Annex 8

REPORT OF THE BILLFISH WORKING GROUP WORKSHOP

International Scientific Committee for Tuna and Tuna-like Species
In the North Pacific Ocean

11-19 February 2014
Honolulu, Hawaii, USA

1.0 INTRODUCTION

An intercessional workshop of the Billfish Working Group (BILLWG) of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) was convened in Honolulu, Hawaii, USA from 11-19 February 2014. The goals of this workshop were to: (1) conduct stock assessment update for the Western and Central North Pacific and Eastern North Pacific Swordfish stocks, and (2) review new information and research to be conducted for the stock assessment of Western and Central North Pacific striped marlin in 2015 and respond to the review of the 2013 stock assessment

Jon Brodziak, Chairman of the BILLWG, welcomed participants from Chinese Taipei, Japan, the Inter-American Tropical Tuna Commission (IATTC), and the United States of America (USA) (Attachment 1). The Chairman noted that no representatives were present from Canada, China, Korea, or Mexico.

2.0 ADOPTION OF AGENDA AND ASSIGNMENT OF RAPPORTEURS

The BILLWG chair Jon Brodziak noted the efforts of the working group (WG) at this meeting would follow the scientific method with particular emphasis placed on empirical testing, open debate, documentation and reproducibility, reporting uncertainty, and peer review.

The meeting agenda was adopted (Attachment 2). It was noted by the WG that data availability would be discussed under agenda item number 5.

Rapporteuring duties were assigned to Jon Brodziak, Yi-Jay Chang, Michael Hinton, Russell Ito, Minoru Kanaiwa, Ai Kimoto, Nan-Jay Su, Darryl Tagami, William Walsh, Annie Yau, and Kotaro Yokawa. The meeting agenda was adopted (Attachment 2).

3.0 COMPUTING FACILITIES

Computing facilities included a website for distribution of working papers and other meeting documents and information and also included internet access.

4.0 NUMBERING OF WORKING PAPERS AND DISTRIBUTION POTENTIAL

Working papers were distributed and numbered (Attachment 3). It was agreed that all of the working papers were to be posted on the ISC website where they will be available to the public, with the possible exception of ISC/14/BILLWG-1/06 which will require approval from the author's organization (Attachment 3).

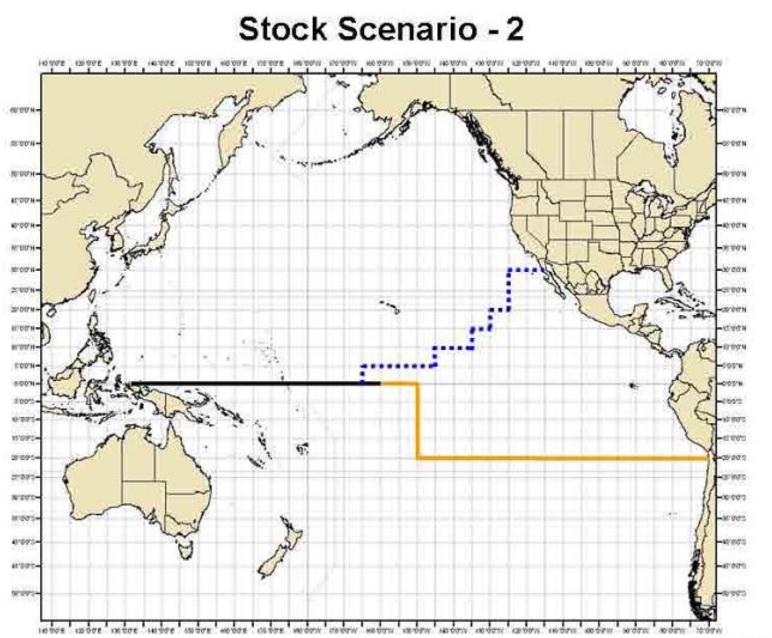
5.0 STATUS OF WORK ASSIGNMENTS

The assignments that stemmed from the May 2013 ISC BILLWG workshop were as follows:

- Collaboration on the North Pacific swordfish stock assessment was expected to be initiated between ISC Members and Collaborative Partners, except Canada, before the next intercessional meeting of the working group.

- Chinese Taipei, Japan, Korea, Mexico, and the USA will provide data updates for the next North Pacific swordfish stock assessment by stock area.

Figure 1. Western and Central North Pacific swordfish (northwest of Equator and dotted line) and Eastern Pacific swordfish (southeast of dotted line and 20º S Latitude to Equator) stock areas.



The ISC BILLWG Chair reported that the BILLWG completed all assignments.

The Chair also noted that additional important tasks were completed.
These were:

- The Fifth International Billfish Symposium was convened in Taipei during November 2013. The symposium was convened by the host ISC Vice-Chair Chi-Lu Sun and ISC Chair Gerard DiNardo. Attendees from the ISC Billfish Working Group included Jon Brodziak, Yi-Jay Chang, Minoru Kanaiwa, Ai Kimoto, Nan-Jay Su, William Walsh, Su-Zan Yeh, and Kotaro Yokawa. Overall, this was a successful symposium and papers from the meeting will be published in Fisheries Research.
- The Pacific blue marlin stock assessment and associated documentation was finalized and sent to the Center for Independent Experts for a technical review of the stock assessment conducted by the ISC Billfish Working Group.

6.0 ANNUAL BILLFISH CATCH AND EFFORT

Two working papers on the topic of annual billfish catch and effort were presented to the WG. The WG reviewed the working papers and discussed the presentations by Ito and Tagami.

6.1 U.S. swordfish fisheries in the North Pacific Ocean presented by Russell Ito (ISC/14/BILLWG-1/06)

This working paper presents catch, effort and catch-per-unit-effort information on U.S. fisheries for swordfish in the North Pacific Ocean. The major gear types employed by U.S. fisheries were harpoon, drift gill net, and longline. The oldest of the fisheries was the California harpoon fishery which dates back to the early 1900's. The California drift gillnet fishery began in early the 1980's and was the dominant fishery for swordfish throughout that decade. This fishery was succeeded by the Hawaii-based longline fishery in 1990 as the largest U.S. fishery for swordfish. The longline fishery is currently the largest fishery for swordfish in the North Pacific Ocean. Longline vessels in Hawaii also migrate to California. This report summarizes historical trends and recent developments for each of these fisheries.

Discussion

The WG noted that while the number of active vessels targeting swordfish in Hawaii has declined in the last 2 years, the number of hooks set remained stable. Also swordfish vessels can fish deep or shallow sets but must declare their intention prior to the start of the trip.

6.2 Spatial distribution of swordfish catches for longline fisheries in the Western Central North Pacific and Eastern Ocean presented by Darryl Tagami (ISC/14/BILLWG-1/03)

This working paper presents recent spatial distributions for swordfish (*Xiphias gladius*) caught in the western central North Pacific and eastern Pacific Ocean from 2007-2012. The data were provided by the WCPFC in the North Pacific and by the IATTC in the eastern Pacific for

longline catches. The purpose is to provide the ISC Billfish Working Group with catch and spatial distribution data for swordfish from WCPFC and IATTC member countries which are not available in the ISC or ISC Working Group's data holdings. This represents the first time this catch data has been made available to the ISC for stock assessment purposes.

Discussion

The WG reviewed the swordfish spatial distribution plots based on fishery data provided by WCPFC and IATTC.

The WG noted that the small catch of swordfish by Belize near Taiwan may be in error. It was also noted that aggregated catch data by 5-degree squares and country (Category II) from the WCPFC and IATTC are typically less accurate and less complete than their annual total catch by country. For this ISC swordfish stock assessment, catch data separated by stock area was provided directly from Japan, Taiwan, Korea, and USA; Category II data from RFMOs were not used. The WG noted that the largest catches of swordfish in the IATTC area were made by Spanish vessels south of the EPO stock boundary.

General Discussion

The U.S. reported that there was no significant change in the Hawaii longline fishery and no new information for swordfish, striped marlin, and Pacific blue marlin. It was reported that more juvenile striped marlin have been caught in the winter months in Hawaii, indicating that above-average recruitment may be occurring in the central North Pacific Ocean.

Taiwan reported that there was no significant change in the longline fishery and no new information for swordfish, striped marlin, Pacific blue marlin, and black marlin.

Japan reported that there was no significant change in the longline fishery and no new information for swordfish, striped marlin, Pacific blue marlin, and black marlin.

IATTC reported that there was no significant change in the longline fishery for their member countries and no new information for swordfish, striped marlin, Pacific blue marlin, and black marlin. It was noted that the IATTC is waiting for recreational catch data from Mexico.

Overall, the WG discussed the magnitude of changes in recent annual catches of billfishes in the North Pacific Ocean in recent years. Each ISC country present at the meeting indicated that the recent fisheries had been relatively stable. It was also noted that there may be some indication of above-average striped marlin recruitment in the Hawaii-based longline fleet catches in 2013 based on observed longline catches of age-0 fish.

7.0 WESTERN AND CENTRAL NORTH PACIFIC SWORDFISH AND EASTERN PACIFIC SWORDFISH STOCK ASSESSMENT DATA

Five working papers on the topic of swordfish stock assessment data inputs were presented to the WG. The WG reviewed the working papers and discussed the presentations by Walsh, Kimoto, and Su.

7.1 Catch rate standardization for swordfish *Xiphias gladius* in the shallow-set sector of the Hawaii-based pelagic longline fishery: 1995-2012 presented by William Walsh (ISC/14/BILLWG-1/05)

This working paper presents an analysis of swordfish *Xiphias gladius* catch rates in the shallow-set sector of the Hawaii-based pelagic longline fishery in 1995−2012 using catch and operational data collected by fishery observers. Swordfish is the target species in this sector, which underwent a closure between 2001 and 2004 due to excessive interactions with protected sea turtles. Because of this temporal gap, the analysis used data from 1995−2000 and 2005−2012. The swordfish catch per set was standardized with a generalized linear model (GLM) with a negative binomial error structure. The GLM included three significant factor variables (fishing year, fishing quarter, begin-set time in 4-h intervals) and four significant continuous (linear) variables (hooks per float, latitude, longitude, sea surface temperature). The fitted GLM reduced the null model AIC by 5.2% and the null deviance by 27.8%. Catch rates peaked in 2006 because effort in the sector ceased after the first quarter, which is usually the most productive season. Catch rates then decreased in 2008-2012, which may have reflected removal of biomass that had built up during the closure or effects of federally-mandated changes in hook and bait types. In either case, catch rates at the beginning and end of the time series were similar. Exact details regarding data preparation and the forward variable selection analysis of deviance table are presented. The annual mean standardized catches per set with associated uncertainty are provided in spreadsheet format. Residuals plots and the fitted GLM are provided in appendices.

Discussion

It was noted that CPUE standardization model for the Hawaii longline fishery was the same as used by Courtney et al. for the 2007 swordfish stock assessment, and that the GAM standardization analyses did not include interaction terms.

The CPUE standardization was based only on Hawaii Observer data from 1995-2012. It was noted that in the U.S. tuna targeted longline trips require 20% observer coverage (since 2001) but the swordfish targeted longline trips require 100% observer coverage (since 2004).

7.2 Updated catch amount of Swordfish (*Xiphias gladius*) by the Japanese coastal, offshore, and distant-water longline fishery in the Pacific presented by Ai Kimoto (ISC/14/BILLWG-1/04)

This document provides the re-estimated and corrected the catch amount of swordfish caught for the period between 1951 and 2012 by Japanese coastal, offshore, and distant-water longliners and other coastal gears for the two stock scenarios with a boundary between the Western-Central North Pacific Ocean (WCNPO) and the Eastern Pacific Ocean (EPO). The official catch table in the North Pacific was also provided. Due to the lack of catch weight data before 1970, they were obtained by multiplying the catch number by the average weight, which was calculated by catch number and weight information. The catch amount before 1970 was estimated using the average weight in the period between 1971 and 1975. The catch amount by training longline vessels in the period between 1973 and 1990 was also estimated using the average weight in each year. The calculation was made by quarter and area. The area was stratified into 4 areas: 3 areas in the North Pacific and 1 area in the EPO, which basically has been used to estimate National catch table in the North Pacific for BILLWG. In the WCNPO, a decreasing trend in the catch amount by offshore and distant-water longliners was observed since 2008, and it reached less than 3,000 tons in 2012. In the EPO, although the catch amount was decreased to below 1,500 tons in the mid-2000s, they were gradually increased to about 3,000 tons and larger than the catch in the WCNPO in the recent years. The catch in the recent years by coastal gears were decreased to about 1,500 tons mainly due to the Great East Japan Earthquake.

Discussion

It was noted that there was no change in the method to calculate mean weights, but there was a change in the area stratification for mean weights. Mean weights were calculated by 5-degree squares to improve accuracy. The WG requested a comparison of mean weights used previously and presently in order to see differences in results between the two methods. Japan has sampling data from 1971. There was no practical difference in the resulting catch weight estimates.

The WG also noted that since the great east Japan earthquake of 2011, some of the Kesennuma longliners temporarily switched from targeting sharks and swordfish to targeting tunas. This was because the processing infrastructure for sharks and swordfish were destroyed in 2011.
Japan corrected swordfish catches: It was also noted that the catch updates included a catch correction of about 1500 mt of swordfish from the EPO to the WCNPO stock.

7.3 Update of catch-per-unit effort distribution of swordfish (*Xiphias gladius*) by the Japanese offshore and distant-water longline fishery in the Pacific presented by Ai Kimoto (ISC/14/BILLWG-1/08)

This document provided several standardized CPUEs by Japanese offshore and distant-water longliners in the Western-Central North Pacific Ocean (WCNPO) since 1952 and the Eastern Pacific Ocean (EPO) since 1955. Based on the previous study in 2009 which applied log-transformed GLM to the aggregated data, the standardized CPUE was simply updated up to 2012. The CPUE in the WCNPO in the recent 5 years remained at the similar level as those in early 2000s, while substantial increase was observed in the EPO since 2005. The similar but smoother was obtained when negative binomial GLM was fitted to the operational data in the both areas. Though the trend was smoother, which usually indicates better reflection of the actual abundance trend, this method can only be applied since 1975 and the calculation periods need to be separated into two series (cut in 1993/1994) due to the limited information of gear configuration, or the limitation in computer resources. Furthermore, alternative standardized CPUE was also calculated by removing the areas 8 and 9 in the WCNPO where are close to the stock boundary. It is because the trend of nominal CPUEs in these areas in the WCNPO appeared not to be similar to those in other WCNPO areas but to those of EPO. This was supposed to suggest the temporal change of the position of stock boundary. The trends of standardized CPUEs by both GLMs were mostly similar, except for the most recent years (2008–2012) when the level of the CPUE without areas became lower than those with the whole WCNPO data. It would be questioned if the data in these areas close to the boundary represented the abundance index of the WCNPO stock. In this study, some alternative series showed similar trends compared to the simple update, while some discrepancies were also found between models or data. It should be well-discussed in the BILLWG how to treat these standardized CPUEs by considering the pros and cons on each CPUE.

