Annex 10

Report of the Billfish Working Group Workshop

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

1-7 June 2017
National Taiwan Ocean University, Keelung, Taiwan

1. OPENING AND INTRODUCTION

1.1 Welcome and 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 held at the National Taiwan Ocean University in Keelung, Taiwan during 1-7 June 2017. The primary goals of this workshop were to review and update the standardization of Japanese longline CPUE for swordfish and to review and finalize North Pacific swordfish stock structure to be used for the 2018 assessment.

Jon Brodziak, Chair of the BILLWG, welcomed participants from Taiwan, Japan, and the United States of America (USA) (Attachment 1). The Chair noted that there were no meeting participants from China, Korea, Canada, or Mexico.

1.2 Adoption of Agenda and Assignment of Rapporteurs

Rapporteuring duties for the working group (WG) were assigned to Jon Brodziak, Yi-Jay Chang, Ching-Ping Lu, Michelle Sculley, Nan-Jay Su, Chi-Lu Sun, Annie Yau, and Su-Zan Yeh. The meeting agenda was adopted on June 1, 2017 (Attachment 2).

1.3 Computing Facilities

Computing facilities included a Google drive named “ISC BILLWG” for the distribution of working papers and other meeting documents and the transfer of other information as well as a Wi-Fi wireless network access point for connection to the Internet.

1.4 Distribution of Working Papers

Working papers were distributed and numbered (Attachment 3) and it was agreed that all finalized working papers would be posted on the ISC website and made available to the public, except working paper 5 which presents research work in progress.

2. STATUS OF WORK PLAN AND ASSIGNMENTS

The WG goals to be addressed at the June 2017 workshop were as follows:

- Review and update the standardization of Japanese longline CPUE for swordfish.
- Review and finalize North Pacific swordfish population structure for the 2018 assessment.
- Review and update billfish biological and fishery information.
- Analyze and describe the spatiotemporal distributions of juvenile and adult swordfish.
- Identify and prioritize uncertainties in billfish stock assessments for management strategy evaluation.
- Provide draft working papers by the start of the meeting on June 1, 2017.

The ISC BILLWG Chair reported that the information needed to achieve the goals was provided at the Keelung meeting through WG presentations, working papers, and discussions. As a result, the ISC BILLWG Chair reported that the assignments for providing draft working papers were completed and noted that the draft working papers needed to be finalized by June 28, 2017.

3. REVIEW AND UPDATE JAPANESE LONGLINE SWORDFISH CPUE

The working paper by Kanaiwa, Shibano, and Ijima provided a review and update of the CPUE standardization analyses for swordfish in the Japanese longline fishery. Kanaiwa presented the working paper and the WG reviewed it and discussed the information.

Update of catch per unit effort of swordfish (Xiphius gladius) by the Japanese offshore and distant-water longline fishery in the Pacific. Presented by Minoru Kanaiwa (ISC/17/BILLWG-1/1)

The updated standardized CPUE for Japanese offshore and distant water longline fishery was provided. The standardization model was the same as was used in the 2014 swordfish stock assessments. The estimated standardized CPUE in the WCPO fluctuated without trend while the standardized CPUE in the EPO exhibited an increasing trend since 2005.

<u>Discussion</u>
There were questions about the operational fishery data and the nominal CPUE for each year, gear, and area. The WG suggested that it would be useful to show this information as well as expand the methodology section of the working paper to include details on the filtering of the data. It was clarified that the same areas were used as in the 2014 CPUE standardization analyses even though there was an analysis that used updated data to investigate whether new areas should be used. The WG noted that there was no practical difference between CPUE standardization results using the new and old areas.

It was clarified that while there have been some changes in the longline fishery reporting requirements after 1994, these changes primarily affected other species and had a negligible effect on swordfish data. The WG noted that the swordfish CPUE standardization presented in this working paper was estimated as a single CPUE index from 1975 to 2015, noting also that the CPUE data were split into three indices for the 2014 swordfish assessment (1952-1974, 1975-1993, 1994-2012). The WG also noted that the current Japanese CPUE were analyzed using

5°x5° aggregated data rather than analyzed set-by-set. The practical difficultly for running a set-by-set CPUE standardization analysis was a lack of computing power, as the set-by-set dataset is very large. The WG noted that some information lost may have been lost in analyzing aggregate data and that a set-by-set analysis would be more useful.

The WG noted that the sharp increase in CPUE after 2005 in the EPO observed in the 2014 CPUE series was also observed in the current CPUE standardization analyses. Two potential reasons for this increase were changes in the target species of the longline fishery or changes in the size composition of the swordfish catch. Both of these potential causes were explored by the presenter and it was suggested that the sharp increase in CPUE could not be adequately explained by either reason. The WG suggested that a working paper describing this exploratory work be submitted to document this information for future reference. It was also noted that the total area fished by Japanese longliners in the EPO has been decreasing since the late 1990s. Overall the WG concluded that the recent increase in swordfish CPUE in the EPO was important to understand and that additional work was recommended to identify the potential causes.

The WG noted that there was no pattern of bias in the quantile residuals of the CPUE fit, although the standardized residuals exhibited a negative bias.

Following the presentation, the WG also requested to see the nominal CPUE trend and sample sizes through time for each factor in the standardization analyses. This information was provided and will be included in the final working paper. A set-by-set CPUE standardization was also presented using the 1994-2016 EPO data to show the effect of using non-aggregated data. The set-by-set and aggregated results were similar and both showed a 5- to 6-fold increase in standardized swordfish CPUE in the EPO since 2005.

