FINAL

ISC/20/ANNEX/07

# ANNEX 07

*20th Meeting of the*
*International Scientific Committee for Tuna*
*and Tuna-Like Species in the North Pacific Ocean*
*Held Virtually*
*July 15-20, 2020*

# REPORT OF THE BILLFISH WORKING GROUP WORKSHOP

**July 2020**

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# ANNEX 07

## *REPORT OF THE BILLFISH WORKING GROUP WORKSHOP*

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

30 January – 3 February 2020
National Taiwan University
Taipei, Taiwan

## 1. OPENING OF THE WORKSHOP

### 1.1. Welcome and Introduction

Hirotaka Ijima, Billfish Working Group Chair opened the meeting. Three members, Chinese Taipei, Japan and United States of America (USA), participated in the meeting. The participating scientists are listed in Attachment 1. Dr. Yi-Jay Chang welcomed the WG members on behalf of the hosting nation.

The Billfish Working Group (WG) of the International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean held a four-day meeting (from 30th January to 3rd February) at the National Taiwan University in Taipei, Taiwan. The main goal of this meeting was to review the biological studies of billfish and to make a collaborative work plan. The WG also confirmed the schedule of upcoming stock assessments.

### 1.2. Review and Approval of Agenda and Assignment of Rapporteurs

The WG circulated the draft agenda prior to the meeting, and reviewed and adopted it at the workshop (Attachment 2). The Chair assigned the rapporteurs for each item on the agenda as follows:

| Item | Rapporteurs |
|---|---|
| 1-3 | H. Ijima |
| 4. a | (WP05) (WP11): M. Kinney and T. Shimose |
| | (P01) (WP03): M. Sculley and Minoru Kanaiwa |
| 4. b | (P02) (P03) (P04): J. Brodziak and Y.J. Chang |
| 4. c | (WP02) (WP09): J. O'Malley and Miyuki Kanaiwa |
| | (WP04): J. Brodziak and CH Lu |
| 4. d | (WP06) (WP07): YJ Chang and Minoru Kanaiwa |
| | (WP08): A. Kurashima and J. O'Malley |
| 5 | (WP01): M. Sculley, J. O'Malley and A. Kurashima |
| 6-10 | H. Ijima |

*WP is the working paper; P is the presentation only.

### 1.3. Numbering Working Papers and Distribution Potential

Working papers were distributed and numbered (Attachment 3). The WG agreed to post on the ISC website and make them available to the public, except ISC/20/BILLWG-01WP03, ISC/20/BILLWG-01WP06, ISC/20/BILLWG-01WP09, and ISC/20/BILLWG-01WP11, which present research in progress.

## 2. REVIEW BIOLOGICAL AND ECOLOGICAL INFORMATION OF BILLFISHES

### 2.1. Growth and maturity

***Review and working plan of re-estimation for growth curve of swordfish and striped marlin in North-West Pacific Ocean. Miyuki Kanaiwa, Yu Sato, Hirotaka Ijima, Akira Kurashima, Tamaki Shimose, and Minoru Kanaiwa. (ISC/20/BILLWG-01/05)***

We reviewed the estimated growth formulae for striped marlin and swordfish. The large differences among the estimated growth formulae in the eastern and western Pacific Ocean were observed. Therefore, we concluded it is necessary to investigate growth formulae in the operational area of Japanese vessels where located in the middle of both Pacific Ocean. We illustrated the framework of our working plan and reported the current progress of sampling.

**<u>Discussion</u>**
The WG noted the objective of the project was to identify which of the two available growth curves from Taiwan and the US are more appropriate for the growth of swordfish and striped marlin caught by Japanese vessels and to compare the annual ages from spines and daily age from otoliths for the first two years. It was also clarified that the initial focus of the study was on juvenile fish, and the next step would be to age older fish. **The WG agreed that one of the goals of the study should be to provide advice on how to use the growth curve in the next striped marlin and swordfish stock assessments.**

The WG asked if aging work was done on digital images (so with a record) or straight from the microscope. The authors responded that the counts and staging work were done on digital images and so were recoded with marks of what was counted.

The WG asked what kind of resolution the location data was in. The authors responded that location information varied. For example, samples collected from the training and research vessels include location information with decimal degree accuracy for latitude and longitude. In comparison, port samples would have locations reported the large-scale region. The authors noted that there was a large hole in the sampling in the central Pacific. **The WG recommended that for future and current work, the resolution of the location data would be useful to include.**

Some WG members were interested in how the focus of a swordfish/striped marlin spine was defined. The WG responded that the focus was measured in the radius according to the shape of the spine section and the authors experience and for the details, please refer to Sun et al., 2002.
The WG was interested in understanding how Stock Synthesis (SS)deals with growth curves and whether a two-stage growth curve would be acceptable. It was clarified that SS does not specifically deal with the growth of very young animals (< the minimum reference age) and so a two-stage growth model would be acceptable for SS in order to specially deal with changing growth between very young and older animals.

The WG asked about a way forward for determining the maximum age. It was suggested that the best way forward on such a topic would be the integration of several methods: growth curves, bomb radiocarbon dating, tagging, etc.

The WG asked if any future bomb radiocarbon work was planned in the HI lab. It was answered that at the moment, no further work was planned. The capacity is there, but future work has not been discussed yet.

***Considering age uncertainty and two stanzas of growth for the Pacific blue marlin (Makaira nigricans) Yi-Jay Chang, Xu-Bang Chang, Jhen Hsu, Wei-Chuan Chiang, Chi-Lu Sun (ISC/20/BILLWG-01/11)***

Age determination of the Pacific blue marlin (Makaira nigricans) was performed by combining methods of otolith of thirteen juvenile (115 - 152 cm eye fork length, EFL cm) and sectioned dorsal fin spines of 616 individuals (142 to 275 cm EFL for females and 180 to 220 cm EFL for males) collected from three fishing ports of Taiwan from September 2016 to January 2018. Otolith micro-increments were counted with ages of 213 - 349 days old. The estimated mean length (146 cm EFL) at year 1 and the growth rate were used to validate the position of the first annual growth band in sectioned fin spines. The average percent error is 10.77 and 9.23% and the coefficient of variation is 15.23 and 13.06% for the male and female annual growth band counts of fin spines, respectively. The decimal ages of the female and males specimens were estimated to be 1.5 - 11 years (142.8 to 262 cm EFL) and 0.5 - 10.5 years (166 to 238 cm EFL), respectively. The marginal increment ratio suggested that the growth bands of blue marlin formed once a year in the third quarter. By integrating the length-at-age data of the present study with the published data of juveniles and large individuals, sex-specific traditional von Bertalanffy growth model (VBGM) and two-stanza growth model (TSGM) coupled with the ageing error by the Bayesian estimation approach were evaluated based on the deviance information criterion (DIC). The results of DIC support the use of the TSGM over the VBGM for both sexes. This study suggests that the TSGM coupled with the ageing-error approach appeared suitable for modeling the sex-specific growth of the Pacific blue marlin with greater flexibility for including ageing uncertainty while VBGM tends to underestimate the median maximum size.