Discussion

Japan reported that there may have been a targeting change in the longline fishery to blue shark, especially in the second quarter of the year (and extending into the third quarter) and in the south of Japan since around 2000. After the Great Earthquake of 2011, the longliners switched from blue sharks and swordfish to tunas and swordfish.

The WG noted that the CPUE standardization presented included a simple update from the previous study, as well as improved analyses using operational data. These analyses were conducted using the same area stratification for CPUE which included 9 sub-areas in the WCNPO and 7 sub-areas in the EPO. The WG requested information on residual patterns. This information was provided and the WG concluded that the model fit was acceptable.

The WG noted that there was a substantial increase in standardized Japanese longline CPUE in the EPO during 2007 to 2010. This was more than a 3-fold increase. The reasons for this increase should be investigated. The WG noted that there was an increase in Spanish nominal CPUE in the EPO during the same time period.

The WG requested an analysis of the possible breakpoints in Japanese CPUE in the EPO during 1994-2012 to account for possible changes in catchability. An analysis was provided which showed that, based on AIC differences for GLM standardizations, the years 2006-2007 appeared to have the lowest AIC and best fit as potential breakpoints.

7.4 Catch estimates of swordfish (*Xiphias gladius*) for the WCNPO and EPO stocks from the Taiwanese fisheries presented by Nan-Jay Su (ISC/14/BILLWG-1/09)

A two-stock scenario was proposed by Ichinokawa and Brodziak (2008), which assumed a western central North Pacific (WCNPO) and an eastern tropical Pacific (EPO) stocks in the North Pacific Ocean. This assumption was supported by genetic studies and the analyses of Japanese longline CPUE which showed a boundary in the southeast Pacific, and was considered to be the best hypothesis for swordfish stock assessment and management in the North Pacific Ocean. This study aimed to estimate swordfish catch from various Taiwanese fisheries for the WCNPO and EPO stocks using available information collected from these fisheries.

Discussion

The finalized Taiwan longline data separating the catch by Distant Water and Offshore fisheries and by WCNPO and EPO was received during the meeting. Highest catches for Offshore longline fishery occurred in the WCNPO, and highest catches for the Distant Water longline fishery was in the EPO. It was noted that Taiwan Offshore and Distant Water longline vessels must report their catch weekly; some vessels currently use VMS.

The primary difference between these finalized catch data and previous catch data sets in ISC 13 was the inclusion of swordfish catches by Taiwanese offshore longline vessels that landed their catch in foreign ports. The revision of swordfish catch by Taiwanese offshore longliners in the period between 2000 and 2002, which produced about 2000 tons of increase of the annual catches in these periods, was proposed. It was explained mainly due to the addition of catches taken by foreign based offshore longliners, and the revisions were conduct using data reported to WCPFC SC 1.

The WG requested that Taiwan provide more information about historical trend of the coverage of log-book data, spatiotemporal distribution pattern of log-book data and number of vessels operated by 5x5 degree squares and month, as well as the method to estimate total catch using these two information, to confirm the validity of proposed revisions of past catches. At the same time, the WG agreed to use this revised data as the input for the stock assessment as the best available data.

7.5 Standardized CPUE of swordfish (*Xiphias gladius*) for the Taiwanese distant-water tuna longline fishery, based on a two-stock scenario in the North Pacific Ocean presented by Nan-Jay Su (ISC/14/BILLWG-1/07)

CPUE (catch per unit effort) of swordfish caught in the Taiwanese distant-water tuna longline fishery was standardized using generalized linear models (GLMs), based on a two-stock scenario in the North Pacific Ocean (i.e., a WCNPO and an EPO stock), as suggested by Ichinokawa and Brodziak (2008). Year, quarter, fishing area, and the two-way interactions between quarter and fishing area were used as predictors in the standardization models for an entire period (1968-2012) and two separate periods of 1968-1999 and 2000-2012 due to changes in targeting species and fishing ground of this fishery. Information on hooks per basket (HPB, available since 1995) was statistically significant in the CPUE standardization models, and therefore was included in the models for 2000-2012. Results showed that, for both stocks, standardized CPUE of swordfish was generally stable during the early period 1968-1999, but increased dramatically after 2000. However, the standardized CPUE of swordfish for the WCNPO stock has stabilized since 2005, while those for the EPO stock showed an increasing trend from 2005 until present.

<u>Discussion</u>

It was noted that there was a substantial increase in swordfish catch in the Distant Water longline fishery in 1999-2000 compared to the 1995-1996 break point from the previous stock assessment. Taiwan reported that there was a change in fishing strategy from targeting albacore to bigeye tuna, as well the eastward expansion of the fishery into the EPO after 2000. The WG requested a comparison of HPB and species composition over time in the WCNPO and the EPO. The information regarding to HPB and catch composition has been presented during the meeting, and the WG agreed that there was a change in fishing strategy around 2000-2001.

It was noted that the CPUE standardization model includes a Quarter-Area interaction term. The WG also requested nominal CPUE patterns for each of the 6 sub-areas in the WCNP and each of the 4 sub-areas in the EPO. The nominal CPUE by area was presented and discussed by WG. The presenter recommended using the Taiwan CPUE with a breakpoint in 2000 instead of 1995 as was used in the previous assessment. The WG concurred with this recommendation and noted that there was a change in both species composition and the HPB data pattern in 2000.

It was suggested to use the Taiwan offshore longline fishery data in addition to the Distant Water longline data. The WG noted that there were limited data for such an analysis.

General Discussion

The WG noted that one of the most important data products from this meeting would be a time series of swordfish catch by stock area. This was achieved and country and fleet-specific catches were tabulated for 1952-2012 for the WCNPO stock and 2007-2012 for the EPO stock, noting that the EPO catch by country information is also available for addition to finalize this information (Appendix 1). The WG also noted that the same prior assumptions were used in the production modeling as were used in the previous swordfish stock assessments in 2009 and 2010 with the exception of minor changes to the inverse-gamma prior for catchability coefficients.

8.0 NORTH PACIFIC SWORDFISH STOCK ASSESSMENT MODELING

One working paper on updated assessment modeling for the EPO swordfish stock was presented to the WG. Another working paper on updated assessment modeling for the WCNPO swordfish stock was also presented to the WG. The WG reviewed the two working papers and discussed the presentations by Yau and Chang.

8.1 Stock assessment of swordfish (*Xiphias gladius*) in the Eastern Pacific Ocean, 2014 presented by Annie Yau ISC/14/BILLWG-1/01)

We present a framework for a stock assessment of swordfish (*Xiphias gladius*) in the Eastern Pacific Ocean using Bayesian surplus production models. Biomass production will be modeled using a 3-parameter production model that allows production to vary from a symmetric Schaefer curve. Input fishery data will include nominal landings of swordfish during 1951–2012, which have fluctuated but overall increased to over 8 thousand metric tons in 2012. Potential relative abundance indices for swordfish will consist of standardized CPUE for Japanese and Chinese-Taipei fisheries. Lognormal prior distributions for intrinsic growth rate and carrying capacity were assumed to be moderately precise with coefficients of variation set at 50%. Goodness-of-fit diagnostics for comparing the fits of alternative model configurations include the root-mean squared error of CPUE fits, standardized CPUE residuals, and model efficiencies. Sensitivity analyses and stock projections under different harvest scenarios will also be conducted.

Discussion

The significant increase in catch by Japan was noted. It was explained that this was a result of increased catch rates against a relatively constant fishing effort, as measured by hooks fished per year.

A difference between catch was seen in the comparison of reports from States and from RFMOs. The expectation would be for agreement, but differences were noted for Korea and Taiwan, with minor differences for Japan. There was a suggested breakpoint in the CPUE series in 2007 for the Japanese longline fishery. There was some speculation as to the cause of the CPUE increase, and an investigation of this observation was mentioned as a future research topic.

Minor changes in catch for Taiwan from that presented to the ISC Plenary were noted. It was noted that this assessment update includes Taiwanese offshore longline catches, which improves the accuracy of the catch data series.

The WG noted that this assessment included new catch data from Peru and Chile and that this improved the accuracy off catch removal estimates from the EPO.

8.2 Update of the stock assessment for Western Central North Pacific Ocean swordfish (*Xiphias gladius*) through 2012 presented by Yi-Jay Chang (ISC/14/BILLWG-1/02)

This document updates the stock assessment of the Western Central North Pacific Ocean swordfish stock conducted in 2009 by the Billfish Working Group of the International Scientific Committee for Tunas and Tuna-Like Species (ISC) (ISC, 2009). Because revised catch and standardized CPUE data for this update have not yet been finalized, we only present the currently available input data and prior distributions for model parameters.

Discussion

It was made clear the increase in Taiwanese catches was likely due to increased reporting of landings made outside Taiwan, offshore longline landings at foreign ports. Prior to 2000, these landings were poorly reported.

It was noted that there was no standardized catch rate for the Taiwanese offshore longline fishery, even though it (in comparison to the Distant Water Longline fishery) takes the majority of the catch. It was explained that there was insufficient reporting of detailed fishing data from the offshore longline fishery to obtain a standardized catch rate. The amount and quality of offshore longline fishery data has improved since 2007.

The WG also noted that the prior assumptions were identical to those of the previous assessment with the exception of catchability priors, which were more diffuse, and less informative. The WG proposed to run an alternative model without using Japanese longline CPUE data from areas 8 and 9 as a sensitivity analysis.

8.3 Model Selection and Model Sensitivity Analyses

The WG reviewed available catch and CPUE standardization information for updating the swordfish stock assessments. The WG also considered the issue of model configuration and evaluated whether changes were warranted to input prior parameters to produce adequate model diagnostics. The WG used a stepwise process of making changes to data or model assumptions in order to select a base case model configuration for both stocks.

A set of model sensitivity runs were also conducted for both stocks to gauge the influence of various data and prior parameter assumptions on model fits. Each sensitivity analysis addressed a specific question and model runs were used to identify the structure of the base case model (i.e., which CPUE series to include) for deriving stock status and conservation information. The requested model sensitivity runs and associated results reflected the WG's prioritization of the data and model configuration issues.

8.3.1 Model Selection for EPO swordfish

The initial base case model for EPO swordfish was set up to match the previous assessment model and had the following configuration:

- All updated catch
- CPUE:
  - Entire Japanese series (1955-2012)
  - Most recent Taiwanese series (2000-2012)
  - Equal annual CPUE error variances by series, i.e., relative CV = 1

In this context, the updated catch consisted of new catch information of

- Catch Biomass Time series 1951-2012
  - Updated catch, 1951-2006:
    - Data from previous assessment, 2010
    - Updated with most recent data from Japan, Taiwan, Peru
  - New catch, 2007-2012:
    - IATTC
    - WCPFC
    - ISC and other countries:
      - Japan, Taiwan, Korea, Mexico, Peru, Chile

For CPUE, the updated time series were taken from Kimoto et al. (ISC/14/BILLWG-1/08) and Sun et al. (ISC/14/BILLWG-1/08). The model structure and prior distribution configuration of the initial base case model was described in Yau et al. (ISC/14/BILLWG-1/08). The prior distributions for the initial base case model were the same as were used in the previous EPO swordfish stock assessment with the exception of the catchability priors which were less informative.

Table 1. Prior distributions for the EPO swordfish production model.

Parameter	Description	Assumed Distribution	Assumed Mean	Assumed CV
r	Intrinsic growth rate	Lognormal	0.5	50%
K	Carrying capacity	Lognormal	75,000 tonnes	50%
S	Production shape parameter	Gamma	1.0	71%
q_i	Catchability coefficient for fleet *i*	Inverse gamma	$1/q$ = 1.0	Variance = 1000
σ^2	Process error	Inverse gamma	0.025	16%
τ^2_i	Observation error for fleet *i*	Inverse gamma	0.223	50%
P_0	Proportion of initial biomass to carrying capactiy	Lognormal	0.90	10%

Based on results of the initial base case model run, there was concern that the production model shape parameter was imprecisely estimated or non-identifiable. A second initial run with two Taiwanese CPUE series (2000-2012 and 1968-1999) confirmed that the shape parameter was not well-determined which created substantial changes in estimates of biological reference points for harvest rate. Later, information was presented that indicated that this initial base case configuration produced MCMC samples that did not converge, e.g., were not representative samples from the posterior distribution. As a result, the WG considered changes to the initial base case model.

In particular, the WG concluded that the treatment of the Japanese longline CPUE series, which was increased markedly in the late-2000s, was causing some misfits of model parameters. This was because the CPUE was being treated as a single continuous abundance index. The WG noted that there were natural breakpoints in the Japanese CPUE in 1975 and 1994 where catch and effort data recording changed. The WG also suggested another breakpoint in 2007 based on the substantial 3-fold increase in CPUE following 2006. This led to the formulation of a second based case EPO model with 4 Japanese longline CPUE time periods and 3 additional catchability and observation error variance parameters. It was expected that this change in the number of parameters would provide more flexibility to fit CPUE trends as well as improve the approximation accuracy of the CPUE observation model. The second base case EPO model had the following configuration:

- All updated catch
- CPUE:
    - 4 Japanese time series
        - 1955-1974 (5 deg by 5 deg data)
        - 1975-1993 (operational data)
        - 1994-2006 (operational data)
        - 2007-2012 (operational data)
    - Most recent Taiwanese series (2000-2012)
    - Relative CV = 1

The second model converged and had reasonable model diagnostic patterns. As a result, the WG concluded that the second base case EPO model was an acceptable candidate model.

