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SOUTH EPO SWORDFISH BENCHMARK ASSESSMENT: PROGRESS REPORT

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The south EPO stock of swordfish was last assessed in 2011 (Hinton and Maunder 2012). The Commission requested that a new benchmark assessment for this stock be conducted, and the task was included in the staff's research workplan (IATTC-93-06b). The work was initiated in the fall of 2020 with the completion of the 1st Technical Workshop on swordfish in the south EPO (SWO-01), where scientists, managers and other stakeholders congregated to discuss the current understanding of biology, fisheries and data to assess the stock.

After the workshop, the staff collaborated with several CPC's to obtain the necessary data and perform auxiliary analyses needed for the assessment. The catches were estimated from several data sources: the 5° by 5° by month data, submitted to the IATTC in compliance with the provision of data resolution (C-03-05), a special submission of data on catches by gear and quarter by Chile, a special submission of trip-by-trip data by Ecuador, consultation of the FAO databases and general literature search. Several indices of abundance were estimated thanks to the collaboration with some CPC's. A collaboration with Japanese scientists allowed for the analysis of the set-by-set operational level data to obtain both a standardized CPUE and a standardized average fish weight (1975-2019, SAC-13-INF-N). A Memorandum of Understanding was signed with Korea, which allowed access to the set- by-set operational level data and made possible the comparisons between indices derived from Japanese and from Korean CPUEs (SAC-13-INF-M). A special submission of the 2° by 2° by set data by Chile and a special submission of set-by-set data with positive catches of swordfish by Spain allowed for the estimation of other indices of abundance and standardized length composition data. The staff also analyzed 1° by 1° by hooks-between-float by month Japanese catch and effort data submitted by Japan in accordance with the data provision resolution (Level 2 data). Length-composition data was available for the distant-water fleets through the routine submission to the IATTC in accordance with the data provision resolution, and for Chile and Ecuador by special submissions for the current work. Age-composition data was made available by Chile in the form of age-length-keys by year, sex, and gear (longline and gillnet, 2000-2019). Chilean scientists also shared with the staff unpublished results regarding transformations between length and weight and between gilled-and-gutted weight and whole weight.

The data compiled for the EPO south of 10°N showed a dramatic increase in catches since the mid-2000s. The average catch per year from 2000 to 2009 was about 15,000 tons, while the average catch per year for 2010 to 2019 almost doubled, to about 29,000 tons. In the last three years of the compilation (2017 - 2019), the average catch was about 34,000 tons. The fleets that are currently the most important are the Spanish longline fleet, which catches about 30% of the total catches, followed by the Chilean gillnet fleet with 22%, and the Ecuadorian longline fleet with 20%.

The indices of abundance continued to show increasing trends similar to those first detected in the 2011 assessment (Hinton and Maunder 2012). The Japanese catch and effort set-by-set operational level data was analyzed using a spatio-temporal model (SAC-13 INF-N), with hooks between floats as a catchability covariate and vessel effects. Due to known and suspected changes in fishing strategy that may have caused that increase in trend, three series where computed: 1976 to 1993, 1994 to 2009, and 2010 to 2019. Nevertheless, the increasing trend persisted. The hypothesis that the Japanese fleet might have implemented changes in gear that increased catchability was investigated by comparing indices constructed in a similar way for both the Japanese and the Korean fleet in areas in the EPO where both fleets overlap (10°N to 10°S, 150°W to 110°W, SAC-13-INF-M). The Korean fleet showed similar increasing trends to the Japanese fleet, which ruled out that the trend was due to changes in strategy specific to the Japanese fleet. The investigation continued by producing indices of abundance from the catch in weight from the Spanish fleet, which also showed increasing trend, and from the catch in numbers by 1,000 hooks from the Chilean longline fleet, with similar results. The possibility that perhaps all the longline fleets might have introduced similar changes in strategy simultaneously that could increase the catchability of the fleets at the same time was ruled as unlikely because an index obtained from the Chilean driftnet fleet also showed increase trends (Barraza et al presentation during SWO-01). The estimation of density conducted by standardizing catch and effort data from the Japanese fleet showed that the there are areas of high density off the coast of Chile and to some extend north and south of the equator, which were somewhat spatially disconnected before 2010. In the last decade, however, the areas of high density of swordfish appeared to have increase in connectivity. Average length and age for some fleets have decreased in the last 20 years, consistent with an increase in biomass through recruitment.

There is considerable uncertainty in stock structure for swordfish in the Pacific Ocean. Three hypotheses of stock structure consistent with the conceptual model for the stock (see SWO-01) are being investigated for the assessment of swordfish in the south EPO:

H1: The stock is distributed south of 5°S and east of 150°W, as in the previous assessment.
H2: The stock is distributed south 10°N and east of 150°W, this hypothesis considers that the equatorial areas and the subtropical areas are connected.
H3: The stock is distributed south 10°N and extended to 170°W, in the central Pacific Ocean.