**Discussion**

The WG asked what the error distribution of the ageing error used in the model was. The author clarified that a log-normal aging error distribution was used, and the standard deviation for males was 0.18 and for females was 0.13.

The WG asked how ageing data prior to 1 was gathered, it was expressed that daily age estimates were taken from otoliths were used for ages prior to 1, after age 1 spine annuli and bomb radiocarbon aging were used.

The WG asked how the location on the spine that was to be cut for slide preparation was defined. The presenter indicated that a standard method was used in which the widest area at the base of the spine was measured, then half of that distance was measured up the spine (towards the tip) to identify the area to make the cut (based on Ehrhardt, 1992).

The WG asked if the ageing error was from one reader or multiple readers. The authors answered that the ageing error was from a single reader who performed multiple reads, and the CVs of the reads were small. Noting that there was no difference between sexes in lengths at age by Shimose et al. (2015) and due to the small sample size of the present study, sexes were combined for developing the first stanza of the age 0-1 fish growth curve.

The WG asked about the large adult age points used in the study, the Andrews bomb radiocarbon estimate (Andrews et al., 2018), and two lengths-at-age observations from Shimose, et al. (2015). The authors believed that they were influential on the growth curves because they provide information on asymptotic length.

The WG suggested validating if the two-stanza growth curve had a smaller correlation between parameters.

The WG asked if the tipping point between the two growth equations matched up with the $L_{50}$. The authors expressed that yes, these were likely quite close.

The WG asked if a two-stanza growth model could be used in SS. It was responded that this is currently being worked on.

The WG asked if this work would be published soon, and the author replied yes, probably. Multiple approaches were combined in the last assessment for blue marlin growth by using a hierarchical meta-analysis, and the information was in a WP but not published. The WG suggested that the authors publish the work as soon as possible so that it could be considered in the blue marlin stock assessment in 2021. The WG noted the age data for adults was sampled in waters near Taiwan with the exception of the data from Andrews et al. (2018) and Shimose et al. (2015). The WG also noted that this sampling region represented a smaller geographic area than the aging data used to produce the 2013 ISC billfish WG growth curves. The WG also encouraged the authors to include the length-at-age data of Hill et al. (1989) caught in waters around Hawaii.

***The development of guideline of sex-identification based on the macro-characters of gonads of swordfish. Akira Kurashima, Hirotaka Ijima and Yasuko Semba. (ISC/20/BILLWG-01/03)***

The sex information is important because growth is different by sex in the swordfish. In many cases, the sex identification (i.e., observation of gonads) needs to be conducted on fishing vessel because swordfish is unloaded as a dress product. Hence, useful manuals for identification based on the macro-character of gonad is necessary for accumulating the accurate sex information on the ship. In this study, the macro-characters of gonads in swordfish were developed for the purpose of improving the accuracy of sex identification onboard based on observation of gonads of each sex throughout various size range. The testes show flatted shape with wave-like margin and have no central pore and thin testicular membrane. On the other hands, the ovaries show oval shape with smooth margin, and have central pore, thick ovarian membrane. The colors of testes and ovaries are very similar, and thus it is difficult to identify their gender by the color. Based on the criteria of sex identification, we verified the sex identification conducted by Japanese observer onboard the offshore longline vessel in 2018 based on their pictures. The accuracy rate (i.e., number of correct identifications by observer per total record with sex identification) was 98.0%, there is no bias in the accuracy rate depending on body size. The non-identification cases accounted for 95.2% in the category of less than 100 cm in eye-fork length, and many of them were discarded or released (80.0%). Non-identification cases ratio without discard and release were higher in juvenile individuals than in adult (27.5% vs. 13.2%). It is considered that this tendency is caused by a difficulty in finding gonads in the body cavity of juvenile individuals. In the future, it is expected to improve the accuracy of sex identification onboard by this sex identification manual.

**Discussion**

The WG asked if this analysis was conducted throughout the entire year, since observers have had difficulties in past studies in Hawaii due to spent gonads (directly following the spawning season). The authors responded that season was not investigated in this study and that most of the animals were immature and so would not be in a post-spawning state because the operation area is near the coast. However, the authors will need to investigate if the season was recorded, and this will also be important to consider when looking at samples taken further from shore. The authors also clarified that they are unable to identify the sex from port sampling because landed swordfish no longer have gonads. It was a challenge for the observers to sex the smallest fish (<100cm), which accounts for the majority of the un-identified genders. There are plans for the observers to photograph the gonads so that they can be identified or verified by scientists. It was also clarified that all the fish are from the coastal areas and not the high seas.

The WG asked if it would be possible to use some kind of classification tree using the photos of the gonads to identify sex. The WG noted that lhmixer is an R package that could be used to estimate the growth of unidentified sex individuals along with sexed individuals. This approach could be used to extract some growth information for unidentified sex individuals, along with sexed ones. The authors responded that they would be interested in such analysis, but they also hope to decrease the number of individuals that are unidentified by analyzing photos of the macro structures and using the criteria they outlined in their paper. The WG was also suggested that a boosted regression tree approach might be applied to classify sex.

***Updating the Billfish WG on a study that examines L50 estimates based on a physiological vs. functional maturity criteria and how they may differ among different species. Eva Schemmel, Brian Langseth, Erin Reed, Joseph O'Malley. (Presentation 1)***

Size at maturity ($L_{50}$) is an important component of stock assessments and is dependent upon classifying individuals in a population as mature or immature. Female $L_{50}$ is most commonly reported as either physiological (cortical alveoli most advanced oocyte stage) or functional (vitellogenic most advanced oocyte stage) maturity. Fish size at functional maturity is generally larger than physiological maturity, however, the magnitude of the difference varies by species. Ideally, collection of reproductive samples should takes place during the spawning season. However, this is not always possible. To determine how physiological vs. functional maturity derived $L_{50}$ estimates affect stock assessments, a multispecies review was done for reef, deepwater, and pelagic species. Negligible to no differences were found between physiological and functional $L_{50}$ estimates for reef fish and relatively small differences were found for deepwater snappers. Larger differences in $L_{50}$ were found for striped marlin (*Kajikia audax*; 3.5 cm) and Hawaiian grouper (*Hyporthodus quernus*; 7.1 cm). We compared estimated modeled biomass from *K. audax* in the Western and Central North Pacific Ocean and *Pristipomoides filamentosus* in the Main Hawaiian Islands using physiological and functional maturity ($L_{50}$) estimates for each species, and found minimal differences for *P. filamentosus*, and larger differences for *K. audax*. This preliminary research suggests that either physiological or functional maturity may be used for deep water snappers and for select reef fish species, but could potentially have impacts for pelagic species.

