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STAFF RECOMMENDATIONS FOR MANAGEMENT AND DATA COLLECTION, 2022

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A. MANAGEMENT

1. TUNAS

1.1. Conservation of tropical tunas: yellowfin, bigeye, and skipjack

Summary

Resolution C-21-04 establishes conservation measures for tropical tunas in the eastern Pacific Ocean during the triennial management cycle of 2022-2024. The strengthened package of management measures seeks to prevent fishing mortality from exceeding the *status quo* conditions[1]. In order to evaluate progress towards the objectives of these measures, the IATTC staff annually analyzes the effects on the stocks of their implementation, and recommends to the Commission, if necessary, changes to the measures in place to be applied in future years.

In 2022, the staff is to evaluate the status of the stocks relying upon various sources of scientific information. For bigeye and yellowfin, current stock status is evaluated based on comparisons of recent stock status indicators relative to results of the 2020 risk analysis, which reflect stock status during the *status quo* period (2017-2019). Considering the healthy status of the yellowfin stock estimated in the 2020 risk analysis, only major departures from the *status quo* would be of concern for yellowfin. The status of skipjack is evaluated based on the 2022 *interim* stock assessment.

As a response to the tasks assigned to the staff under paragraphs 10 and 35 of resolution C-21-04, the staff does not find scientific support to recommend any modifications to the resolution:

- Considering the results of the 2020 risk analysis for bigeye, fishing mortality should not exceed the

[1] Defined as the average fishing mortality (F) during the most recent 3-year period (2017-2019).

status quo conditions. The stock status indicators confirmed that the *status quo* has not been exceeded for bigeye.

- The 2020 risk analysis for yellowfin estimates that the stock is healthy and there are no trends of concern in the stock status indicators to change this conclusion.
- The 2022 *interim* skipjack assessment indicates that the stock is healthy.

1.1.1. Background

Resolution C-21-04 establishes the conservation measures for tropical tunas in the eastern Pacific Ocean (EPO) during the triennial management cycle of 2022-2024. The resolution consists of a package of management measures designed to prevent fishing mortality from exceeding the *status quo* conditions, which are defined as the average fishing mortality (F) during the most recent 3-year period (2017-2019). According to the overall results of the 2020 risk analysis for the management of the tropical tuna fishery in the EPO, the stocks of yellowfin, bigeye and skipjack were all assessed to be in a healthy condition at the start of 2020. In order to maintain the healthy status of these stocks, additional precautionary measures to prevent fishing mortality from exceeding the *status quo* conditions were recommended by the IATTC staff and the Scientific Advisory Committee (SAC), in particular those measures related to the management of the floating-object fishery. Following these recommendations, Resolution C-21-04 extends most provisions of resolution C-20-06 onto 2022-2024 (*e.g.,* 72-day closure for the purse-seine fishery, catch limits on the longline fishery). In addition, new measures were introduced, and existing measures related to the fishery on fish-aggregating devices were adjusted (FADs): 1) Individual Vessel Limits (IVL) on bigeye tuna catch, which are associated with extended days of closure for those purse-seine vessels exceeding the limits, 2) reduced limits on active FADs by vessel size-class, and 3) new FAD data provisions.

Per paragraph 10 of C-21-04, in the event that the *status quo* conditions are exceeded despite the new measures, the IATTC staff shall propose to the Commission an update of its recommendations for these conservation measures. In addition, paragraph 35 tasks the staff to analyze the effects on the stocks of the implementation of these measures, and previous conservation and management measures, and will propose, if necessary, appropriate measures to be applied in future years. Although the effect of measures implemented under Resolution C-21-04 on 1 January 2022 can only be evaluated in 2023 when data from the 2022 fishing year is available for analysis, the staff has evaluated whether the *status quo* conditions have been exceeded in the years of 2020 and 2021.