The WG noted, however, that there was no strong evidence that there was a change in the catchability of the Japanese longline fleets in the EPO around 2007. The choice of 2007 as a breakpoint was heuristic but not supported by obvious substantial changes in the hooks per basket, species composition of the catch, or other targeting information. As a result, the WG chose to investigate a third alternative model that did not include a breakpoint in Japanese CPUE in 2007. The third base case EPO model had the following configuration:

- All updated catch
- CPUE:
    - 3 Japanese time series
        - 1955-1974 (5 deg by 5 deg data)
        - 1975-1993 (operational data)
        - 1994-2012 (operational data)
    - Most recent Taiwanese series (2000-2012)
    - Relative CV = 1

This third model converged and had reasonable model diagnostic patterns. As a result, the WG concluded that the third base case EPO swordfish model was an acceptable candidate model and was preferable to the second model because it had similar explanatory power and fewer parameters.

The WG next addressed the issue of whether it might be appropriate to include the early 1968-1999 Taiwanese longline CPUE series in the third base case model. A priori, it was consistent to not include the early-period Taiwanese CPUE in the update because CPUE data prior to 1995 was not used in the 2009 assessment due to concerns about low sample size and limited information on swordfish trend. Nonetheless, the WG noted that the resulting model configuration with the early-period Taiwanese CPUE did not converge and produced model diagnostics that were not acceptable by the WG. As a result, the base case model selection was the third model.

8.3.2 Model Sensitivity Analyses for EPO swordfish

Following the WG agreement on the selection of the base case EPO swordfish model, the WG requested to see the effects of changing the assumed value of the input prior means for intrinsic growth rate (r), carrying capacity (K), initial proportion of carrying capacity (P[1]), and production model shape parameter (M). These are all key model parameters for the production model analyses. The WG requested that the base case model be run with the mean values for each of these priors changed by ±25% of their input value, i.e., 0.75*value and 1.25*value. These were considered to be useful high and low bounds for understanding which parameter was most important and more importantly, whether assessment results were robust to a 25% in an input prior.

The sensitivity analyses using high (+25%) and low (-25%) values of input prior means for the four parameters generally indicated that the model results were robust to changes in the prior assumptions (Table 2). Estimates of biomass and harvest rate trend and scale were also robust to the high and low alternative prior means (Figures 2 and 3). Overall, this suggested that the priors were not unduly influential for the base case EPO swordfish production model results.

Table 2. Effects of high (+25%) and low (-25%) changes in prior means on model parameters including maximum sustainable yield (MSY), exploitable biomass to produce MSY (BMSY), and harvest rate to produce MSY (HMSY).

	Base case		***High r***		***Low r***		***High K***		***Low K***	
Parameter	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
r	0.454	0.192	0.536	0.236	0.370	0.153	0.436	0.194	0.462	0.197
K	66.00	15.53	64.81	15.58	67.65	15.57	70.78	18.46	61.19	14.56
M	0.871	0.610	0.773	0.589	1.027	0.707	0.993	0.953	0.996	0.769
P1	0.878	0.089	0.879	0.089	0.877	0.090	0.880	0.089	0.881	0.089
BMSY	31.33	6.86	30.09	6.71	33.08	7.27	34.14	10.46	29.54	6.43
B1951	57.84	14.43	56.82	14.42	59.20	14.46	62.17	17.21	53.79	13.47
B1951status	1.85		1.89		1.79		1.82		1.82	
B2012	59.80	22.13	58.19	21.23	61.56	22.40	63.24	23.35	54.90	20.61
B2012status	1.91		1.93		1.86		1.85		1.86	
HMSY	0.178	0.064	0.193	0.070	0.160	0.055	0.170	0.060	0.191	0.068
H1951	2.04E-05	5.18E-06	2.07E-05	5.24E-06	1.98E-05	4.82E-06	1.91E-05	4.96E-06	2.19E-05	5.61E-06
H1951status	1.14E-04		1.08E-04		1.24E-04		1.12E-04		1.15E-04	
H2012	0.19	0.07	0.19	0.07	0.18	0.07	0.18	0.07	0.21	0.08
H2012status	1.06		1.00		1.14		1.05		1.08	
MSY	5.38	1.65	5.58	1.75	5.12	1.57	5.62	2.17	5.43	1.64

Table 2. Continued.

	High P[1]		Low P[1]		High M		Low M	
Parameter	Mean	SE	Mean	SE	Mean	SE	Mean	SE
r	0.451	0.195	0.434	0.188	0.414	0.186	0.482	0.207
K	62.65	15.15	70.27	16.46	65.38	17.05	68.19	15.78
M	1.107	0.861	0.759	0.493	1.281	1.181	0.697	0.413
P1	1.108	0.116	0.652	0.066	0.883	0.089	0.875	0.089
BMSY	30.79	7.01	32.72	7.23	32.76	9.40	31.41	6.88
B1951	69.26	17.68	45.76	11.37	57.61	15.89	59.54	14.59
B1951status	2.25		1.40		1.76		1.90	
B2012	55.92	20.48	63.56	23.28	57.85	21.43	62.24	22.68
B2012status	1.82		1.94		1.77		1.98	
HMSY	0.193	0.066	0.158	0.055	0.181	0.061	0.171	0.062
H1951	1.70E-05	4.37E-06	2.57E-05	6.34E-06	2.06E-05	5.41E-06	1.97E-05	4.80E-06
H1951status	8.81E-05		1.62E-04		1.14E-04		1.15E-04	
H2012	0.20	0.07	0.18	0.06	0.19	0.07	0.18	0.07
H2012status	1.04		1.12		1.08		1.05	
MSY	5.74	1.71	4.99	1.47	5.70	1.88	5.18	1.60

Figure 2. Sensitivity of estimates of exploitable biomass to changes in prior means for EPO swordfish.

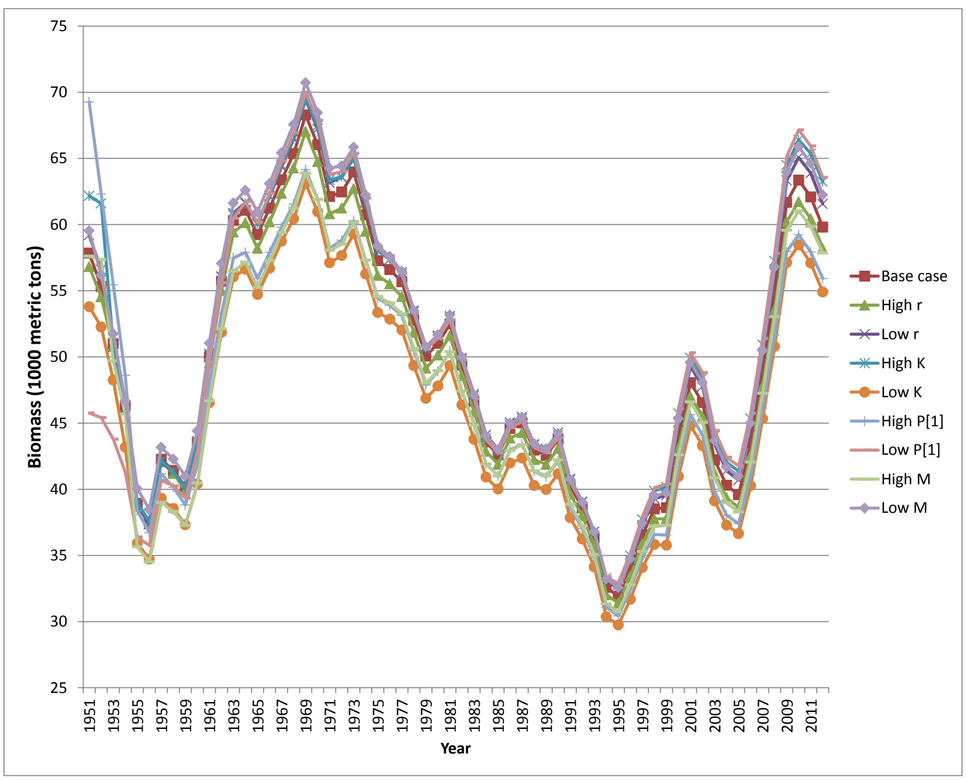
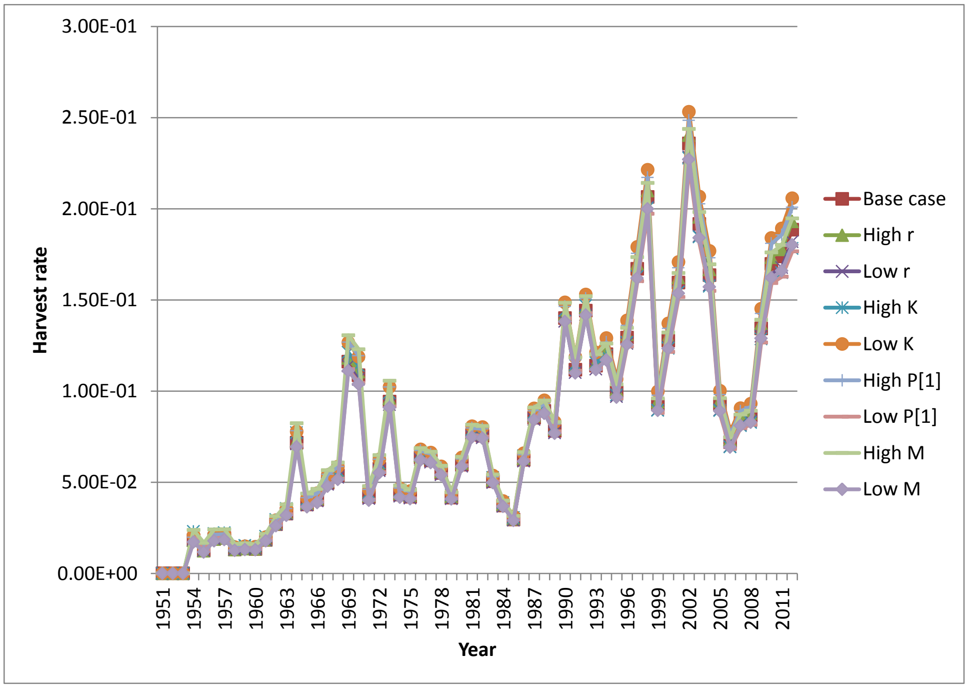


Figure 3. Sensitivity of estimates of harvest rate to changes in prior means for EPO swordfish.



8.4.1 Model Selection for WCNPO swordfish

The initial base case model for WCNPO swordfish was similar to the previous assessment model and had the following configuration:

- All updated catch
- CPUE:
    - Entire Japanese series (1952-2012)
    - Both Taiwanese series (1969-1999 and 2000-2012)
    - Both Hawaii series (1995-2000 and 2004-2012)
    - Relative CPUE error variances for each series

In this context, the updated catch consisted of new catch information of

- Catch Biomass Time series 1951-2012
    - Updated catch, 1951-2006:
        - Data from previous assessment, 2009
        - Updated with most recent data from Japan and Taiwan
    - New catch, 2007-2012:
        - ISC Countries
        - IATTC
        - WCPFC

For CPUE, the updated time series were taken from Kimoto et al. (ISC/14/BILLWG-1/08), Sun et al. (ISC/14/BILLWG-1/07), and Walsh et al. (ISC/14/BILLWG-1/08). The model structure and prior distribution configuration of the initial base case model was described in Chang et al.

(ISC/14/BILLWG-1/05). The prior distributions for the initial base case model were the same as were used in the previous WCNPO swordfish stock assessment (Table 3), with the exception of catchability priors.

The initial base case candidate model using observed relative CVs for CPUE error variances did not produce a reasonable fit to the early-period Taiwanese time series. An alternative model configuration that used equal error variance for each CPUE series produced a better fit to the observed CPUE and was consistent with the previous assessment. As a result, the WG chose to go forward with a second base case candidate model that included the assumption of equal variance through time for each CPUE series and that excluded the early-period Taiwanese CPUE. The second base case model for WCNPO swordfish was similar to the previous assessment model and had the following configuration:

- All updated catch
- CPUE:
    - Entire Japanese series (1952-2012)
    - Most recent Taiwanese series (2000-2012)
    - Both Hawaii series (1995-2000 and 2005-2012)
    - Relative CV=1

The WG requested an alternative model run that used the Japanese longline CPUE without the inclusion of catch-effort data from areas 8 and 9, along the border of the WCNPO and EPO swordfish stocks. These areas appeared to have different CPUE trends than adjacent areas in the WCNPO stock region (see Kimoto et al. ISC/14/BILLWG-1/08). The model fit with the alternative CPUE without area 8 and 9 produced a poorer fit to the Taiwanese and Hawaii CPUE. The WG agreed that this was a useful sensitivity analysis and that the exclusion of the area 8 and 9 data was not warranted.

The WG also requested an alternative model run that used a CV of 50% for the lognormal prior distribution of the proportion of initial carrying capacity. In this context, it was thought that allowing for a more diffuse prior might provide more flexibility for the model to fit the initial stock biomass trends. It was noted, however, that there was minimal fishing on swordfish during the World War II period. As a result, one could expect the initial mean assumption of 90% of carrying capacity with a CV of 10% to be likely an accurate reflection of an unfished resource status, although there was no information presented about this assumption. Regardless, the WG observed that the higher CV=50% did not produce an overall improvement to model fit to the CPUE and that the deviance information criterion value for the base case with a CV of 10% was 2.7 units lower than the CV of 50% indicating a lower likelihood for the model with CV=50%. The RMSE values CPUE series were also smaller for the base case model indicating a better fit to the CPUE data. Based on this information, the WG agreed to use the base case model with a CV=10%, which it noted, was consistent with the previous stock assessment.

Table 3. Prior distributions for the WCNPO swordfish production model.

Parameter	Description	Prior
r	Intrinsic growth rate (yr^{-1})	$r \sim \log N\left(\log(0.5), \sigma_r^2\right);\ CV_r = 0.5$
K	Carrying capacity (1000 mt)	$K \sim \log N\left(\log(150), \sigma_K^2\right);\ CV_K = 0.5$
M	Shape parameters	$M \sim Gamma(2,2)$
q	Catchability coefficient	$1/q \sim Gamma(0.01, 0.01)$
τ_i^2	Observation error variance	$1/\tau^2 \sim Gamma(2, 0.45)$
P_1	Initial condition	$P_1 \sim \log N\left(\log(0.9), \sigma_{P_1}^2\right);\ CV_{P_1} = 0.1$
σ^2	Process error variance	$1/\sigma^2 \sim Gamma(4, 0.1)$

8.4.2 Model Sensitivity Analyses for WCNPO swordfish

The WG made a request to measure the effects of changing the assumed value of the input prior means for intrinsic growth rate (r), carrying capacity (K), initial proportion of carrying capacity (P[1]), and production model shape parameter (M) for WCNPO swordfish. Similar to the base case EPO swordfish model, the WG requested that the base case WCNPO model be run with the mean values for each of these priors changed by ±25% of their input value, e.g., 0.75*value and 1.25*value. Running the model with these high and low bounds would help identify which parameter was most important, and more importantly, whether assessment results were robust to a 25% in an input prior.

