Stock Assessment Report for Swordfish (*Xiphias gladius*) in the North Pacific through 2021

ISC Billfish Working Group

6/1/23

## Abstract

We present the benchmark stock assessment for the North Pacific swordfish (*Xiphias gladius*, NP SWO) stock conducted in 2023 by the ISC Billfish Working Group (BILLWG). The 2023 assessment consisted of applying a Stock Synthesis model with the best-available life history parameters and catch, abundance index, and length composition data for 1975-2021. The results indicated that population biomass (age 1 and older) for the NP SWO stock fluctuated around an average of 83000 mt during 1975-2021 and was estimated to be 88,750 mt in 2021. Estimated fishing mortality has generally declined from the 1970s to the late-1990s, slightly increased again to the 2001, and then continued declining to average 0.09 year-1 in 2019-2021. Fishing mortality has been below FMSY for the entire assessment period. There are no defined reference points for North Pacific swordfish in the Western and Central Pacific Fisheries Commission (WCPFC), therefore stock status is based upon maximum sustainable yield (MSY) reference points. The current or recent 3-year average spawning biomass of 34900 mt (average for 2019-2021) was 2.5 times greater than SSBMSY and the current fishing mortality (average for ages 1 – 10 during 2018-2020) was 51% above FMSY. The base case model indicated that under current conditions the NP SWO stock was very likely not overfished (>99% probability) and was very likely not subject to overfishing (>99% probability) relative to MSY-based reference points.

# Executive Summary: North Pacific swordfish (*Xiphias gladius*) Stock Assessment

**Stock Identification and Distribution:** The North Pacific swordfish (*Xiphias gladius,* NP SWO) stock area was defined to be the waters of the North Pacific Ocean contained in the Western and Central Pacific Fisheries Commission Convention Area bounded by the equator and the waters of the Inter-American Tropical Tuna Commission Convention Area north of 10°N ([Figure S1](#fig-stockareas)). All available fishery data from the stock area were used for the stock assessment. For the purpose of modeling observations of CPUE and size composition data, it was assumed that there was an instantaneous mixing of fish throughout the stock area on a quarterly basis. The stock was modeled using a fleets-as-areas approach with separate catch and index fleets for the WCNPO and EPO region delineated in ([Figure S1](#fig-stockareas)).

**Catches:** The NP SWO catches were high from the 1970’s to the 1980’s averaging about 14,000 mt per year during 1975-1990, peaked with unusually high catches in 1998 -2000, and then generally declined to the current levels around 11,000. Catches by most fleets have generally declined, while minor catches by other WCPFC countries have generally increased, except in in the last three years ([Figure S2](#fig-catchbycountry)). Overall, longline fishing gear has accounted for the vast majority of NP SWO catch.

**Data and Assessment:** Catch and size composition data were collected from ISC countries (Chinese Taipei, Japan, and USA) and the WCPFC and IATTC. Standardized catch-per-unit effort (CPUE) data used to measure trends in relative abundance were provided by Chinese Taipei, Japan, and USA. The NP SWO stock was assessed using an age- and length-structured assessment Stock Synthesis (SS3) model fit to time series of standardized CPUE and size composition data. Life history parameters for growth and maturity were updated for this benchmark stock assessment. The value for stock-recruitment steepness used for the base case model was *h* = 0.9. The assessment model was fit to relative abundance indices and size composition data in a likelihood-based statistical framework. Maximum likelihood estimates of model parameters, derived outputs, and their variances were used to characterize stock status and to develop stock projections. Several sensitivity analyses were conducted to evaluate the effects of changes in model parameters, including natural mortality rate at age, stock-recruitment steepness, growth curve parameters, and female length at 50% maturity, as well as uncertainty in the input data and model structure.

**Status of Stock:** Estimates of population biomass fluctuated around an average of 82,800 mt during 1975-2021 and was estimated to be 88,800 mt in 2021 ([Figure S3a](#fig-summarybiomass-1)). Initial estimates of female spawning stock biomass (SSB) averaged around 27,600 mt in the late 1970s. SSB was at its highest level of 35,780 metric tons in 2021, and was at its minimum of 22,415 mt in 1981. Overall, spawning stock biomass has been relatively stable for the entirety of the assessment period ([Figure S3b](#fig-summarybiomass-2)). Estimated fishing mortality (arithmetic average of F for ages 1 – 10) decreased from 0.17 year-1 in 1978 to a minimum of 0.087 year-1 in 2021 ([Figure S3 (c)](#fig-summarybiomass-3)). It averaged roughly F=0.088 during 2019-2021 or about 51% of FMSY with a relative fishing mortality of F/FMSY = 0.087 in 2021. Fishing mortality has been below FMSY since the beginning of the assessment time period and has had a declining trend with the exception of a high peak in 1998 coinciding with high catch by the US LL fleet. Recruitment (age-0 fish) estimates averaged approximately 838,000 during 1975-2021. While recruitment varied, there was no apparent trend in recruitment strength over time ([Figure S3d](#fig-summarybiomass-4)). Overall, total annual catches are declining, catch per unit effort is increasing, and recruitment is relatively stable. When the status of NP SWO is evaluated relative to MSY-based reference points, the 2021 spawning stock biomass of 35,778 mt is 220% above SSBMSY (16,000 mt) and the 2019-2021 fishing mortality is about 49% below *F*MSY. Therefore, relative to MSY-based reference points, overfishing is very likely not occurring (>99% probability) and the NP SWO stock is very likely not overfished (>99% probability, [Figure S4](#fig-Kobe)).

**Table S1.** Reported catch (mt) used in the stock assessment along with annual estimates of population biomass (age-1 and older, mt), female spawning biomass (mt), relative female spawning biomass (SSB/SSBMSY), recruitment (thousands of age-0 fish), fishing mortality (average F, ages 1–10), relative fishing mortality (F/FMSY), and spawning potential ratio of North Pacific swordfish (*Xiphias gladius*).

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **2016** | **2017** | **2018** | **2019** | **2020** | **2021** | **Mean1** | **Min1** | **Max1** |
| Reported Catch | 12,648 | 11,831 | 12,730 | 11,093 | 10,731 | 10,136 | 9,539 | 12,876 | 19,230 |
| Population Biomass | 83,200 | 86,835 | 89,418 | 89,617 | 89,992 | 88,755 | 65,723 | 80,587 | 89,992 |
| Spawning Biomass | 28,205 | 29,785 | 31,661 | 33,761 | 35,159 | 35,778 | 22,415 | 28,777 | 35,778 |
| Relative Spawning Biomass | 1.72 | 1.82 | 1.93 | 2.06 | 2.15 | 2.18 | 1.37 | 1.76 | 2.18 |
| Recruitment (age 0) | 964,401 | 746,962 | 783,354 | 739,400 | 624,962 | 633,046 | 595,771 | 838,473 | 1,430,430 |
| Fishing Mortality | 0.10 | 0.09 | 0.10 | 0.09 | 0.09 | 0.09 | 0.09 | 0.12 | 0.19 |
| Relative Fishing Mortality | 0.55 | 0.52 | 0.57 | 0.49 | 0.50 | 0.49 | 0.49 | 0.68 | 1.09 |
| Spawning Potential Ratio | 0.34 | 0.37 | 0.37 | 0.42 | 0.43 | 0.44 | 0.24 | 0.33 | 0.44 |

**Biological Reference Points:** MSY-based biological reference points were computed for the base case model with SS (Table S2). The point estimate of annual catch at FMSY was calculated to be 14,924 mt. The point estimate of the spawning biomass to produce MSY (adult female biomass) was 16,388 mt. The point estimate of FMSY, the fishing mortality rate to produce SSBMSY (average fishing mortality on ages 1 – 10) was 0.18 and the corresponding equilibrium value of spawning potential ratio at SSBMSY was 19%.

**Projections:** Stock projections for NP SWO were conducted using SS3.3. No recruitment deviations nor log-bias adjustment were applied to the future projections. Projections are reported as the mean and standard deviation around 100 bootstrapped model runs for each scenario. Projections started in 2022 and continued through 2031 under 5 levels of fishing mortality. The five fishing mortality stock projection scenarios were: (1) F status quo (average F during 2019-2021), (2) FMSY, (3) F at 20%SSB(F=0) which was calculated from the mean dynamic SSB0 in the last five years, (4) F(2008-2010) which is the reference years for the proposed CMM for NP SWO, and (5) FLow at F30%SPR. Results show the projected female spawning stock biomasses and the catch biomasses under each of the scenarios (Table S3 and [Figures S5](#fig-projectionssb) and S[6](#fig-projectioncatch)).

**Conservation information:** The NP SWO stock has produced annual yields of around 11,500 mt per year since 2016, or about 2/3 of the MSY catch amount. This suggests the stock may be able to support somewhat higher yields. Swordfish stock status is positive with no evidence of excess fishing mortality above FMSY or substantial depletion of spawning potential. It was also noted that retrospective analyses show that the assessment model appears to underestimate spawning potential in recent years.

**Special Comments**: The lack of sex-specific size data and the simplified treatment of the spatial structure of swordfish population dynamics remained as two important sources of uncertainty for improving future assessments.

**Table S2.** Estimates of biological reference points along with estimates of fishing mortality (F), spawning stock biomass (SSB), recent average yield (C), and spawning potential ratio (SPR) of Western and Central North Pacific striped marlin, derived from the base case model assessment model, where SSBF=0 indicates the average 20-year dynamic B0 estimate, 20%SSBF=0 is the associated reference point, and MSY indicates the maximum sustainable yield reference point.

|  |  |
| --- | --- |
| **Reference Point** | **Estimate** |
| F20%SSB(F=0) (age 1-10) | 0.53 |
| FMSY (age 1-10) | 0.63 |
| F2021  (age 1-10) | 0.58 |
| F2019-2021 | 0.68 |
| SSBF=0 | 18,600 mt |
| 20%SSBF=0 | 3,720 mt |
| SSBMSY | 2,920 mt |
| SSB2021 | 1,696 mt |
| SSB2019-2021 | 1,359 mt |
| C20%SSB(F=0) | 14,814 mt |
| CMSY | 14,924 mt |
| C2019-2021 | 10,653 mt |
| SPR20%SSB(F=0) | 22% |
| SPRMSY | 19% |
| SPR2021 | 44% |
| SPR2019-2021 | 43% |

**Table S3.** Projected mean values of North Pacific swordfish spawning stock biomass (SSB, mt) and catch (mt) under five constant fishing mortality rate (F) scenarios during 2022-2031.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **2022** | **2023** | **2024** | **2025** | **2026** | **2027** | **2028** | **2029** | **2030** | **2031** |
| **Scenario 1: F20%SSB(F=0)** | | | | | | | | | | |
| SSB | 40,457 | 38,288 | 36,295 | 35,452 | 35,425 | 35,611 | 36,064 | 36,387 | 36,264 | 36,478 |
| Catch | 16,906 | 14,986 | 13,531 | 13,120 | 13,298 | 13,612 | 13,875 | 14,053 | 14,161 | 14,220 |
| **Scenario 2: F1998-2000** | | | | | | | | | | |
| SSB | 41,567 | 40,422 | 38,952 | 38,309 | 38,371 | 38,565 | 39,133 | 39,534 | 39,336 | 39,625 |
| Catch | 14,302 | 13,389 | 12,608 | 12,428 | 12,656 | 12,967 | 13,224 | 13,399 | 13,509 | 13,572 |
| **Scenario 3: Low F (FSPR30%)** | | | | | | | | | | |
| SSB | 42,268 | 42,368 | 41,811 | 41,756 | 42,235 | 42,712 | 43,610 | 44,300 | 44,162 | 44,705 |
| Catch | 11,370 | 11,249 | 11,096 | 11,255 | 11,623 | 11,990 | 12,263 | 12,445 | 12,557 | 12,631 |
| **Scenario 4: FMSY** | | | | | | | | | | |
| SSB | 38,291 | 34,051 | 31,164 | 29,979 | 29,800 | 29,894 | 30,225 | 30,452 | 30,322 | 30,473 |
| Catch | 23,395 | 17,817 | 14,992 | 14,169 | 14,264 | 14,565 | 14,812 | 14,966 | 15,052 | 15,095 |
| **Scenario 5: FStatus Quo (Average F2019-2021)** | | | | | | | | | | |
| SSB | 38,828 | 35,056 | 32,339 | 31,201 | 31,036 | 31,138 | 31,489 | 31,733 | 31,602 | 31,765 |
| Catch | 21,803 | 17,218 | 14,723 | 13,981 | 14,082 | 14,379 | 14,627 | 14,785 | 14,875 | 14,921 |

|  |
| --- |
| Figure S1: Western and Central North Pacific Ocean and North Eastern Pacific Ocean swordfish stock boundaries for the 2023 North Pacific swordfish assessment. Spatial structure is treated implicitly using fleets as areas. |

|  |
| --- |
| Figure S2: Annual catch of NP swordfish by country or commission and area. |

|  |  |  |  |
| --- | --- | --- | --- |
| |  | | --- | | (a) | | |  | | --- | | (b) | |

|  |  |  |  |
| --- | --- | --- | --- |
| |  | | --- | | (c) | | |  | | --- | | (d) | |

Figure S3: Time series of estimates of (a) population biomass (age 1+), (b) spawning biomass, (c) instantaneous fishing mortality (average for age 1-10, year-1), and (d) recruitment (age-0 fish) for North Pacific swordfish (Xiphias gladius) derived from the 2023 stock assessment. The circles represents the maximum likelihood estimates by year for each quantity and the error bars represent the uncertainty of the estimates (95% confidence intervals), green dashed lines indicate the dynamic SSBMSY and FMSY reference points.

|  |
| --- |
| Figure S4: Kobe plot of the time series of estimates of relative fishing mortality (average of age 1-10) and relative spawning stock biomass of North Pacific swordish (Xiphias gladius) during 1977-2020. The first white dot indicates 1975, subsequent dots are in 5-year increments. Shading indicates 50%, 80%, and 95% confidence intervals, respectively. |
| Figure S5: Historical and projected trajectories of spawning biomass from the North Pacific swordfish base case model based upon F scenarios. Dashed line indicates the spawning stock biomass at SSBMSY. The list of projection scenarios can be found in Table S3. |

|  |
| --- |
| Figure S6: Historical and projected trajectories of catch from the North Pacific swordfish base case model based upon F scenarios. The list of projection scenarios can be found in Table S3. |

# 2023 North Pacific Swordfish Assessment

## Introduction

The Billfish Working Group (BILLWG or WG) of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) completed a benchmark stock assessment for North Pacific swordfish (*Xiphias gladius*, NP SWO) in 2018 (ISC, 2018). The assessment results indicated that the stock status was not overfished and overfishing was not occurring relative to MSY-based reference points. The BILLWG agreed to conduct a new benchmark stock assessment in 2023. The BILLWG held a hybrid data preparatory meeting in Yokohama, Japan December 2022 to evaluate new stock structure, updated life history parameters and fishery data (ISC, 2023). Then the BILLWG conducted the stock assessment at a hybrid meeting in Honolulu, HI in April 2023. This report describes the 2023 stock assessment for the NP SWO stock. The best available scientific information including the up-to-date catch, catch-per-unit-effort (CPUE), and composition data from 1975-2021 were provided by individual ISC countries, the Western and Central Pacific Fisheries Commission (WCPFC), and the Inter-American Tropical Tuna Commission (IATTC). The 2023 assessment was an age-structured integrated-assessment model using the modeling platform Stock Synthesis (SS) version 3.30.20.

## Materials and Methods

### Spatial and Temporal Stratification

The geographic area encompassed in the assessment for NP SWO was the North Pacific Ocean bounded by the equator in the WCPFC convention area boundary at 150°W and 10°N in the IATTC convention area ([Figure 1](#fig-stockareas2)). Three types of data were used: fishery-specific catches, relative abundance indices, and length measurements. The fishery data were compiled for 1975-2021, noting that the catch data and length composition data were compiled and modeled on a quarterly basis. Available data, sources of data, and temporal coverage of the datasets used in the stock assessment are summarized in [Figure 2](#fig-dataplot). Further details are presented below.

