical Tuna Commission; WCPFC, Western and Central Pacific Fisheries Commission; VAR, any combination of flags; Fishing gears: LL, longline; LLdeep, deepset longline; DRIFT, driftnet; BAIT, bait fishery; Other, other fishing gear (e.g. troll, handline, net, harpoon, and others); PS, purse seine gear; Fleet characteristics: LTLL, large tonnage longline (referring to the size of vessels engaged in fishing); STLL, small tonnage longline (referring to the size of vessels engaged in fishing).

3.2.3 *Catch*

Catch was included in the model on a quarterly basis (by calendar year and quarter) from 1971 to 2024 for the 11 fishing fleets (Table 2; Figure 4). Three Japanese catch time series were used in the assessment. F1_JPN_EarlyLL included coastal, offshore, and distant water longline, and other gears for years 1971–1993. F2_JPN_LateLL included catch from all longline gears for 1994–2024. The catch series for the Japanese “Early” period (F1) and “Late” period (F2) were divided in 1993 because of significant changes in the logbook reporting system, which required the CPUE data to be standardized in different time periods and the corresponding harvest fleets to be divided similarly. F4_JPN_DRIFT_BAIT was catch from high seas large-mesh driftnet, coastal driftnet, and bait fishing for 1972–2024. Catch for this fleet was available annually, so was divided equally among the 4 quarters each year.

Three Chinese Taipei catch time series, available annually 1971–2024, were divided equally among quarters within each year for each fleet and used in the assessment. F5_TWN_LTLL and F6_TWN_STLL included catch from the high seas longline fishery by large tonnage and small tonnage longline vessels, respectively. F7_TWN_Other included the aggregated catch for all other Chinese Taipei vessels and gear types, operating primarily nearer to Chinese Taipei, including coastal longline, gillnet, setnet, harpoon, and other gears.

Two catch time series were available from the U.S. F11_US_LL included quarterly catches (in numbers) from longline gear in American Samoa and Hawai’i from 1993–2024. F12_US_Other was the aggregation of quarterly catch for all gear types, primarily troll and handline, recorded in Hawai’i from 1971–2024. This catch timeseries also included early estimates of longline catch in Hawai’i between 1971–1992, which was before the main development of the F12 longline fleet and only available in metric tons, so are maintained separately from the F11 timeseries starting in 1993.

Catch estimates were compiled from the IATTC and WCPFC. F8_IATTC_LL included quarterly estimated catch of all longline vessels in the eastern Pacific Ocean as recorded by the IATTC for all flags other than Japan, Chinese Taipei, and the United States for 1983–2024. F9_WCPFC_LL included annual catch estimates, divided quarterly, of all longline vessels in the western Pacific Ocean as recorded by the WCPFC for all flags other than Japan, Chinese Taipei, and the United States for 1971–2024.

F10_VAR_PS_Other was the summation of catch from all flags and gear types Pacific-wide that were not included in any of the other catch fleets from 1971–2024. These included catch reported by both the IATTC and WCPFC for purse seine, troll, handline, harpoon, and miscellaneous or unspecified gears.

The historical maximum estimated annual BUM catch by weight was 27,072 mt in 2003. The historical minimum reported catch was 9,345 mt in 1971. Annual estiamted catch by weight declined from 24,821 mt in 2016 to 12,958 mt in 2023, with a notable one-year increase of over 25% to 17,738 mt in 2024.

3.2.4 Abundance Indices

The six CPUE indices used in the 2026 Pacific blue marlin stock assessment (Table 3) were assigned to the modal quarter of the highest catch of the corresponding harvest fleet based upon the recommendations of the member providing the index. This corresponded to the first quarter for all indices except S8_US_LLdeep, which was assigned to the second quarter. The CPUE indices were all from longline fishing fleets and are in units of number of fish per thousand hooks. The CPUE indices were assumed to be linearly proportional to biomass, where catchability (q) was assumed to be constant and the survey fleet was attributed to the first month of the quarter assigned.

The CPUE indices for the Japanese “Early” period (S1) and “Late” period (S9) were divided in 1993 because of significant changes in the logbook reporting system, which required the CPUE data to be standardized in different time periods. The indices were standardized and annual standard error (SE) in natural log-scale (*ln(SE)*) were estimated using a habitat modeling-based standardization approach (Jusup and Kai 2026a) .

There were 3 CPUE indices from Chinese Taipei which were standardized over three separate time periods (“Early”, S4; “Mid”, S5; and “Late”, S10) due to changes in the logbook reporting for the longline fleet, with breaks in 1978/1979 and 1999/2000. The indices were standardized and *ln(SE)* were estimated from the distant water tuna longline fishery logbook data using a spatio-temporal delta-lognormal generalized linear mixed modeling framework (Yeh and Chang 2026a).

There was a single CPUE index provided by the United States (S8_US_LLdeep) which was based on logbook data for longline deep-sets only; although shallow-sets targeting swordfish do catch some Pacific blue marlin, most catch is on deep-sets targeting tunas. Hence, choosing only a single set type for the index could help eliminate artifacts caused by high zero-catch sets from the shallow-set, and interannual variability in fishing fleet targeting behavior. The index was standardized and *ln(SE)* were estimated from logbook data using a generalized linear mixed modelling approach (Sculley 2026a).

An *a priori* analysis of the CPUE indices was conducted to evaluate the potential for conflict within the indices. The analysis was performed based upon the methods from the ‘diags’ component of the FLCore package (version 2.6., Kell et al. 2007) in R (version 4.5, R Core Team 2026). This analysis provides a standardized method to plot and summarize CPUE data so that modelers can better evaluate their input data into assessment models. Each CPUE index was fit using a LOESS smoother with only year as an explanatory variable, and the residuals from that smoother were examined graphically. Next, all CPUE indices were fit together by a single LOESS smoother using fleet as an explanatory factory, and the residuals of each index to the overall fit were examined. A pairwise correlation analysis was used to evaluate similarities and discrepancies in the trends of each pair of indices. Finally, a hierarchical clustering analysis using a set of dissimilarities was conducted to identify significant clusters of indices.

Visual inspection of the CPUE timeseries indicates both S5_TWN_LTLL_Mid and S9_JPN_LL_Late show strong decreasing trends over time, whereas other indices, particularly S8_US_LLdeep show less contrast (Figure 5). All 3 indices from the recent time period show a variable or decreasing trend in the last 10 years, with S10_TWN_LTLL_Late indicating sudden increase in CPUE in 2024 (

Table 3). Both the Japan and Chinese Taipei indices show a rapid increase in the 1970s–1980s, followed by decline into 1990.

To look at deviations from the overall trends, the residuals from the overall LOESS smoother to each observation by index are compared in Figure 6. This allows for conflicts between indices to be highlighted by patterns in the residuals, autocorrelation within indices identified, which may be due to year-class effects, or the identification of other potentially important factors not included in the standardization of the CPUE. The results highlight potentially strong conflict between S1_JPN_LL_early and S5_TWN_LTLL_Mid, which suggests these indices may be sampling different segments of the Pacific blue marlin population, either demographically or spatially. It is also notable that both Japan and Chinese Taipei late indices (S9 and S10) showed a sharp increase in CPUE in the final year (2024) that could not be explained by the overall LOESS smoother function. This is consistent with a large increase in the CPUE indices and the reported catch of small Pacific blue marlin throughout the Pacific, which the BILLWG believes indicates a strong recruitment pulse that may have occurred during the 2020s COVID period.

Most of the temporally overlapping CPUE indices have moderate to strong positive correlations (Figure 7). S1_JPN_LL_early appears to be positively correlated with the S5_TWN_LTLL_mid (corr = +0.68) and the S9_JPN_LL_Late appears to be positively correlated with S8_US_LLdeep (corr = +0.71). The strongest negative correlation (corr = -0.49) occurred between S5_TWN_LTLL_mid and S8_US_LLdeep, suggesting potential conflict between these two indices. The hierarchical cluster analysis suggests that S10_TWN_LTLL_Late may be dissimilar from the other indices, suggesting disagreement between the underlying trends of the stock sampled (Figure 8). However, the apparent uniqueness of S10_TWN_LTLL_Late may also be driven by the anomalously high 2024 CPUE estimate for this index.

3.2.5 Size Composition Data

Six size composition time series, by year and quarter, were used in the 2026 Pacific blue marlin stock assessment (Table 1); five as length composition data (Figure 9) and one as weight composition data (Figure 10). All length composition data were input as counts per 5 cm bin between 50 and 320 cm eye to fork length (EFL). In the data and as used in SS3, all length and weight bins are lower edge inclusive, e.g., the 70 cm length bin is all individuals 70 cm and larger, but less than 75 cm. The very few individuals recorded under 50 cm were added to the 50 cm bin in the input data.

Length composition data were used in the stock assessment for all years of the Japanese longline fleets F1 (early) and F2 (late) for 1971–2024. Length data for the JPN late longline fleet initially included as a mix of specified female, male, and unknown (combined) lengths. However, initial analyses of these length data revealed that only 10–20% of fish identified to sex in these fleets were female, and it was unlikely that the wide spatial coverage of these fleets would cause such vastly different selectivity of the sexes, therefore, all length observations for Japanese fishing and survey fleets were input to the SS3 models as combined sex for this assessment.

Length composition from IATTC purse seine vessels were used for F10_VAR_PS_Other. These data were available starting in 1990, however, only size composition data from 2006–2024 were included in the final base model because improved size composition recording in 2006 revealed earlier data were not complete (ISC 2026b). Similarly, length composition data were initially included starting in 1994 for F11_US_LL, however, preliminary analyses revealed an abrupt shift in apparent size composition from small to larger fish in 2004 was likely due to a shift in reporting, not behavior of the fishing fleet. Therefore, only size data starting in 2004 were included for F11_US_LL. Length data for F11_US_LL were included as a mix of specified female, male, and combined lengths, allowing for differential female and male selectivity.

The longline fleets caught fish with a mean of around 160–180 cm EFL, with the largest fish observed in the F2_JPN_LateLL is the 1990s. The F5_TWN_LTLL fleet was characterized by a more defined mode in length comps at approximately 175 cm EFL from 2005–2024. F10_VAR_PS_Other length composition data were from purse seine gear, and showed the largest average size of approximately 200 cm EFL 2006–2024.

Size composition data by weight (kg) for F4_JPN_DRIFT_BAIT were used in the model. Weight compositions are referred to as “generalized size compositions” in SS3 and bins can be specified differently among fleets or irregularly binned to be narrower at smaller weights when fish are expected to grow quickly, and wider at larger weights. For F4_JPN_DRIFT_BAIT, weight data were available sporadically between 1977 and 1998, and were binned in 10 kg increments from 30 to 150 kg, and 20 kg increments from 160 to 320 kg, with individuals less than 30 kg comprising the smallest bin. Most fish from F4_JPN_DRIFT_BAIT were 90–140 kg.

The BILLWG originally sought to conduct this assessment using area-specific indices and size composition data (divided by 170°W longitude) for the JPN and TWN late longline fleets to account for the common observation that blue marlin caught in the eastern Pacific ocean and farther from the equator were larger (as shown in the conceptual model developed by the BILLWG at the data preparatory meeting; Figure 1Figure 2). However, strong data conflicts were apparent during stock assessment development and the BILLWG ultimately decided to return to the single-area indices and size composition data similar to the approach in the 2021 Assessment (ISC 2021), although a model run with the east-west definition was included in the Sensitivity Analyses.

3.2.6 Model Description

This assessment was conducted with Stock Synthesis (SS3) version V3.30.24.1-safe released September 18, 2025 using ADMB version 13.2. (Methot and Wetzel 2013). All model specifications were discussed at the BILLWG Data Preparatory Meeting (ISC 2026a) and finally agreed upon by the BILLWG at the Assessment Meeting (ISC 2026b). The model has a single area with two sexes and four seasons (quarters). Spawning was assumed to occur July 1, while annual recruitment was assumed to occur Aug 1. Sex-specific growth parameters were from the Chang et al. (2025) 2-stanza growth model, re-parameterized for the SS3 Schnute-Richards formulation using Growth_Age_for_L1= 0.5 years and Growth_Age_for_L2 = 27 years (Table 4; Figure 11). Weight was assumed to be an allometric function of length, female maturity was a logistic function of length (Table 4; Figure 12 Figure 13), and the fraction female at recruitment was fixed at 0.5. The first mature age was 2 years and fecundity was proportional to mature female spawning biomass. Natural mortality was sex- and age-specific based on the maximum age estimator using Lorenzen scaling of the updated Chang et al. (2025) two-stage growth model as detailed in Brodziak (2026) (Table 5).

The stock-recruitment relationship followed a Beverton-Holt spawner-recruit model with steepness (*h*) fixed at 0.87 in the base model (Brodziak et al. 2015). Main recruitment deviations were estimated from 1975–2024 which summed to zero and sigmaR (σ_r) was fixed equal to 0.4. Early recruitment deviations were estimated from 1961–1974 to enable the population to have non-equilibrium length and age composition at the start of the model. Recruitment deviations were bias-adjusted based upon the estimates from Methot and Taylor (2011), ramping linearly between zero in 1959 to 0.88 in 1973, with full bias adjustment continuing until the terminal year of the model.

The base case assessment model start year was 1971, however, historical catch data indicate the Pacific blue marlin stock has experienced fishing since at least 1950, and hence would be in a fished condition in 1971. Initial *F* was estimated assuming equilibrium catch equal to the average of the total estimate catch for 1968–1972 from the WCPFC Yearbook data. This catch amount was assigned entirely to F1_JPN_EarlyLL during the first quarter.

3.2.7 Data Observation Models

The assessment model fit three data components: 1) total catch; 2) relative abundance indices; and 3) size (length or weight) composition data. The observed total catches were assumed to be unbiased and relatively precise, and were fitted assuming a lognormal error distribution with standard error (*SE*) of 0.05. The relative abundance indices were assumed to have lognormally distributed errors with SE in log-space (*ln(SE)*) which was $log(SE) = \sqrt{log(1 + CV^2)}$, where CV is the standard error of the observation divided by the mean value of the observation.

Four of the six indices' *ln(SE)* were increased from the estimates from the CPUE standardization values by an annual additional amount, ranging from 0.002 for S1_JPN_LL_early to 0.176 for S5_TWN_LTLL_Mid (Table 6). The amount of additional *ln(SE)* was agreed to by the BILLWG at the Stock Assessment Workshop and was chosen to increase each index *ln(SE)* within the assessment model to the root-mean-square-errors (RMSE) displayed by that index.

The six CPUE indices were assigned to the modal quarter of the highest catch of the corresponding harvest fleet based upon the recommendations of the country providing the index. This corresponded to the first quarter for all indices except S8_US_LLdeep, which was assigned to the second quarter. The CPUE indices were assumed to be linearly proportional to biomass, where catchability (*q*) was assumed to be constant and was freely estimated for each index.

The size composition data were assumed to follow a multinomial error distribution with the variance determined by effective sample sizes. Measurements of fish are usually not random samples from the entire population. Rather, they tend to be highly correlated within a set or trip (Pennington et al. 2002). The effective sample size is usually substantially lower than the actual number of fish measured because the variance within each set or trip is substantially lower than the variance within a population. The initial sample sizes (effective sample size; *effN*) were calculated consistently across all fleets for the SS3 input. First, any quarter with fewer than 15 individuals measured was excluded. For fleets with sex-specific length data, length information was entered in two matrices: a combined-sex (unspecified) matrix and a female-male matrix. Any quarter in which fewer than 30 individuals were measured for either females or males was re-assigned to the combined-sex. The *effN* inputs to SS3 were calculated as the number of individuals measured for each quarter and sex (combined or female-male), divided by 10, and capped at 50 to reduce the influence of quarters with very large sample sizes.

3.2.8 Data Weighting

Index data were prioritized in this assessment based on the principle that relative abundance indices (CPUEs) should be fitted well because abundance indices are a direct measure of population trends and scale, and other data components such as size composition data should not induce poor fits to the abundance indices (Francis 2011). To achieve this, size composition data were adjusted among fleets and downweighed relative to other likelihood components following a modified Francis (2011) multinomial distribution T.A1.8 approach, as agreed upon by the BILLWG at the stock assessment meeting (ISC 2026b). First, the model was fit on the input *effN* values previous described. The resulting fitted model variance was compared to the input data variance using the R package r4ss (Taylor et al. 2017) function tune_comps() to yield the recommended Francis (2011) multinomial distribution T.A1.8 *effN* multiplier for each size composition fleet. These "tuning" suggestions are scalars that can be used to adjust the *effN* for each size composition fleet, and balance the relative informativeness among the size composition fleets. Values greater than 1 decrease the observed variance of the input data, giving it more "weight" within the SS3 likelihood function. For this assessment, these suggested tuning scalars ranged from 1 to 4.1 (Table 7). In order to reduce the contrast between fleets, these values were natural log transformed and then scaled to 0.2 to reduce the overall influence of size compositions relative to other components (such as CPUE indices) within the model likelihood. In order to prevent any fleet's size composition data from losing influence in the likelihood altogether, the final effN adjustments were assigned a minimum value of 0.1.

3.2.9 Estimation of Fishery Selectivity

Selectivity was estimated as a double-normal curve for 5 or the 6 fishing fleets with size composition data, whereas only F10_VAR_PS_Other was assumed to follow logistic selectivity (Table 8). The parameters of the double-normal selectivity function were unconstrainted, therefore the model had the flexibility to adopt a function where selectivity at maximum size was greater than zero, including equal to 1 to mimic a logistic selectivity function. F2_JPN_LateLL had time-varying selectivity with two sets of double-normal selectivity function parameters estimated independently for 1994–2003 and 2004–2024 to account for a sudden shift in selectivity occurring in 2004 that was apparent in the size composition data. F11_US_LL, which had sex-specific length composition data, had 4 additional estimated parameters to allow for differential male and female selectivity. Selectivity for the fleets that lacked size composition data were assumed to equal (mirror) the fitted selectivity for F5_TWN_LTLL. All survey fleets in this assessment are fishery-dependent, hence were mirrored to the fishing fleets from which the indices were calculated.

3.2.10 Convergence Criteria

The model was assumed to have converged if the standard error of the estimated parameters could be derived from the inverse of the negative Hessian matrix. Various convergence diagnostics were also evaluated. Excessive CVs (>50%) on estimated parameters would suggest uncertainty in the parameter estimates or model structure. A gradient of >0.001 would suggest poorly fit parameter estimates. The correlation matrix was also evaluated to identify highly correlated (>95%) and non-informative (<0.01) parameters. Parameter estimates at or near numeric bounds were also indicative of poor model fit.

3.2.11 Model Diagnostics

Several diagnostics have been evaluated for their utility to identify data conflicts and model misspecification within integrated stock assessment models (Carvalho et al. 2017). However, Carvalho et al. conclude there is no single diagnostic that can be used to identify a misspecified model, instead, the authors suggest simultaneously considering a range of diagnostic results, such as goodness-of-fit measures for indices of abundance and size composition data, runs tests, likelihood profiles of leading parameters, retrospective analysis, hindcasting/cross-validation analyses, and comparison to results from different population models (Carvalho et al. 2017, 2021).

3.2.11.1 Goodness-of-Fit Indices of Abundance

Residuals are examined for patterns to evaluate whether the model assumptions have been met. Many statistics exist to evaluate the residuals for desirable properties. One way is to calculate, for each abundance index, the root-mean-square-error (RSME) was used as a goodness-of-fit diagnostic, with relatively low RMSE values (i.e., RMSE < 0.3) being indicative of a good fit.

3.2.11.2 Goodness-of-Fit Size Composition Data

Comparisons between the observed and expected mean values of composition data from Francis (2011) were used for model diagnostics. Pearson residuals for size composition data fits were also used as a model diagnostic.

3.2.11.3 Runs Test

The runs test evaluates the residuals of the CPUE indices and size composition mean length trends. This is a nonparametric test for randomness in the sequence of residuals relying on a 2-sided p-value to estimate the number of positive or negative residuals in a row (i.e., a "run"; Wald and Wolfowitz 1940; Carvalho et al. 2021). The runs test can be applied to CPUE or size composition data. A p-value less than alpha = 0.05 suggests residuals are not random and instead exhibit a pattern over time, hence the model is unable to fit the data well and may be mis-specified.

3.2.11.4 R_0 likelihood profile

An R_0 likelihood component profile was performed by sequentially fixing the equilibrium recruitment parameter, R_0, on the natural log scale, ($ln(R_0)$), to a range of values. The relative change in negative log-likelihood units over the range of fixed values for *ln(R_0)* (the R_0 profile) was compared among the SS3 model likelihood components for CPUE, size composition, initial equilibrium catch, and recruitment deviations using several criteria. First, a relatively large change in negative log-likelihood units along the R_0 profile was diagnostic of a relatively informative data source for that particular model. Second, a difference in the location of the minimum negative log-likelihood along the R_0 profile among data sources was diagnostic of either conflict in the data or model misspecification.

3.2.11.5 Retrospective analysis

Retrospective analysis is a way to detect bias and model misspecification (Hurtado-Ferro et al. 2015). A retrospective analysis was implemented by sequentially eliminating the five most recent years of data from the full stock assessment base model (a 5 year "peel") and then re-estimating all stock assessment model parameters from each peel and from the full model. Then Mohn's rho was calculated for the biomass and fishing mortality peels, which measures the severity of the retrospective pattern. Values higher than 0.20 and lower than -0.15 can indicate problematic retrospective patterns and may point to model misspecification, data conflicts, or poor fits to the data.

3.2.11.6 Prediction skill

In addition to evaluating the retrospective patterns of the model, understanding how well a model predicts future years is key to evaluating projections. To do so, hindcasting cross-validation was used to predict the next years' observed data from the retrospective peel (Carvalho et al. 2021). Then the forecast bias is estimated by comparing the forecasted values from the retrospective peel to the full model. To evaluate the predictive skill, the mean absolute scaled error (MASE) is used to determine if the predicted value improves the model forecast compared to the baseline. A MASE score of >1 indicates that the average model forecasts are worse than a random walk model, and a value of 0.5 indicates the model has prediction skill. The hindcasting cross-validation and MASE scores were calculated for the five CPUE indices in the last five years of the assessment.

3.2.11.7 Age-structured production model

An age-structured production model (ASPM: Maunder and Piner 2015; Carvalho et al. 2017) was implemented by fixing selectivity to the estimated values from the SS3 base model, fixing recruitment equal to the stock recruitment curve obtained from the fully integrated stock assessment model, and then estimating the remaining parameters of the stock assessment model. Trends in relative spawning stock size were compared from the fully integrated stock assessment model and the ASPM.

Carvalho et al. (2017) suggests that if the ASPM is able to fit well to the indices of abundance that have good contrast (i.e. those that have declining and/or increasing trends), then this is evidence of the existence of a production function, and the indices will likely provide information about absolute abundance. On the other hand, Carvalho et al. (2017) suggests that if there is not a good fit to the indices, then the catch data alone cannot explain the trajectories depicted in the indices of relative abundance. This can have several causes: (i) the stock is recruitment-driven; (ii) the stock has not yet declined to the point at which catch is a major factor influencing abundance; (iii) the base model is incorrect; or (iv) the indices of relative abundance are not proportional to abundance.

3.2.12 *Sensitivity Analyses*

The BILLWG agreed to conduct a series of sensitivity analyses (Table 9) to examine the effects of plausible alternative model assumptions and data input to the stock status. These analyses were:

(1) **Sensitivity analysis on alternative catch estimates**: The BILLWG conducted four sensitivity analyses for alternate catch inputs. These were: start the model in 1950 with input estimated catches back to that year; include estimated additional catch for the F5_TWN_LTLL to account for underreported catch from foreign ports; modify catch by 10% (increase and decrease) for all years/fleets to account for possible discards and species misidentification.

(2) **Sensitivity analysis on alternative data inputs and error assumptions**: There were four sensitivity analyses for alternate model input data configurations. These included splitting the Japan and Chinese Taipei late longline survey indices and size composition data into separate "East" and "West" components, divided by 170°W longitude, to account for expected differences in the size selectivities of the longline fleets in these two areas. There was also a sensitivity run using weight composition data for the Chinese Taipei longline fishing fleets (F5 and F6) instead of the length composition data for fleet F5 in the base model. Finally, the BILLWG investigated the effects of assuming time-varying catchability in the Chinese Taipei late longline index (S10) and estimating additional error for all CPUE indices except S1_JPN_LL_late within the SS3 model.

(3) **Sensitivity analysis on natural mortality**: The BILLWG conducted three sensitivity analyses for natural mortality (M)-at-age. These included using Ms-at-ages that were one standard deviation lower (low M) and one standard deviation higher (high M) than the base value according Brodziak (2026). The alternate estimation approach presented in Brodziak (2026) that relied on updating the meta-analysis estimates of M at age was also included as a sensitivity run.

(4) **Sensitivity analysis on steepness**: The BILLWG conducted three additional sensitivity runs on steepness (h). Steepness was fixed at higher value (h=0.95), lower value (h=0.75), and much lower value (h=0.65) compared to the base case value (h=0.87).

(5) **Sensitivity analysis on growth**: Three sensitivity runs on growth were conducted. These included using the 25th and 75th percentile of posterior parameter estimates from the base two-stanza growth model (Chang et al. 2025), as well as identical parameters to those used in the "New Growth" model from the 2021 Pacific blue marlin stock assessment (ISC 2021).

(6) **Sensitivity analysis on maturity**: The BILLWG conducted two sensitivity runs on the value of the inflection point for the logistic maturity at length function. The length at 50% female maturity was fixed at values 10% higher and lower than the base case value.

(7) **Sensitivity analysis on length-weight**: The BILLWG conducted three sensitivity runs on the β parameter within the function of weight at length within the model: $W_L = \alpha L^{\beta}$: 10% higher and lower than the base case value (2.956 for females and 2.975 for males) and fixed equal to 3.0.

(8) **Sensitivity analysis on initial conditions**: The BILLWG conducted four additional sensitivity runs to explore the effects of assumptions made regarding the exploitation of the stock at the start of the model in 1971 and the associated equilibrium length compositions, which can be influenced by estimated early recruitment deviations. These sensitivity runs included estimating F in 1970 freely (without any equilibrium catch data input); modify equilibrium catch to 50% and 200% of

the 1968–1972 average value from the base model; and estimate main recruitment deviations beginning in 1990 together with early recruitment deviations beginning in 1981.

3.2.13 Future Projections

Deterministic future projections were conducted in SS3 to evaluate the impact of various levels of fishing mortality on future SSB and yield. Bootstrap model input datasets (N=100) were created using the SS3 bootstrap function and were minimized as was done for the base model. Future stock projections were then run for each bootstrapped model to estimate the uncertainty around future stock status. The future projection routine calculated the future SSB and yield that would occur, assuming relative fishing mortality among fleets equal to average 2021–2023, terminal year selectivity (2024), and no deviations from the stock-recruit relationship. The projections started in 2025 and continued through 2034 under fishing mortality levels corresponding to four harvest scenarios:

1. **High F Scenario** (**F_{High}**): Apply the fishing mortality rate corresponding to the maximum fishing intensity (SPR) over the timeseries, which occurred in 2003;
2. **F_{MSY} Scenario** (**F_{MSY}**): Apply the estimate of the F_{MSY} fishing mortality rate to the stock estimates beginning in 2025;
3. **2021–2023 F Scenario** (**F_{recent}**): Apply the fishing mortality rate corresponding to the average fishing intensity (SPR) from 2021–2023;
4. **$F_{30\%SPR}$ Scenario** (**$F_{30\%SPR}$**): Apply the fishing mortality rate corresponding to SPR = 30%.

