A Preliminary Base-case model in SS3.30 for the 2023 North Pacific Swordfish Assessment

Michelle L Sculley

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Michelle L. Sculley,\* Yi-Jay Chang,+ Hirotaka Ijima^

\*NOAA NMFS Pacific Islands Fisheries Science Center, Honolulu, HI

michelle.sculley@noaa.gov

+National Taiwan University, Taipei, Taiwan

^Fisheries Research Agency, Yokohama, Japan

# Abstract

A preliminary base-case model in Stock Synthesis 3.30 for North Pacific (NP) swordfish (*Xiphias gladius*) is described for consideration as the 2023 base-case model. The base-case model covers the Western and Central North Pacific north of the Equator and the Eastern Pacific Ocean north of 10°N from 1975 to 2021. It includes data from three International Scientific Committee for the Conservation of Tuna and Tuna-like Species (ISC) countries and other countries in aggregate from the Western and Central Pacific Fisheries Commission (WCPFC) and the Inter-American Tropical Tuna Commission (IATTC). This paper describes the data available for inclusion in the base-case model and the a proposed base-case model. The model converges and appears to fit the data well. Initial diagnostics do not indicate major problems. Preliminary results suggest the North Pacific swordfish stock is being not fished above FMSY and spawning stock biomass is above SSBMSY.

# Introduction

The International Scientific Committee for the Conservation of Tuna and Tuna-like Species (ISC) Billfish Working Group (BILLWG) has proposed to run a benchmark assessment on North Pacific swordfish (*Xenopus gladius),* SWO). Data were compiled from the International Scientific Committee for North Pacific Tuna and Tuna-like Species (ISC) member countries and other Western and Central Pacific Fisheries Commission (WCPFC) and Inter-American Tropical Tuna Commission (IATTC) countries. Countries were asked to contribute catch, CPUE, and size-frequency data. It was decided to run the assessment using a sex-specific model in Stock Synthesis version 3.30 (Methot and Wetzel, 2013) with fleets-as-areas spearating the Eastern Pacific Ocean (EPO) region from the Western and Central North Pacific (WCNPO) region, as defined in the December 2022 BILLWG meeting. The available data and the preliminary model results and diagnostics for a base-case model will be presented in this document for consideration at the ISC BILLWG SWO stock assessment meeting.

# Methods

## Spatial Temporal Structure

Data were compiled by region assuming a two region model of the North Pacific Ocean with boundaries based upon those detailed in Ichinokawa and Brodziak (2008) with the modification that the Eastern Pacific Ocean (EPO) region ends at the equator (Figure 1). Countries were asked to contribute catch, CPUE, and length frequency data partitioned by these two regions so that the North Pacific could be modeled with two implicit areas using fleets as areas. The working group agreed to start model in 1975.

## Definition of Fisheries

Data are available for thirty different fleets in the WCNPO: 18 catch time series, 12 CPUE indices of which one is a recruitment index, and two environmental indices. The fleet names and numbers are detailed in Table 1. The data available for each fleet is in Figure 2. The acronyms in the fleet names are defined as follows: WCNPO is Western and Central North Pacific Ocean; EPO is Eastern Pacific Ocean; OSDWLL is offshore distant water longline; OSDWCOLL is offshore distant water and coastal longline; early is the early time period; late is the late time period, Area1 and 2 are the Japanese fishery areas in the WCNPO as defined in Ijima 2018; OSDF is offshore driftnet gear; CODF is coastal driftnet gear, JPN\_WCNPO\_Other is Japanese small-scale coastal longline vessels which are not under obligation to submit logbook data, bait, and net fishing gear; DWLL is distant water longline gear, TWN\_WCNPO\_Other is Taiwanese offshore longline, coastal longline, gillnet, harpoon and other gears; LL is longline gear; shallow is the Hawaii shallow-set sector; deep is the Hawaii deep-set sector; GN is gillnet gear; US\_WCNPO\_Other is harpoon and other gears; Mex\_LL\_EPO is Mexican longline gear in the EPO; WCPFC\_LL is longline gear in the WCNPO; IATTC\_LL is longline gear in the EPO north of the equator; IATTC\_LL\_Overlap is longline gear in the overlap area of the IATTC convention area and the WCNPO areas.

## Catch

The 18 time series of catch for the WCNPO model were divided into early and late periods to coincide with divisions of the CPUE indices (Table 1, Figure 2). Three ISC countries contributed catch time series: Japan, Taiwan, and the US. In addition, catch from countries reporting to the WCPFC and IATTC were obtained from each RFMO, respectively. The CV for catch was set to 0.05 for all fleets. Catch for fleets with only annual data were divided equally into each quarter.

## Relative Abundance Indices

The ten CPUE indices available for inclusion in the WCNPO model are detailed in the input data working paper by Sculley and Yau (WP01) submitted to this meeting. The CPUE were assigned to a quarter based upon the recommendations of the country providing the index and are assumed to represent the quarter in which the highest catches take place for each fishery. Japanese longline fleets (S1-4) were all assigned to quarter 1; Taiwanese longline fleets (S5 and S6) were assigned to quarter 3; US longline deep-set (S7) was assigned to quarter 2, US longline shallow-set (S8 and S9) were assigned to quarter 2, and US gillnet (S10) was assigned to quarter 4. Of these, fleets S5 and S10 were excluded from the base-case model. In the base-case model, Taiwanese fleet S5 (longline early) was excluded from the likelihood estimation (but included in the model along with a selectivity) because of poor data quality (Chang, pers. comm.). US gillnet fleet S10 was similarly excluded from the likelihood estimation but included in the model along with a selectivity because the area covered was very small compared to the WCNPO region and it was suggested that it may not represent dynamics of the entire population. US longline deep-set fleet S7 was included as an index of recruitment because the fishery catches large numbers of young-of-the-year fish (Fleet type 33, Sculley et al. 2018). 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. The minimum CV was scaled to a minimum of 0.25 or the root-mean-square error (RMSE) (i.e., square root of the residual variance) of what we would expect the assessment model to fit the CPUE index best by adding a constant to each CV value. This was calculated as the square root of the residual variance of a loess smoother fit to each index (Francis 2011, Lee et al., 2014).

where *Y*t is the observed CPUE in year *t* on the log scale, is the predicted CPUE in year *t* from the smoother fit to the data on the log scale, and *N* is the number of CPUE observations. RMSE values for each index are listed in Table 2. If the input SE was greater than these values, it was left unchanged.