The WG noted that the EPO is a region with a relatively shallow oxygen minimum zone, which may compress swordfish habitat in comparison to other regions and increase swordfish interactions with longline hooks. The WG also noted that recent increases in sea water temperatures in the EPO may also reduce dissolved oxygen levels which may increase the habitat compression even more.

4. REVIEW AND FINALIZE NORTH PACIFIC SWORDFISH POPULATION STRUCTURE

One working paper and two presentations on the topic of North Pacific swordfish population structure were presented to the WG. The WG reviewed and discussed the working papers presented by Chang, Lu, and Brodziak.

Evaluating stock structure hypotheses for swordfish (Xiphias gladius) in the Pacific Ocean using size composition statistics of Taiwanese distant water longliners. Presented by Yi-Jay Chang (ISC/17/BILLWG-1/4)

Delineating the stock structure of a harvested fish species is a major pre-requisite for conducting reliable stock assessments and providing effective management. Although the current stock assessment for the North Pacific swordfish was based on a two-stock working hypothesis, there is no consensus on Pacific swordfish population stock structure according to observations from genetic studies, life history, and fishery characteristics (CPUE). In this study, we evaluated the stock structure hypotheses for swordfish (*Xiphias gladius*) in the Pacific Ocean by using size composition statistics from the Taiwanese distant water longliners. There was a substantial spatial and temporal variability of swordfish size based on the examination of fishery statistics and the spatially explicit nonlinear models. Furthermore, several stock structure hypotheses were evaluated by using model selection of generalized linear models.

Discussion

The WG noted that the percentage of deviance explained was low for both length and weight models. The WG discussed how model selection was performed for the generalized additive model (GAM) analyses. The presenter clarified that variable selection was based on the likelihood ratio test implemented in the R package "gam". The WG suggested it may also be useful to consider the flexible "mgcv" package for the GAM analyses. The presenter clarified how the 7-stock area hypothesis in the working paper was derived and suggested further revisions were probably needed based on the information in Lu et al. (2016). The WG discussed the use of weight and length data for identifying stock structure and questioned whether average fish size was a reliable indicator for evaluating stock structure hypotheses.

Bayesian analyses of Pacific swordfish (Xiphias gladius) genetic differentiation using multilocus single nucleotide polymorphism (SNP) data. Presented by Ching-Ping Lu (Presentation only)

There is no consensus on the population structure of Pacific swordfish, and current-working hypotheses based on genetic and fisheries data include variations of two, three, and four stocks. In this study the hypothesis of panmixia for Pacific swordfish was tested using multilocus analyses of single-copy nuclear DNA loci on 891 swordfish collected in 16 localities. Sampling coverage differs from all previous genetic studies by offering a more comprehensive representation of tropical areas and by including early life history stages (ELS). Accordingly, samples of larvae, juveniles, and adults were characterized at 10 loci containing 20 informative SNPs, 19 of which were genotyped using high resolution melting analysis (HRMA) and one as a restriction fragment length polymorphism (RFLP). Additionally, two short sequence repeat (SSR) loci were characterized. Exact tests of genetic differentiation, analyses of molecular variance (AMOVA), principal coordinates analysis (PCoA), Bayesian analyses using STRUCTURE and GENELAND conducted on these data all rejected the hypothesis of panmixia for Pacific swordfish, and identified Taiwan as the most highly differentiated sample. Samples from temperate areas differed from most tropical samples (SST > 24 °C), but genetic heterogeneity was also detected among several tropical samples. By contrast, no differences were detected among temperate samples despite the considerable geographic distances (up to 18,000 km) separating them. Further, Bayesian analyses using both STRUCTURE and GENELAND suggested a pattern of genetic differentiation in Pacific swordfish more complex than a simple separation of tropical and temperate regions, with no clear delineation of geographic boundaries as those displayed by Atlantic swordfish. AMOVAs conducted to test models of population structure based on fisheries data failed to yield significant proportions of among-group variance. The observed patterns of genetic differentiation of Pacific swordfish are discussed in reference to studies of reproductive biology, tagging experiments, and previous genetic studies conducted on this species.

<u>Discussion</u>

The WG discussed the presentation by Dr. Lu on genetic structure of Pacific swordfish based on Lu et al. (2016). In this context, the WG noted that there was a previously agreed-upon structure used for assessing the North Pacific swordfish resource of the ISC Billfish Working Group but that there was some uncertainty about the stock structure, especially in the eastern Pacific Ocean. The WG noted that the application of more modern genetic techniques showed that significant genetic differences exist among swordfish sampling locations.

The WG discussed the results of the several genetic analyses conducted to assess population genetic structure by Lu et al. (2016). There were tropical and temperate genetic differentiation patterns. Also there was genetic heterogeneity found among tropical samples. The WG noted that none of fishery-based stock structure models were significant from the AMOVA tests but the 3-stock hypothesis from Ichinokawa and Brodziak (2008) was an adequate approximation of stock structure.

Overall the new research suggested that there were two major swordfish genetic clusters in the Pacific Ocean and these were so-called tropical and temperate genetic patterns. The genetic model in Lu et al. (2016) shows complex genetic population structure in the Pacific. The WG noted that there would be benefits of increased sampling at finer spatial scales to better understand and resolve the observed pattern of genetic differentiation.

