FINAL

ISC/21/ANNEX/08

ANNEX 08

21st Meeting of the
International Scientific Committee for Tuna
and Tuna-Like Species in the North Pacific Ocean
Held Virtually
July 12-21, 2021

REPORT OF THE BILLFISH WORKING GROUP WORKSHOP

July 2021

Left Blank for Printing

ANNEX 08

REPORT OF THE BILLFISH WORKING GROUP WORKSHOP

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

9-11, 16 March 2021 (JST)
Virtual Meeting

1. OPENING AND INTRODUCTION

1.1. Welcoming Remarks

Hirotaka Ijima, the Billfish Working Group chair, opened the workshop meeting. Scientists from Chinese Taipei, Japan, United States of America (USA), Pacific Community Oceanic Fisheries Program, and the Inter-American Tropical Tuna Commission (IATTC) participated in the meeting. The participating scientists are listed in Attachment 1.

1.2. Introduction

The Billfish Working Group (WG) of the International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean (ISC) held a virtual three-day meeting by webinar. The goals of the meeting were: i) review the progress of the Pacific blue marlin stock assessment, ii) discuss the rebuilding plan for North Pacific striped marlin, iii) discuss the stock boundary of swordfish in the North Pacific, and iv) discuss the request from WCPFC Commission.

1.3. Standard Meeting Protocols

The WG chair introduced protocols for the webinar meeting. Cisco Webex was used for this meeting, and the working papers on the agenda were presented and discussed.

2. ADOPTION OF AGENDA AND ASSIGNMENT OF RAPPORTEURS

Prior to the meeting, The WG adopted the draft agenda of the meeting (Attachment 2). The WG chair assigned the numbers for the working papers (Attachment 3) and the rapporteurs for the four agenda items as follows:

Working paper	Item	Rapporteur
ISC/21/BILLWG-01/01	5	M Kanaiwa, M Kinney
ISC/21/BILLWG-01/02	5	M Kanaiwa, M Kinney
ISC/21/BILLWG-01/03	4	S Griffiths, A Kurashima
ISC/21/BILLWG-01/04	5	Y-J Chang, N D Barth
ISC/21/BILLWG-01/05	7	M Sculley, Y-J Chang
ISC/21/BILLWG-01/06	6	S Griffiths, H Ijima
Presentation 1	4	J Brodziak, N D Barth
Presentation 2	6	M Sculley, M Kinney

3. NUMBERING WORKING PAPERS AND DISTRIBUTION POTENTIAL

The WG agreed to post the finalized working papers on the ISC website and make them publicly available.

4. REVIEW THE PROGRESS OF THE PACIFIC BLUE MARLIN STOCK ASSESSMENT

Natural Mortality Rates of Pacific Blue Marlin. Jon Brodziak (ISC/21/BILLWG-01/03)

In this working paper, we use meta-analytical approach to estimate the natural mortality rates of Pacific blue marlin (*Makaira nigricans*) by gender and age. The meta-analyses applied both theoretical and empirical models to predict natural mortality rate as a function of life history parameters or observed mortality rates. Life history parameters from two growth models were used to estimate natural mortality rates of female and male Pacific blue marlin in two separate scenarios. The two sex-specific growth models were the old growth model from Chang et al. (2013) and the new growth model from Chang et al. (2020). We evaluated the relative plausibility of fourteen potential models to estimate natural mortality under the old growth model scenario, which was the best scientific information available in the most recent benchmark assessment of Pacific blue marlin (ISC 2013). Of these, seven models were eliminated because they produced implausible parameter estimates or because they were redundant with a more recent model analysis. We used the seven remaining plausible models to estimate sex-specific natural mortality rates under both growth model scenarios. Fixed-effects, random effects, and unweighted-average analyses were applied to a total of seven methods to estimate natural mortality rates. These analyses to combine natural mortality estimates across models were similar to those conducted by Lee and Chang (2013) and included identical assumptions about the precision of life history parameters for Pacific blue marlin that were applied to weight the various estimates of adult natural mortality rates. We scaled the estimates of adult natural mortality rates of female and male blue marlin to estimate juvenile natural mortality rates using an allometric relationship between natural mortality and body weight due to Lorenzen (1996). This rescaling approach to calculate juvenile natural mortality was similar to that used by Lee and Chang (2013). Under the old growth model scenario, the results of the meta-analysis indicated that there was no detectable heterogeneity in effect sizes among the seven estimators for both genders. In comparison under the new growth model scenario, some heterogeneity in effects sizes was found but the point estimate of adult female natural mortality based on a random effects analysis were implausibly high. As a result, the fixed-effects meta-analyses were applied to predict the adult natural mortality rates of Pacific blue marlin under both growth model scenarios.

Under the old growth model scenario based on growth parameters from Chang et al. (2013), the results indicated that the combined estimates of adult natural mortality rates for females and males were $M_{F,4+} = 0.20$ and $M_{M,1+} = 0.38$, which corresponded to adult ages of age-4 and older for females and age-1 and older for males with 95% prediction intervals of $(0.17, 0.22)$ and $(0.34, 0.43)$, respectively. The scaled estimates of juvenile natural mortality rates at ages 0 to 3 for females were $M_{F,0} = 0.44$, $M_{F,1} = 0.38$, $M_{F,2} = 0.32$, and $M_{F,3} = 0.26$, respectively, while for males, the scaled estimate of the natural mortality rate at age-0 was $M_M = 0.44$. The coefficients of variation for the adult female and male natural mortality rates based on the old growth model were 5.5% and 4.4%, respectively.

Under the new growth model scenario based on growth parameters from Chang et al. (2020), the results indicated that the combined estimates of adult natural mortality rates for females and males were $M_{F,4+} = 0.30$ and $M_{M,1+} = 0.35$, which corresponded to adult ages of age-4 and older for females and age-1 and older for males with 95% prediction intervals of $(0.28, 0.32)$ and $(0.31, 0.40)$, respectively. The scaled estimates of juvenile natural mortality rates at ages 0 to 3 for females were $M_{F,0} = 0.41, M_{F,1} = 0.35, M_{F,2} = 0.33$, and $M_{F,3} = 0.32$, respectively, while for males, the scaled estimate of the natural mortality rate at age-0 was $M_M = 0.41$. The coefficients of variation for the adult female and male natural mortality rates based on the new growth model were 2.5% and 4.9%, respectively.

<u>Discussion</u>

The WG asked about the two-stage growth curve presented at the last ISC BILLWG meeting and if the parameters from that analysis had been included in this research. The author indicated that he did not use the two-stage growth curve presented at the last meeting as the parameters from that growth curve where not available to him. The two-stage growth curve author indicated he could share the parameters so such an analysis could be done. **The WG agreed that an analysis with the two-stage growth curve would be done and the natural mortality estimates based on the two-stage growth curve were submitted during the meeting** (see Table 1).

It was noted that the t_0 of -4 in the presentation seems very low for such a fast going species, and as such it would flatten the growth curve (e.g. reduce K) leading to a low M. The author indicated that a t_0 of -4 is quite low but it indicates the nature of the fishery, in that very few individuals age 0 or even age 1 are caught. The author answered that the k parameter and its usefulness to M are likely mostly influenced by the adults but it is true that some influences from t_0 are inherent but not of great concern.