The sensitivity analyses for the input prior means of the four parameters showed that the model results were robust to changes in the prior assumptions (Table 4). Estimates of biomass and harvest rate trend and scale were also insensitive to the high and low alternative prior means (Figures 4 and 5). Overall, this indicated that prior assumptions were not driving the results of the base case WCNPO swordfish production model.

Table 4. Effects of high (+25%) and low (-25%) changes in prior means on model parameters including maximum sustainable yield (MSY), exploitable biomass to produce MSY (BMSY), and harvest rate to produce MSY (HMSY).

Parameter	High K		Low K		High r		Low r	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
r	0.57	0.21	0.59	0.22	0.66	0.26	0.49	0.18
K	128.01	25.74	116.55	23.09	121.30	24.71	127.08	25.62
M	0.97	0.46	1.01	0.46	0.87	0.42	1.13	0.50
MSY	14.93	1.86	14.89	1.75	15.13	1.86	14.67	1.77
BMSY	62.71	12.24	57.64	11.14	58.26	11.37	64.16	12.73
HMSY	0.25	0.06	0.27	0.06	0.27	0.06	0.24	0.05
DIC	-185.92		-184.47		-185.13		-185.95	
RMSE_JP	0.033		0.034		0.033		0.033	
RMSE_TW2	0.038		0.038		0.038		0.038	
RMSE_H	2.277		2.269		2.268		2.274	
RMSE_JP	0.802		0.795		0.799		0.802	
RMSE_TW2	0.179		0.181		0.183		0.180	
correlation_CPUE_H	0.407		0.414		0.415		0.410	

Parameter	High P1		Low P1		High M		Low M	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
r	0.58	0.22	0.56	0.21	0.55	0.21	0.62	0.23
K	113.54	23.74	129.02	26.34	122.22	24.73	125.00	25.07
M	1.15	0.57	0.94	0.45	1.07	0.51	0.87	0.38
MSY	15.32	1.89	14.53	1.61	14.91	1.79	14.91	1.80
BMSY	57.34	11.51	62.88	12.41	60.97	12.07	60.12	11.72
HMSY	0.28	0.06	0.24	0.05	0.25	0.06	0.26	0.06
DIC	-181.32		-189.43		-185.24		-185.72	
RMSE_JP	0.035		0.032		0.033		0.033	
RMSE_TW2	0.038		0.038		0.038		0.038	
RMSE_H	2.263		2.280		2.270		2.273	
RMSE_JP	0.779		0.819		0.798		0.802	
RMSE_TW2	0.188		0.177		0.183		0.183	
correlation_CPUE_H	0.421		0.403		0.414		0.410	

Figure 4. Sensitivity of estimates of exploitable biomass to changes in prior means for WCNPO swordfish.

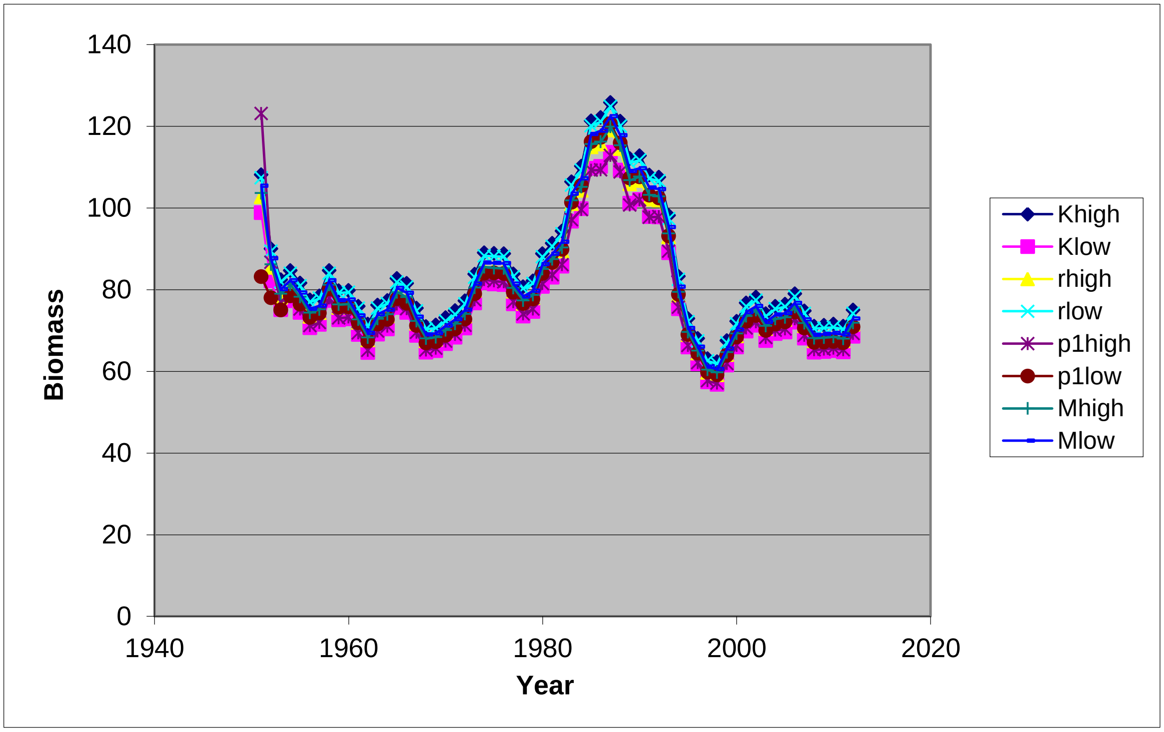
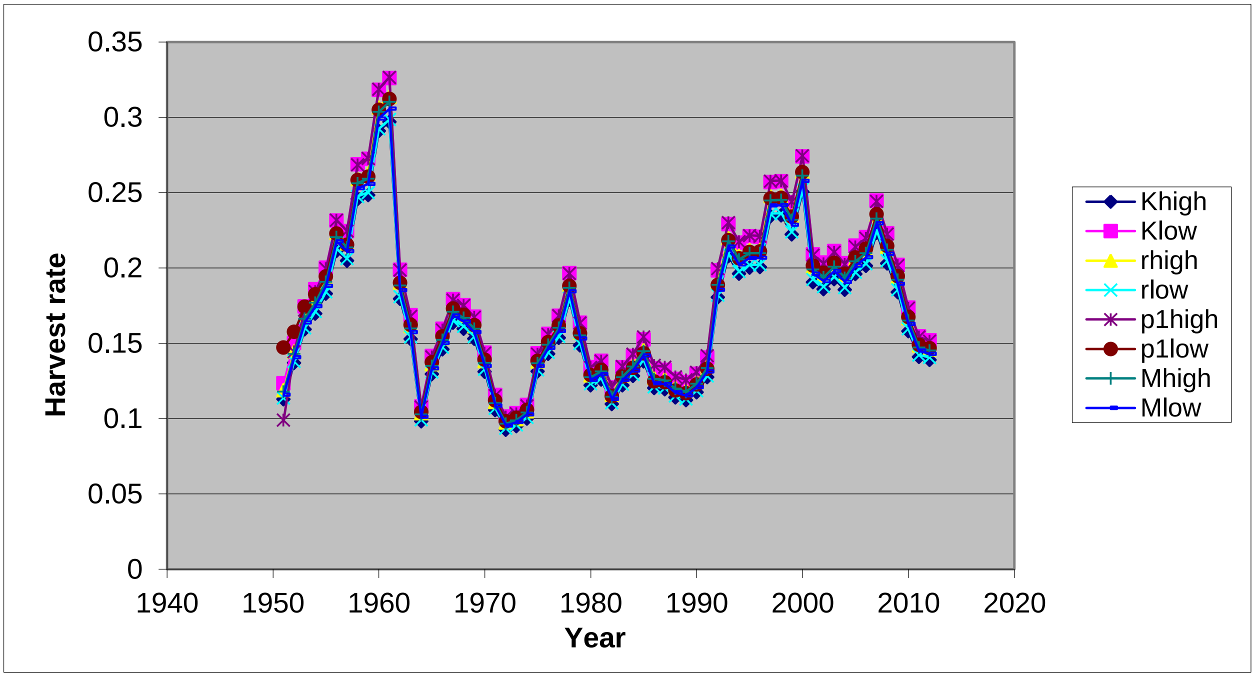


Figure 5. Sensitivity of estimates of harvest rate to changes in prior means for WCNPO swordfish.



9. Adoption of Assessment Updates for WCNPO and EPO Swordfish

After reviewing all requested runs for each model (see section 8), the WG agreed to adopt the updated base-case stock assessment results by the Bayesian surplus production models. This base case model is described in ISC/14/BILLWG-1/02 and /BILLWG-1/01 for the WCNPO and EPO, respectively, with some modifications to the input data described here. Relative abundance indices consist of CPUE series, and both the WCNPO and EPO model use a single Taiwanese CPUE series for more recent years from 2000-2012. The WCNPO model assumes the entire Japanese CPUE series is a single series from 1952-2012, while the EPO model uses three separate Japanese CPUE series: 1) 1955-1974 CPUE calculated using catch and effort data aggregated into 5° by 5° grids, 2) 1975-1993 CPUE calculated using operational data, and 3) 1994-2012 CPUE calculated using operational data. The relative coefficients of variation for all CPUE series were assumed to be 1 which is consistent with assumptions from the previous assessment for both stocks. The models both use updated catch data from 1951 to 2012, available life history information which is assumed to be the same as the accepted life history information used in the previous assessment, and CPUE series for fisheries by Japan and Taiwan, with the WCNPO using an additional CPUE series from the Hawaiian longline fishery (Table 5). The specific configuration of the base case models are described in detail below.

a. Input Data: Catch and CPUE Time Series

The total catch biomass data for swordfish in the WCNPO and the EPO were gathered from all available sources which included Japan, Taiwan, Korea, Chile, the Western and Central Pacific Fisheries Commission, and the Inter-American Tropical Tuna Commission for the period between 1951 and 2012 (Table 5 and Figure 6). The catch data in the WCNPO showed a decreasing trend in catches in the recent years, while substantial increases were observed in the most recent years in the EPO. The standardized CPUE (catch per 1000 hooks) by country were also provided by national scientists from Taiwan, Japan, and USA and summarized (Table 5 and Figure 7). Life history information was assumed to be the same as the information used in the previous assessment.

Figure 6. Catch biomass (1000 mt) used in the final model settings for the WCNPO (left panel) and the EPO (right panel) swordfish stocks.

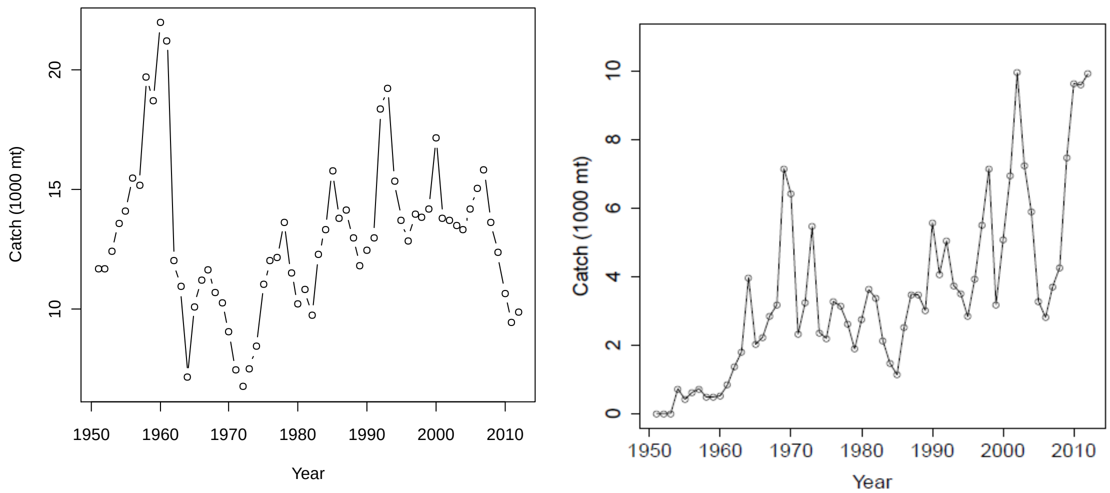


Figure 7. Standardized CPUE (catch per 1000 hooks) used in the final model settings for the WCNPO (left panel) and the EPO (right panel) stocks.

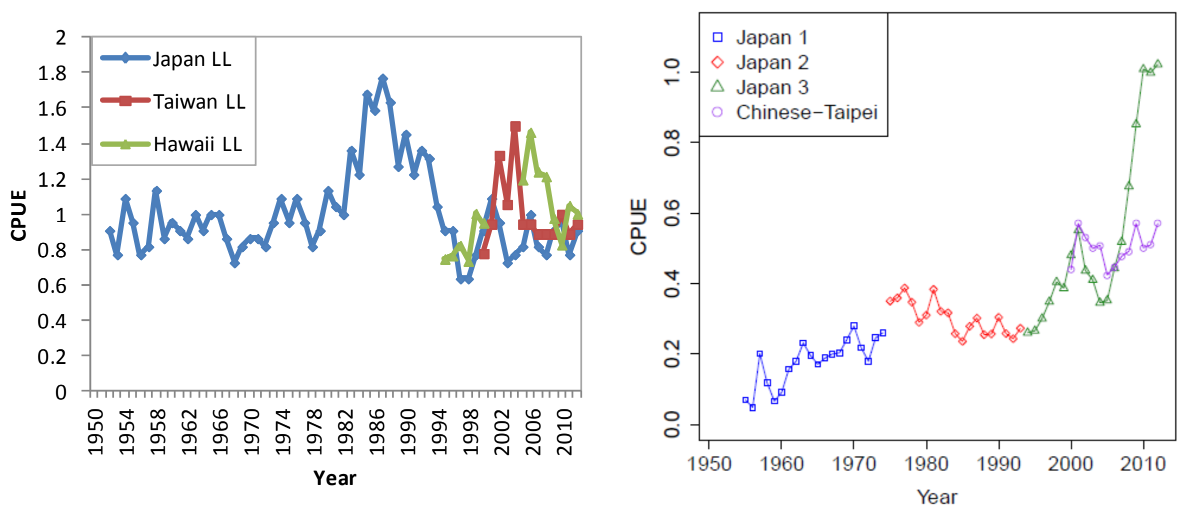


Table 5. Catch biomass (1000 mt) and standardized CPUE used in the final model settings for the WCNPO (left) and the EPO (right) swordfish stocks.