North Pacific swordfish stock structure for the 2018 assessment. Presented by Jon Brodziak (Presentation only)

Jon Brodziak presented information on the stock structure of North Pacific swordfish for the 2018 stock assessment to be conducted by the WG. The presentation included background information from the 2014 stock assessment. This consisted of a review of the fishery-based stock definitions proposed by Ichinokawa and Brodziak (2008) and the results of using these stock definitions in the 2014 North Pacific swordfish stock assessments.

Here it was noted that the term "stock" was considered to be a <u>*self-sustaining intraspecific group of randomly mating individuals whose demographic and genetic trajectories are mostly independent of other such groups*</u>.

This is a common definition of a stock for fisheries applications (Carvalho and Hauser 1994, Waples 1998). It was also noted that there were two new sources of information on North Pacific stock structure for the 2018 stock assessment. The first was a tagging study by Abascal et al. (2010) which showed that swordfish cross the southern eastern Pacific Ocean swordfish stock boundary at 20ºS. The second was the study by Lu et al. (2016) which showed that Pacific swordfish have a complex genetic population structure and suggested the existence of tropical and temperate genetic differentiation patterns.

Based on the new information and the existing treatment of North Pacific swordfish stock structure, five stock structure scenarios were proposed for the WG to consider, or modify as needed.

The five proposed scenarios were:

1. Status Quo Scenario
    a. Assess WCNPO Stock
    b. Assess EPO Stock
2. Revised Status Quo Scenario I
    a. Assess WCNPO Stock
    b. Do Not Assess EPO Stock
3. North Pacific Management Unit Scenario
    a. Assess a Single Entire North Pacific Ocean Management Unit
4. Account for Some Stock Structure Uncertainty Scenario
    a. Assess WCNPO Stock
    b. Assess a Single Entire North Pacific Ocean Management Unit
5. Revised Status Quo Scenario II
    a. Assess WCNPO Stock
    b. Assess EPO Stock with a Revised Southern Stock Boundary Move to the Equator

<u>Discussion</u>

The WG reviewed available information used to define the current stock structure, and also reviewed the most recent stock assessments for both the WCNPO and EPO swordfish stocks. It was noted that the current stock boundary comes from Ichinokawa and Brodziak (2008) based on analyses of spatial patterns in Japanese longline CPUE data. This is one source of information among many, and some of the other information sources such as catch patterns from other countries and publications on genetic differentiation provided support for splitting the Pacific swordfish population into multiple stocks, noting that the stock boundaries would vary depending on the information source chosen.

The WG discussed the relative merits of the five stock structure scenarios and how to move forward and identify the stock structure scenario to be used for the 2018 benchmark assessment. The WG considered the scientific evidence and uncertainty, assessment workloads, and the existing management boundaries in their evaluation of the proposed scenarios. Two challenges for assessing the EPO stock were identified: fitting a structured assessment model to the increasing Japanese longline CPUE in the EPO and the lack of jurisdictional overlap with WCPFC area. Overall, the WG expected that there would be enough information to attempt a structured stock assessment for WCNPO swordfish.

The WG agreed to proceed with the scenario to account for some stock structure uncertainty by assessing:

1. The WCNPO stock (boundary same as used in 2014) as a benchmark assessment, attempting to use Stock Synthesis or similar structured model, and

2. The single North Pacific swordfish stock north of the Equator as a supplementary assessment scenario, attempting to use Stock Synthesis or similar structured model.

The WG also noted that since the 2018 assessment will be a benchmark assessment, the amount of work may be substantial and so the scope of the 2018 assessment efforts may need to be scaled according to time and manpower availability. In this context, the WG noted that the WCNPO stock assessment would be the primary assessment for providing the best available scientific information for fishery management of swordfish in the North Pacific Ocean by the WCPFC. In comparison, the assessment of a single North Pacific stock was considered to be a secondary assessment, noting that this work would be conducted contingent on time and data availability for the EPO region.

5. REVIEW AND UPDATE BILLFISH BIOLOGICAL AND FISHERY INFORMATION

Two working papers on the topic of best available information for determining life history parameters of Pacific billfishes were presented to the WG. Yau presented life history and fishery information for Pacific blue marlin from the most recent WG stock assessment. Chang presented ongoing research on determining the length at age one for Pacific blue marlin (*Makaira nigricans*) using dual hard-parts of fin-spines and otoliths. The WG reviewed and discussed the presentations by Yau and Chang.

Summary of life history and stock status for Pacific blue marlin, western and central north Pacific Ocean striped marlin, and north Pacific swordfish. Presented by Annie Yau (ISC/17/BILLWG-1/2)

The ISC Billfish Working Group, in its 2016-2017 work plan, agreed to update its webpage information (ISC 2016a). To that end, this working paper presents standardized figures of the best available life history information for Pacific billfish species regularly assessed by the group and summary figures of recent stock assessment results for these species (ISC 2014a, 2014b, 2015, 2016b). This document provides such figures for three species: blue marlin (*Makaira nigricans*), striped marlin (*Kajikia audax*), and swordfish (*Xiphias gladius*). The final species is presented as two separate swordfish stocks, the Western-Central North Pacific (WCNPO) stock and the Eastern- Pacific Ocean (EPO) stock. Sexual dimorphism is apparent for both blue marlin and swordfish and these species’ life history information is presented by gender. This working paper also includes background information on the derivation of each figure along with relevant equations and parameter sources.