For female natural mortality, it was noted that some of the estimates have quite different standard errors, but for males, the errors were more consistent, what is the reason for this? The author indicated that the range of the errors coming out of the estimates come directly from the parameter estimates for key life history variables. The WG asked if the scale of input values led to more variation in the estimates. The author indicated that based on the equations used, the different input variables will affect the range of predicted values. This would mean that scale, as well, as how the equation treats the parameter, could alter the natural mortality estimates. The WG asked if a normal distribution was assumed for each variable and the meta-analysis output. The author indicated that normalcy was assumed and that in the assessment it is likely that M will be a fixed value, which means this assumption will not have a large impact.

The WG asked if the author had seen the Then et al (2015) analysis of M as it indicates that certain empirical estimates are "best" (and has some re-parameterizations for some) and it was asked if some of those could be used here. The author indicated that it was unlikely this would make much of a difference, but if this information could be shared, the author could look into it.

The WG had some follow-up discussion after this presentations discussion section about the use of values for the two-stage growth model in the presented mortality analysis. There were some concerns about the marked difference in parameter estimates from the old growth model from the 2016 assessment to those from the two-stage analysis. After some misunderstandings it was understood which parameters should be used (which were not as different from the old growth parameter estimates) and the analysis will go forward.

Current Progress on the 2021 Pacific BUM Assessment. Michelle Sculley (Presentation 1)

An update on the current progress of the 2021 Pacific BUM stock assessment was presented. Two base-case model options were presented, one using the parameters from the 2016 BUM assessment ("Old Growth") and one using the growth parameters estimated by Chang et al and presented at the BUM Data Prep meeting in November ("New Growth"). The old growth model indicates that there are still some concerns about fits to size data and CPUE indices, with conflicts between the TWN longline and HI longline indices. The new growth model has fewer conflicts but similar concerns remain. Several steps forward were suggested to the working group for consideration and recommendation. These included adjusting the effective sample size minimum for size data, excluding some years of TWN size data, eliminating HI longline index, and how to address the problem with recruitment driving the initial population size estimates.

Discussion

The WG discussed the length composition data for the Taiwanese longline fleet. In 2016 assessment, Taiwanese longline the WG used length composition data that began in 2005. It was noted that this SS3 model used the data from 1980, but earlier data may have quality issues. Thus, it should be dropped. The WG also discussed data weighting for the length composition data. The author wanted to get feedback on the minimum sample size threshold used (15 vs. 25). This item still needs to be discussed by the working group via email.

The WG discussed the conflict between CPUEs. This SS model includes US longline CPUE but the last stock assessment did not use it because the residuals of US Hawaii longline CPUE showed historical patterns and conflict in the R_0 profile. The WG acknowledged that weighting between the CPUEs would need to be conducted in the upcoming stock assessment.

It was noted that there is still a residual pattern in the length composition data. The WG also has to address the concern that the R0 profile indicates the strong influence of a fixed parameter (recruitment deviations) but should mainly be driven by the data (length comp/ CPUE).

The WG noted that the CV for the size at age of large fish was estimated from the growth model and was much smaller than the last stock assessment. The WG recommends keeping the CVs the same as before, even if we change the other growth parameters. The author answered that it would use the old CV values with the new growth parameters.

The difficulty to comment on issues in detail without having checked the model settings was noted. However, the current models with the new growth appear better than the old ones. **The WG members agreed to develop the SS model sharing the input files between the US, Taiwan, and Japan to discuss the issues carefully intersessionally. The development of the model will continue via sharing the input files on the WG google drive.**

The WG discussed the recruitment deviations before the starting year (1960-1970). The SS model assumes the equilibrium recruitment during this period. The WG noted a need to fix the strong residual pattern in early recruitment. It was suggested to set the simple deviation model in the early model development, and when the conflicts improve, the full bias adjustment will then be addressed. The WG noted that important to consider the impacts of other longline fisheries on blue marlin recruitment prior to the model start period. The recruitment at the start of this model may not be at equilibrium.

The WG confirmed the developing model process. **In the data preparatory meeting of the Pacific blue marlin stock assessment, the WG agreed to fit two growth curves (Chang et al., 2013 and Chang et al., 2020) to the data, evaluate model diagnostics, and choose the most appropriate growth curve for the base case model.**

5. REBUILDING PLAN FOR THE NORTH PACIFIC STRIPED MARLIN

Correction to the US Hawaii Longline Striped Marlin Catch from Years 2010–2017. Michelle Sculley (ISC/21/BILLWG-01/01)

An error was found in the 2019 striped marlin stock assessment catch data. The US Hawaii longline catch from 2010 to 2017 used in the 2019 stock assessment included the entire North Pacific rather than just the western and central North Pacific area west of 150°W that is the WCNPO striped marlin stock area. This document aims to explain how the working group estimated the catch for the US Hawaii longline fleet and provides the corrected catch from 2010 to 2017.

<u>Discussion</u>

The WG agreed to revise the US Hawaii longline catch of striped marlin for SS.

Update to the 2019 Western and Central North Pacific Ocean Striped Marlin Stock Assessment Michelle Sculley (ISC/21/BILLWG-01/02)

An error was found in the 2019 western and central North Pacific Ocean (WCNPO) striped marlin (*Kajikia audax*) stock assessment catch data. The US Hawaii longline catch from years 2010–2017 included the entire North Pacific rather than just the western and central North Pacific area west of 150°W that was assessed. This document provides the results of the 2019 North Pacific striped marlin stock assessment with the corrected US Hawaii longline catch and a comparison with the original 2019 striped marlin assessment.

<u>Discussion</u>

The WG noted Japanese catch statistics also will change and that would require rerunning the assessment. **The WG agreed that a new benchmark assessment should be performed in 2022 to address many of the changes proposed to the model.**

Some Rebuilding Analyses for the Western and Central North Pacific Ocean Striped Marlin Stock Jon Brodziak (ISC/21/BILLWG-01/04)

In this working paper, we describe analyses and stochastic stock projections to develop an interim rebuilding plan for the Western and Central North Pacific Ocean (WCNPO) striped marlin stock. This stock is currently estimated to be depleted and experiencing excess fishing mortality relative to maximum sustainable yield-based reference points. The projection analyses described in this working paper are based on a January 2021 revision of the benchmark 2019 stock assessment of WCNPO striped marlin. The revised 2021 stock assessment was conducted to incorporate minor corrections to the catch time series for the USA longline fleet during 2010-2017 with all other assessment data inputs being the same as used in the 2019 benchmark assessment. The interim rebuilding plan has the goals of rebuilding the spawning biomass of the stock to 20% of the unfished level, or 20%$SB_{F=0}$ = 3,493 mt, within a rebuilding time horizon of up to 15 years (2020-2034) and with a probability of rebuilding success of least 60%. There are three management strategy scenarios developed for these rebuilding analyses: a phased scenario, a constant fishing mortality scenario, and a constant quota scenario. The phased rebuilding scenario was designed to gradually reduce harvest quotas for the aggregate international longline fleet in order to rebuild the stock by 2034 and provide some periods of stable annual catch quotas for reducing fishing mortality on striped marlin. The constant F scenario was designed to determine the constant fishing mortality rate and associated fishing effort to be applied during 2022-2034 to rebuild the stock with at least 60% probability by 2034. Similarly, the constant quota scenario was designed to determine the constant catch biomass quota to be applied during 2022-2034 to rebuild the stock with at least 60% probability by 2034. Given the projected catch quotas and spawning biomasses to meet the rebuilding goals, the probabilities of rebuilding the stock were calculated for each of the rebuilding scenarios. The results of the rebuilding analyses showed that, under the phased scenario, the rebuilding probabilities increased from P=0.05 in 2022 to P=0.60 in 2034. In comparison, the rebuilding probabilities under the constant F scenario increased from about P=0.07 in 2022 to P=0.60 in 2032. Similarly, under the constant quota scenario, the rebuilding probabilities increased from P=0.07 in 2022 to P=0.60 in 2034. Last, we discuss some of the key characteristics and uncertainties of the three harvest scenarios to rebuild the WCNPO striped marlin stock.

