INTER-AMERICAN TROPICAL TUNA COMMISSION

1ST TECHNICAL WORKSHOP ON SWORDFISH IN THE SOUTH EPO

Review current state of knowledge, identify available data sources, review stock assessment assumptions for swordfish in the south EPO

(by videoconference)

15-17 December 2020

REPORT OF THE MEETING

CONTENTS

1. BACKGROUND

The Inter-American Tropical Tuna Commission (IATTC) mandate under the Antigua Convention is to ensure the long-term conservation and sustainable use of tuna, tuna-like species, and other species in the eastern Pacific Ocean (EPO), which it achieves through promoting, coordinating and conducting scientific research, and adopting conservation and management measures. This includes swordfish, which is a target in the EPO of both high-seas longline fisheries and coastal and recreational fisheries.

The IATTC staff last assessed the southern EPO swordfish stock in 2011 (Hinton and Maunder 2012), using an integrated stock assessment model fitted to a longline-based index of abundance and length-frequency data from multiple fisheries. The species is included in the staff's research workplan (IATTC-95-08), and a benchmark assessment is scheduled for 2021.

This workshop, which will establish the foundations for the assessment, aims to promote collaboration between the IATTC staff, the Secretariat for the Pacific Community (SPC), and scientists from IATTC Members and Cooperating non-Members (CPCs).

2. OBJECTIVES

The workshop (see agenda in Appendix 1), and its preparatory work, brought together scientists interested in contributing to this regional effort. The objectives were to: 1) promote a regional investigation of swordfish in the southern EPO; 2) review the current state of knowledge of the stock; 3) construct a conceptual model of the population and fishery; 4) identify and understand data sets available from different fisheries/regions that can be used in the assessment; and 5) plan the next steps for the stock assessment process.

This report reviews the activities and discussions conducted during the videoconference.

3. WORKSHOP DESIGN

Due to time limitations, individual presentations were pre-recorded, and made available to participants on a secure channel in advance of the workshop. The staff moderated an online forum of topics of interest prior to the workshop and prepared a summary literature review; the conclusions from the submitted work and review by topic were presented during the meeting by videoconference (Appendix 1) as a basis for further discussion and decisions. The meeting by videoconference was held on the Zoom platform and consisted of three daily sessions, each three hours long, dedicated to discussion of the topics. The online forum was open from 16 November to 17 December 2020 and the videoconference meeting took place on 15-17 December, 1300-1600 h PST (2100-0000 h UTC).

4. WORKSHOP DESCRIPTION

4.1. OVERVIEW

The workshop was facilitated and chaired by Dr. Carolina V. Minte-Vera, of the Stock Assessment Program, and it was opened by IATTC Coordinator of Scientific Research, Dr. Alexandre Aires-da-Silva. The following staff members were appointed rapporteurs: Haikun Xu and Jon Lopez (Day 1), Cleridy Lennert-Cody and Shane Griffith (Day 2), Mark Maunder and Juan Valero (Day 3). The workshop was attended by 52 external participants (Figure 1) and 22 IATTC staff members (Appendix 2).

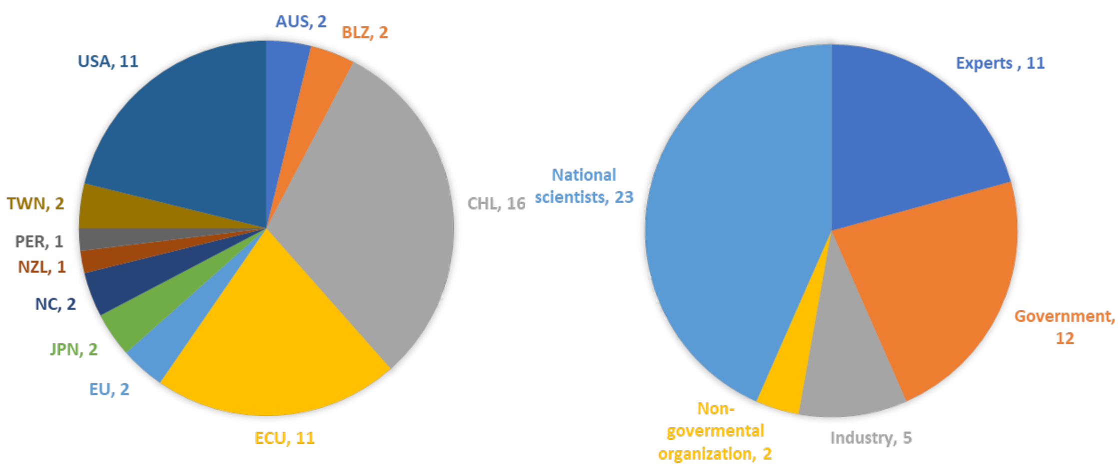

FIGURE 1. Number of external participants of the videoconference of the 1st Technical Workshop on Swordfish in the southern EPO according to their connecting location (left) and type of affiliation.

FIGURA 1. Número de participantes externos en la videoconferencia del 1er Taller Técnico sobre el Pez Espada en el OPO sur según su ubicación de conexión (izquierda) y tipo de afiliación.

4.2. PRESENTATIONS

Fourteen recorded presentations were submitted in advance to the live videoconference (see Appendix 3 for the abstracts):

Stock structure / conceptual model

Aguila, R.D., Sepulveda, C., Aalbers, S., Bremer, J.A. An innovative approach to solve the genetic population structure of Pacific Swordfish: integrating genomics and electronic tagging data

Barría, P., Mora, S., Urzúa, A., González,F., Ortega, J., Miranda, H., Ponce, F., González, A., Devia, D., Lazo, J. Conceptual model of the swordfish (*Xiphias gladius*) life history in the south eastern Pacific Ocean.

Cerna, F.*, Cid, L., Cabello,R., Vidal, L. Age and growth in south eastern Pacific swordfish off Chile

Espindola, F. Influence of ENSO on the spatio-temporal distribution of swordfish catches in the south Pacific Ocean

González, F. , Cortez, B., Faudez, V., Barría, P. Swordfish stock unit in the south eastern Pacific Ocean

Moore, B. Review of biology, stock structure, fisheries and status of swordfish in the Pacific Ocean

Sepulveda, C.* Aalbers, M.S. An overview of swordfish electronic tagging studies off the U.S. West Coast (PIER Research 2005-2020)

Zárate, P., Clavijo, L. Cari, I. Swordfish (*Xiphias gladius*) tagging in Chilean waters.

Biology

Mora, S., Ortega, J.C., Barría. Reproductive aspects of the swordfish (*Xiphias gladius*) in the south eastern Pacific Ocean

Cerna, [op. cit.] growth, longevity

Moore, B [op. cit.] natural mortality

Fisheries definitions

Gonzalez, A.G. Barría, P. Characterization of the swordfish *(Xiphias gladius*) fishery in Chile

National data

Devia, D., González, A., Mora, S., Ortega, J., Miranda, H., Barraza, A., Cerna, F., Urzúa, A., Gonzalez, F., Barría, P. Swordfish (Xiphias gladius) data composition in Chilean fisheries.

Indices of abundance

Barraza, A., Barría, P., Miranda, H. (IFOP-Chile). Estimation of a statistical model for standardized CPUE

Modelling

Espíndola, F. (IFOP-Chile). Stock assessment model for swordfish in the south Pacific Ocean

Ducharme-Barth, N. Stock assessment of swordfish in the southwest Pacific Ocean: 2017 recap & 2021 proposal

Sculley, M. 2018 Western and Central North Pacific Swordfish assessment

4.3. LIVE PRESENTATIONS AND DISCUSSIONS

On the first day of the videoconference, the Chair presented the background for the S EPO assessment of 2021, an overview of the 2011 stock assessment and a review of the information on stock structure that included elements from the recorded presentations as well as the conceptual model for the swordfish stock of the south EPO. The second day focused on biology and data with an emphasis on the indices of abundance. The third day focused on the recommendations by the participants and the plan for future work on the stock assessment. The authors of the recorded presentations were invited to complement the information presented in the review presentation. A summary of the topics and the discussions are presented below.