<u>Discussion</u>
The WG noted that there was a discrepancy between female and male size at age one in the EPO area. The discrepancy was not consistent with the expected pattern of early life history stage growth. The WG recommended that the growth curves and other life history information for the EPO swordfish stock be revisited. The WG noted that sex-specific life history parameters were not available for striped marlin, and suggested that the availability of sex-specific information would influence whether a sex-specific assessment model was used or not. The WG also noted that the natural mortality rates at age differed between sexes for some species, and that this implied that differences in sex ratios at age could be expected. The WG discussed the differences in biomass-per-recruit values of blue marlin females and males at the youngest ages and concluded that these were due to differences in natural mortality rates by gender. The WG suggested that it would be helpful to include the original references for the billfish life history relationships in the working paper. The WG noted that catch, spawning biomass, and fishing

mortality of the EPO swordfish all had an increasing trend for the recent 10 years and that this was an unusual pattern. The WG also discussed the format and type of assessment results that will be updated on the ISC webpage. Overall, the WG agreed that the figures provided useful information that, with some modifications, could be posted on the ISC webpage.

Determination of length-at-the first age for the Pacific blue marlin (Makaira nigricans) using dual hard-parts of fin-spines and otoliths. Presented by Yi-Jay Chang (ISC/17/BILLWG-1/5)

Age determination and growth estimation of blue marlin in the western Pacific Ocean blue marlin (*Makaira nigricans*) were examined using fin-spine sections and otolith micro-increments. Length-weight, dorsal fin spines, and otolith were collected monthly at the fishing ports of Tunkang, Xinkang and NanFanAo from September 2016 to April 2017. In total, 306 dorsal fins and 52 otoliths were collected. In this study, twenty-five specimens with clear rings (134 - 198 eye-to-fork length, unit cm EFL) and four specimens (144 - 162 cm EFL) with otolith micro-increment counts were used to determine the length-at-the first age. Otolith micro-increments were counted with ages of 209 - 374 days old. The predicted EFL-at-age 1 was estimated at 161.78 cm EFL by applying the von Bertalanffy growth function to the observed EFL-at-age (in days). The distribution of the back-calculated EFLs at the time of the first growth-band formation ranged from 80 to 180 cm. Ongoing work of conducting the age determination and growth estimation of blue marlin by using the dual hard-parts of fin-spines and otoliths will help to eliminate the misidentification of false-annual growth bands formed before a fish reaches age one. Therefore, age determination from bulk fin-spine sections will be improved.

<u>Discussion</u>
The study focused on the age determination and growth estimation of blue marlin in the western Pacific Ocean. The WG discussed the preliminary results of the study and the number of otoliths that will be analyzed in the ongoing study. The WG discussed the discrepancy of the mean length-at-age of the Pacific blue marlin among various studies including Shimose et al. (2015) and Su et al. (2016). The WG noted the differences of the estimated mean length-at-the first age between the fin-spine sections and otolith micro-increment counts. The protocol for counting blue marlin otolith micro-increments was clarified by the presenter. The authors noted that the method and technique to process the otoliths is being improved as part of the ongoing study.

6. ANALYZE AND DESCRIBE THE SPATIOTEMPORAL DISTRIBUTION OF JUVENILE AND ADULT SWORDFISH

Two working papers on the spatiotemporal distribution of swordfish were presented to the WG. Sculley presented results of an analysis of trends in swordfish length composition data from the Hawaii longline fishery. Su presented an analysis of environmental effects on the spatial distribution of swordfish. The WG reviewed and discussed the presentations by Sculley and Su.

An exploratory analysis of trends in swordfish (Xiphias gladius) length composition data from the Hawaiian longline fishery. Presented by Michelle Sculley (ISC/17/BILLWG-1/3)

Generalized additive models were applied to explore the relative influence of spatial, temporal, and environmental predictors on the distribution of swordfish (*Xiphias gladius*) fishery length frequency data from the Pacific Islands Regional Observer Program database on the Hawaiian longline fishery during 1994-2016. Spatial predictors were more generally influential on swordfish length than temporal factors. Environmental variables such as sea surface temperature, the Pacific Decadal Oscillation index, and the Southern Oscillation Index were sometimes significant but did not explain a substantial portion of the variance in the data. Models of the deep-set sector explained 30-50% of the deviance while models of the shallow-set sector explained less than 25% of the deviance. The deep-set sector does not target swordfish, primarily captures small young-of-the-year (<100cm) individuals, and had much higher annual variability in length. The shallow-set sector targets swordfish, catches primarily large swordfish, and has had relatively low annual variability. Spatial patterns indicate that large fish are caught in the more northern latitudes while smaller fish are caught closer to the equator. Overall, due to the significant differences between the length composition of the shallow-set and deep-set catch, the deep-set data is unlikely to be representative of the targeted swordfish fishery. However, the deep-set data did primarily consist of small fish with a median length of 82 cm and may contain information on annual recruitment strength. It would be useful to compare the patterns observed in this analysis with those from other fisheries to see if the conclusions drawn here are applicable to the entire North Pacific swordfish population.