Discussion

The WG members asked if it current interim rebuilding plan of the goals of rebuilding the spawning biomass of the WCNPO MLS stock to 20% of the unfished level could reflect the potential productivity shift that has been identified for the WCNPO striped marlin (Chang et al., 2020). The author noted there is a good reason to examine dynamic SSB_0 for the WCNPO MLS stock since the stock productivity may have changed over time. However, the WG noted there is no clear instruction by the WCPFC NC and WCPFC commission about what types of rebuilding targets (SSB_0 versus dynamic SSB_0) should be conducted.

Noting that the fishing mortality estimates have been higher than the F_{MSY} for a long time, a WG member stated that it is important to characterize the impacts of excess catch on the stock trajectory and what the fishing members could do on the relative change of fishing mortality or catch in terms of stock conservation.

There were concerns about the potential for inconsistencies in the modeling time-step between the stock assessment model (SS, seasonal) and the rebuilding model (AGEPRO, annual) and the uncertainty estimated in the numbers-at-age between the bootstrap method and the delta method (Hessian matrix). One WG member noted it may be necessary to adjust for the difference between the bootstrap 95% CI and the 95% CI from the hessian because bootstrap results appears to depart from normality (Ijima 2019, Stewart et al., 2013).

The WG also discussed how the recruitment in 2018 should be treated in the rebuilding analyses because there is little data to inform the estimation of the 2018 recruitment, but no consensus was reached at the meeting. The one of WG members noted that 2018 recruitment is estimated from the spawner-recruitment relationship and is higher than recent recruitment. This has an impact on projections and may be optimistic. However, these stochastic projections did not use a spawner-recruitment relationship as agreed on by the WG in the benchmark assessment. The author responded that the above issues could be resolve by additional analyses, but it would not be possible to resolve the issues during this meeting, and it should be considered as a longer-term project of the ISC BILLWG.

The author noted that although the proposed rebuild analysis is based on the 2019 assessment model with the corrected USA catch, the WG members did not have enough time to discuss this analysis in detail because of the time constraints.

The WG also noted several issues that were raised about the 2019 MLS assessment during this meeting and in the 2019 WCPFC SC meeting. Therefore, the WG recommended having a benchmark assessment meeting for the WCNPO MLS stock in March 2022 and an additional MLS rebuilding analyses meeting in April 2022.

The WG requested that the WCPFC NC and commission provide a clear definition for the unfished rebuilding target (20%$SSB_{F=0}$). Clarification was needed on the definition of 20%$SSB_{F=0}$ from WCPFC NC and if a dynamic SSB0 was requested, then the target year for rebuilding would also be required. The WG will provide a summary the above comments to the WCPFC NC and commission as a list of comments about the current rebuilding analyses, which will be discussed at the next WG meeting.

6. STOCK BOUNDARY OF SWORDFISH IN THE NORTH PACIFIC

Stock structure of swordfish in the Pacific Ocean 1st TECHNICAL WORKSHOP ON S EPO SWORDFISH. Carolina Minte-Vera (Presentation 2)

IATTC stock assessment scientist, Carolina Minte-Vera, presented an overview of the discussions at the 1st technical workshop on swordfish in the southern Eastern Pacific Ocean (EPO) (held virtually on 15-17 December 2020), with an emphasis on stock structure. Her presentation concluded with a proposal from the IATTC staff for the ISC BILL WG to consider with regards to defining new boundaries of the northern EPO stock in light of new information arising from the workshop.

The objectives of the workshop included to undertake review of the current state of knowledge of the swordfish stock in the southern EPO and to construct a conceptual model of the structure and dynamics of the population and its associated fisheries. The workshop was attended by 52 external participants and 22 IATTC staff. The external participants were scientists from national fisheries agencies and the SPC, experts on the biology, ecology and fisheries of swordfish, representatives from government agencies, the fishing industry, non-governmental organizations, IATTC CPCs (including ISC members such as Japan and Chinese Taipei), and WCPFC Member countries, including Australia and New Zealand.

Regarding stock structure, several genetic, biological and tagging studies were summarized. The most recent results from a long-term electronic tagging study by Chugey Sepulveda and Scott Aalbers of the Pfleger Institute of Environmental Research (PIER) showed swordfish tagged off California frequently moved across the existing stock boundary currently assumed for swordfish in the North Pacific Ocean. Most tagged swordfish moved seasonally from California into either the EPO stock area (to the south or southeast along Baja California and towards the equator) or the Western and Central North Pacific (WCNP) management unit (to the west or southwest towards the Hawaiian Islands). The PIER team recently developed a methodology for dorsal fin-mounting of Argos transmitting tags to swordfish, which resulted in multi-year tag deployments that has not been possible with previously used tagging methods. These long-term deployments have now greatly increased our understanding of inter-annual movements and stock structure of swordfish in the EPO. The conceptual model for the southern EPO was presented, which was largely based on decades of research by Chilean colleagues, who showed the population to be heavily influenced by the state of the Humboldt Current. Swordfish show seasonal movement from assumed coastal foraging areas, where frontal areas with high productivity occur, to the offshore and tropical areas, where spawning occurs. The tagging data collected off California suggests a similar seasonal movement pattern occurs in the northern EPO, where the California current is the primary factor influencing movement. Analysis of CPUE data supported the conceptual model in that offshore areas have higher CPUE in the boreal summer in the northern hemisphere and in the Austral summer in the Southern hemisphere. The equatorial area had highest CPUE during quarters 1 and 2, indicating a possible alternate use of those areas by the northern and southern EPO swordfish.

The 2011 IATTC southern EPO swordfish assessment defined the stock as being the area south of 5°S and east of 150°W. The IATTC will assess this stock in 2021, but will consider the inclusion of areas between 5°S and 10°N in the assessment, either in the base case or in sensitivity analyses, due to the increase in catches in that area in recent years (Figures 1 and 2). The IATTC presented a proposal that the "triangle" area north of 10°N (the white area in Figure 1) be included in future assessments of the northern EPO swordfish stock.