**<u>Discussion</u>**

The WG suggested that for striped marlin, the $L_{50}$ results presented were within the modeled sensitivity in the assessment, and so were not of major concern. It was responded that while true, the information is still important in terms of understanding $L_{50}$ and could be more important for cold-water species where differences between physiological and functional maturity are likely to be larger.

The WG clarified that functional maturity has evidence of the previous spawning, and physiological maturity does not. The WG noted that there is a big difference between the $L_{50}$ in Taiwan (181 cm EFL) and the US/Hawaii (161 cm EFL), and it was hypothesized that this might be due to different stocks, migration, or different growth rates.

## 2.2. Geostatistical model

***The distribution of larval fish on the Pacific Ocean: Applying a geostatistical model analysis. Hirotaka Ijima. (Presentation 2)***

Constructing a mathematical model and understanding the behavior of the population dynamics is a fundamental study and plays an essential role in wildlife conservation and management. In highly migratory species such as tuna and billfish, it is known that there is substantial uncertainty in recruitment that has a large effect on the population growth rate. Tuna and billfish have been suggested that recruitment uncertainty depends on the ocean environment but, the causal relationship between recruitment and the environment is unknown. Besides, the spawning ground and season of these species are not also well understood. In this study, we constructed the latest geostatistical model using the larval survey data and estimated the spawning ground and the latent spatial field that affects the appearance of tuna and billfish larval.

**Discussion**

The WG noted that standardized larval sampling was used (trawling, sorting, identifying tuna larvae) during 1956-1998 (~79K trawl samples) and the author focused on the 12 most abundantly sampled species in the Pacific.

The WG noted that the larval log(cpue) visual patterns indicate that there are 4 subarea hotspots for swordfish and 3 subarea hotspots for striped marlin in the Pacific. The author showed that the 15 and 20 minutes tows were typical and had similar catches of larvae. The implication was that there was no need to standardize by effort.

The WG noted that some species exhibit seasonal patterns with larvae present in both summer and winter but also that these are seasonal patterns aggregated across the North and South Pacific which have different temperature and solar radiation patterns by season.

The WG noted that billfish larvae are shallower than tuna larvae.

***Quantifying the distribution of swordfish (Xiphias gladius) density in the Hawaii-based longline fishery. Michelle Sculley and Jon Brodziak (Presentation 3)***

The Hawaii-based longline fishery targeting bigeye tuna and swordfish is the most economically important fishery in Hawaii. An improved understanding of the distribution of swordfish within this fishery and how it changes in response to environmental conditions is critical for predicting potential climate change impacts to the fishery. The multi-species Vector-Autoregressive Spatio-Temporal (VAST) model was used to estimate abundance and density of swordfish within the Hawaii-based longline fishing grounds. Swordfish and bigeye tuna catch per unit effort were used in a spatial dynamics factor analysis to help estimate swordfish density in time periods when the swordfish fishery was closed. Although the model was unable to fully account for the significant changes in fishery regulations in 2000, it provided quantified estimates of swordfish density and distribution and information on how those distributions may change in response to environmental variables. Swordfish density center of gravity was found to correlate with the Southern Oscillation Index (SOI) averaged during the swordfish spawning season (April – July), with swordfish densities centered further north and east during positive SOI (cooler sea temperatures) and further south and west during negative SOI (warmer sea temperatures).

**Discussion**

The WG noted that swordfish distribution was estimated in relation to environmental forcing in the North Pacific using the geostatistical model VAST. VAST uses Gaussian Markov Random

Field (GMRF) and is a spatiotemporal mixed effects delta-distribution model that can incorporate multiple covariates.

The WG asked how the model uses the correlation between swordfish and bigeye catch in the statistical model. The authors noted that bigeye and swordfish catches in the shallow- and deep-set sectors were used to measure the density of swordfish across the Pacific in space and time. They used a multispecies VAST model with bigeye and swordfish along with trip type (tuna, swordfish, mixed) and lunar illumination (significant for swordfish catch per unit effort (CPUE) in previous standardizations) along with random effects for different vessels with a delta-lognormal distribution for encounters (using a Poisson distribution) and positive catch (using a lognormal distribution). The authors clarified that they use the negative correlation between bigeye and swordfish catch to fill in the swordfish CPUE information from the shallow-set sector during the shallow-set fishery closure.

The WG asked which is the true trend of CPUE for swordfish (i.e., is it the flat trend in deep-sector or decline trend in shallow-sector) and why the nominal of the deep-sector was flat and the standardized CPUE trend was decreasing. The authors responded that the deep-sector catches juvenile swordfish and the shallow-sector catches large commercially valuable swordfish.

The authors noted that higher water temperature near Hawaii in the future may push swordfish to the north and east leading to suboptimal feeding or larval survival conditions.

The WG asked how to use the standardized CPUE for stock assessment, if at all. The authors mentioned that the CPUE for HI longline in the most recent swordfish assessment was split into 3 time-series (early-shallow, late-shallow, all-deep) and that this model should not be considered for use in the next stock assessment due to challenges incorporating covariates into the model.

***Modelling the spatio-temporal dynamics of Pacific saury in the Northwestern Pacific Ocean by using a Vector-Autoregressive Spatio-Temporal Model. Jhen Hsu and Yi-Jay Chang. (Presentation 4)***

We quantified the spatio-temporal dynamics of the Pacific saury (Cololabis saira) in the Northwestern Pacific Ocean between 2001 and 2017 by using the Vector-Autoregressive Spatio-Temporal Model. Results indicated that the high density area of the Pacific saury was located in the coastal and offshore waters off Japan (35-45 °N and 140-155 °E) during the studied period. There is evidence that the spatial distribution of the Pacific saury has gradually shifted eastward over time. We investigated whether the Pacific saury has shifted which can be attributed to changes in a single environmental variable or climatic index, the multiple environmental variables and climatic indices, and the unexplained spatio-temporal factors. Results indicated neither a single environmental variable or climatic index nor the linear combination of them could explain the spatial distribution shift of the Pacific saury. Instead, the change in spatial distribution is the most strongly attributed to the 'unexplained' factors. We suggest that any studies regarding the likely impacts of future environmental changes on the Pacific saury should first quantify the proportion of historical variation that can be explained by the variables that are available for forecasting.