3.3 Results

3.3.1 Estimated Selectivity

Estimated model selectivity suggests Pacific blue marlin are fully selected by the JPN longline fishing fleets at approximately 155 cm EFL whereas the TWN LTLL fleet selects for larger individuals, with fish fully selected at just over 200 cm EFL (Figure 14). The mixed gears within the JPN driftnet and baitfish fishery catch a narrower range of large fish (205 cm EFL). The size composition data from IATTC purse seine catch was applied to the aggregated purse seine catch Pacific-wide and included small amounts of catch from other non-longline gears not included in other fleets (F10_VAR_PS_Oth). This was the only fleet with assumed logistic selectivity and selected for the largest fish (50% selected at 190 cm EFL and 95% selected at approximately 220 cm EFL). Sex-specific selectivity in the U.S. LL fleet suggests that females are never more than 50% selected (likely caused by limited spatial overlap between the fishery near the equator and the larger females at more northern latitudes), whereas males are fully selected by 170 cm EFL. Selectivity of the JPN LL fleet during the late period was time-varying, being roughly logistic 1994–2003 and dome-shaped 2004–2024 (Figure 15).

3.3.2 Estimated Recruitment Deviations

Estimated recruitment deviations were negative from 1961–1976 (Figure 16), suggesting that an era of particularly poor recruitment allowed improved model fit to the positive trend in CPUE from the early timeseries (see Goodness-of-Fit for CPUE indices). Recruitment deviations fluctuated between periods of positive and negative values for the remainder of the timeseries, and anomalously poor recruitment occurred in 1998–1999 and a very strong recruitment was estimated in 2023. However, it is important to note variance on the recruitment deviation estimates was high, and the 95% confidence intervals spanned zero in all years, suggesting information to estimate recruitment deviations were sparse in the base model.

3.3.3 Model Convergence

All estimated parameters in the base model were within the set bounds, the final gradient of the model was 8.6×10^{-5}, and the Hessian matrix for the parameter estimates was positive definite, indicating the model converged to a minimum. Only one of the 30 model runs using jittered starting parameter values failed to converge. Of the converged models, 6 runs had unreasonably high estimates of the initial F parameter (>2.77) and exhibited unlikely biomass trends over time and smaller $\ln(R_0)$ estimates (Figure 17). One run had an estimated initial F value close to zero, suggesting the stock was unfished in 1971, which is contrary to available data from the Pacific longline fisheries going back to at least 1950. Most jitter runs converged at $ln(R_0)$ = 6.98437, which was the estimate of the base model (Figure 18). The jitter analysis indicates a global minimum was obtained (i.e., there was no evidence of a lack of convergence), however, alternate local minimums within the negative loglikelihood surface exist with very different (albeit unreasonable) values estimated for initial F, indicating that initial F estimation is a source of some uncertainty in the base model.

3.3.4 Model Diagnostics

3.3.4.1 Goodness-of-Fit for CPUE indices

Goodness-of-fit diagnostics are in Table 6, and plots of predicted and observed CPUE by fleet for the base model are shown in Figure 19. Root-mean-square-errors (RMSE) was smaller than 0.3, suggesting good fit, for all indices except for S5_TWN_LTLL_Mid. S5_TWN_LTLL_Mid was characterized by high contrast over a period of 21 years and also had the greatest negative correlation with another index as indicated by the correlation analysis (Figure 7), hence it is expected that this index would present a challenge to model fit.

3.3.4.2 Residuals Analysis of Size Composition Data

Comparisons between the timeseries aggregated size composition data and the base model indicate general agreement of modes, but suggest some misfitting, particularly in the JPN LL fleets that tend to underestimate the smallest and largest sizes (Figure 20Figure 21). Fits to the annual length compositions by fleet generally fail to capture the full magnitude of trends in size over time (Figure 22) and some patterns in the residuals persist (Figure 23). This is an important area for future data improvements and model development. Increased spatial resolution of size data or sex-specific size compositions for more fleets may allow for improved model fit.

3.3.4.3 Runs test

The CPUE indices for four of six fleets passed the runs test (Figure 24). Index fits for the TWN Late and U.S. LL fleets did not pass the runs test, and showed several strong runs of positive or negative residuals to the model fit. The size composition time series by season for two of the six fleets with size data passed the runs test (Figure 25Figure 26). So, although the model fit average annual size data somewhat (Figure 22), it generally failed to capture the full range of size trends over time, resulting in periods of positive and negative residuals that are particularly amplified by the seasonal basis of the runs test.

3.3.4.4 ln(R_0) likelihood profile

Profiles of change in total loglikelihood for values of ln(R_0) ranging from approximately 6.28 to 7.68 indicate length composition provides the majority of the information for population scale, whereas the index component contributes less, yet the maximum likelihood estimates of ln(R_0) generally agree (Figure 27). The total index loglikelihood was primarily driven by the JPN LL Late, TWN LL mid, and the US LL indices (Table 10 and Figure 28). Size compositions from the JPN LL Late and the purse seine/various flags and gears fleet (F10_PS_Var_Other) were the primary drivers of the loglikelihood profile of *ln(R_o)*, but the maximum likelihood value of *ln(R_o)* was within +/- 0.2 of the base model for all fleets except TWN and US LL fleets (Table 11

Table 12; Figure 29Figure 30), suggesting general agreement among data sources.

3.3.4.5 Retrospective Analysis

A retrospective analysis was conducted for the last 5 years of the assessment to evaluate whether there were any strong changes in parameter estimates through time (Figure 31). The trajectories of estimated SSB and F showed there was a slight tendency of overestimation for SSB in recent years and underestimation for F. The Mohn's rho for SSB (+0.05) and F (-0.04) were close to zero, suggesting the retrospective pattern is not substantial. However, such strong agreement among retrospective runs may indicate terminal years' data have little influence on the model, hence the model may be primarily sensitive to other components, such as early catch or CPUE timeseries, initial F, recruitment deviations, or life history assumptions.

3.3.4.6 Prediction skill

Results of the hindcast with cross-validation indicate two of the three CPUE indices within the last five years of the assessment had MASE scores greater than or equal to one, indicating a poor predictive ability of the model (Figure 32). The JPN LL Late CPUE index had the worst predictive ability, as two of the five predicted years were outside of the 95% confidence interval of the CPUE index and had a MASE score of 1.48. The TWN LTLL Late index had the best predictive skill (MASE=0.88) but was generally flat until the terminal year. The BILLWG noted prediction skill of models is often low in the terminal years of data, and is expected to be particularly challenging given the possible increase in stock biomass suggested by the jump in 2024 CPUE values for the JPN and TWN longline fleets.

Predictive skill for the length composition data was better than for the CPUE data, indicated by all four fleets having MASE values less than 1 (Figure 33). Further, all but one of the predicted length composition data points were within the 95% confidence intervals of the original input data. However, length over time has been fairly consistent from 2019–2024, hence the model is predicting no changes in length over time, and subtracting uninformative data is not expected to influence model predictions away the recent average.

3.3.4.7 Age-structured production model

Results from the ASPM model showed a nearly identical population trend as the full model but suggested a much narrower 95% confidence interval (Figure 34). This suggests the catch and CPUE indices alone provide sufficient information to understand the underlying production of the stock, however the size composition data and deviation from the spawner-recruit relationship provide valuable inference on model uncertainty. The two models show slight divergence in the final 5 years, indicating that the sudden increase in two of the three CPUE indices in 2024 is having a strong influence on the estimated stock biomass absent information from the size composition data.

3.3.5 Stock Assessment Results

Initial estimates of Pacific blue marlin female SSB were 133,100 mt in 1971, and then steadily declined to an average of 39,600 mt from 2007–2020, followed by a 19% increase to 47,240 mt in 2024, which is the highest SSB since 2001 (Table 13 and Figure 35). SSB has been relatively stable and the median value has been above SSB_{MSY} for the entirety of the assessment period.

Estimates of population biomass (age 1 and older) generally tracked SSB over time, declining from 183,150 mt in 1993 to 123,300 mt in 1999, with a steady further decline to average 102,490 mt in 2021–2023, and a terminal year increase to an estimated 127,300 mt in 2024 (the highest level since 1998).

Estimated fishing mortality rate (F, expressed as exploitation rate of biomass) increased through the 1970s–1990s, and fluctuated around 0.2 before declining to 0.12 in 2023 and 0.14 in 2024. Previous ISC stock assessments for Pacific blue marlin reported fishing mortality rate as the instantaneous average rate for ages 1–10, which we report in this assessment for consistency. Reported as exploitation rate of biomass, F exhibited greater contrast and volatility during the timeseries, increasing from 0.04 in 1971 to maximum 0.23 in 2003. Expressed as the instantaneous rate averaged of ages 1–10, F increased from 0.06 to 0.20 over the same time period. Regardless of the units used, fishing mortality rate has been below F_{MSY} for the entire assessment period.

Estimated annual recruitment (age-0 fish) averaged approximately 935,900 individuals during 1971–2024 and showed interannual variability averaging 2.7% change but otherwise did not exhibit an overall trend. There were several years with notably lower recruitment, including 1994–1997, and some particularly strong recruitment years in 1976, 1991, and 2023. However, estimated recruitment in 2023, which was the second highest value of the timeseries and only 1 year before the terminal year of the assessment, is not well estimated in the model.

3.3.6 Biological Reference Points

MSY-based biological reference points and a depletion-based reference point (20% of virgin population mature female biomass; denoted 20%SSB_0) were computed for the base model (Table 14). The point estimate of annual catch at F_{MSY} was 24,306 mt and at 20%SSB_0 was 24,119 mt. The point estimate of the female spawning stock biomass to produce MSY (mature female biomass) was 31,651 mt. The point estimate of F_{MSY}, the fishing mortality rate to produce SSB_{MSY} was 0.26 (when F is calculated as exploitation of total biomass) or 0.22 (when F is calculated as average F for ages 1–10). $F_{20\%SSB0}$, the fishing mortality rate to maintain the population at 20%SSB_0 was 0.23 (F as exploitation rate of total biomass) or 0.20 (average F for ages 1–10). The corresponding equilibrium value of spawning potential ratio (SPR) at SSB_{MSY} was 19.6%; SPR corresponding to 20%SSB_0 was 23%.

3.3.7 Stock Status

The recent spawning biomass of 42,038 mt (average for 2021–2023) was approximately 1.3 times higher than SSB_{MSY} (SSB_{MSY} = 31,651 mt) and the recent F (average for 2021–2023) was 52% F_{MSY}. The base model indicated under current conditions the Pacific blue marlin stock was virtually certain to be not overfished (>99% probability) and was virtually certain to not be subject to overfishing (>99% probability) relative to MSY-based reference points (Figure 36).

3.3.8 Sensitivity Analyses

The BILLWG completed all 24 of the 26 sensitivity runs and compared the SSB and the F trajectories to those of the base model (Figure 37). The only sensitivity cases where the model failed to minimize were the +/- 10% β value within the length-weight relationship. The BILLWG also produced a Kobe plot to compare the stock status of the recent years among 24 sensitivity runs (Figure 38).

The sensitivity analyses run for this assessment indicated the model is most sensitive to growth, natural mortality, and maturity assumptions, and somewhat sensitive to alternate size composition data inputs. However, estimated SSB and F in the later years of the model are relatively robust to potential errors in observed catch, assumed spawner-recruit steepness, or alternate approaches to estimating initial F.

3.3.9 Stock Projections

Future projections showed the trajectories of SSB and catch for 2025–2034 for four scenarios (Future Projections). For the F_{Recent} scenario, which is based on the relatively low catch years of 2021–2023, projected catch would be below 2024 levels for the first three years (range 16,158 to 17,505 mt) and would increase to only 80% of MSY by the last projection year (Table 15; Figure 39Figure 40). Projected catches below MSY in this F_{Recent} scenario would be concurrent with an increase of biomass to well over SSB_{MSY} by 2034. The projections suggest fishing the stock at F_{MSY} would be associated with an immediate increase to well over the historical maximum catch, followed by a decrease to MSY by 2034 as the SSB is depleted. The other two projection scenarios exhibited SSB and Catch trends intermediate between the F_{Recent} and F_{MSY} scenarios, because even the peak F estimate of 2003 was less than F_{MSY}, and catch is expected to initially increase, then drop, over the projection period as the SSB becomes depleted. The most consistent catch scenario over the next 10 years was $F_{30\%SPR}$, where annual catches for 2025–2034 would be essentially constant at approximately 23,000 mt per year.

3.4 Conclusions

3.4.1 Conservation information

The Pacific blue marlin stock has produced annual yields from 13,690–20,400 mt per year since 2019, or about 53–84% of the MSY catch amount. This suggests the stock may be able to support somewhat higher yields. Pacific blue marlin stock status is positive with no evidence of excess F above F_{MSY} or substantial depletion of spawning potential or spawning stock biomass relative to MSY.

3.5 Acknowledgments

We thank the fishery stakeholders, data providers, and participants in the ISC Billfish Working Group meetings for their help in preparing and providing information for this assessment of Pacific blue marlin.

3.6 References

Brodziak, J. 2013. Combining Information on Length-Weight Relationships for Pacific Blue Marlin. ISC/13/BILLWG-1/01.

Brodziak, J. 2026. Natural Mortality Rates for the Pacific Blue Marlin Stock. ISC/26/BILLWG-01/05.

Brodziak, J., M. Mangel, and C. Sun. 2015. Stock-recruitment resilience of North Pacific striped marlin based on reproductive ecology. Fisheries Research 166:140–150.

Carlisle, A. B., E. Randall, M. C. Arostegui, J. E. Ganong, and B. A. Block. 2016. Influence of temperature and oxygen on the distribution of blue marlin (*Makaira nigricans*) in the Central Pacific. Fisheries Oceanography (July 2015):1–15.

Carvalho, F., A. E. Punt, Y. Chang, M. N. Maunder, and K. R. Piner. 2017. Can diagnostic tests help identify model misspecification in integrated stock assessments? Fisheries Research 192:28–40.

Carvalho, F., H. Winker, D. Courtney, M. Kapur, L. Kell, M. Cardinale, M. Schirripa, T. Kitakado, D. Yemane, K. R. Piner, M. N. Maunder, I. Taylor, C. R. Wetzel, K. Doering, K. F. Johnson, and R. D. Methot. 2021. A cookbook for using model diagnostics in integrated stock assessments. Fisheries Research 240:105959.

Chang, Y., T. Shimose, X. Chang, A. Furuyama, J. Hsu, M. Kanaiwa, W. Chiang, J. K. T. Brodziak, M. Kai, H. Ijima, M. L. Sculley, and M. J. Kinney. 2025. Estimation of the two-stanza growth curves with age determination uncertainty for Pacific blue marlin (*Makaira nigricans*) in the western and central North Pacific Ocean. ICES Journal of Marine Science 82(8).

Francis, R. I. C. C. 2011. Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68:1124–1138.

Hurtado-Ferro, F., C. S. Szuwalski, J. L. Valero, S. C. Anderson, C. J. Cunningham, K. F. Johnson, R. Licandeo, C. R. McGilliard, C. C. Monnahan, M. L. Muradian, K. Ono, K. A. Vert-Pre, A. R. Whitten, and A. E. Punt. 2015. Looking in the rear-view mirror: bias and retrospective patterns in integrated, age-structured stock assessment models. ICES Journal of Marine Science2 72(1):99–110.

Ijima, H. 2021. Update Japanese longline abundance index of Pacific blue marlin (*Makaira nigricans*) estimate by the habitat model. ISC/21/BILLWG-03/01.

ISC. 2021. Stock Assessment Report for the Pacific Blue Marlin (*Makaira nigricans*) through 2019. ISC/21/Annex/10.

ISC. 2026a. Report of the Billfish Working Group Workshop, 13-19 January, 2026. International Scientific Committee for Tuna and Tuna-like Species, Yokohama, Japan.

ISC. 2026b. Report of the Billfish Working Group Workshop, 28 April - 4 May, 2026. International Scientific Committee for Tuna and Tuna-like Species, Honolulu, Hawaii.

Jusup, M., and M. Kai. 2026a. Update of the Japanese longline index for Pacific blue marlin (*Makaira nigricans*) using the habitat model (1994-2024). ISC/26/BILLWG-01/06.

Jusup, M., and M. Kai. 2026b. Update of the Japanese catch and length-frequency data for Pacific blue marlin (*Makaira nigricans*) from 1971 to 2024. ISC/26/BILLWG-01/09.

Kell, L. T., I. Mosqueira, P. Grosjean, J.-M. Fromentin, D. Garcia, R. Hillary, E. Jardim, S. Mardle, M. A. Pastoors, J. J. Poos, F. Scott, and R. D. Scott. 2007. FLR: an open-source framework for the evaluation and development of management strategies. ICES Journal of Marine Science 64(4):640–646.

Maunder, M. N., and K. R. Piner. 2015. Contemporary fisheries stock assessment: many issues still remain. ICES Journal of Marine Science 72(1):7–18.

Methot, R. D., and C. R. Wetzel. 2013. Stock synthesis: a biological and statistical framework for fish stock assessment and fishery management. Fisheries Research 142:86–99.

Pennington, M., L.-M. Burmeister, and V. Hjellvik. 2002. Assessing the precision of frequency distributions estimated from trawl-survey samples. Fishery Bulletin 100:74–80.

R Core Team. 2026. R: A language and environment for statistical computing.

Sculley, M. 2026a. Standardization of Pacific Blue Marlin Catch Per Unit Effort in the Hawaii Longline Fishery from 1995-2024. ISC/26/BILLWG-01/08.

Sculley, M. 2026b. Summary of US Catch and Size of Pacific Blue Marlin. ISC/26/BILLWG-01/11.

Shimose, T., M. Fujita, K. Yokawa, H. Saito, and K. Tachihara. 2009. Reproductive biology of blue marlin *Makaira nigricans* around Yonaguni Island, southwestern Japan. Fisheries Science 75:109–119.

Su, N., C. Sun, A. E. Punt, S. Yeh, and G. Dinardo. 2011. Modelling the impacts of environmental variation on the distribution of blue marlin, *Makaira nigricans*, in the Pacific Ocean. ICES Journal of Marine Science 68(6):1072–1080.

Sun, C.-L., Y.-J. Chang, C.-C. Tszeng, S.-Z. Yeh, and N.-J. Su. 2009. Reproductive biology of blue marlin (*Makaira nigricans*) in the western Pacific Ocean. Fishery Bulletin 107:420–432.

Taylor, I. G., I. J. Stewart, A. C. Hicks, T. M. Garrison, A. E. Punt, J. R. Wallace, C. R. Wetzel, J. T. Thorson, Y. Takeuchi, K. Ono, C. C. Monnahan, C. C. Stawitz, Z. T. A'mar, A. R. Whitten, K. F. Johnson, R. L. Emmet, and S. C. Anderson. 2017. r4ss.

Wald, A., and J. Wolfowitz. 1940. On a test whether two samples are from the same population. Annals of Mathematical Statistics 11:147–162.

Yeh, Z.-W., and Y. Chang. 2026a. CPUE standardization of blue marlin (*Makaira nigricans*) for the Taiwanese distant-water tuna longline fishery in the Pacific Ocean during 1971 - 2024. ISC/26/BILLWG-01/07.

Yeh, Z.-W., and Y. Chang. 2026b. Blue marlin (*Makaira nigricans*) catch and size data of Taiwanese fisheries in the Pacific Ocean. ISC/26/BILLWG-01/10.

3.7 Tables

Table 1. List of fleets with catch, CPUE indices, and size composition data in the base model for the 2026 Pacific blue marlin stock assessment. Catch and CPUE units are either biomass (B) or numbers (N). Size data were available as combined sex (U), female (F), and male (M), in either length or weight.

Fleet name	Fleet number	Member	Description	Units	Size data	Source
F1_JPN_EarlyLL	1	Japan	Coastal, offshore, and distant water longline, other gears, 1971–1993	B	Length (U), 1971–1993	Ijima (2021); Jusup and Kai (2026b)
F2_JPN_LateLL	2	Japan	Offshore and distant water longline east, 1994–2024	B	Length (U), 1994–2024	Jusup and Kai (2026b)
F4_JPN_DRIFT_BAIT	4	Japan	High-seas large-mesh driftnet, coastal driftnet, and bait fishing 1972–2024	B	Weight (U), some years from 1977–1998	Jusup and Kai (2026b)
F5_TWN_LTLL	5	Chinese Taipei	Large tonnage longline, 1971–2024	B	Length (U), 2014–2024	Yeh and Chang (2026b)
F6_TWN_STLL	6	Chinese Taipei	Small tonnage longline, 1971–2024	B	NA: Selectivity mirrors F5_TWN_LTLL	Yeh and Chang (2026b)
F7_TWN_Other	7	Chinese Taipei	Coastal longline, gillnet, setnet, harpoon, and others, 1971–2024	B	NA: Selectivity mirrors F5_TWN_LTLL	Yeh and Chang (2026b)

Fleet name	Fleet number	Member	Description	Units	Size data	Source
F8_IATTC_LL	8	Various flags	Longline, 1983–2024	B	NA: Selectivity mirrors F5_TWN_LTLL	Minte-Vera, pers. com.
F9_WCPFC_LL	9	Various flags	Longline, 1971–2024	B	NA: Selectivity mirrors F5_TWN_LTLL	WCPFC
F10_VAR_PS_Other	10	Various flags	All gears and flags not otherwise included: purse seine, troll, handline, harpoon, others, 1971–2024	B	Length (U), 2006–2024 from IATTC purse seine (only fleet w/ *a priori* logistic selectivity)	Minte-Vera, pers. com.; WCPFC
F11_US_LL	11	U.S.	American Samoa and Hawaii, longline shallow and deep combined, 1993–2024.	Num	Length (U/F/M), 2004–2024. Sex-specific selectivity	Sculley (2026b)
F12_US_Other	12	U.S. (Hawaii)	Troll, handline, 1971–2024, and longline, 1971–1992	B	NA: Selectivity mirrors F11_US_LL	Sculley (2026b)
S1_JPN_EarlyLL	13	Japan	Offshore and distant water longline, 1975–1993	Num	NA: Selectivity mirrors F1_JPN_EarlyLL	Ijima (2021)
S4_TWN_LTLL_Early	16	Chinese Taipei	Large tonnage longline, 1971–1978	Num	NA: Selectivity mirrors F5_TWN_LTLL	Yeh and Chang (2026a)

Fleet name	Fleet number	Member	Description	Units	Size data	Source
S5_TWN_LTLL_Mid	17	Chinese Taipei	Large tonnage longline, 1979–1999	Num	NA: Selectivity mirrors F5_TWN_LTLL	Yeh and Chang (2026a)
S8_US_LLdeep	20	U.S. (Hawaii)	Longline, deep-set only, 1995–2024	Num	NA: Selectivity mirrors F11_US_LL	Sculley (2026a, 2026b)
S9_JPN_LateLL	21	Japan	Offshore and distant water longline, 1994–2024	Num	NA: Selectivity mirrors F2_JPN_LateLL	Jusup and Kai (2026a)
S10_TWN_LTLL_Late	22	Chinese Taipei	Large tonnage longline, 2000–2024	Num	NA: Selectivity mirrors F5_TWN_LTLL	Chang, Pers. Comm.

Table 2. Timeseries of catch by fleet submitted for the 2026 Pacific blue marlin stock assessment. Catch units are thousands of fish for fleet F11 and metric tons for all fleets. Fleets are F1_JPN_EarlyLL, F2_JPN_LateLL, F4_JPN_DRIFT_BAIT, F5_TWN_LTLL, F6_TWN_STLL, F7_TWN_Other, F8_IATTC_LL, F9_WCPFC_LL, F10_VAR_PS_Other, F11_US_LL, F12_US_Other, and described in more detail in Table 1.

Year	Season	F1	F2	F4	F5	F6	F7	F8	F9_	F10	F11	F12
1971	1	1938.189			26	332.75	151		15	42.5		13.637
1971	2	1707.881			26	332.75	151		15	42.5		12.929
1971	3	1934.985			26	332.75	151		15	42.5		16.156
1971	4	1444.607			26	332.75	151		15	42.5		7.688
1972	1	2612.648		3.689	50.75	301.25	138.5		15.75	44.5		4.697
1972	2	2307.136		3.689	50.75	301.25	138.5		15.75	44.5		8.033
1972	3	2189.031		3.689	50.75	301.25	138.5		15.75	44.5		9.903
1972	4	1647.288		3.689	50.75	301.25	138.5		15.75	44.5		2.394
1973	1	2949.208		71.574	56.25	412.5	138		18.75	54		8.664
1973	2	2694.06		71.574	56.25	412.5	138		18.75	54		4.258
1973	3	1745.656		71.574	56.25	412.5	138		18.75	54		17.303
1973	4	2087.311		71.574	56.25	412.5	138		18.75	54		7.91
1974	1	2553.676		71.82	40.25	534.75	127.75		21.75	60.25		6.451
1974	2	2142.61		71.82	40.25	534.75	127.75		21.75	60.25		9.04
1974	3	1797.688		71.82	40.25	534.75	127.75		21.75	60.25		28.342
1974	4	1807.085		71.82	40.25	534.75	127.75		21.75	60.25		12.922
1975	1	1722.561		231.939	37	657	157.75		29.5	61.25		13.848
1975	2	1405.744		231.939	37	657	157.75		29.5	61.25		11.345
1975	3	1745.073		231.939	37	657	157.75		29.5	61.25		14.749
1975	4	1323.689		231.939	37	657	157.75		29.5	61.25		7.856
1976	1	1659.145		192.832	44	322.75	170.5		197	52.25		5.4
1976	2	2006.91		192.832	44	322.75	170.5		197	52.25		5.366
1976	3	2237.052		192.832	44	322.75	170.5		197	52.25		36.81
1976	4	1995.421		192.832	44	322.75	170.5		197	52.25		38.863
1977	1	2272.466		293.183	36.25	293.75	128		163.25	72.5		31.814
1977	2	2199.572		293.183	36.25	293.75	128		163.25	72.5		32.467

Year	Season	F1	F2	F4	F5	F6	F7	F8	F9_	F10	F11	F12
1977	3	2001.008		293.183	36.25	293.75	128		163.25	72.5		72.454
1977	4	2045.534		293.183	36.25	293.75	128		163.25	72.5		29.341
1978	1	2645.89		266.619	15.75	408.25	96.75		191.75	46.25		23.156
1978	2	2933.715		266.619	15.75	408.25	96.75		191.75	46.25		87.912
1978	3	2427.544		266.619	15.75	408.25	96.75		191.75	46.25		105.154
1978	4	2012.679		266.619	15.75	408.25	96.75		191.75	46.25		27.46
1979	1	2527.729		167.498	105.5	406.5	137		347.25	58.75		25.619
1979	2	3020.767		167.498	105.5	406.5	137		347.25	58.75		68.214
1979	3	2401.972		167.498	105.5	406.5	137		347.25	58.75		79.98
1979	4	2448.51		167.498	105.5	406.5	137		347.25	58.75		24.844
1980	1	3625.266		247.926	122.5	283.5	162.25		267.75	53.5		23.439
1980	2	2974.496		247.926	122.5	283.5	162.25		267.75	53.5		58.56
1980	3	2351.92		247.926	122.5	283.5	162.25		267.75	53.5		76.264
1980	4	2287.105		247.926	122.5	283.5	162.25		267.75	53.5		42.585
1981	1	3032.218		332.782	115.75	453.25	104.5		316.75	59.75		38.507
1981	2	3337.029		332.782	115.75	453.25	104.5		316.75	59.75		56.196
1981	3	2522.765		332.782	115.75	453.25	104.5		316.75	59.75		86.69
1981	4	2194.676		332.782	115.75	453.25	104.5		316.75	59.75		37.412
1982	1	3321.002		277.195	76	532.25	108.25		349.25	54.25		31.084
1982	2	3409.028		277.195	76	532.25	108.25		349.25	54.25		61.635
1982	3	2781.276		277.195	76	532.25	108.25		349.25	54.25		75.359
1982	4	2293.791		277.195	76	532.25	108.25		349.25	54.25		38.597
1983	1	3377.449		285.804	68	530.25	223.5		197	60.5		15.511
1983	2	3125.871		285.804	68	530.25	223.5	7.74	197	60.5		40.869
1983	3	2294.869		285.804	68	530.25	223.5	0.22	197	60.5		66.238
1983	4	2512.001		285.804	68	530.25	223.5		197	60.5		37.909
1984	1	4425.009		105.516	95.5	447.25	273.25		283.5	110		19.892
1984	2	3742.992		105.516	95.5	447.25	273.25		283.5	110		25.246
1984	3	2973.921		105.516	95.5	447.25	273.25		283.5	110		81.734
1984	4	2898.345		105.516	95.5	447.25	273.25		283.5	110		30.89
1985	1	3559.643		173.155	53	296.75	202.5		327.25	128		30.995