<u>Discussion</u>

The WG discussed the current stock boundaries of the three putative swordfish stocks in the Pacific Ocean and how to address the areas not currently included within the boundaries of those stocks. The WG does not currently include the area south of California and north of 10°N in the WCNPO swordfish assessment area. The catches the industrial longline fleet in this area does not appear to be large relative to the WCNPO area, but the industrial and artisanal Mexican longline fleet fishes in this region and catches of swordfish are unknown but may be substantial. Catch from these Mexican fisheries are currently not required to be reported to the IATTC as vessels are generally licensed to catch sharks and billfishes are an apparent non-targeted species. It will be important for the ISC to invite Mexican scientists to collaborate on the swordfish assessment to provide the WG with catch data, or at least guidance on indicative catches of swordfish in this region.

The WG also discussed the equatorial area (south of 10°N). There is a hypothesis that both north and south EPO stocks might mix in the equatorial area for foraging. In addition, recent catches may be from north of the equator. However, the IATTC and ISC BILLWG may need to undertake further studies, such as electronic tagging to resolve this hypothesis. Alternatively, the WG might be able to undertake sensitivity analyses in the stock assessment to explore this issue further.

The WG noted that hotspots of swordfish catches occur between 150°W to 160°W and asked why the east-west boundary for SWPO and SEPO swordfish stocks is set at 150°W degrees. It was noted there is not a lot of information on the potential extent of mixing between the different assessment regions and this hotspot. The author answered that IATTC also discussed this topic in their workshop. IATTC proposes to undertake a sensitivity analysis to include some of the catch west of this boundary.

The WG agreed that SWO move across the previous stock boundary north of 10°N as indicated by the latest electronic tagging data (Sepulveda et al., 2020).

The WG agreed that since the southern EPO SWO stock extended to 10°N, the "triangle" area near Mexico that was not included in the ISC or IATTC stock assessments would be included in the WCNPO stock assessment. The WG could address the catch in this area in two ways: 1. Treat the northern EPO area using fleets-as-areas in a North Pacific wide

assessment or 2. Develop a two-region North Pacific SWO assessment using tagging data to estimate movement across the stock boundary.

The WG agreed that a more detailed analysis would need to be undertaken to incorporate fully the newest data on swordfish stock boundaries in order to produce a scientifically supported new stock boundary.

Also, the WG agreed to include catches in the area not included in the ISC, IATTC, and WCPFC stock assessments (an area bounded by 0°-10°N and 150°W-165°W) using sensitivity analyses.

Movement ecology of swordfish (Xiphias gladius) in the northwestern Pacific Ocean using electronic tags and stable isotope analysis. Wei-Chuan Chiang, Shian-Jhong Lin, Qi-Xuan Chang, Ching-Tsun Chang, Michael K. Musyl, Yuan-Shing Ho (ISC/21/BILLWG-01/06 rev1)

Swordfish (*Xiphias gladius*) is a highly migratory apex predator distributed from tropical to temperate oceans. The objective of this research is to use a combination of stable isotope analysis (SIA) and electronic tagging experiments to identify swordfish trophic position and movement behavior in eastern Taiwan. In total, 165 swordfish muscle samples (59-210 cm eye-orbit fork length, EFL) were examined for trophic position and population dynamics. δ15N and δ13C values for swordfish ranged from 7.9 to 14.3‰ and -18.9 to -15.4‰, respectively, and were all positively correlated with size. Mid-water prey species were major food resources for swordfish (e.g., Cephalopoda and Bramidae spp.) diet, which was highly diverse. Three swordfish were tagged pop-up satellite archival tags (PSATs) and tags remain affixed from 14 and 229 days-at-liberty. From the tagging location in eastern Taiwan, pop-up locations ranged northwards to the East China Sea, southwest to the South China Sea and another to the southeast off the Philippines. The total linear displacements were from 631 to 1,605 km from deployment to pop-up locations and the fish demonstrated pronounced diel vertical movement patterns reaching daytime of depths >400 m (15–20°C) and occupying the surface mixed layer <100 m at nighttime (occasionally experiencing temperatures of 32.9°C). Distributions of time spent at depth were significantly different between daytime and nighttime where fish displayed a regular crepuscular pattern of ascending into the surface layer at dusk and remaining there until the following dawn where the fish descended past the mixed-layer depth. This pattern has been reported previously and suggests swordfish follow the diel vertical migrations of prey organisms comprising the deep sound scattering layer to exploit them effectively as a resource. Because of its unique physiological and morphological adaptations (such as vascular counter current heat exchangers), swordfish can search for food resources more effectively in cooler temperatures and exploit more resources of the water column than other fishes.

Discussion

The WG acknowledged that the stomach content analysis was incomplete, but a suggestion was made that the authors consider using the classification and regression tree approach from Leanne Fuller (IATTC) to determine statistically at what sizes swordfish diets change, rather than creating size class categories a priori to compare diets.

The WG noted the high proportion of the diet that was comprised of “unidentified fishes” due to billfishes having rapid digestion rates. He stated that these data are not helpful when analyzing the data, especially for use in ecosystem models. The member then asked if the authors could remedy this problem by identifying prey using otoliths. The presenter agreed with this suggestion and said his colleagues had recently finished stomach content analysis for bigeye tuna using otoliths to identify highly digested prey. The author said they would take the same approach when analyzing the swordfish diets.

7. JAPANESE FISHERY STATISTICS AND MISTAKE IN THE WCNPO MLS SS FILE

The quality of Japanese catch statistics and reports of mistake in the SS3 model for the Western Central North Pacific striped marlin. Hirotaka Ijima (ISC/21/BILLWG-01/05)

In order to verify a stock assessment of the Western Central North Pacific striped marlin, this paper confirmed the quality of the Japanese catch statistics. The high seas driftnet and longline fisheries were focused. The driftnet catch was estimated again using the original landing note written by the prefecture government staff and some vessels' logbook data. For longline catch, the result of the Stock Synthesis 3 model was compared with the statistics submitted to the WCPFC. The estimated driftnet catch is still a tentative value, as it has to be checked for consistency with other species, but the statistics so far may have been underreported. Thus, the ISC billfish working group needs to consider its impact on the WCNPO striped marlin stock assessment. Longline catches are generally similar, except during periods when training vessel catches were not reported to the WCPFC. I also found an input error about a growth curve in the stock assessment model. In general, the growth curve has a significant influence on the stock assessment results. Therefore, the ISC billfish working group must recalculate the stock synthesis model using a correct assumption of striped marlin growth.

Discussion

There was significant discussion on the error in the growth curve from Japan. It was noted that the input parameters for the growth curve were correct, but SS sets the size at age-0 to be the smallest bin size, which is 50cm, while the Sun et al., 2011 paper estimates a size at age-0 to be 92cm. This would change the shape of the estimated growth curve, and should be explored in the next assessment.

The WG agreed that for the Japanese longline fisheries, using fishery catch in numbers would be more accurate for future assessments than using catch in weight because catch in weight is estimated from semi-dressed weight using a conversion factor. It was noted that within the assessment model, catch in numbers is converted to catch in weight using representative size samples from the fishery, of which Japan has substantial data.

The WG noted that the difference between the Japanese catch reported to WCPFC and to ISC are different because catches are estimated. ISC BILLWG catch in weight is estimated from SS while the WCPFC catch in weight is estimated by Japanese data managers from catch in numbers.