**Discussion**

Taking the opportunity of the venue of the geostatistical model section in this workshop, a relevant geostatistical study of the Pacific saury (could be applied to the ISC billfishes) was presented at the meeting.

The WG asked for clarification on the unexplained variables. It was clarified by the authors that the unexplained variation is due to environmental impacts that cannot be measured, or included in the model such as dissolved oxygen, currents, or fishing effort.

The WG noted that the input data includes fishing effort by various nations including Russia, Taiwan, Japan, and others. A factorial approach to including environmental variables, such as SST and SOI, was used. The model creates a spatial map of the distribution based on discrete knots that is typical in additive Gaussian models. The authors investigated the relative impacts of various environmental variables, i.e., SST, SOI. The results show higher spatial correlations north-south versus east-west. The WG noted that the unexplained variable has the most influence on the prediction of the saury's distribution and discussed what it may be represent in the fish population dynamics. It was noted that there were higher densities around coastal Japan early in the time series (2001-2007) followed by lower densities later (after 2008). Results suggested an eastward shifting distribution of density through time as well as some slight northward shifting through time. Most variation is unexplained but some minor variation is explained by SST as well as climate and environment index (SOI?). The WG noted that SST and SOI may be confounding when they are both included in the species distribution model.

The WG noted that there were some uncertainties about the interpretation of the analysis regarding the changes in saury distribution. It was noted that they could be driven by the effect of the fishing effort moving versus environmental forcing in space and time. The WG discussed whether the result of shifting in saury's distribution could be related to changes in data coverage overtime or fishing effort distribution. The presenter clarified that the data coverage is consistent for the model time period. However, the impact of fishing effort distribution on fish distribution shifts is still unknown and could be evaluated in the future.

The WG valued the work of understanding the relative importance of each explanatory variable in the species distribution model.

### 2.3. Migration

***Review of horizontal migration of swordfish, striped marlin and blue marlin using electrical tags. Akira Kurashima, Hirotaka Ijima and Yasuko Semba. (ISC/20/BILLWG-01/02)***

The billfish is a highly migratory fish, and their stock assessment has been performed in each RFMOs. However, there is no consensus about their population structure although population structure is important for stock assessment. The information of horizontal movements is one of key factor for recognizing of population structure. In this study, horizontal movement pathways estimating by electrical tags about swordfish, striped marlin, and blue marlin were summarized for the purpose of clarifying the task of further study. Tagging studies of swordfish have been performed in the worldwide. In some individuals, return migration likes seasonal migration were observed but not return individuals also observed. Their pathways don't overlap among each research fields, i.e., the North west Pacific, the North east Pacific, the South west Pacific, off South Africa, and the North Atlantic. In striped marlin, tagging studies were limited in the East Pacific and the South Pacific, were not overlap among these areas. As well as swordfish, return and non-return migration was reported. In blue marlin, tagging studies was most limited than the other two species, and there was only report from the central Pacific and the Atlantic. In the Pacific, blue marlin showed widely migration beyond the equator. In the Atlantic, almost blue marlin in the Gulf of Mexico or the Caribbean Sea stay within this area, while widely migration observed in open water. These observed movements are narrow than range of genetic population structure in almost cases, they do not across each research field. More extended observations or tagging studies at boundary of previous studies area is necessary to resolve the actual population structure.

**Discussion**
The WG commented on the lack of striped marlin tagging studies in the North Pacific, especially around Taiwanese and Japanese waters. **The WG recommends that future tagging studies be prioritized, especially for striped marlin.** The WG stated that WCPFC SC does not consider striped marlin a northern stock but it is ambiguous biologically because they do occur north of 20°N.

The WG noted that this review is a good first look at tagging and genetic data that may provide information on billfish stock structure. The WG noted that there are a large number of conventional tags that are not included in the WP (e.g. Ortiz et al., 2003). The WG also noted that some of the data from the Domeier et al., 2006 research in Hawaii was not included in the WP. **The WG recommended that all data sources be included in future research. The WG also recommended that biological studies that may be indicative of stock structure be included in future stock structure research.**

The WG asked for clarification on how data were extracted from previous studies for the WP. The presenter reiterated that they overlaid the maps from the papers and traced the tracks. The WG asked about situations when the data was not pathways but points. The presenter stated that they connected closest point-to-point data.

**The WG requested collaborative stock structure research for the upcoming assessments. The WG recommended that biological information be included in future work exploring stock structure of billfishes, with specific interest in striped marlin stock structure. The WG noted that Japan, US, and Taiwan should work together on this subject for a publication.**

The WG noted that the US (SWFSC) and SPC has a large amount of billfish conventional tagging data that has not been provided to ISC Billfish WG. The WG noted that the data would be helpful. PIFSC will attempt to obtain the data in a collaborative research framework.

***Movement patterns and habitat preferences of five species of billfish in northwestern Pacific Ocean. Wei-Chuan Chiang. (ISC/20/BILLWG-01/09)***

To investigate movement patterns, habitat preferences and vertical thermal niche, PSATs were deployed on five species of billfish (4 sailfish, 11 black marlin, 14 blue marlin, 1 striped marlin and 3 swordfish) using harpoon, longline and set-net fishing gear in southeastern Taiwan. Linear displacements ranged from 73 to 3,579 km from deployment to pop-up locations with average speeds of 0.1 to 9.6 km/hour. Most probable tracks (MPTs) calculated by the Kalman filter suggested that swordfish moved southwards after release whereas black marlin made distinct seasonal movements. For sailfish, all movements were confined to the East China Sea, and striped marlin moved to South China Sea. No seasonal movement patterns were observed in blue marlin but MPTs from the longest deployments revealed highly variable and complex movement patterns. Regardless of tagging location or season of release, none of the tagged billfishes travelled to the central Pacific Ocean. Diving depths and ambient water temperature ranged from the surface to 737 m and from 6°C to 33°C. All species showed oscillatory dive behavior from the surface mixed layer to ~200–700 m and exhibited clear diel patterns occupying shallower depths at nighttime than during daytime. Comparative vertical niche is discussed among the species.

**Discussion**
The WG noted that tag deployment on swordfish could be done by harpooning in Eastern Pacific (Dewar et al., 2011). This fact may be indicative of different swordfish behavior across the Pacific.