Discussion

There were questions about the details of the clustering analysis. It was clarified that minimum distance was used in the clustering analysis, which specified a normal distribution of response variable (eye-fork length). Clustering of months was pursued because 1) exploratory data analyses indicated that patterns were not aligning with traditional quarter breaks, and 2) when quarter was investigated as a variable in the GAMs, it was not a significant factor.

There was a question about why larger swordfish were sexed more frequently than smaller fish, and it's likely that it's much easier to identify the sex of larger fish especially given time constraints on the vessels. There was a comment that the probability of correctly identifying the sex depends on whether the fish is immature or not, so it's possible that unidentified individuals are more likely immature than not. Ultimately there was no way to know why a particular fish was not identified to sex. There was a suggestion to run all the GAMs with only sexed data and compare to results of GAMs that assigned sexes to unsexed fish.

The final GAMs for the shallow set fishery all had month as a significant explanatory variable, although month only explained 1-3% of the deviance. There was a question of why month was used since the cluster analysis showed there was only one cluster and thus all months are not different. Month was included in the GAMs for the shallow set fishery because so little deviance was explained, and as a result, all potential variables were tested for significance. There was a suggestion to run the deep set GAMs with month instead of cluster, since the cluster analysis was based on data from all deep set data but some of the GAMs use subsets of the deep set data. But it was noted that for each of the individual deep set GAMs, there were differences between cluster 1 (August to March) and cluster 2 (April to July). It was pointed out that month was significant but included as a factor and not as a "by" variable (Wood 2006). Including month as a by variable would result in a much higher number parameters and thus much higher AIC values, and would not result in a parsimonious model. It was clarified that cluster is included as a by variable in the GAMs for the deep set. There was also a request to include that information in the working paper and this was completed during the meeting.

The spatial and temporal resolution of environmental variables was clarified. Sea surface temperature (SST) was available at monthly 1/10th of degree resolution, and a minimum distance algorithm was used to pull the closest SST value to each begin-set location. In comparison, the PDO and SOI are ocean-wide indices measured at a monthly time scale.

There was a suggestion to explore the use of hooks per basket as a GAM factor, especially if there are spatial differences in the number of hooks per basket. Originally this variable was not included because splitting into deep and shallow is based on hooks per basket so in large part already accounts for this factor. The effect of hooks per basket has been explored extensively over the years in many other analyses of the Hawaii longline observer data (e.g., Walsh and Brodziak 2014), and it has been shown that splitting into deep and shallow set sectors accounts for the hooks per basket effect. Additional work was discussed and it was clarified that the hooks per basket values did not vary substantially in space and that the majority of the shallow- (4-5 HPB) and deep-set sectors (25, 27, or 30 HPB) used a narrow range of hooks per basket.

It was clarified that the spike in number of swordfish measured in 2005-2006 was due to both an increase in observer coverage and the continued practice of measuring all fish. After 2006, increased observer coverage remained but the fish sampling protocol was changed to have every third fish measured.

Environmental effects on the spatial distribution of swordfish as inferred from data for the Taiwanese distant-water tuna longline fishery in the Pacific Ocean. Presented by Nan-Jay Su (ISC/17/BILLWG-1/6)

Fishery data of swordfish for the Taiwanese distant-water tuna longline fishery and the environmental variables including chlorophyll-a concentration, mixed layer depth, sea surface height, sea surface salinity, sea surface temperature and lunar phase in the Pacific Ocean were collected and analyzed in this study. Generalized additive models were used to model the relationships between environmental variables and catch-rates of swordfish. The effects considered, including the six oceanographic covariates, were all statistically significant in the GAMs, with a very large proportion of deviance explained by latitude. Swordfish CPUE was found to be decreasing with sea surface temperature, mixed layer depth and chlorophyll-a concentration. The nominal and predicted catch-rates showed similar spatial patterns and were high between latitudes 10°N–10°S in the central Pacific Ocean. The forecast ability for the area of high swordfish abundance was further illustrated through the analysis of potential hotspot areas. The results of the hotspot analysis in this study could form the basis for time-area management if there was a wish to reduce swordfish catches.

Discussion

The WG discussed how the mixed layer depth data were obtained and included in the analysis. The WG noted an area of potential high CPUE off Baja California. The presenter clarified that while these high CPUE areas were predicted by the linear model, there were no fishery data from those spatial cells. The WG noted that the Taiwanese fleet had areas of high predicted and observed CPUE in the EPO.

7. IDENTIFY AND PRIORITIZE UNCERTAINTIES FOR MANAGEMENT STRATEGY EVALUATION

Identify and prioritize uncertainties in billfish stock assessments for management strategy evaluation. Presented by Jon Brodziak (Presentation only)

Jon Brodziak presented a general algorithm for conducting management strategy evaluations (e.g., Punt et al. 2014). The algorithm consisted of six primary steps which can be described as:

1. Identify the management objectives. The first step proceeds by establishing the concepts of what the set of management objectives for the fishery system should be. Each chosen objective must then have one or more performance metrics, which represent the objective in a tangible manner.
2. Identify the uncertainties. The second step begins with a broad view of the types of important uncertainties that affect the understanding and prediction of the fishery system. This includes observation errors for data inputs and process errors for system dynamics. It also includes structural uncertainties for models of system processes, including the implementation of management strategies. The overall goal is to find the management strategies that are robust to the uncertainties, which will be simulated through the evaluation process.
3. Construct the set of operating models. The third step is to build a set of mathematical models to represent the fishery system. These models represent the dynamics of the fishery system and must include components for the population dynamics fishery resources and the fleet dynamics of the fishery. These models also need to specify how information is gathered from the fishery system including the data observation processes, the likelihood components relating the dynamics to the observations, and the implementation of management measures to control the fishery system. Multiple operating models are to be expected because fishery systems are complex, i.e. have many components and interrelationships among components, and have components that are typically not observable with a high degree of certainty.
4. Set parameters of operating models. The fourth step is to estimate the parameters of each operating model and characterize parameter uncertainty. This is typically accomplished by fitting the model to observed or simulated data from the fishery system.
5. Identify the management strategies. The fifth step is to identify the set of feasible management options that could be implemented to influence the dynamics of the fishery system to achieve the management objectives.
6. Conduct the management strategy simulation experiment. The last step requires that the set of paired combinations of operating model and management strategy be simulated with sufficient randomization and replications to assess the relative performance for achieving the management objectives. The information from these simulated combinations is summarized and contrasted to understand the characteristics of the management strategies and their relative performance. The last step may lead to revisions of previous steps in an iterative process of scientific refinement for public policy analysis.

Discussion

Although the Northern Committee of WCPFC has not requested that the ISC Billfish Working Group address the topic of management strategy evaluations (MSEs), the WG discussed several uncertainties of the billfish stocks because it may be necessary for future assessment and management approaches that include MSEs of North Pacific billfish stocks. The WG discussed the presentation and considered how MSEs could be potentially applied to North Pacific billfish stocks. The WG identified three important sources of uncertainty for conducting MSEs of billfish stock assessments: process error, parameter error, and model uncertainty. It was noted that there can be overlap between the three types of errors and how errors are classified will depend on how they are defined in the model. Here is a preliminary list of these sources of uncertainty for billfish stock assessments.

Sources of process error:

- Recruitment, natural mortality, movement, and availability or selectivity due to fish movements
- Depensatory effects at low stock sizes
- Presence of sexual dimorphism as well as other sex-specific characteristics and use of a pooled-sex model
- Lack of spatial and temporal representation

Sources of parameter error:

- A lack of data and lack of spatial coverage for relevant processes
    - Growth, natural mortality, and other biological processes
    - Errors in aging, age-length keys, and estimates of maximum age
    - Species identification errors
    - Inaccuracy of historical catch
    - Lack of information on discards
    - Misreporting of catch, effort, or size composition
    - A lack of sampling in the recent time period for estimation of life history parameters
- Small sample size of data and choices in data weighting

Sources of model uncertainty:

- Hyperstability in CPUE versus proportionality of CPUE to relative abundance
- Changes in fishing gear and fishery targeting
- Uncertainty in stock structure and boundaries
- Uncertainty in fish movements, either for directional migrations or diffusive movements
- A lack of information on multispecies interactions such as predation, prey availability, and competition for resources
- Changes in the definitions of fleet through time and space

8. OTHER BUSINESS

The WG discussed other business, including future assessments, future meetings, and other issues.

8.1 Future Assessments

The WG agreed to conduct a benchmark assessment of North Pacific swordfish in 2018.

8.2 Future Meetings

The next meeting of the ISC Billfish Working Group will be held Vancouver, British Columbia on July 10, 2017.

The data preparation meeting for the 2018 North Pacific swordfish stock assessment will be held in Honolulu during December 2017 or January 2018. The WG tentatively proposed the dates of 17-23 January 2018 for the data preparation meeting.

8.3 Future Work Assignments

The WG will need to discuss and identify the time period for the 2018 North Pacific swordfish stock assessment before the data preparation meeting, noting that fishery data are available from 1952-2016.

Nominations for a new WG Chair are requested from participating ISC countries and should be sent to the WG Chair by 30 June 2017. In addition, nominations for a new WG Vice Chair will also be requested from participating ISC countries and should be sent to the WG Chair by June 30, 2017. Elections for the new WG Chair and Vice Chair will be held at the July 10, 2017 WG meeting in Vancouver, British Columbia.

The WG Chair will request that the ISC Chair ensure that the ISC Website be updated to include ISC15 Plenary information. In particular, the WG Chair will request that deprecated links, such as the Rules and Procedure URL on the ISC Website be removed to eliminate confusion over historic and current ISC rules and procedures.

The WG Chair requests that the USA, Japan, and Taiwan scientific delegations identify at least one stock assessment scientist from each of their countries who will serve on the data preparation and modeling teams for the 2018 North Pacific swordfish stock assessment by July 10, 2017.

9. ADJOURNMENT

The workshop was adjourned at 2:41 PM on 6 June 2017. The WG Chair expressed his appreciation to the rapporteurs and to all participants for their contributions to completing a successful ISC Billfish Working Group meeting. The WG Chair also expressed his appreciation to the National Taiwan Ocean University and the Fisheries Agency of Taiwan for their efforts and contributions to hosting this meeting.

10. REFERENCES

Carvalho, G., Hauser, L. 1994. Molecular genetics and the stock concept in fisheries. Rev Fish Biol Fish 4: 326-350.

Ichinokawa, M., Brodziak, J., 2008. Stock boundary between possible swordfish stocks in the northwest and southeast Pacific judged from fisheries data of Japanese longliners. International Scientific Committee for Tuna and Tuna-like species in the North Pacific Ocean ISC/08/Special Session on Billfish Stock Structure/04:14.