### Definition of Fisheries

A total of 19 fleets catching NP SWO were defined on the basis of country, gear type, location, and time period, where each fishery was assumed to target a distinct component of the stock. Descriptions and data sources to characterize the nineteen fisheries that catch NP SWO are summarized in Table 1. These fisheries included five longline fleets from Japan, three longline fleets from the USA, and two longline fleets from Chinese Taipei. Four additional fleets from Japan included the driftnet catches for two time periods: 1975-1993 and 1994-2021 and two fleets to encompass all other Japanese NP SWO catches in the early and late periods. There was one additional fleet for any additional catches and two additional fleets from the US for the gillnet and all other catches which included handline and troll catches. Finally, there was one fleet for each region containing the various flags not otherwise included, one for the EPO (IATTC) and one for the WCNPO (WCPFC).

### Catch

Catch was input into the model on a quarterly basis (i.e., by calendar year and quarter) from 1975 to 2021 for the 19 individual fleets. Catch was reported in terms of thousands of fish for Japanese and US longline fleets, all others reported catch in biomass (metric tons: mt).

Three countries (i.e., Chinese Taipei, Japan, and the USA) provided national catch data (Hirotaka Ijima, NRIFSF, personal communication; Yi-Jay Chang, NTU, personal communication; Russell Ito, NOAA NMFS, personal communication). The NP SWO catches for all other fishing countries were collected from WCPFC category I and II data (WCPFC Yearbook 2021) and IATTC category I and II data (need reference).

The resulting best available data on NP SWO catch by fishery from 1975-2021 were tabulated and are shown in [Figure 3](#fig-catchbyfleet) and Table 2. The historical maximum and minimum annual NP SWO catches were 19,230 mt in 1998 and 9,539 mt in 1995, respectively. Overall, annual catch of NP SWO generally declined since 1998. The recent mean annual catch of NP SWO during 2019-2021 was 10,600 mt.

### Abundance Indices

Relative abundance indices for NP SWO based on standardized CPUE were prepared for this assessment and are shown in [Figure 4](#fig-FLRsmoother) and Tables 1 and 3. A generalized linear mixed model using R-INLA was used to produce a spatio-temporal model for areas one and two as identified in the 2018 assessment (Kanaiwa and Ijima 2018) Japanese CPUE data were also standardized in two-time periods (Early:1975-1993 and Late:1994-2021) due to the change of Japanese logbook reporting requirements (Jusup *et al.,* 2023).

Operational fishing data collected by observers in the Hawaiian longline fishery during 1995-2021 were used in the CPUE standardization for US longline fleets (Bohaboy and Sculley, 2023). The fishery operates in two sectors: a shallow-set sector targeting swordfish and a deep-set sector targeting tunas. The NP SWO are caught as bycatch in the deep-set sector and a target species in the shallow-set sector. These data were standardized into a three CPUE time series using general additive models, with a continuous index for the deep-set sector and two indices for shallow-set: 1995-2000 and 2004-2021, to account for the fishery closure from 2001 to 2004. As the majority of the fish caught in the deep-set sector are young of the year, this CPUE index is treated as a recruitment index in the model (fleet setting 33) and not fit as a traditional CPUE index.

The distant-water longline fleet from Chinese Taipei was standardized from 2000-2021 using a spatio-temporal model (Hsu and Chang, 2023).

Visual inspection of four indices of late period (S2, S4, S5, and S8) showed three of the indices indicated a generally increasing trend in the last 5-10 years, with the exception of the US LL shallow-set index ([Figure 4](#fig-FLRsmoother)). After consideration of the area of the North Pacific that the US index represents, the WG agreed that the trend of the US LL shallow-set index may not be representative of the overall abundance of adult swordfish in the North Pacific. This fishery targets a small area of the Pacific north of the Hawaiian Islands, has historically be subject to partial-year closures due to interactions with protected species, and fishing captains react to changing fuel costs, market price, etc. when determining when and where to target swordfish. In addition, the model did not fit to the Chinese Taipei index well. Due to these reasons, and conflicts in the indices identified when profiling the likelihood based upon R0, S5 and S8 were ultimately excluded from the model.

### Size Composition Data

Quarterly fish length composition data from 1975–2021 for nine fleets were used for the assessment and are summarized in Table 1. Length frequency data were compiled using 5-cm length bins from 10 to 260 cm. The lower boundary of each bin was used to define each bin for all length-composition data, and each observation consisted of the actual number of NP SWO measured. The length composition data were agreed upon at the BILLWG data preparatory meeting as the best available scientific information for the 2023 stock assessment.

[Figure 5](#fig-LengthDataPlot) shows the quarterly length compositions. Most of the fisheries adult individuals. The longline fleets caught fish with a mean of around 140-150 cm EFL while F2 caught slightly larger fish, mean 160 cm EFL. F7 caught the largest fish on average, 180cm EFL, and the US longline deep-set sector fleet caught smaller fish on average than any of the other fleets (mean size 130cm EFL, with a median at ~55 cm EFL).

The aggregate length composition distributions were relatively consistent between fleets, with the exception of the US Longline fleet ([Figure 17](#fig-SizeAggFits)). Most longline length composition distributions had a single mode around 150-160cm EFL, while the US deep-set fleet had a large peak around 55 cm EFL and a long, fat tail. Ultimately, due to challenges fitting the US deep-set fleet (F9) and the small component of catch it represented, it was not included in the final base-case model. Similarly, F5 was not included in the final base-case model due to conflict with the other size composition data and low sample size.

### Model Description

The stock assessment for NP SWO was conducted using SS version 3.30.20.00-SAFE released 09/30/2022 programed via Otter Research ADMB 13.0 (Methot and Wetzel 2013). The model was set up as a single area model with a single sex and four seasons (quarters), with the WCNPO and EPO regions modeled implicitly using fleets-as-areas. Spawning was assumed to occur in quarter two while recruitment was assumed to occur in July (month 7). Age at recruitment was calculated based upon the model estimated average selectivity at age based upon the quarterly selectivity at length. The maximum age of NP SWO was set to 15 years. Age-specific natural mortality was used (Table 4) as agreed upon in the BILLWG data preparatory meeting (ISC, 2023). The age at length L1 was set to age 0.5, the CV of the growth curve was set to 0.1 for young fish and 0.1 for old fish and was assumed to be the same for both sexes. The sex ratio at birth was assumed to be 1:1. The growth curve used a von Bertalanffy growth curve for ages 0.5-15 with a K = 0.246 for females and 0.271 for males, a length at age 15 (*L2*) = 226.3 cm EFL for females and 206.4 cm EFL for males, and the size at age 0.5 (*L1*) = 80.1 cm EFL for females and 83.4 cm EFL for males. A Beverton-Holt spawner-recruit relationship was used with steepness (h) set at 0.9 and sigmaR (σr) rescaled to 0.42.

### Data Observation Models

The assessment model fit three data components: 1) total catch; 2) relative abundance indices; and 3) length 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 log-normally distributed errors with SE in log-space (log(SE)) which was , where CV is the standard error of the observation divided by the mean value of the observation and sqrt is the square root function.

Five CPUEs (S1, S2, S3, S4, and S8) were assigned to quarter one. S5 was assigned to quarter three and S6 and S7 were assigned to quarter 2, which roughly coincided with the quarters in which the most catch was reported for each fleet. The CPUE indices were assumed to be linearly proportional to biomass where catchability (*q*) was assumed to be constant and occur in the first month of the quarter assigned.

The CVs for each CPUE index were assumed to be equal to their respective calculated SEs on the log scale (Table 5). The minimum CV was scaled to a minimum of 0.2 and then re-weighted if the suggested variance was greater than the input variance based upon the Francis method using the root-mean-square error (RMSE, i.e., square root of the residual variance, Francis 2011).

The length composition data were assumed to have multinomial error distributions with the error variances determined by the 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 effective sample size for all fleets was set equal to 1/10 of the total number of samples in each quarter, in alignment with previous assessments (ISC, 2018). In addition, quarters with fewer than 15 total samples were removed from the time series due to limited sample size and the maximum number of samples was set to 50 to reduce the influence of very large sample sizes, as agreed upon by the modeling sub-group.

### Estimation of Fishery Selectivity

Selectivity was estimated as a double-normal curve for all fleets, except for F2, the Chinese Taipei longline fishery, and F4, other IATTC fleets in the EPO, which were estimated as asymptotic logistic ([Figure 9](#fig-EOYselec)). Two fleets had time varying selectivity: F1 ([Figure 7](#fig-F1TVSelec)) and F2 ([Figure 8](#fig-F2TVSelec)). All other fleets were mirrored to the fleet that was believed to have the most similar selectivity pattern (Table 6).

***Data Weighting***

Index data were prioritized in this assessment based on the principles that relative abundance indices should be fitted well because abundance indices are a direct measure of population trends and scale, and that other data components such as composition data should not induce poor fits to the abundance indices (Francis, 2011).

It is common practice to re-weight some or all data sets in two stages (Francis, 2011). Input length composition sample sizes and CPUE data iteratively re-weighted in stage 2, but only if the re-weighting decreased the sample size or increased the CV of the CPUE index.

### 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.* (2017) determined that there was no single diagnostic that worked well in all of the cases they evaluated. Instead, they recommend the use of a carefully selected range of diagnostics that proved to increase the ability to detect model misspecification.

Key stock assessments diagnostics identified by Carvalho *et al.* (2017) and Carvalho *et al.* (2021) were implemented to evaluate the base case model.

#### Retrospective analysis

Retrospective analysis is a way to detect bias and model misspecification (Hurtado-Ferro *et al.* 2014). A retrospective analysis was applied to the base-case model results. The diagnostic was implemented here by sequentially eliminating the five most recent years of data from the full stock assessment base case 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 (Hurtado-Ferro *et al.* 2014). 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.

#### 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 (Carvalho *et al.,* 2021). 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.

#### R0 likelihood profile

An R0 likelihood component profile (Lee *et al.* 2014) was applied to the base-case model results. The diagnostic was implemented here by sequentially fixing the equilibrium recruitment parameter, R0, on the natural log scale, log(R0), to a range of values. The relative change in negative log-likelihood units over the range of fixed values for log(R0) (the R0 profile) was compared among the SS model likelihood components for CPUE, length-composition, initial equilibrium catch, and recruitment deviations using two diagnostic tests. First, a relatively large change in negative log-likelihood units along the R0 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 R0 profile among data sources was diagnostic of either conflict in the data or model misspecification (or both).

#### Age-structured production model

An age-structured production model (ASPM; Maunder and Piner 2015; Carvalho *et al.* 2017) was applied to the base-case model results.

The diagnostic was implemented here by fixing selectivity to its estimated values in the fully integrated stock assessment 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) suggest 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) suggest 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-case model is incorrect; or (iv) the indices of relative abundance are not proportional to abundance.

#### 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.

#### 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.

#### 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 (Carvalho *et al.* 2021, Wald and Wolfowitz 1940). In other words, this test uses a 2-sided p-value to estimate the number of positive or negative residuals in a row (a “run”). CPUE or size composition data that fail the runs test indicate that there may be a pattern in the residuals and the model is unable to fit the data well or is miss-specified.

### Future Projections

Deterministic future projections were conducted in SS to evaluate the impact of various levels of fishing mortality on future SSB and yield. No recruitment deviations and log-bias adjustment were applied to the future projections in this study. Projections were based upon 100 bootstrap runs to estimate the uncertainty around future stock status. The future projection routine calculated the future SSB and yield that would occur while the specific fishing mortality, selectivity patterns, and relative fishing mortality proportions depended on the specific harvest scenarios. The last three model years’ (2019-2021) selectivity patterns and relative fishing mortality rates were used in the population future projections. It was assumed that future recruitment would be similar to the stock recruitment curve (S/R Curve).The projections started in 2022 and continued through 2031 under five different harvest scenarios:

1. **2008-2010 F Scenario** **(F2008-2010)**: Use the average fishing intensity (SPR) from 2008-2010 and apply the corresponding fishing mortality rate to the stock estimates beginning in 2022; this corresponds to the proposed NP SWO CMM;
2. **FMSY Scenario** **(FMSY)**: Apply the estimate of the FMSY fishing mortality rate to the stock estimates beginning in 2022;
3. **Status Quo F Scenario** **(FStatusQuo)**: This is the average F (age 1-10) during 2019-2021;
4. **Low F Scenario** **(FLow)**: Apply an FSPR30% fishing mortality rate to the stock estimates beginning in 2022;
5. **F20%SSBF=0****Scenario** **(FBtgt):** Apply the estimate of F which produces 20%SSBF=0 based upon the average of the last five years dynamic B0, which roughly corresponds to F19%.

## Results

### Base Case Model

Results for the base case model provided estimates of biological reference points for NP SWO and included trends in estimates of total stock biomass, spawning stock biomass, recruitment, and fishing mortality, along with a Kobe plot indicating stock status over time.

### Model Convergence

All estimated parameters in the base case model were within the set bounds, and the final gradient of the model was <0.0001 and the hessian matrix for the parameter estimates was positive definite, which indicated that the model had converged to a local or global minimum. Results from 100 model runs with different random initial starting values for estimated parameters using the internal “jitter” routine in SS supported the result that a global minimum was obtained (i.e., there was no evidence of a lack of convergence to a global minimum, [Figure 10](#fig-jitter)).

### Model Diagnostics

[Figure 11](#fig-OverallLikelihood) showed the results of the likelihood profile on virgin recruitment (ln(R0))for each data component. Detailed information on changes in negative log-likelihoods among the various fishery data sources are shown in Tables 7 and 8 and [Figure 12](#fig-CPUELikelihood) and [Figure 13](#fig-SizeLikelihood).

Changes in the likelihood of each data component indicated how informative that data component was to the overall estimated model fit. Ideally, relative abundance indices should be the primary sources of information on the population scale in a model (Francis, 2011).

There was a reasonable about of information in the size data and survey (CPUE) data to inform the lower bound of R0, but only the size composition data contributed to an estimate of the upper bound of R0 ([Figure 11](#fig-OverallLikelihood)). Generally, all the data agreed upon the maximum likelihood estimate of ln(R0) = 6.84. The Chinese Taipei size composition data contributed the most to the estimate of ln(R0) ([Figure 13](#fig-SizeLikelihood)), and the Japanese longline late CPUE index in area 1 and the US longline deep-set sector CPUE index contributed to most to the survey estimate of ln(R0) ([Figure 12](#fig-CPUELikelihood)).

There were some differences in the location of the minimum negative log-likelihood along the R0 profile observed among data likelihood components for the base case model. The two-stage Francis approach seemed to have reduced the conflict, but did not eliminate it.

#### Goodness-of-Fit Indices of Abundance

Goodness-of-fit diagnostics were presented in Table 5, and plots of predicted and observed CPUE by fishery for the base case model were shown in [Figure 14](#fig-ExpCPUE).

The fit to the CPUE indices can be summarized into two groups by the contribution to the total likelihood (contributed group of S1, S2, S3, S4, S6, and S7; uncontributed group of S5 and S8). Table 5 showed that RMSE was smaller than 0.3 for all indices except for S5. This result indicates that the model fits to these CPUE indices were good.

#### Residuals Analysis of Size Composition Data

Comparisons between the observed and expected mean values of length composition data from Francis (2011) were used for model diagnostics. [Figure 15](#fig-SizeCompFits) shows the 95% credible intervals for mean value for the nine length composition data sets. The model fit passed through almost all of the credible intervals.