The WG asked the physical impacts of tagging by the harpoon fishery. The author responded that billfish tagged by the harpoon has a longer time-at-liberty (average of 130 days) than rod and reel tagged fish (average of 90 days), so tagging impacts may be less for harpoon tagged fish relative to rod and reel tagged fish (Musyl et al., 2011).

The WG asked where marlins are tagged when a harpoon is used. The author stated that scientists originally requested that fish be tagging on the dorsal side towards the head. However, fishermen suggest more towards the tail (under the second dorsal fin) because the tag will last longer.

The WG asked for clarification on the blue marlin movement relative to environmental conditions. The presenter stated that based on the case in the Eastern Pacific Ocean (Carlisle et al, 2017), blue marlin move more southern in an el Nino year. The WG encouraged the study conducted in the Western Pacific to include more environmental data be used to explain blue marlin movement as well as respond to future climate change.

The WG suggested that fishery information (e.g., CPUE) be included in analysis. The WG indicated that the CPUE data for the harpoon fisheries might not be on the appropriate spatial scale to be included in the analysis.
The WG noted that there may be behavioral differences between billfish in the waters north and south of Japan.

***Preliminary result of horizontal and vertical movements of swordfish in the North-west Pacific; A note of swimming behavior of single swordfish. Akira Kurashima, Yuki Fujinami, Hirotaka Ijima and Yasuko Semba. (ISC/20/BILLWG-01/04)***

The tagging studies of swordfish using electrical tags were have been performed in the world although the long-term observations (more than half year) were reported in only 6 individuals in the North west Pacific. It needs more observation for understanding their migration. Hence, we performed tagging for swordfish to collect long-term tracking data using PSATs in the North west Pacific. Tagging swordfish were caught by pelagic longline, tagged for the individual having active condition. Two tagging methods, tagging on the deck and on the water, were performed in this study. As a result, a swordfish tagged on the deck was flouted in water surface after release, were caught with PSATs. On the other hands, a swordfish tagged on the water swam away actively and dying sign was not observed, long-term observation data among 172 days were collected. In the horizontal movement, the wide migration was not observed, and did not move across Kuroshio extension. There is a possibility that this swordfish had been stay the breeding ground. In the vertical movement, this swordfish showed daily vertical movement as well as previous study. In daytime, this fish falls to depth 500–800m, usually stayed at about depth 600m. In April to early June, secondary diving to about depth 800m was observed. This is seventh long-term observation in the North west Pacific. However, the long-term observation is not so many, it is necessary to accumulate further tracking data to clarify the migration pattern in the North west Pacific and population connectivity in other area.

**Discussion**

The WG noted that the long-term observation was limited in the Northwest Pacific Ocean, it is essential to improve the resolution of the tracking data for understanding the population connectivity of the swordfish in the Northwest Pacific Ocean.

The WG asked whether the gender of PSAT tagged fish could be identified. The presenter answered that it is difficult to identify gender, but if we had a genetic marker, it would be possible. The WG suggested, in the future, collecting tissue samples when tagging to collect gender information.

The WG noted that basking behavior is different from typical daytime depth distributions based on other studies.

***Movements of swordfish (Xiphias gladius) in the northeastern Pacific Ocean as determined by electronic tags (2002-2019). Shane Griffiths, Chugey Sepulveda and Scott Aalbers (ISC/20/BILLWG-01/10)***

An overview of the horizontal movements of swordfish (Xiphias gladius) tagged in the Eastern North Pacific (ENP) using electronic tags is provided in relation to existing stock boundaries for the period from 2002 to 2019. We summarize existing movement data published for swordfish tagged within the ENP (primarily off the U.S. West Coast n=120) and also provide preliminary data through January, 2020 from ongoing studies off southern California (n=16). These data suggest that: (1) swordfish movements do not directly follow the current boundaries used to differentiate ENP stocks; (2) trans-equatorial movements are limited; and (3) movements are confined to the area east of the Hawaiian Islands (163°W). Although these data provide insight towards a better understanding of swordfish movement patterns in the ENP, additional multi-year tagging tracks are necessary to establish more definitive regional stock boundaries for the purposes of stock assessment.

**Discussion**
The WG noted that swordfish migrates across the current stock boundaries.
**The WG recommended that stock boundaries be discussed before the next data preparation meeting for the WCNPO swordfish stock assessment.**

### 2.4. Other information

***On the Probable Distribution of Stock-Recruitment Steepness for Western and Central North Pacific Swordfish. Jon Brodziak (ISC/20/BILLWG-01/06)***

The resilience of a stock-recruitment relationship is a key characteristic for modeling the population dynamics and fishery productivity of living marine resources. Steepness determines the expected resiliency of a fish stock to harvest and is important for the estimation of biological reference points such as maximum sustainable yield. Stock-recruitment steepness was a primary uncertainty for the determination of stock status and biological reference points in the most recent stock assessment (ISC 2018) of Western and Central North Pacific swordfish (*Xiphias gladius*). To address this uncertainty, we applied the method of Mangel et al. (2010) and Brodziak et al. (2015) to quantify the probable distribution of steepness for swordfish using new information on the mean batch fecundity, spawning frequency, and spawning season duration. Results indicated that, under an assumption of Beverton-Holt stock-recruitment dynamics, the median steepness of swordfish was 0.95 with a 95% probable range of (0.89, 0.99). This suggested that Western and Central North Pacific swordfish was highly resilient to reductions in spawning potential. Results also indicated that variation in some reproductive and life history parameters had an important influence on the distribution of steepness. In particular, sensitivity analyses showed that steepness was most sensitive to body girth, mean egg weight, and most importantly, early life history stage survival. Sensitivity analyses also confirmed that the effects of changes in life history parameters on steepness were consistent with expected increases or decreases in reproductive output due to changes in body weight or fecundity.

**Discussion**
The WG discussed whether potential correlations among the life history parameters were included in the analysis. It was noted that potential correlations could be considered in future work.

The presenter clarified that a coefficient of variation (CV) value of 10% was used for each parameter independently in the Monte Carlo simulation.

The WG also noted the analysis was the same as the approach used for the WCNPO striped marlin (Brodziak et al. 2015). This approach has been provided as a simple useful tool for estimating the probable distribution of stock-recruitment steepness for the stock assessment purposes.

The WG discussed the uncertainty of the steepness distribution. The presenter clarified that the uncertainty could be described by a statistical beta probability density function and could be included in the integrated stock assessment model (e.g., stock synthesis). The WG noted that the early life history stage parameters (i.e., early life history stage duration and mortality) have the most influence on the steepness estimation than other parameters.