The management of the tropical tuna fishery in the EPO is mainly driven by the estimate of the fishing mortality corresponding to the maximum sustainable yield (F_{MSY}) for the species that requires the strictest management (Resolution C-16-02). Despite skipjack historically not having a formal stock assessment, its higher productivity relative to the other tropical tunas, along with a similar susceptibility to that of bigeye, has been used to infer that it would not be the species that requires the strictest management and therefore management has been based on either yellowfin or bigeye. Since the risk analysis estimated that the fishing mortality for bigeye has a higher probability of exceeding the target and limit reference points, bigeye fishing mortality was used for driving the management of tropical tunas. Due to various reasons, the staff recommended that additional precautionary measures were needed to ensure that fishing mortality would not increase beyond the *status quo* average fishing mortality conditions (2017-2019).

In 2022, the staff evaluates the status of the stocks relying upon various sources of scientific information. For bigeye and yellowfin, current stock status is evaluated based on comparisons of recent stock status indicators relative to results of the 2020 risk analysis, which reflects stock status during the *status quo* period (2017-2019). Considering the healthy status of the yellowfin stock estimated in the 2020 risk analysis, only major departures from the *status quo* would be of concern. The status of skipjack is evaluated based on the 2022 *interim* stock assessment.

1.1.2. Rationale for staff recommendations

The technical rationale underlying the staff's recommendations for the conservation of tropical tunas in

2022 is summarized below.

1.1.2.a Stock status: the *status quo* conditions (2017-2019)

In 2020, the staff conducted new benchmark assessments for bigeye and yellowfin (SAC-11-06, SAC-11-07). These assessments represent a fundamental change from the staff's previous 'best assessment' approach: they are the basis for a 'risk analysis' (SAC-11-08), using the methods described in SAC-11 INF-F, in which a variety of reference models are used to represent plausible alternative assumptions about the biology of the fish, the productivity of the stocks, and/or the operation of the fisheries, thus effectively incorporating assessment uncertainty into the management advice as it is formulated.

The results below summarize the stock status for the tropical tunas (yellowfin, bigeye and skipjack) at the start of 2020. The reported status of the stocks is associated with the average fishing mortality conditions for the tropical tuna in the EPO during 2017-2019 (the *status quo* period).

Yellowfin and bigeye: The overall results of the 2020 risk analysis, expressed in terms of the probabilities of exceeding the reference points specified in the harvest control rule (HCR) under resolution C-16-02, are presented in **Table A**.

Table A. Stock status[2] of yellowfin, bigeye, and skipjack tunas, expressed in terms of the probabilities of exceeding the reference points specified in the HCR.

	Probability (%) of exceeding RP		
Target RP	**Yellowfin**	**Bigeye**	**Skipjack[3]**
$F_{cur}>F_{MSY}$	9	50	<50
$S_{cur}<S_{MSY}$	12	53	<53
Limit RP			
$F_{cur}>F_{LIMIT}$	0	5	<5
$S_{cur}<S_{LIMIT}$	0	6	<6

For **yellowfin**, the overall results of the risk analysis, which include all 48 reference models, indicate only a 9% probability that the fishing mortality corresponding to the maximum sustainable yield (F_{MSY}) has been exceeded[4] (**Figure 1a**). There is a 12% probability that the spawning stock biomass corresponding to the maximum sustainable yield (S_{MSY}) has been breached. The probability that the F and S limit reference points have been exceeded is zero.

For **bigeye**, the overall results of the risk analysis, which include 44[5] reference models, indicate a 50% probability that F_{MSY} has been exceeded and a 53% probability that S_{cur} is below S_{MSY} (**Figure 1b**). Although resolution C-16-02 does not specify the acceptable level of probability of exceeding the target reference points, these probabilities are at about a reasonable arbitrary reference level of 50%, considering that, at F_{MSY}, S will fluctuate around the target reference point (S_{MSY}) due to interannual recruitment fluctuations. F will also fluctuate around the target reference point (F_{MSY}) under the days of closure management due to interannual fluctuations in catchability and distribution of purse-seine effort among set types. With respect to the limit reference points, the probabilities that the F and S limit reference points have been exceeded are not negligible ($P(F_{cur}>F_{LIMIT})$ = 5%; $P(S_{cur}<S_{LIMIT})$ = 6%), but they are below the 10% threshold for triggering an action specified in resolution C-16-02.