Fits to the annual length compositions by fleet could be improved ([Figure 16](#fig-SizeCompResid)), with few obvious systematic patterns observed in the residuals (e.g., patterns of positive or negative residuals) making it difficult to objectively determine how to improve the fits. This is an important area for future model development. For example, more flexible selectivity curves (or time blocks) in combination with alternative binning of length composition data could be examined in the future to account for the jagged distributions observed in seasonal length compositions. Alternatively, different area stratification of fleets could be explored in the future to either increase sample size or smooth the length-frequency distributions. In this assessment both of these options were explored for several of the fleets, including the IATTC EPO size data and the US LL data, especially the deep-set sector which was ultimately excluded from the base-case model, however the BILLWG ultimately selected a simpler model as improving the fit to the size data often required additional parameters, while accepting a slightly degraded fit to the data allowed the focus to remain on improving the CPUE fit and maintaining as many degrees of freedom in the model as possible.

Assuming standardized residuals were normally distributed, 95% of the measurements would fall within 2 standard deviations of the mean. The majority of Pearson residuals did meet this criteria, although F3 and F8, the U.S. longline shallow-set data in the early and late periods showed stronger residual patterns when compared to the other fleets ([Figure 16](#fig-SizeCompResid)).

Overall, the model fit the length modes in length composition data aggregated by fishery fairly well using the input effective sample sizes ([Figure 17](#fig-SizeAggFits)). However, F4 still showed some misfit.

#### Runs test

The CPUE indices for all fleets included in the likelihood (S1 - S4, and S7) passed runs test ([Figure 18](#fig-CPUERunstest)) that indicated the model fitted well. S5 and S8 were not fit in the likelihood, so we expect some misfit. S6 is not fit as a survey/CPUE index, so the interpretation of the runs test for this fleet is less straightforward as there are many data sources that contribute to estimating recruitment. The length composition data for five fleets passed the runs test ([Figure 19](#fig-SizeRunsTest)). The length-composition data for F01 Japanese LL area 1 late could pass the runs test if an additional time block is included in the selectivity estimates. However, this also increased the number of parameters estimated and did not change the overall model result. The BILLWG agreed that the priority was to fit the CPUE data and therefore estimated the F01 size data without the second time block. F4 IATTC size data also failed the runs test. This fleet is an aggregate of many fleets and gears catching swordfish in the EPO. This means that the selectivity of the fleet is unlikely to be consistent between years or quarters and would cause problems when fitting. In addition, the aggregate distribution of the size composition data for this fleet has sharp peaks at a few size classes, which causes issues in estimating selectivity and indicates that these data should be evaluated more closely for inclusion in the future.

#### Retrospective Analysis

A retrospective analysis was conducted for the last 5 years of the assessment time horizon to evaluate whether there were any strong changes in parameter estimates through time. The results of the retrospective analysis are shown in [Figure 20](#fig-retros). The trajectories of estimated SSB and F showed that there was a slight tendency of overestimation for SSB in recent years and underestimation for F. In addition, the Mohn’s rho for SSB (-0.14) and F (0.14) fell within the range of acceptable values (-0.15 to 0.20), suggesting that the retrospective pattern is not substantial.

#### Prediction skill

Results of the hindcast with cross-validation indicate that of the five CPUE indices at the end of the assessment horizon, only the Japanese LL area 2 fleet had reasonable predictive ability (MASE = 0.85), with all other fleets MASE > 1 ([Figure 21](#fig-CPUEHCxval)). Comparing the predictive ability of the size composition data, two fleets had good predictive ability (MASE <0.5, F3 and F9), one had good predictive ability (0.5<MASE <1, F2) and two had poor predictive ability (MASE <1, F1 and F7, [Figure 22](#fig-LenHCxval)).

#### Age-structured production model

Results from the ASPM model showed a similar population trend as the full model although the scale of the ASPM is larger than the base-case model ([Figure 23](#fig-ASPM)). This suggests that while the Catch and CPUE data do provide information for the production function, the size composition data provide information about the overall scale of the population.

### Stock Assessment Results

Estimates of population biomass (estimated biomass of age 1 and older fish at the beginning of the year) fluctuated around an average of 82,800 mt during 1975-2021 and was estimated to be 88,800 mt in 2021 ([Figure 24a](#fig-summarybiomass2-1)). Overall, population biomass has increased slightly over time.

Initial estimates of female spawning stock biomass (SSB) averaged around 27,600 mt in the late 1970s. SSB was at its highest level of 35,778 metric tons in 2021, and was at its minimum of 22,415 mt in 1981. Overall, spawning stock biomass has been relatively stable and above SSBMSY for the entirety of the assessment period ([Figure 24b](#fig-summarybiomass2-2)).

Estimated fishing mortality (arithmetic average of F for ages 1 – 10) decreased from 0.17 year-1 in 1978 to a minimum of 0.09 year-1 in 2021 (Table 9 and [Figure 24c](#fig-summarybiomass2-3)). It averaged roughly F=0.09 during 2019-2021 or about 51% of FMSY with a relative fishing mortality of F/FMSY = 0.09 in 2021. Fishing mortality has been below FMSY since the beginning of the assessment time period and has had a declining trend with the exception of a high peak in 1998 coinciding with high catch by the US LL fleet.

Recruitment (age-0 fish) estimates averaged approximately 838,000 during 1975-2021. While the overall pattern of recruitment varied, there was no apparent trend in recruitment strength over time (Table 9 and [Figure 24d](#fig-summarybiomass2-4)). Overall, total annual catches are declining, catch per unit effort is increasing, and recruitment is relatively stable.

### Biological Reference Points

MSY-based biological reference points were computed for the base case model with SS (Table 10). The point estimate of annual catch at FMSY was calculated to be 14,924 mt. The point estimate of the spawning biomass to produce MSY (adult female biomass) was 16,388 mt. The point estimate of FMSY, the fishing mortality rate to produce SSBMSY (average fishing mortality on ages 1 – 10) was 0.18 and the corresponding equilibrium value of spawning potential ratio at SSBMSY was 19%.

### Stock Status

There are no defined reference points for North Pacific swordfish in the Western and Central Pacific Fisheries Commission (WCPFC), therefore stock status is based upon maximum sustainable yield (MSY) reference points. The current or recent 3-year average spawning biomass of 34,900 mt (average for 2019-2021) was 2.5 times greater than SSBMSY and the current fishing mortality of 0.09 (average for ages 1 – 10 during 2019-2021) was 51% above FMSY. The base case model indicated that under current conditions the NP SWO stock was very likely not overfished (>99% probability) and was very likely not subject to overfishing (>99% probability) relative to MSY-based reference points ([Figure 25](#fig-Kobe2)).

### Sensitivity Analyses

In the April 2023 BILLWG workshop, the BILLWG agreed to conduct a series of sensitivity analyses (Table 11) to examine the effects of plausible alternative model assumptions and data input to the stock status. These analyses were:

1. **Sensitivity analysis on natural mortality**: The BILLWG conducted two sensitivity analyses for natural mortality (M)-at-age. These were a low M scenario where Ms-at-ages were 10% lower than those of the base-case model and a high M scenario where Ms-at-ages were 10% higher than those of the base case model.
2. **Sensitivity analysis on steepness**: The BILLWG conducted three additional sensitivity runs on steepness (h). Steepness was fixed at higher value (h=0.99), lower value (h=0.81), and much lower value (h=0.70) compared to the base-case value (h=0.9).
3. **Sensitivity analysis on growth**: Two sensitivity runs on growth were conducted, one increasing the size at age Amax by 10% and one using an alternative growth curve from Sun *et al.,* (2002).
4. **Sensitivity analysis on maturity**: The BILLWG conducted three sensitivity runs on the maturity ogive. The maturity ogive was fixed at the values 10% higher and lower than the base-case value and used an alternative ogive from Wang *et al.,* (2003).
5. **Sensitivity analysis on catch**: The BILLWG conducted three sensitivity runs on catch and stock structure. One removed the Vietnam and Chinese catch. Two others addressed stock structure concerns, one including all catch in the North Pacific including between the equator and 10N in the EPO and one including the “orphan” catch between 165°W and 150°W and the equator and 5°N that is not included in any base-case assessment for the three Pacific swordfish stocks.
6. **Sensitivity analysis on modeling structure**: The BILLWG conducted eleven additional sensitivity runs to explore the effects of changes in the model assumptions made during the model development: 1) a model setting Amin to 1 which was used in the 2018 assessment; 2) a model without the inclusion of the S8 US deep-set LL recruitment index; 3) a model with the selectivity pattern for Chinese Taipei longline size data set as double normal; 4.) a model including the size data from the US deep-set LL fleet; 5.) six models using a single CPUE index to inform relative abundance, and 7.) a model including all the CPUE indices available.

The BILLWG completed all 24 sensitivity runs and compared the SSB and the F trajectories to those of the base-case model ([Figure 26](#fig-Sensitivity)). The BILLWG also produced a Kobe plot to compare the stock status of the recent years among 24 sensitivity runs. The result showed that there was no clear pattern of the stock status (improvement or deterioration, [Figure 27](#fig-sensitvityKobe)).

The sensitivity analyses run for this assessment indicated that the model is not very sensitivity to alternative parameterizations, alternative catch time series, and alternative model configurations. All of the sensitivities run indicated the stock was not overfished and overfishing was not occurring, with the majority of the runs overlapping considerably with the base-case model ([Figure 27](#fig-sensitvityKobe)).

### Stock Projections

Future projection showed the trajectories of SSB and catch as well as those mean values during 2022-2031 for five scenarios (Table 12 and [Figure 28](#fig-projectionssb) and [Figure 29](#fig-projectioncatch)). For each scenario, initial SSB and catch increase as all projections use higher Fs than the fishing mortality in the final year of the assessment. For scenario 3, Fstatus quo, SSB continues to increase until 2031. For all other scenarios, catch begins to decrease then stabilize, but projections suggest that the stock can withstand additional fishing pressure in the next 10 years without decreasing SSB below MSY levels. In all scenarios, catch would increase due to the increase in fishing mortality.

## Conclusions

### Conservation information

The NP SWO stock has produced annual yields of around 11,500 mt per year since 2016, or about 2/3 of the MSY catch amount. This suggests the stock may be able to support somewhat higher yields. Swordfish stock status is positive with no evidence of excess fishing mortality above FMSY or substantial depletion of spawning potential. It was also noted that retrospective analyses show that the assessment model appears to underestimate spawning potential in recent years.

## 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 North Pacific swordfish.

## References

Bohaboy, E. and Sculley M. (2023). Standardization of Western and Central North Pacific swordfish (*Xiphias gladius*) Catch Per Unit Effort in the Hawai’i longline fishery from 1995-2021. ISC/22/BILLWG-02/02.

Brodziak, J. (2020). On the probably distribution of stock-recruitment steepness for Western and Central North Pacific swordfish. ISC/20/BILLWG-01/06.

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

Carvalho, F., Winker, H., Courtney, D., Kapur, M., Kell, L., Cardinale, M. Schirripa, M., Kitakado, T., Yemane, D., Piner, K.R., Maunder, M.N., Taylor, I., Wetzel C.R., Doering, K. Johnson, K.F. and Methot, R.D. (2021). A cookbook for using model diagnostics in integrated stock assessments. Doi: 10.1016/j.fishres.2021.105959

DeMartini, E.E., Uchiyama, J.H., Humphreys Jr., R.L., Sampaga, J.D. and Williams, H.A. (2007). Age and growth of swordfish (*Xiphias gladius*) caught by the Hawaii-based pelagic longline fishery. Fish. Bull. 105:356-367.

Francis, R. I. C. C. (2011). Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68(6): 1124-1138.

Hsu, J. and Chang, Y-J. (2023). Catch, length data and standardized CPUE of swordfish caught by the Taiwanese fisheries in North Pacific Ocean. ISC/22/BILLWG-02/07.

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

International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific [ISC]. (2018). Stock assessment of swordfish in the North Pacific Ocean in 2018, Report of the Billfish Working Group Stock Assessment Workshop.

International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific [ISC]. (2023). Report of the Billfish Working Group Workshop. 13, 15-18 December 2023.

Jusup, M., Koike, H. and Ijima, H. (2023). CPUE Standardization for Pacific Swordfish (*Xiphias gladius*) caught by the Japanese longline fishery: A GLMM analysis using the R software package R-INLA. ISC/22/BILLWG-02/06

Kanaiwa M. and Ijima H. (2018). Abundance indices of Swordfish (*Xiphias gladius*) by the Japanese offshore and distant-water longline fishery in the North-Western Central Pacific. ISC/18/BILLWG-01/07.

Kapur, M., Brodziak, J. Fletcher, E. and Yau, A. (2017). Summary of Life History and Stock Assessment Results for Pacific Blue Marlin, Western and Central North Pacific Striped Marlin, and North Pacific Swordfish. ISC/17/BILLWG-01/02.

Lee, H.-H., K. R. Piner, R. D. Methot Jr and M. N. Maunder (2014). Use of likelihood profiling over a global scaling parameter to structure the population dynamics model: An example using blue marlin in the Pacific Ocean. Fisheries Research 158: 138-146.

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

Methot Jr, 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.

Nishikawa, Y., M. Honma , S. Ueyanagi , S. Kikkawa. (1985). Average distribution of larvae of oceanic species of scombroid fishes, 1956-1981. Far Seas Fish. Res. Lab., S Series 12, 99p.

Pennington, M., Burmeister, L. M., and Hjellvik, V. (2002). Assessing the precision of frequency distributions estimated from trawl-survey samples. Fishery Bulletin, US, 100: 74–81.

Sun, C-L., Wang, S-P., and Yeh, S-Z. (2002). Age and growth of the swordfish (*Xiphias gladius* L.) in the waters around Taiwan determined from anal-fin rays. Fishery Bulletin, 100(4), pp. 822-835.

Wald, A., and Wolfowitz, J. (1940). On a test whether two samples are from the same population. Annals of Mathematical Statistics, Institute of Mathematical Statistics11: 147-162.

Wang, S-P., Sun, C-L., Yeh, S-Z. (2003). Sex ratios and sexual maturity of swordfish (*Xiphias* gladius L.) in the waters of Taiwan. Zoological Studies. 42(4): 529-539.