Year	Season	F1	F2	F4	F5	F6	F7	F8	F9_	F10	F11	F12
1985	2	3081.567		173.155	53	296.75	202.5		327.25	128		42.657
1985	3	2009.548		173.155	53	296.75	202.5		327.25	128		50.545
1985	4	2109.275		173.155	53	296.75	202.5		327.25	128		23.83
1986	1	3643.409		134.785	46	430.75	260	0.29	312.5	135.5		35.908
1986	2	3903.544		134.785	46	430.75	260	1.99	312.5	135.5		59.356
1986	3	2562.946		134.785	46	430.75	260	9.68	312.5	135.5		82.965
1986	4	2337.911		134.785	46	430.75	260	11.21	312.5	135.5		47.598
1987	1	3168.561		133.31	49.5	1154.25	249	72.9	901.75	116.5		36.205
1987	2	3948.979		133.31	49.5	1154.25	249	91.74	901.75	116.5		66.079
1987	3	3567.206		133.31	49.5	1154.25	249	65.72	901.75	116.5		96.252
1987	4	2734.977		133.31	49.5	1154.25	249	95.39	901.75	116.5		65.322
1988	1	4218.267		146.591	80	705.5	318.75	49.19	874.75	126.25		39.036
1988	2	3301.101		146.591	80	705.5	318.75	14.04	874.75	126.25		38.791
1988	3	2347.824		146.591	80	705.5	318.75	25.63	874.75	126.25		110.8
1988	4	1881.076		146.591	80	705.5	318.75	14.16	874.75	126.25		102.952
1989	1	2629.04		169.22	111.25	661	168.25	19.74	628	129.5		75.938
1989	2	2801.753		169.22	111.25	661	168.25	7.72	628	129.5		122.161
1989	3	2440.935		169.22	111.25	661	168.25	16.64	628	129.5		155.996
1989	4	2277.036		169.22	111.25	661	168.25	41.28	628	129.5		156.957
1990	1	2710.658		124.455	109.25	432.5	149.25	25.85	575	177.5		76.841
1990	2	2528.48		124.455	109.25	432.5	149.25	53.4	575	177.5		139.96
1990	3	1659.312		124.455	109.25	432.5	149.25	105.15	575	177.5		228.888
1990	4	2210.48		124.455	109.25	432.5	149.25	133.75	575	177.5		99.942
1991	1	2793.152		86.086	180	538	136	173.72	506.5	222.5		41.298
1991	2	3034.564		86.086	180	538	136	148.37	506.5	222.5		93.591
1991	3	1816.205		86.086	180	538	136	71.43	506.5	222.5		125.074
1991	4	2128.408		86.086	180	538	136	80.15	506.5	222.5		87.422
1992	1	3207.383		77.231	30.5	942.75	152.25	171.07	764.5	200.75		74.166
1992	2	3203.273		77.231	30.5	942.75	152.25	164.54	764.5	200.75		53.484
1992	3	2210.511		77.231	30.5	942.75	152.25	65.92	764.5	200.75		92.214
1992	4	2018.331		77.231	30.5	942.75	152.25	154.72	764.5	200.75		42.059

Year	Season	F1	F2	F4	F5	F6	F7	F8	F9_	F10	F11	F12
1993	1	3165.133		82.642	112.25	969	141.75	113.67	813.75	200	3.9	24.624
1993	2	3260.163		82.642	112.25	969	141.75	132.71	813.75	200	9.24	39.27
1993	3	2560.441		82.642	112.25	969	141.75	42.07	813.75	200	7.18	140.183
1993	4	2649.125		82.642	112.25	969	141.75	30.13	813.75	200	6.64	109.407
1994	1		3266.94	73.542	150.75	751.75	63.75	96.84	919.5	267.5	4.19	70.875
1994	2		3390.493	73.542	150.75	751.75	63.75	35.05	919.5	267.5	6.22	67.671
1994	3		3046.626	73.542	150.75	751.75	63.75	18.33	919.5	267.5	10.9	131.785
1994	4		3057.104	73.542	150.75	751.75	63.75	12.88	919.5	267.5	5.3	29.82
1995	1		2941.082	77.723	81.5	955	237.75	60.47	1224.75	296	4.94	13.065
1995	2		3198.674	77.723	81.5	955	237.75	74.94	1224.75	296	12.7	73.163
1995	3		2811.798	77.723	81.5	955	237.75	44.54	1224.75	296	13.2	136.585
1995	4		2263.451	77.723	81.5	955	237.75	51.44	1224.75	296	15.5	93.006
1996	1		1597.717	70.59	46.75	824.5	82	47.3	866.75	325.5	7.64	123.15
1996	2		1661.194	70.59	46.75	824.5	82	31.21	866.75	325.5	9.43	90.288
1996	3		1356.846	70.59	46.75	824.5	82	22.53	866.75	325.5	9.57	135.632
1996	4		1227.759	70.59	46.75	824.5	82	30.79	866.75	325.5	9.31	59.712
1997	1		1396.189	76.985	26	906.25	71.25	41.02	838.25	311.25	3.732	35.004
1997	2		1887.216	76.985	26	906.25	71.25	52.98	838.25	311.25	16.18	91.678
1997	3		1982.923	76.985	26	906.25	71.25	56.3	838.25	311.25	17.919	141.326
1997	4		1915.203	76.985	26	906.25	71.25	178.14	838.25	311.25	7.48	111.587
1998	1		1764.11	84.118	52.25	900.75	39.75	159.43	1334.75	368	4.524	58.937
1998	2		1922.456	84.118	52.25	900.75	39.75	113.57	1334.75	368	7.164	24.34
1998	3		1604.024	84.118	52.25	900.75	39.75	17.15	1334.75	368	8.048	93.24
1998	4		1379.239	84.118	52.25	900.75	39.75	17.74	1334.75	368	8.795	66.486
1999	1		1409.89	61.49	32.75	840.5	47.5	19.02	1340.25	398.75	5.004	61.662
1999	2		1335.951	61.49	32.75	840.5	47.5	21.02	1340.25	398.75	8.659	33.134
1999	3		1272.847	61.49	32.75	840.5	47.5	54.66	1340.25	398.75	8.255	138.973
1999	4		1230.688	61.49	32.75	840.5	47.5	59.69	1340.25	398.75	4.827	60.693
2000	1		1197.462	53.619	28.5	1934.25	63	16.87	1143.5	198.5	2.72	52.051
2000	2		1238.522	53.619	28.5	1934.25	63	25.1	1143.5	198.5	4.493	28.082
2000	3		1551.745	53.619	28.5	1934.25	63	33.46	1143.5	198.5	11.206	75.54

Year	Season	F1	F2	F4	F5	F6	F7	F8	F9_	F10	F11	F12
2000	4		1319.071	53.619	28.5	1934.25	63	23.48	1143.5	198.5	6.343	41.575
2001	1		1086.394	73.788	146.25	2181.5	76	42.48	1549	192.25	2.564	20.059
2001	2		1463.463	73.788	146.25	2181.5	76	62.92	1549	192.25	8.822	67.925
2001	3		1387.675	73.788	146.25	2181.5	76	87.96	1549	192.25	12.87	143.643
2001	4		1334.622	73.788	146.25	2181.5	76	93.86	1549	192.25	12.48	48.608
2002	1		1260.516	63.211	123.75	2171.25	28.5	38.8	1677.75	227.75	8.17	41.44
2002	2		1399.692	63.211	123.75	2171.25	28.5	20.04	1677.75	227.75	8.01	65.622
2002	3		1062.324	63.211	123.75	2171.25	28.5	0.68	1677.75	227.75	6.12	89.773
2002	4		973.032	63.211	123.75	2171.25	28.5	35.44	1677.75	227.75	5.27	14.103
2003	1		1402.109	52.881	301.75	1894.25	45.75	12.61	2342.5	258.75	6.69	10.027
2003	2		1257.097	52.881	301.75	1894.25	45.75	14.49	2342.5	258.75	12.5	60.468
2003	3		1004.038	52.881	301.75	1894.25	45.75	5.38	2342.5	258.75	4.75	75.968
2003	4		1077.036	52.881	301.75	1894.25	45.75	11.1	2342.5	258.75	10.85	33.479
2004	1		1287.348	52.881	364	1605.25	38	95.93	1816.25	256.75	7.171	49.782
2004	2		1164.564	52.881	364	1605.25	38	120.59	1816.25	256.75	7.35	49.51
2004	3		1062.343	52.881	364	1605.25	38	69.64	1816.25	256.75	6.01	54.33
2004	4		1086.79	52.881	364	1605.25	38	66.45	1816.25	256.75	6.84	14.556
2005	1		1231.145	57.062	376.5	1851	34.25	69.26	2105.5	421.5	5.827	17.419
2005	2		1029.065	57.062	376.5	1851	34.25	60.6	2105.5	421.5	8.787	64.63
2005	3		953.277	57.062	376.5	1851	34.25	17.14	2105.5	421.5	4.469	82.826
2005	4		715.445	57.062	376.5	1851	34.25	6.41	2105.5	421.5	6.2	18.986
2006	1		734.294	42.551	419.5	1437.75	14.25	41.3	1964	407.5	4.75	16.223
2006	2		1042.93	42.551	419.5	1437.75	14.25	73.71	1964	407.5	9.25	35.234
2006	3		923.813	42.551	419.5	1437.75	14.25	84.28	1964	407.5	9.41	57.005
2006	4		865.033	42.551	419.5	1437.75	14.25	30.38	1964	407.5	10.04	40.434
2007	1		962.555	58.538	317.75	1280	10	61.55	1463.25	468	4.54	24.961
2007	2		920.85	58.538	317.75	1280	10	45.79	1463.25	468	6.98	40.068
2007	3		748.014	58.538	317.75	1280	10	42.52	1463.25	468	4.71	47.385
2007	4		707.439	58.538	317.75	1280	10	20.59	1463.25	468	6.68	9.514
2008	1		761.425	57.8	227.5	1370.25	10.5	19.29	1422.25	382.25	5.43	14.481
2008	2		999.711	57.8	227.5	1370.25	10.5	11.37	1422.25	382.25	9.55	32.079

Year	Season	F1	F2	F4	F5	F6	F7	F8	F9_	F10	F11	F12
2008	3		940.621	57.8	227.5	1370.25	10.5	11.6	1422.25	382.25	4.62	88.492
2008	4		724.275	57.8	227.5	1370.25	10.5	6.37	1422.25	382.25	7.17	44.084
2009	1		841.456	53.619	334.5	1189	7.75	37.08	1553	328	5.27	35.032
2009	2		925.166	53.619	334.5	1189	7.75	38.28	1553	328	9.91	40.766
2009	3		799.999	53.619	334.5	1189	7.75	46.17	1553	328	7.23	69.496
2009	4		860.634	53.619	334.5	1189	7.75	76.91	1553	328	3.76	21.608
2010	1		908.439	78.953	372.5	1423.5	12	66.59	1446	385.75	3.45	29.014
2010	2		1324.062	78.953	372.5	1423.5	12	153.87	1446	385.75	8.93	30.094
2010	3		1035.322	78.953	372.5	1423.5	12	79.54	1446	385.75	5.84	59.776
2010	4		793.931	78.953	372.5	1423.5	12	144.61	1446	385.75	3.47	18.442
2011	1		830.403	83.626	332.75	1266.25	11.75	87.65	1384.75	417.25	6.259	19.882
2011	2		1141.486	83.626	332.75	1266.25	11.75	79.82	1384.75	417.25	8.48	36.833
2011	3		843.766	83.626	332.75	1266.25	11.75	107.92	1384.75	417.25	4.284	99.699
2011	4		663.179	83.626	332.75	1266.25	11.75	16.84	1384.75	417.25	6.05	35.819
2012	1		680.837	72.312	321	1217	10.5	370.12	1537	584.25	3.85	27.525
2012	2		931.594	72.312	321	1217	10.5	170.36	1537	584.25	7.243	27.483
2012	3		900.875	72.312	321	1217	10.5	230.53	1537	584.25	3.201	61.981
2012	4		724.471	72.312	321	1217	10.5	226.44	1537	584.25	4.98	14.522
2013	1		806.997	46.732	263.75	1402	6	321.98	1670.75	651.25	3.597	21.921
2013	2		1098.224	46.732	263.75	1402	6	385.7	1670.75	651.25	6.534	39.556
2013	3		888.656	46.732	263.75	1402	6	172.83	1670.75	651.25	4.808	71.463
2013	4		586.877	46.732	263.75	1402	6	94.68	1670.75	651.25	6.61	15.544
2014	1		677.288	46.24	306.25	1415.75	36	224.64	1986.25	762	5.23	20.46
2014	2		899.851	46.24	306.25	1415.75	36	130.16	1986.25	762	10.674	58.338
2014	3		736.728	46.24	306.25	1415.75	36	163.99	1986.25	762	4.954	52.15
2014	4		520.674	46.24	306.25	1415.75	36	274.46	1986.25	762	6.823	25.39
2015	1		590.868	49.684	507	1194	48.5	200.68	1942.75	819.75	5.626	13.582
2015	2		722.469	49.684	507	1194	48.5	177.92	1942.75	819.75	15.079	58.252
2015	3		661.903	49.684	507	1194	48.5	145.32	1942.75	819.75	3.219	75.71
2015	4		556.801	49.684	507	1194	48.5	233.22	1942.75	819.75	13.172	45.874
2016	1		816.468	44.027	442	989.5	46.75	397.52	1824	1392.75	7.208	21.209

Year	Season	F1	F2	F4	F5	F6	F7	F8	F9_	F10	F11	F12
2016	2		897.26	44.027	442	989.5	46.75	82.72	1824	1392.75	10.1	32.719
2016	3		578.669	44.027	442	989.5	46.75	72.02	1824	1392.75	4.378	58.113
2016	4		551.047	44.027	442	989.5	46.75	117.68	1824	1392.75	8.687	37.516
2017	1		524.664	33.942	314.75	1155.75	36.25	231.08	1265.25	769.5	7.35	25.998
2017	2		583.317	33.942	314.75	1155.75	36.25	262.84	1265.25	769.5	10.614	48.141
2017	3		632.392	33.942	314.75	1155.75	36.25	339.67	1265.25	769.5	10.538	47.537
2017	4		476.458	33.942	314.75	1155.75	36.25	224.64	1265.25	769.5	9.911	30.006
2018	1		407.709	44.273	227.5	969.5	29.75	250.3	1305.5	798.5	7.741	26.188
2018	2		603.367	44.273	227.5	969.5	29.75	252.3	1305.5	798.5	12.512	55.491
2018	3		505.213	44.273	227.5	969.5	29.75	326.99	1305.5	798.5	7.818	43.702
2018	4		397.805	44.273	227.5	969.5	29.75	409.08	1305.5	798.5	9.084	38.402
2019	1		355.438	43.781	171	949.75	30.25	253.69	1345.75	786	9.987	23.639
2019	2		614.39	43.781	171	949.75	30.25	111.29	1345.75	786	20.958	46.979
2019	3		482.637	43.781	171	949.75	30.25	94.75	1345.75	786	14.025	62.162
2019	4		335.606	43.781	171	949.75	30.25	235.83	1345.75	786	15.59	30.616
2020	1		283.106	30.253	111	603.75	36.75	440.09	996.17	1039.29	9.19	41.247
2020	2		397.416	30.253	111	603.75	36.75	298.23	996.17	1039.29	9.477	21.863
2020	3		290.137	30.253	111	603.75	36.75	281.59	996.17	1039.29	9.708	21.425
2020	4		227.499	30.253	111	603.75	36.75	386.72	996.17	1039.29	10.184	16.3
2021	1		255.263	41.567	93.5	581.25	35	411.8	891.82	681.89	6.912	20.973
2021	2		398.478	41.567	93.5	581.25	35	141.56	891.82	681.89	9.134	27.603
2021	3		309.551	41.567	93.5	581.25	35	56.5	891.82	681.89	6.46	36.822
2021	4		238.329	41.567	93.5	581.25	35	82.78	891.82	681.89	9.194	34.109
2022	1		210.038	32.958	91.75	650.75	54.75	117.52	885.08	786.05	7.511	54.954
2022	2		393.443	32.958	91.75	650.75	54.75	60.4	885.08	786.05	8.955	20.71
2022	3		307.612	32.958	91.75	650.75	54.75	133.41	885.08	786.05	7.98	27.597
2022	4		238.622	32.958	91.75	650.75	54.75	172.78	885.08	786.05	9.596	19.387
2023	1		290.273	40.583	97	669	28.75	62.44	1136.81	365.66	7.24	30.072
2023	2		366.868	40.583	97	669	28.75	80.21	1136.81	365.66	8.413	21.37
2023	3		269.304	40.583	97	669	28.75	75.64	1136.81	365.66	4.204	30.716
2023	4		306.66	40.583	97	669	28.75	84.5	1136.81	365.66	7.005	14.836

Year	Season	F1	F2	F4	F5	F6	F7	F8	F9_	F10	F11	F12
2024	1		310.978	40.583	151.5	907.75	87.75	78.02	1494.48	169.79	8.396	13.95
2024	2		492.787	40.583	151.5	907.75	87.75	106.84	1494.48	169.79	15.649	29.604
2024	3		441.405	40.583	151.5	907.75	87.75	67.31	1494.48	169.79	16.048	49.702
2024	4		362.652	40.583	151.5	907.75	87.75	86.34	1494.48	169.79	19.565	34.346

Table 3. Standardized catch-per-unit-effort (CPUE; in number per 1000 hooks) indices and input standard error (SE) in natural log-scale (i.e., ln(SE)) of CPUE for the 2026 Pacific blue marlin stock assessment. See Table 1 for detailed descriptions of each survey index.

	S1_JPN_EarlyLL		S4_TWN_LTLL_Early		S5_TWN_LTLL_Mid		S8_US_LLdeep		S9_JPN_LateLL		S10_TWN_LTLL_Late	
Year	CPUE	SE	CPUE	SE	CPUE	SE	CPUE	SE	CPUE	SE	CPUE	SE
1971			0.77	0.22								
1972			1.18	0.29								
1973			0.79	0.19								
1974			1.02	0.27								
1975	0.33	0.19	1.11	0.35								
1976	0.33	0.19	1.37	0.47								
1977	0.25	0.19	0.64	0.21								
1978	0.4	0.19	1.13	0.36								
1979	0.46	0.2			1.77	0.27						
1980	0.47	0.2			1.33	0.21						
1981	0.55	0.2			1.43	0.21						
1982	0.55	0.2			1.27	0.2						
1983	0.44	0.2			1.01	0.17						
1984	0.7	0.21			1.16	0.2						
1985	0.48	0.2			1.43	0.27						
1986	0.49	0.2			0.94	0.18						
1987	0.48	0.2			0.8	0.13						
1988	0.46	0.2			1.01	0.15						
1989	0.48	0.2			0.77	0.14						
1990	0.46	0.2			0.97	0.19						
1991	0.44	0.2			0.91	0.17						
1992	0.45	0.2			0.45	0.12						
1993	0.57	0.2			0.74	0.14						
1994					1.5	0.24			1.88	0.19		
1995					0.72	0.15	0.29	0.35	2.22	0.18		
1996					0.66	0.12	0.24	0.3	1.3	0.19		

Year	S1_JPN_EarlyLL CPUE	S1_JPN_EarlyLL SE	S4_TWN_LTLL_Early CPUE	S4_TWN_LTLL_Early SE	S5_TWN_LTLL_Mid CPUE	S5_TWN_LTLL_Mid SE	S8_US_LLdeep CPUE	S8_US_LLdeep SE	S9_JPN_LateLL CPUE	S9_JPN_LateLL SE	S10_TWN_LTLL_Late CPUE	S10_TWN_LTLL_Late SE
1997					0.52	0.11	0.23	0.29	1.22	0.19		
1998					0.79	0.14	0.18	0.27	1.34	0.19		
1999					0.84	0.16	0.17	0.25	1.16	0.21		
2000							0.14	0.23	1.21	0.19	0.6	0.08
2001							0.21	0.28	1.11	0.19	0.82	0.15
2002							0.16	0.23	1.14	0.19	0.95	0.27
2003							0.2	0.26	1.11	0.19	0.94	0.14
2004							0.16	0.22	1.23	0.2	1.02	0.14
2005							0.16	0.21	1.25	0.2	1.24	0.15
2006							0.17	0.22	1.1	0.2	0.96	0.14
2007							0.11	0.18	1.07	0.21	0.83	0.14
2008							0.13	0.18	0.88	0.21	0.72	0.14
2009							0.13	0.18	0.95	0.21	0.74	0.09
2010							0.11	0.17	1.25	0.19	0.93	0.13
2011							0.12	0.18	1.02	0.2	0.85	0.12
2012							0.09	0.15	0.93	0.2	1	0.15
2013							0.11	0.16	1.13	0.19	1.15	0.16
2014							0.13	0.17	1.1	0.2	1.05	0.15
2015							0.16	0.19	1.04	0.2	1.16	0.07
2016							0.13	0.16	1.28	0.2	1.21	0.09
2017							0.15	0.17	1.06	0.21	1.15	0.12
2018							0.14	0.17	0.97	0.21	0.98	0.11
2019							0.17	0.19	1	0.21	1.12	0.16
2020							0.13	0.16	0.75	0.21	0.96	0.1
2021							0.11	0.14	0.72	0.22	1.02	0.12
2022							0.12	0.15	0.94	0.22	0.96	0.14
2023							0.1	0.14	0.84	0.22	0.9	0.15
2024							0.16	0.18	1.39	0.22	1.71	0.18

Table 4. Life history and model specification parameter values for the Pacific blue marlin base case stock assessment model.

Parameter	Value		Reference
	Female	Male	
Growth Age for L_1	0.5		
Growth Age for L_2	27		
Length at A_{min}	134.69	133.28	Chang et al. (2025)
Length at A_{max}	267.54	199.52	Chang et al. (2025)
Von Bertalanffy K	0.22	0.12	Chang et al. (2025)
Richards growth coefficient	0.77	4×10^{-4}	Chang et al. (2025)
CV L_1	0.08	0.07	Chang et al. (2025)
CV L_2	0.09	0.08	Chang et al. (2025)
Weight-length alpha	1.844×10^{-5}	1.37×10^{-5}	Brodziak (2013)
Weight-length beta	2.956	2.975	Brodziak (2013)
Fraction female at settlement	0.5		
Length at 50% maturity	179.76		Shimose et al. (2009); Sun et al. (2009)
Maturity at length slope	-0.2039		Shimose et al. (2009); Sun et al. (2009)
Fecundity	Proportional to mature female spawning biomass		
Spawning timing	July		
Settlement timing	August		
Virgin recruitment (R_0)	Estimated		
Spawner-recruit steepness (h)	0.87		Brodziak et al. (2015)
Sigma R	0.4		
Model start year	1971		
Initial fishing mortality	Estimated for F1_JPN_EarlyLL with input equilibrium catch equal to average 1968–1972 (8,402 mt annually).		

Table 5. Natural mortality rate at age values and standard deviation for female and male Pacific blue marlin in the base stock assessment model (Brodziak 2026)*.*

	Natural Mortality Rate at Age		Standard Deviation	
Age	Female	Male	Female	Male
0	0.40	0.45	0.13	0.15
1	0.32	0.37	0.11	0.12
2	0.29	0.35	0.10	0.12
3	0.26	0.33	0.09	0.11
4	0.25	0.32	0.08	0.11
5	0.23	0.31	0.08	0.10
6	0.22	0.30	0.07	0.10
7	0.22	0.30	0.07	0.10
8	0.21	0.29	0.07	0.10
9	0.21	0.29	0.07	0.10
10	0.20	0.29	0.07	0.10
11	0.20	0.29	0.07	0.10
12	0.20	0.29	0.07	0.10
13	0.20	0.28	0.07	0.09
14–27	0.19	0.28	0.06	0.09

Table 6. Number of observations (N), mean input standard error (SE) in natural log-space (i.e., ln(SE)), root-mean-square-errors (RMSE), additional additive ln(SE), and total ln(SE) for the relative abundance indices in the Pacific blue marlin base model.

Fleet	N	Mean Input ln(SE)	RMSE	Additional ln(SE)	Total ln(SE)
S1_JPN_LL_early	19	0.198	0.156	0.002	0.2
S4_TWN_LTLL_Early	8	0.295	0.281	--	0.295
S5_TWN_LTLL_Mid	21	0.174	0.326	0.176	0.35
S8_US_LLdeep	31	0.204	0.221	0.058	0.262

S9_JPN_LateLL	31	0.202	0.13	--	0.202
S10_TWN_LTLL_Late	25	0.136	0.181	0.06	0.196

Table 7. Effective sample size (effN) adjustment values applied to size composition data by fleet in the Pacific blue marlin base model. Size composition data were in weight for F4_JPN_DRIFT_BAIT and length for all other fleets.

Fleet name	Suggested Francis T.A1.8 value	ln(value)	Scaled to maximum 0.2	Final effN adjustment values
F1_JPN_EarlyLL	3.807	1.337	0.189	0.189
F2_JPN_LateLL	1.038	0.037	0.005	0.1
F4_JPN_DRIFT_BAIT	1.944	0.665	0.094	0.1
F5_TWN_LTLL	2.463	0.901	0.127	0.127
F10_VAR_PS_Oth	3.294	1.192	0.168	0.168
F11_US_LL	4.126	1.417	0.200	0.2

Table 8. Selectivity assumptions by fleet for the Pacific blue marlin base case stock assessment. The selectivity curves for fisheries lacking size composition data were assumed to be the same as (i.e., mirrored to) closely related fisheries or fisheries operating in the same area. Survey fleets (fishery-dependent catch per unit effort indices), which are denoted by S, were mirrored to the fishing fleets from which the indices were calculated.

Fleet	**Selectivity Function**
F1_JPN_EarlyLL	Double-normal
F2_JPN_LateLL	Double-normal; time-varying (blocks 1994–2003 and 2004–2024).
F4_JPN_DRIFT_BAIT	Double normal
F5_TWN_LTLL	Double-normal
F6_TWN_STLL	Mirror F5_TWN_LTLL
F7_TWN_Other	Mirror F5_TWN_LTLL
F8_IATTC_LL	Mirror F5_TWN_LTLL
F9_WCPFC_LL	Mirror F5_TWN_LTLL
F10_VAR_PS_Other	Logistic
F11_US_LL	Double-normal, sex-specific
F12_US_Other	Mirror F11_US_LL
S1_JPN_EarlyLL	Mirror F1_JPN_EarlyLL
S4_TWN_LTLL_Early	Mirror F5_TWN_LTLL
S5_TWN_LTLL_Mid	Mirror F5_TWN_LTLL
S8_US_LLdeep	Mirror F11_US_LL
S9_JPN_LateLL	Mirror F2_JPN_LateLL
S10_TWN_LTLL_Late	Mirror F5_TWN_LTLL

Table 9. Complete list of sensitivity runs conducted for the 2026 stock assessment of Pacific blue marlin.