The WG discussed possible future research directions for improving the early life history stage information. The WG concluded that these analyses provided an objective basis for either setting a fixed input steepness value for WCNPO swordfish of h=0.95 or setting an input prior beta distribution for steepness in the next WCNPO swordfish stock assessment.

***Which recruitment scenario is most likely for conducting future stock projections of Western and Central North Pacific Ocean striped marlin? Jon Brodziak and Michelle Sculley (ISC/20/BILLWG-01/07)***

Several additional analyses were conducted to address the request of the Northern Committee of the Western and Central North Pacific Fisheries Commission for the ISC Billfish Working Group to provide advice on which recruitment scenario was most likely for the 2019 Western and Central North Pacific Ocean striped marlin stock assessment projections. Linear regression analyses were used to evaluate the time trend of the recruitment estimates from the stock assessment and results showed a significant long-term decline in age-0 recruits. This indicated that using a long-term recruitment trend for the future projections was not consistent with the observed recent recruitment values. The long-term decline in recruitment, combined with the better out-of-sample predictive accuracy of the short-term recruitment scenario and the observation that recruitment for billfishes are generally positively auto-correlated, led us to conclude that the short-term recruitment scenario was the most likely recruitment scenario for conducting future stock projections for Western and Central North Pacific Ocean striped marlin.

**Discussion**

The WG asked why the mean square error (MSE) for the long-term recruitment scenario was higher than the short-term scenario. The WG suggested that the observed recruitment in 2018 may not be informative and should be considered carefully in the analysis. The author noted that the inverse weighting of the prediction errors by the observed recruitment variability for the short- and long-term prediction models fully accounted for the higher variability in the 2018 recruitment. As such, the point that the short-term recruitment model had 10-fold higher accuracy for predicting the 2017 and 2018 recruitments in comparison to the long-term recruitment model was a valid conclusion. The author also commented that an additional predictive analysis with the 2018 recruitment removed would be included in the revised working paper. The author noted that, in this case, the short-term recruitment model showed over a 100-fold better predictive accuracy for the 2017 recruitment in comparison to the long-term recruitment model.

The author explained that the study is an empirical approach for determining the recruitment scenario objectively for the future stock rebuilding that has been concerned by the managers and stakeholders. The presenter clarified the method of predicting the 2017 and 2018 recruitments. **In response to the Northern Committee request for which recruitment model was more likely, the WG concluded that given the evidence the short-term recruitment model was the most likely model to use for conducting stochastic stock projections for WCNPO striped marlin.**

***Blue marlin (Makaira nigricans) catch and size data of Taiwanese fisheries in the Pacific Ocean. Hung-I Liu, Ren-Fen Wu, Yi-Jay Chang, Shyh-Jiun Wang. (ISC/20/BILLWG-01/08)***

The average annual catch of blue marlin of Taiwanese fisheries in the Pacific Ocean from 2009 to 2018 was 6,356 M.T., and the major catch caught by the offshore longline fishery. The mean length of blue marlin catch seemed relatively stable (ranging between 172.8 and 186.8 cm LJFL, lower jaw fork length) for the distant-water tuna longline fishery during 2009-2018, and the sample size had not changed much over the last 10 years.

**Discussion**

The WG wanted to clarify that the data will be used in the next assessment. The catch and size data that was reported in the WG will be submitted to the next data preparatory meeting.

The WG asked about the details of the size-composition data. The presenter stated that the size information is not sex-specific and observed lower-jaw fork length (LJFL).

The WG asked why catch increased after 2000. The presenter stated that after 2000 the catch of OSLL included foreign port landing. The WG wanted to make sure that double counting was not occurring based on Taiwanese fleet landing in foreign ports. The authors response that there is no double counting of catch, the revision of the catch data for swordfish and blue marlin to include the amount of the foreign based off-shore fishery after 2000 was submitted to Anonymous(2005) and had been adopted (ISC 2013).

The WG asked about the operating area of Taiwan and confirmed that the operations outside of Taiwanese EEZ are increasing since 2000.

The WG asked if there were comparisons of length composition data among Taiwan fleets. The authors stated that a preliminary comparison was made, and could be presented in the next meeting if requested.

## 3. COLLABORATION WORK

***Collaborative biological sampling of highly migratory species. Michael J. Kinney and Joseph O'Malley (ISC/20/BILLWG-01/01)***

For highly migratory species, such as tuna and billfish, basic biological processes like growth and reproduction are notoriously difficult to accurately estimate. The Billfish Working Group (BILLWG) indicated that improved estimates of these basic biological processes were key components in efforts to reduce model uncertainty in the assessment of such animals. Here, the United States, as a member of the BILLWG, propose a collaborative biological sampling effort in order to improve estimates of growth, maturity, and stock structure by allowing analysis of a more representative sample set collected in a uniform manner from multiple nations across the North Pacific. Our current proposal is only an outline of a general sampling strategy, designed to help establish agreement on a collaborative approach, while also identifying key players who can serve as lead scientists. These leads will insure adherence to a sampling design, as well as undertake specific areas of life history research utilizing the samples collected during the collaborative effort.

**Discussion**

1) Sampling design: The WG discussed what kind of sampling approach the authors propose for biological parameters. The presenter responded that the WP outlines a general size-stratified design. Also discussed was a size-stratified approach based on a spatial framework (e.g., Eastern, Central, and Western Pacific), but that will be a conversation with the point people from each country.

**The WG agreed that it needs to be discussed, and it should be standardized between all the countries and have a single lab analyzing a particular component (i.e., aging striped marlin) so that interagency variability is reduced or eliminated.**

2) Who is the primary country contact? Each country delegation discussed among themselves who the country-specific contact would be. **It was decided that Yi-Jay Chang will serve as the Taiwan representative, Minoru Kanaiwa would serve as the Japan representative, and Michael Kinney would serve as the US representative (**Table 1**).**

The WG suggested that China, Mexico, Canada, and South Korea be included in the research and a representative be identified. The Billfish WG Chair indicated that he would reach out to the other countries during ISC Plenary to explain the plan and request their participation in this research.

3) Parameter estimation: The WG pointed out that the several labs have ongoing projects for life history, which are fine. However, the WG stated that they would like a single parameter estimate for each life history aspect for assessment purposes.

The WG discussed sharing expertise among different labs, so a single lab conducts the specific research rather than different groups providing different estimates. This would eliminate potential biases based on different labs using different techniques.