2011 Model

The previous assessment model for swordfish had the following characteristics:

- Implemented in the SS3 platform
- Used the base-case model approach
- Stock boundaries were the 5°S parallel and the 150°W meridian
- A one-area model (no movement modelled)
- Areas-as-fleets approach: coastal and offshore areas separated by the 90°W meridian
- Six fisheries defined, three in each area ("offshore": west of 90°W: F1, F3 and F5; and "coastal": east of 90°W: F2, F4, F6):
    - F1 - CHL industrial LL
    - F2- CHL artisanal + PER
    - F3 and F4 - Longline "JPN-Like" (JPN, KOR, TWN, OTH)
    - F5 and F6 - Longline ESP
- Selectivities were time invariant, except for F6, which had a time block in selectivity (Pre-2000, Post-1999)
- Longline-derived indices of abundance: one for each area obtained using the CPUE from the Japanese fleet (scale of 1 by 1 by hooks per basket categories (HPB < 8; 8 < HPB < 12; 12 < HPB < 16; and HPB ≥ 16) standardized using a Delta-lognormal GLM model that includes latitude-longitude, HPB, time variables. Both indices are fit assuming a CV = 0.2
- Time period: 1945–2010, the model starts from virgin conditions, recruitment deviations estimated from year 1964 on
- Two-sex model with different growth assumptions for males and females, variability of size at age CV = 10%
- Annual model with seasonal spawning (on quarters 1 and 2)
- Data that had no season information were assigned to quarter 2
- Natural mortality (M) assumed to be 0.4
- Accumulator max age in model set to 15 years
- Spawner-recruit assumption: Beverton-Holt curve with steepness of 1 (sensitivity 0.75)
- Available data included length-composition data for each fishery except F2, and age-composition data for F1 and F2
- For the age-composition data: the model predicted less fish in the plus group than observed in the data, an indication for the need to revisit M assumptions (or movement)
- For "Japan-like" fisheries: the model predicted less small and very large animals than observed in the data, an indication for the need to revisit M and selectivity curve assumptions; maybe there is a need for more flexible curves such as splines
- The model estimated a stable biomass up to 1965, followed by a decline until 1995 and a steady increase afterwards, following the index of abundance. The increase in the index of abundance is simultaneous to the increase in overall catches, concomitant to the arrival of the Spanish fleet.
- The fishing mortality was estimated to be stable and very low
- The MSY was estimated to be 25,000 t (B_{MSY}/B_0 = 0.2)
- $B_{\mathrm{recent}}/B_{\mathrm{MSY}}$ = 10.40
- F_{mult} = 17.92 ($F_{\mathrm{mult}} = F_{\mathrm{MSY}}/F_{\mathrm{cur}}$)

The assessment model's spatial coverage overlapped with the Chilean model (same area, Espindola 2010) and the WCPFC assessment (which included the overlap area of jurisdiction between IATTC and WCPFC in the EPO, south 4°S, 150°W-130°W).

Evidence for stock structure

For this workshop, the following operational definition of stock was adopted: "Groups of fish that have limited interaction such that fishing on one group has a limited impact on the dynamics of the other group". Studies on swordfish spawning areas, nursery areas, genomics, movement, life-history variation, catch spatial distribution by decade, spatial variation of catch trends, spatial distribution of nominal CPUE for the Japanese and the Korean fleet and trends in CPUE for the Japanese fleet were presented and a discussion on those aspects followed.

Dr. Chugey Sepulveda commented on his recorded presentation "An overview of swordfish electronic tagging studies off the U.S. West Coast", where he pointed out that swordfish tagged off California frequently moved across existing stock boundary lines currently assumed for the assessment of swordfish in the north Pacific Ocean. He commented that most tagged swordfish seasonally moved from California into either the eastern Pacific Ocean (EPO) stock area (to the south or southeast along Baja California and towards the equator) or into the Western and Central North Pacific (WCNP) management unit (to the west or southwest towards the Hawaiian Islands). His team has recently shifted to using dorsal-fin mounted Argos transmitters on swordfish, a technology that has led to the generation of multi-year tracks. To date, the tagging work has shown that swordfish tagged off the US West Coast have not been observed to move west of 165W° longitude or south of the equator. Swordfish tagged off California tend to move away from the Southern California foraging grounds in January and February towards subtropical and tropical regions. For some individuals, changes in daily vertical and horizontal movements have been documented around 17°N-24°N 140°W-148°W during the purported spawning season. This is a region that also coincides with previous reports of high gonadosomatic indices and may represent an area where potential spawning activity may occur. The tagging work has also identified repeated seasonal movements in which fish return to the same tagging location in subsequent years (suggesting some form of seasonal site fidelity). Sepulveda noted that his team will continue to couple long-term horizontal and vertical movement data in an effort to provide insights into foraging and putative spawning areas in the Pacific. Ongoing genetic analyses with collaborators from the Alvarado-Bremer Laboratory attempt to better address stock structure issues using several different techniques simultaneously. Dr. Sepulveda also stressed the importance of tag retention and multi-year tracks for understanding inter-annual movement patterns and stock structure. In the past, it has been difficult to record swordfish movements over extended periods (>1 yr.); however, with the recent changes in both the tag attachment techniques and tag technology, his team is now getting reliable access to multi-year datasets. Sepulveda finished by stating that the data his team has collected to date do not support current stock structure delineation hypotheses for the North Pacific and that his team will continue the tagging efforts in hopes of better understanding seasonal movement patterns for this species.

The Chair pointed out that Chile found that more females are caught by their fishery, which might suggest gender difference in movement behaviors.

Dr. Karen Evans informed that SNPs[1] have been analyzed to investigate connectivity; they found no differentiation between fish collected in Australia and in the Western and Central Pacific. They will keep doing genetic analyses and their results will be presented at the next WCPFC scientific meeting. They have been tagging and collecting tissue samples simultaneously. Regarding tagging data, she stated that only part of the movement pattern was observed (only a few months). Gender difference in movement

[1] SNPs: Single nucleotide polymorphisms

patterns may exist, but so far there is not a genetic marker for sex that can be used to discriminate the tissue samples taken. The samples are stored to be analyzed once such marker becomes available. The Chair asked whether there was any tagging close to 150°W, where the 2011 stock assessment limit was, to help determine the western stock boundary. **Dr. Karen Evans** said there has barely been sampling in that area but they are exploring some options for French Polynesia, but it will take time.

Two participants asked about the origin of the assumption for the southern stock boundary of the North Pacific swordfish assessment. The Chair clarified that it is based on cluster analysis of spatial areas regarding the trends in longline catches (a study authored by Ichinokawa and Brodziak). **Dr. Michelle Scully,** author of the recorded presentation 2018 "Western and Central North Pacific Swordfish assessment" confirmed that information and added that that boundary line was produced for the 2009 stock assessment and that the Billfish Working Group inspected tagging, genetics and biological sampling information and re-assesses the assumption with new data every year. The working group continues that assumption unless clear evidence shows otherwise, which has not been the case so far.

Dr. Alvarado-Bremer commented on the recorded presentation "An innovative approach to solve the genetic population structure of Pacific Swordfish: integrating genomics and electronic tagging data" of which he is a co-author. Genetic studies show more than one single stock in the Pacific Ocean; analyzed genetic markers show difference between different places in the Pacific Ocean. Genetic evidence has also provided evidence of heterogeneity of S EPO about other areas. While the nature of the population structure of Pacific swordfish is not as well defined as other areas, there is a consensus from the genetic perspective that the Pacific swordfish population is not a single panmictic unit, and that heterogeneity among regions exist.

Regarding the sampling for genomic studies, **Dr. Alvarado-Bremer** pointed out that his lab holds 2000 samples of swordfish tissues obtained in a collaborative study with the IATTC. Those samples do not have the necessary quality for next-generation sequencing techniques. To undertake such studies, high-quality fin samples from live or recently dead animals (before the *rigor mortis* takes place), preserved in alcohol and refrigerated, are needed. In tropical climates, DNA degrades faster than in colder waters. Therefore, more samples taken on board fishing vessels need to be taken.

Dr. Brad Moore complemented his recorded presentation "Review of biology, stock structure, fisheries and status of swordfish in the Pacific Ocean" by stressing that there is heterogeneity in the life history traits in the Pacific Ocean, correcting for the different length measurements used (lower jaw fork length vs. eye - fork length). On the growth curves used, there is new information available. **Dr. Jessica Farley** confirmed new growth work conducted in Australia with otoliths. The growth pattern is slower and the asymptotic length is smaller than the fish sampled in Chile.

Dr. Fidelina Gonzalez commented on her recorded presentation "Swordfish stock unit in the south eastern Pacific Ocean " that differentiation between the S EPO stock, a New Zealand group and other ocean basins was found within a control region of mtDNA (273 base pairs on a specific section of the mtDNA located between ETAS and CSB from Control Region (Jemt et al. 2015; Viñas et al. 2010; Lu et al. 2006; Alvarado-Bremer 1995; Altschul et al. 1990) when whole mtDNA was analyzed, 800+ bases pairs, differentiation was not found).