Run name	Run number	Description
Catch estimates		
base_case_catch_1950	1	Model start 1950s (as early as possible); complete catch estimates for all fleets
base_case_catch_TWNearly	2	TWN_LTLL estimate missing catch from foreign ports.
base_case_catch_misID	3	Adjust catch for discards and species mis-ID - decrease catch by 10% for all years/fleets
base_case_catch_discards	4	Adjust catch for discards and species mis-ID - increase catch by 10% for all years/fleets
Data inputs and error assumptions		
base_case_estimateCPUEVar	5	Estimate additional CPUE variance within the model
base_case_eastwestSplit	6	Split TWN and JPN CPUE indices into East and West
base_case_TWNcatchabiltiy	7	Use time block on catchability for S10 starting in 2012
base_case_TWNweight	8	Use weight composition data for TWN STLL and LTLL
Natural mortality		
base_case_lowM	9	Updated Lorenzen NatM vectors -1stddev
base_case_highM	10	Updated Lorenzen NatM vectors +1stddev
base_case_metaanalysis	11	Updated meta-analysis
Stock recruitment steepness		
base_case_h065	12	Alternative stock-recruitment steepness, lower h, h = 0.65
base_case_h075	13	Alternative stock-recruitment steepness, lower h, h = 0.75
base_case_h095	14	Alternative stock-recruitment steepness, higher h, h = 0.95
Growth		
base_case_75growth	15	25th percentile posteriors from Chang et al. 2025
base_case_25growth	16	75th percentile posteriors from Chang et al. 2025
base_case2021NewGrowth	17	Use biological parameters from the 2021 New Growth model
Maturity		
base_case_high_L50	18	Alternative maturity, +10%(base): L50 = 197.7 cm
base_case_low_L50	19	Alternative maturity, -10%(base): L50 = 161.8 cm
Length-Weight		
base_case_betahigh	20	Brodziak (2013) meta-analysis β high - increase by 10%
base_case_betalow	21	Brodziak (2013) meta-analysis β low - decrease by 10%
base_case_beta3	22	β = 3
Initial conditions		
base_case_FreeF	23	Estimate F freely in the model
base_case_LowCatch	24	Set equilibrium catch to 0.5x 1968–1972 average
base_case_HighCatch	25	Set equilibrium catch to 2x 1968–1972 average
base_case_MainRecDevs	26	Start main rec devs in 1990, early rec devs 1981

Table 10. Relative negative loglikelihoods of abundance index data components in the base model over a range of fixed levels of virgin recruitment in log-scale (ln(R_0)). Likelihoods are relative to the minimum negative log-likelihood (best-fit) for each respective data component. Colors indicate relative likelihood (green: low negative log-likelihood, better-fit; red: high negative log-likelihood, poorer-fit). Maximum likelihood estimate of ln(R_0) was 6.98. See Table 1 for a description of the abundance indices.

ln(R0)	S1	S4	S5	S8	S9	S10
6.28	6.74	0.02	3.41	1.04	6.51	5.31
6.38	0.20	0.91	6.94	1.69	6.82	3.39
6.43	0.0	1.07	6.35	1.60	7.52	4.83
6.48	4.17	0.11	3.10	1.24	6.84	5.09
6.53	4.26	0.15	4.39	0.59	6.75	6.22
6.58	4.77	0.23	2.03	0.62	4.01	4.34
6.63	5.70	0.27	1.09	0.55	3.50	4.54
6.68	5.59	0.30	0.73	0.49	2.50	3.97
6.73	4.79	0.37	0.97	0.47	1.88	3.63
6.78	4.37	0.39	0.47	0.31	1.35	3.70
6.83	3.56	0.36	0.08	0.12	0.82	3.69
6.88	2.71	0.28	0.05	0.00	0.37	3.37
6.93	2.07	0.20	0.04	0.03	0.08	2.97
6.98	**1.65**	**0.15**	**0.0**	**0.22**	**0.00**	**2.59**
7.03	1.39	0.11	0.0	0.51	0.07	2.19
7.08	1.23	0.09	0.02	0.83	0.20	1.80
7.13	1.14	0.07	0.06	1.14	0.36	1.45
7.18	1.07	0.05	0.11	1.42	0.52	1.16
7.23	1.03	0.04	0.17	1.66	0.67	0.92
7.28	1.00	0.03	0.22	1.88	0.81	0.72
7.33	0.98	0.03	0.28	2.07	0.94	0.57
7.38	0.96	0.02	0.33	2.25	1.06	0.44
7.43	0.95	0.02	0.38	2.40	1.18	0.33
7.48	0.94	0.01	0.42	2.54	1.28	0.24
7.53	0.93	0.01	0.47	2.66	1.39	0.16
7.58	0.92	0.01	0.51	2.77	1.48	0.10
7.63	0.92	0.00	0.54	2.87	1.57	0.05
7.68	0.91	0.00	0.58	2.97	1.66	0.00

Table 11. Relative negative log-likelihoods of length composition data components in the base model over a range of fixed levels of virgin recruitment in log-scale ($ln(R_0)$). Likelihoods are relative to the minimum negative log-likelihood (best-fit) for each respective data component. Colors indicate relative likelihood (green: low negative log-likelihood, better-fit; red: high negative log-likelihood, poorer-fit). Maximum likelihood estimate of $ln(R_0)$ was 6.98. See Table 1 for a description of the composition data.

ln(R0)	F1	F2	F5	F10	F11
6.28	35.98	22.32	7.43	5.86	8.12
6.38	23.13	17.31	7.34	4.97	7.73
6.43	15.00	22.03	6.05	4.57	7.57
6.48	6.62	31.08	4.58	4.00	6.57
6.53	3.11	34.85	5.11	3.46	4.98
6.58	3.53	12.65	3.18	3.87	8.93
6.63	19.69	11.03	2.21	3.73	5.22
6.68	18.35	8.19	1.90	3.19	4.66
6.73	0.34	5.01	1.86	2.67	4.22
6.78	0.00	2.99	1.48	2.27	3.57
6.83	0.25	1.57	1.02	1.69	2.67
6.88	0.73	0.62	0.87	0.77	1.80
6.93	1.40	0.11	0.82	0.10	1.17
6.98	**2.13**	**0.00**	**0.67**	**0.00**	**0.77**
7.03	2.76	0.20	0.53	0.48	0.51
7.08	3.29	0.58	0.45	1.43	0.34
7.13	3.72	1.05	0.40	2.64	0.22
7.18	4.09	1.54	0.36	3.94	0.13
7.23	4.42	2.04	0.33	5.22	0.07
7.28	4.72	2.53	0.29	6.44	0.03
7.33	5.01	3.01	0.25	7.57	0.01
7.38	5.28	3.47	0.21	8.61	0.00
7.43	5.53	3.92	0.17	9.56	0.00
7.48	5.77	4.34	0.13	10.43	0.01
7.53	6.00	4.74	0.10	11.22	0.03
7.58	6.22	5.12	0.06	11.95	0.05
7.63	6.42	5.49	0.03	12.61	0.07
7.68	6.62	5.83	0.00	13.21	0.09

*Table 12. Relative negative log-likelihoods of size frequency data components in the base model over a range of fixed levels of virgin recruitment in log-scale (ln(R_0)). Likelihoods are relative to the minimum negative log-likelihood (best-fit) for each respective data component. Colors indicate relative likelihood (green: low negative log-likelihood, better-fit; red: high negative log-likelihood, poorer-fit). Maximum likelihood estimate of ln(R_0) was 6.98. See Table 1***Error! Reference source not found.*** *for a description of the composition data.*

ln(R0)	F4
6.28	0.01
6.38	0.18
6.43	0.13
6.48	0.16
6.53	0.12
6.58	0.12
6.63	0.02
6.68	3.65
6.73	0.03
6.78	0.01
6.83	0.00
6.88	0.01
6.93	0.02
6.98	**0.04**
7.03	0.05
7.08	0.06
7.13	0.07
7.18	0.08
7.23	0.09
7.28	0.10
7.33	0.11
7.38	0.12
7.43	0.12
7.48	0.13
7.53	0.13
7.58	0.14
7.63	0.14
7.68	0.15

Table 13. Time series of mature female spawning stock biomass (SSB, metric ton), total biomass (age 1 and older, metric ton), age-0 recruitment (thousands of fish), fishing mortality as annual exploitation of biomass, and instantaneous fishing mortality (age 1–10) for the Pacific blue marlin base model. SD = standard deviation.

	Spawning Stock Biomass (mt)		Age 1+ Biomass (mt)		Recruitment (1000 age-0 fish)		Fishing Mortality as Annual Exploitation of Biomass		Instantaneous Fishing Mortality Ages 1–10	
Year	Estimate	SD	Estimate	SD	Estimate	SD	Estimate	SD	Estimate	SD
1971	133084	14276	217857	22752	944	262	0.04	<0.01	0.06	0.01
1972	127466	14126	213388	22817	955	261	0.05	0.01	0.07	0.01
1973	122364	14081	209618	22836	878	229	0.06	0.01	0.08	0.01
1974	118698	14078	204002	22394	647	180	0.06	0.01	0.07	0.01
1975	115685	13943	194799	21460	738	201	0.06	0.01	0.07	0.01
1976	111250	13543	186007	20654	1001	270	0.06	0.01	0.08	0.01
1977	105124	13033	182653	20362	1048	306	0.07	0.01	0.08	0.01
1978	100650	12668	183512	20548	1141	328	0.08	0.01	0.09	0.01
1979	98720	12603	185903	21076	1169	328	0.08	0.01	0.1	0.01
1980	98269	12797	189428	21703	982	289	0.08	0.01	0.1	0.01
1981	99132	13152	189689	22158	1102	310	0.09	0.01	0.1	0.01
1982	99043	13502	189193	22577	1410	360	0.09	0.01	0.11	0.01
1983	98573	13766	194951	23342	1010	293	0.09	0.01	0.09	0.01
1984	100066	14107	197794	23866	962	269	0.1	0.01	0.11	0.01
1985	101777	14525	192528	23677	970	266	0.08	0.01	0.09	0.01
1986	101394	14627	190283	23332	1073	281	0.09	0.01	0.11	0.01
1987	97508	14473	187503	23009	1085	284	0.13	0.02	0.14	0.02
1988	91861	14247	180230	22814	1062	288	0.12	0.01	0.13	0.02
1989	90042	14102	176877	22647	1053	285	0.1	0.01	0.11	0.01
1990	89791	13989	176483	22378	1005	277	0.09	0.01	0.1	0.01
1991	90047	13847	177216	22076	1293	335	0.1	0.01	0.1	0.01
1992	89290	13636	181646	21513	1099	326	0.11	0.01	0.11	0.01
1993	88524	13249	183150	20511	1093	319	0.13	0.01	0.14	0.01
1994	86403	12646	179048	18938	734	225	0.14	0.01	0.12	0.01
1995	82111	11793	168591	17812	814	232	0.16	0.02	0.15	0.02
1996	77332	11115	153212	16665	753	214	0.12	0.01	0.11	0.01
1997	73483	10484	146830	15623	624	178	0.14	0.02	0.13	0.01
1998	67379	9823	135582	14673	614	176	0.15	0.02	0.14	0.01
1999	61372	9250	123318	13847	941	254	0.15	0.02	0.14	0.02
2000	54952	8690	119659	13157	1000	282	0.18	0.02	0.15	0.02
2001	48886	8074	119522	12772	920	274	0.21	0.02	0.18	0.02
2002	44979	7648	115833	12477	1070	285	0.21	0.02	0.18	0.02
2003	42652	7395	116195	12284	1000	243	0.23	0.02	0.2	0.02
2004	41770	7269	114777	12297	806	194	0.21	0.02	0.18	0.02
2005	41845	7301	112571	12258	819	191	0.23	0.02	0.2	0.02

Year	Spawning Stock Biomass (mt)		Age 1+ Biomass (mt)		Recruitment (1000 age-0 fish)		Fishing Mortality as Annual Exploitation of Biomass		Instantaneous Fishing Mortality Ages 1–10	
	Estimate	**SD**	**Estimate**	**SD**	**Estimate**	**SD**	**Estimate**	**SD**	**Estimate**	**SD**
2006	40789	7329	106563	12085	768	185	0.22	0.02	0.19	0.02
2007	39401	7272	101626	11912	849	197	0.19	0.02	0.17	0.02
2008	38954	7186	101440	11732	886	207	0.19	0.02	0.16	0.02
2009	38894	7063	103128	11661	880	208	0.19	0.02	0.16	0.02
2010	39168	6976	105190	11659	888	211	0.2	0.02	0.17	0.02
2011	39709	6956	105870	11653	925	221	0.19	0.02	0.16	0.02
2012	40517	6954	108568	11647	971	226	0.19	0.02	0.16	0.02
2013	40778	6932	111543	11714	951	224	0.2	0.02	0.16	0.02
2014	40920	6927	113210	11724	936	209	0.21	0.02	0.17	0.02
2015	40672	6926	112730	11750	759	185	0.22	0.02	0.18	0.02
2016	39594	6932	108443	11772	876	187	0.23	0.02	0.19	0.02
2017	38868	6983	104023	11845	777	175	0.2	0.02	0.16	0.02
2018	38946	7036	103193	12003	761	168	0.19	0.02	0.16	0.02
2019	39065	7126	101913	12137	737	171	0.2	0.02	0.17	0.02
2020	39099	7236	99122	12289	673	171	0.17	0.02	0.13	0.02
2021	40365	7370	98388	12461	727	190	0.14	0.02	0.11	0.01
2022	42117	7518	100637	12765	1044	268	0.14	0.02	0.11	0.01
2023	43633	7675	108435	13653	1386	440	0.12	0.02	0.09	0.01
2024	47244	8012	127300	16849	931	379	0.14	0.02	0.11	0.02

Table 14. Estimated biological reference points derived from the base model for Pacific blue marlin where F is the fishing mortality rate, expressed as exploitation of biomass or instantaneous annual F of ages 1–10. SPR is annual spawning potential ratio, SSB is spawning stock biomass (mature female biomass), SSB_0 is virgin unfished SSB, and MSY is maximum sustainable yield.

Reference Point	Estimate
F as exploitation(biomass)	
F_{MSY}	0.26
$F_{20\%SSB0}$	0.23
F_{2003}	0.23
$F_{2021–2023}$	0.13
Average F ages 1–10	
F_{MSY}	0.22
$F_{20\%SSB0}$	0.20
F_{2003}	0.20
$F_{2021–2023}$	0.11
Spawning Stock Biomass (SSB, mt)	
SSB_0	192,529
SSB_{MSY}	31,651
$20\%SSB_0$	38,506
SSB_{2003}	42,652
$SSB_{2021–2023}$	42,038
Catch (C, mt)	
C_{MSY}	24,306
$C_{20\%SSB[0]}$	24,119
C_{2003}	27,073
$C_{2021–2023}$	13,662
Spawning Potential Ratio (SPR)	
SPR_{MSY}	0.196
$SPR_{20\%SSB0}$	0.230
SPR_{2003}	0.209
$SPR_{2021–2023}$	0.381

Table 15. Projected median values of blue marlin spawning stock biomass (SSB, mt) and catch (mt) in 2025–2034 for each future catch scenario.

Year	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Scenario 1: F_{High}										
SSB	53,390	50,126	47,384	45,292	43,642	42,530	41,649	40,950	40,418	39,970
Catch	28,998	27,390	26,414	25,647	25,233	24,833	24,506	24,263	24,129	24,001
Scenario 2: F_{MSY}										
SSB	51,646	46,467	42,614	40,069	38,360	37,143	36,262	35,680	35,140	34,765
Catch	32,992	30,396	28,563	27,326	26,518	25,875	25,437	25,110	24,899	24,705
Scenario 3: F_{Recent}										
SSB	56,574	60,297	62,837	65,475	67,469	69,089	70,349	71,131	71,741	72,218
Catch	16,158	16,873	17,505	18,102	18,566	18,930	19,147	19,293	19,408	19,514
Scenario 4: $F_{30\%SPR}$										
SSB	54,642	54,136	53,702	53,663	53,502	53,386	53,290	53,090	53,045	53,019
Catch	23,256	23,050	23,009	22,901	22,902	22,874	22,861	22,873	22,863	22,874

3.8 FIGURES

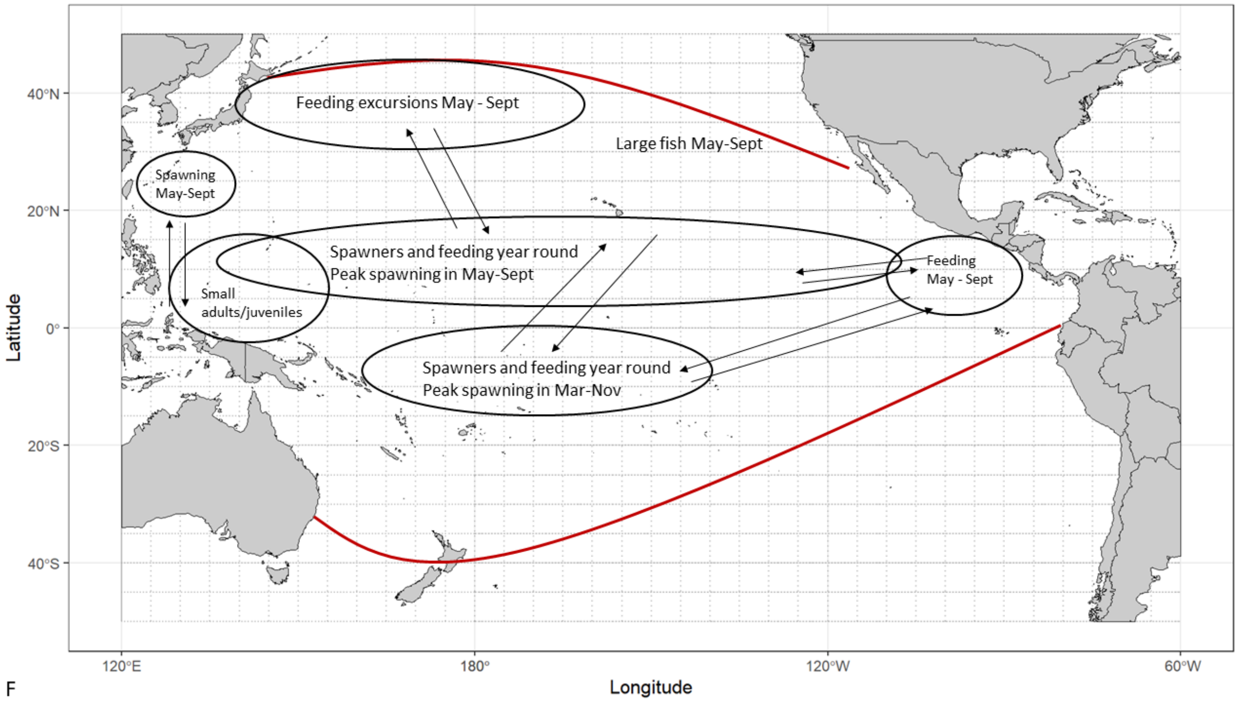


Figure 1. A diagram of the conceptual model developed by the BILLWG for female Pacific blue marlin. Arrows show general exchange of fish, not directed movement. The red boundary represents approximate habitat range of Pacific blue marlin.

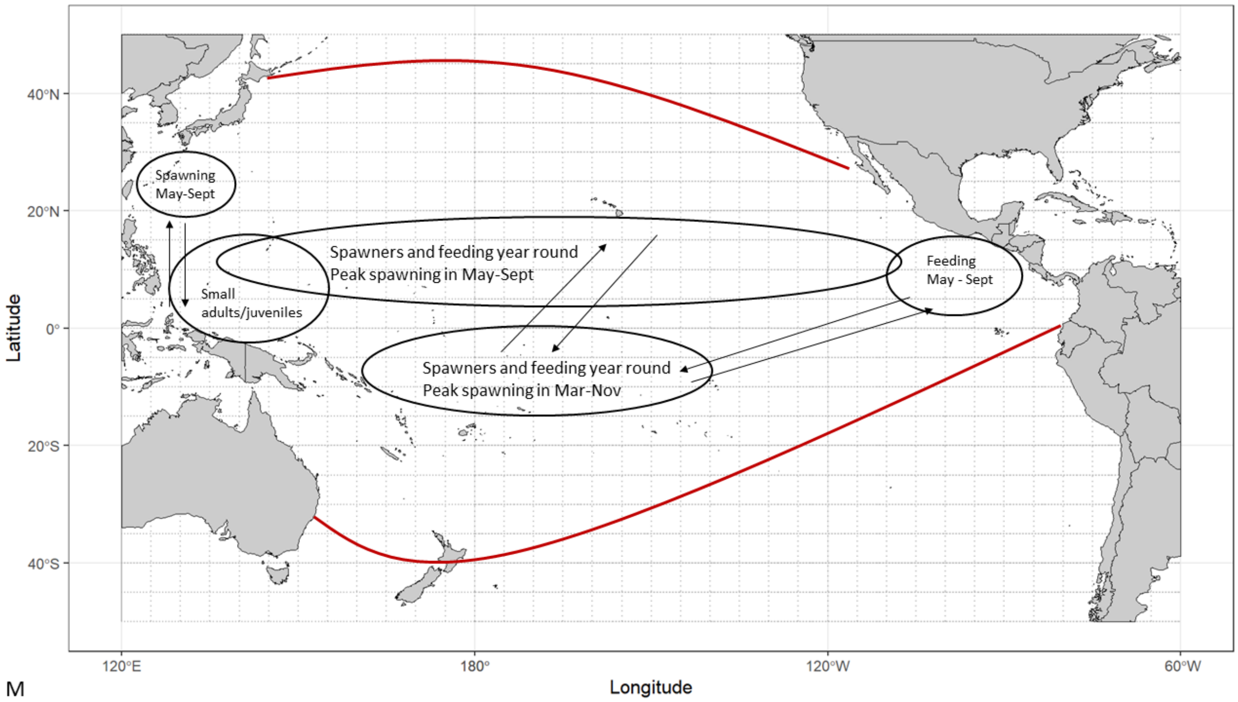


Figure 2. A diagram of the conceptual model developed by the BILLWG for male Pacific blue marlin. Arrows show general exchange of fish not directed movement. The red boundary represents approximate habitat range of Pacific blue marlin.

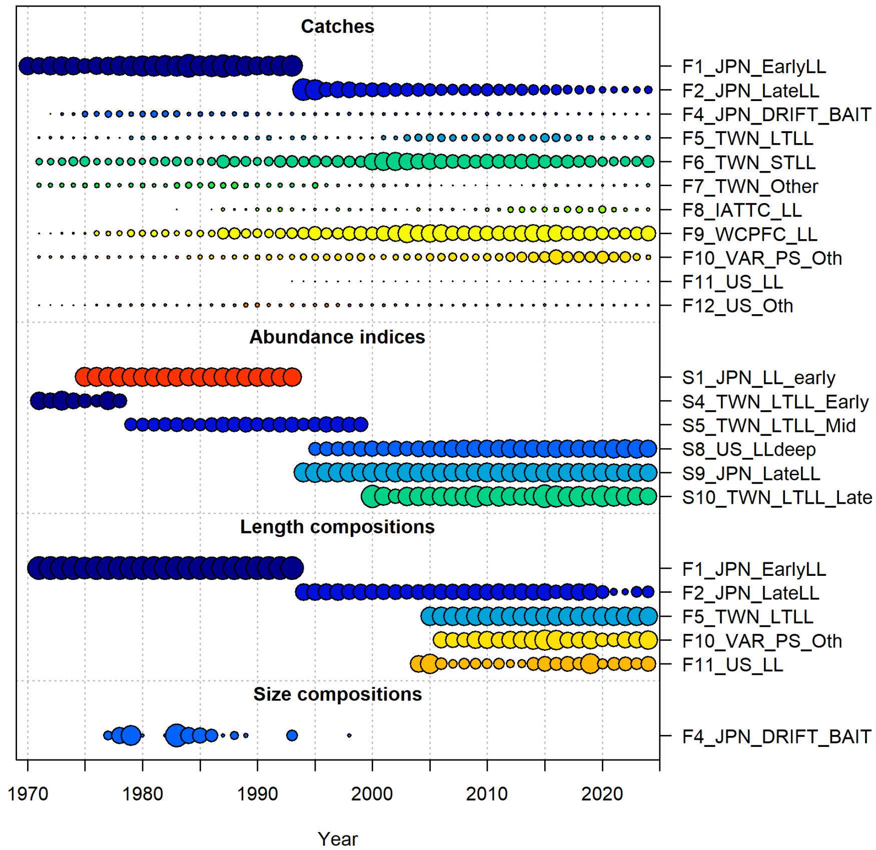


Figure 3. Catch, CPUE index, and size composition data included in the 2026 Pacific blue marlin stock assessment. The size of the bubble indicates the relative number of observations available..

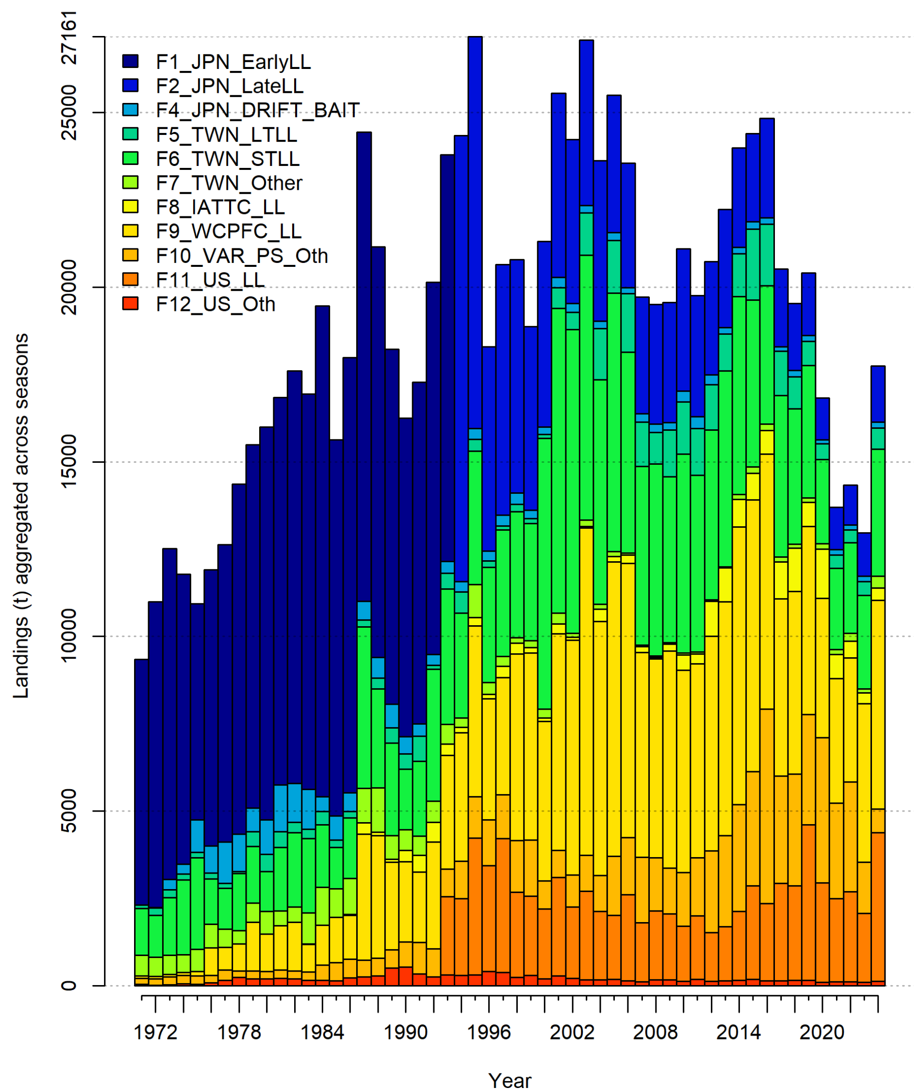


Figure 4. Total annual catch of blue marlin 1971–2024. See Table 1 for descriptions of each fishing fleet.