**The WG agreed to explore having the life history workshop during the blue marlin data preparatory meeting in Japan in late 2020.** It was recommended that the workshop have morning talks and in the afternoons do hands on evaluation of ages, etc. For the data preparatory meeting, **the WG recommended that all parties be prepared to discuss the details of their work.**

4) Role for data storage on ISC server for specific projects regarding billfish: The acting chair of the Stats WG suggested that one solution for data storage would be on the ISC server for specific projects regarding billfish. It would be a shared data server to provide the opportunity to access information rapidly. Tracking the data collection would prevent over and unnecessary sampling. The WG also pointed out that tracking sampling in real time is important to ensure that all the samples needed are collected between countries.

5) Work plan for bio-sampling table: The WG began refining the proposed work plan for the bio-sampling table (Table 2). It was also suggested that this approach could also be used for pooling countries' tagging data but was not the plan on the outset.

There was extensive discussion about the different projects, who would take the lead on coordinating them, and what their priority level was for striped marlin, swordfish, and blue marlin. **The WG agreed that striped marlin should be addressed first since they are currently overfished.**

Table 1. Point of contact for each country.

| ISC Coordinators (Focus Group) |
|---|
| Yi-Jay Chang (TW) |
| Minoru Kanaiwa (JP) |
| Michael Kinney (US) |
| Hirotaka Ijima (ISC BILLWG Chair) |

Table 2. Draft version of life history projects to be carried out using the collaborative biological sampling program.

| No | Species | Category | Project description | Priority | Proposed Project Lead |
|---|---|---|---|---|---|
| 1 | All Billfish | Data and sample collection | Collaborative biological sampling of highly migratory species | High | US: Michael Kinney (Participants: JP, TW, US) |
| 2 | Striped Marlin | Biological parameter | Update estimation of growth curve and key parameters like Linf | High | JP: Minoru Kanaiwa (Participants: JP, TW, US) |
| 3a | Striped Marlin | Biological parameter | Definition of maturity from frozen samples | High | JP: Akira Kurashima |
| 3b | Striped Marlin | Biological parameter | Update estimation of size at 50% maturity | High | US: Michael Kinney (Participants: JP, TW, US) |
| 4 | Striped Marlin | Biological parameter | Update of estimation of weight-length relationship. Update of conversion factor. Length conversion factors. | Low | TW: Yi-Jay Chang (Participants: JP, TW, US) |
| 5 | Striped Marlin | Stock structure | Collection, and storage of genetic information in line with biological sampling protocol | Low | US will look to fill this project need. (Participants: JP, TW, US) |
| 6 | Striped Marlin | Stock structure | Genetic marker for sex identification | Mid | On hold until genetic storage is settled. (Participants: JP, TW, US) |
| 7 | Striped Marlin | Stock structure | Tagging data and analysis | Mid | TW: Wei-Chuam Chiang (Participants: JP, TW, US) |

Table 2 continued.

| No | Species | Category | Project description | Priority | Proposed Project Lead |
|---|---|---|---|---|---|
| 8 | Swordfish | Biological parameter | Update estimation of growth curve and key parameters like Linf | High | US: Michael Kinney (Participants: JP, TW, US) |
| 9a | Swordfish | Biological parameter | Definition of maturity from frozen samples | High | JP: Akira Kurashima |
| 9b | Swordfish | Biological parameter | Update estimation of size at 50% maturity | Low | JP: Akira Kurashima (Participants: JP, TW, US) |
| 10 | Swordfish | Stock structure | Collection, and storage of genetic information in line with biological sampling protocol | Low | US will look to fill this project need. (Participants: JP, TW, US) |
| 11 | Swordfish | Stock structure | Tagging data and analysis | Mid | TW: Wei-Chuam Chiang (Participants: JP, TW, US) |
| 12 | Swordfish | Biological parameter | Genetic marker for sex identification | Mid | JP: Akira Kurashima (Participants: JP, TW, US) |
| 13 | Blue Marlin | Biological parameter | Update estimation of growth curve and key parameters like Linf. | Low | TW: Yi-Jay Chang (Participants: JP, TW, US)* |

*JPN has some additional samples which may be possible to share.

## 4. FUTURE MEETINGS

The WG discussed the scheduled billfish stock assessments (Table 2). The WG discussed collaborating with IATTC on a northeast Pacific swordfish stock assessment. The chair will discuss IATTC's plans when he visits La Jolla, CA this spring and report back to the WG.

**Table 2.** Provisional assessment schedule 2020-2024 that was modified SC15 outcomes document (WCPFC 2019). WCPFC scheduled swordfish every four years and, other billfish every five years. IATTC scheduled swordfish stock assessment in 2021.

| Species | Stock | Last assessment | 2020 | 2021 | 2022 | 2023 | 2024 |
|---|---|---|---|---|---|---|---|
| Striped marlin | SWPO | 2019 | | | | X | |
| | WCNPO | 2019 | | | | | X |
| | EPO | 2008 | | | | | |
| Swordfish | SWPO | 2017 | | X | | | |
| | WCNPO | 2018 | | | X | | |
| | EPO | 2014 | | X | | | |
| Blue marlin | PO | 2016 | | X | | | |

The WG adopted a tentative schedule for upcoming the WG meetings.

| | |
|---|---|
| Venue: Japan (Mie University)<br>Date: Autumn 2020 | Data preparatory meeting for the Pacific blue marlin stock assessment and Biological methodology workshop |
| Venue: United States of America (Hawaii NOAA PIFSC)<br>Date: February-April 2021 | The stock assessment meeting for the Pacific blue marlin |

## 5. OTHER ITEMS

The BILLWG chair noted that the cover of the working paper should be consistent. The chair will specify the format of the working paper and will distribute it before the next billfish working group meeting.

## 6. VISITING FISHING PORT (NAN-FANG AO) BY APPLICANTS

The WG members visited the fishing port (Nan-Fang Ao) and watched the auction of billfish and sharks caught by the longline fishery. One sample of swordfish spines from a small individual was collected.

## 7. CIRCULATE WORKSHOP REPORT

The WG Chair prepared a draft of the report, and the WG reviewed the draft report by all present. The provisional report will be editorially revised by the WG Chair and distribute via email for WG members to finalize.

## 8. ADJOURNMENT

The BILLWG workshop was adjourned at 05:36 PM on 3 February 2020. The WG Chair expressed appreciation of the hosts (Dr. Yi-Jay Chang, National Taiwan University, and the Fisheries Agency of Taiwan) for their hospitality and overall arrangements. He also thanked the participant scientists for their collaboration in future biology studies.