Additionally, prior to 2000, catches reported to WCPFC did not include Japanese training vessel catches but these catches are included in the ISC BILLWG catch.

8. OTHER ITEMS

The WG discussed the request from WCPFC commission.

> *The Commission requested the ISC to:*
>
> *i) examine differences between ISC stock assessment catch estimates by CCM and WCPFC catch estimates, and work with the Scientific Services Provider to provide an assessment of the shortcomings; ii) provide explanation why the striped marlin stock decreased and the fishing mortality increased after a drastic decrease in fishing effort by high seas driftnet fisheries in the early 1990s; and iii) develop a roadmap to address the issues identified in the latest stock assessment by ISC.*

i) Examine differences between ISC stock assessment catch estimates by CCM and WCPFC catch estimates, and work with the Scientific Services Provider to provide an assessment of the shortcomings

The WG discussed the working paper ISC/21/BILLWG-01/05 and concluded that WCPFC Japanese longline fishery statistics and the output from SS are similar. These two catch weights were estimated using different methods and therefore the values differ slightly.

SPC noted that for longline fisheries where the catch is recorded as numbers it is not surprising that when converted to biomass (mt) the WCPFC biomass catch estimates and the SS biomass catch estimates are different. This is due to the different approach taken for converting numbers to biomass for the WCPFC catch estimates and for the stock assessment, whether it is SS or MFCL. The WCPFC catch estimates are converted from numbers to biomass using a simple conversion using the average weight of the individuals caught on that trip or within the reporting strata. In the stock assessment, the catch in biomass is a product of the numbers caught, the fishery selectivity function, and the weight-at-age of individuals. Though these methods will produce catch estimates in biomass that are similar, it is reasonable and expected that some differences will exist. When conducting the stock assessment it is important to account for potential conversion error by using the catch in the original recorded units, which for longline fisheries is in terms of numbers.

ii) Provide explanation why the striped marlin stock decreased and the fishing mortality increased after a drastic decrease in fishing effort by high seas driftnet fisheries in the early 1990s

The WG group discussed why the fishing mortality increases in 1994 despite the loss of large catch from the Japanese driftnet. The WG members that this could be caused by multiple factors: 1.) The model assumes that the selectivity for Japanese driftnet catches in 1975-1993 have the same selectivity as those in the Japanese coastal driftnet fishery from 1994 to 2017, although there is no size data available from 1975-1993. This selectivity targets large adult striped marlin, which means that the model is assuming the majority of the catch from 1975 to 1993 is large adult fish. In 1994, the majority of the catch is from CCM longline fleets, which catch predominately juvenile striped marlin. This assumed shift from catching large adults to small juveniles would result in an increase in fishing mortality even if the overall catch has decreased. 2.) The CPUE time series has a break in 1993 to 1994, which could be driving a shift in the model results due to a lack of continuity. 3.) The Japanese logbook data also change their reporting requirements in 1993 to 1994, which could contribute to the shift in fishing mortality, however not all CCMs agreed that this would drive the change in fishing mortality.

The WG noted that excluding data prior to 1994 in the MLS assessment was explored in the 2019 assessment meeting. The WG compared two models that started in 1994. A sensitivity run fixing the initial equilibrium catch (run 22, MLS SAR, ISC 2019, Figure 3 a) showed no difference in the base-case model results. In contrast, estimating the initial equilibrium catch (Model 2 in the Carvalho, et al. 2019, Figure 3 b) resulted in the same trend but produced different estimates of initial population size. One WG member noted that SSB_0 was strongly associated with the initial equilibrium catch. However, the WG did not have strong information to justify setting the initial catch (5,000mt). **The WG agreed to estimate the initial equilibrium catch in the stock assessment model, and agreed that differences due to starting year were likely driven by the uncertainty in catches before 1993.**

iii) Develop a roadmap to address the issues identified in the latest stock assessment by ISC

The WG suggested that the WG revise the work plan to assess WCNPO striped marlin in 2022 and postpone commencement of the NP swordfish assessment to 2023 to address many of the concerns both presented in this meeting and highlighted in the 2019 MLS SAR. For example, there were concerns about providing a rebuilding plan in 2021 and then reassessing the stock in 2022 (Table 2). However, it was noted that the rebuilding plan would be updated after each assessment, and that the rebuilding plan should be presented to managers noting that the WG plans to run a new benchmark assessment in 2022 and and also plans to update the rebuilding plan accordingly.

9. CIRCULATE WORKSHOP REPORT

The WG Chair prepared a draft workshop report and reviewed it with the WG members. The provisional report was editorially revised by the WG Chair and distributed via email for WG members to finalize.

10. ADOPTION

The WG adjourned the BILLWG workshop meeting at 11:56am on 16 March 2021 (JTS). The WG Chair expressed appreciation to the participating scientists for their collaboration in the stock assessment work.

11. REFERENCES

Andrews, A.H., Humphreys Jr, R.L. and Sampaga, J.D., 2018. Blue marlin (*Makaira nigricans*) longevity estimates confirmed with bomb radiocarbon dating. Canadian Journal of Fisheries and Aquatic Sciences, 75(1), 17-25.

Brodziak, J., 2013. Combining Information on Length-Weight Relationships for Pacific Blue Marlin. ISC/13/BILLWG-1/01.

Brodziak, J., and Mangel, M., 2011. Probable values of stock-recruitment steepness for north Pacific striped marlin. ISC/11/BILLWG-2/11.

Brodziak, J., Mangel, M., and Sun, C.L., 2015 Stock-recruitment resilience of North Pacific striped marlin based on reproductive ecology. Fisheries Research, 166, 140-150.

Carvalho, F., Kapur, M., and Ijima H. 2019. Comparison between Preliminary Stock Synthesis Models for the 2019 WCNPO Striped Marlin Stock Assessment. ISC/19/BILLWG-2/04.

Chang, Y.J., Lee, H.H., Brodziak, J., DiNardo, G., and Sun, C.L., 2013. A Bayesian hierarchical meta-analysis of blue marlin (*Makaira nigricans*) growth in the Pacific Ocean. ISC/13/BILLWG-1/02

Chang, Y.J., Shimose, T., Kanaiwa, M., Chang, X.B., Masubuchi, T., Yamamoto, A., Kanaiwa, M., 2020. Estimation of the two-stanza growth curves with ageing uncertainty for the Pacific blue marlin (*Makaira nigricans*). ISC/20/BILLWG-02/03

Chang, Y.J., Winker, H., Sculley, M., Hsu, J., 2020 Evaluation of the status and risk of overexploitation of the Pacific billfish stocks considering non-stationary population processes. Deep Sea Research Part II: Topical Studies in Oceanography, 175, 104707.

Ijima H., 2019. Update of future projection program SSfuture C++. ISC/19/ALBWG-02/07.

ISC. 2019. Stock assessment report for Striped marlin (*Kajikia audax*) in the western and central North Pacific Ocean. ISC/19/ANNEX/11.

Lee, H.H and Chang, Y.J., 2013. Age-structured Natural Mortality for Pacific Blue Marlin Based on Meta- analysis and an Ad Hoc Model. ISC/13/BILLWG-1/07.