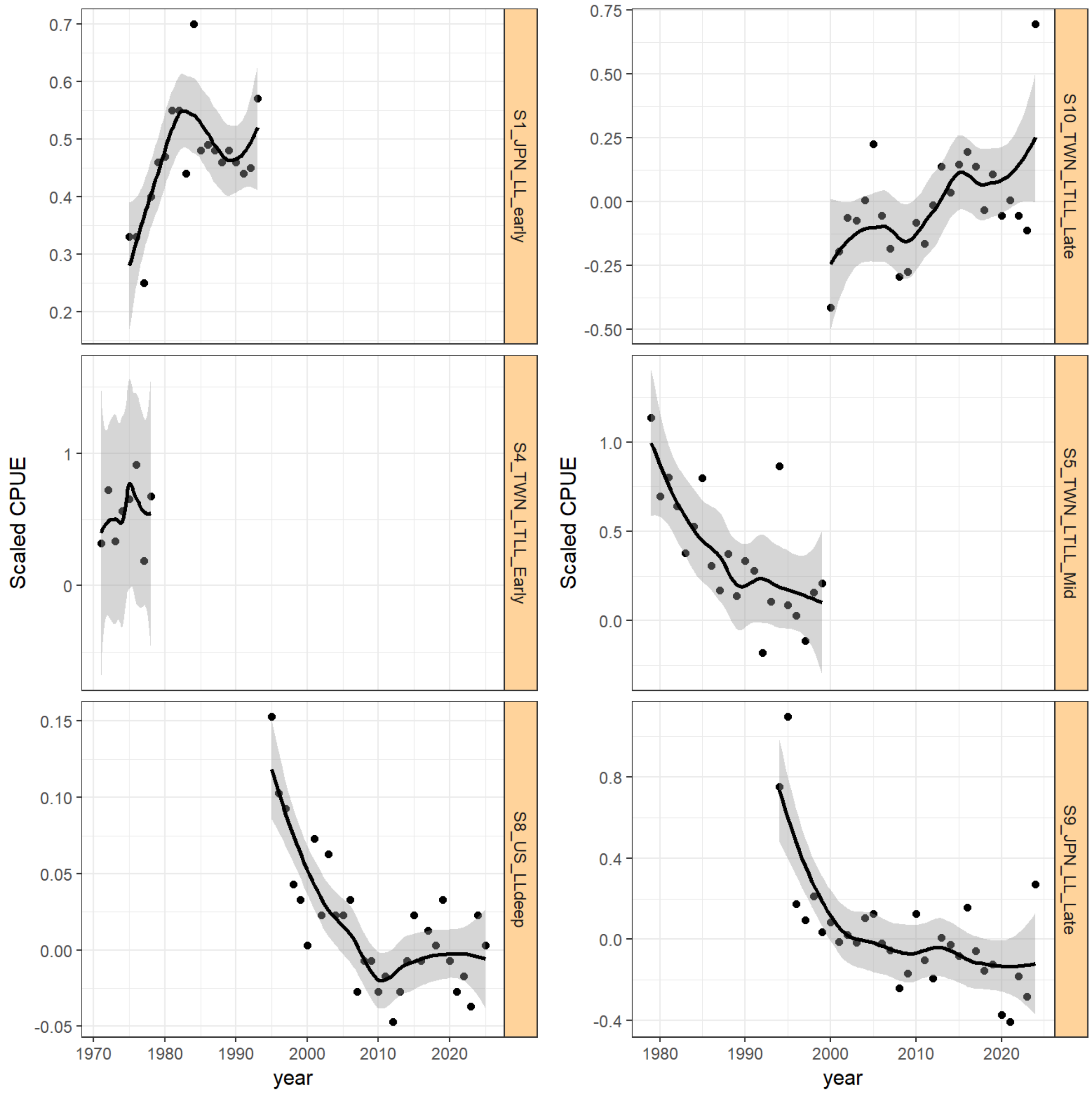


Figure 5. Plot of CPUE index by fleet with a simple LOESS smoother fit to each time series.

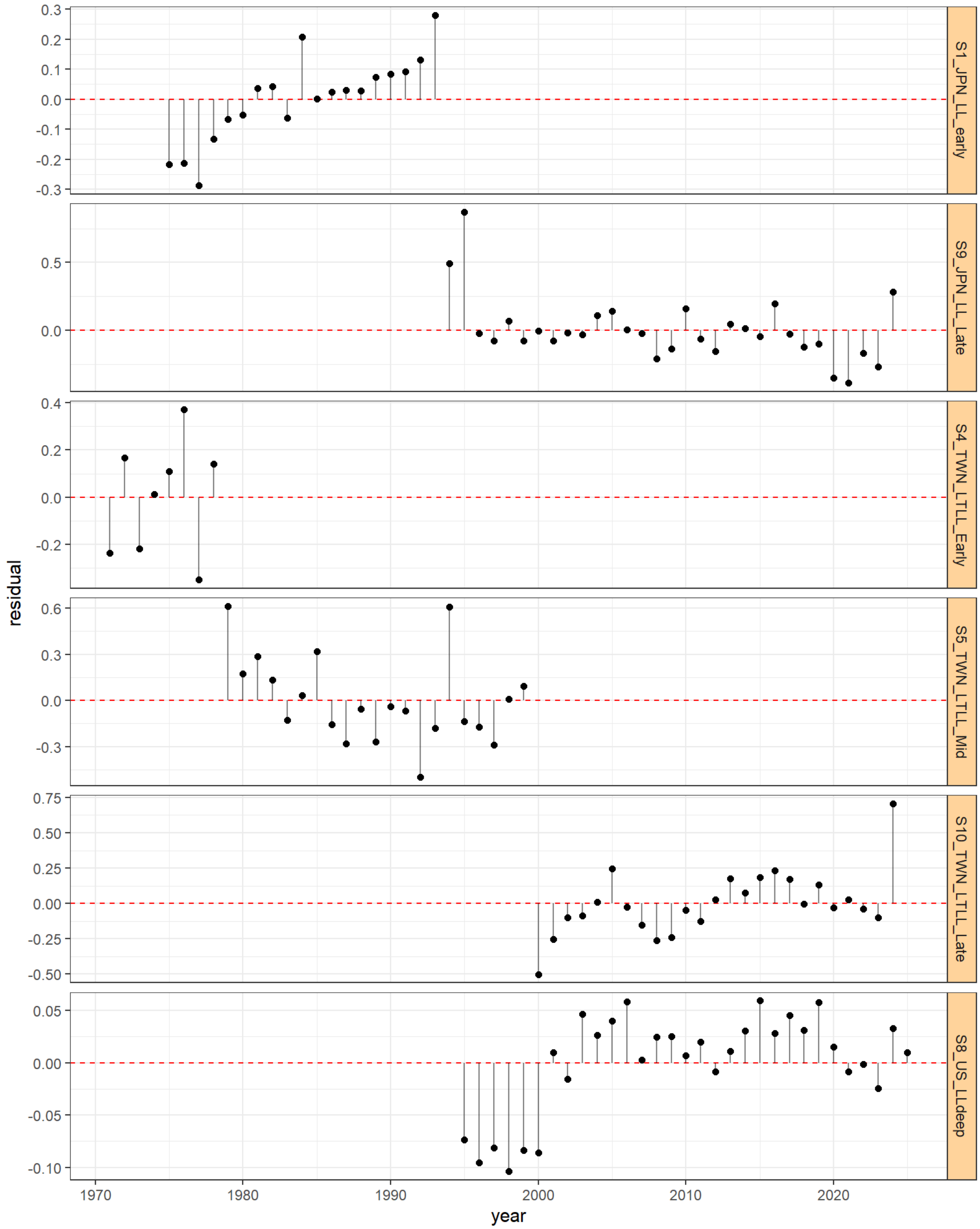


Figure 6. Time series of residuals from the overall LOESS smoother fit to each CPUE index.

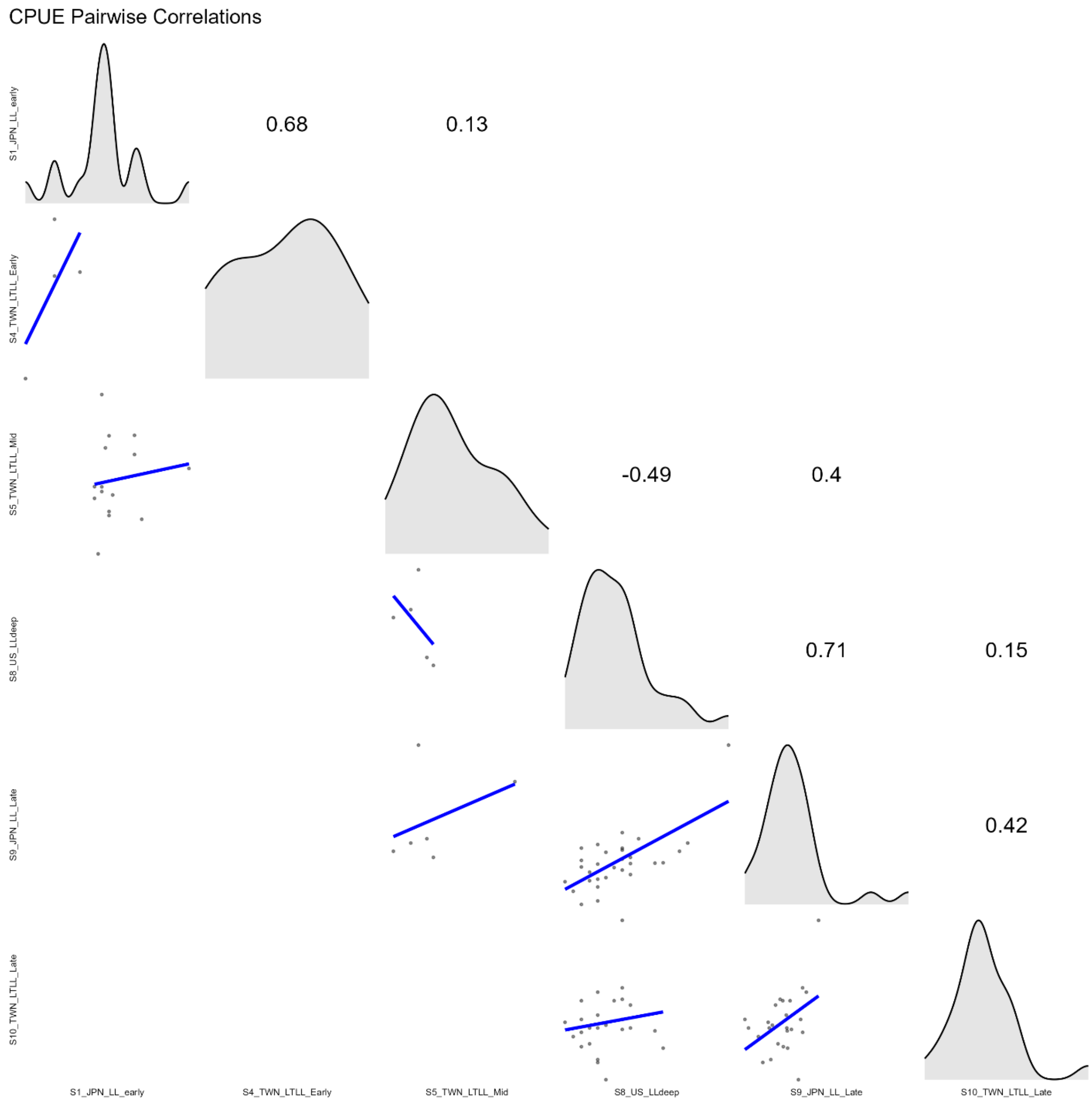


Figure 7. Pairwise scatterplots with blue regression lines (lower left), correlation coefficients (top right), and the range of observations to illustrate correlations among all CPUE indices (central diagonal).

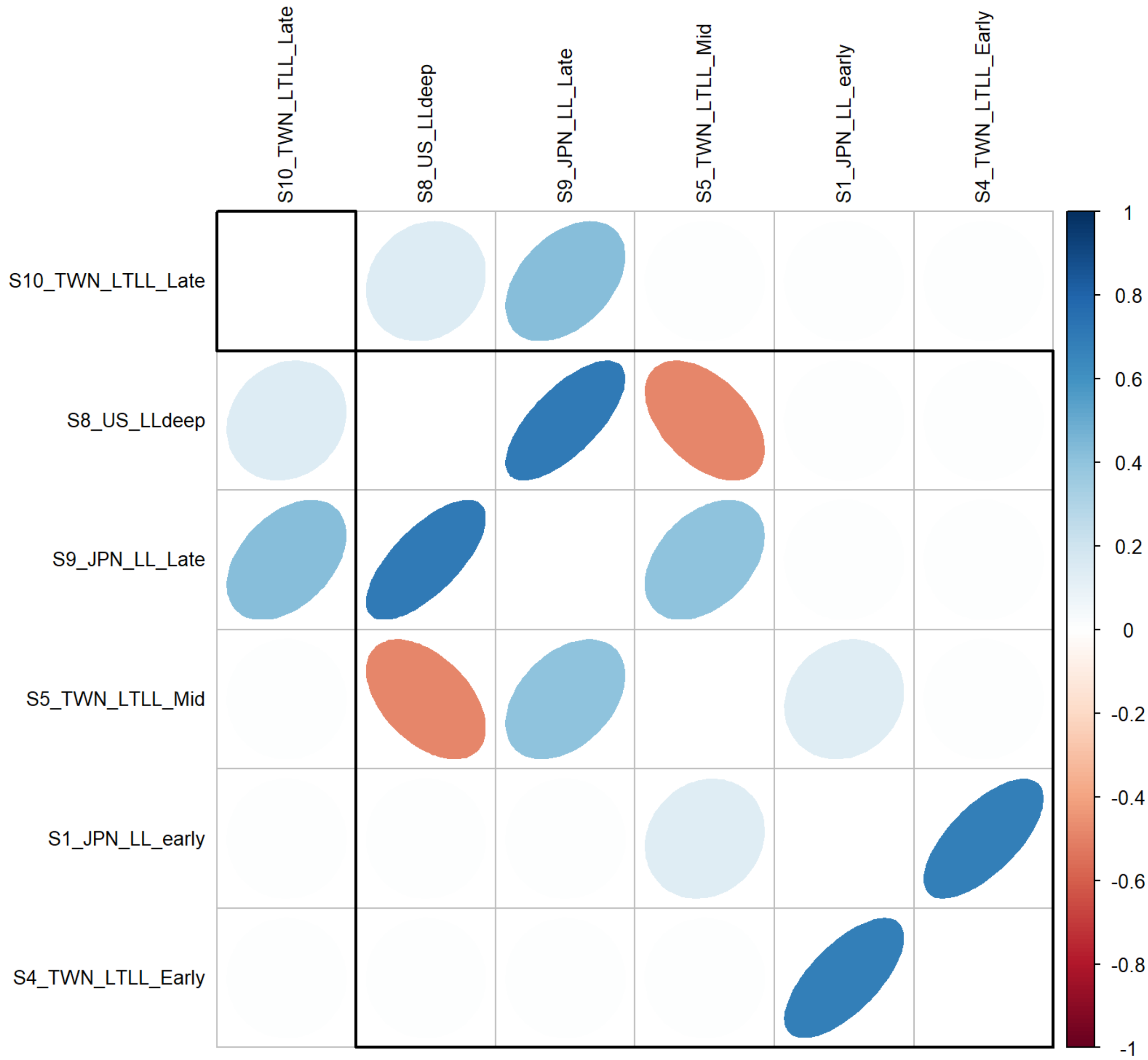


Figure 8. Plot of the correlation matrix for CPUE indices. Blue indicates a positive correlation and red indicates a negative correlation. The order of the indices and the rectangular boxes are chosen based on a hierarchical cluster analysis using a set of dissimilarities for the indices being clustered.

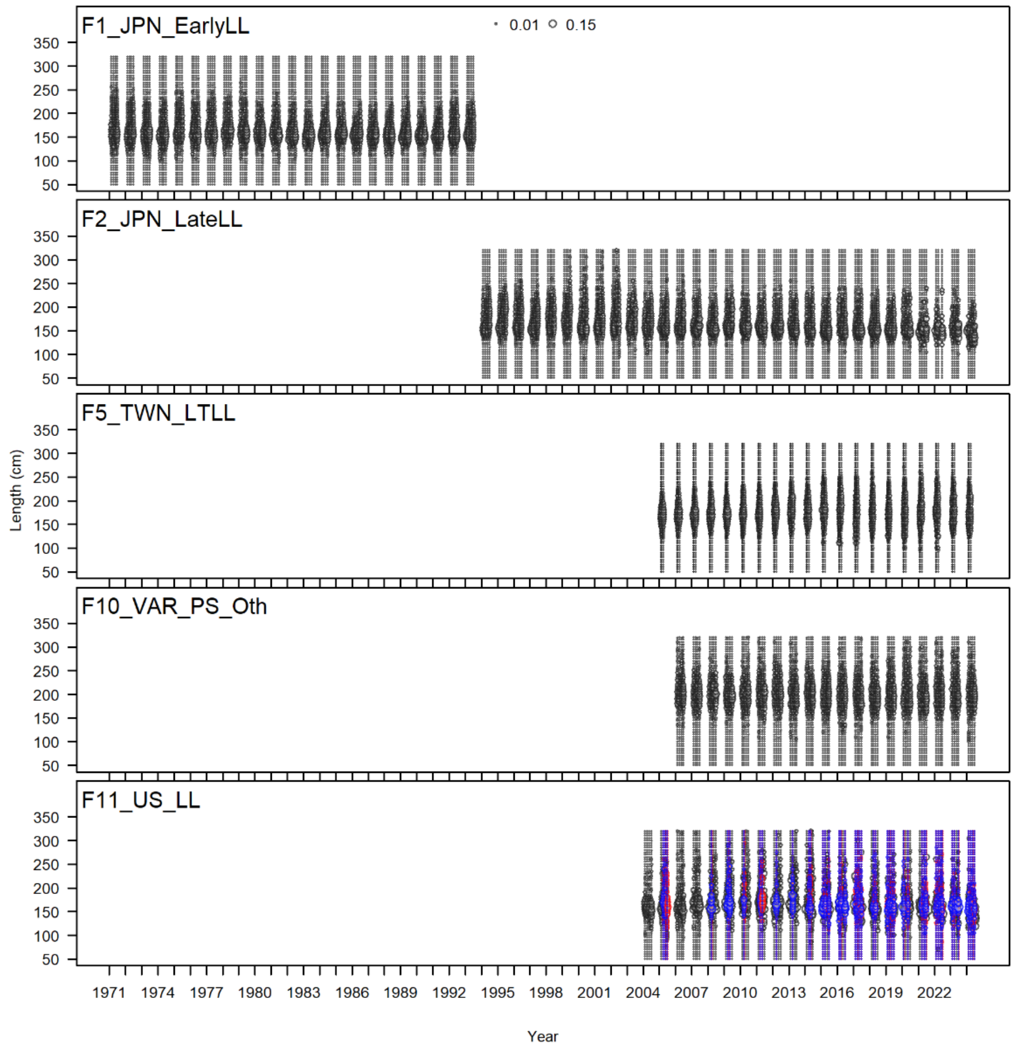


Figure 9. Length composition data for 5 fleets in the 2026 Pacific blue marlin stock assessment.

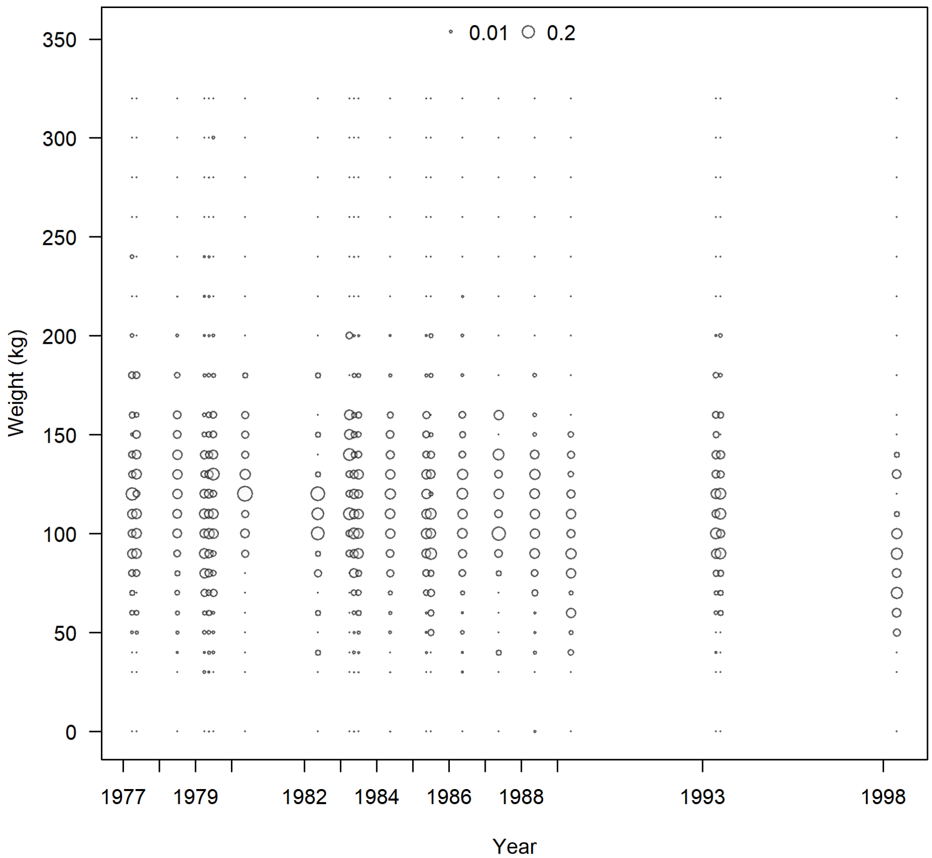


Figure 10. F4_JPN_DRIFT_BAIT weight composition data by year and quarter.

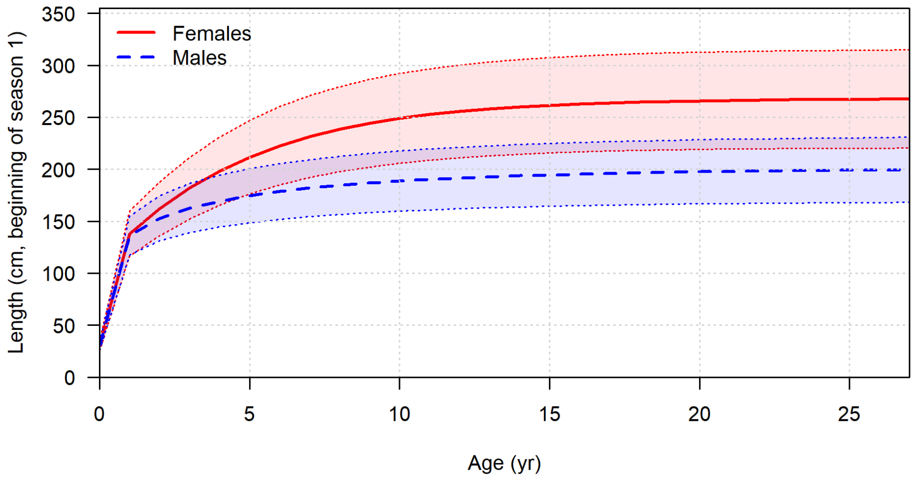


Figure 11. Length as a function of age for female (red) and male (blue) Pacific blue marlin in the base model following the two-stanza growth model from Chang et al. (2025). Shaded areas are the 95% distribution of length.

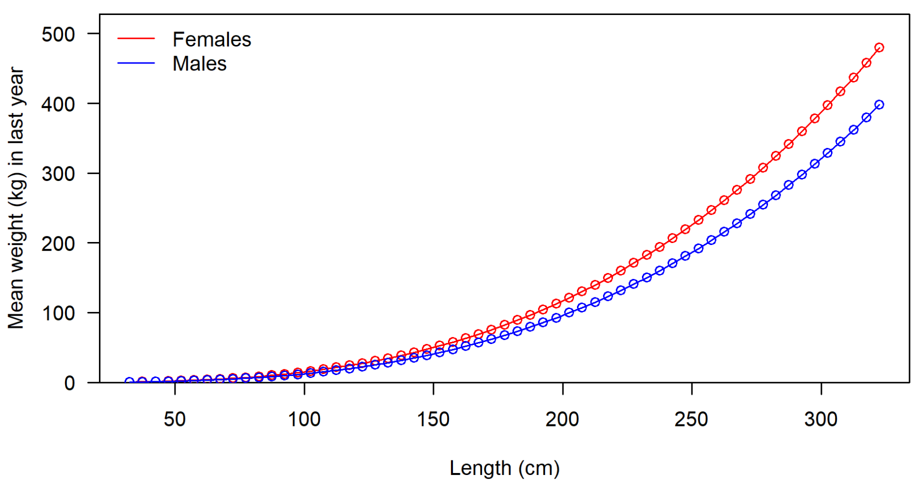


Figure 12. Weight as a function of length for female (red) and male (blue) Pacific blue marlin in the base model.

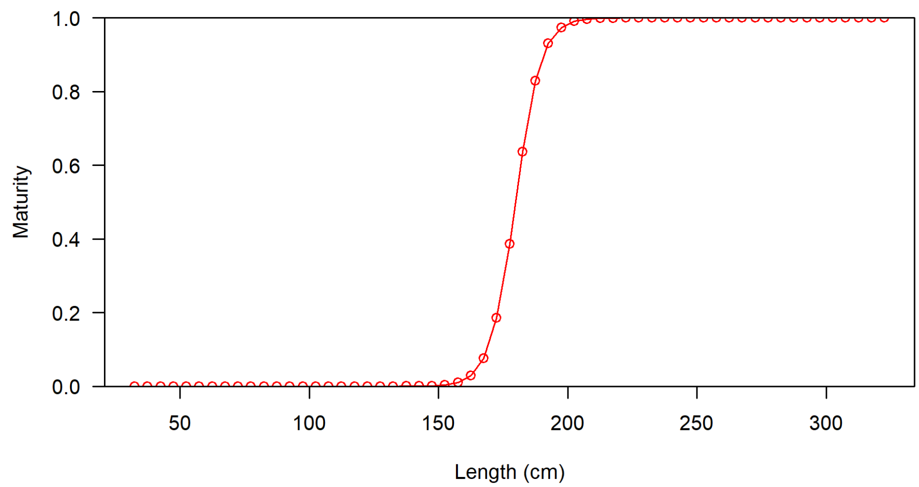


Figure 13. Pacific blue marlin female proportional maturity as a function of length in the base model.