## Length Composition

Length composition data were available for seven WCNPO fleets; length composition data were detailed in the input data working paper (WP01) submitted for this meeting (Figure 2). Length composition data were available in quarterly time steps. Quarters with fewer than 15 total samples were removed from the time series due to limited sample size, as agreed upon by the modeling sub-group. In addition, the length composition data for F5 were excluded as they only represented two time periods and were sparse. Data were fit using a multinomial error structure. Length composition data were weighted using the 2-stage process based upon the Francis (2011) method. In the first stage, the effective sample size was scaled to a mean of 25 by multiplying each number of samples by a constant. The second stage weighting was attempted based upon the T.A1.8 equation (Francis 2011) as calculated by the model using r4ss, an R package for plotting SS results (R version 3.4.0, R Core Team, 2017, r4ss version 1.28.0, Taylor et al., 2017). However, because the model was sensitive to reweighting of the length composition data, input sample sizes were not iteratively re-weighted in stage 2.

## Initial Base-case Model Description

The assessment was conducted with Stock Synthesis (SS) version 3.30.08.03-SAFE released 09/29/2017 using Otter Research ADMB 11.6 (Methot and Wetzel 2013). The WCNPO model was set up as a single area model with two sexes and four seasons (quarters). Spawning was assumed to occur in May (month 5) 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 swordfish was set to 15 years. Sex specific biological parameters were used, with sex- and age-specific natural mortality (Table 3) as agreed upon in the BILLWG data preparatory meeting (ISC Billfish WG 2018). In addition, the CV of the growth curve was set to 0.1 for males and females, and the sex ratio at birth was assumed to be 1:1. The model used a Beverton-Holt spawner-recruit relationship with steepness (h) fixed at 0.9 and sigmaR (σr) fixed at 0.6.

Twenty-eight fleets were included in the model: 18 catch fleets and 8 survey fleets. The population was assumed to be in equilibrium prior to 1951, with an estimated equilibrium exploitation catch of 20 mt per quarter (80 mt annual total). This estimated catch was based upon a linear regression fit to the annual catch of the F1 data from 1952-1960 and extrapolated to 1951.

Main recruitment deviations were estimated from 1975-2016. The recruitment deviations were bias-adjusted based upon the estimates from Methot and Taylor (2011) provided from the model results. No bias adjustment was applied to recruitment deviations from 1952-1963. 1964-1982 was the “ramp-up” period where the bias adjustment of σr was 0 at the beginning of the period and increased linearly to the maximum bias adjustment 0.95 in 1982. Full bias adjustment was from 1983-2016. The early period of recruitment deviations represents a data-poor period where there is little information to drive recruitment. The main recruitment period represents a data-rich period where there is enough data to drive the bias-adjustment of the recruitments. The ramp up period allows for a gradual ramp up of the bias-adjustment between the data-poor and data-rich periods.

The population model and the fishery length data had 51 five cm length bins from 10-260+ cm. The population had 16 annual ages from age 0 to 15+. There were no age data. Fishery length data were used to estimate selectivity patterns which controlled the size distribution of the fishery removals. All fleets with length data were estimated as six parameter double normal (dome-shaped) selectivity patterns except for the IATTC Overlap length data which was estimated as a two parameter asymptotic logistic selectivity pattern. Survey selectivity patterns mirrored their respective catch fleets (Table 4). Including dome-shaped selectivity on fleets F1-2, F6, F10, and F12-14 resulted in better fits to the length frequency data. An asymptotic lognormal selectivity was used for IATTC Overlap, F18, because the fleet was comprised of multiple countries’ length composition data. Selectivity parameter priors were assumed to be diffuse lognormal for the asymptotic lognormal model and diffuse symmetric beta for the double normal model.

Model estimated time series of total biomass (B in metric tons, mt = 1000 kg), age 1+ total biomass (B1+ mt), female spawning biomass (SSB mt) and recruitment (R in 1000s of fish) were tabulated on an annual basis. Annual exploitation rate (F) was calculated as Catch/B1+. Stock status indicators were calculated based upon MSY-based reference points as proxies, given that the WCPFC has not set biological or other reference points for swordfish.

## Convergence Criteria and Diagnostics

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

Several diagnostics were run to evaluate the fit of the model to the data. An Age-Structure Population Model (APSM) was used to evaluate the influence of the length composition data on the population trends (Carvalho *et al.*, 2017). The ASPM was also used to explore how each CPUE index informed the population trends by running one-off ASPMs for each index. Profiling the likelihood on R0, where the R0 is fixed at a range ofvalues around the maximum likelihood estimate and then the likelihood is estimated, was used to identify influential data components (Lee *et al.,* 2014). A runs test was used to evaluate randomness in the residuals of the CPUE data (Carvalho *et al.,* 2021). Residual plots and plots of the observed vs expected data were examined to evaluate goodness-of-fit. Finally, a retrospective analysis and hindecast cross-validation were used to evaluate the predictive ability of the model (Carvalho *et al.,* 2021).

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