Need: WCPFC yearbook citation and IATTC citation

## Tables

Table 1. Descriptions of fisheries catch and abundance indices included in the base case model for the stock assessment including fishing countries, time-period, and reference sources for CPUE standardizations.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Catch Index** | **Abundance Index** | **Fleet Name** | **Time Period** | **Length Comp Used?** | **Source** |
| F1 | S1 - Y | JPN\_WCNPO\_OSDWCOLL\_late\_Area1 | 1994-2021 | Y | Jusup et al., 2023 |
| F2 | S5 - N | TWN\_WCNPO\_DWLL\_late | 2000-2021 | Y | Hsu and Chang, 2023 |
| F3 | S8 - N | US\_WCNPO\_LL\_shallow\_late | 2004-2021 | Y | Bohaboy, E. and Sculley M. (2023). |
| F4 | - | IATTC | 1975-2021 | Y | - |
| F5 | - | JPN\_EPO\_OSDWLL | 1975-2016 | N | - |
| F6 | S2 - Y | JPN\_WCNPO\_OSDWLL\_early\_Area1 | 1975-1993 | Y | Jusup et al., 2023 |
| F7 | - | JPN\_WCNPO\_CODF | 1993-2021 | Y | - |
| F8 | S7 - Y | US\_WCNPO\_LL\_shallow\_early | 1993-2001 | Y | Bohaboy, E. and Sculley M. (2023). |
| F9 | S6 - Y | US\_WCNPO\_LL\_deep | 1996-2021 | N | Bohaboy, E. and Sculley M. (2023). |
| F10 | - | JPN\_WCNPO\_OSDF | 1975-1992 | - | - |
| F11 | - | JPN\_WCNPO\_Other\_early | 1975-1993 | - | - |
| F12 | - | JPN\_WCNPO\_Other\_late | 1994-2021 | - | - |
| F13 | - | TWN\_WCNPO\_DWLL\_early | 1975-1999 | - | - |
| F14 | - | TWN\_WCNPO\_Other | 2001-2021 | - | - |
| F15 | - | US\_WCNPO\_GN | 1980-2021 | - | - |
| F16 | - | US\_WCNPO\_Other | 1975-2021 | - | - |
| F17 | S3 - Y | JPN\_WCNPO\_OSDWLL\_early\_Area2 | 1975-1993 | - | Jusup et al., 2023 |
| F18 | S4 - Y | JPN\_WCNPO\_OSDWLL\_late\_Area2 | 1994-2021 | - | Jusup et al., 2023 |
| F19 | - | WCPFC | 1975-2021 | - |  |

Table 2. Time series of catch by fleet submitted for the 2023 North Pacific swordfish stock assessment. Starred fleets are in numbers of fish, all others are in metric tons. See Table 1 for and explanation of fleet numbers.

|  |  | **Fleet** | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Quarter** | **1\*** | **2** | **3\*** | **4** | **5\*** | **6\*** | **7** | **8\*** | **9\*** | **10** |
| 1975 | 1 | - | - | - | 60 | 134 | 30770 | - | - | - | 668 |
| 1975 | 2 | - | - | - | 60 | 2440 | 17705 | - | - | - | 668 |
| 1975 | 3 | - | - | - | 60 | 1615 | 12619 | - | - | - | 668 |
| 1975 | 4 | - | - | - | 60 | 1565 | 41163 | - | - | - | 668 |
| 1976 | 1 | - | - | - | 12 | 5557 | 38251 | - | - | - | 872 |
| 1976 | 2 | - | - | - | 12 | 2304 | 18186 | - | - | - | 872 |
| 1976 | 3 | - | - | - | 12 | 1197 | 13094 | - | - | - | 872 |
| 1976 | 4 | - | - | - | 12 | 2449 | 33783 | - | - | - | 872 |
| 1977 | 1 | - | - | - | 33 | 684 | 49038 | - | - | - | 586 |
| 1977 | 2 | - | - | - | 33 | 2231 | 22981 | - | - | - | 586 |
| 1977 | 3 | - | - | - | 33 | 107 | 10027 | - | - | - | 586 |
| 1977 | 4 | - | - | - | 33 | 26 | 34195 | - | - | - | 586 |
| 1978 | 1 | - | - | - | 153 | 52 | 43277 | - | - | - | 618.75 |
| 1978 | 2 | - | - | - | 153 | 32 | 24013 | - | - | - | 618.75 |
| 1978 | 3 | - | - | - | 153 | 31 | 10488 | - | - | - | 618.75 |
| 1978 | 4 | - | - | - | 153 | 3 | 35618 | - | - | - | 618.75 |
| 1979 | 1 | - | - | - | 58 | 13 | 42977 | - | - | - | 245.75 |
| 1979 | 2 | - | - | - | 58 | 88 | 23783 | - | - | - | 245.75 |
| 1979 | 3 | - | - | - | 58 | 134 | 16868 | - | - | - | 245.75 |
| 1979 | 4 | - | - | - | 58 | 13 | 35079 | - | - | - | 245.75 |
| 1980 | 1 | - | - | - | 145 | 0 | 25886 | - | - | - | 436.5 |
| 1980 | 2 | - | - | - | 145 | 159 | 18370 | - | - | - | 436.5 |
| 1980 | 3 | - | - | - | 145 | 246 | 7342 | - | - | - | 436.5 |
| 1980 | 4 | - | - | - | 145 | 1386 | 18055 | - | - | - | 436.5 |
| 1981 | 1 | - | - | - | 79 | 326 | 31977 | - | - | - | 462 |
| 1981 | 2 | - | - | - | 79 | 592 | 26258 | - | - | - | 462 |
| 1981 | 3 | - | - | - | 79 | 201 | 7085 | - | - | - | 462 |
| 1981 | 4 | - | - | - | 79 | 3389 | 19099 | - | - | - | 462 |
| 1982 | 1 | - | - | - | 84 | 2876 | 24296 | - | - | - | 314.25 |
| 1982 | 2 | - | - | - | 84 | 1530 | 18874 | - | - | - | 314.25 |
| 1982 | 3 | - | - | - | 84 | 1302 | 5932 | - | - | - | 314.25 |
| 1982 | 4 | - | - | - | 84 | 4785 | 26181 | - | - | - | 314.25 |
| 1983 | 1 | - | - | - | 201 | 2914 | 45609 | - | - | - | 240.5 |
| 1983 | 2 | - | - | - | 201 | 84 | 28709 | - | - | - | 240.5 |
| 1983 | 3 | - | - | - | 201 | 365 | 8857 | - | - | - | 240.5 |
| 1983 | 4 | - | - | - | 201 | 1313 | 25184 | - | - | - | 240.5 |
| 1984 | 1 | - | - | - | 167 | 914 | 29375 | - | - | - | 242.75 |
| 1984 | 2 | - | - | - | 167 | 395 | 20684 | - | - | - | 242.75 |
| 1984 | 3 | - | - | - | 167 | 201 | 14954 | - | - | - | 242.75 |
| 1984 | 4 | - | - | - | 167 | 793 | 28957 | - | - | - | 242.75 |
| 1985 | 1 | - | - | - | 23 | 1 | 40738 | - | - | - | 256.5 |
| 1985 | 2 | - | - | - | 23 | 0 | 40438 | - | - | - | 256.5 |
| 1985 | 3 | - | - | - | 23 | 2 | 20984 | - | - | - | 256.5 |
| 1985 | 4 | - | - | - | 23 | 8 | 34442 | - | - | - | 256.5 |
| 1986 | 1 | - | - | - | 182 | 1877 | 48762 | - | - | - | 292.5 |
| 1986 | 2 | - | - | - | 182 | 1280 | 32783 | - | - | - | 292.5 |
| 1986 | 3 | - | - | - | 182 | 812 | 15570 | - | - | - | 292.5 |
| 1986 | 4 | - | - | - | 182 | 1896 | 33316 | - | - | - | 292.5 |
| 1987 | 1 | - | - | - | 240 | 3967 | 57744 | - | - | - | 227.5 |
| 1987 | 2 | - | - | - | 240 | 1316 | 29781 | - | - | - | 227.5 |
| 1987 | 3 | - | - | - | 240 | 291 | 13396 | - | - | - | 227.5 |
| 1987 | 4 | - | - | - | 240 | 3869 | 30346 | - | - | - | 227.5 |
| 1988 | 1 | - | - | - | 266 | 1261 | 56695 | - | - | - | 262 |
| 1988 | 2 | - | - | - | 266 | 194 | 31357 | - | - | - | 262 |
| 1988 | 3 | - | - | - | 266 | 1144 | 10481 | - | - | - | 262 |
| 1988 | 4 | - | - | - | 266 | 3476 | 19719 | - | - | - | 262 |
| 1989 | 1 | - | - | - | 298 | 2725 | 33352 | - | - | - | 349.25 |
| 1989 | 2 | - | - | - | 298 | 648 | 23892 | - | - | - | 349.25 |
| 1989 | 3 | - | - | - | 298 | 88 | 8249 | - | - | - | 349.25 |
| 1989 | 4 | - | - | - | 298 | 121 | 18244 | - | - | - | 349.25 |
| 1990 | 1 | - | - | - | 344 | 37 | 36962 | - | - | - | 256.5 |
| 1990 | 2 | - | - | - | 344 | 12 | 23450 | - | - | - | 256.5 |
| 1990 | 3 | - | - | - | 344 | 43 | 6777 | - | - | - | 256.5 |
| 1990 | 4 | - | - | - | 344 | 0 | 12224 | - | - | - | 256.5 |
| 1991 | 1 | - | - | - | 451 | 0 | 22310 | - | - | - | 106 |
| 1991 | 2 | - | - | - | 451 | 3 | 19652 | - | - | - | 106 |
| 1991 | 3 | - | - | - | 451 | 42 | 7672 | - | - | - | 106 |
| 1991 | 4 | - | - | - | 451 | 14 | 17279 | - | - | - | 106 |
| 1992 | 1 | - | - | - | 305 | 0 | 27527 | - | - | - | 210 |
| 1992 | 2 | - | - | - | 305 | 1 | 24231 | - | - | - | 210 |
| 1992 | 3 | - | - | - | 305 | 2 | 9727 | - | - | - | 210 |
| 1992 | 4 | - | - | - | 306 | 7 | 12483 | - | - | - | 210 |
| 1993 | 1 | - | - | - | 212 | 1 | 29415 | 73 | - | - | - |
| 1993 | 2 | - | - | - | 212 | - | 29960 | 73 | - | - | - |
| 1993 | 3 | - | - | - | 212 | - | 11229 | 73 | - | - | - |
| 1993 | 4 | - | - | - | 212 | - | 19258 | 73 | - | - | - |
| 1994 | 1 | 34547 | - | - | 81 | - | - | 105.25 | - | - | - |
| 1994 | 2 | 26453 | - | - | 81 | - | - | 105.25 | - | - | - |
| 1994 | 3 | 8556 | - | - | 82 | - | - | 105.25 | - | - | - |
| 1994 | 4 | 23342 | - | - | 85 | - | - | 105.25 | - | - | - |
| 1995 | 1 | 27886 | - | - | 93 | - | - | 140.25 | - | - | - |
| 1995 | 2 | 21059 | - | - | 94 | - | - | 140.25 | - | - | - |
| 1995 | 3 | 7541 | - | - | 94 | 21 | - | 140.25 | - | - | - |
| 1995 | 4 | 21734 | - | - | 94 | 198 | - | 140.25 | - | - | - |
| 1996 | 1 | 30962 | - | - | 99 | 151 | - | 107 | 11831 | 117 | - |
| 1996 | 2 | 23750 | - | - | 98 | - | - | 107 | 13928 | 269 | - |
| 1996 | 3 | 7590 | - | - | 98 | - | - | 107 | 3162 | - | - |
| 1996 | 4 | 15239 | - | - | 99 | 1 | - | 107 | 10648 | - | - |
| 1997 | 1 | 31260 | - | - | 93 | - | - | 91.25 | 17341 | 57 | - |
| 1997 | 2 | 17006 | - | - | 93 | - | - | 91.25 | 16864 | 220 | - |
| 1997 | 3 | 5509 | - | - | 93 | 97 | - | 91.25 | 2474 | - | - |
| 1997 | 4 | 19071 | - | - | 97 | 23 | - | 91.25 | 5413 | - | - |
| 1998 | 1 | 28378 | - | - | 155 | - | - | 117.75 | 15789 | 157 | - |
| 1998 | 2 | 16626 | - | - | 156 | - | - | 117.75 | 17850 | 424 | - |
| 1998 | 3 | 4813 | - | - | 154 | - | - | 117.75 | 4441 | - | - |
| 1998 | 4 | 15686 | - | - | 154 | - | - | 117.75 | 4450 | - | - |
| 1999 | 1 | 22310 | - | - | 112 | - | - | 181 | 16332 | 242 | - |
| 1999 | 2 | 15843 | - | - | 112 | - | - | 181 | 13714 | 426 | - |
| 1999 | 3 | 6029 | - | - | 113 | - | - | 181 | 4393 | - | - |
| 1999 | 4 | 18573 | - | - | 113 | - | - | 181 | 11325 | - | - |
| 2000 | 1 | 27538 | 21.475 | - | 789 | - | - | 202 | 16659 | 137 | - |
| 2000 | 2 | 14112 | 21.475 | - | 789 | - | - | 202 | 17268 | 415 | - |
| 2000 | 3 | 7651 | 21.475 | - | 795 | - | - | 202 | 3447 | - | - |
| 2000 | 4 | 21135 | 21.475 | - | 791 | - | - | 202 | 677 | - | - |
| 2001 | 1 | 24407 | 28.275 | - | 261 | 199 | - | 183 | 1597 | 152 | - |
| 2001 | 2 | 10468 | 28.275 | - | 264 | - | - | 183 | 880 | 432 | - |
| 2001 | 3 | 9113 | 28.275 | - | 265 | - | - | 183 | - | - | - |
| 2001 | 4 | 16518 | 28.275 | - | 259 | - | - | 183 | - | - | - |
| 2002 | 1 | 22057 | 48.25 | - | 39 | 1 | - | 291 | - | 1468 | - |
| 2002 | 2 | 9737 | 48.25 | - | 35 | - | - | 291 | - | 775 | - |
| 2002 | 3 | 9579 | 48.25 | - | 35 | 1 | - | 291 | - | - | - |
| 2002 | 4 | 18673 | 48.25 | - | 38 | - | - | 291 | - | - | - |
| 2003 | 1 | 18649 | 106.8 | - | 253 | - | - | 282.5 | - | 303 | - |
| 2003 | 2 | 7495 | 106.8 | - | 311 | 1 | - | 282.5 | - | 895 | - |
| 2003 | 3 | 5907 | 106.8 | - | 338 | - | - | 282.5 | - | - | - |
| 2003 | 4 | 21308 | 106.8 | - | 227 | - | - | 282.5 | - | - | - |
| 2004 | 1 | 20930 | 150.025 | - | 324 | - | - | 263.75 | - | 758 | - |
| 2004 | 2 | 4682 | 150.025 | - | 291 | - | - | 263.75 | - | 1279 | - |
| 2004 | 3 | 6765 | 150.025 | - | 285 | - | - | 263.75 | - | - | - |
| 2004 | 4 | 25366 | 150.025 | 1324 | 285 | - | - | 263.75 | - | - | - |
| 2005 | 1 | 27767 | 67.475 | 8944 | 344 | - | - | 238.75 | - | 373 | - |
| 2005 | 2 | 7049 | 67.475 | 11003 | 336 | - | - | 238.75 | - | 1143 | - |
| 2005 | 3 | 5149 | 67.475 | - | 338 | - | - | 238.75 | - | - | - |
| 2005 | 4 | 24261 | 67.475 | 1313 | 333 | - | - | 238.75 | - | - | - |
| 2006 | 1 | 20221 | 65.8 | 13435 | 452 | - | - | 199 | - | 448 | - |
| 2006 | 2 | 8960 | 65.8 | - | 450 | - | - | 199 | - | 1221 | - |
| 2006 | 3 | 8540 | 65.8 | - | 450 | - | - | 199 | - | - | - |
| 2006 | 4 | 32613 | 65.8 | - | 450 | - | - | 199 | - | - | - |
| 2007 | 1 | 30939 | 58.2 | 15169 | 331 | - | - | 207 | - | 386 | - |
| 2007 | 2 | 10286 | 58.2 | 4727 | 306 | - | - | 207 | - | 1381 | - |
| 2007 | 3 | 5693 | 58.2 | 183 | 302 | - | - | 207 | - | - | - |
| 2007 | 4 | 25850 | 58.2 | 763 | 304 | - | - | 207 | - | - | - |
| 2008 | 1 | 20548 | 58.375 | 11651 | 330 | - | - | 162 | - | 478 | - |
| 2008 | 2 | 6804 | 58.375 | 4380 | 335 | - | - | 162 | - | 2034 | - |
| 2008 | 3 | 5519 | 58.375 | 503 | 329 | - | - | 162 | - | - | - |
| 2008 | 4 | 22764 | 58.375 | 3808 | 330 | - | - | 162 | - | - | - |
| 2009 | 1 | 18926 | 43.225 | 7769 | 322 | - | - | 170.25 | - | 509 | - |
| 2009 | 2 | 5692 | 43.225 | 8437 | 322 | - | - | 170.25 | - | 1550 | - |
| 2009 | 3 | 7225 | 43.225 | 823 | 320 | - | - | 170.25 | - | - | - |
| 2009 | 4 | 20683 | 43.225 | 1480 | 316 | - | - | 170.25 | - | - | - |
| 2010 | 1 | 13092 | 61.6 | 9238 | 304 | - | - | 123.5 | - | 707 | - |
| 2010 | 2 | 4282 | 61.6 | 5091 | 328 | - | - | 123.5 | - | 1049 | - |
| 2010 | 3 | 7625 | 61.6 | 392 | 338 | - | - | 123.5 | - | - | - |
| 2010 | 4 | 19457 | 61.6 | 2406 | 330 | - | - | 123.5 | - | - | - |
| 2011 | 1 | 9469 | 96.975 | 9530 | 257 | - | - | 48.25 | - | 554 | - |
| 2011 | 2 | 3498 | 96.975 | 4530 | 241 | - | - | 48.25 | - | 1175 | - |
| 2011 | 3 | 4694 | 96.975 | - | 235 | - | - | 48.25 | - | - | - |
| 2011 | 4 | 16139 | 96.975 | 2120 | 244 | - | - | 48.25 | - | - | - |
| 2012 | 1 | 12241 | 72.875 | 7898 | 223 | - | - | 97.25 | - | 554 | - |
| 2012 | 2 | 4745 | 72.875 | 4741 | 207 | - | - | 97.25 | - | 1555 | - |
| 2012 | 3 | 4163 | 72.875 | - | 210 | - | - | 97.25 | - | - | - |
| 2012 | 4 | 15592 | 72.875 | 1598 | 208 | - | - | 97.25 | - | - | - |
| 2013 | 1 | 12647 | 60.25 | 5730 | 287 | - | - | 77.25 | - | 502 | - |
| 2013 | 2 | 7097 | 60.25 | 1994 | 278 | - | - | 77.25 | - | 1635 | - |
| 2013 | 3 | 3981 | 60.25 | - | 280 | - | - | 77.25 | - | - | - |
| 2013 | 4 | 14080 | 60.25 | 3005 | 285 | - | - | 77.25 | - | - | - |
| 2014 | 1 | 11480 | 37.175 | 8421 | 416 | - | - | 67 | - | 673 | - |
| 2014 | 2 | 5868 | 37.175 | 3930 | 398 | - | - | 67 | - | 1713 | - |
| 2014 | 3 | 3789 | 37.175 | 724 | 389 | - | - | 67 | - | - | - |
| 2014 | 4 | 15885 | 37.175 | 2374 | 412 | - | - | 67 | - | - | - |
| 2015 | 1 | 15586 | 93.75 | 10670 | 271 | - | - | 69.25 | - | 904 | - |
| 2015 | 2 | 5499 | 93.75 | 3546 | 297 | - | - | 69.25 | - | 2336 | - |
| 2015 | 3 | 5058 | 93.75 | - | 270 | - | - | 69.25 | - | - | - |
| 2015 | 4 | 16280 | 93.75 | 772 | 274 | - | - | 69.25 | - | - | - |
| 2016 | 1 | 18777 | 128.425 | 5220 | 266 | - | - | 75.75 | - | 1101 | - |
| 2016 | 2 | 7547 | 128.425 | 3344 | 212 | - | - | 75.75 | - | 2167 | - |
| 2016 | 3 | 7134 | 128.425 | 447 | 196 | 37 | - | 75.75 | - | - | - |
| 2016 | 4 | 20562 | 128.425 | 719 | 208 | 27 | - | 75.75 | - | - | - |
| 2017 | 1 | 15374 | 88.9 | 5584 | 315 | - | - | 72.75 | - | 1134 | - |
| 2017 | 2 | 9219 | 88.9 | 6068 | 307 | - | - | 72.75 | - | 2793 | - |
| 2017 | 3 | 6499 | 88.9 | - | 333 | - | - | 72.75 | - | - | - |
| 2017 | 4 | 18618 | 88.9 | 2276 | 336 | - | - | 72.75 | - | - | - |
| 2018 | 1 | 18985 | 130.15 | 5750 | 397 | - | - | 57.5 | - | 1075 | - |
| 2018 | 2 | 8524 | 130.15 | 360 | 403 | - | - | 57.5 | - | 3010 | - |
| 2018 | 3 | 7829 | 130.15 | - | 376 | - | - | 57.5 | - | - | - |
| 2018 | 4 | 15925 | 130.15 | - | 356 | - | - | 57.5 | - | - | - |
| 2019 | 1 | 11842 | 91.25 | 3435 | 458 | - | - | 60.5 | - | 774 | - |
| 2019 | 2 | 8858 | 91.25 | - | 419 | - | - | 60.5 | - | 2533 | - |
| 2019 | 3 | 4382 | 91.25 | - | 419 | - | - | 60.5 | - | - | - |
| 2019 | 4 | 13367 | 91.25 | - | 431 | - | - | 60.5 | - | - | - |
| 2020 | 1 | 14105 | 100.125 | 2933 | 470 | - | - | 72.5 | - | 687 | - |
| 2020 | 2 | 10003 | 100.125 | - | 464 | - | - | 72.5 | - | 1890 | - |
| 2020 | 3 | 7436 | 100.125 | - | 443 | - | - | 72.5 | - | - | - |
| 2020 | 4 | 19566 | 100.125 | 1661 | 451 | - | - | 72.5 | - | - | - |
| 2021 | 1 | 14105 | 69.275 | 3575 | 470 | - | - | 72.5 | - | 503 | - |
| 2021 | 2 | 10003 | 69.275 | 2350 | 464 | - | - | 72.5 | - | 1956 | - |
| 2021 | 3 | 7436 | 69.275 | - | 443 | - | - | 72.5 | - | - | - |
| 2021 | 4 | 19566 | 69.275 | 412 | 451 | - | - | 72.5 | - | - | - |