The second hypothesis (H2) is considered here as reference because of the connectivity shown in the last decade between equatorial areas and subtropical areas off Chile, as well as the recent increase in catches in the equatorial areas.

A reference stock assessment model using the H2 stock structure hypothesis was built in stock synthesis 3.3.19. Fisheries were defined by area of operation, gear, and origin of the fleet (Spain, other distant water fleets, coastal fleets). The areas were defined using tree analyses of all available length-composition data. The model is an annual model with four seasons and uses the areas-as-fleet approach. The model is fit to nine indices of abundance derived from the standardization of the catch and effort of the longline fleets from Japan, Spain, and Chile. For Chile and Spain, standardized length frequencies were also obtain using spatio-temporal models. The assessment model was also fit to age- and length-composition data, which was weighted using the Francis approach. Other assumptions were similar to the 2011 assessment.

The model fit well all indices of abundance and composition data. The solution found by the model to explain increasing indices with increasing catches was to increase recruitment. Since 2000 most recruitment deviations were estimated to be above the mean and since 2008 all recruitment deviations were estimated to be considerably larger than the average recruitment. Diagnostic analysis for integrated models showed that a model with constant recruitment fit only to the indices of abundance (ASPM, Age-structured production model) needs a much higher average recruitment to explain the catches. If recruitment is allowed to vary by year (ASPM_DEV), increasing recruitment is estimated since the mid-

80s and recruitments much larger than the average are estimated after 2010 to be able to explain the simultaneous increase in catch and indices of abundance. In contrast, if the model is fit only to composition data, a model with constant recruitment shows a continuous decline of the population since the early 60's (CCA, catch curve analysis). If recruitments are estimated for every year (CCA_DEV) the population increases in the mid-90s, levels off from 2000s to 2010, and then decreases in the last decade. The maximum likelihood solution found by the integrated model was a compromise between the contradictory information from the indices and from the composition data.

Several hypotheses may explain the apparent increase in recruitment, and subsequent increase in biomass, estimated by the integrated model:

- Real increase in abundance. The smaller average sizes in some fisheries are consistent with the hypothesis of increase in recruitment that led to increase in abundance.
- Increase in availability. Since indices derived from different fleets and gear show increase in density, the apparent increase may not be an effect of change in strategies of a particular fleet or type of gear, but rather a general change in availability to all the gears.
- Increase both in abundance and availability. A combination of the two hypotheses above is another explanation because the underlying cause for increase in availability may also be a favorable condition for the population and may have caused the increase in productivity (through higher recruitment).
- Stock structure and connectivity. Indices derived from the New Zealand fleet in the western Pacific Ocean show increase in density at similar times that the indices in the EPO (SAC-13-INF-M). Connectivity from the equatorial area and the south sub-tropical EPO seems to have increased after 2010, perhaps the connectivity the WCPO might also have increased.

The four hypotheses have divergent implications. If there is real increase productivity, and if continued, the stock may continue to sustain large catches. If it is rather an increase in availability, the indices should not be used to assess the stock, and the assessment should be based on catch-curve analysis type of models. If the apparent increase is due to movement from outside the EPO (stock structure and connectivity hypothesis), the population should be assessed in conjunction with data from the WCPO. Alternative information may be needed to distinguish among these hypotheses such as close-kin analyses and genetic studies, studies of habitat modelling and changes in oceanography, and tagging data. For the assessment, the two extreme hypotheses (increase in abundance or increase in availability) should be modelled.

The short -term plan to conclude the assessment is to improve the reference model so that the hypotheses of increase in abundance (emphasis on indices) and increase in availability (emphasis on composition data) can be adequately represented. Emphasis will be made on refining the modelling of selectivities, including changes in selectivity, due to its effect on interpreting composition data. Further diagnostic analyses will be done as well as some key sensitivities: to alternative stock structure hypotheses, natural mortality (M=0.4 vs M=0.2), and steepness of the stock-recruitment relationship (h=1 vs h=0.75). In the long-term, other analysis should be done such as expanding the modeling of density into the WC Pacific Ocean, continue studying changes in longline catch strategies and its influence in catchability, include oceanographic variables in the standardization of the CPUE (specifically presence of warm-core eddies). Long -term studies for the stock should include close-kin mark-recapture experiments to estimate abundance, movement, stock structure, and natural mortality, in conjunction with tagging studies.

REFERENCE

Hinton, M.G. and Maunder, M.N. 2012. Status of swordfish in the eastern Pacific Ocean in 2010 and outlook for the future. IATTC Stock Assessment Report 12. Status of the tuna and billfish stocks in 2010. Pag. 133 – 177.