Sepulveda CA, Wang M, Aalbers SA, Alvarado-Bremer JR., 2020. Insights into the horizontal movements, migration patterns, and stock affiliation of California swordfish. Fisheries Oceanography 29 (2), 152-168.

Shimose T., Fujita M., Yokawa K., Saito H., and Tachihara K., 2009 Reproductive biology of blue marlin *Makaira nigricans* around Yonaguni Island, southwestern Japan. Fisheries Science, 75 109-119.

Stewart, I. J., A. C. Hicks, I. G. Taylor, J. T. Thorson, C. Wetzel, and S. Kupschus. 2013. A comparison of stock assessment uncertainty estimates using maximum likelihood and Bayesian methods implemented with the same model framework. Fisheries Research 142, 37–46.

Sun, C.L., Chang, Y.J., Tszeng, C.C., Yeh, S.Z., and Su, N.J., 2009. Reproductive biology of blue marlin (*Makaira nigricans*) in the western Pacific Ocean. Fishery Bulletin. 107:420-432.

Sun, C. L., Hsu, W. S., Chang, Y. J., Yeh, S. Z., Chiang, W. C., and Su, N. J., 2011. Age and growth of striped marlin (*Kajikia audax*) in waters off Taiwan: A revision. ISC/11/BILLWG-2/07.

Then, A. Y., Hoenig, J. M., Hall, N. G., Hewitt, D. A., & Handling editor: Ernesto Jardim., 2015. Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. ICES Journal of Marine Science, 72(1), 82-92.

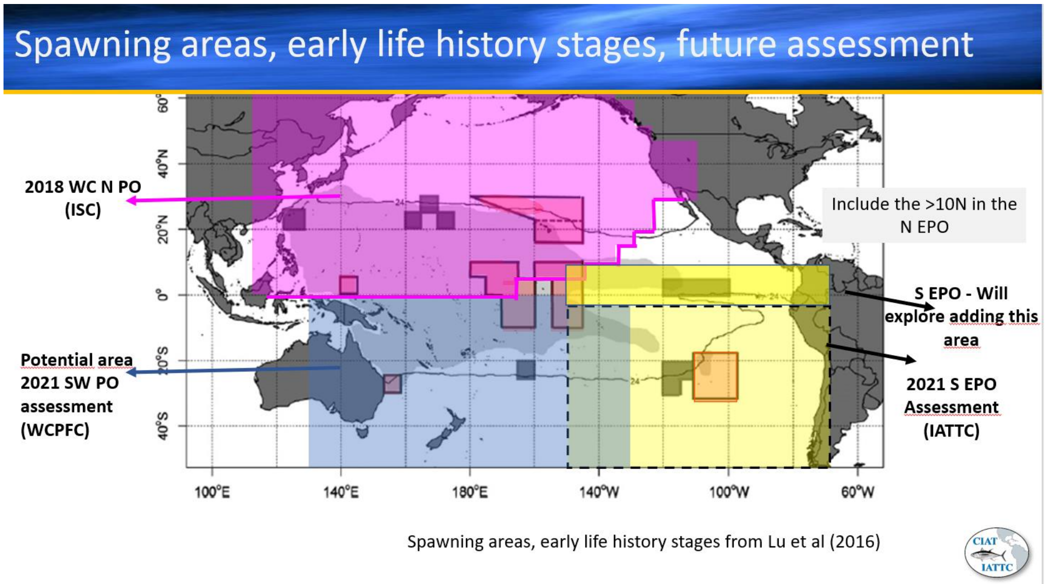


Figure 1. Known swordfish spawning areas (polygons), regions were early life history stages have been found (gray shaded areas), and the assumed stock boundaries of the previous and upcoming stock assessments of swordfish in the Pacific Ocean.

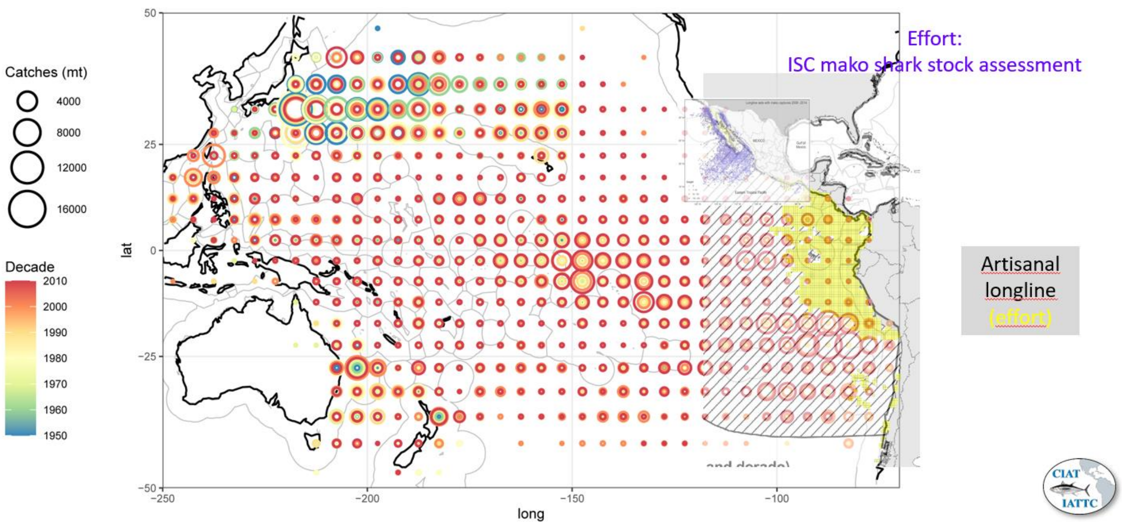
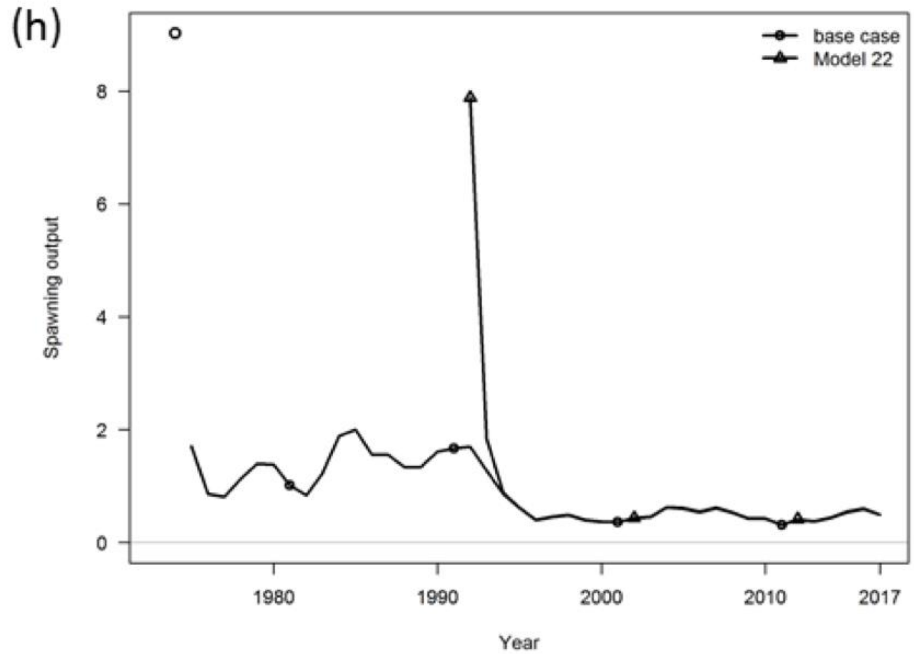