Dr. Alvarado-Bremer commented that they also did a study for the mtDNA of 50 fish, with all base pairs, and that the results presented by Dr. Gonzalez seem intriguing. He will run the analysis of his data set exclusively with the section used by the study presented by Dr. Gonzalez (the 200+ base pairs from some section of the whole mtDNA). Results are apparently similar to other species.

Conclusion: The integrative approach, of combining multiple tools such as electronic tagging, genomics, fisheries and biological studies to get a complete picture, was pointed out by several participants as the way forward for the study of stock structure of swordfish in the Pacific Ocean.

Conceptual model

One participant observed that recent longline catches seem to match areas where females with high gonadosomatic index were found, and that the standardized CPUE does not seem to show much effect of vessels. He questioned whether a covariate may be missing. A discussion followed with the representative from Japan and is reported below together with the indices of abundance discussion.

Dr. Patricio Barría gave an overview of the recorded presentation *"*Conceptual model of the swordfish (*Xiphias gladius*) life history in the south eastern Pacific Ocean*".* He pointed out that Chile has information on animals ranging from 100 cm to 330 cm of lower-jaw fork length. The conceptual model for the S EPO swordfish (Figure 2) is based on foraging and reproductive migrations and poses two questions: i) how far north do adults to go spawn and ii) what is the area for juveniles? The stock is highly associated with the Humboldt current dynamics. The areas under the influence of the Humboldt current are areas of high productivity. The influence of the Humboldt current may go up to 200-300 miles away from the continent and even up to 100°W. The higher primary productivity occurs in frontal areas. High prey density in coastal area provides feeding grounds. In January-February large/mature individuals move to the east to feed, CPUE also increases in the Chilean fishery at that time, then move north in July to September. Later, turbulence pushes fish to move westward and disappear. They would go to spawning areas, to increase survival of eggs/larvae. The 24°C isotherm determines spawning ground, but it is not known exactly where they go. When fish finish spawning, they move away from the spawning ground to foraging area. Not much is known about the early life stage. Juveniles concentration drops close to the coastline, but little is known about juvenile movement. However, juveniles have been found from the continent to 60 miles off Peru.

Dr. Mora added that the pattern of gonadosomatic index has been found in other studies of animals from the Chilean coast (i.e., spawning in summer). Data on amount of fatty acids support the same conclusion. Females above a certain size are always more prevalent than males in the Chilean driftnet fisheries (that is, in shallow areas) in the same size range.

A participant asked why the Chilean fleet does not use longline gear. **Dr. Patricio Barría** responded that gillnet fishing, unlike longline fishing, does not use bait and does not require large vessels, thus it is due to an economic reason. Longline vessels are large (usually >18 m) while net vessels are smaller (<18 m). When using nets, fishers can set the net where the oceanic fronts happen, perpendicularly, as animals move across fronts. **Dr. Chugey Sepulveda** commented that this is a very different fishing strategy from what is used in the north EPO, where the fish are spread offshore and the longline gear is more effective (60-80 km from the coast).

The recent population increase may be associated with the increase in squid density, which is an important prey for swordfish. **Dr. Francisco Ponce** added that the SWO that comes from the South in Chile eats mackerel.

Dr. Patricia Zarate added that spawning females were found around Isla de Pascua. **Dr. Francisco Ponce** added that larvae move through the Nazca sea mountains because of the eddies.

Dr. Patricio Barría pointed out that the catch map showed annual catch and Hinton's work suggests swordfish in the northern and southern hemispheres behave differently in the different seasons and a catch map by season would be more informative to help determine the spatial structure. In the catch map by quarter, the areas with high catches may be reproduction/spawning areas. If the large catches in the tropics occur in Jan/Feb, they should correspond to the south stock. High catches in other quarters should correspond to the north stock.

A recommendation was made to look at the Japanese CPUE maps by season to help decide spatial limits. The seasonal maps were produced and discussed in the following day (Figure 3).

Conclusion: The conceptual model (Figure 2) alternating migrations towards foraging areas in the zone of influence of the Humboldt current and to spawning areas in warm waters is supported by seasonal patterns in the catches of the industrial longline fleets, and effort and CPUE of the Japanese fleet (Figure 3). Further analyses are needed to clarify the extent of the migrations.

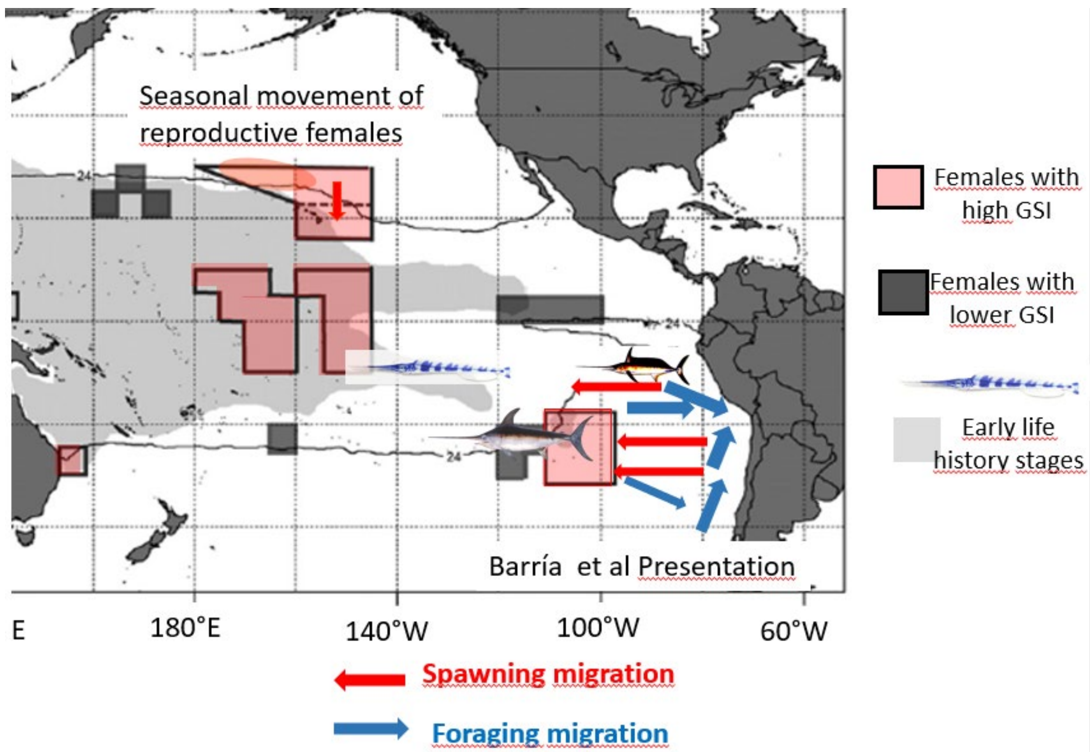

FIGURE 2. Conceptual model for the S EPO swordfish (Barría *et al.*) overlaid on map of known spawning and early life history areas (compiled by Lu *et al.* 2016).

FIGURA 2. Modelo conceptual para el pez espada del OPO sur (Barría *et al.*) superpuesto sobre un mapa de áreas conocidas de desove y ciclo vital temprano (compilado por Lu *et al.* 2016).