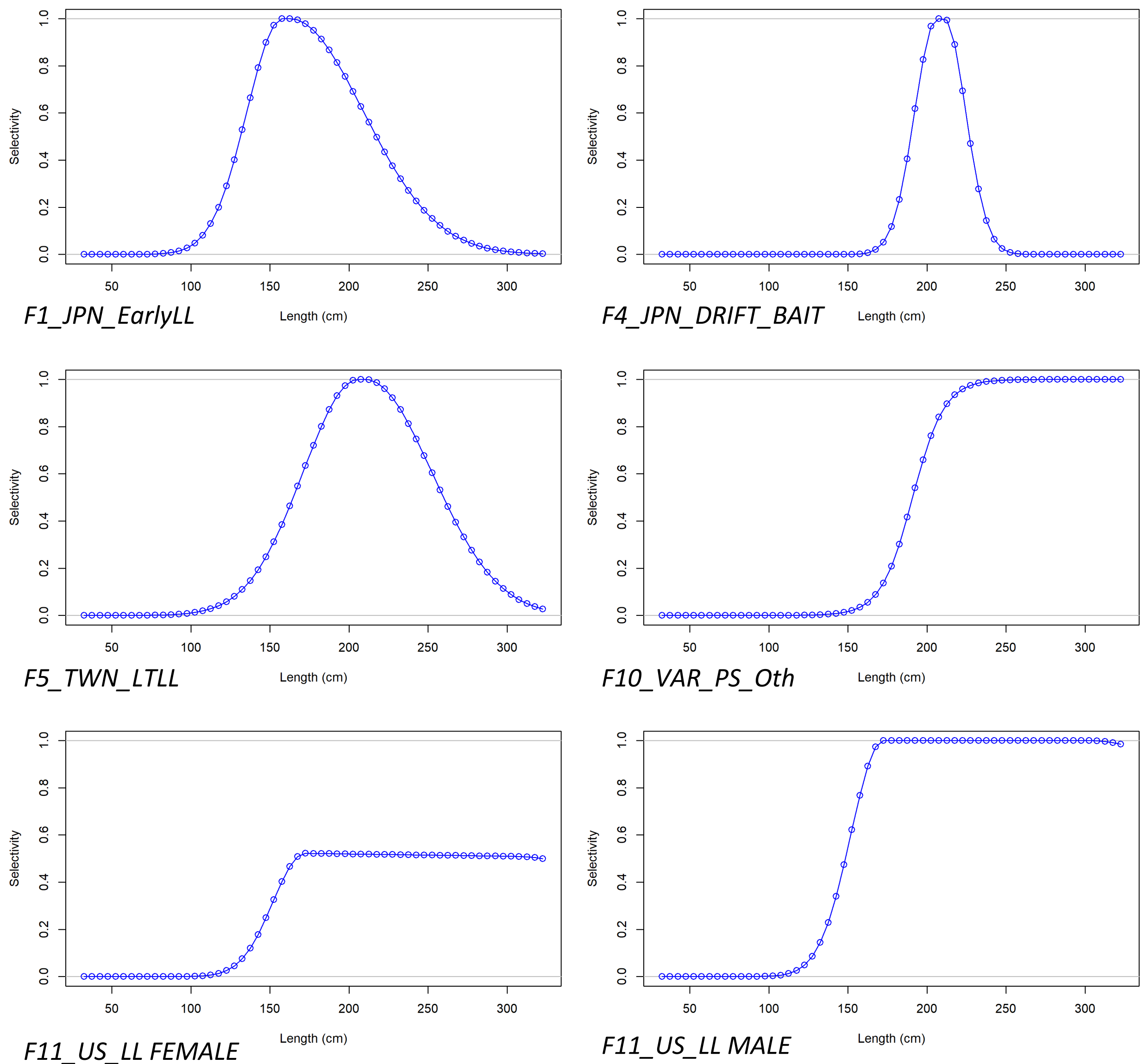


Figure 14. Estimated length-based selectivity of fishing fleets with constant selectivity over time in the base model.

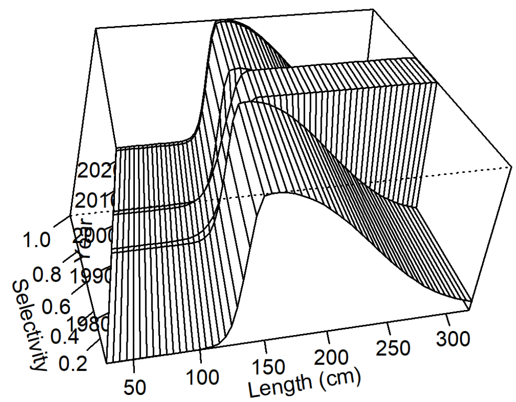


Figure 15. Time-varying selectivity at length of F2_JPN_LateLL. Selectivity was roughly logistic 1994–2003 and dome-shaped 2004–2024. Note F2_JPN_LateLL does not have data before 1994, hence the apparent selectivity for years 1971–1993 is not applied within the model.

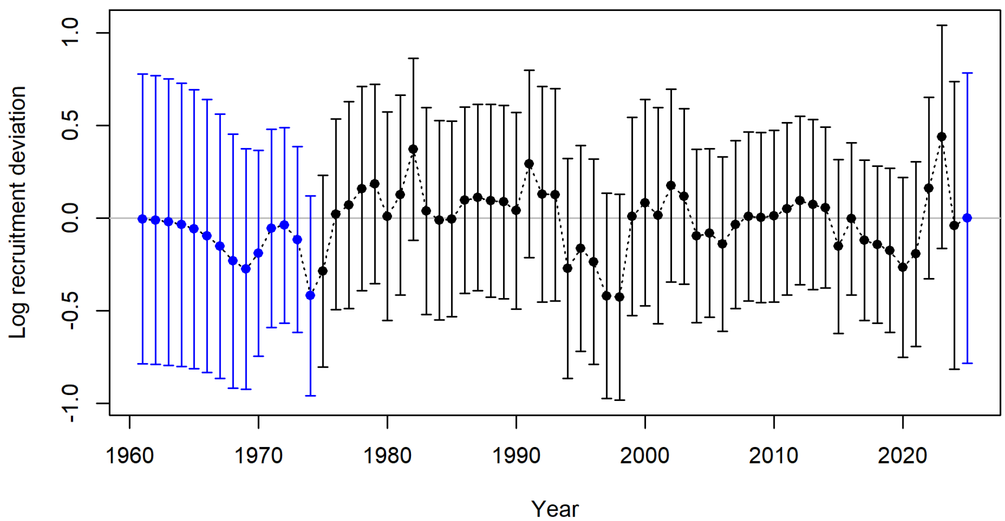


Figure 16. Estimated annual deviations from the stock-recruit relationship for the base model. Error bars show the 95% confidence interval.

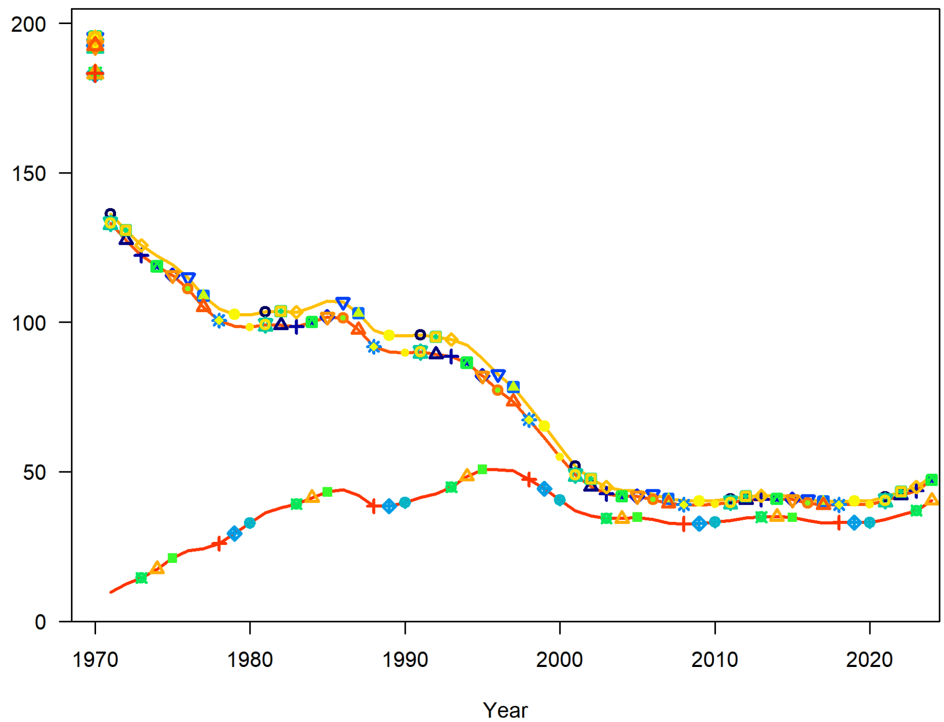


Figure 17. Spawning stock biomass (mt) timeseries for 28 jitter runs of the base model.

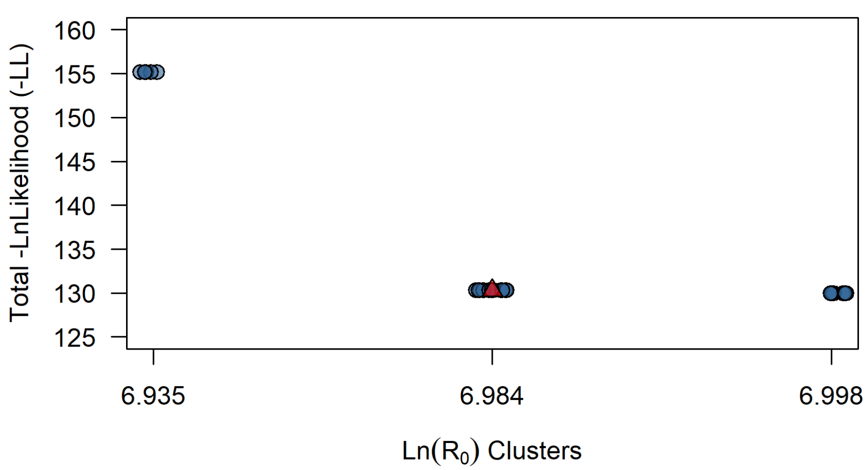


Figure 18. Plot of ln(R0) against total -loglikelihood for 28 jitter runs (blue circles) of the base model (ln(R0) = 6.98437; red triangle).

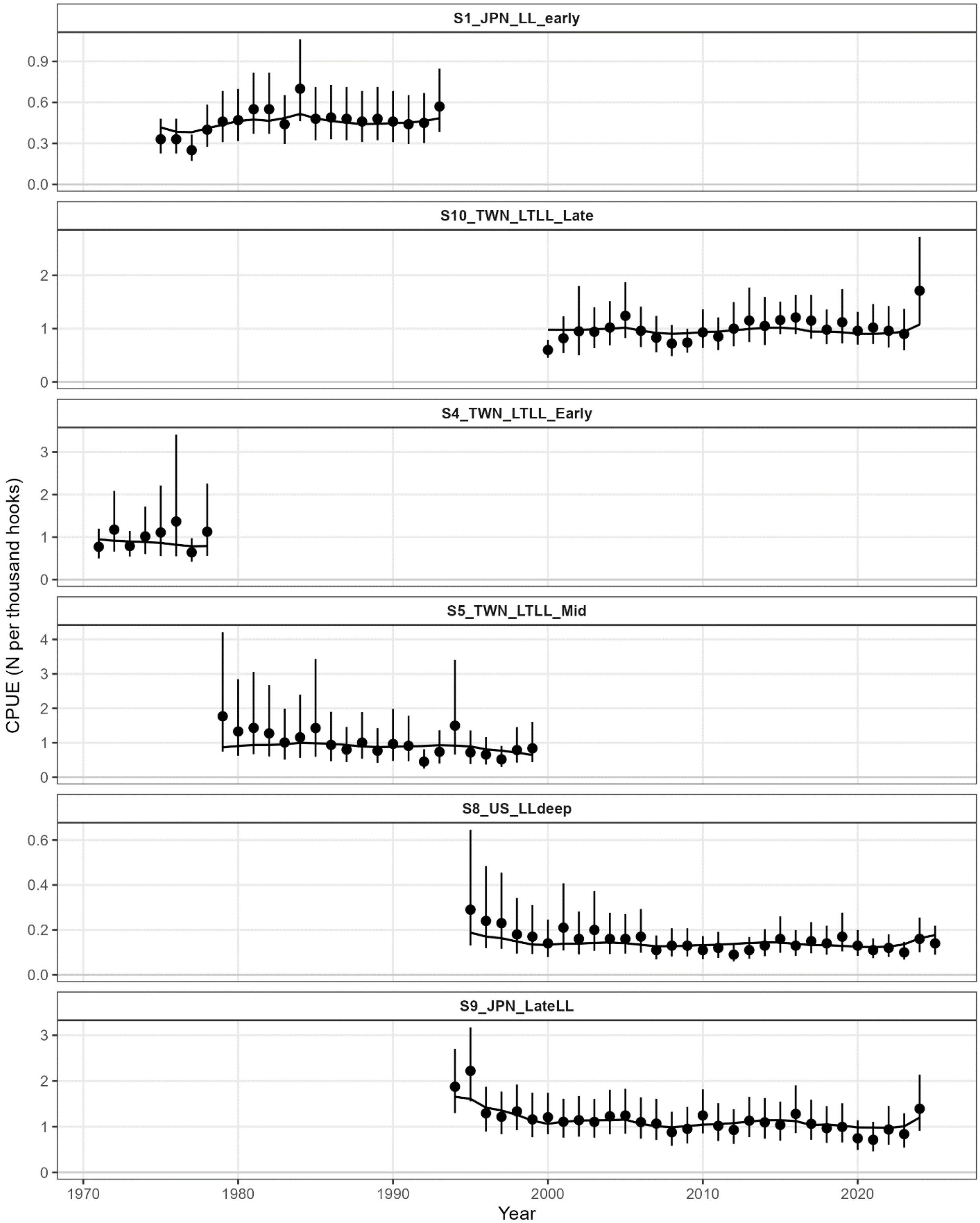


Figure 19. Base model fit (lines) to CPUE indices (points). Error bars are +/- 1.96 SE (total adjusted value, see Table 6).

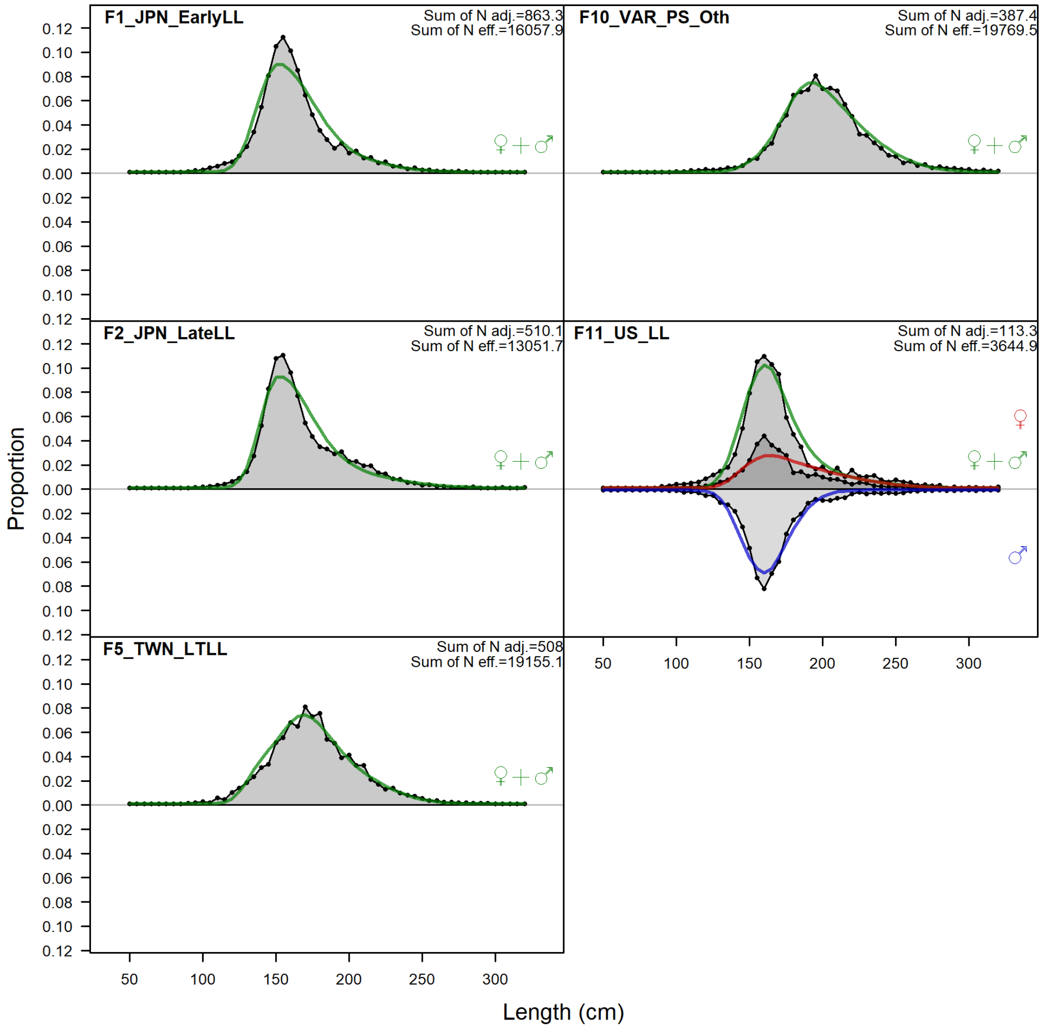


Figure 20. Aggregated length (cm) composition input data (gray) and base model fits, which are shown for females and males separately for F11_US_LL (red and blue lines, respectively) but are for combined sex for all other fleets (green lines).

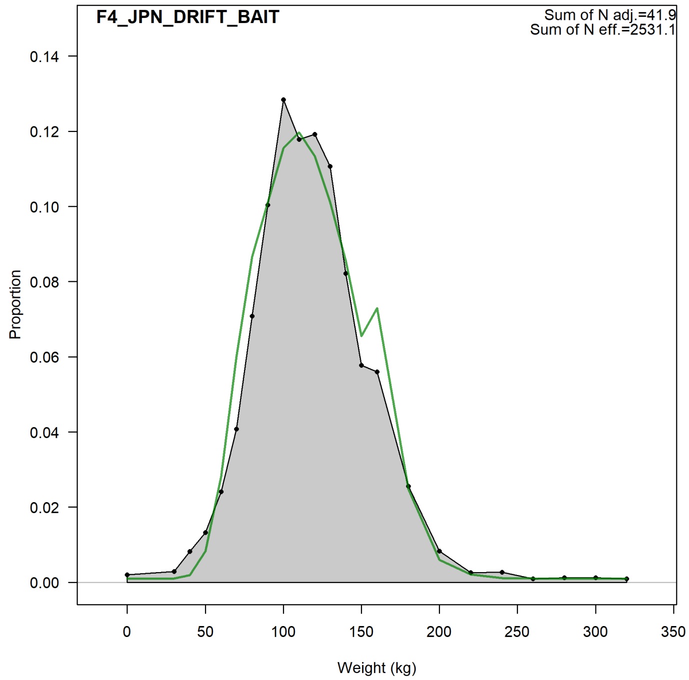


Figure 21. Aggregated weight (kg) composition input data (gray) and base model fits (green lines) for F4_JPN_DRIFT_BAIT.

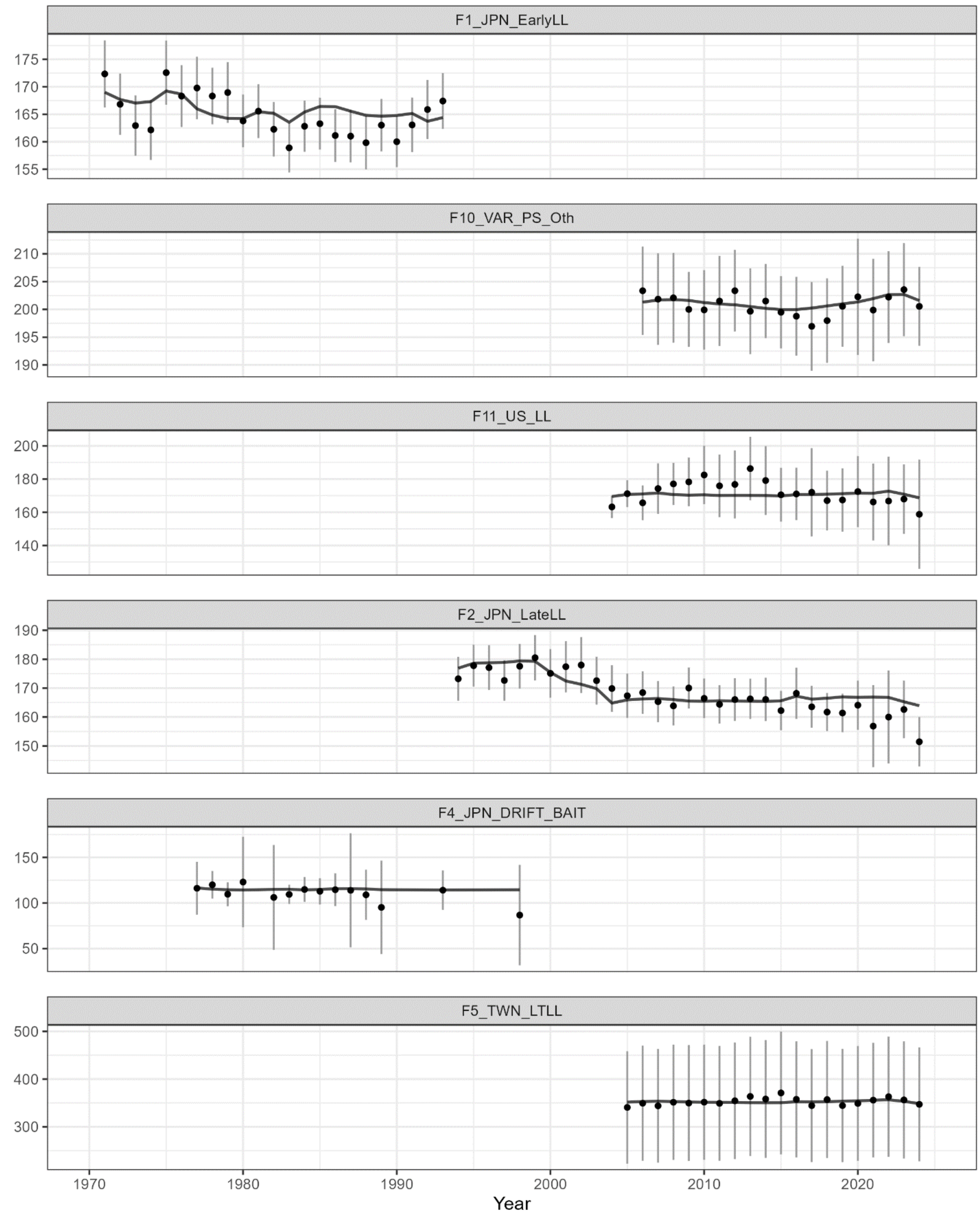


Figure 22. Base model fit (lines) to annual average size (points). Error bars are +/- 1.96 SE (Final EffN adjusted value, see Table 7). Size data are weight (kg) for F4_JPN_DRIFT_BAIT and length (cm) for all other fleets.

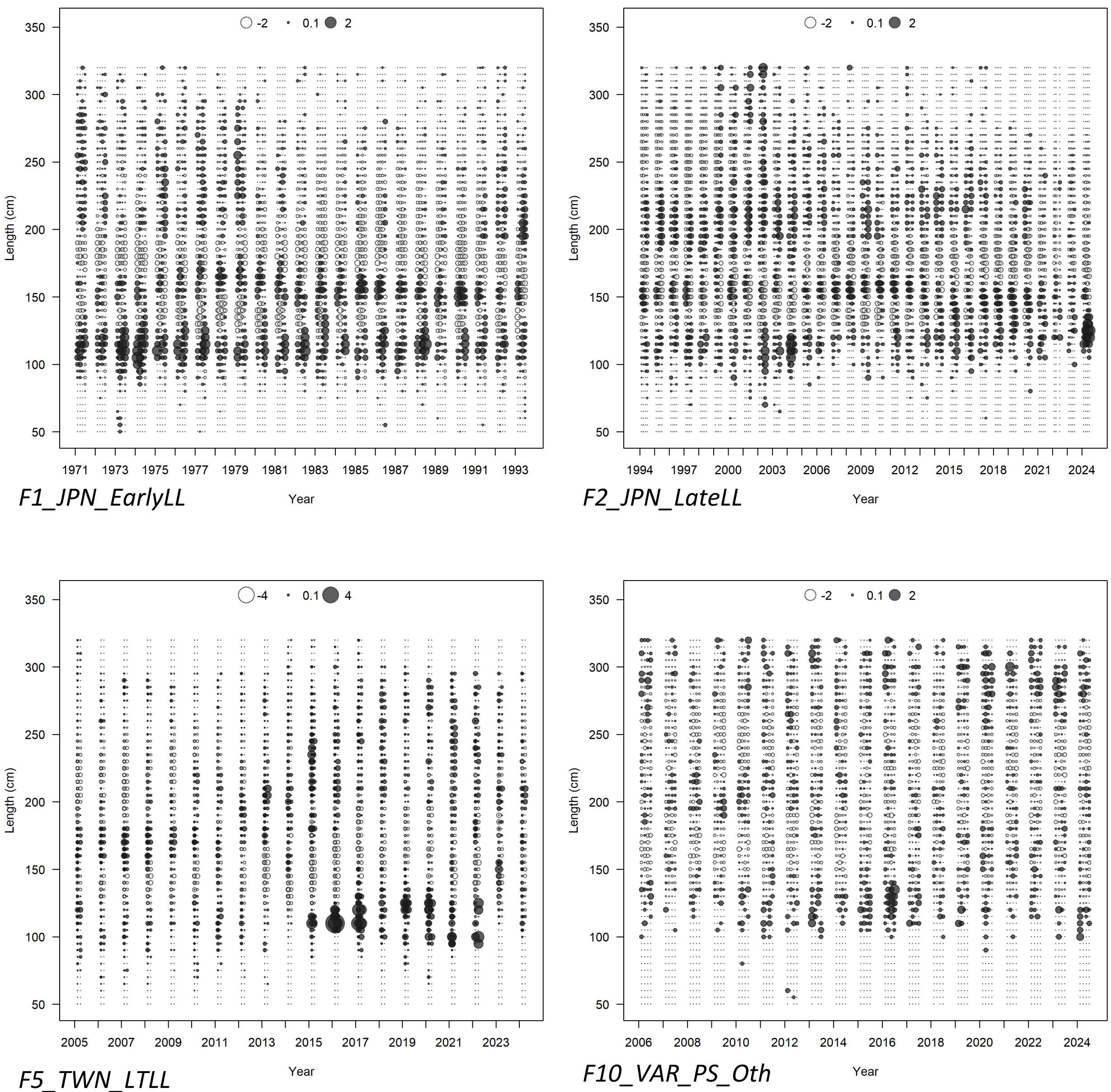
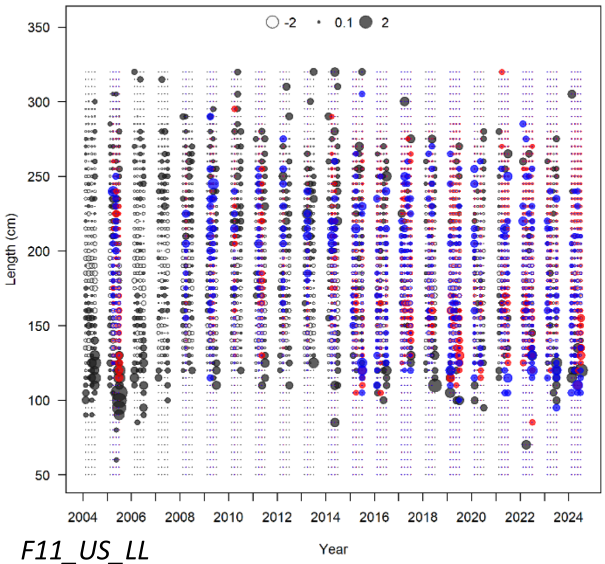
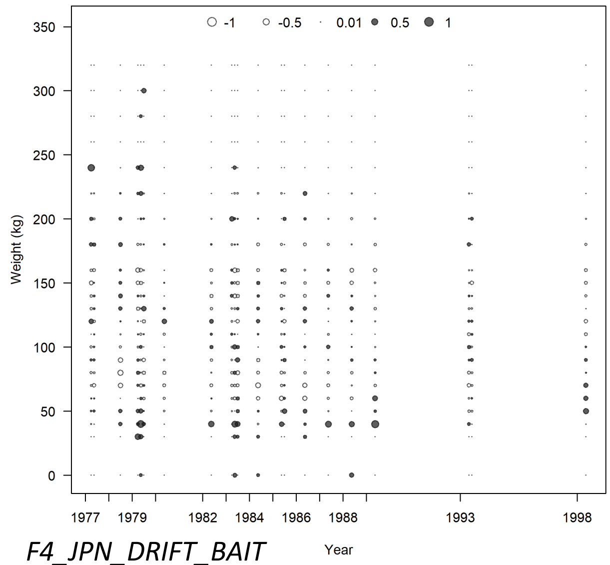


Figure 23. Residuals between the base model and size composition by fleet. Solid symbols represent positive residuals (composition data were greater than model predicted composition) and open symbols represent negative residuals (composition data were less than model predicted composition). When available, size composition data were sex-specific for females (red) and males (blue).