|  |  | **Fleet** | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Quarter** | **11** | **12** | **13** | **14** | **15** | **16** | **17\*** | **18\*** | **19** |
| 1975 | 1 | 225.75 | - | 7.25 | - | - | 142.5 | 7122 | - | 36 |
| 1975 | 2 | 225.75 | - | 7.25 | - | - | 142.5 | 2734 | - | 33 |
| 1975 | 3 | 225.75 | - | 7.25 | - | - | 142.5 | 1098 | - | 71 |
| 1975 | 4 | 225.75 | - | 7.25 | - | - | 142.5 | 1913 | - | 61 |
| 1976 | 1 | 314.75 | - | 5.75 | - | - | 13.75 | 10648 | - | 47 |
| 1976 | 2 | 314.75 | - | 5.75 | - | - | 13.75 | 4813 | - | 49 |
| 1976 | 3 | 314.75 | - | 5.75 | - | - | 13.75 | 1682 | - | 36 |
| 1976 | 4 | 314.75 | - | 5.75 | - | - | 13.75 | 4703 | - | 33 |
| 1977 | 1 | 290.25 | - | 9 | - | - | 84.25 | 6793 | - | 56 |
| 1977 | 2 | 290.25 | - | 9 | - | - | 84.25 | 3626 | - | 36 |
| 1977 | 3 | 290.25 | - | 9 | - | - | 84.25 | 1252 | - | 44 |
| 1977 | 4 | 290.25 | - | 9 | - | - | 84.25 | 3551 | - | 37 |
| 1978 | 1 | 323.5 | - | 0 | - | - | 428 | 12176 | - | 38 |
| 1978 | 2 | 323.5 | - | 0 | - | - | 428 | 4715 | - | 21 |
| 1978 | 3 | 323.5 | - | 0 | - | - | 428 | 1552 | - | 23 |
| 1978 | 4 | 323.5 | - | 0 | - | - | 428 | 2935 | - | 28 |
| 1979 | 1 | 315.75 | - | 1.725 | - | - | 96.5 | 17810 | - | 47 |
| 1979 | 2 | 315.75 | - | 1.725 | - | - | 96.5 | 5343 | - | 47 |
| 1979 | 3 | 315.75 | - | 1.725 | - | - | 96.5 | 2204 | - | 33 |
| 1979 | 4 | 315.75 | - | 1.725 | - | - | 96.5 | 3133 | - | 32 |
| 1980 | 1 | 323 | - | 2.5 | - | 40 | 157 | 21348 | - | 49 |
| 1980 | 2 | 323 | - | 2.5 | - | 40 | 157 | 5293 | - | 37 |
| 1980 | 3 | 323 | - | 2.5 | - | 40 | 157 | 2030 | - | 28 |
| 1980 | 4 | 323 | - | 2.5 | - | 40 | 157 | 11503 | - | 37 |
| 1981 | 1 | 231.5 | - | 0.35 | - | 115.25 | 71.75 | 31031 | - | 50 |
| 1981 | 2 | 231.5 | - | 0.35 | - | 115.25 | 71.75 | 6211 | - | 50 |
| 1981 | 3 | 231.5 | - | 0.35 | - | 115.25 | 71.75 | 3901 | - | 50 |
| 1981 | 4 | 231.5 | - | 0.35 | - | 115.25 | 71.75 | 3102 | - | 57 |
| 1982 | 1 | 283.75 | - | 0.25 | - | 227.75 | 19.9 | 16726 | - | 51 |
| 1982 | 2 | 283.75 | - | 0.25 | - | 227.75 | 19.9 | 3850 | - | 53 |
| 1982 | 3 | 283.75 | - | 0.25 | - | 227.75 | 19.9 | 1282 | - | 50 |
| 1982 | 4 | 283.75 | - | 0.25 | - | 227.75 | 19.9 | 4322 | - | 49 |
| 1983 | 1 | 319.25 | - | - | - | 330.25 | 109 | 20451 | - | 51 |
| 1983 | 2 | 319.25 | - | - | - | 330.25 | 109 | 3025 | - | 44 |
| 1983 | 3 | 319.25 | - | - | - | 330.25 | 109 | 1106 | - | 46 |
| 1983 | 4 | 319.25 | - | - | - | 330.25 | 109 | 5680 | - | 47 |
| 1984 | 1 | 371.75 | - | - | - | 525.25 | 193.5 | 28619 | - | 49 |
| 1984 | 2 | 371.75 | - | - | - | 525.25 | 193.5 | 4102 | - | 41 |
| 1984 | 3 | 371.75 | - | - | - | 525.25 | 193.5 | 1788 | - | 41 |
| 1984 | 4 | 371.75 | - | - | - | 525.25 | 193.5 | 5205 | - | 52 |
| 1985 | 1 | 344 | - | - | - | 747.5 | 103.25 | 24213 | - | 52 |
| 1985 | 2 | 344 | - | - | - | 747.5 | 103.25 | 4014 | - | 48 |
| 1985 | 3 | 344 | - | - | - | 747.5 | 103.25 | 1706 | - | 57 |
| 1985 | 4 | 344 | - | - | - | 747.5 | 103.25 | 6300 | - | 60 |
| 1986 | 1 | 327.5 | - | - | - | 517.25 | 101 | 15201 | - | 63 |
| 1986 | 2 | 327.5 | - | - | - | 517.25 | 101 | 3686 | - | 60 |
| 1986 | 3 | 327.5 | - | - | - | 517.25 | 101 | 2050 | - | 64 |
| 1986 | 4 | 327.5 | - | - | - | 517.25 | 101 | 4365 | - | 67 |
| 1987 | 1 | 286 | - | 0.5 | - | 382.25 | 67.5 | 19566 | - | 94 |
| 1987 | 2 | 286 | - | 0.5 | - | 382.25 | 67.5 | 4473 | - | 82 |
| 1987 | 3 | 286 | - | 0.5 | - | 382.25 | 67.5 | 2237 | - | 87 |
| 1987 | 4 | 286 | - | 0.5 | - | 382.25 | 67.5 | 10187 | - | 73 |
| 1988 | 1 | 266 | - | - | - | 344 | 67 | 23634 | - | 87 |
| 1988 | 2 | 266 | - | - | - | 344 | 67 | 3702 | - | 63 |
| 1988 | 3 | 266 | - | - | - | 344 | 67 | 1658 | - | 64 |
| 1988 | 4 | 266 | - | - | - | 344 | 67 | 11571 | - | 64 |
| 1989 | 1 | 336 | - | 3.975 | - | 310.75 | 31.25 | 24255 | - | 82 |
| 1989 | 2 | 336 | - | 3.975 | - | 310.75 | 31.25 | 4637 | - | 70 |
| 1989 | 3 | 336 | - | 3.975 | - | 310.75 | 31.25 | 1237 | - | 69 |
| 1989 | 4 | 336 | - | 3.975 | - | 310.75 | 31.25 | 4487 | - | 75 |
| 1990 | 1 | 220.75 | - | 19.775 | - | 282.75 | 28 | 20917 | - | 116 |
| 1990 | 2 | 220.75 | - | 19.775 | - | 282.75 | 28 | 3130 | - | 85 |
| 1990 | 3 | 220.75 | - | 19.775 | - | 282.75 | 28 | 1326 | - | 78 |
| 1990 | 4 | 220.75 | - | 19.775 | - | 282.75 | 28 | 3355 | - | 65 |
| 1991 | 1 | 264.75 | - | 4 | - | 236 | 17.5 | 11474 | - | 91 |
| 1991 | 2 | 264.75 | - | 4 | - | 236 | 17.5 | 2871 | - | 98 |
| 1991 | 3 | 264.75 | - | 4 | - | 236 | 17.5 | 1284 | - | 77 |
| 1991 | 4 | 264.75 | - | 4 | - | 236 | 17.5 | 3662 | - | 63 |
| 1992 | 1 | 407.75 | - | 3.5 | - | 339 | 30.75 | 8819 | - | 99 |
| 1992 | 2 | 407.75 | - | 3.5 | - | 339 | 30.75 | 2756 | - | 110 |
| 1992 | 3 | 407.75 | - | 3.5 | - | 339 | 30.75 | 1520 | - | 88 |
| 1992 | 4 | 407.75 | - | 3.5 | - | 339 | 30.75 | 2567 | - | 62 |
| 1993 | 1 | 437.75 | - | 13.5 | - | 353 | 83.25 | 6548 | - | 105 |
| 1993 | 2 | 437.75 | - | 13.5 | - | 353 | 83.25 | 2495 | - | 212 |
| 1993 | 3 | 437.75 | - | 13.5 | - | 353 | 83.25 | 1394 | - | 318 |
| 1993 | 4 | 437.75 | - | 13.5 | - | 353 | 83.25 | 2838 | - | 150 |
| 1994 | 1 | - | 87.25 | - | - | 198 | 46.25 | - | 5089 | 157 |
| 1994 | 2 | - | 87.25 | - | - | 198 | 46.25 | - | 2452 | 378 |
| 1994 | 3 | - | 87.25 | - | - | 198 | 46.25 | - | 1191 | 279 |
| 1994 | 4 | - | 87.25 | - | - | 198 | 46.25 | - | 1462 | 159 |
| 1995 | 1 | - | 116.25 | 11.475 | - | 192.75 | 33 | - | 3701 | 192 |
| 1995 | 2 | - | 116.25 | 11.475 | - | 192.75 | 33 | - | 2110 | 241 |
| 1995 | 3 | - | 116.25 | 11.475 | - | 192.75 | 33 | - | 999 | 183 |
| 1995 | 4 | - | 116.25 | 11.475 | - | 192.75 | 33 | - | 1580 | 123 |
| 1996 | 1 | - | 162.5 | 1.6 | - | 190.25 | 25.25 | - | 3847 | 183 |
| 1996 | 2 | - | 162.5 | 1.6 | - | 190.25 | 25.25 | - | 1869 | 190 |
| 1996 | 3 | - | 162.5 | 1.6 | - | 190.25 | 25.25 | - | 845 | 157 |
| 1996 | 4 | - | 162.5 | 1.6 | - | 190.25 | 25.25 | - | 2567 | 164 |
| 1997 | 1 | - | 103.5 | 3.75 | - | 177 | 25.5 | - | 2351 | 89 |
| 1997 | 2 | - | 103.5 | 3.75 | - | 177 | 25.5 | - | 1742 | 73 |
| 1997 | 3 | - | 103.5 | 3.75 | - | 177 | 25.5 | - | 787 | 73 |
| 1997 | 4 | - | 103.5 | 3.75 | - | 177 | 25.5 | - | 1319 | 85 |
| 1998 | 1 | - | 137.5 | 5 | - | 232.75 | 18.5 | - | 1832 | 139 |
| 1998 | 2 | - | 137.5 | 5 | - | 232.75 | 18.5 | - | 1831 | 130 |
| 1998 | 3 | - | 137.5 | 5 | - | 232.75 | 18.5 | - | 857 | 110 |
| 1998 | 4 | - | 137.5 | 5 | - | 232.75 | 18.5 | - | 1412 | 127 |
| 1999 | 1 | - | 117.5 | 14.8 | - | 151.5 | 29.25 | - | 3312 | 150 |
| 1999 | 2 | - | 117.5 | 14.8 | - | 151.5 | 29.25 | - | 1908 | 227 |
| 1999 | 3 | - | 117.5 | 14.8 | - | 151.5 | 29.25 | - | 1252 | 205 |
| 1999 | 4 | - | 117.5 | 14.8 | - | 151.5 | 29.25 | - | 2088 | 219 |
| 2000 | 1 | - | 140 | - | - | 162.25 | 30.75 | - | 3282 | 260 |
| 2000 | 2 | - | 140 | - | - | 162.25 | 30.75 | - | 2441 | 281 |
| 2000 | 3 | - | 140 | - | - | 162.25 | 30.75 | - | 962 | 265 |
| 2000 | 4 | - | 140 | - | - | 162.25 | 30.75 | - | 1731 | 223 |
| 2001 | 1 | - | 71 | - | 953.25 | 93.75 | 17.75 | - | 2818 | 218 |
| 2001 | 2 | - | 71 | - | 953.25 | 93.75 | 17.75 | - | 2336 | 257 |
| 2001 | 3 | - | 71 | - | 953.25 | 93.75 | 17.75 | - | 1339 | 215 |
| 2001 | 4 | - | 71 | - | 953.25 | 93.75 | 17.75 | - | 2124 | 237 |
| 2002 | 1 | - | 62.75 | - | 941.5 | 75.5 | 23.25 | - | 3192 | 348 |
| 2002 | 2 | - | 62.75 | - | 941.5 | 75.5 | 23.25 | - | 2748 | 380 |
| 2002 | 3 | - | 62.75 | - | 941.5 | 75.5 | 23.25 | - | 948 | 227 |
| 2002 | 4 | - | 62.75 | - | 941.5 | 75.5 | 23.25 | - | 1551 | 242 |
| 2003 | 1 | - | 63.5 | - | 856.225 | 54 | 32 | - | 2402 | 486 |
| 2003 | 2 | - | 63.5 | - | 856.225 | 54 | 32 | - | 3649 | 364 |
| 2003 | 3 | - | 63.5 | - | 856.225 | 54 | 32 | - | 1158 | 241 |
| 2003 | 4 | - | 63.5 | - | 856.225 | 54 | 32 | - | 1490 | 356 |
| 2004 | 1 | - | 68.5 | - | 777.625 | 45.5 | 30 | - | 5808 | 362 |
| 2004 | 2 | - | 68.5 | - | 777.625 | 45.5 | 30 | - | 5102 | 350 |
| 2004 | 3 | - | 68.5 | - | 777.625 | 45.5 | 30 | - | 1056 | 300 |
| 2004 | 4 | - | 68.5 | - | 777.625 | 45.5 | 30 | - | 875 | 345 |
| 2005 | 1 | - | 133.5 | - | 855.25 | 55 | 21.75 | - | 3459 | 357 |
| 2005 | 2 | - | 133.5 | - | 855.25 | 55 | 21.75 | - | 1682 | 261 |
| 2005 | 3 | - | 133.5 | - | 855.25 | 55 | 21.75 | - | 1442 | 177 |
| 2005 | 4 | - | 133.5 | - | 855.25 | 55 | 21.75 | - | 1657 | 206 |
| 2006 | 1 | - | 148.75 | - | 976.775 | 110.75 | 20 | - | 5029 | 286 |
| 2006 | 2 | - | 148.75 | - | 976.775 | 110.75 | 20 | - | 2794 | 261 |
| 2006 | 3 | - | 148.75 | - | 976.775 | 110.75 | 20 | - | 1326 | 210 |
| 2006 | 4 | - | 148.75 | - | 976.775 | 110.75 | 20 | - | 845 | 258 |
| 2007 | 1 | - | 123.75 | - | 934.525 | 122.5 | 16.25 | - | 2700 | 277 |
| 2007 | 2 | - | 123.75 | - | 934.525 | 122.5 | 16.25 | - | 2939 | 246 |
| 2007 | 3 | - | 123.75 | - | 934.525 | 122.5 | 16.25 | - | 986 | 215 |
| 2007 | 4 | - | 123.75 | - | 934.525 | 122.5 | 16.25 | - | 1295 | 258 |
| 2008 | 1 | - | 132 | - | 843.375 | 101.25 | 18.25 | - | 4361 | 360 |
| 2008 | 2 | - | 132 | - | 843.375 | 101.25 | 18.25 | - | 2250 | 341 |
| 2008 | 3 | - | 132 | - | 843.375 | 101.25 | 18.25 | - | 760 | 286 |
| 2008 | 4 | - | 132 | - | 843.375 | 101.25 | 18.25 | - | 551 | 321 |
| 2009 | 1 | - | 134.75 | - | 782.375 | 63.25 | 14 | - | 975 | 374 |
| 2009 | 2 | - | 134.75 | - | 782.375 | 63.25 | 14 | - | 1341 | 347 |
| 2009 | 3 | - | 134.75 | - | 782.375 | 63.25 | 14 | - | 425 | 293 |
| 2009 | 4 | - | 134.75 | - | 782.375 | 63.25 | 14 | - | 482 | 393 |
| 2010 | 1 | - | 87.75 | - | 564.475 | 15.5 | 10 | - | 3019 | 577 |
| 2010 | 2 | - | 87.75 | - | 564.475 | 15.5 | 10 | - | 2192 | 487 |
| 2010 | 3 | - | 87.75 | - | 564.475 | 15.5 | 10 | - | 660 | 395 |
| 2010 | 4 | - | 87.75 | - | 564.475 | 15.5 | 10 | - | 445 | 364 |
| 2011 | 1 | - | 62 | - | 759.85 | 29.75 | 7.25 | - | 902 | 336 |
| 2011 | 2 | - | 62 | - | 759.85 | 29.75 | 7.25 | - | 1160 | 460 |
| 2011 | 3 | - | 62 | - | 759.85 | 29.75 | 7.25 | - | 709 | 305 |
| 2011 | 4 | - | 62 | - | 759.85 | 29.75 | 7.25 | - | 423 | 322 |
| 2012 | 1 | - | 90.25 | - | 712.925 | 29.5 | 3.25 | - | 958 | 719 |
| 2012 | 2 | - | 90.25 | - | 712.925 | 29.5 | 3.25 | - | 1217 | 770 |
| 2012 | 3 | - | 90.25 | - | 712.925 | 29.5 | 3.25 | - | 444 | 569 |
| 2012 | 4 | - | 90.25 | - | 712.925 | 29.5 | 3.25 | - | 389 | 583 |
| 2013 | 1 | - | 118 | - | 373.9 | 23.75 | 5 | - | 668 | 953 |
| 2013 | 2 | - | 118 | - | 373.9 | 23.75 | 5 | - | 1196 | 940 |
| 2013 | 3 | - | 118 | - | 373.9 | 23.75 | 5 | - | 322 | 822 |
| 2013 | 4 | - | 118 | - | 373.9 | 23.75 | 5 | - | 463 | 856 |
| 2014 | 1 | - | 133.5 | - | 592.475 | 31.75 | 4.75 | - | 894 | 849 |
| 2014 | 2 | - | 133.5 | - | 592.475 | 31.75 | 4.75 | - | 1029 | 971 |
| 2014 | 3 | - | 133.5 | - | 592.475 | 31.75 | 4.75 | - | 650 | 755 |
| 2014 | 4 | - | 133.5 | - | 592.475 | 31.75 | 4.75 | - | 539 | 784 |
| 2015 | 1 | - | 122.25 | - | 584.6 | 24.75 | 6.25 | - | 998 | 1105 |
| 2015 | 2 | - | 122.25 | - | 584.6 | 24.75 | 6.25 | - | 1507 | 1001 |
| 2015 | 3 | - | 122.25 | - | 584.6 | 24.75 | 6.25 | - | 432 | 744 |
| 2015 | 4 | - | 122.25 | - | 584.6 | 24.75 | 6.25 | - | 440 | 825 |
| 2016 | 1 | - | 107.5 | - | 309.4 | 43.25 | 20.5 | - | 616 | 1233 |
| 2016 | 2 | - | 107.5 | - | 309.4 | 43.25 | 20.5 | - | 1772 | 1262 |
| 2016 | 3 | - | 107.5 | - | 309.4 | 43.25 | 20.5 | - | 209 | 919 |
| 2016 | 4 | - | 107.5 | - | 309.4 | 43.25 | 20.5 | - | 179 | 929 |
| 2017 | 1 | - | 142.75 | - | 386.5 | 44.75 | 19.75 | - | 556 | 802 |
| 2017 | 2 | - | 142.75 | - | 386.5 | 44.75 | 19.75 | - | 1108 | 768 |
| 2017 | 3 | - | 142.75 | - | 386.5 | 44.75 | 19.75 | - | 350 | 599 |
| 2017 | 4 | - | 142.75 | - | 386.5 | 44.75 | 19.75 | - | 242 | 640 |
| 2018 | 1 | - | 188.75 | - | 372.025 | 37 | 20.25 | - | 561 | 1001 |
| 2018 | 2 | - | 188.75 | - | 372.025 | 37 | 20.25 | - | 1020 | 1199 |
| 2018 | 3 | - | 188.75 | - | 372.025 | 37 | 20.25 | - | 245 | 654 |
| 2018 | 4 | - | 188.75 | - | 372.025 | 37 | 20.25 | - | 233 | 669 |
| 2019 | 1 | - | 139.75 | - | 396.625 | 13 | 50.25 | - | 409 | 755 |
| 2019 | 2 | - | 139.75 | - | 396.625 | 13 | 50.25 | - | 648 | 948 |
| 2019 | 3 | - | 139.75 | - | 396.625 | 13 | 50.25 | - | 274 | 589 |
| 2019 | 4 | - | 139.75 | - | 396.625 | 13 | 50.25 | - | 214 | 652 |
| 2020 | 1 | - | 124 | - | 339.375 | 8.75 | 33.5 | - | 1291 | 556 |
| 2020 | 2 | - | 124 | - | 339.375 | 8.75 | 33.5 | - | 909 | 581 |
| 2020 | 3 | - | 124 | - | 339.375 | 8.75 | 33.5 | - | 77 | 263 |
| 2020 | 4 | - | 124 | - | 339.375 | 8.75 | 33.5 | - | 105 | 282 |
| 2021 | 1 | - | 124 | - | 181.1 | 3.25 | 15.75 | - | 1291 | 556 |
| 2021 | 2 | - | 124 | - | 181.1 | 3.25 | 15.75 | - | 909 | 581 |
| 2021 | 3 | - | 124 | - | 181.1 | 3.25 | 15.75 | - | 77 | 263 |
| 2021 | 4 | - | 124 | - | 181.1 | 3.25 | 15.75 | - | 105 | 282 |