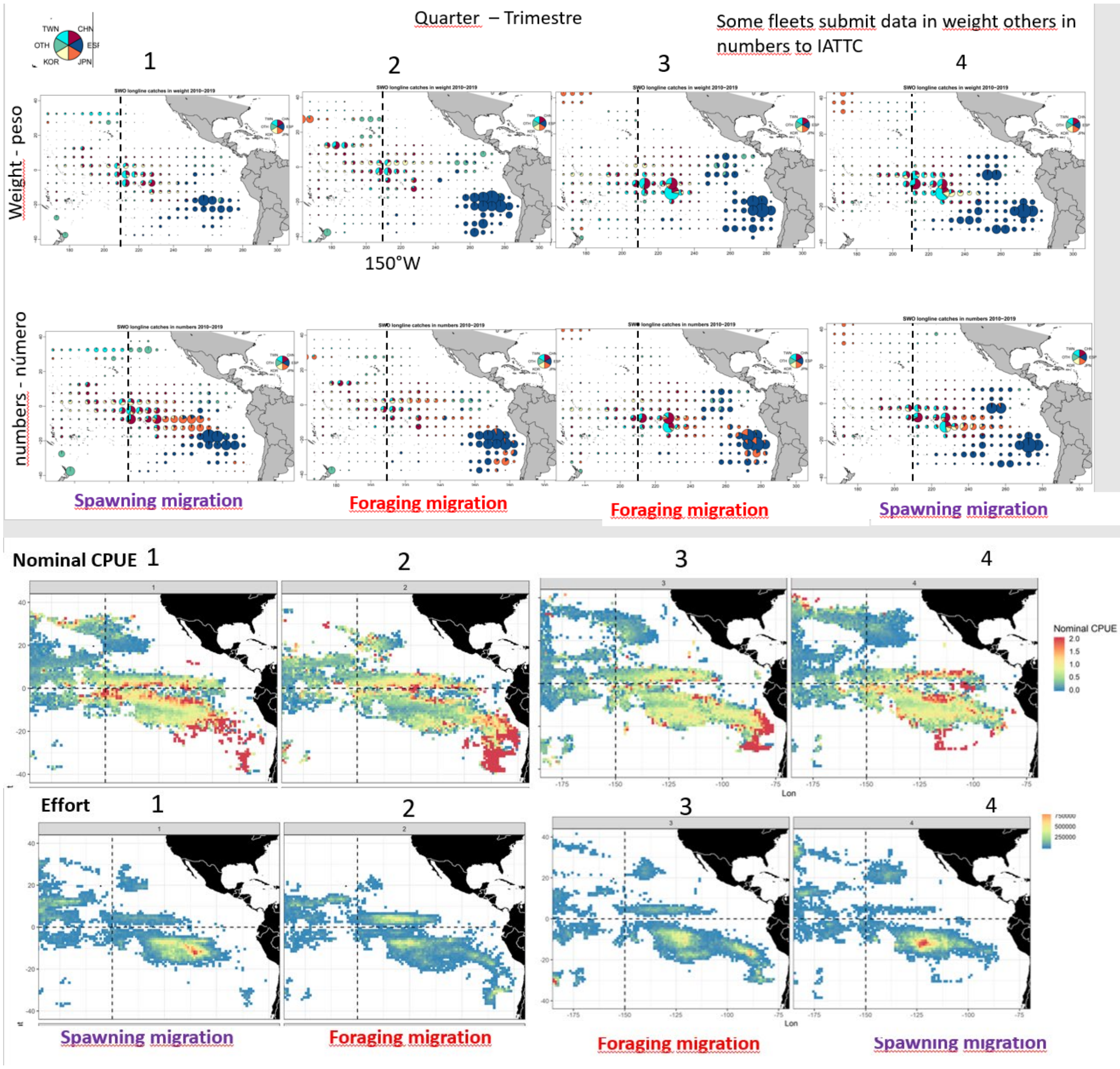

FIGURE 3. Catches (2010-2019) reported to the IATTC in weight and number by the industrial longline fleets. Nominal CPUE and effort for the Japanese fleet aggregated by quarter pointing to the corresponding migration season of the conceptual model of swordfish in the south EPO. The dashed lines are the 150°W meridian and the equator.

FIGURA 3. Capturas (2010-2019) reportadas a la CIAT en peso y número por las flotas palangreras industriales. CPUE nominal y esfuerzo de la flota japonesa agrupados por trimestre señalando la estación de migración correspondiente del modelo conceptual del pez espada en el OPO sur. Las líneas punteadas son el meridiano 150°O y la línea ecuatorial.

Stock structure assumptions for the 2021 assessment

The Chair proposed to have a stock structure in the assessment that allows for the addition of a band from 0 to 10°N, as fisheries, and another area south of the equator, because it would be easier to exclude that band in case an alternative stock structure assumption is investigated. In addition, a sensitivity of expanding the western boundary towards 155°W was suggested (to encompass areas that seem to be continuous in catches).

Guillermo Morán, from Ecuador, pointed that swordfish is important for Ecuador and that they would provide data to supplement information where it is missing for areas in the northern boundary of the S EPO swordfish stock, in the tropical EPO, to get a more complete picture.

Dr. Nicholas Ducharme-Barth, from SPC, offered their help in terms of data that may be needed to model any sensitivities if the stock boundary is extended towards the west, to 155°W.

A participant noted that, in previous assessments, the base-case model assumption was to have a northern boundary at 5°S and made a proposal to maintain that base case, but run analyses where the catches (area) to north are included. It was not clear whether fish at 10°N were coming to spawn in the southern spawning area. More studies are needed to clarify the importance of animals north of 5°S to the southern stock. The northern limit is not clearly defined, and so further research is required.

A participant asked whether the Mexican longline catches (north of 10°N) were so small that they do not shown in the maps. What happens to it? Will it be assessed somehow? It was pointed out that the technology to allow for multi-year (and season) tagging has been applied only in the last two years, but it is already showing movement from the US south to the equator, especially during the months of February-April. So, it seems that perhaps individuals north of the equator that move south are not included. **Scott Alberts** commented that from the movement data they have (tagging in the California coast) a large proportion of swordfish moves south towards the equator, but not over the equator. But there may be bias due to less tagging in the tropics.

A participant asked whether there was a possibility to include farther north areas because tagging shows movement from the north to near equatorial areas and, since it seems easier, to drop data once it is in the model rather than to include new data if it is needed. Fish seem to change behavior close to the equator and disappear for longer periods of time. The Chair pointed out that time is limited to explore all hypotheses. **Dr. Alexandre Aires-da-Silva** acknowledged that tagging data does show stronger connectivity than assumed in the ISC assessments, but the amount of connectivity [to the southern stock] is not clear and more data is needed to explore the connectivity. He clarified, that at this time, expanding to northern latitudes may be premature given the limited tagging and other information for a broader geographic area. We encourage the continuation of swordfish tagging to improve the definition of stock boundaries.

The Chair proposed to explore the data from the Spanish fleet, which targets swordfish, in addition to the Japanese fleet data, define alternatives or refinements to two spatial structures, one similar to that used by Hinton in 2011, and one including the near equatorial areas.

A participant from Chile pointed out that they agree on the previous limits used in the last assessment but are uncertain about the boundary crossing towards north of the equator, because there is an ecological barrier there. They think that old assessment borders are good.

Conclusion: The group agreed to have a short follow-up meeting to discuss the stock structure after further analyses and, if additional analyses could not be done for some reason, the staff would keep the old assumption on structure, with the addition of an equatorial fishery that could be included or excluded as alternative hypotheses.

Biological assumptions

Growth

Dr. Francisco Cerna explained that the female maximum age estimated for the Chilean catches was 17 years based on the fin spines. The age data was validated for the first two years using daily increment data, and a growth increment for one tagged fish. The daily increments in otoliths for fish of 2+ years have not been used because they are small and fragile, and there is compression of the rings. A well-polished section of otolith is needed to allow for the rings to be visible. The count of rings in otoliths has not given good results for older fish, which is why they use the annal fin spines that are easier to manipulate. The growth rates are faster for Chilean fish than those caught in Hawaii. **Dr. Patricio Barria** added that the growth curve was based on data from the longline fleet and that there is information by sex, and there are age-length keys available for every year. A participant commented that the availability of size–age keys allows for the age and length data to be entered in the assessment model and growth can be estimated inside the model, and variation in growth by year can be explored.

Dr. Jessica Farley presented a study done in the western and central Pacific Ocean comparing fish aged with fin rays and with otoliths, and the conclusion is that aging with fin rays may be underestimating age in the oldest age group. She added that they are planning to use the decline in bomb radiocarbon for validating the age of swordfish.

A participant suggested to have a plus group at a younger age in the assessment model to account for potential biases in the aging of older fish.

Reproductive biology

Dr. Patricio Barría: The number of mature females in the Chilean catches is not high; by the end of the year there few and not enough to produce a maturity ogive. The way they establish the maturity is by measuring the diameter of oocytes and applying the scale DeMartini developed for Hawaii. They have not found many stages 6-7 (fully mature in DeMartini scale). There are two studies that could be used for the stock assessment: Easter Island and Hawaii. There is variation on size at maturity, and the functional form should be discussed since it will also affect the estimation of natural mortality, depending on the method used. **Dr. Sergio Mora** commented that they measure the amount of fat per fish by length, which is related to reproductive period. This information could be used to determine the average maturity at length. The data on the amount of fat per fish by length were compared with data on size at maturity from Easter Island and they correspond well.

Length-weight, weight-weight and length-length relationships

A participant from Chile stated that they may have a few years of length-weight data that could be used to derive length-weight relationships for males and females. **Dr. Patricio Barría** complemented that the data were taken from the industrial longline fleet from 2001 to 2010, when every trip carried a scientific technician on board. After 2010, vessel owners had no obligation to carry a scientific technician onboard. The information on whole weight and trunk weight was obtained, as well as eye to fork length and lower jaw to fork length from which the relationships could be estimated.