F11_US_LL



F4_JPN_DRIFT_BAIT

Figure 23. Continued.

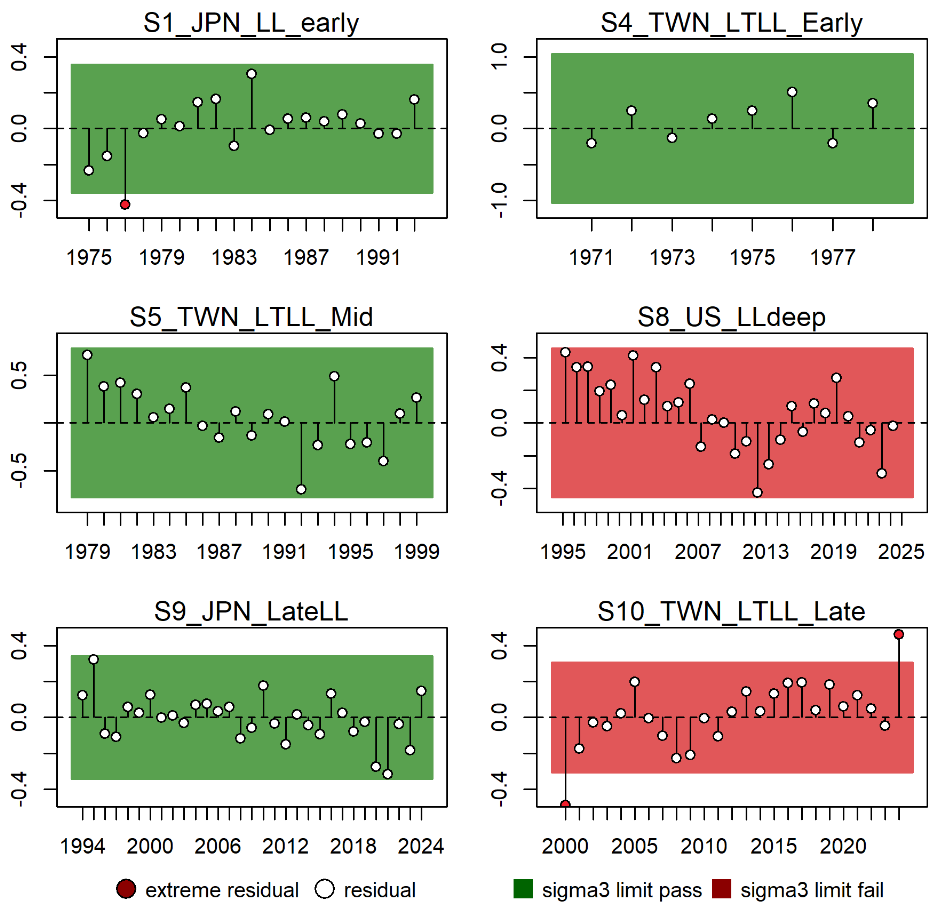


Figure 24. Runs tests of the base model for each CPUE index.

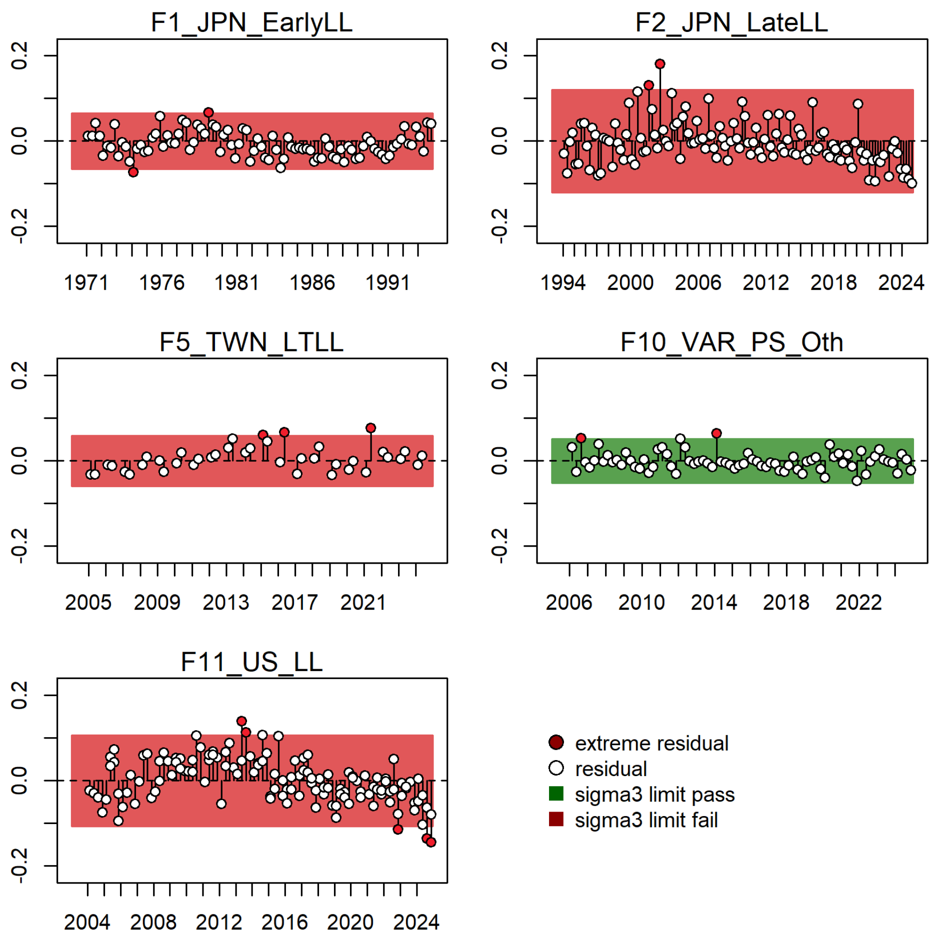


Figure 25. Runs tests of the base model for each length composition time series.

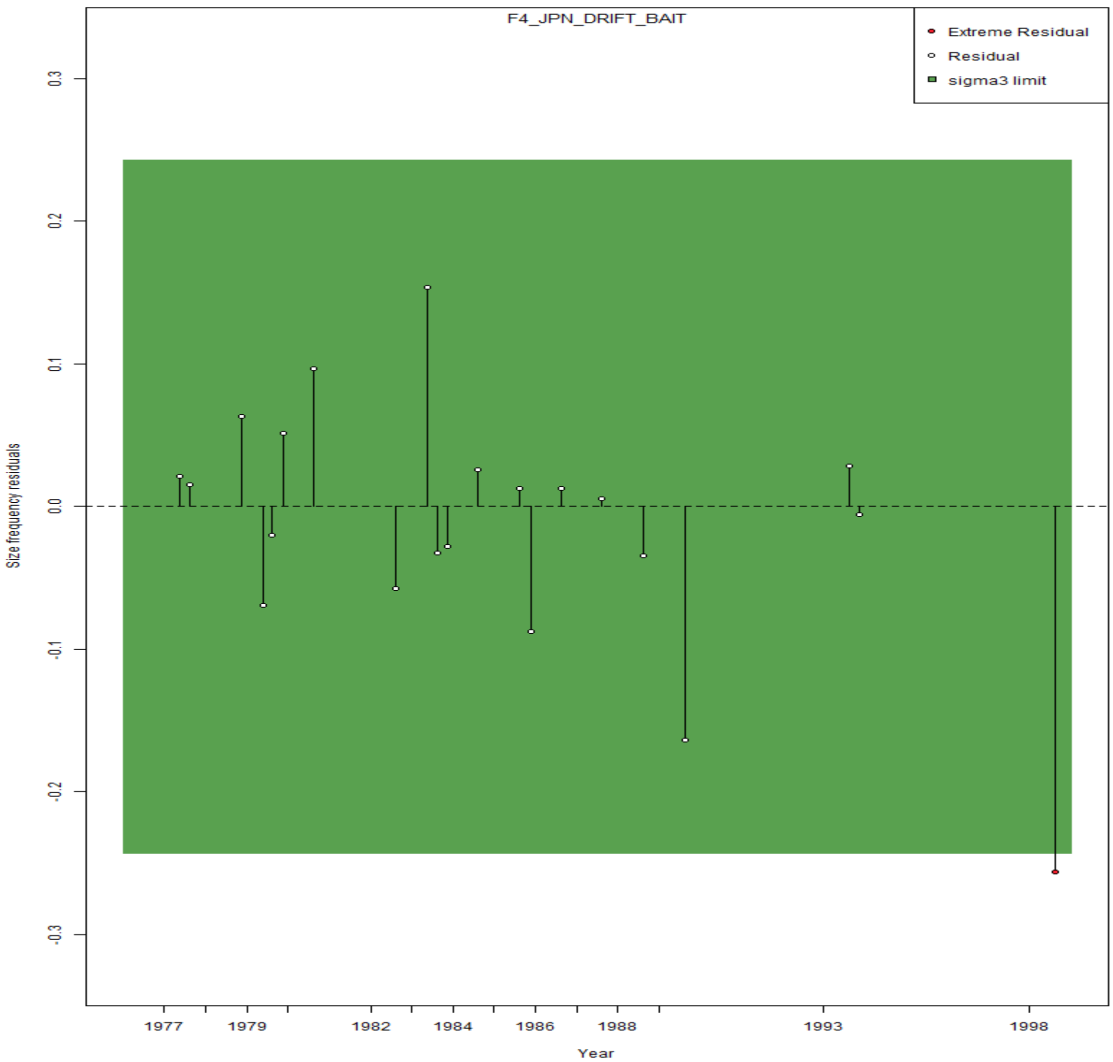


Figure 26. Runs tests of the base model for the F4_JPN_DRIFT_BAIT weight composition data.

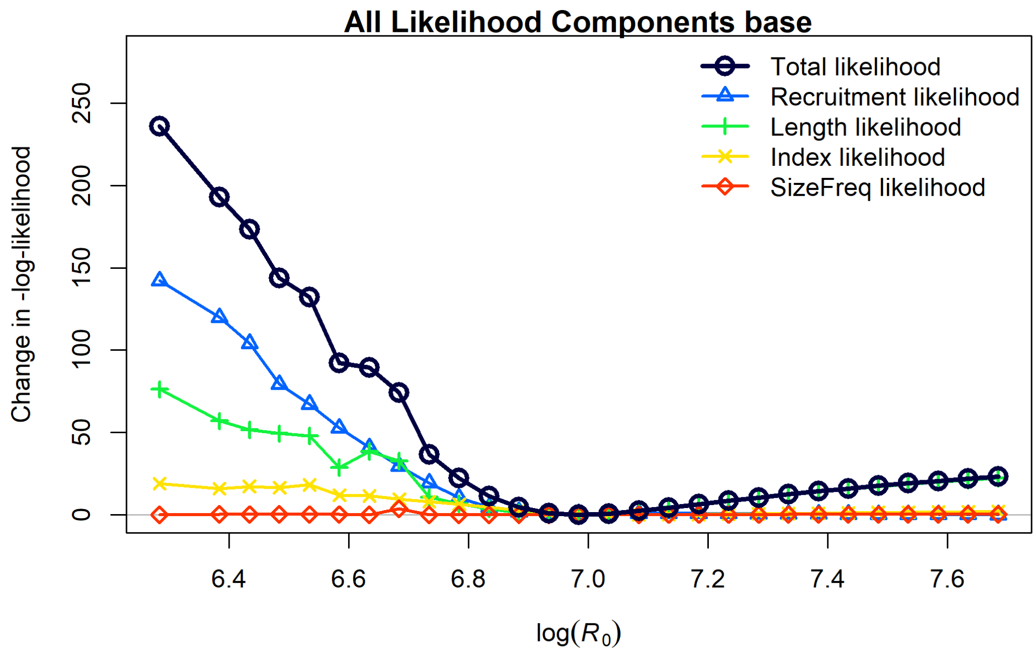


Figure 27. Loglikelihood profile over ln(R0) by likelihood component for the base model.

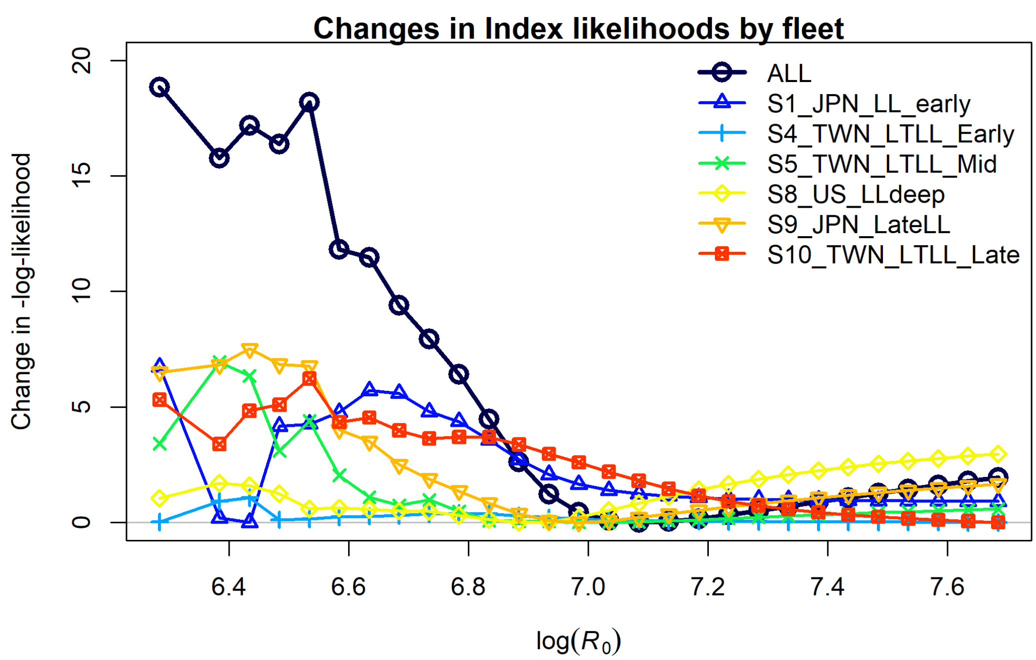


Figure 28. Loglikelihood profile over ln(R0) by CPUE index for the base model.

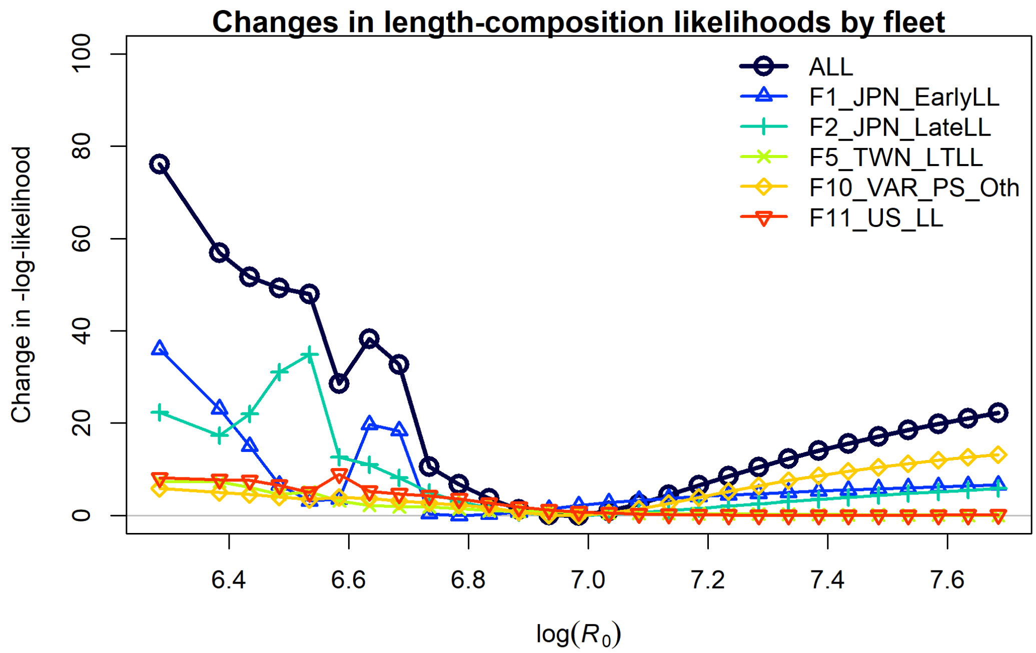


Figure 29. Loglikelihood profile over ln(R_0) by fleet length composition for the base model.

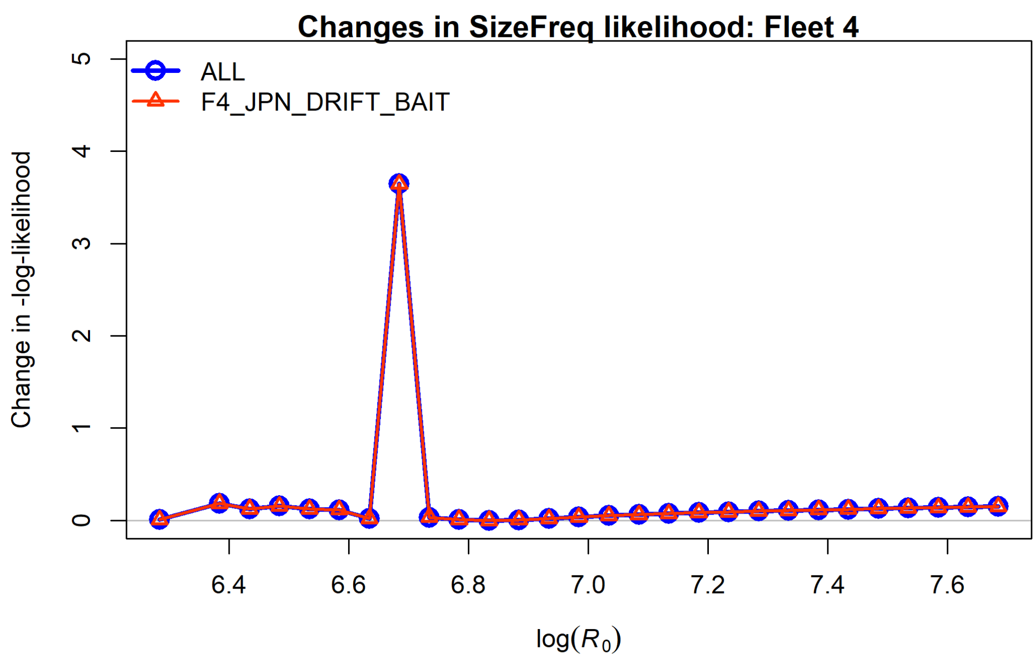


Figure 30. Loglikelihood profile over ln(R_0) by fleet weight composition for the base model.

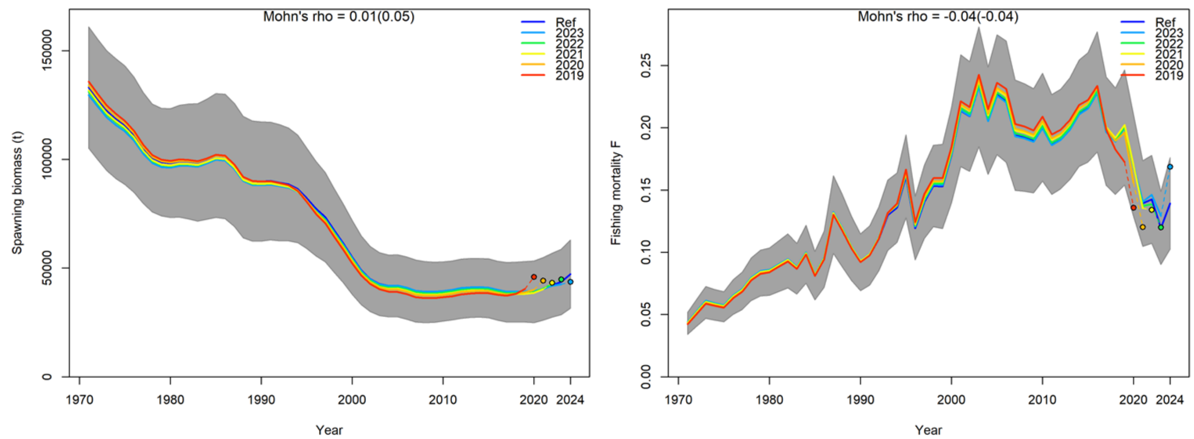


Figure 31. Retrospective analysis of spawning biomass (left) and fishing mortality (F, as exploitation of biomass; right) for the whole time series consisting of 5 reruns of the base model each fitted with one more year of data removed from the base model (blue line). The grey shade areas indicate 95% confidence intervals for base model.

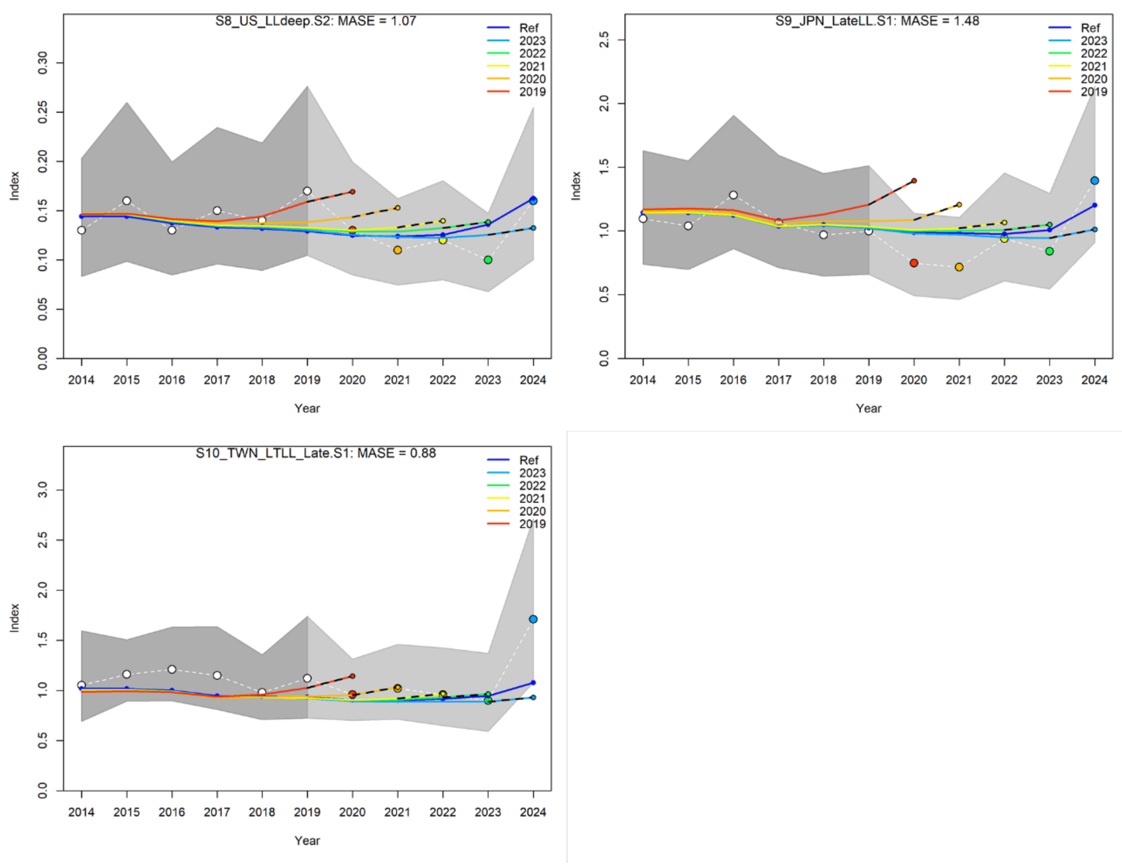


Figure 32. Hind casting cross-validation (HCxval) results for S8_US_deep, S9_JPN_LateLL, and S10_TWN_LTLL_Late, showing observed (large points with dashed line), fitted (solid lines), and

one-year-ahead forecast values (small terminal points) for the base model. The observations used for cross-validation are highlighted as color-coded solid circles with associated 95% confidence intervals (light-grey shading). The model reference year refers to the endpoint of each one-year-ahead forecast and the corresponding observation. The mean absolute scaled error (MASE) score associated with each CPUE time series is denoted in each panel.

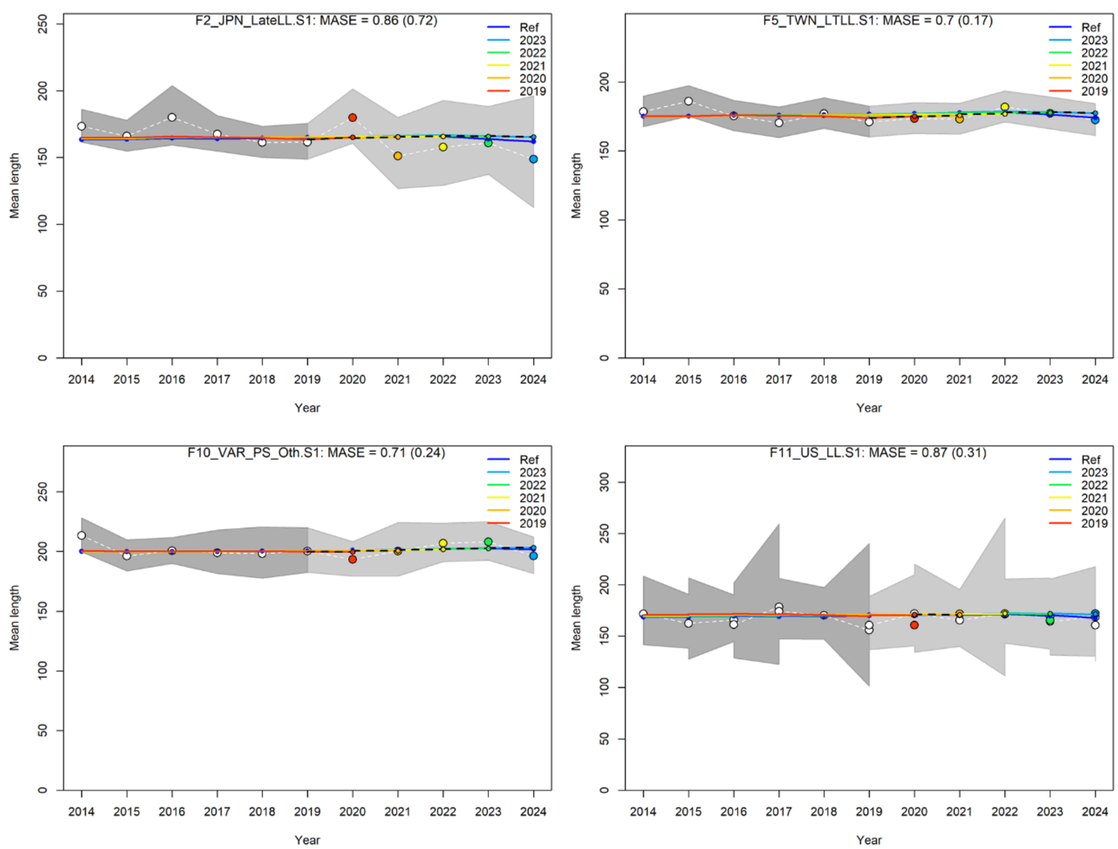


Figure 33. Hind casting cross-validation (HCxval) results for F2_JPN_LateLL, F5_TWN_LTLL, F10_VAR_PS_Oth, and F11_US_LL size composition mean lengths, showing observed (large points with dashed line), fitted (solid lines), and one-year-ahead forecast values (small terminal points) in the base model. The observations used for cross-validation are highlighted as color-coded solid circles with associated 95% confidence intervals (light-grey shading). The model reference year refers to the endpoint of each one-year-ahead forecast and the corresponding observation. The mean absolute scaled error (MASE) score associated with each size composition time series is denoted in each panel..

