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

ISC Billfish Working Group

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## 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 88754.6 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 2018-2021. 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 yeild (MSY) refernce 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 14000 mt per year during 1975-1990, peaked with unusually high catches in 1998 -2000, and then generally declined to the current levels around 11000. 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 82800 mt during 1975-2021 and was estimated to be 88800 mt in 2021 ([Figure S3 (a)](#fig-summarybiomass-1)). Initial estimates of female spawning stock biomass (SSB) averaged around 27600 mt in the late 1970s. SSB was at its highest level of 35778.2 metric tons in 2021, and was at its minimum of 22415 mt in 1981. Overall, spawning stock biomass has been relatively stable for the entirety of the assessment period ([Figure S3 (b)](#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 838000 during 1975-2021. While the overall pattern of recruitment varied, there was no apparent trend in recruitment strength over time ([Figure S3 (d)](#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 35778 mt is 220% below SSBMSY (16000 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).

**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 14924 mt. The point estimate of the spawning biomass to produce MSY (adult female biomass) was 16388 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 SS3.30. No recruitment deviations nor log-bias adjustment were applied to the future projections. The absolute future recruitments were based on two recruitment scenarios: the expected stock-recruitment relationship. 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 SSB in the 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 11500 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.

**Table S3.** Projected median values of Western and Central North Pacific striped marlin spawning stock biomass (SSB, mt) and catch (mt) under five constant fishing mortality rate (F) and two recruitment scenarios during 2021-2040. For scenarios which have a 50% probability of reaching the target of 20%SSBF=0, the year in which this occurs is provided; NA indicates projections that did not meet this criterion.

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| 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. |

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

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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.

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| 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. |

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| 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. |