Table 3. Standardized catch-per-unit-effort (CPUE; in number per 1000 hooks) indices and input standard error (SE) in log-scale (i.e., log(SE)) of lognormal error of CPUE for the striped marlin from the Western and Central North Pacific Ocean used in the stock assessment. Index descriptions can be found in Table 1.

| **Fleet** | **S1** | | **S2** | | **S3** | | **S4** | | **S5** | | **S6** | | **S7** | | **S8** | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **CPUE** | **CV** | **CPUE** | **CV** | **CPUE** | **CV** | **CPUE** | **CV** | **CPUE** | **CV** | **CPUE** | **CV** | **CPUE** | **CV** | **CPUE** | **CV** |
| 1976 | 0.44 | 0.19 | - | - | 0.33 | 0.20 | - | - | - | - | - | - | - | - | - | - |
| 1977 | 0.38 | 0.19 | - | - | 0.31 | 0.21 | - | - | - | - | - | - | - | - | - | - |
| 1978 | 0.39 | 0.18 | - | - | 0.26 | 0.19 | - | - | - | - | - | - | - | - | - | - |
| 1979 | 0.36 | 0.17 | - | - | 0.25 | 0.19 | - | - | - | - | - | - | - | - | - | - |
| 1980 | 0.25 | 0.14 | - | - | 0.46 | 0.22 | - | - | - | - | - | - | - | - | - | - |
| 1981 | 0.26 | 0.14 | - | - | 0.26 | 0.19 | - | - | - | - | - | - | - | - | - | - |
| 1982 | 0.47 | 0.22 | - | - | 0.29 | 0.20 | - | - | - | - | - | - | - | - | - | - |
| 1983 | 0.45 | 0.18 | - | - | 0.34 | 0.20 | - | - | - | - | - | - | - | - | - | - |
| 1984 | 0.36 | 0.17 | - | - | 0.36 | 0.20 | - | - | - | - | - | - | - | - | - | - |
| 1985 | 0.44 | 0.20 | - | - | 0.35 | 0.20 | - | - | - | - | - | - | - | - | - | - |
| 1986 | 0.54 | 0.28 | - | - | 0.36 | 0.21 | - | - | - | - | - | - | - | - | - | - |
| 1987 | 0.61 | 0.33 | - | - | 0.43 | 0.21 | - | - | - | - | - | - | - | - | - | - |
| 1988 | 0.49 | 0.23 | - | - | 0.41 | 0.21 | - | - | - | - | - | - | - | - | - | - |
| 1989 | 0.43 | 0.21 | - | - | 0.34 | 0.20 | - | - | - | - | - | - | - | - | - | - |
| 1990 | 0.34 | 0.16 | - | - | 0.34 | 0.20 | - | - | - | - | - | - | - | - | - | - |
| 1991 | 0.42 | 0.18 | - | - | 0.28 | 0.20 | - | - | - | - | - | - | - | - | - | - |
| 1992 | 0.42 | 0.20 | - | - | 0.26 | 0.20 | - | - | - | - | - | - | - | - | - | - |
| 1993 | 0.47 | 0.25 | - | - | 0.23 | 0.20 | - | - | - | - | - | - | - | - | - | - |
| 1994 | - | - | 0.42 | 0.18 | - | - | 0.27 | 0.19 | - | - | - | - | - | - | - | - |
| 1995 | - | - | 0.36 | 0.19 | - | - | 0.21 | 0.18 | - | - | 0.26 | 0.21 | 6.13 | 0.20 | - | - |
| 1996 | - | - | 0.41 | 0.22 | - | - | 0.32 | 0.20 | - | - | 0.16 | 0.20 | 6.78 | 0.20 | - | - |
| 1997 | - | - | 0.46 | 0.22 | - | - | 0.28 | 0.20 | - | - | 0.10 | 0.21 | 7.83 | 0.20 | - | - |
| 1998 | - | - | 0.36 | 0.19 | - | - | 0.28 | 0.20 | - | - | 0.14 | 0.20 | 7.84 | 0.20 | - | - |
| 1999 | - | - | 0.37 | 0.20 | - | - | 0.30 | 0.20 | - | - | 0.13 | 0.20 | 7.48 | 0.20 | - | - |
| 2000 | - | - | 0.44 | 0.24 | - | - | 0.32 | 0.20 | 0.59 | 0.27 | 0.11 | 0.20 | 7.91 | 0.20 | - | - |
| 2001 | - | - | 0.40 | 0.22 | - | - | 0.35 | 0.21 | 1.13 | 0.23 | 0.12 | 0.20 | - | - | - | - |
| 2002 | - | - | 0.38 | 0.22 | - | - | 0.32 | 0.20 | 1.43 | 0.21 | 0.15 | 0.20 | - | - | - | - |
| 2003 | - | - | 0.27 | 0.18 | - | - | 0.28 | 0.19 | 1.01 | 0.22 | 0.14 | 0.20 | - | - | - | - |
| 2004 | - | - | 0.28 | 0.16 | - | - | 0.25 | 0.18 | 1.12 | 0.20 | 0.18 | 0.20 | - | - | - | - |
| 2005 | - | - | 0.30 | 0.16 | - | - | 0.24 | 0.19 | 0.95 | 0.19 | 0.13 | 0.20 | - | - | 14.96 | 0.20 |
| 2006 | - | - | 0.33 | 0.17 | - | - | 0.30 | 0.20 | 0.69 | 0.19 | 0.13 | 0.20 | - | - | 16.54 | 0.20 |
| 2007 | - | - | 0.39 | 0.19 | - | - | 0.33 | 0.21 | 0.72 | 0.21 | 0.13 | 0.20 | - | - | 13.71 | 0.20 |
| 2008 | - | - | 0.26 | 0.15 | - | - | 0.33 | 0.21 | 0.56 | 0.21 | 0.12 | 0.20 | - | - | 12.84 | 0.20 |
| 2009 | - | - | 0.35 | 0.18 | - | - | 0.32 | 0.21 | 0.71 | 0.21 | 0.12 | 0.20 | - | - | 10.42 | 0.20 |
| 2010 | - | - | 0.32 | 0.18 | - | - | 0.25 | 0.19 | 0.72 | 0.21 | 0.11 | 0.20 | - | - | 9.52 | 0.20 |
| 2011 | - | - | 0.30 | 0.19 | - | - | 0.22 | 0.18 | 0.62 | 0.21 | 0.10 | 0.20 | - | - | 10.43 | 0.20 |
| 2012 | - | - | 0.30 | 0.20 | - | - | 0.20 | 0.18 | 0.84 | 0.21 | 0.11 | 0.20 | - | - | 9.07 | 0.20 |
| 2013 | - | - | 0.29 | 0.19 | - | - | 0.21 | 0.18 | 0.84 | 0.21 | 0.11 | 0.20 | - | - | 9.09 | 0.20 |
| 2014 | - | - | 0.30 | 0.19 | - | - | 0.20 | 0.18 | 0.79 | 0.22 | 0.14 | 0.20 | - | - | 9.35 | 0.20 |
| 2015 | - | - | 0.31 | 0.18 | - | - | 0.31 | 0.21 | 1.09 | 0.19 | 0.15 | 0.19 | - | - | 10.44 | 0.20 |
| 2016 | - | - | 0.43 | 0.21 | - | - | 0.30 | 0.21 | 1.08 | 0.20 | 0.13 | 0.20 | - | - | 12.07 | 0.20 |
| 2017 | - | - | 0.51 | 0.24 | - | - | 0.22 | 0.19 | 1.32 | 0.20 | 0.13 | 0.20 | - | - | 12.01 | 0.20 |
| 2018 | - | - | 0.67 | 0.32 | - | - | 0.27 | 0.20 | 1.68 | 0.18 | 0.13 | 0.19 | - | - | 10.06 | 0.20 |
| 2019 | - | - | 0.49 | 0.25 | - | - | 0.27 | 0.20 | 1.14 | 0.19 | 0.10 | 0.20 | - | - | 8.81 | 0.20 |
| 2020 | - | - | 0.47 | 0.24 | - | - | 0.31 | 0.22 | 1.42 | 0.18 | 0.08 | 0.20 | - | - | 9.15 | 0.20 |
| 2021 | - | - | 0.40 | 0.21 | - | - | 0.39 | 0.24 | 1.55 | 0.17 | 0.09 | 0.20 | - | - | 7.32 | 0.20 |