[2] Defined as the spawning biomass (S) at the start of 2020 or the average fishing mortality (F) during the most recent three years (2017-2019).

[3] A conventional stock assessment was not available for skipjack in 2020. Results inferred from PSA analysis indicate that the status of skipjack should be more optimistic than bigeye (see skipjack section below). Therefore, the probability of exceeding the reference points for skipjack should be lower than for bigeye.

[4] In this report, the terms "overfished" and "overfishing" are not used, because the Commission has not defined the threshold probabilities associated with those terms.

[5] Four of the 48 models did not converge for bigeye.

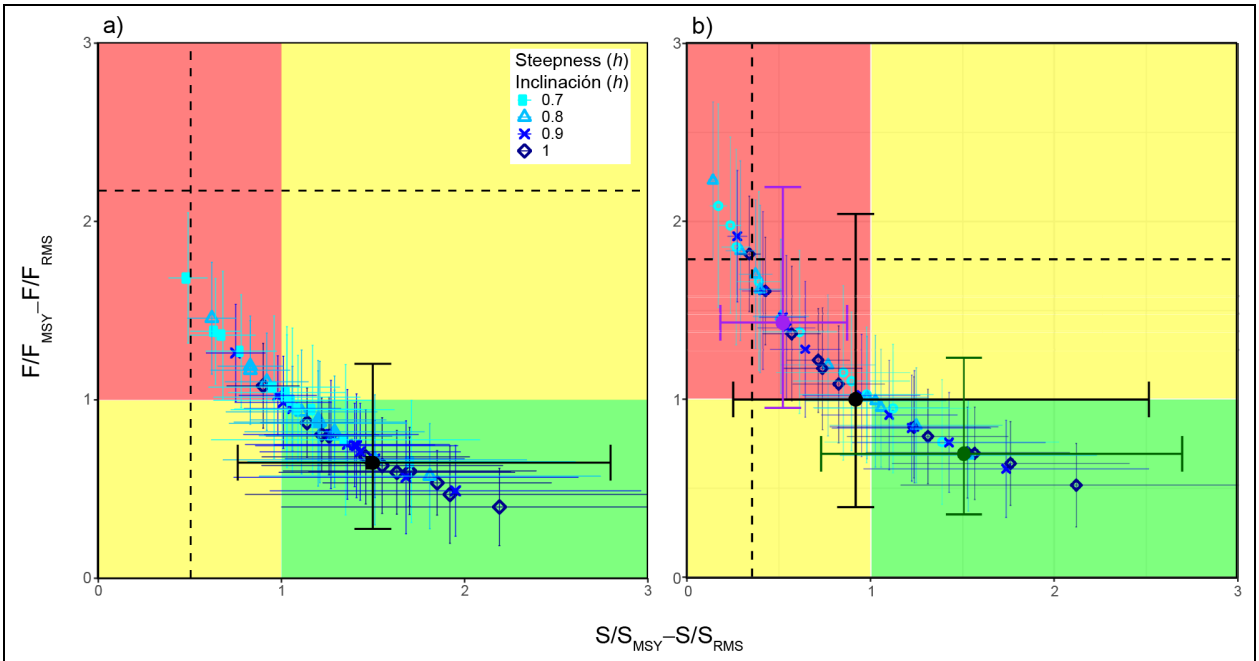

FIGURE 1. Kobe (phase) plot showing the current estimates of spawning stock size (S) and fishing mortality (F) of **(a) yellowfin** and **(b) bigeye tuna** relative to their MSY reference points. The colored panels are separated by the target reference points (S_{MSY} and F_{MSY}) and limit reference points (dashed lines). The center point for each model indicates the current stock status, based on the average fishing mortality (F) over the last three years. The solid black circle represents all models combined. For bigeye (b), the purple and green solid circles represent, respectively, the stock status for the 'pessimistic' and 'optimistic' states related to the bimodal pattern in the risk analysis (see section 1.1.2.c). The lines around each estimate represent its approximate 95% confidence interval.