International Scientific Committee for Tuna and Tuna-like species in the North Pacific Ocean [ISC] (2016a) Report of the 16th meeting of the International Scientific Committee for Tuna and Tuna-like species in the North Pacific Ocean. Sapporo, Hokkaido, Japan. Annex 10. Available at: http://isc.fra.go.jp/pdf/ISC16/Plenary_report/ISC16_Final_Report.pdf

ISC (2016b) Stock Assessment Update for Blue Marlin (*Makaira nigricans*) in the Pacific Ocean through 2014. Sapporo, Hokkaido, Japan. Annex 10. Available at: http://isc.fra.go.jp/pdf/ISC13/Annex 10- Blue marlin stock assessment.pdf

ISC (2015) Stock Assessment Update for Striped Marlin (*Kajikia audax*) in the Western and Central North Pacific Ocean Through 2013. Yokohama, Japan. Available at: http://isc.fra.go.jp/pdf/BILL/ISC15_BILL_2/ISC_15_BILL-2_WP02_final.pdf

ISC (2014a) Stock assessment of swordfish (*Xiphias gladius*) in the Eastern Pacific Ocean through 2012. Honolulu, HI.
Available at: http://isc.fra.go.jp/pdf/BILL/ISC14_BILL_1/ISC_14_BILLWG-1_01.pdf

ISC (2014b) Stock assessment of Western and Central North Pacific Ocean swordfish (*Xiphias gladius*) through 2012. Honolulu, HI USA. Available at: http://isc.fra.go.jp/pdf/BILL/ISC14_BILL_1/ISC_14_BILLWG-1_02.pdf

Lu, C.P., Smith, B., Hinton, M., Alvarado Bremer, J. 2016. Bayesian analyses of Pacific swordfish (*Xiphias gladius L.)* genetic differentiation using multilocus single nucleotide polymorphism (SNP) data. Journal of Experimental Marine Biology and Ecology, 482:1-17.

Punt, A., Butterworth, D., de Moor, C., De Oliveira, J., Haddon, M. 2014. Management strategy evaluation: best practices. Fish and Fisheries, 17:303-334.

Shimose, T., Yokawa, K., Tachihara, K. (2015) Age determination and growth estimation from otolith micro-increments and fin spine sections of blue marlin (*Makaira nigricans*) in the western North Pacific. Marine and Freshwater Research, 2015, 66, 1116–1127.

Su, N.J., Sun, C.L., Tai, C.Y., Yeh, S.Z. (2016). Length-based estimates of growth and natural mortality for blue marlin (*Makaira nigricans*) in the northwest Pacific Ocean. Journal of Marine Science and Technology, 24(2): 370-378.

Walsh, W. A. and J. Brodziak 2015. Billfish CPUE standardization in the Hawaii longline fishery: Model selection and multimodel inference. Fisheries Research 166: 151-162.

Waples, R. 1998. Separating the wheat from the chaff: patterns of genetic differentiation in high gene flow species. Journal of Heredity, 89:438-450.

Wood, S.N., 2006. Generalized additive models: An introduction with R. Chapman & Hall, Boca Raton. 392 p.

ATTACHMENT 1. LIST OF PARTICIPANTS

Chinese Taipei

Yi-Jay Chang
Institute of Oceanography
National Taiwan University, Taipei, Taiwan
yjchang@ntu.edu.tw

Ching-Ping Lu
Information Division
Overseas Fisheries Development Council,
Taipei, Taiwan
michellecplu@gmail.com

Nan-Jay Su
Department of Environmental Biology and
Fisheries Science
National Taiwan Ocean University,
Keelung, Taiwan
nanjay@ntou.edu.tw

Chi-Lu Sun
Center of Excellence for the Oceans
National Taiwan Ocean University,
Keelung, Taiwan
chilu@ntu.edu.tw

Su-Zan Yeh
Department of Environmental Biology and
Fisheries Science
National Taiwan Ocean University,
Keelung, Taiwan
suzanyeh@ntu.edu.tw

Japan

Hirotaka Ijima
National Research Institute of Far Seas
Fisheries
5-7-1 Orido, Shimizu
Shizuoka, Japan 424-8633
ijima@affrc.go.jp

Minoru Kanaiwa
Mie University, Graduate School of
Bioresources
1577 Kurima Machiya cho
Tsu, Mie, Japan 514-8507
minoru.kanaiwa@gmail.com

United States

Jon Brodziak
NOAA Fisheries, NMFS
Pacific Islands Fisheries Science Center,
1845 Wasp Blvd.,
Honolulu, HI, 96818
jon.brodziak@noaa.gov

Michelle Sculley
NOAA Fisheries, NMFS
Pacific Islands Fisheries Science Center,
1845 Wasp Blvd.,
Honolulu, HI, 96818
michelle.sculley@noaa.gov

Annie Yau
NOAA Fisheries, NMFS
Pacific Islands Fisheries Science Center,
1845 Wasp Blvd.,
Honolulu, HI, 96818
annie.yau@noaa.gov

ATTACHMENT 2. MEETING AGENDA

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

BILLFISH WORKING GROUP (BILLWG)