Figure 2. Total reported retained catches by decade of industrial longline fisheries (colored circles) at 5°x5° resolution, and overlays of known effort of domestic commercial and artisanal longline fleets that catch swordfish in the EPO (IATTC presentation).

a



b

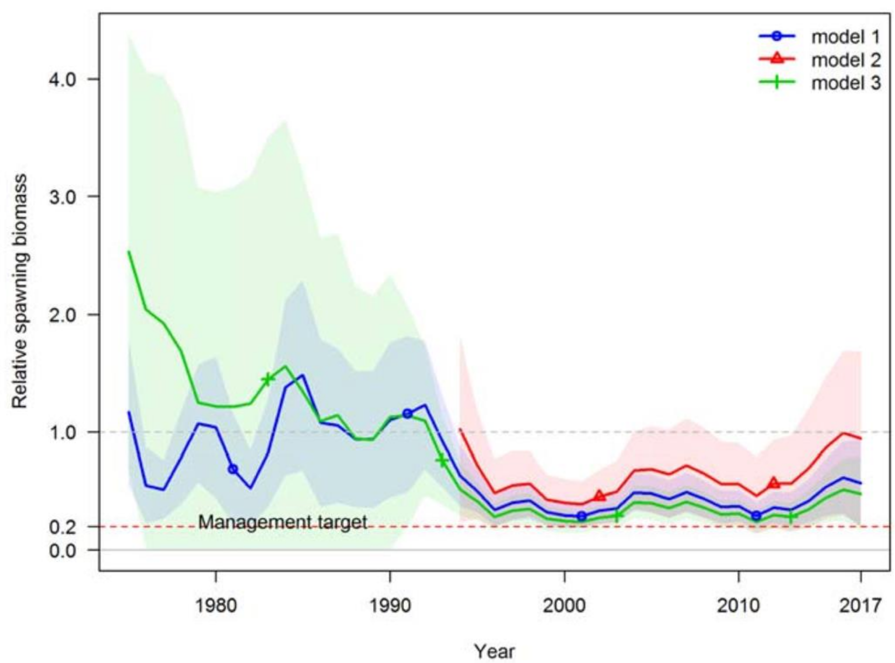


Figure 3. The comparison two models that started in 1994. a: sensitivity run fixing the initial equilibrium catch (Model 22) that y-axis is SSB. b: estimating the initial equilibrium catch (Model 2) that y-axis is SSB/20%SSB_0.

Table 1. Biological parameters for the Pacific blue marlin stock assessment models. Values will be added to shaded cells before commencement of the stock assessment meeting.

Parameter	2016 base	Alternative	Reference
Growth_Age_for_L1	1	0.5	Chang et al. (2013), Chang et al (2020)
Growth_Age_for_L2	26	20	Chang et al. (2013), Chang et al (2020) Andrews (2018)
NatM _Fem_GP_1	M_0=0.42, M_{1-3}=0.37, M_{4+}=0.22	M_0=0.41, M_1=0.35, M_2=0.33, M_3=0.32, M_{4+}=0.3	Lee and Chang (2013), Brodziak (WP03)
L_at_Amin_Fem_GP_1	144	136.13	Chang et al. (2013) , Chang et al (2020)
L_at_Amax_Fem_GP_1	304.178	249.1	Chang et al. (2013), Chang et al (2020)
VonBert_K_Fem_GP_1	0.107	0.31	Chang et al. (2013), Chang et al (2020)
Richards_Fem_GP_1	-	0.000468	Chang et al (2020)
CV_young_Fem_GP_1	0.14	0.13	Chang et al. (2013), Chang et al (2020)
CV_old_Fem_GP_1	0.15	0.15	Chang et al. (2013), Chang et al (2020)
NatM_Mal_GP_1	M_0=0.42, M_{1+}=0.37	M_0=0.41, M_{1+}=0.35	Lee and Chang (2013), Brodziak (WP03)
L_at_Amin_Mal_GP_1	144	136.13	Chang et al. (2013), Chang et al (2020)
L_at_Amax_Mal_GP_1	226	206.4	Chang et al. (2013), Chang et al (2020)
VonBert_K_Mal_GP_1	0.211	0.18	Chang et al. (2013), Chang et al (2020)
CV_young_Mal_GP_1	0.14	0.2	Chang et al. (2013), Chang et al (2020)
CV_old_Mal_GP_1	0.1	0.1	Chang et al. (2013), Chang et al (2020)
Wtlen_1_Fem	1.84E-05	1.84E-05	Brodziak (2013)
Wtlen_2_Fem	2.956	2.956	Brodziak (2013)
Mat50%_Fem	179.76	179.76	Sun et al. (2009), Shimose et al. (2009)
Mat_slope_Fem	-0.2039	-0.2039	Sun et al. (2009), Shimose et al. (2009)
Fecunditiy	Proportional to spawning biomass	Proportional to spawning biomass	Sun et al. (2009)
Wtlen_1_Mal	1.37E-05	1.37E-05	Brodziak (2013)
Wtlen_2_Mal	2.975	2.975	Brodziak (2013)
Spawning season	2	2	Sun et al. (2009)
R0	-	-	Estimate
Steepness	0.87	0.87	Brodziak and Mangel (2011), Brodziak et al. (2015)

Table 2. Road map for the WCNPO striped marlin stock assessment and rebuilding plan.

Year	Day, Month	Meeting	Remarks
2021	6-10, 12 Apr (JST)	BILLWG Stock Assessment meeting for BUM	
2021	12, July	BILLWG Webinar	
2021	14-19, July	ISC21 Webinar	
2021	11-19, Aug	WCPFC SC Palau	
2021	Sep	WCPFC NC	Confirm the definition of rebuilding target and suggest the change of stock assessment schedule.
2021	Dec	WCPFC Commission	Confirm the definition of rebuilding target and suggest the change of stock assessment schedule.
2021	Dec mid	BILLWG Data preparatory meeting for MLS	
2022	Mar	BILLWG Benchmark Stock Assessment meeting for MLS	
2022	Apr	BILLWG Rebuilding meeting for MLS	
…	…	…	…
2022	Nov	BILLWG Data preparatory meeting for SWO	

ATTACHMENT 1. LIST OF PARTICIPANTS

Chinese Taipei

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

Wei-Chuan Chiang
Eastern Marine Biology Research Center Fisheries Research Institute, Taiwan
wcchiang@mail.tfrin.gov.tw

Jhen Hsu
Institute of Oceanography National Taiwan University, Taipei, Taiwan
jhenhsu@ntu.edu.tw

Japan

Akira Kurashima
Fisheries Resources Institute,
Fisheries Stock Assessment Center
5-7-1 Orido, Shimizu
Shizuoka, Japan 424-8633
akura@affrc.go.jp