Natural Mortality

Dr. Mark Maunder presented his newly developed equation to represent natural mortality at age from juveniles to adults. The equation describes high natural mortality for juveniles that is the same for both sexes and decreases towards adulthood. Natural mortality then increases as the individuals mature and is different between males and females. Defaults are suggested for some of the parameters based on approaches described in the literature.

A discussion followed on the approach to natural mortality to be taken and on other information that could be used a as proxy (for example predation rates of juveniles). **Dr. Nicholas Ducharme-Barth** pointed that SPC intend to revisit age-specific scenarios for the coming SW PO assessment and perhaps use the published life history meta-analysis. **Dr. Ana Alegre**, who has studied stomach contents of several pelagic species off Peru, pointed out that she has not encountered swordfish in the stomachs of marlins and sharks that she has studied. **Dr. Ilia Cari** (and later, **Dr. Patricia Zarate**) mentioned that there is information on stomach contents collected in Chile. Dr. Cari mentioned that, based on diet analysis and stable isotopes analysis, there are indication that swordfish is a component of the diet of pelagic sharks. Therefore, when considering the indices of abundance, it is important to consider predator abundance. Another participant mentioned that sharks eat swordfish in the south of Chile. **Dr. Patricio Barría** also added that they have data on the weight of juveniles that could be used to derive the juvenile natural mortality.

<u>Stock-recruitment assumptions</u>

Dr. Nicholas Ducharme-Barth pointed that for the WCPFC 2021 assessment of swordfish in the S WCPO, they will apply a similar approach as used in past for tunas, range of steepness options instead of just one value.

A participant suggested looking at the Brodziak method to develop prior probability density functions for the steepness parameter. **Dr. Mark Maunder** suggested that before using that method, the assumption of the method should be reviewed since some assumptions seem unreliable. He stated that spatio-temporal and oceanographic considerations may be more useful for predictions instead of variations on stock-recruitment relationship, for stocks that are highly fecund pelagic spawners, such as swordfish.

<u>Indices of abundance</u>

Preliminary indices of abundance using the Japanese data were shown, as well as the nominal catch rates for the Spanish fleets and indices of abundance derived from the standardization of catch and effort from the longline and driftnet Chilean fleets. Also, the changes in CPUE and distribution of the Chilean longline fleet within a year were shown. The Japanese indices show an increasing trend with an abrupt increase after the year 2010. A review on the changes in gear in the Japanese fleet was mentioned, and shows the introduction of light sticks in the mid 1990's. The Spanish and Chilean indices seem more stable.

A participant noted that adding Vessel IDs and HBF to the standardization model of the Japanese catch and effort data does not seem to have much effect and asked whether the models may be missing an important covariate and whether there may be any covariates that may be used to indicate target changes. **Dr. Ijima** from Japan mentioned that there can be target shifting, and there may have been a change to swordfish since 2010, but no solid data exist to support this yet. In addition, he commented that they do not have data on the use of light sticks or indications that their use may have an effect on swordfish catch rates, or whether it was introduced rapidly or slowly over time, and it is therefore unknown if/how the effect occurred over time. His opinion is that it could have been introduced gradually and so the effect is gradual. He recommended to cut the series or do time block in the assessment model at around 2000 to account for gear changes. Finally, he pointed out that, when using HBF, the material of the line is also important: before (prior to 1994) mostly natural materials were used that are heavier than the artificial materials used later (nylon). Thus, the number of HBF needed to be increased to have the gear fish in the desired depth. They split the series in 1994 when using it to produce indices of abundance because it is difficult to standardize for those gear changes, and 1994 is when the new logbook system was implemented that has information on gear material.

A participant asked whether the size of the fish was considered in the standardization using the spatiotemporal model, as for in the Japanese fleet the size varies considerably between areas. The sizes were not considered. It was suggested that they be considered when developing the indices.

A participant noted that if the areas-as-fleets approach is used, it is important to recognize seasonal migration, and that swordfish of different sizes appear in different areas.

One participant asked about the Spanish fleet data and whether their logbook data would be available to obtain indices of abundance. **Dr. Josu Santiago** said that they will evaluate to what extent we could provide detailed information that exists for the past 15 years on location (from VMS) and operational level data (from logbooks). They also have a minimum level of observer coverage and they may have information on length and sex data. **Mrs. Lucia Sarricolea Balufo** stated that Spain is willing to fully collaborate with the stock assessment.

Dr. Alan Barraza Saez commented on his recorded presentation, *"Estimation of a statistical model for standardized CPUE",* that some time ago they considered spatio-temporal models but due to the computational and data needs, they decided to use a GLM Tweedie, considering location and time, but could also include depth.

For the Chilean indices, the staff suggested that spatio-temporal modeling could be used for CPUE and size-compositions and that the staff would evaluate available resources to collaborate/assist in the construction of spatio-temporal models by the Chilean colleagues. The staff pointed out the one of advantages to include size data in the standardization is to obtain size distribution that would represent the index of abundance as opposed to just using the size-frequency of the fisheries to represent the index.

Dr. Fernando Espindola commented on the mention to his recorded presentation, "Influence of ENSO on the spatio-temporal distribution of swordfish catches in the south Pacific Ocean*",* that what was shown as depletion during a year may in fact be changes in the catch rates due to changing in oceanographic conditions. The spatial part of this is important because most of the catches occur in the southern area (where there is a large presence of eddies). So, this "depletion" it is not really depletion of a cohort over time but the effect of oceanography.

Dr. Patricia Zarate mentioned that they have used satellite data to relate environment conditions to catch rates for longliners and driftnets.

As a general conclusion for biology, the Chilean delegation offered to share data and information needed for several of the biological processes being modeled.

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6. RECOMMENDATIONS FROM THE PARTICIPANTS

A list of recommendations from the participants of the workshop was drafted and discussed. It was clarified that these recommendations were to be seen more as a guide for the incoming assessment, as well as research priorities and suggestions to be followed to improve the understanding of swordfish and elucidate uncertainties that would improve future assessments. It was also pointed out that for some recommendations, the samples may be available, but to undertake the study it will require collaborations, equipment, training and funding. The recommendations are priorities on the record to help seek funding to help initiate regional research.

Recommendations derived from the discussions done in the 1st technical workshop on the S EPO Swordfish

I. 2021 S EPO Assessment:

A. Model/assumption

1. Analyze the Spanish CPUE data to look for information on stock structure.
2. Study the seasonality of standardized catch rates in the equatorial zone to discriminate the timing of movements from the northern stock and the southern stock.
3. Estimate spatiotemporal models with size-frequency data to explore the seasonal patterns of migration from N EPO and S EPO to equatorial areas under the Hinton & Deriso hypothesis of the swordfish in the northern and southern hemispheres behaving differently.
4. Decide on base-case stock structure based on those analyses
5. In case of no conclusive evidence by early February 2021, data for both 2011 stock structure assumption (150°W south of 5°S) and adding the equatorial band (5°S to 10°N) will be included in the model to test alternative hypotheses.
6. Add data west of 150°W as a sensitivity
7. Explore Maunder model for natural mortality
8. Fit growth-cessation model
9. Include uncertainty in longevity (the maximum age may be underestimated)
10. Explore variation in growth over years
11. Explore prior on steepness, while mindful of the assumptions of the approach
12. Use proportion of fat by fish length as a proxy to maturity at length
13. Do not transform maturity at length into maturity at age due to added bias; use maturity at length directly in the stock assessment
14. Update length–weight , lower jaw fork length–eye fork length and processed weight–total weight relationship with multi-year data from Chile and other fleets (if available)
15. Estimate the dry weight – total weight relationship from Chilean data to apply to Lorenzen's method for juvenile mortality
16. Explore stomach content data from ecosystem studies to assess whether predation mortality would be high for juvenile swordfish.