INTERCESSIONAL WORKSHOP
ANNOUNCEMENT and DRAFT AGENDA

Meeting Site:	Distant Synchrony Auditorium, Room 307 Building of the College of Life Sciences Center of Excellence for the Oceans National Taiwan Ocean University 2 Bei-Ning Road, Keelung, 20224 Taiwan
Meeting Dates:	June 1-7, 2017
Goals:	Review and update the standardization of Japanese longline CPUE for swordfish. Review and finalize North Pacific swordfish population structure for the 2018 assessment. Review and update billfish biological and fishery information. Analyze and describe the spatiotemporal distributions of juvenile and adult swordfish. Identify and prioritize uncertainties in billfish stock assessments for management strategy evaluation.
Meeting Attendance:	Please respond to Jon Brodziak (Email: Jon.Brodziak@noaa.gov) if you plan on attending this meeting
Working Papers:	Submit working papers to Jon Brodziak by **Monday May 29th**. Authors who miss this deadline must bring 15 hard copies of their working paper to the meeting.
Local Contact:	Dr. Chi-Lu Sun, Chair Professor Center of Excellence for the Oceans National Taiwan Ocean University 2 Bei-Ning Road, Keelung, 20224 Taiwan Email: chilu@ntu.edu.tw

BILLWG Contact: Dr. Jon Brodziak, ISC Billfish Working Group Chairman
NOAA Fisheries
Pacific Islands Fisheries Science Center
1845 Wasp Boulevard, Honolulu, HI 96818, USA
Email: Jon.Brodziak@NOAA.GOV Tel: (+1)808-725-5617

DRAFT AGENDA

June 1 (Thursday), 930-1000 – Registration

June 1 (Thursday), 1000-1630

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 Plan and Assignments
6. Review and update Japanese longline swordfish CPUE
   a. Effects of fish size on CPUE
   b. Fishery definitions and selectivity modeling
   c. Analysis of CPUE time series by area
   d. Size composition time series by area
   e. Update CPUE standardization model

June 2 (Friday), 930-1700

6. Review and update Japanese longline swordfish CPUE: Continued
   a. Effects of fish size on CPUE
   b. Fishery definitions and selectivity modeling
   c. Analysis of CPUE time series by area
   d. Size composition time series by area
   e. Update Japanese longline CPUE standardization model
7. Review and update billfish biological and fishery information
   a. Life history parameters
   b. Fishery data

June 3 (Saturday), 930-1700

8. Analyze and describe the spatiotemporal distribution of juvenile and adult swordfish
   a. Review of existing information

b. Analyses of Hawaii longline fishery data

9. Review and discuss North Pacific swordfish population structure
    a. Single stock hypothesis
    b. Two stock hypothesis

June 4 (Sunday), No meeting

June 5 (Monday), 930-1700

7. Review and update billfish biological and fishery information, as needed
    a. Life history parameters
    b. Fishery data
8. Analyze and describe the spatiotemporal distribution of juvenile and adult swordfish.
    a. Review of existing information
    b. Analyses of Hawaii longline fishery data
9. Review and discuss North Pacific swordfish population structure, as needed
    a. Single stock hypothesis
    b. Two stock hypothesis
10. Identify and prioritize uncertainties for management strategy evaluation
    a. Use of life history information
    b. Fishery definitions and selectivity modeling c. Catch time series
11. Other Business
    a. Election of BILLWG Chair and Vice Chair
    b. Future meetings
    c. Work assignments
    d. Other items
12. Rapporteurs Complete Report Sections

June 6 (Tuesday), 930-1700

13. Complete Workshop Report and Circulate; WG reviews Report

June 7 (Wednesday), 930-1700

14. Clearing of Report
15. Adjournment

ATTACHMENT 3. WORKING PAPERS

ISC/17/BILLWG-1/01	Update of catch per unit effort of swordfish (*Xiphius gladius*) by the Japanese offshore and distant-water longline fishery in the Pacific Minoru Kanaiwa, Ayumi Shibano, Hirotaka Ijima minoru.kanaiwa@gmail.com
ISC/17/BILLWG-1/02	Summary of life history and stock status for Pacific blue marlin, western and central north Pacific Ocean striped marlin, and north Pacific swordfish Maia Kapur, Jon Brodziak, Eric Fletcher, Annie Yau maia.kapur@noaa.gov
ISC/17/BILLWG-1/03	An exploratory analysis of trends in swordfish (*Xiphias gladius*) length composition data from the Hawaiian longline fishery Michelle Sculley, Jon Brodziak, Annie Yau, Maia Kapur michelle.sculley@noaa.gov
ISC/17/BILLWG-1/04	Evaluating stock structure hypotheses for swordfish (*Xiphias gladius*) in the Pacific Ocean using size composition statistics of Taiwanese distant water longliners Yi-Jay Chang, Chi-Lu Sun, Min-Sian Su, Nan-Jay Su, Su-Zan Yeh yjchang@ntu.edu.tw
ISC/17/BILLWG-1/05	Determination of length-at-the first age for the Pacific blue marlin (*Makaira nigricans*) using dual hard-parts of fin-spines and otoliths Yi-Jay Chang, Xu-Bang Chang, Chi-Lu Sun yjchang@ntu.edu.tw
ISC/16/BILLWG-1/06	Environmental effects on the spatial distribution of swordfish as inferred from data for the Taiwanese distant-water tuna longline fishery in the Pacific Ocean Nan-Jay Su, Chi-Lu Sun, Jia-Hao Chang, Yi-Jay Chang, Su-Zan Yeh nanjay@ntou.edu.tw