Skipjack: The highly productive life-history of skipjack makes the development of any conventional stock assessment very challenging. This results from marked fluctuations in abundance along with uncertainty about the reliability of indices of abundance for skipjack. While no form of conventional assessment was available for skipjack in 2020, the IATTC staff relied on a Productivity and Susceptibility Analysis (PSA) rationale to make inferences about the stock status of skipjack. Through this PSA assessment rationale, since skipjack and bigeye have about the same susceptibility to the purse-seine gear in the EPO PSA (Duffy *et al*. 2019), and skipjack is the most productive of the two species, if bigeye is healthy skipjack can be inferred to be healthy. In 2020, the staff has combined the PSA rationale with the quantitative elements of the risk analysis for tropical tuna in the EPO. This combined PSA-risk analysis assessment indicated that the skipjack stock status at the start of 2020, reflecting the stock status associated with *status quo* fishing mortality conditions (2017-2019), was healthy (**Table A**).

1.1.2.b Current stock status and status relative to the *status quo* conditions of 2017-2019

In order to evaluate the current stock status of the tropical tunas in the EPO and status relative to the *status quo* conditions, in 2022 the staff is putting forward the following scientific work:

- The two 2020 **benchmark stock assessment reports**, for bigeye (SAC-11-06) and yellowfin (SAC-11-07), presenting the results from all reference models for each species (model fits, diagnostics, derived quantities and estimated parameters that define stock status in 2020);
- The 2020 **risk analysis** (SAC-11-08) specific for tropical tunas, using the methods described in SAC-11 INF-F, which assesses current stock status and quantifies the probability (risk) of exceeding target and limit reference points specified in the IATTC harvest control rule, as well as the expected consequences of alternative management measures in terms of closure days;

- **Investigation of potential bias** in the tropical tuna catch estimates caused by the COVID-19 pandemic (SAC-13-05)
- **Stock status indicators** (SAC-13-06) for all three tropical tuna species (yellowfin, bigeye, and skipjack);
- **A 2022 stock assessment (*interim*) for skipjack in the EPO** (SAC-13-07);
- The following **recommendations** by the staff for the conservation of tropical tunas which take into consideration all the above.

An important development from the implementation C-21-04 is that the PSA rationale previously used by the staff to assess skipjack on an *interim* basis (see section 1.1.2.a) is no longer valid. Since the additional measures established under C-21-04 were specifically designed to prevent the *status quo* conditions to be breached for bigeye (the species with the strictest need for stronger measures), these measures do not necessary prevent increased fishing mortality for the other two species, in particular skipjack. For example, the new IVL scheme for bigeye catches could result in a change of fishing strategies by purse-seine vessels with increased fishing mortality for skipjack. Therefore, the stock status of skipjack can only be evaluated through a conventional stock assessment. In 2022, the staff has successfully developed a new stock assessment (*interim*) for skipjack as previously planned (IATTC 98 INF-F). Although the assessment is termed *interim* by the staff, the staff considers it reliable for management advice (SAC-13-07). The term *interim* results from additional improvements being expected on the skipjack assessment under the ongoing 2021-proposed methodology and workplan to develop a stock assessment for skipjack in the EPO that includes tagging data (see Document SAC-12-06). Spatio-temporal modelling is used to analyze the recently available tagging data obtained by the IATTC multi-year Regional Tuna Tagging Program in the EPO (RTTP-EPO 2019-2020, Project E.4.a) and addresses the issues of incomplete mixing of the tagged fish. Preliminary results of the spatio-temporal analysis will be presented at the 2022 SAC (SAC-13-08), and the final benchmark assessment at the 2023 SAC. The inclusion of the information from the tagging data is expected to improve the assessment results. However, the staff believes that the *interim* assessment and the analyses to evaluate the robustness of the management advice to the model assumptions can be used for management advice for skipjack (SAC-13-07).

As a response to the tasks assigned to the staff under paragraphs 10 and 35 of resolution C-21-04, the staff does not find scientific support to recommend any modifications to the resolution, for the following reasons:

For the tropical tuna fishery in the EPO, in general:

1 - The preliminary 2020 and 2021 data for total well volumes of purse-seine vessels show that the capacity of the purse-seine fleet operating in the EPO in these years was respectively 9% and 4% below the average capacity levels operating during the *status quo* period (2017-2019) (SAC-13-03).