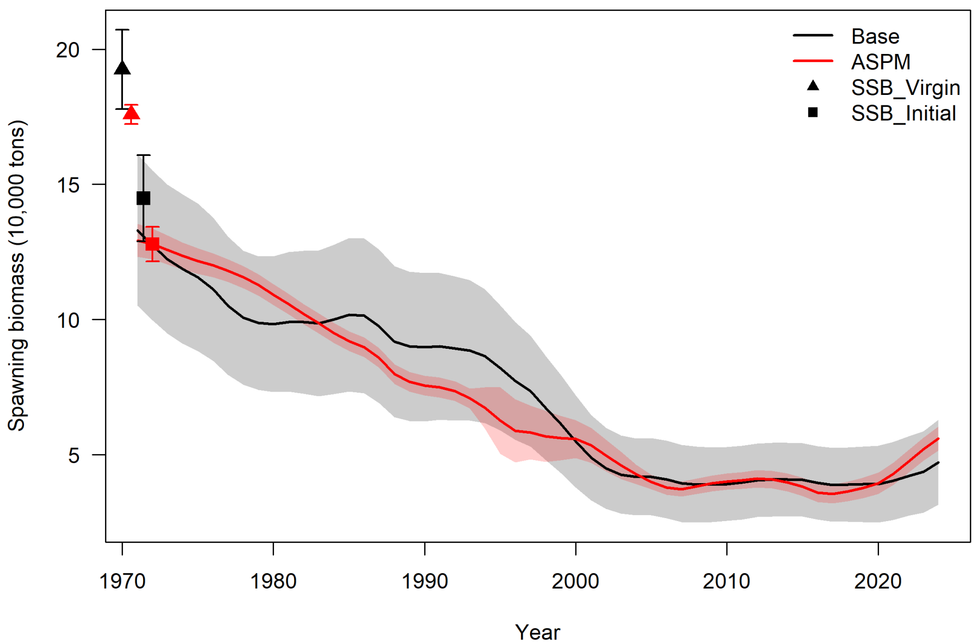
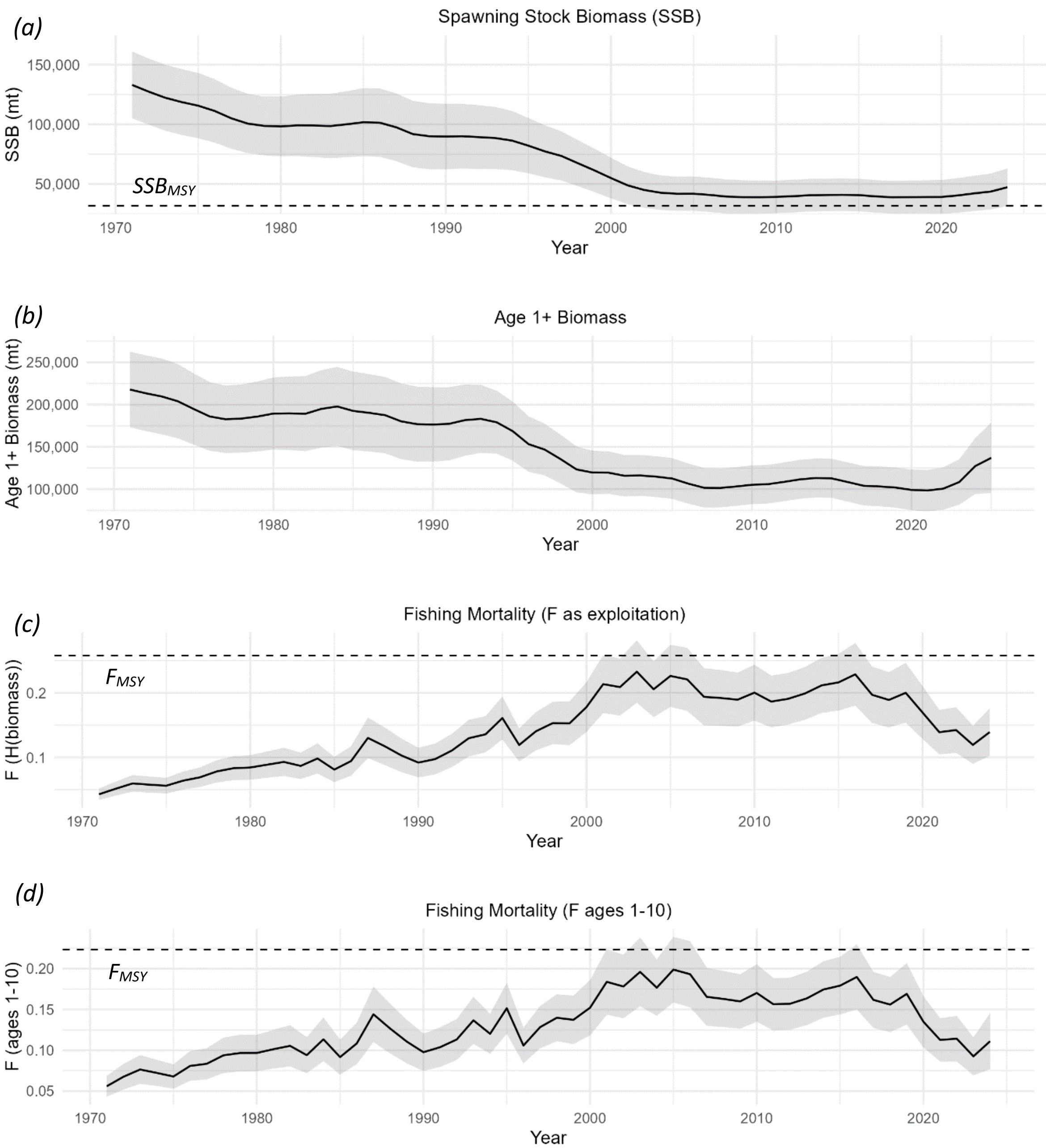


Figure 34. Spawning stock biomass trajectories from the base model (black) and ASPM model (red). Shaded areas indicate 95% confidence intervals, and symbols show estimated unfished spawning biomass (SSB_Virgin; triangles) and initial spawning biomass (SSB_Initial; squares) with 95% confidence intervals.


(a)
Spawning Stock Biomass (SSB)
SSB (mt)
150,000
100,000
50,000
SSB_MSY
1970
1980
1990
2000
2010
2020
Year
(b)
Age 1+ Biomass
Age 1+ Biomass (mt)
250,000
200,000
150,000
100,000
1970
1980
1990
2000
2010
2020
Year
(c)
Fishing Mortality (F as exploitation)
F (H(biomass))
0.2
0.1
F_MSY
1970
1980
1990
2000
2010
2020
Year
(d)
Fishing Mortality (F ages 1-10)
F (ages 1-10)
0.20
0.15
0.10
0.05
F_MSY
1970
1980
1990
2000
2010
2020
Year

(e)

Figure 35. Time series of estimates of (a) spawning biomass, SSB; (b) population biomass (age 1+); (c) fishing mortality (F) as exploitation of biomass; (d) instantaneous F (average for age 1–10); and (e) recruitment (age-0 fish) for blue marlin. The solid line represents the maximum likelihood estimates by year for each quantity, the shaded areas are 95% confidence intervals, dashed lines indicate the static SSB_{MSY} and F_{MSY} reference points.

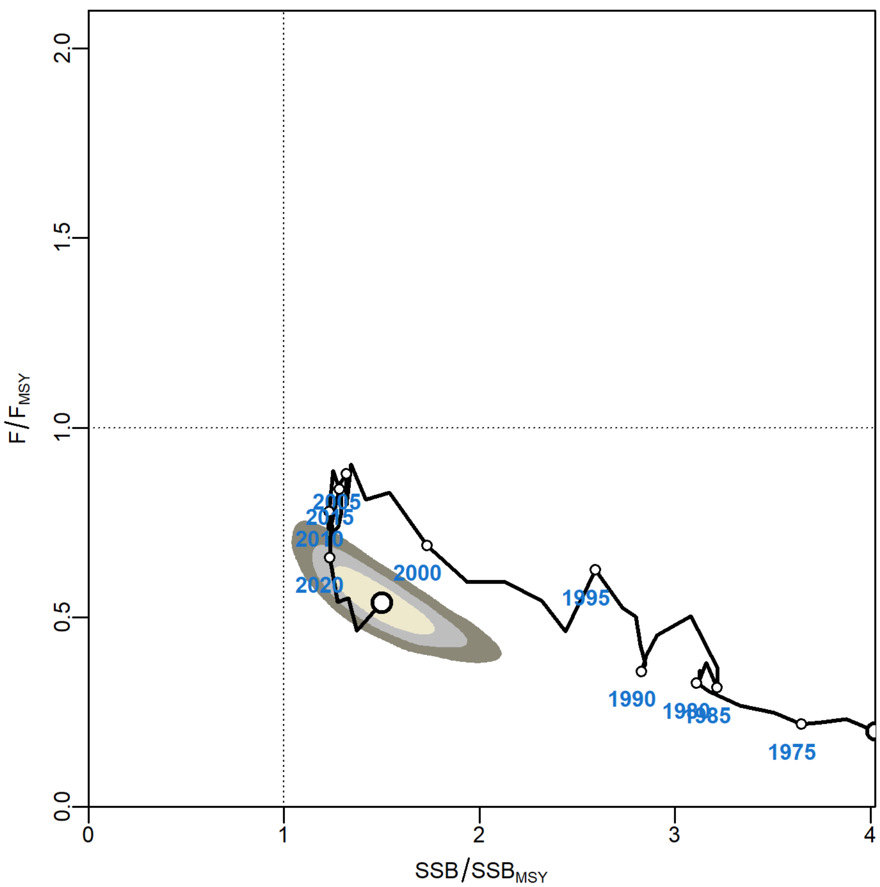


Figure 36. Kobe plot of the timeseries of estimates of mature female spawning stock biomass (SSB) and fishing mortality (as exploitation of biomass) relative to MSY values (SSBMSY and FMSY, respectively) of Pacific blue marlin during 1971–2024. The earliest white symbol indicates 1971, subsequent years are labeled in 5-year increments. Shading indicates 50% (innermost), 80%, and 95% confidence intervals of terminal year (2024) stock status.

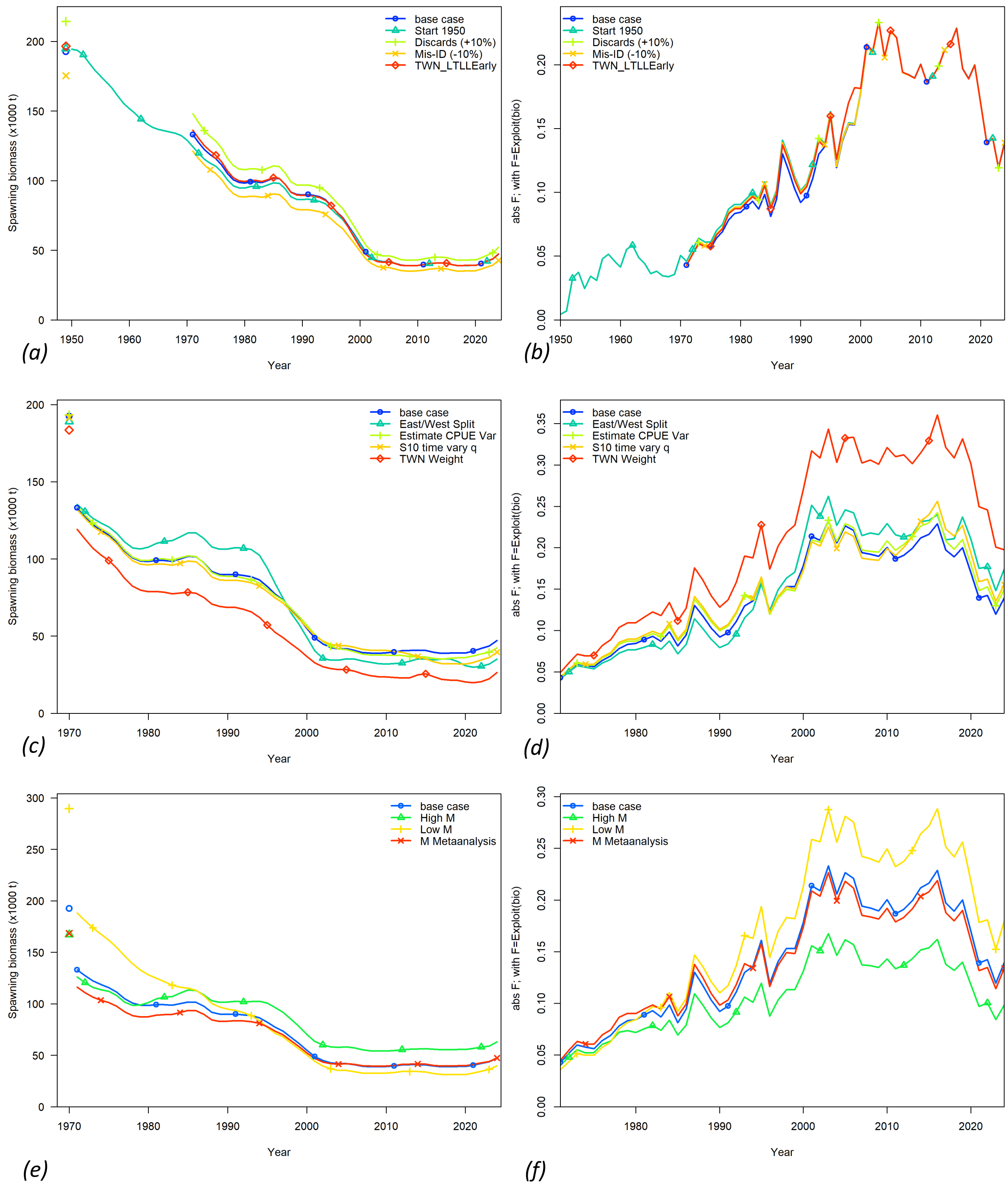


Figure 37. Spawning biomass (left column) and fishing mortality (right column) showing sensitivity model runs conducted for the 2026 assessment of Pacific blue marlin. Models are described in Table 9: (a-b) catch; (c-d) input data and error assumptions; (e-f) natural mortality; (g-h) spawner-recruit steepness; (i-j) growth; (k-l) maturity; (m-n) length-weight; (o-p) initial fishing mortality and recruitment deviations.

Figure 37 continued.

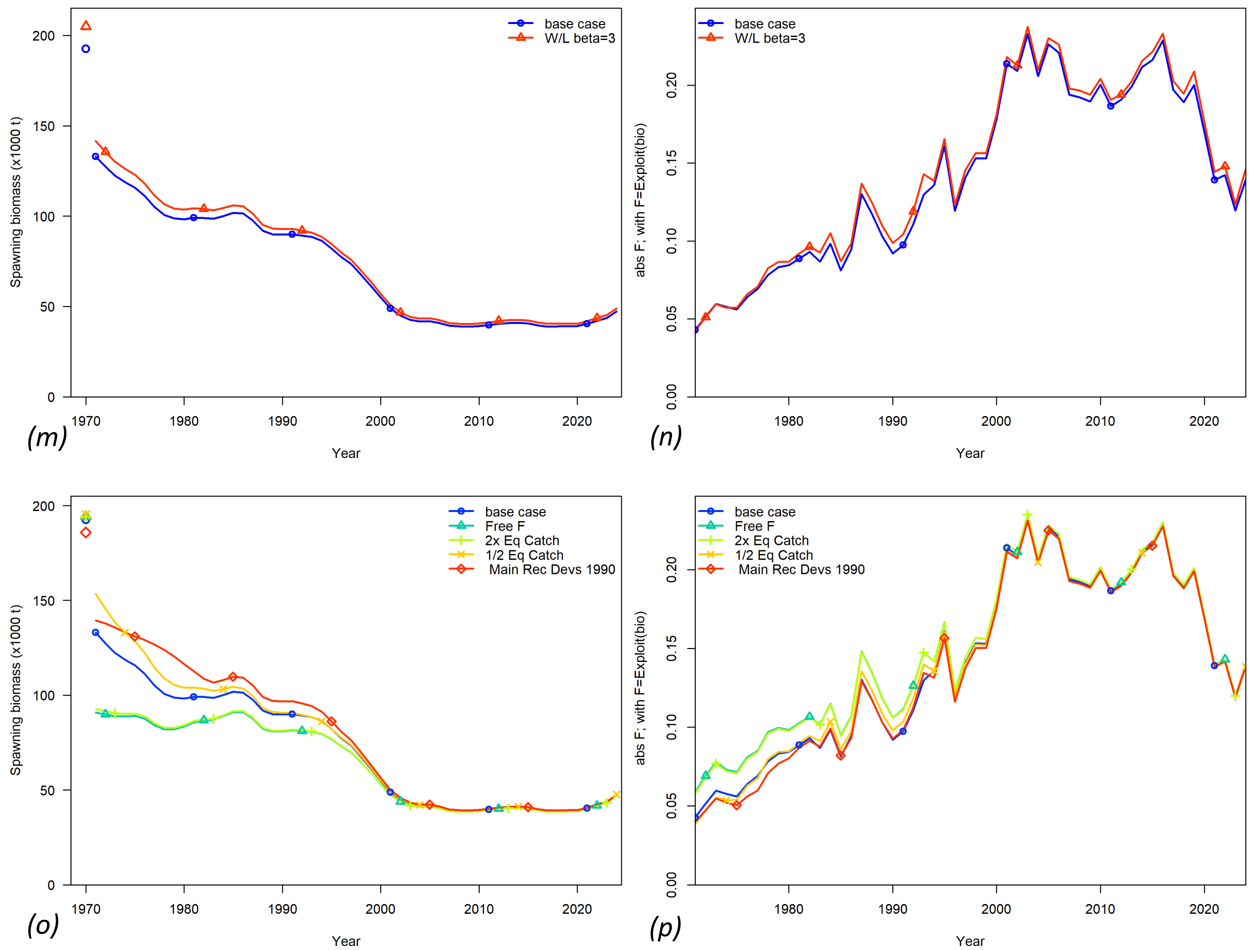


Figure 37 continued.

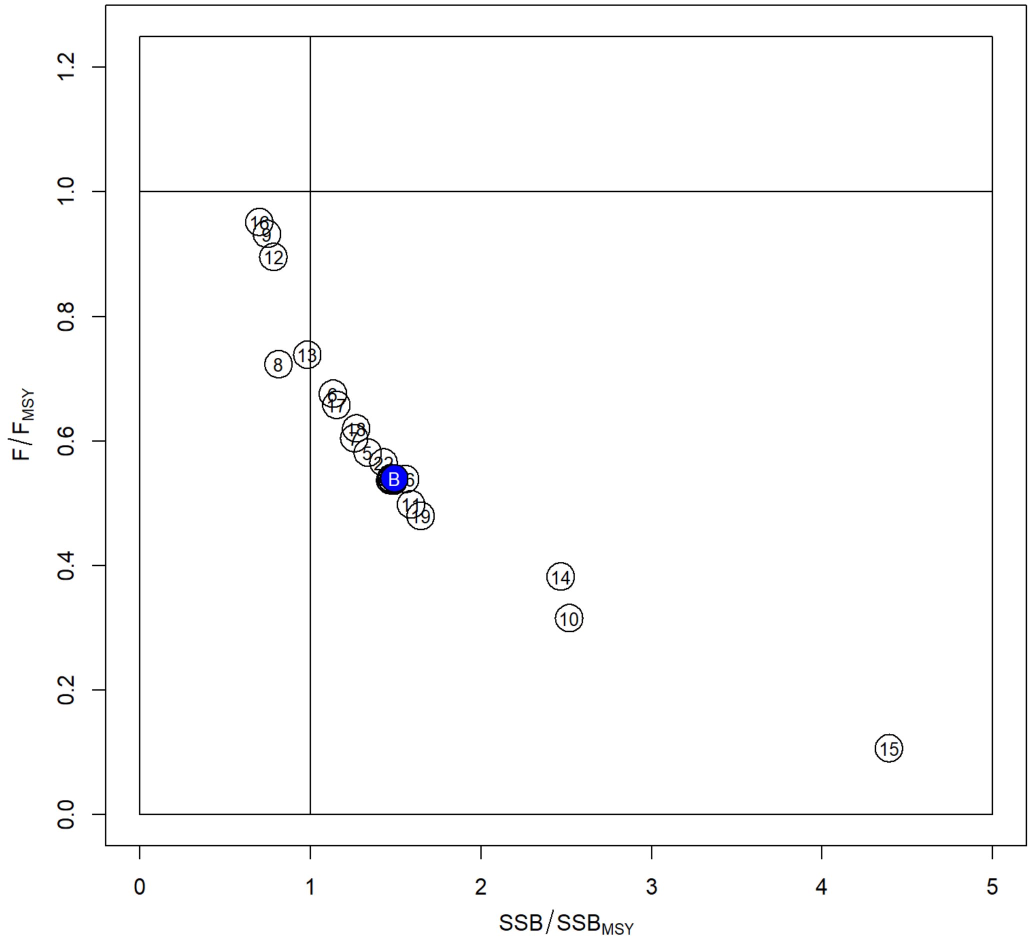


Figure 38. Kobe plot of terminal year stock status for each of the sensitivity runs (circled numbers) and the base model (solid blue dot). Each number corresponds to the sensitivity run in Table 9.

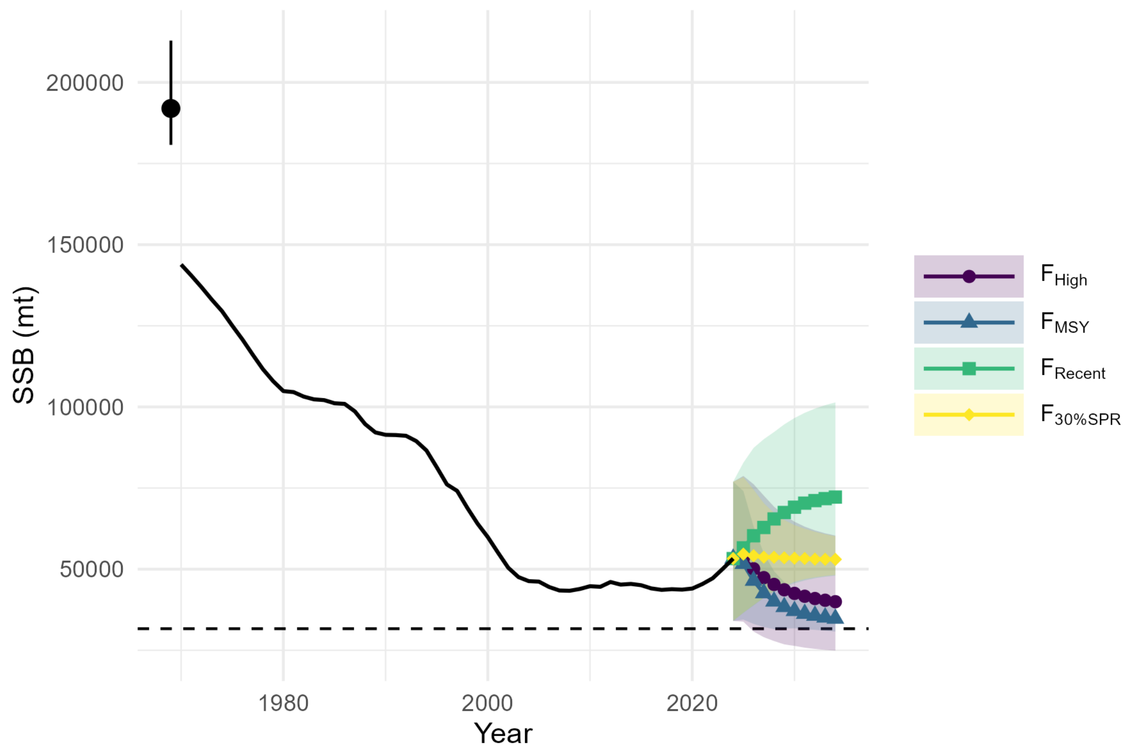


Figure 39. Historical and projected trajectories of spawning biomass from the Pacific blue marlin base model based upon F scenarios. The solid lines and symbols are the median value of the 100 bootstrap model runs and the shaded ribbon is the 95% confidence interval. Dashed line indicates the spawning stock biomass at MSY. Projection scenarios are described in Future Projections .

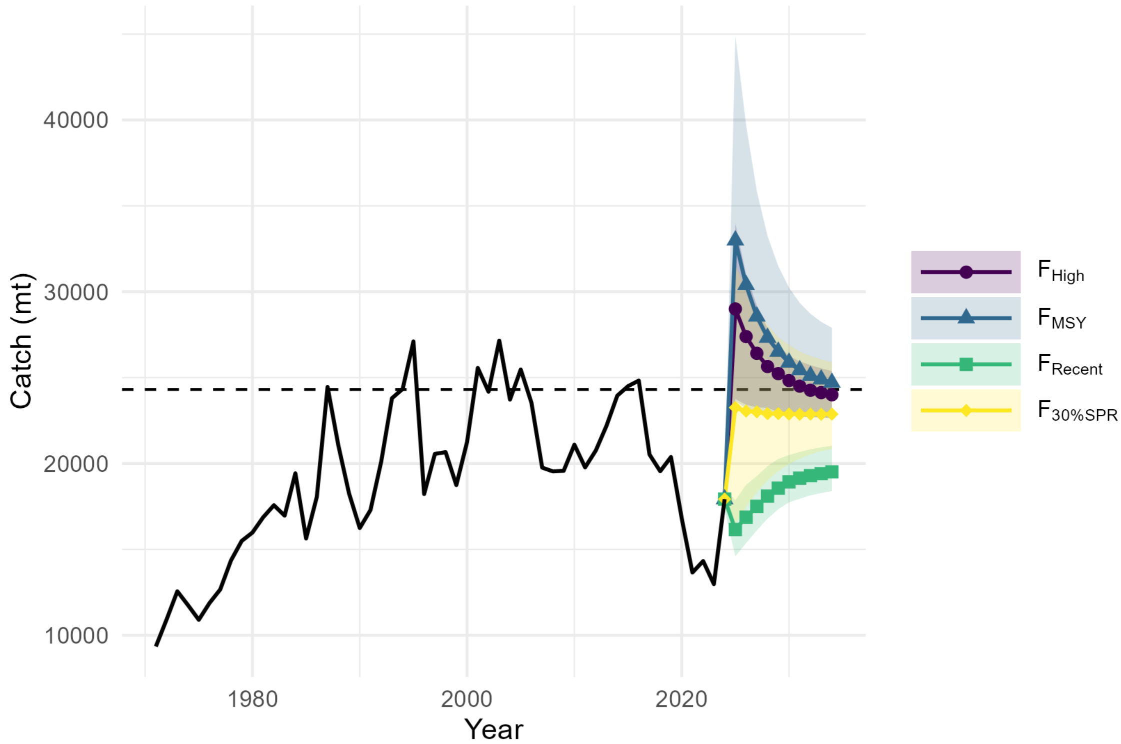


Figure 40. Historical and projected trajectories of catch from the Pacific blue marlin base model based upon F scenarios. The solid lines and symbols are the median value of the 100 bootstrap model runs and the shaded ribbon is the 95% confidence interval. The dashed line indicates MSY. Projection scenarios are described in Future Projections.