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## Attachment 1 - List of participants


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*The billfish working group photo.*

## Attachment 2 - Meeting Agenda

**BILLFISH WORKING GROUP (BILLWG)**
***THE INTERNATIONAL SCIENTIFIC COMMITTEE FOR TUNA AND TUNA-LIKE SPECIES IN THE NORTH PACIFIC***

Intercessional Workshop Announcement and Draft Agenda

30 January – 3 February 2020
National Taiwan University
Taipei, Taiwan

| | |
|---|---|
| **Meeting Site:** | Room #215, Institute of Oceanography, National Taiwan University, No. 1, Section 4, Roosevelt Rd, Da'an District, Taipei City, Taiwan 10617 |
| **Meeting Dates:** | January 30 - February 3, 2020 |
| **Meeting Goals:** | Review biological and ecological information (e.g., growth, maturity, spawning ground, migration, stock structure, and environmental effect) of billfishes that distributes in the Pacific Ocean and discuss, and to make the collaboration work plan. The WG also confirmed the schedule of the stock assessment. |
| **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 Thursday January 23th. Authors who miss this deadline must bring 15 hard copies of their working paper to the meeting. |
| **Local Contact:** | Dr. Yi-Jay Chang (Assistant Professor) Institute of Oceanography, National Taiwan University, No. 1, Section 4, Roosevelt Rd, Da'an District, Taipei City, Taiwan 10617<br>Email: yjchang@ntu.edu.tw |
| **BILLWG Contact:** | Dr. Hirotaka Ijima Tuna Fisheries Resources Group Tuna and Skipjack Resources Division National Research Institute of Far Seas Fisheries 5-7-1 Orido, Shimizu-ku, Shizuoka-shi, 424-8633, JAPAN E-mail: ijima@affrc.go.jp Phone: +81-543-36-6044 |

## AGENDA

**January 30 (Thursday), 9:30-10:00 Registration**
**January 30 (Thursday), 10:00-16:30**

1. Opening of Billfish Working Group (BILLWG) Workshop
   a. Welcoming Remarks
   b. Introductions
2. Adoption of Agenda and Assignment of Rapporteurs
3. Numbering Working Papers and Distribution Potential
4. Review biological and ecological information of billfishes
   a. Growth and maturity
   b. Geostatistical model
   c. Migration
   d. Other information

**January 31 (Friday), 9:30-17:00**

4. Review biological and ecological information of billfishes
   a. Growth and maturity
   b. Geostatistical model
   c. Migration
   d. Other information

**February 1 (Saturday), 9:30-17:00**

5. Collaboration work
6. Future meetings
7. Other items

**February 2 (Sunday), No meeting**
**February 3 (Monday), 7:00-12:00**

8. Visiting fishing port (Nan-Fang Ao) by applicants

**February 3 (Monday), 13:00-17:00**

9. Circulate workshop report
10. Adjournment

## Attachment 3 - Working Papers and Presentations

| | |
|---|---|
| ISC/20/BILLWG-01/01 | Collaborative biological sampling of highly migratory species.<br>Michael J. Kinney and Joseph O'Malley<br>michael.kinney@noaa.gov |
| ISC/20/BILLWG-01/02 | Review of horizontal migration of swordfish, striped marlin and blue marlin using electrical tags.<br>Akira Kurashima, Hirotaka Ijima and Yasuko Semba<br>akura@affrc.go.jp |
| ISC/20/BILLWG-01/03 | The development of guideline of sex-identification based on the macro-charaters of gonads of swordfish.<br>Akira Kurashima, Hirotaka Ijima and Yasuko Semba<br>akura@affrc.go.jp |
| ISC/20/BILLWG-01/04 | Preliminary result of horizontal and vertical movements of swordfish in the North-west Pacific; A note of swimming behavior of single swordfish.<br>Akira Kurashima, Yuki Fujinami, Hirotaka Ijima and Yasuko Semba<br>akura@affrc.go.jp |
| ISC/20/BILLWG-01/05 | Review and working plan of re-estimation for growth curve of swordfish and striped marlin in North-West Pacific Ocean.<br>Miyuki Kanaiwa, Yu Sato, Hirotaka Ijima, Akira Kurashima, Tamaki Shimose, and Minoru Kanaiwa<br>k-miyuki@bio.mie-u.ac.jp |
| ISC/20/BILLWG-01/06 | On the Probable Distribution of Stock-Recruitment Steepness for Western and Central North Pacific Swordfish.<br>Jon Brodziak<br>jon.brodziak@noaa.gov |
| ISC/20/BILLWG-01/07 | Which recruitment scenario is most likely for conducting future stock projections of Western and Central North Pacific Ocean striped marlin?<br>Jon Brodziak and Michelle Sculley<br>jon.brodziak@noaa.gov |
| ISC/20/BILLWG-01/08 | Blue marlin (Makaira nigricans) catch and size data of Taiwanese fisheries in the Pacific Ocean.<br>Hung-I Liu, Ren-Fen Wu, Yi-Jay Chang, Shyh-Jiun Wang<br>luoe@ofdc.org.tw |
| ISC/20/BILLWG-01/09 | Movement patterns and habitat preferences of five species of billfish in northwestern Pacific Ocean.<br>Wei-Chuan (Riyar) Chiang, Michael K. Musyl, Hsien-Chung Lin, Yuan-Shin Ho, Chi-Lu Sun, Gerard DiNardo, June-Ru Chen<br>wcchang@mail.tfrin.gov.tw |

| | |
|---|---|
| ISC/20/BILLWG-01/10 | Movements of swordfish (*Xiphias gladius*) in the northeastern Pacific Ocean as determined by electronic tags (2002-2019).<br>Shane Griffiths, Chugey Sepulveda and Scott Aalbers<br>sgriffiths@iattc.org |
| ISC/20/BILLWG-01/11 | Considering age uncertainty and two stanzas of growth for the Pacific blue marlin (*Makaira nigricans*).<br>Yi-Jay Chang, Xu-Bang Chang, Jhen Hsu, Wei-Chuan Chiang, and Chi-Lu Sun.<br>yjchang@ntu.edu.tw |
| Presentation 01 | Updating the Billfish WG on a study that examines L50 estimates based on a physiological vs. functional maturity criteria and how they may differ among different species.<br>Eva Schemmel, Brian Langseth, Erin Reed, Joseph O'Malley. |
| Presentation 02 | The distribution of larval fish on the Pacific Ocean: Applying a geostatistical model analysis.<br>Hirotaka Ijima |
| Presentation 03 | Quantifying the distribution of swordfish (*Xiphias gladius*) density in the Hawaii-based longline fishery.<br>J Michelle Sculley and Jon Brodziak |
| Presentation 04 | Modelling the spatio-temporal dynamics of Pacific saury in the Northwestern Pacific Ocean by using a Vector-Autoregressive Spatio-Temporal Model. |