Hirotaka Ijima
Fisheries Resources Institute,
Fisheries Stock Assessment Center
2-12-4 Fukuura, Yokohama
Kanagawa, Japan 236-8648
ijima@affrc.go.jp

Minoru Kanaiwa
Mie University, Graduate School of Bioresources
1577 Kurima Machiya cho
Tsu, Mie, Japan 514-8507
kanaiwa@bio.mie-u.ac.jp

Takahito Masubuchi
Mie University, Graduate School of Bioresources
1577 Kurima Machiya cho
Tsu, Mie, Japan 514-8507
0818taka@gmail.com

Tamaki Shimose
Fisheries Resources Institute,
Fisheries Stock Assessment Center
1551-8, Tairamachi, Nagasaki, Nagasaki, Japan 851-2213
shimose@affrc.go.jp

Atsuya Yamamoto
Mie University, Graduate School of Bioresources
1577 Kurima Machiya cho
Tsu, Mie, Japan 514-8507
a_yamamoto@bio.mie-u.ac.jp

United States

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

Felipe Carvalho
NOAA Fisheries, NMFS
Pacific Islands Fisheries Science Center, 1845 Wasp Blvd.,
Honolulu, HI, 96818
felipe.carvalho@noaa.gov

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

Michael Kinney
NOAA Fisheries, NMFS
Pacific Islands Fisheries Science Center, 1845 Wasp Blvd.,
Honolulu, HI, 96818
michael.kinney@noaa.gov

Russell Ito
NOAA Fisheries, NMFS
Pacific Islands Fisheries Science Center,
1845 Wasp Blvd.,
Honolulu, HI, 96818
russell.ito@noaa.gov

SPC

Nicholas Ducharme Barth
Pacific Community Oceanic Fisheries Program
B.P. D5 | 98848 Noumea, New Caledonia | Nouméa, Nouvelle-Calédonie
nicholasd@spc.int

IATTC

Shane Griffiths
Inter-American Tropical Tuna Commission
Ecosystem Program
8901 La Jolla Shores Drive, La Jolla, CA, 92037, USA.
sgriffiths@iattc.org

Carolina Minte-Vera
Inter-American Tropical Tuna Commission
Stock Assessment Program
8901 La Jolla Shores Drive, La Jolla, CA, 92037, USA.
cminte@iattc.org

ATTACHMENT 2. MEETING AGENDA

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

BILLFISH WORKING GROUP (BILLWG)

BILLWG WORKSHOP ANNOUNCEMENT and AGENDA

Meeting Style:	Webinar meeting using Webex The WG chair will inform the link at the day before the meeting.
Meeting Dates:	9:00-13:00, 9-11th, 16th March (Japan Time) 8:00-12:00, 9-11th, 16th March (Taiwan Time) 11:00-15:00, 9-11th, 16th March (New Caledonia Time) 14:00-18:00, 8-10th, 15th March (US Hawaii Time) 16:00-20:00, 8-10th, 15th March (US San Diego Time)
Meeting Goals:	• Review a progress of Pacific blue marlin stock assessment. • Discuss the rebuilding plan for the North Pacific striped marlin. • Decide the stock boundary of swordfish in the North Pacific. • Discuss the request from WCPFC commission.
Meeting Attendance:	Please respond to Hirotaka Ijima (Email: ijima@affrc.go.jp) if you plan on attending this meeting
Working Papers:	Submit working papers to Hirotaka Ijima by March 1st.
BILLWG Contact:	Hirotaka Ijima (Ph.D, ISC BILLWG Chair) Highly Migratory Resources Division, Fisheries Stock Assessment Center, Fisheries Resources Institute (FRI), Japan Fisheries Research and Education Agency. 2-12-4 Fukuura, Kanazawa-ku, Yokohama, Kanagawa, 236-8648, JAPAN E-mail: ijima@affrc.go.jp TEL: +81-543-36-6044

AGENDA

March 9th (Tuesday), 9:00 - 13:00 (JST)

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. Numbering working papers and distribution potential
4. Review a progress of Pacific blue marlin stock assessment

ISC/21/BILLWG-01/03: Natural Mortality Rates of Pacific Blue Marlin
Presentation 1: Progress of Pacific blue marlin stock assessment

March 10th (Wednesday), 9:00 - 13:00 (JST)

5. Rebuilding plan for the North Pacific striped marlin

ISC/21/BILLWG-01/01: Correction to the US Hawaii Longline Striped Marlin Catch from 2010-2017
ISC/21/BILLWG-01/02: Update to the 2019 Western and Central North Pacific Ocean Striped Marlin Stock Assessment
ISC/21/BILLWG-01/04: Some Rebuilding Analyses for the Western and Central North Pacific Ocean Striped Marlin Stock

6. Stock boundary of swordfish in the North Pacific

Presentation 2

March 11th (Thursday), 9:00 - 13:00 (JST)

6. Stock boundary of swordfish in the North Pacific

ISC/21/BILLWG-01/06: Title Movement ecology of swordfish (Xiphias gladius) in the northwestern Pacific Ocean using electronic tags and stable isotope analysis

7. Japanese fishery statistics and mistake in the WCNPO MLS SS3 file

ISC/21/BILLWG-01/05: The quality of Japanese catch statistics and reports of mistake in the SS3 model for the Western Central North Pacific striped marlin.

8. Work plan of the BILLWG
9. Other items

March 16th (Tuesday), 9:00 - 13:00 (JST)

10. Circulate workshop report
11. Adoption

ATTACHMENT 3. THE LIST OF WORKING PAPERS.

ISC/21/BILLWG-01/01	Correction to the US Hawaii Longline Striped Marlin Catch from Years 2010–2017. Michelle Sculley michelle.sculley@noaa.gov
ISC/21/BILLWG-01/02	Update to the 2019 Western and Central North Pacific Ocean Striped Marlin Stock Assessment. Michelle Sculley michelle.sculley@noaa.gov
ISC/21/BILLWG-01/03	Natural Mortality Rates of Pacific Blue Marlin. Jon Brodziak jon.brodziak@noaa.gov
ISC/21/BILLWG-01/04	Some Rebuilding Analyses for the Western and Central North Pacific Ocean Striped Marlin Stock. Jon Brodziak jon.brodziak@noaa.gov
ISC/21/BILLWG-01/05	The quality of Japanese catch statistics and reports of mistake in the SS3 model for the Western Central North Pacific striped marlin. Hirotaka Ijima ijima@affrc.go.jp
ISC/21/BILLWG-01/06	Movement ecology of swordfish (*Xiphias gladius*) in the northwestern Pacific Ocean using electronic tags and stable isotope analysis. Wei-Chuan Chiang, Shian-Jhong Lin, Qi-Xuan Chang, Ching-Tsun Chang, Michael K. Musyl, Yuan-Shing Ho wcchiang@mail.tfrin.gov.tw
Presentation 1	Current Progress on the 2021 Pacific BUM Assessment. Michelle Sculley
Presentation 2	Stock structure of swordfish in the Pacific Ocean 1st TECHNICAL WORKSHOP ON S EPO SWORDFISH. Carolina Minte-Vera