WCNPO				
		CPUE		
		Japan	Taiwan	USA
Year	Total Catch (1000 mt)	Distant-water and Offshore Longline	Distant-water Longline	HW Longline
1951	11.68			
1952	11.69	0.20		
1953	12.41	0.17		
1954	13.59	0.24		
1955	14.10	0.21		
1956	15.48	0.17		
1957	15.19	0.18		
1958	19.72	0.25		
1959	18.73	0.19		
1960	21.97	0.21		
1961	21.22	0.20		
1962	12.01	0.19		
1963	10.93	0.22		
1964	7.15	0.20		
1965	10.11	0.22		
1966	11.23	0.22		
1967	11.65	0.19		
1968	10.68	0.16		
1969	10.28	0.18		
1970	9.04	0.19		
1971	7.44	0.19		
1972	6.75	0.18		
1973	7.52	0.21		
1974	8.43	0.24		
1975	11.04	0.21		
1976	12.01	0.24		
1977	12.16	0.21		
1978	13.63	0.18		
1979	11.51	0.20		
1980	10.22	0.25		
1981	10.84	0.23		
1982	9.76	0.22		
1983	12.28	0.30		
1984	13.34	0.27		
1985	15.76	0.37		
1986	13.79	0.35		
1987	14.12	0.39		
1988	12.98	0.36		
1989	11.83	0.28		
1990	12.48	0.32		
1991	12.99	0.27		
1992	18.35	0.30		
1993	19.23	0.29		
1994	15.35	0.23		
1995	13.73	0.20		8.33
1996	12.86	0.20		8.54
1997	13.95	0.14		9.18
1998	13.82	0.14		8.2
1999	14.19	0.17		11.2
2000	17.14	0.20	0.14	10.61
2001	13.79	0.24	0.17	
2002	13.72	0.21	0.24	
2003	13.48	0.16	0.19	
2004	13.32	0.17	0.27	
2005	14.17	0.18	0.17	13.33
2006	15.05	0.22	0.17	16.32
2007	15.80	0.18	0.16	13.83
2008	13.63	0.17	0.16	13.53
2009	12.37	0.20	0.16	10.9
2010	10.67	0.21	0.18	9.23
2011	9.46	0.17	0.16	11.7
2012	9.86	0.20	0.17	11.18

EPO					
		CPUE			
		Japan			Taiwan
Year	Total Catch (1000 mt)	Distant-water and Offshore Longline1	Distant-water and Offshore Longline2	Distant-water and Offshore Longline3	Distant-water Longline
1951	0.00				
1952	0.00	0.20			
1953	0.00	0.17			
1954	0.72	0.24			
1955	0.41	0.21			
1956	0.61	0.17			
1957	0.72	0.18			
1958	0.48	0.25			
1959	0.48	0.19			
1960	0.52	0.21			
1961	0.83	0.20			
1962	1.36	0.19			
1963	1.79	0.22			
1964	3.97	0.20			
1965	2.02	0.22			
1966	2.23	0.22			
1967	2.84	0.19			
1968	3.16	0.16			
1969	7.15	0.18			
1970	6.41	0.19			
1971	2.32	0.19			
1972	3.23	0.18			
1973	5.46	0.21			
1974	2.37	0.24			
1975	2.19		0.21		
1976	3.27		0.24		
1977	3.13		0.21		
1978	2.63		0.18		
1979	1.88		0.20		
1980	2.76		0.25		
1981	3.62		0.23		
1982	3.36		0.22		
1983	2.12		0.30		
1984	1.46		0.27		
1985	1.13		0.37		
1986	2.51		0.35		
1987	3.48		0.39		
1988	3.46		0.36		
1989	3.01		0.28		
1990	5.57		0.32		
1991	4.07		0.27		
1992	5.03		0.30		
1993	3.73		0.29		
1994	3.50			0.23	
1995	2.83			0.20	
1996	3.94			0.20	
1997	5.50			0.14	
1998	7.14			0.14	
1999	3.18			0.17	
2000	5.08			0.20	0.14
2001	6.94			0.24	0.17
2002	9.94			0.21	0.24
2003	7.24			0.16	0.19
2004	5.87			0.17	0.27
2005	3.27			0.18	0.17
2006	2.80			0.22	0.17
2007	3.70			0.18	0.16
2008	4.26			0.17	0.16
2009	7.47			0.20	0.16
2010	9.63			0.21	0.18
2011	9.59			0.17	0.16
2012	9.91			0.20	0.17

b. Model Setup and Runs

A comparison of the prior parameters for both the WCNPO and EPO base case models is provided in Table 6. These priors are the same as those used in the previous assessment, with the exception of the catchability coefficients whose previous shape and scale values were assumed to be 0.001 instead of 0.01. The EPO and WCNPO models differ only in their assumed prior mean value for carrying capacity, K, which is assumed to be 150,000 mt in the WCNPO and 75,000 mt in the EPO. The WCNPO model was run for 800,000 iterations, sampled with a thinning rate of 25 with a burn-in period of 200,000 for three chains for a total of 72,000 samples. The EPO model was run for 130,000 iterations, sampled with a thinning rate of 5 with a burn-in period of 10,000 for three chains for a total of 72,000 samples.

Table 6. Comparison of prior parameter distributions for Bayesian state-space models for the WCNPO and EPO swordfish stocks.

Parameter	**Description**	**WCNPO stock**	**EPO stock**
r	Intrinsic growth rate (yr^{-1})	$r \sim \log N\left(\log(0.5), \sigma_r^2\right);\ CV_r = 0.5$	$r \sim \log N\left(\log(0.5), \sigma_r^2\right);\ CV_r = 0.5$
K	Carrying capacity (1000 mt)	$K \sim \log N\left(\log(150), \sigma_K^2\right);\ CV_K = 0.5$	$K \sim \log N\left(\log(75), \sigma_K^2\right);\ CV_K = 0.5$
M	Shape parameters	$M \sim Gamma(2,2)$	$M \sim Gamma(2,2)$
q	Catchability coefficient	$1/q \sim Gamma(0.01,0.01)$	$1/q \sim Gamma(0.01,0.01)$
τ_i^2	Observation error variance	$1/\tau^2 \sim Gamma(2,0.45)$	$1/\tau^2 \sim Gamma(2,0.45)$
P_1	Initial condition	$P_1 \sim \log N\left(\log(0.9), \sigma_{P_1}^2\right);\ CV_{P_1} = 0.1$	$P_1 \sim \log N\left(\log(0.9), \sigma_{P_1}^2\right);\ CV_{P_1} = 0.1$
σ^2	Process error variance	$1/\sigma^2 \sim Gamma(4,0.1)$	$1/\sigma^2 \sim Gamma(4,0.1)$

$CV_\theta = \left(\exp\left(\sigma_\theta^2\right) - 1\right)^{1/2}$

c. Model Diagnostics

Convergence of each model was tested by applying the Gelman & Rubin, Geweke, and Heidelberger & Welch convergence tests to the major model parameters of r, K, M, P1, catchability coefficients (q), process error variance, and observation error variance. Both base case models for the WCNPO and the EPO converged.

The fits of the base case model to standardized relative abundance indices by fishery (CPUE) were reviewed and evaluated by the WG. In general, both the WCNPO model and EPO model fit their respective CPUE series well, as illustrated visually by the plots of standardized log residuals in Figure 8 and Figure 9. Standardized log residuals for both models generally passed tests for skewness, kurtosis, and normality (using a Shapiro-Wilks test), with a few minor exceptions.

Additional model diagnostics consisted of calculating DIC values, root-mean-squared error (RMSE) of CPUE fits, and correlation (ρ) between CPUEs (Table 7). RMSEs were generally low for CPUE fits for both models, and many CPUE series were highly positively correlated.

Table 7. Summary of model diagnostics for a Bayesian state-space model for the WCNPO and EPO swordfish stocks.

Parameter	WCNPO stock	Parameter	EPO stock
	Mean		Mean
DIC	-185.49	DIC	-112.84
RMSE_JP (1952-2012)	0.03	RMSE_JP (1952-1974)	0.05
RMSE_TW (2000-2012)	0.04	RMSE_JP (1975-1993)	0.05
RMSE_HW (1995-2012)	2.27	RMSE_JP (1994-2012)	0.17
ρ_CPUE_JP (1952-2012)	0.80	RMSE_TW (2000-2012)	0.11
ρ_CPUE_TW (2000-2012)	0.18	ρ_CPUE_JP (1952-1974)	0.61
ρ_CPUE_HW (1995-2012)	0.41	ρ_CPUE_JP (1975-1993)	0.58
		ρ_CPUE_JP (1994-2012)	0.80
		ρ_CPUE_TW (2000-2012)	0.43

Figure 8. Bayesian surplus production base case model fits (solid red line) to standardized CPUE (blue circles and line) for swordfish in the WCNPO (left panels) and standardized log residuals (right panels), for the Japanese distant-water and offshore longline fisheries from 1952-2012 (JP DW&OD LL, top panels), the Taiwanese distant-water longline fishery from 2000-2012 (TW DW LL, middle panels), and the Hawaii longline fishery from 1995-2000, and 2005-2012 (HW LL, bottom panels).

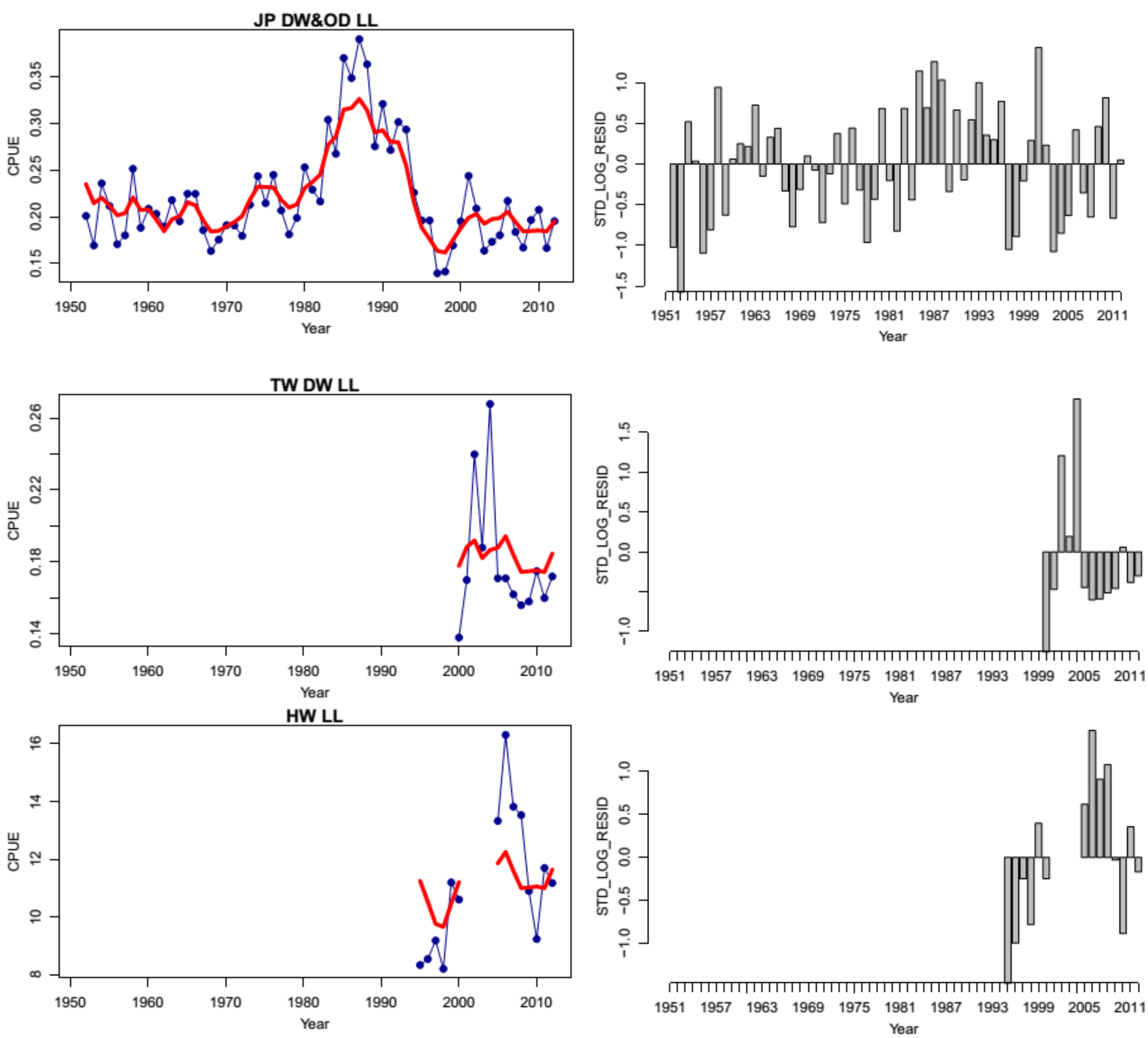
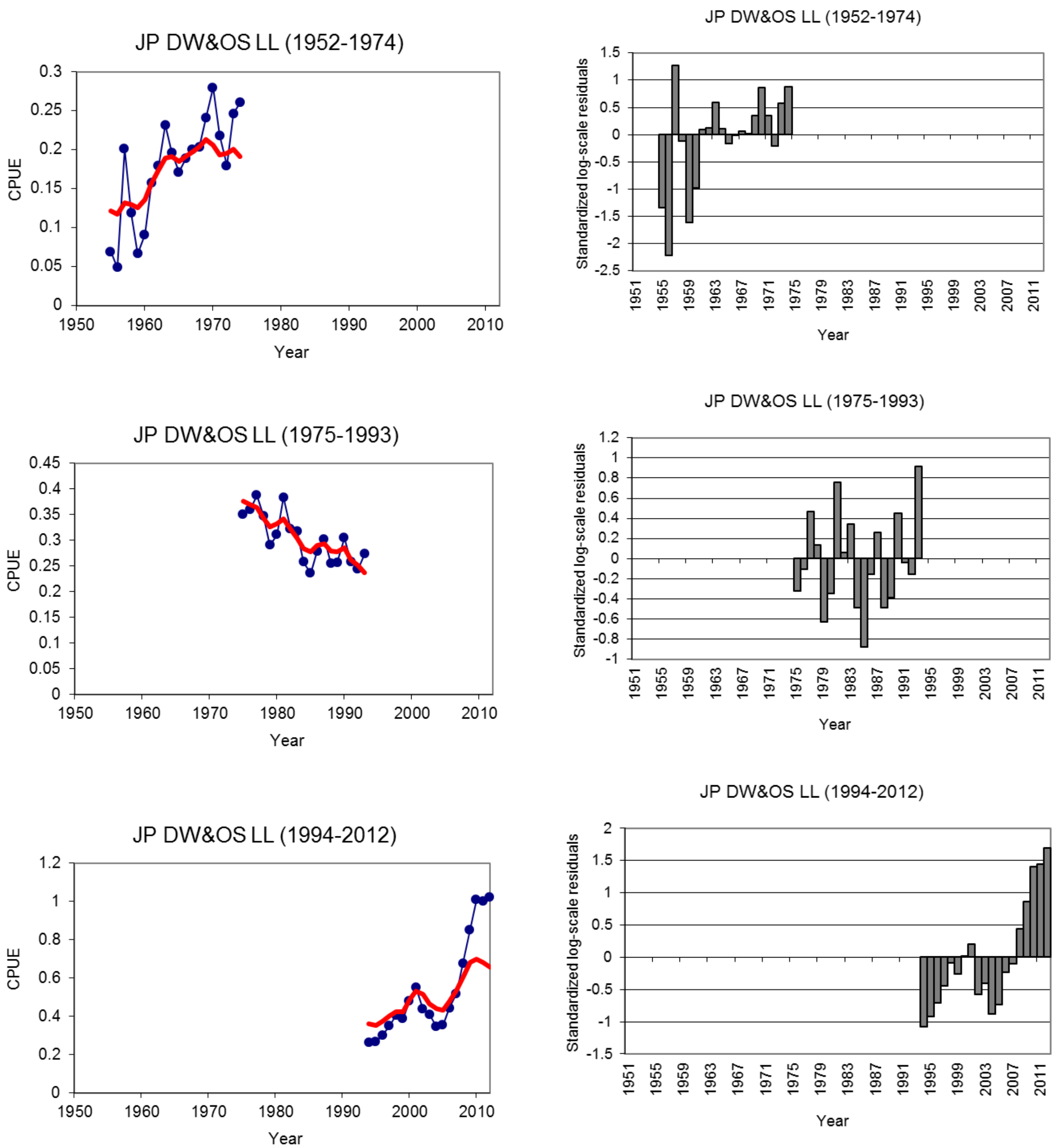
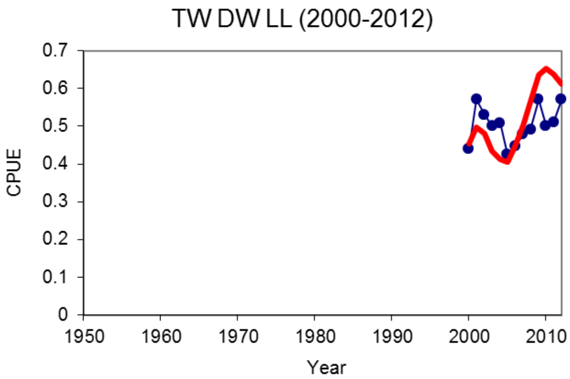
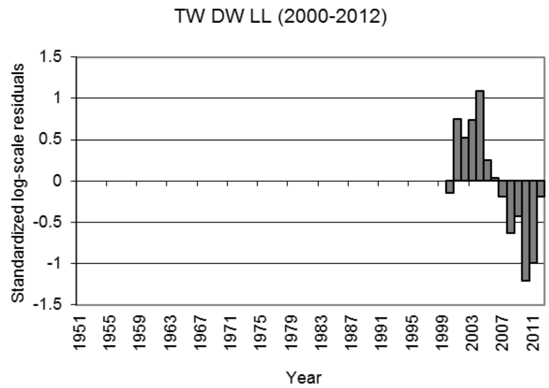