Table 4. Key life history parameters and model structures for the North Pacific swordfish stock assessment.

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Female** | **Male** | **Reference** |
| Growth age for L1 | 0.5 | 0.5 | - |
| Growth age for L2 | 15 | 15 | - |
| Natural mortality | 0.42 (0) | 0.4 (0) | Kapur et al. 2017 |
|  | 0.37 (1) | 0.38 (1) |  |
|  | 0.32 (2) | 0.37 (2) |  |
|  | 0.27 (3) | 0.37 (3) |  |
|  | 0.22 (4+) | 0.37 (4) |  |
|  |  | 0.37 (5) |  |
|  |  | 0.36 (6+) |  |
| L at Amin GP 1 | 80.1 | 83.2 | DeMartini et al. 2007 |
| L at Amax GP 1 | 226.3 | 206.4 | DeMartini et al. 2007 |
| VonBert K GP 1 | 0.246 | 0.271 | DeMartini et al. 2007 |
| CV young GP 1 | 0.1 | 0.1 |  |
| CV old GP 1 | 0.1 | 0.1 |  |
| Weight – length par 1 | 1.30E-05 | 1.30E-05 | DeMartini et al. 2007 |
| Weight – length par 2 | 3.07 | 3.07 | DeMartini et al. 2007 |
| 50% maturity length | 143.68 | - | Kapur et al. 2017 |
| Mat slope | -0.1034 | - |  |
| Fecunditiy | Proportional to spawning biomass | - |  |
| Spawning season | July | | Nishikawa 1985 |
| 11111111111111111111111111111111111R0 | 0.42 | |  |
| Steepness | 0.9 | | Brodziak 2020 |

Table 5. Mean input standard error (SE) in log-space (i.e., log(SE)) of lognormal error and root-mean-square-errors (RMSE) for the relative abundance indices for North Pacific swordfish used in the base-case model. S5 (TWN LL) and S8 (US LL shallow-late) were not included in the total likelihood.

|  |  |  |  |
| --- | --- | --- | --- |
| **Fleet** | ***N*** | **Input log(SE)** | **RMSE** |
|
| S1\_JPN\_WCNPO\_OSDWLL\_early\_Area1 | 18 | 0.201 | 0.15 |
| S2\_JPN\_WCNPO\_OSDWCOLL\_late\_Area1 | 28 | 0.203 | 0.18 |
| S3\_JPN\_WCNPO\_OSDWLL\_early\_Area2 | 18 | 0.202 | 0.17 |
| S4\_JPN\_WCNPO\_OSDWLL\_late\_Area2 | 28 | 0.198 | 0.16 |
| S5\_TWN\_WCNPO\_DWLL\_late | 22 | 0.205 | 0.32 |
| S6\_US\_WCNPO\_LL\_deep | 27 | 0.20 | 0.13 |
| S7\_US\_WCNPO\_LL\_shallow\_early | 6 | 0.20 | 0.03 |
| S8\_US\_WCNPO\_LL\_shallow\_late | 17 | 0.20 | 0.19 |

Table 6. Fishery-specific selectivity assumptions for the North Pacific swordfish stock assessment. The selectivity curves for fisheries lacking length composition data were assumed to be the same as (i.e., mirror gear) closely related fisheries or fisheries operating in the same area.

|  |  |
| --- | --- |
| **Fleet** | **Selectivity Function** |
| F1 | Double-normal – Time Varying |
| F2 | Asymptotic logistic - Time Varying |
| F3 | Double normal |
| F4 | Asymptotic logistic |
| F5 | Mirror F4 |
| F6 | Double-normal |
| F7 | Double-normal |
| F8 | Double-normal |
| F9 | Mirror F8 |
| F10 | Mirror F6 |
| F11 | Mirror F6 |
| F12 | Mirror F1 |
| F13 | Mirror F2 |
| F14 | Mirror F1 |
| F15 | Mirror F2 |
| F16 | Mirror F2 |
| F17 | Mirror F3 |
| F18 | Mirror F3 |
| F19 | Mirror F2 |
| S1 | Mirror F6 |
| S2 | Mirror F1 |
| S3 | Mirror F3 |
| S4 | Mirror F3 |
| S5 | Mirror F2 |
| S6 | None |
| S7 | Mirror F8 |
| S8 | Mirror F3 |

Table 7. Relative negative log-likelihoods of abundance index data components in the base case model over a range of fixed levels of virgin recruitment in log-scale (log(R0)). 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 log(R0) was 6.84. See Table 1 for a description of the abundance indices. S5 and S8 were not included in the total likelihood.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ln(R0) | S1 | S2 | S3 | S4 | S6 |
| 6.2 | 3.04 | 8.83 | 0.66 | 3.70 | 9.18 |
| 6.3 | 3.16 | 8.83 | 1.07 | 3.03 | 8.03 |
| 6.4 | 3.36 | 7.36 | 0.02 | 2.58 | 6.19 |
| 6.5 | 1.37 | 15.13 | 0.81 | 2.50 | 3.55 |
| 6.6 | 2.30 | 4.70 | 0 | 1.27 | 2.11 |
| 6.7 | 0.70 | 2.53 | 0.28 | 0.32 | 0.04 |
| 6.8 | 0.04 | 0.61 | 0.89 | 0 | 0 |
| 6.84 | 0 | 0.36 | 1.01 | 0.05 | 0.21 |
| 6.9 | 0 | 0.15 | 1.07 | 0.11 | 0.45 |
| 7 | 0.04 | 0.02 | 1.08 | 0.19 | 0.71 |
| 7.1 | 0.09 | 0 | 1.04 | 0.25 | 0.86 |
| 7.2 | 0.14 | 0.05 | 0.99 | 0.28 | 0.96 |
| 7.3 | 0.19 | 0.11 | 0.94 | 0.31 | 1.03 |
| 7.4 | 0.23 | 0.18 | 0.89 | 0.32 | 1.09 |
| 7.5 | 0.27 | 0.25 | 0.85 | 0.33 | 1.14 |
| 7.6 | 0.30 | 0.31 | 0.81 | 0.34 | 1.18 |
| 7.7 | 0.33 | 0.37 | 0.78 | 0.35 | 1.21 |
| 7.8 | 0.36 | 0.43 | 0.76 | 0.36 | 1.24 |

Table 9. Relative negative log-likelihoods of length composition data components in the base case model over a range of fixed levels of virgin recruitment in log-scale (log(R0)). 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 log(R0) was 6.84. See Table 1 for a description of the composition data.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| ln(R0) | F1 | F2 | F3 | F4 | F6 | F7 | F8 |
| 6.2 | 2.65 | 14.23 | 0 | 2.11 | 27.94 | 2.31 | 6.94 |
| 6.3 | 5.87 | 13.58 | 0.10 | 2.02 | 14.20 | 2.20 | 4.21 |
| 6.4 | 1.45 | 12.10 | 0.14 | 1.89 | 11.83 | 2.04 | 3.30 |
| 6.5 | 9.85 | 8.15 | 0.39 | 1.56 | 7.27 | 1.64 | 6.27 |
| 6.6 | 0 | 8.50 | 0.44 | 1.53 | 2.18 | 1.61 | 1.27 |
| 6.7 | 0.05 | 4.57 | 0.96 | 1.13 | 0.06 | 1.21 | 0.82 |
| 6.8 | 0.87 | 0.62 | 1.88 | 0.65 | 0 | 1.03 | 0.56 |
| 6.84 | 1.04 | 0 | 2.18 | 0.55 | 0.08 | 1.01 | 0.49 |
| 6.9 | 1.28 | 0.06 | 2.50 | 0.47 | 0.20 | 0.99 | 0.41 |
| 7 | 1.67 | 1.63 | 2.89 | 0.35 | 0.36 | 0.92 | 0.30 |
| 7.1 | 2.04 | 4.03 | 3.16 | 0.26 | 0.49 | 0.81 | 0.22 |
| 7.2 | 2.36 | 6.67 | 3.36 | 0.19 | 0.59 | 0.65 | 0.15 |
| 7.3 | 2.66 | 9.27 | 3.50 | 0.13 | 0.67 | 0.46 | 0.10 |
| 7.4 | 2.92 | 11.73 | 3.61 | 0.09 | 0.72 | 0.31 | 0.08 |
| 7.5 | 3.15 | 14.02 | 3.70 | 0.06 | 0.77 | 0.24 | 0.06 |
| 7.6 | 3.34 | 16.10 | 3.78 | 0.03 | 0.81 | 0.14 | 0.04 |
| 7.7 | 3.51 | 18.00 | 3.84 | 0.01 | 0.84 | 0.06 | 0.02 |
| 7.8 | 3.66 | 19.72 | 3.89 | 0 | 0.87 | 0 | 0 |

Table 9. Time series of total biomass (age 1 and older, metric ton), spawning biomass (metric ton), age-0 recruitment (thousands of fish), and instantaneous fishing mortality (age 1-10, year-1) for the 2023 North Pacific swordfish estimated in the base-case model. SD = standard deviation.

| **Year** | **Age 1+ biomass (mt)** | | **Spawning biomass (mt)** | | | **Recruitment (1000 age-0 fish)** | | | **Instantaneous fishing mortality** | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Mean** | **Mean** | | **SD** | **Mean** | | **SD** | **Mean** | | **SD** |
| 1975 | 78466 | 28295 | | 18702 | 777 | | 273 | 0.13 | | 0.03 |
| 1976 | 79051 | 28426 | | 15741 | 768 | | 255 | 0.15 | | 0.03 |
| 1977 | 76981 | 28165 | | 13091 | 704 | | 226 | 0.14 | | 0.03 |
| 1978 | 74911 | 27121 | | 11181 | 596 | | 192 | 0.17 | | 0.03 |
| 1979 | 69354 | 25744 | | 9889 | 683 | | 233 | 0.16 | | 0.03 |
| 1980 | 65723 | 24384 | | 8950 | 1169 | | 383 | 0.15 | | 0.03 |
| 1981 | 67123 | 22415 | | 8108 | 937 | | 346 | 0.13 | | 0.02 |
| 1982 | 70283 | 22796 | | 7620 | 772 | | 284 | 0.11 | | 0.02 |
| 1983 | 74496 | 23978 | | 7521 | 1430 | | 394 | 0.14 | | 0.03 |
| 1984 | 79859 | 25288 | | 7632 | 1017 | | 283 | 0.12 | | 0.02 |
| 1985 | 85036 | 25899 | | 7787 | 933 | | 235 | 0.14 | | 0.02 |
| 1986 | 86914 | 27908 | | 8164 | 888 | | 275 | 0.14 | | 0.02 |
| 1987 | 87231 | 29242 | | 8482 | 825 | | 214 | 0.15 | | 0.02 |
| 1988 | 85070 | 29278 | | 8614 | 813 | | 201 | 0.15 | | 0.02 |
| 1989 | 82207 | 29180 | | 8620 | 675 | | 217 | 0.13 | | 0.02 |
| 1990 | 79792 | 29174 | | 8563 | 711 | | 222 | 0.12 | | 0.02 |
| 1991 | 78010 | 29914 | | 8418 | 777 | | 230 | 0.11 | | 0.02 |
| 1992 | 78049 | 29519 | | 8113 | 727 | | 212 | 0.12 | | 0.02 |
| 1993 | 76954 | 28766 | | 7630 | 673 | | 185 | 0.12 | | 0.02 |
| 1994 | 74709 | 27973 | | 6730 | 698 | | 157 | 0.10 | | 0.01 |
| 1995 | 74073 | 28180 | | 5921 | 1323 | | 150 | 0.09 | | 0.01 |
| 1996 | 79740 | 27529 | | 5303 | 752 | | 99 | 0.09 | | 0.01 |
| 1997 | 82983 | 28322 | | 5003 | 708 | | 94 | 0.09 | | 0.01 |
| 1998 | 85797 | 31019 | | 5004 | 1202 | | 134 | 0.19 | | 0.02 |
| 1999 | 81786 | 29254 | | 5001 | 822 | | 109 | 0.12 | | 0.01 |
| 2000 | 82916 | 27872 | | 4967 | 707 | | 99 | 0.14 | | 0.01 |
| 2001 | 80057 | 28485 | | 5022 | 729 | | 98 | 0.12 | | 0.01 |
| 2002 | 79474 | 29426 | | 5100 | 881 | | 108 | 0.11 | | 0.01 |
| 2003 | 79614 | 29287 | | 5106 | 1019 | | 121 | 0.11 | | 0.01 |
| 2004 | 81089 | 28684 | | 5064 | 1192 | | 134 | 0.11 | | 0.01 |
| 2005 | 85253 | 28137 | | 5032 | 851 | | 110 | 0.11 | | 0.01 |
| 2006 | 87537 | 29204 | | 5096 | 819 | | 101 | 0.13 | | 0.01 |
| 2007 | 87127 | 30073 | | 5217 | 791 | | 96 | 0.13 | | 0.01 |
| 2008 | 85142 | 30776 | | 5326 | 746 | | 91 | 0.12 | | 0.01 |
| 2009 | 83044 | 30795 | | 5368 | 660 | | 84 | 0.12 | | 0.01 |
| 2010 | 80447 | 30722 | | 5365 | 774 | | 93 | 0.11 | | 0.01 |
| 2011 | 79212 | 30696 | | 5322 | 728 | | 92 | 0.10 | | 0.01 |
| 2012 | 79056 | 30022 | | 5231 | 758 | | 96 | 0.11 | | 0.01 |
| 2013 | 78097 | 29510 | | 5138 | 896 | | 112 | 0.10 | | 0.01 |
| 2014 | 78997 | 28759 | | 5053 | 971 | | 123 | 0.11 | | 0.01 |
| 2015 | 80374 | 27947 | | 5003 | 1016 | | 130 | 0.11 | | 0.01 |
| 2016 | 83200 | 28205 | | 5046 | 964 | | 130 | 0.10 | | 0.01 |
| 2017 | 86835 | 29785 | | 5211 | 747 | | 109 | 0.09 | | 0.01 |
| 2018 | 89418 | 31661 | | 5455 | 783 | | 113 | 0.10 | | 0.01 |
| 2019 | 89617 | 33761 | | 5713 | 739 | | 116 | 0.09 | | 0.01 |
| 2020 | 89992 | 35159 | | 5896 | 625 | | 112 | 0.09 | | 0.01 |
| 2021 | 88755 | 35778 | | 6009 | 633 | | 122 | 0.09 | | 0.01 |