B. Data

1. Include length and age composition data by sex when available
2. When using Japanese longline data to estimate indices of abundances, start the series in 1994 because of changes in the material of the main line from natural fibers (heavier) to nylon (lighter). The fishers need to use more HBF to get to the same depth when using nylon than when using natural fiber. Thus, the HBF will have different effect on those two situations

3. Incorporate data from Ecuador
4. Incorporate operational level data from Spain into CPUE standardization analyses
5. Explore spatiotemporal models to produce indices of abundance, include size data in the standardizations (Japanese, Korean, Spanish and Chilean data may be used to produce indices)
6. Include Chilean data on age-length keys as conditional age-at-length data

Recommendations for research

II. Research

A. Stock structure/movement

1. Apply an integrative approach to stock discrimination using multiple tools, in a regional coordinated and collaborative way, with a sampling design that will allow for the advancement of the understanding of the stock structure of swordfish in the PO, such as those described below.
2. Tag fish with new tagging technology that allows for multi-year tracks
3. Continue the development of tags that would be less invasive to the animals and easier to remain attached for a longer time
4. Collect tissue samples from live animals and preserve in alcohol (and refrigerated) for future genetic work genomic studies, stable isotope studies and biochemical specifics components, in particular when tagging animals
5. Reward fishers that would return the tags in addition to gonad samples from the tagged fish
6. Study sexual genetic markers to allow for sex discrimination of swordfish
7. Re-analyze available genetic data in the specific section of mitochondrial DNA studied by Dr. Gonzalez to compare with other available samples (discussion between F. Gonzalez and Alvarado-Bremer)
8. Continue current tagging programs
9. Sample and tag fish in the spawning areas for genetic analysis and movement to determine the origin of spawning fish, special focus on the equatorial Central Pacific Ocean, around 150°W, and areas northwest of Rapa Nui (20°S, 100°W), to determine the origin of those spawners and elucidate the spawning area of the S EPO stock.
10. Re-analyze depth data in tracks of tagged animals to detect potential changes in behavior that may be due to spawning and map those areas.
11. Continuously revisit stock structure assumption in swordfish assessments based on the most up to date biological information
12. Continue studying mesoscale oceanographic processes on forcing of swordfish population processes, stock structure and connectivity

B. Biology

1. Attempt to age larger individuals using otoliths to address potential underestimation of annuli in spines as shown in studies from Australia
2. Continue pursuing validation of growth increments of large fish
3. Explore variation in growth over years
4. Monitor prey and predators (squid, sharks) to understand changes in the swordfish indices of abundance and to what extent that may be related to increase in prey densities and decrease in predator densities
5. Collect sex data whenever possible (e.g. onboard observers) to understand different life-history strategies by sex

III. Data

1. Report length and age composition data by sex when available
2. Add more gear characteristic in the data to be collected in logbooks and by on-board observers such as the use of light stick in longliners or other technological changes that may increase the catchability of the gear for swordfish
3. Continue studies about changes in targeting in the longline fleets.

7. WORKPLAN

The following workplan was agreed among the participants of the workshop:

TABLE 1. Workplan for the stock assessment of swordfish in the south EPO	
2021	
January	Work with Chilean, Spanish, Ecuadorian and SPC colleagues in data preparation
	Perform analysis on stock structure
	Consolidate catch estimations
	Consolidate length frequency distributions
February	Continue study of changes in targeting for the Japanese fleet
	Estimate indices of abundance
	Zoom meeting about stock structure / indices
	Estimate growth cessation curve
	Compute M at age and sex
	Include data and new assumptions on newest SS3 model
March	Fit base case model
	Explore sensitivities
	Zoom meeting about model results
April	Prepare report
May	Presentation at SAC12

Regarding the workplan, **Dr. Patricio Barría** pointed out that it may be somewhat tight for Chilean scientists as they have collective vacation in February. It might be difficult for them to participate in a February meeting. They also pointed out that a more specific workplan for data preparation may be needed for them.

APPENDIX 1. Agenda

INTER-AMERICAN TROPICAL TUNA COMMISSION

1ST TECHNICAL WORKSHOP ON SWORDFISH IN THE SOUTHERN EPO

Review current state of knowledge, identify available data sources, review stock assessment assumptions for swordfish in the southern EPO

(by videoconference)

15-17 December 2020

Objectives

The workshop, and its preparatory work, will bring together scientists interested in contributing to this regional effort. The objectives are to: 1) promote a regional investigation of swordfish in the southern EPO; 2) review the current state of knowledge of the stock; 3) construct a conceptual model of the population and fishery; 4) identify and understand data sets available from different fisheries/regions that can be used in the assessment; and 5) plan the next steps for the stock assessment process.

Tentative agenda of videoconference

Day 1

1. Introduction to meeting
2. Mention of recorded presentations
3. Background on swordfish issues in the EPO
4. Previous IATTC Stock Synthesis model for swordfish: description and analysis
5. Stock structure / Conceptual model of dynamics
    a. overview presentation

    Discussion

Day 2

6. Biology overview presentation:
    a. Growth
    b. Natural mortality
    c. Reproduction (maturity, fecundity, frequency)

    Biology discussion

7. Fisheries definitions
8. Review of data sources:
    a. Catch by gear and area
    b. Other data for model fit (*e.g*. tagging)
    c. Composition (age, length, weight, sex composition, length-weight relationship, dressed weight-full weight relationship)
    d. Catch-per-unit-effort (CPUE)

    Data sources discussion – focus on indices of abundance

Day 3

9. Modeling discussion

    a. Overarching hypothesis
    b. Other uncertainties
10. Review of recommendations
11. Workplan for model improvement

APPENDIX 2. List of participants

1er Taller Técnico sobre el pez Espada en el OPO Sur 1st Technical Workshop on Swordfish in the South EPO

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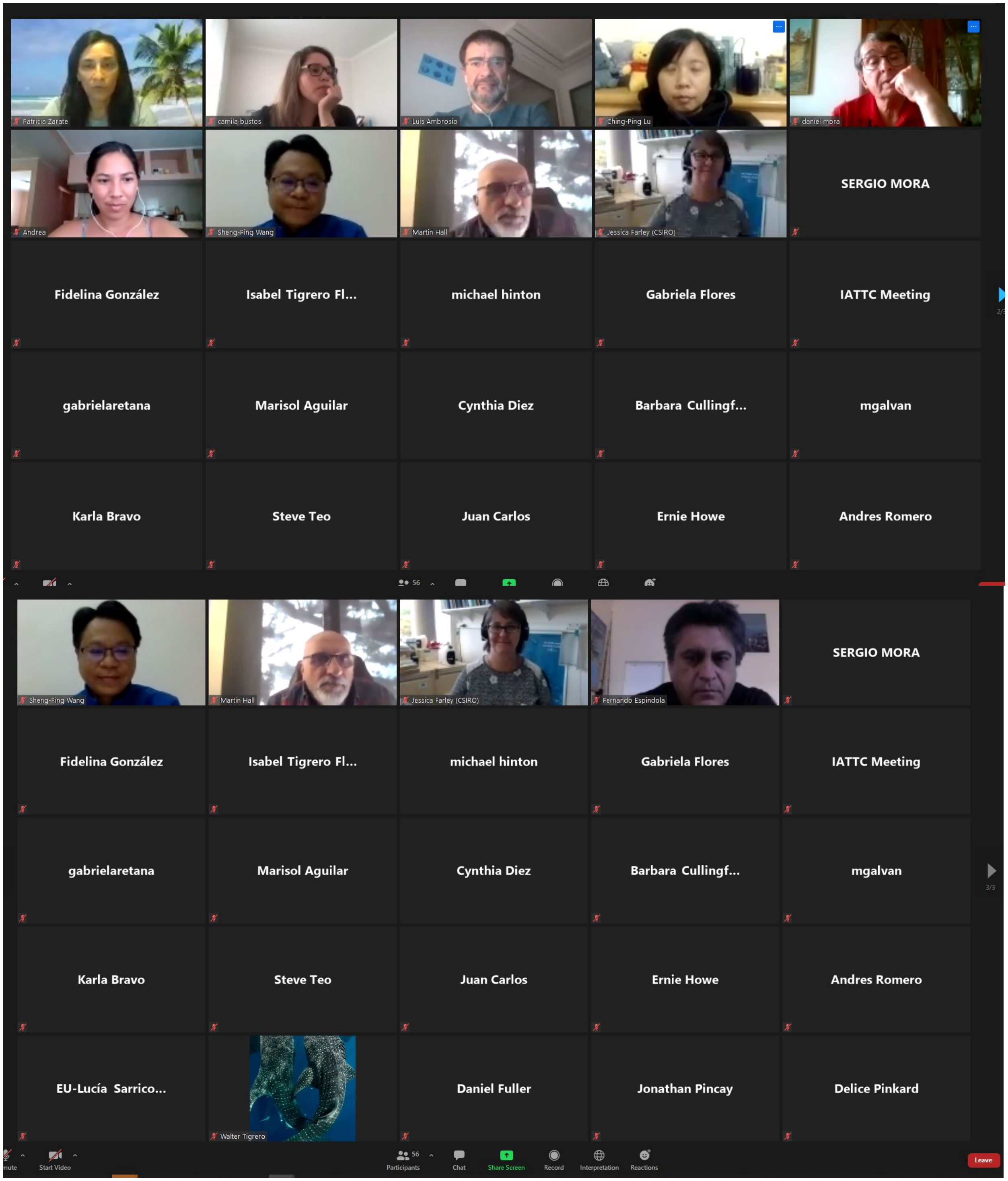
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Jonathan Pincay
Delice Pinkard
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Participants
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Record
Interpretation
Reactions
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APPENDIX 3. Abstracts of the recorded presentations