Figure 9. Bayesian surplus production base case model fits (solid red line) to standardized CPUE (blue circles and line) for swordfish in the EPO (left panels) and standardized log residuals (right panels), for the Japanese distant-water and offshore longline fisheries from 1955-1974 (top panels), 1975-1993 (panels second from top), and 1994-2012 (panels third from top), and the Taiwanese distant-water longline fishery from 2000-2012 (bottom panels).







d. Model Results

Results for the base case models were reviewed by the WG and included posterior estimates of prior parameters such as r, K, M, and P1, as well as estimates of total stock biomass in 1000 mt, harvest rate, and the status of these two with respect to BMSY and HMSY. Posterior parameter values estimated for the WCNPO are similar to values estimated in the previous assessment, and are also similar to the initially assumed prior values (Table 8). Similarly, the posterior parameter values estimated for the EPO are similar to values estimated in the previous assessment, and are also similar to initially assumed prior values (Table 8). The estimate for the production shape parameter, M = 0.87, is slightly lower for the EPO base case model than in the previous assessment, where M = 0.96. However in both the previous assessment of swordfish EPO and in this assessment, the estimated error around M is relatively high. Estimates of MSY-based biological reference points (MSY, BMSY, and HMSY) are also provided (Table 8).

The estimated biomass levels for both stocks through time mostly remained above the BMSY level. The estimated base case model results indicated that the WCNPO stock abundance was at a relatively constant level since early the 2000s, and harvest rate showed a decreasing trend in the same recent time period (Table 9 and Figure 10). The EPO stock biomass showed an increasing trend since the early 2000s, while the harvest rate was estimated to increase and eventually exceed HMSY in the most recent years with a about a 55% probability (Table 9 and Figure 11). For both stocks, similar trends in total biomass were obtained in comparison to the previous assessment.

The status of biomass and harvest relative to biological reference points was also estimated in the model and plotted as a Kobe plot for each swordfish stock (Figure 12). Based on the base case results, the WCNPO stock is not currently overfished and is not currently experiencing overfishing. The EPO stock is also currently not overfished but is experiencing overfishing with a 55% probability.

Table 8. Comparison of estimated means and standard deviations (SD) of production model parameters and MSY-based biological reference points for the WCNPO and EPO swordfish stocks.

Parameter	WCNPO stock		Parameter	EPO stock	
	Mean	SD		Mean	SD
r	0.58	0.22	r	0.45	0.19
K	123.66	24.63	K	66.00	15.53
M	0.98	0.45	M	0.87	0.61
P1	0.85	0.09	P1	0.88	0.09
MSY	14.92	1.82	MSY	5.38	1.65
BMSY	60.72	11.79	BMSY	31.33	6.86
HMSY	0.25	0.06	HMSY	0.18	0.06

Table 9. Comparison of estimated mean values of exploitable biomass and harvest rate along with 95% credibility intervals for the WCNPO and EPO swordfish stocks.

Year	**WCNPO stock**						**EPO stock**					
	Exploitable biomass			Harvest rate			Exploitable biomass			Harvest rate		
	Mean	Lower 95% C.I.	Upper 95% C.I.	Mean	Lower 95% C.I.	Upper 95% C.I.	Mean	Lower 95% C.I.	Upper 95% C.I.	Mean	Lower 95% C.I.	Upper 95% C.I.
1951	104.60	67.86	155.30	0.12	0.08	0.17	57.84	34.10	90.92	0.00	0.00	0.00
1952	87.01	53.66	133.10	0.14	0.09	0.22	55.32	30.47	91.51	0.00	0.00	0.00
1953	79.61	48.64	123.40	0.16	0.10	0.26	50.99	25.03	87.42	0.00	0.00	0.00
1954	81.83	50.04	126.70	0.18	0.11	0.27	46.31	19.90	83.80	0.02	0.01	0.04
1955	78.77	48.22	122.10	0.19	0.12	0.29	38.93	13.60	69.94	0.01	0.01	0.03
1956	74.86	45.86	116.50	0.22	0.13	0.34	37.54	14.57	68.04	0.02	0.01	0.04
1957	75.76	46.48	117.90	0.21	0.13	0.33	42.26	18.35	74.15	0.02	0.01	0.04
1958	81.88	50.88	126.50	0.25	0.16	0.39	41.42	18.26	73.40	0.01	0.01	0.03
1959	76.98	47.47	119.30	0.26	0.16	0.39	40.18	17.54	71.51	0.01	0.01	0.03
1960	77.21	47.85	119.90	0.30	0.18	0.46	43.50	19.87	76.60	0.01	0.01	0.03
1961	73.29	44.50	115.30	0.31	0.18	0.48	49.99	24.31	86.15	0.02	0.01	0.03
1962	68.93	40.07	110.80	0.19	0.11	0.30	55.72	27.87	96.33	0.03	0.01	0.05
1963	73.50	43.42	116.80	0.16	0.09	0.25	60.31	30.45	103.90	0.03	0.02	0.06
1964	74.68	44.36	117.70	0.10	0.06	0.16	61.08	30.67	105.60	0.07	0.04	0.13
1965	80.05	48.71	124.90	0.13	0.08	0.21	59.24	29.01	103.90	0.04	0.02	0.07
1966	78.82	47.99	122.50	0.15	0.09	0.23	61.24	30.21	106.80	0.04	0.02	0.07
1967	72.97	44.19	114.10	0.17	0.10	0.26	63.38	31.28	111.20	0.05	0.03	0.09
1968	68.54	41.08	107.50	0.17	0.10	0.26	65.36	32.11	114.80	0.05	0.03	0.10

1969	68.85	41.23	108.20	0.16	0.09	0.25	68.28	33.78	119.80	0.12	0.06	0.21
1970	70.63	42.47	110.80	0.14	0.08	0.21	66.02	31.38	117.70	0.11	0.05	0.20
1971	72.23	43.60	112.80	0.11	0.07	0.17	62.12	29.11	111.70	0.04	0.02	0.08
1972	74.62	45.27	116.40	0.10	0.06	0.15	62.46	30.57	110.10	0.06	0.03	0.11
1973	81.01	49.71	125.50	0.10	0.06	0.15	63.97	32.22	111.60	0.09	0.05	0.17
1974	86.16	53.17	133.00	0.10	0.06	0.16	60.73	30.38	106.30	0.04	0.02	0.08
1975	85.99	53.06	132.70	0.14	0.08	0.21	57.27	29.55	98.70	0.04	0.02	0.07
1976	85.85	52.62	133.00	0.15	0.09	0.23	56.60	29.07	97.85	0.06	0.03	0.11
1977	81.04	49.45	125.90	0.16	0.10	0.25	55.67	28.37	97.01	0.06	0.03	0.11
1978	77.99	47.39	121.60	0.19	0.11	0.29	52.76	26.46	92.33	0.06	0.03	0.10
1979	79.28	47.65	124.40	0.15	0.09	0.24	50.06	25.04	88.06	0.04	0.02	0.08
1980	85.73	51.90	134.30	0.13	0.08	0.20	51.02	25.67	89.17	0.06	0.03	0.11
1981	88.18	53.49	137.90	0.13	0.08	0.20	52.49	26.59	91.67	0.08	0.04	0.14
1982	91.10	55.19	142.70	0.11	0.07	0.18	49.36	24.66	86.56	0.08	0.04	0.14
1983	102.70	62.85	159.20	0.13	0.08	0.20	46.64	23.05	81.92	0.05	0.03	0.09
1984	106.30	64.33	165.70	0.13	0.08	0.21	43.57	21.38	76.67	0.04	0.02	0.07
1985	116.90	70.68	183.80	0.14	0.09	0.22	42.58	20.94	74.65	0.03	0.02	0.05
1986	117.70	69.76	186.90	0.12	0.07	0.20	44.58	22.38	77.73	0.06	0.03	0.11
1987	121.30	71.88	191.80	0.12	0.07	0.20	45.01	22.72	78.49	0.09	0.04	0.15
1988	116.70	69.49	184.80	0.12	0.07	0.19	42.96	21.56	75.13	0.09	0.05	0.16
1989	108.00	64.43	170.30	0.12	0.07	0.18	42.56	21.41	74.11	0.08	0.04	0.14
1990	108.70	65.89	169.80	0.12	0.07	0.19	43.79	22.45	75.97	0.14	0.07	0.25
1991	104.10	63.33	162.70	0.13	0.08	0.21	40.30	20.33	71.03	0.11	0.06	0.20
1992	103.80	63.69	161.70	0.19	0.11	0.29	38.59	19.66	67.59	0.14	0.07	0.26
1993	94.69	57.20	148.60	0.22	0.13	0.34	36.32	18.27	64.18	0.11	0.06	0.20
1994	80.19	47.79	127.00	0.20	0.12	0.32	32.58	15.90	58.57	0.12	0.06	0.22
1995	70.20	42.07	110.30	0.21	0.12	0.33	31.90	15.39	58.12	0.10	0.05	0.18
1996	65.65	39.74	102.60	0.21	0.13	0.32	33.96	16.79	61.31	0.13	0.06	0.23
1997	60.86	37.04	94.96	0.24	0.15	0.38	36.55	18.25	65.48	0.17	0.08	0.30
1998	60.20	36.72	93.78	0.24	0.15	0.38	38.51	19.23	69.23	0.21	0.10	0.37
1999	65.18	39.97	100.90	0.23	0.14	0.36	38.60	18.64	70.94	0.09	0.04	0.17
2000	69.82	43.34	107.80	0.26	0.16	0.40	44.02	22.46	78.79	0.13	0.06	0.23
2001	74.02	45.14	115.00	0.20	0.12	0.31	48.04	24.94	85.24	0.16	0.08	0.28
2002	75.47	46.18	117.10	0.19	0.12	0.30	46.54	24.26	82.48	0.24	0.12	0.41
2003	71.61	43.87	111.40	0.20	0.12	0.31	42.22	20.88	76.80	0.19	0.09	0.35
2004	73.37	44.92	114.20	0.19	0.12	0.30	40.30	19.56	73.82	0.16	0.08	0.30
2005	73.86	45.66	114.30	0.20	0.12	0.31	39.58	18.99	72.78	0.09	0.04	0.17
2006	76.32	47.17	117.80	0.21	0.13	0.32	43.52	21.48	79.04	0.07	0.04	0.13
2007	72.29	44.42	111.90	0.23	0.14	0.36	48.80	24.52	87.77	0.08	0.04	0.15
2008	68.62	41.86	106.90	0.21	0.13	0.33	54.84	27.81	98.52	0.09	0.04	0.15
2009	68.77	41.88	107.00	0.19	0.12	0.30	61.68	31.35	111.30	0.13	0.07	0.24
2010	68.97	41.98	107.40	0.16	0.10	0.25	63.36	31.47	116.20	0.17	0.08	0.31
2011	68.56	41.97	106.70	0.15	0.09	0.23	62.09	29.85	115.40	0.17	0.08	0.32
2012	72.50	44.51	112.20	0.14	0.09	0.22	59.80	27.70	113.50	0.19	0.09	0.36

Figure 10. Estimates of exploitable biomass (top panel) and harvest rate (bottom panel) from the base case model for WCNPO swordfish. Estimated mean values (black circles and solid line), standard error bars, and estimated biological reference points (BMSY and HMSY, dotted line) are presented.