Table 10. Estimated biological reference points derived from the Stock Synthesis base case model for North Pacific swordfish where F is the instantaneous annual fishing mortality rate, SPR is the annual spawning potential ratio, SSB is spawning stock biomass, and SSB(F=0) indicates the average 5-year SSB0 estimate, 20%SSB­(F=0) is the associated reference point, and MSY is the maximum sustainable yield reference point.

|  |  |
| --- | --- |
| **Reference Point** | **Estimate** |
| F20%SSB(F=0) (age 1-10) | 0.53 |
| FMSY (age 1-10) | 0.63 |
| F2020  (age 1-10) | 0.58 |
| F2019-2021 | 0.68 |
| SSBF=0 | 18,600 mt |
| 20%SSBF=0 | 3,720 mt |
| SSBMSY | 2,920 mt |
| SSB2021 | 1,696 mt |
| SSB2019-2021 | 1,359 mt |
| C20%SSB(F=0) | 14,814 mt |
| CMSY | 14,924 mt |
| C2019-2021 | 10,653 mt |
| SPR20%SSB(F=0) | 22% |
| SPRMSY | 19% |
| SPR2021 | 44% |
| SPR2019-2021 | 43% |

Table 11. Complete list of sensitivity runs conducted for the 2023 stock assessment of North Pacific swordfish.

|  |  |  |  |
| --- | --- | --- | --- |
| **RUN** | **NAME** | **DESCRIPTION** | |
| **Alternative Life History Parameters: Natural Mortality** | | | |
| 1 | base\_case\_highM | Alternative natural mortality rates are 10% lower than in the base case | |
| 2 | base\_case\_lowM | Alternative natural mortality rates are 10% higher than in the base case | |
| **Alternative Life History Parameters: Stock-Recruitment Steepness** | | | |
| 3 | base\_case\_h070 | Alternative lower steepness with h=0.70 | |
| 4 | base\_case\_h081 | Alternative lower steepness with h=0.81 | |
| 5 | base\_case\_h099 | Alternative higher steepness with h=0.99 | |
| **Alternative Life History Parameters: Growth Curves** | | | |
| 6 | base\_case\_large\_Amax | Alternative growth curve with a 10% larger maximum size for each sex. | |
| 7 | base\_case\_Sun\_Growth | Alternative growth curves using growth parameters from Sun et al. (2002) | |
| **Alternative Life History Parameters: Maturity Ogive** | | | |
| 8 | base\_case\_high\_L50 | Alternative maturity ogives with L50 set 10% higher than base case | |
| 9 | base\_case\_low\_L50 | Alternative maturity ogives with L50 set 10% lower than base case | |
| 10 | base\_case\_Wang2003 | Alternative maturity ogives with converted L50 from Wang et al. (2003) | |
| **Alternative catch assumption** | | | |
| 11 | Drop\_VNCN\_catch | Drop the Vanuatu and Chinese catch | |
| 12 | NP\_all\_catch | Use all catches in North Pacific Ocean | |
| 13 | Orphan catch | Use the catch of unclaimed area between 3 Pacific sword fish stocks | |
| **Alternative model setting assumption** | | | |
| 14 | Change Amin to 1.0 | Alternative setting of Amin | |
| 15 | Fit to S6 | Lambda of US Deep CPUE change to 0 | |
| 16 | Alternative selectivity of TW | Alternative selectivity of Taiwanese to double normal | |
| 17 | Add F9 of size data | Add the size data of US Deep LL | |
| 18a | S1 and S2 | Include only the S1 and S2 CPUE indices | |
| 18b | S3 and S4 | Include only the S3 and S4 CPUE indices | |
| 18c | S5 only |  | Include only on S5 CPUE index |
| 18d | S7 only |  | Include only the S7 CPUE index |
| 18e | S8 only |  | Include only the S8 CPUE index |
| 18f | S7 and S8 |  | Include only the S7 and S8 CPUE indices |
| 19 | All CPUE scenario | Use all CPUEs including the dropped CPUE | |

Table 12. Projected median values of North Pacific swordfish spawning stock biomass (SSB, mt) and catch (mt) in 2022-2031.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **2022** | **2023** | **2024** | **2025** | **2026** | **2027** | **2028** | **2029** | **2030** | **2031** |
| **Scenario 1: F20%SSB(F=0)** | | | | | | | | | | |
| SSB | 40,457 | 38,288 | 36,295 | 35,452 | 35,425 | 35,611 | 36,064 | 36,387 | 36,264 | 36,478 |
| Catch | 16,906 | 14,986 | 13,531 | 13,120 | 13,298 | 13,612 | 13,875 | 14,053 | 14,161 | 14,220 |
| **Scenario 2: F1998-2000** | | | | | | | | | | |
| SSB | 41,567 | 40,422 | 38,952 | 38,309 | 38,371 | 38,565 | 39,133 | 39,534 | 39,336 | 39,625 |
| Catch | 14,302 | 13,389 | 12,608 | 12,428 | 12,656 | 12,967 | 13,224 | 13,399 | 13,509 | 13,572 |
| **Scenario 3: Low F (FSPR30%)** | | | | | | | | | | |
| SSB | 42,268 | 42,368 | 41,811 | 41,756 | 42,235 | 42,712 | 43,610 | 44,300 | 44,162 | 44,705 |
| Catch | 11,370 | 11,249 | 11,096 | 11,255 | 11,623 | 11,990 | 12,263 | 12,445 | 12,557 | 12,631 |
| **Scenario 4: FMSY** | | | | | | | | | | |
| SSB | 38,291 | 34,051 | 31,164 | 29,979 | 29,800 | 29,894 | 30,225 | 30,452 | 30,322 | 30,473 |
| Catch | 23,395 | 17,817 | 14,992 | 14,169 | 14,264 | 14,565 | 14,812 | 14,966 | 15,052 | 15,095 |
| **Scenario 5: FStatus Quo (Average F2019-2021)** | | | | | | | | | | |
| SSB | 38,828 | 35,056 | 32,339 | 31,201 | 31,036 | 31,138 | 31,489 | 31,733 | 31,602 | 31,765 |
| Catch | 21,803 | 17,218 | 14,723 | 13,981 | 14,082 | 14,379 | 14,627 | 14,785 | 14,875 | 14,921 |

## Figures

|  |
| --- |
| Figure 1: Western and Central North Pacific Ocean and North Eastern Pacific Ocean swordfish stock boundaries for the 2023 North Pacific swordfish assessment. Spatial structure is treated implicitly using fleets as areas. |

|  |
| --- |
| Figure 2: Catch, CPUE index, and size composition data included in the 2023 NP swordfish stock assessment. The size of the bubble indicates the relative number of observations available. |

|  |
| --- |
| Figure 3: Total annual catch of the North Pacific swordfish by all fisheries harvesting the stock during 1975-2021. See Table 1 for the reference code for each fishery. |

|  |
| --- |
| Figure 4: Plot of CPUE index by fleet with a simple loess smoother fit to each time series. This provides information on the general trend of the indices considered for inclusion in the model and identifies potential conflict between indices. |

|  |
| --- |
|  |

|  |
| --- |
|  |

Figure 5: Length Composition data available in 5cm size bins for the 2023 North Pacific swordfish (Xiphias gladius) stock assessment.

|  |
| --- |
| Figure 6: Aggregated Size comp data (grey) and model fit (green) |

|  |
| --- |
| Figure 7: Time-varying selelctivity estimated for F01 Japanese LL Area 1 Late. |

|  |
| --- |
| Figure 8: Time-varying selectivity estimated for F02 Chinese Taipei LL late. |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| |  | | --- | | F03\_US\_WCNPO\_LL\_shallow\_late | |  | |  | | --- | | F04\_IATTC | |

|  |  |  |
| --- | --- | --- |
| |  | | --- | | F06\_JPN\_WCNPO\_OSDWLL\_early\_Area1 | | F07\_JPN\_WCNPO\_CODF |

|  |
| --- |
| F08\_US\_WCNPO\_LL\_shallow\_early |

Figure 9: Selectivity estimates for each of the five fleets without time-varying parameters.

|  |
| --- |
| Figure 10: Plot of RO versus total likelihood for 100 jitter runs for the base-case model (black points). The base-case model is indicated by the red point. |

|  |
| --- |
| Figure 11: Likelihood profile over R0 for the base-case model: total likelihood (black circles), recruitment (blue triangles), length composition data (light blue crosses), and survey/CPUE indices (yellow x). |

|  |
| --- |
| Figure 12: Likelihood profile over R0 by CPUE index for the base-case model. |

|  |
| --- |
| Figure 13: Likelihood profile over R0 for each length composition time series for the base-case model. |

|  |
| --- |
| Figure 14: Model fits to the standardized catch-per-unit-effort (CPUE) data sets from different fisheries for the base case scenario. The line is the model predicted value and the points are observed (data) values. The vertical lines represent the estimated confidence intervals (± 1.96 standard deviations) around the CPUE values. S5 and S8 were not included in the total likelihood. |

|  |
| --- |
| *Figure 15: Fits to the annual mean length length composition data. The blue line indicates the estimated mean length, open dots indicate input mean length with black bars indicating the distribution of the length data with the added* *variance.* |

Figure 15: Continued.

|  |  |
| --- | --- |
|  |  |
| *Figure 16:* *Quarterly residual plots the length composition data by fleet. Open circles indicate negative residuals and closed circles indicate positive residuals.* |  |

|  |  |
| --- | --- |
|  |  |

|  |
| --- |
|  |

Figure 16: Continued.

|  |
| --- |
| Figure 17: Aggregated Size comp data (grey) and model fit (green) |

|  |
| --- |
| Figure 18: Results from a runs test for each CPUE index. Red indicates the index failed the test (residuals are not random), green indicates the index passed the test. |

|  |
| --- |
| Figure 19: Results from a runs test for each size composition time series. Red indicates the time series failed the test (residuals are not random), green indicates the time series passed the test. |

|  |
| --- |
| Figure 20: Retrospective analysis of spawning biomass (left) and fishing mortality (right) for the whole time series (top) and the last 20 years (bottom) consisting of 5 reruns of the base case model each fitted with one more year of data removed from the base case model (blue line). |
| Figure 21: Hind casting cross-validation (HCxval) results for Japanese longline late area 1 (top right), Japanese LL late area 2 (top left), Chinese Taipei deep water longline late (center right), US Hawaii deep-set longline (center left) CPUE, and US Hawaii deep-set longline (bottom left) fits, showing observed (large points with dashed line), fitted (solid lines), and one-year-ahead forecast values (small terminal points) in the old growth 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 22: Hind casting cross-validation (HCxval) results for 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 old growth 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 23: Spawning stock biomass trend for the ASPM model run (dashed line, triangles) and the base-case model (solid line, circles). Grey shading indicates 95% confidence intervals for each model. |

|  |  |  |  |
| --- | --- | --- | --- |
| |  | | --- | | (a) | | |  | | --- | | (b) | |

|  |  |  |  |
| --- | --- | --- | --- |
| |  | | --- | | (c) | | |  | | --- | | (d) | |

Figure 24: Time series of estimates of (a) population biomass (age 1+), (b) spawning biomass, (c) instantaneous fishing mortality (average for age 1-10, year-1), and (d) recruitment (age-0 fish) for North Pacific swordfish (Xiphias gladius) derived from the 2023 stock assessment. The circles represents the maximum likelihood estimates by year for each quantity and the error bars represent the uncertainty of the estimates (95% confidence intervals), green dashed lines indicate the dynamic SSBMSY and FMSY reference points.

|  |
| --- |
| Figure 25: Kobe plot of the time series of estimates of relative fishing mortality (average of age 1-10) and relative spawning stock biomass of North Pacific swordish (Xiphias gladius) during 1977-2020. The first white dot indicates 1975, subsequent dots are in 5-year increments. Shading indicates 50%, 80%, and 95% confidence intervals, respectively. |
| |  |  |  | | --- | --- | --- | | a | *b* | | | *c* | d | | | *e* | | f | |  | | |      |  | | --- | |  |      |  | | --- | | g |      |  | | --- | | h |      |  | | --- | | i |      |  | | --- | | j |      |  | | --- | | k |      |  | | --- | | l |      |  | | --- | | m |      |  | | --- | | n |   Figure 26: Trajectories of spawning stock biomass (left) and fishing mortality (right) for the 24 sensitivity analyses listed in Table 14, compared to the base-case model: (a -b) Runs 1 and 2 use alternative natural mortality parameters; (c-d) Runs 3-5 use alternative steepness parameters; (e-f) Runs 6 and 7 use alternative growth parameters; (g-h) Runs 8-10 use alternative maturity ogives; (i-j) Runs 11-13 use alternative catch scenarios; (k-l) runs 14-17 use alternative model assumptions; and (m-n) Runs 18a-f and 19 use alternative CPUE configurations. |

|  |
| --- |
| Figure 27: Kobe plot showing the terminal-year stock status for the base case model (grey B) and the sensitivity analyses as indicated by the run numbers. For the list of sensitivity runs, please see Table 12. |
| Figure 28: Historical and projected trajectories of spawning biomass from the North Pacific swordfish base case model based upon F scenarios. Dashed line indicates the spawning stock biomass at SSBMSY. The list of projection scenarios can be found in Table S3. |

|  |
| --- |
| Figure 29: Historical and projected trajectories of catch from the North Pacific swordfish base case model based upon F scenarios. The list of projection scenarios can be found in Table S3. |