Aguila, R.D., Sepulveda, C., Aalbers, S., Bremer, J.A. An innovative approach to solve the genetic population structure of Pacific Swordfish: integrating genomics and electronic tagging data

No Abstract

Barraza, A., Barría, P., Miranda, H. (IFOP-Chile). *Estimación de un modelo estadístico para la CPUE estandarizada* (uploaded on 10/Dec/2020) [EN: *Estimation of a statistical model for standardized CPUE*]

Abstract:

In Chile, systematic monitoring of the swordfish fishery has been carried out from 2001 to 2020, in the artisanal drift-net fleet and a surface longline fleet that had industrial and artisanal vessels. One of the goals of the study is to analyze an index of relative abundance of the different fishing areas and fleets that catch swordfish, through the estimation of the catch per unit of effort (CPUE), considering factors related to vessel characteristics, temporal and geographical characteristics of the fishing area, etc.

CPUE modelling is based on a compound Gamma-Poisson GLM (Zhang, 2013), which corresponds to a particular case of a Tweedie GLM (Jϕrgensen, 1987; 1997), which allows us to simultaneously model the number of analysis units (set or trip) with catch along with the associated catch quantity. The historical records of the longline fleet correspond to 2001-2018, where 15,115 sets were observed, and the historical records of the drift-net fleet are from 2001-2018, with a total of 1,599 trips.

Regarding the CPUE in the longline fleet, its catch is composed of immature fish, while the catch of the drift-net fleet is composed of mature fish. The CPUE estimate for the longline and drift-net fleets that target swordfish has positive trends with inter-annual variations in the southern EPO fishing areas.

Resumen:

En Chile, se han realizado monitoreos sistemáticos de la pesquería del pez espada desde el año 2001 hasta el 2020, en la flota redera artesanal y una flota palangrera de superficie, que tenía embarcaciones industriales y artesanales. Uno de los propósitos del estudio es analizar un índice de abundancia relativa de las diferentes zonas de pesca y flotas que capturan pez espada, por medio de la estimación de la captura por unidad de esfuerzo (CPUE), considerando factores relacionados con las características de la embarcación, características temporales y geográficas del lugar de pesca.

La modelación de la CPUE, se basa en un GLM Gamma-Poisson compuesto (Zhang, 2013), que corresponde a un caso particular de un GLM Tweedie (Jϕrgensen, 1987; 1997), el cual, nos permite modelar simultáneamente el número de unidades de análisis (lance o viaje) con captura junto con la cantidad de captura asociada. Los registros históricos de la flota palangrera corresponden al período 2001-2018, donde se observaron 15.115 lances, y los registros históricos de la flota redera son del período 2001-2018, con un total de 1.599 viajes.

Respecto de los resultados de la CPUE en la flota palangrera, su captura está constituida por ejemplares inmaduros, en cambio, en la flota redera, su captura está constituida por ejemplares maduros. La estimación de CPUE para la flotas palangreras y rederas que capturan como especie objetivo el pez espada presentan tendencias positivas con variaciones interanuales en las zonas de pesca del OPSO.

Barría, P., Mora, S., Urzúa, A., González,F., Ortega, J., Miranda, H., Ponce, F., González, A., Devia, D., Lazo, J. Modelo conceptual del ciclo de vida del pez espada (Xiphias gladius) en el Océano Pacífico Sur Oriental

Resumen

Cerna, F., Cid, L., Cabello,R., Vidal, L. Edad y Crecimiento en pez espada del Pacifico sur-este frente a Chile

Resumen

Devia, D., González, A., Mora, S., Ortega, J., Miranda, H., Barraza, A., Cerna, F. , Urzúa, A., Gonzalez, F., Barría, P. Composición de datos del pez espada (Xiphias gladius) en las pesquería de Chile.
Resumen

Ducharme-Barth, N (SPC- South Pacific Community). *Stock assessment of swordfish in the southwest Pacific Ocean: 2017 recap & 2021 proposal* (uploaded on 08/Dec/2020).
No abstract

Espíndola, F. (IFOP-Chile). *Influencia del ENSO en la distribución espacio-temporal de las capturas del pez espada en el Océano Pacífico Sur* (uploaded on 11/Dec/2020)
Resumen
Se determinó el patrón de distribución espacio-temporal de los rendimientos de pesca (tasa de captura) de pez espada (Xiphias gladius) de la flota palangrera industrial chilena, mediante el uso de series de tiempo. Se empleo información de las bitácoras de pesca registradas por observadores científicos entre enero de 2001 y diciembre de 2005. Se observó un ciclo anual característico en los rendimientos de pesca, con valores altos de marzo a julio-agosto, y desplazamientos de la flota palangrera de sur a norte de 38° a 32°S, en un rango de TSM de 17° a 19°C. Posteriormente, los rendimientos disminuyeron en dirección norte desde los 32°S con TSM mayores a 20°C. Este patrón espacio-temporal fue determinado con una alta coherencia cuadrada (79%) en las series temporales de las tasas de captura nominal y la componente latitudinal. Además, para la serie temporal de la tasa de captura nominal se establecieron fluctuaciones de baja frecuencia con períodos de 28, 38 y 59 días. Esta variabilidad intraestacional en los rendimientos de pesca estaría relacionada con las variaciones de mesoescala en las condiciones oceanográficas frente a las costas de Chile. Posteriormente, usando datos ambientales provenientes de sensores remotos, se determinó los cambios en la posición espacial de la isoterma de 18°C en relación a los cambios espacio temporal de los rendimientos de pesca (CPUE) del pez espada. Se obtuvieron coeficientes de correlación entre el centro de gravedad latitudinal (CGL) de la CPUE y

Espíndola, F. (IFOP-Chile). *Modelo de evaluación de stock para el pez espada en el Océano Pacífico Sur (*uploaded on 11/Dec/2020)
Resumen
Se presenta la evaluación de stock del pez espada (*Xiphias gladius*) en el océano Pacífico sur (OPS), la cual ha experimentado cambios debido a las hipótesis empleadas, plataforma de trabajo y disponibilidad de datos. En un comienzo, se asumió un proceso espacial que diferencia los efectos selectivos con los de un patrón de residencia local edad-específico. Es decir, una porción de una clase de edad en un área para un año dado es modelado como un proceso separable entre una preferencia por edad a un área y a un efecto año. Sin embargo, los resultados no fueron adecuados ya que el parámetro área, permanecía constante para todas las áreas. Posteriormente, se adopta otro esquema de evaluación, en que cada flota opera en una única zona de pesca y no existiría un patrón edad-específico, ya que la información disponible indica que hay sólo un limitado intercambio de individuos de un área geográfica a otra. Luego, el modelo de evaluación es conducido usando el código de programación ADMB, bajo el esquema de edad-estructurado e integrando las diferentes fuentes de información biológica-pesquera. Y finalmente, se avanzo en la implementación del código de evaluación en la plataforma de evaluación Stock Synthesis. El modelo de evaluación del pez espada se encuentra en estado de desarrollo, ya que quedan aún por hacer diferentes pruebas al modelo, como el análisis retrospectivo, perfil de verosimilitud y peso de los datos usados en el modelo. A demás, de evaluar otros supuestos estructurales, dada la alta presencia de diferentes flotas que operan en diferentes áreas y vulneran

diferentes individuos de la población. En general, el modelo de evaluación tiene un adecuado ajuste a los desembarques, para los índices de abundancia y en menor medida las estructuras de tamaños para las diferentes flotas que operan el OPS. Esto debido principalmente a que las diferentes flotas presentan efectos selectivos distintos en función del arte de pesca, en la zona donde operan y por año. De acuerdo al modelo de evaluación, los reclutamientos habrían presentado anomalías negativas a comienzos de la serie, sin embargo, esta tendencia se revierte a mediados de los 70, alcanzando valores significativos en los 80 y finales de los 90. Producto de los últimos reclutamientos la biomasa desovante ha crecido sosteniblemente, luego de alcanzar su mínimo en el año 1985. Al final del período analizado, la biomasa desovante se encuentra cercana a las 41 mil toneladas. En términos de la reducción de la población, esta se encontraría al 60%, valor por sobre en nivel biológico de referencia objetivo del 50%.