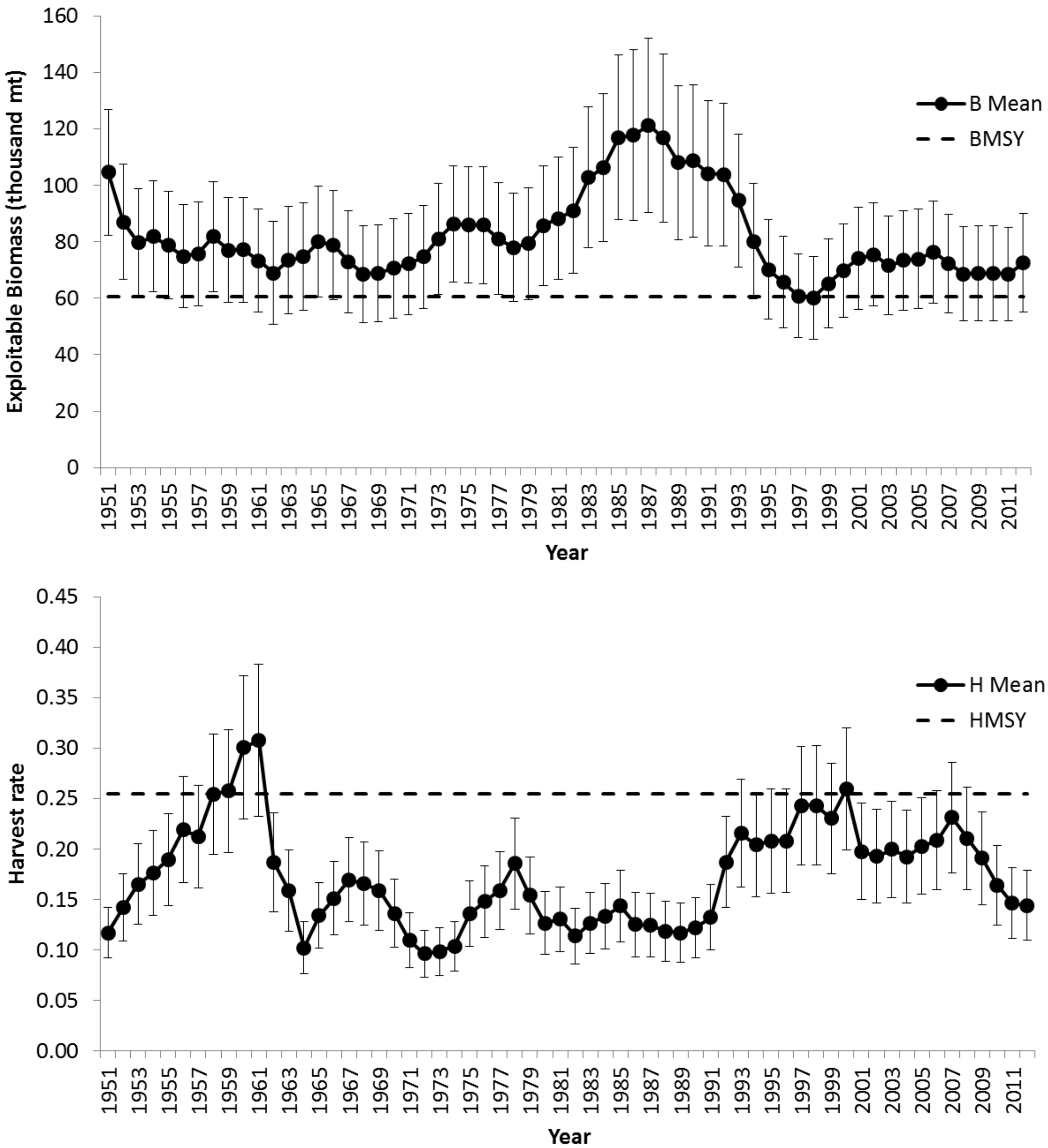


Figure 11. Estimates of exploitable biomass (top panel) and harvest rate (bottom panel) from the base case model for EPO swordfish. Estimated mean values (black circles and solid line), standard error bars, and estimated biological reference points (BMSY and HMSY, dotted line) are presented.

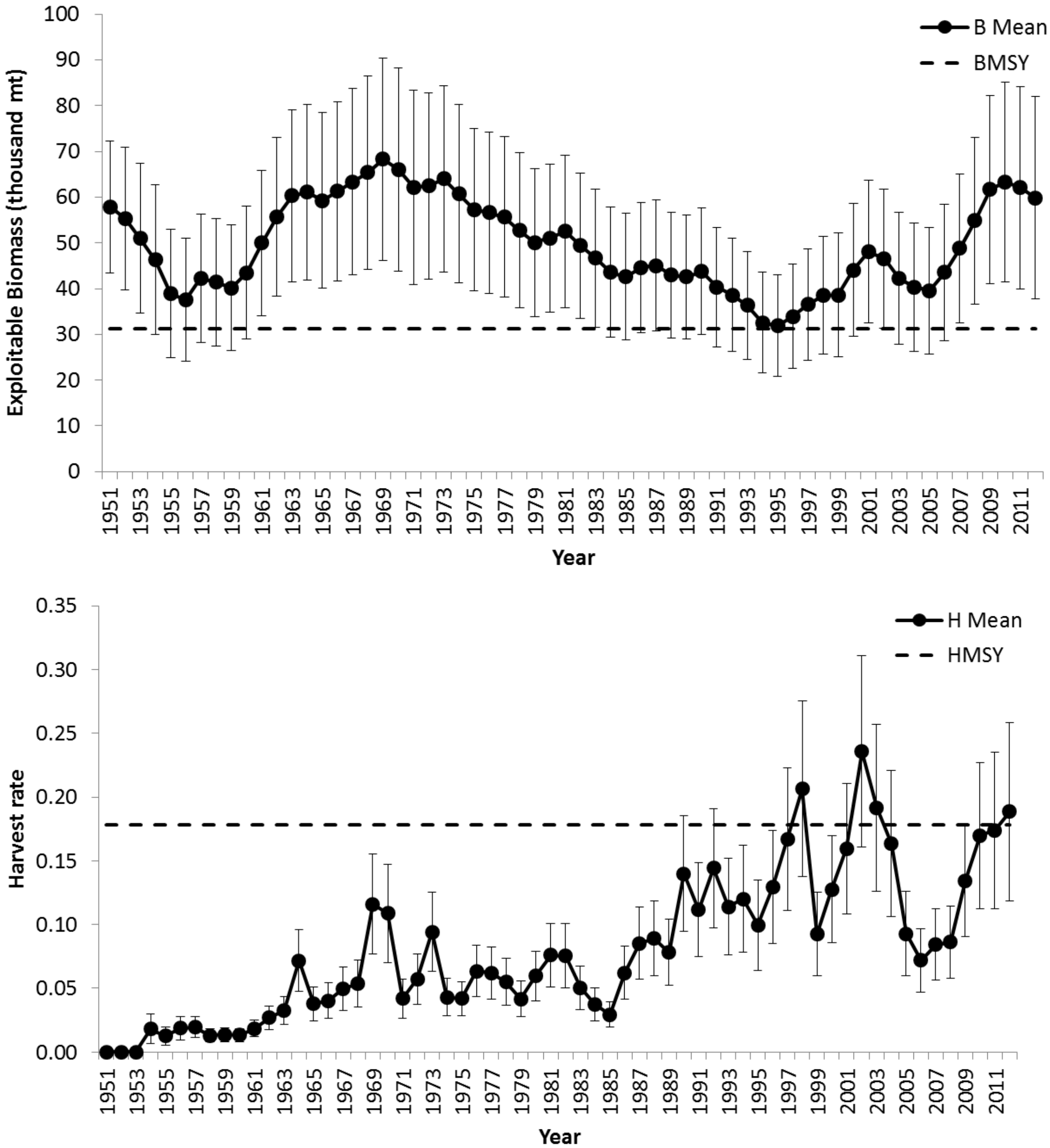
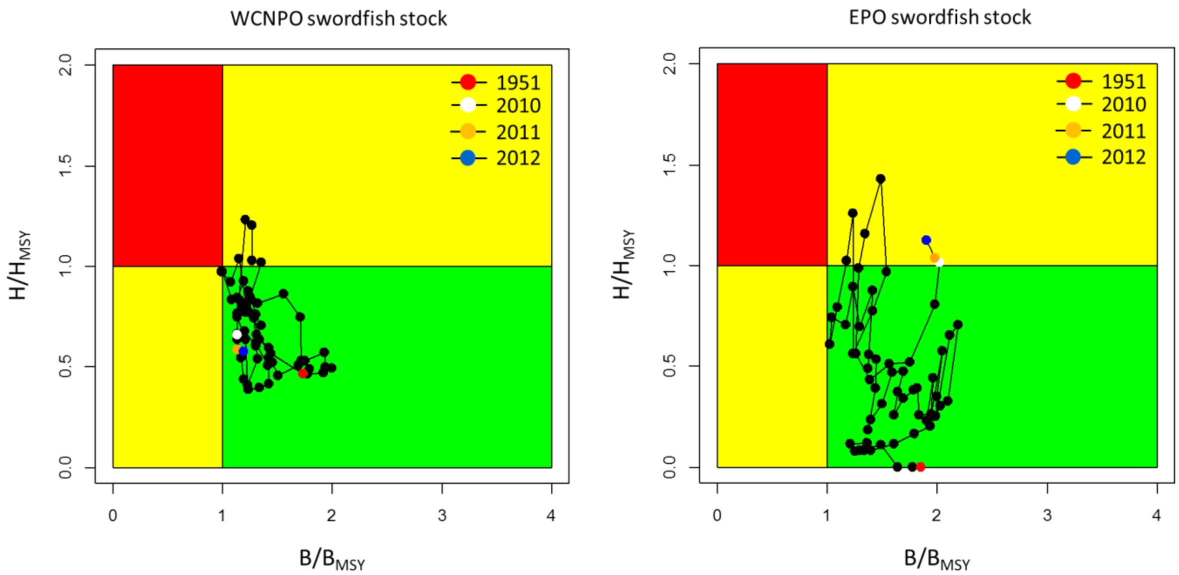


Figure 12. Kobe plots indicating the stock status of the WCNPO (left panel) and the EPO (right panel) swordfish stocks relative to MSY-based biological reference points.



e. Future Work

The working group agreed that a retrospective analysis for the most recent 7 years should be conducted for both the WCNPO and EPO swordfish stocks after the end of the session, with the results reported in the final working paper(s) describing the stock assessments of swordfish in the WCNPO and EPO. Additionally, the working group agreed that the following projections should also be run after the end of the session and reported in the final working paper(s):

- Status quo fishing mortality
- Status quo fishing effort from the most recent 3 years
- Status quo catch from the most recent 3 years
- 0.5*F_{MSY}, 0.75*F_{MSY}, F_{MSY}, 1.25*F_{MSY}, and 1.5*F_{MSY}
- The maximum historically observed single-year F.

10.0 NORTH PACIFIC STRIPED MARLIN STOCK ASSESSMENT

The WG agreed to conduct a stock assessment update for the WCNPO striped marlin stock in 2015 using the approach from the previous assessment in 2011 and 2012. For this purpose, the WG plans to have two meetings: data preparation and assessment modeling. The data preparation meeting will be held in Honolulu in the during winter 2014. The assessment modeling meeting will be held in the spring 2015 (the host country for this meeting to be determined).

11.0 OTHER BUSINESS

The WG discussed other business, including ISC BILLWG participation, future meetings, and work assignments.

11.1 ISC Billfish Working Group Participation

The Chair acknowledged the importance of participation from both the IATTC and the SPC in the completion of a striped marlin stock assessment and expressed hope that their active participation will continue. It was noted that the SPC has been participating in BILLWG meetings at the WCPFC's request and will continue to do so if the request is continued.

11.2 Future Meetings and Timeline

Preceding the ISC14 in Taipei, Taiwan, the BILLWG will meet 14 July 2014 to prepare the conservation advice and information needed to present to the ISC 14 Plenary.

In winter 2014, the BILLWG will meet to prepare and review catch, size composition, and CPUE data for the update of the Western and Central North Pacific striped marlin stock assessment. This will include CPUE standardizations.

It is to be determined what country will agree to host the next intercessional BILLWG workshop which is expected to be scheduled for spring 2015.

11.3 Assignments

11.3.1 BILLWG Assignments

The BILLWG members were assigned a number of tasks. These tasks include:

- Submit finalized copies of all working papers presented at this meeting to the BILLWG Chair by 21-March-2014.
- Complete stock projections for WCNPO and EPO swordfish stocks.
- Complete a North Pacific swordfish stock assessment document for the ISC Plenary and WCPFC SC10 meetings by June.
- Update North Pacific striped marlin, swordfish if available, and Pacific blue marlin catch tables.

11.3.2 Future Work

The results of an ongoing new genetic study indicate the possibility of a more complicated stock structure than that adopted by the ISC Billfish Working Group (Figure 1). It was pointed out that the results of swordfish stock assessments may change using the newly proposed stock structure. The results of the analysis of Japanese longline CPUE suggest the possibility of a temporal change of the current stock boundary between WCNPO and EPO stocks. Thus, the WG recommended that the issue of swordfish stock structure be revisited in the near future and if possible, in close collaboration with IATTC and other appropriate scientists, to review the current WG stock structure hypothesis for the north Pacific swordfish.