González, F. , Cortez, B., Faudez, V., Barría, P. Unidad poblacional del pez espada en Oceano Pacífico Sur Oriental
Resumen

Moore, B. Review of biology, stock structure, fisheries and status of swordfish in the Pacific Ocean

Mora, S., Ortega, J.C., Barría. Aspectos reproductivos del pez espada (Xiphias gladius) en el Pacifico sur oriental [Reproductive aspects of the swordfish (Xiphias gladius) in the south eastern Pacific Ocean]
Resumen

Pizarro, A.G. Barría, P. *Caracterización de la pesquería del pez espada (Xiphias gladius) en Chile* [EN: *Characterization of the swordfish (Xiphias gladius) fishery in Chile*] (uploaded on 10/Dec/2020)
Abstract:
This presentation reviews the development of the swordfish (*Xiphias gladius*) fishery in Chile since the first records in the 1940s. The National Fishing Service (Servicio Nacional de Pesca) database was used to describe the historical series of landings, while data collected by scientific observers on board fishing vessels and in the main landing ports of these fleets were used to characterize the operation of the fleets that catch swordfish, as well as the composition of their catches and landings. Finally, data provided by the Economics Section of the IFOP from Customs information was used for the analysis of swordfish exports.
The results showed that, for more than 40 years, the swordfish fishery was an artisanal coastal activity whose landings did not exceed 500 tons per year. However, in the mid-80s, the opening of the international market led to the development of a large artisanal drift-net fleet as well as an industrial longline fleet, which resulted in an exponential growth in landing levels. In the 2000s, the increase in the international price of oil caused a progressive decrease in the fishing operations of the longline fleet, registering its last trips in 2018.
In recent years, landings of swordfish in the country were around 6,000 tons per year, positioning Chile as one of the main countries exploiting this resource in the southern EPO. During the 2019 season, the artisanal drift-net fleet represented more than 99.8% of these landings, of which 66% was exported (mainly to Europe), which created important economic income for this artisanal activity.

Resumen:
Se reseña el desarrollo de la pesquería del pez espada (*Xiphias gladius*) en Chile desde los primeros registros realizados en la década de los 40´s. Para la descripción de la serie histórica de los desembarques se utilizó la base de datos del Servicio Nacional de Pesca, mientras que para la caracterización de la operación de las flotas que capturan pez espada, y la composición de sus capturas y desembarques se emplearon los datos levantados por observadores científicos desplegados a bordo de embarcaciones

pesqueras y en los principales puertos de desembarque de estas flotas. Finalmente, para el análisis de las exportaciones de pez espada se usaron datos aportados por la Sección Economía del IFOP a partir de información de Aduanas.
Los resultados mostraron que por más de 40 años la pesquería de pez espada era una actividad artesanal costera cuyos desembarques no superaban las 500 toneladas anuales. Sin embargo, a mediados de la década de los 80´s, la apertura del mercado internacional impulsó el desarrollo de una gran flota redera artesanal así como una flota palangrera industrial, lo que originó un crecimiento exponencial en los niveles de desembarque. En la década del 2000 el incremento del precio internacional del petróleo provocó la disminución progresiva de las operaciones de pesca de la flota palangrera, registrando sus últimos viajes el año 2018.
En los últimos años, los desembarques de pez espada en el país oscilaron en torno a las 6.000 toneladas anuales, posicionando a Chile como uno principales países que operan sobre este recurso en el Pacífico Sur Oriental. Durante la temporada 2019 la flota redera artesanal representó más del 99,8% de estos desembarques, exportándose el 66% de este recurso, principalmente a Europa, lo que generó importantes ingresos económicos a esta actividad artesanal.

Sepulveda, C.* Aalbers, M.S. (PIER - Pfleger Institure of Environmental Research). *An overview of swordfish electronic tagging studies off the U.S. West Coast* (PIER Research 2005-2020) (uploaded on 08/Dec/2020).
No abstract

Sculley, M. 2018 Western and Central North Pacific Swordfish assessment (uploaded on 13/Dec/2020)
No abstract

Zárate,P. Clavijo, L. & Cari, I.. *Marcaje del pez espada (Xiphiasgladius) en aguas chilenas* (uploaded on 13/Dec/2020)
No abstract

APPENDIX 4. Guiding questions

1. **Stock structure**
    - What is the evidence of a distinct stock in the S EPO?
    - What is the north boundary?
    - What is the west boundary?
    - How much they mix with other stocks?
    - Should we include catches that maybe also included in other assessments (overlap areas?)

2. **Conceptual model**
    - Where are the spawning zones? When are they in those zones?
    - Are there non-spawning zones? When are they in those zones?
    - Where are the early life-history stages? When are they in those zones?
    - Are they associated with any oceanographic condition or topographic feature?
    - What are the depths of occupancy during day and night? How those behaviors affect the catchability of the fishing gears?
    - What is the time scale that would best approximate the dynamics (quarterly or annually)?
    - Can we use a one area model approximating any spatial dynamics using the "areas-as-fleet" approach? Or do we need an actual spatial model?

3. **Biology:**

    a. **Growth**

- Males and females growth differently.
- What growth curve to use? Are there any updates to the study by Cerna? How should we model the juvenile growth? (as noted in SAC-02- 09: "growth function described adult swordfish well, but not the rapid allometric growth of juveniles"
- Is there any attempt to further validate the age?
- Are there studies comparing labs? How does the methods used in the WCPO compare to those use in the EPO?
- What is the variability of size at age for males and females?
- Are there any tagging studies of large animals to inform the growth rates at those sizes?
- Are there any updates of the length-weight relationship, dressed weight-full weight relationship from Cerna? Any study done in the Spanish fleet?

    b. **Natural mortality**

- What is the maximum age registered for males and females?
- Should the natural mortality be different for males and females?

- Should the natural mortality be different by age?
- Are there any tagging studies to inform natural mortality at size or age?
- Are there any tagging studies to inform longevity?

c. Reproduction (maturity, fecundity, frequency of spawning)

- What reproductive parameters should we use (steepness, maturity, fecundity)?
- Where spawning takes place and in what conditions?
- What stock-recruitment relationship assumptions should we consider? (steepness, variability of recruitment)

4. Fisheries definitions

- Six fleets where defined in the previous model:

Fishery	Description	Principal area of operation
F1	Chile industrial longline	Offshore – west of 90°W
F2	Chile artisanal and Peru	Coastal – east of 90°W
F3	Japan and Japan-like longline	Offshore
F4	Japan and Japan-like tuna longline	Coastal
F5	Spain longline	Offshore
F6	Spain longline	Coastal

  - Should we maintain those or define others?
  - Are those definitions/boundaries supported by length frequency data or other information?
  - Do we need to add the artisanal catches of Ecuador?
  - Do their selectivities change by season (for example because of movement of fish or changes in oceanography?)
  - Are there any changes over time in the fishing strategies that could inform changes in selectivity?
  - Do we need spatial structure in the fisheries other than Coastal/Offshore?

5. Review of data sources:

d. Catch by gear and area

- Is the longline catch data accurate?
- What are the catches of the artisanal fleets?
- Are there any know discards in any fleets?
- Do we need to convert from processed weight to round weight?

e. Catch-per-unit-effort (CPUE)

- How the CPUE from Japan, Korea and Spain compare?
- What gear variables should we use in the standardization?

- Is there use of light stick? When was introduced?
- Should we use oceanographic variables in the standardization? How much they influence catchability? Does it need to include depth?
- Should we use or delta-lognormal spatiotemporal models or delta-lognormal GLMs for the standardization? (to ensure the whole “area” is covered each year and to apply area weighting)
- Are there any spatial changes in the fisheries?

f. Other data (*e.g*. tagging)

- Are there other data that could be used to fit the assessment model (e.g. growth increment data from tagging experiments, movement (recaptured conditioned), or mark-recapture)?

g. Composition (age, length, weight, sex composition, length-weight relationship, dressed weight-full weight relationship)

- What is the length/age/sex composition of the Chilean fleet? How it is estimated?
- What are the length/age/sex compositions of the JPN/KOR/CHN/TWN fleets? How are estimated?
- What is length/age/sex composition of the Spanish fleet? How it is estimated?
- Are there length/age/sex composition for other fleets?

6. Modeling

- What are the main hypotheses to explain the dynamics of S EPO SWO?
- What are the main uncertainties to address?
- Should we use the best-assessment approach or a risk analysis approach?

7. Workplan

- What is the timeline/workplan for the assessment?