Japan presented information on nominal CPUE (both in number and weight) of Spanish longliners operating in the IATTC area south of 5 degrees S (east of 150E) in the period between 1990 and 2012 (personal communication, Spanish fishery scientist Dr. Jaime Mejuto). The nominal CPUE has a rapidly increasing trend during 2007- 2010 which is similar to the marked increase in the standardized CPUE of Japanese longliners in the EPO. Spanish and Japanese longliners comprise two major fleets in the EPO area and further study is recommended to understand the reason for the recent increases in EPO swordfish CPUE

12.0 ADJOURNMENT

The workshop was adjourned at 3:25PM on 19 February 2014. The BILLWG Chairman expressed his appreciation to the rapporteurs and to all participants for their contributions and cooperation in completing a successful meeting. The Chairman also expressed his appreciation for the diligent effort of Yi-Jay Chang and Annie Yau to successfully complete the modeling work during the workshop.

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Attachment 2. Agenda

INTERNATIONAL SCIENTIFIC COMMITTEE FOR TUNA AND TUNA-LIKE SPECIES IN THE NORTH PACIFIC

BILLFISH WORKING GROUP (BILLWG)

INTERCESSIONAL WORKSHOP ANNOUNCEMENT

Meeting Site: Hawaii Imin International Conference Center at Jefferson Hall
1777 East-West Road
Honolulu, HI 96848

Meeting Dates: February 11-19, 2014

Goals: Conduct stock assessment update for the Western and Central North Pacific and Eastern North Pacific Swordfish stocks. Review new information and research to be conducted for the stock assessment of Western and Central North Pacific striped marlin in 2015 and respond to the CIE review of the 2013 stock assessment.

Attendance Deadline: Please respond to Lennon Thomas (email: Lennon.Thomas@noaa.gov) if you are not attending this meeting by **Friday, 7-Feb-2014.**

Working Paper Deadline: Submit working papers to Lennon Thomas (email: Lennon.Thomas@noaa.gov). **Authors are responsible for bringing their own copies (10) on the first day of the meeting.**

Local Contact: Jon Brodziak
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Tel: (808) 983-2964 Email: Jon.Brodziak@noaa.gov

AGENDA

February 11 (Tuesday), 1000-1030 – Registration

February 11 (Tuesday), 1030-1700

1. Opening of Billfish Working Group (BILLWG) Workshop
    a. Welcoming Remarks
    b. Introductions
    c. Standard Meeting Protocols

2. Adoption of Agenda and Assignment of Rapporteurs

3. Computing Facilities
   a. Access
   b. Security Issues

4. Numbering Working Papers and Distribution Potential

5. Status of Work Assignments

6. Annual Billfish Catch/Effort (Category I, II, & III data)
   a. Review of Recent Fishery Information and Existing Catch Projections (through 2013)
      (i) North Pacific Swordfish
      (ii) North Pacific Striped Marlin
      (iii) Pacific Blue Marlin

7. Western and Central North Pacific Swordfish and Eastern North Pacific Swordfish Stock Assessment Data
   a. Life History Information Sources
   b. Catch
   c. CPUE Time Series
   d. Other Information

8. North Pacific Swordfish Stock Assessment Modeling (if time permits)
   a. Use of Life History Information
   b. Fishery Definitions and Selectivity Modeling
   c. Catch Time Series
   d. Fitting CPUE Time Series

February 12 (Wednesday), 930-1700

8. Stock Assessment Modeling: Continued
   a. Use of Life History Information
   b. Catch Time Series
   c. Fitting CPUE Time Series
   d. Model Runs
   e. Model Diagnostics
   f. Model Results
   g. Biological Reference Points
   h. Sensitivity Analyses
   i. Stock Projections

February 13 (Thursday), 930-1700

8. Assessment Modeling: Continued
   a. Use of Life History Information

b. Catch Time Series
c. Fitting CPUE Time Series
d. Model Runs
e. Model Diagnostics
f. Model Results
g. Biological Reference Points
h. Sensitivity Analyses
i. Stock Projections

February 14 (Friday), 930-1700

8. Assessment Modeling: Continued
   a. Use of Life History Information
   b. Catch Time Series
   c. Fitting CPUE Time Series
   d. Model Runs
   e. Model Diagnostics
   f. Model Results
   g. Biological Reference Points
   h. Sensitivity Analyses
   i. Stock Projections

February 15 (Saturday), 930-1300

8. Assessment Modeling: Continued
   a. Use of Life History Information
   b. Catch Time Series
   c. Fitting CPUE Time Series
   d. Model Runs
   e. Model Diagnostics
   f. Model Results
   g. Biological Reference Points
   h. Sensitivity Analyses
   i. Stock Projections

February 16 (Sunday), No Meeting

February 17 (Monday), 930-1700

9. Adoption of Assessment Updates for WCNPO and EPO Swordfish
   a. Use of Life History Information
   b. Catch Time Series
   c. Fitting CPUE Time Series
   d. Model Runs
   e. Model Diagnostics
   f. Model Results

g. Biological Reference Points
h. Sensitivity Analyses
i. Stock Projections

10. North Pacific Striped Marlin Stock Assessment
    a. CIE Review of 2012 Assessment
    b. Plan for Preparation of Assessment Data for 2015 Update
    c. Plan for Assessment Modeling for 2015 Update

11. Other Business
    a. 5th International Billfish Symposium
    b. ISC Billfish Working Group Participation
    c. ISC Billfish Working Group Webpage
    d. Other Items

February 18 (Tuesday), 930-1700

12. Rapporteurs and Participants Complete Report Sections

13. Complete Workshop Report and Circulate; Working Group Reviews Report

February 19 (Wednesday), 930-1500

14. Clearing of Report

15. Adjournment

Attachment 3. Working Papers

ISC/14/BILLWG-1/01	Stock assessment of swordfish (*Xiphias gladius*) in the Eastern Pacific Ocean, 2014. Annie Ji-Hi Yau, Yi-Jay Chang, and Jon Brodziak. (Annie.Yau@noaa.gov)
ISC/14/BILLWG-1/02	Update of the stock assessment for Western Central North Pacific Ocean swordfish (*Xiphias gladius*) through 2012. Yi-Jay Chang, Annie Yau, and Jon Brodziak. (Yi-Jay.Chang@noaa.gov)
ISC/14/BILLWG-1/03	Spatial distribution of swordfish catches for longline fisheries in the Western Central North Pacific and Eastern Ocean. Darryl Tagami, Haiying Wang, and Yi-Jay Chang. (Darryl.Tagami@noaa.gov)
ISC/14/BILLWG-1/04	Updated catch amount of Swordfish (*Xiphias gladius*) by the Japanese coastal, offshore, and distant-water longline fishery in the Pacific. Ai Kimoto and Kotaro Yokawa. (aikimoto@affrc.go.jp)
ISC/14/BILLWG-1/05	Catch rate standardization for swordfish *Xiphias gladius* in the shallow-set sector of the Hawaii-based pelagic longline fishery: 1995-2012. William Walsh and Jon Brodziak. (William.Walsh@noaa.gov)
ISC/14/BILLWG-1/06	U.S. swordfish fisheries in the North Pacific Ocean. Russell Y. Ito and John Childers. (russell.ito@noaa.gov)
ISC/14/BILLWG-1/07	Standardized CPUE of swordfish (*Xiphias gladius*) for the Taiwanese distant-water tuna longline fishery, based on a two-stock scenario in the North Pacific Ocean. Chi-Lu Sun, Nan-Jay Su, and Su-Zan Yeh. (chilu@ntu.edu.tw)
ISC/14/BILLWG-1/08	Update of catch-per-unit effort distribution of swordfish (*Xiphias gladius*) by the Japanese offshore and distant-water longline fishery in the Pacific. Ai Kimoto, Minoru Kanaiwa, and Kotaro Yokawa. (aikimoto@affrc.go.jp)
ISC/14/BILLWG-1/09	Catch estimates of swordfish (*Xiphias gladius*) for the WCNPO and EPO stocks from the Taiwanese fisheries. Nan-Jay Su, Chi-Lu Sun, Wei-Jen Wang, Shyh-Jiun Wang, and Su-Zan Yeh. (chilu@ntu.edu.tw)

Appendix 1. Swordfish catches (thousand metric tons) by stock area and country for the Western and Central North Pacific stock, 1952-2012, and the Eastern Pacific Ocean stock, 2007-2012, where “NA” means “not available”.

Western and Central North Pacific stock

Year	Japan Distant Water and Offshore Longline	Japan Other	Taiwan Distant Water Longline	Taiwan Offfshore Longline and Other	Korea Longline	USA Hawaii Longline	USA Other	Other	Total
1951	7245	4432	NA	NA	NA	NA	NA	NA	11677
1952	8888	2801	NA	NA	NA	NA	NA	NA	11689
1953	10794	1612	NA	NA	NA	NA	NA	NA	12405
1954	12543	1047	NA	NA	NA	NA	NA	NA	13591
1955	13050	1047	NA	NA	NA	NA	NA	NA	14097
1956	14590	890	NA	NA	NA	NA	NA	NA	15480
1957	14207	983	NA	NA	NA	NA	NA	NA	15190
1958	18510	1209	NA	NA	NA	NA	NA	NA	19719
1959	17181	1031	NA	518	NA	NA	NA	NA	18731
1960	19983	1342	NA	647	NA	NA	NA	NA	21972
1961	19398	1432	NA	391	NA	NA	NA	NA	21221
1962	9950	1508	NA	556	NA	NA	NA	NA	12014
1963	9644	922	NA	361	NA	NA	NA	NA	10926
1964	5594	1183	0	368	NA	NA	NA	NA	7145
1965	7506	2249	0	358	NA	NA	NA	NA	10113
1966	8809	1897	0	520	NA	NA	NA	NA	11226
1967	9845	1125	0	681	NA	NA	NA	NA	11651
1968	8067	1839	0	775	NA	NA	NA	NA	10681
1969	7508	1920	0	850	NA	NA	NA	NA	10278
1970	5280	2223	0	909	NA	5	622	NA	9039
1971	5437	909	0	995	0	1	102	NA	7444
1972	4814	891	0	873	0	0	175	NA	6753
1973	4833	1307	0	979	0	0	403	NA	7522
1974	4791	2193	0	1016	0	0	428	NA	8428
1975	5835	3575	11	1052	0	0	570	NA	11043
1976	6386	4747	10	807	0	0	55	NA	12005
1977	7452	3505	3	683	165	17	337	NA	12162
1978	7532	3769	0	558	53	9	1712	NA	13633
1979	8168	2246	7	694	NA	7	386	NA	11508
1980	5655	3038	11	679	47	5	788	NA	10223

Western and Central North Pacific stock

Year	Japan Distant Water and Offshore Longline	Japan Other	Taiwan Distant Water Longline	Taiwan Offfshore Longline and Other	Korea Longline	USA Hawaii Longline	USA Other	Other	Total
1981	6638	2774	1	681	NA	3	746	NA	10843
1982	5312	2392	1	904	39	5	1111	NA	9764
1983	7318	2239	0	949	9	5	1758	NA	12278
1984	7001	2458	0	997	42	3	2838	NA	13339
1985	9114	2402	0	825	22	2	3399	NA	15764
1986	8160	2480	0	667	7	2	2469	NA	13785
1987	8695	2054	1	1518	35	24	1795	NA	14122
1988	8144	2112	0	1040	21	24	1638	NA	12979
1989	5942	2741	4	1529	30	218	1361	NA	11825
1990	5390	1909	5	1463	41	2436	1238	NA	12482
1991	4377	1483	10	1570	3	4508	1035	NA	12986
1992	6911	2471	2	1716	5	5700	1540	NA	18345
1993	7955	2043	58	1484	11	5909	1768	NA	19228
1994	7015	2127	0	1374	49	3176	1604	NA	15345
1995	6005	2412	71	1360	7	2713	1165	NA	13733
1996	6260	2141	10	733	11	2502	1203	NA	12860
1997	6250	1992	20	1419	69	2881	1315	NA	13946
1998	5590	2207	22	1219	100	3263	1416	NA	13817
1999	5292	2241	63	1446	102	3100	1943	NA	14187
2000	5398	2480	64	3476	147	2949	2630	NA	17144
2001	5194	1915	121	3903	255	220	2181	NA	13789
2002	5199	2370	155	3793	284	204	1715	NA	13720
2003	4794	2442	144	3554	247	147	2156	NA	13484
2004	4939	2834	502	3327	300	213	1200	NA	13315
2005	5054	2777	269	3505	339	1622	307	297	14170
2006	5805	2897	203	3891	389	1211	523	133	15051
2007	5916	3337	191	3744	170	1735	555	151	15799
2008	3979	2960	162	3443	351	2014	478	244	13631
2009	3729	2710	147	3222	280	1817	306	163	12375
2010	3660	1918	231	2324	278	1676	119	463	10670
2011	2430	1320	366	2999	256	1623	237	226	9456
2012	2446	1680	576	3049	245	1418	110	338	9863

Eastern Pacific Ocean stock

Country	Belize	Chile	China	French Polynesia	Japan	Korea
Data Source	IATTC	Chile	IATTC	IATTC	Japan	Korea
Fishery	Longline		Longline	Longline	Offshore + Distant Water	Longline
Year	Catch (mt)	Catch (mt)	Catch (mt)	Catch (mt)	Catch (mt)	Catch (mt)
2007	-	246	49.8	27.9	1385.5	283.5
2008	-	312	660.0	35.1	1634.4	423.5
2009	-	391	573.1	37.0	2078.9	687.1
2010	110.5	472	857.5	30.6	2652.7	397.9
2011	230.2	182	1570.6	39.9	3093.6	714.7
2012	287.7	221	1552.1	55.2	2985.6	601.4

Country	Mexico	Peru	Spain	Taiwan	United States	Vanuatu	
Data Source	Mexico	IATTC	IATTC	Taiwan	WCPFC	WCPFC	Grand Total Catch (mt)
Fishery	Longline		Longline	Longline	Longline	Longline	
Year	Catch (mt)		Catch (mt)	Catch (mt)	Catch (mt)	Catch (mt)	
2007	171.6	46	661.1	819	1.6	8.7	3700.7
2008	241.9	124	389.7	439	-	2.0	4261.6
2009	393.8	25	2546.4	739	1.3	0.0	7472.6
2010	221.9	5	3780.0	1101	1.5	-	9630.6
2011	257.3	50	2364.1	1076	-	7.8	9586.2
2012	257.3	50	2377.0	1509	4.6	9.2	9910.2