2 - The number of sets on floating objects has remained below the *status quo* level since 2020, respectively 24% and 5% below this level for the years of 2020 and 2021 (**Table B, Figure 2a**).

3 - Taking into consideration the 2020 risk analysis for bigeye and yellowfin and results from the new interim assessment for skipjack tuna, bigeye remains assessed as the species in need for the strictest measures. Therefore, management advice should focus on evaluating the current status of bigeye relative to the *status quo* conditions.

For bigeye:

4 - Although the estimated bigeye catches in 2020 were 19% above the 2017-2019 average *status quo* level of 65,937 (**Table B**), this estimate was biased high due to the effect of the COVID-19 pandemic on the operations of the IATTC port-sampling program (SAC-13 INF-L). After bias correction (18% positive bias), the 2020 bigeye catch is estimated at 69,901 tons (SAC-13-05), which is slightly above (6%) the *status quo* level. The estimated purse-seine bigeye catch for 2021 (56,861 tons) is 14% below the *status quo* level. After bias correction for the effect of the COVID-19 pandemic, the 2021 catch is estimated to be even lower (48,088 tons), 27% below the *status quo* level

(SAC-13-05). However, the 2021 bias correction should be considered preliminary, and may be subject to revision in the coming year.

For yellowfin:

5 - There are no concerns with the stock status of yellowfin tuna. The risks of exceeding the established target and limit reference points under resolution C-16-02 are extremely low.

6 - The estimated 2020 and 2021 purse-seine catches of yellowfin on floating objects are respectively well below (13-28%) or at about the *status quo* levels (-2% to +7%), even when the COVID bias adjusted estimates are considered (**Table B**). The yellowfin stock status indicators for other set types (dolphin and unassociated sets) show no changes of concern in 2020 and 2021 relative to the *status quo* (SAC-13-06). In addition, the preliminary 2020 and 2021 data for total well volumes of purse-seine vessels with DML show that fishing capacity for these vessels did not exceed the *status quo* levels.

For skipjack:

7 - The 2020 and 2021 skipjack catches on floating objects are respectively 14% below and at about (2% above) the *status quo* levels. Bias adjustment corrections for the effects of the COVID-19 pandemic only slightly changed these estimates (**Table B**). The skipjack stock status indicators for other set types (dolphin and unassociated sets) show no changes of concern in 2020 and 2021 relative to the *status quo*. Although presented for completeness, the comparisons above with the *status quo* levels are no longer necessary for skipjack since a conventional stock assessment is now available which evaluates stock status relative to reference points.

8 - A new stock assessment is available for skipjack tuna which the staff considers reliable for use in management advice (SAC-13-07). Despite the current fishing mortality estimated to be higher than the *status quo*, the fishing mortality is below the level corresponding to the target reference point, and the target and limit biomass reference points have not been exceeded.

Table B. Purse-seine well volumes, in cubic meters, and estimated number of sets on floating objects during the *status quo* period (average 2017-2019), and the years of 2020 and 2021. Two estimates for the retained catches (in metric tons) are also shown for each tropical tuna species in these years: the best scientific estimate (BSE; see Table A-7 of SAC-13-03) and the estimates adjusted for bias (BiasAdjst) due to the effect of the COVID-19 pandemic on the port sampling operations (see SAC-13-05). The percent change of the yearly estimates relative to the *status quo* is shown at the bottom of the table.

Year-Año	Capac-ity (m^3)	Sets OBJ	Catch OBJ (t)					
			Yellowfin		Skipjack		Bigeye	
			BSE	Bi-asAdjst	BSE	Bi-asAdjst	BSE	Bi-asAdjst
SQ (2017-2019)	263,923	15,998	62,050		221,474		65,937	
2020	241,331	12,151	44,461	53,924	191,399	190,243	78,208	69,901
2021	253,323	15,139	66,488	60,701	225,132	239,692	56,861	48,088
2020	-8.6	-24.0	-28.3	-13.1	-13.6	-14.1	18.6	6.0
2021	-4.0	-5.4	7.2	-2.2	1.7	8.2	-13.8	-27.1

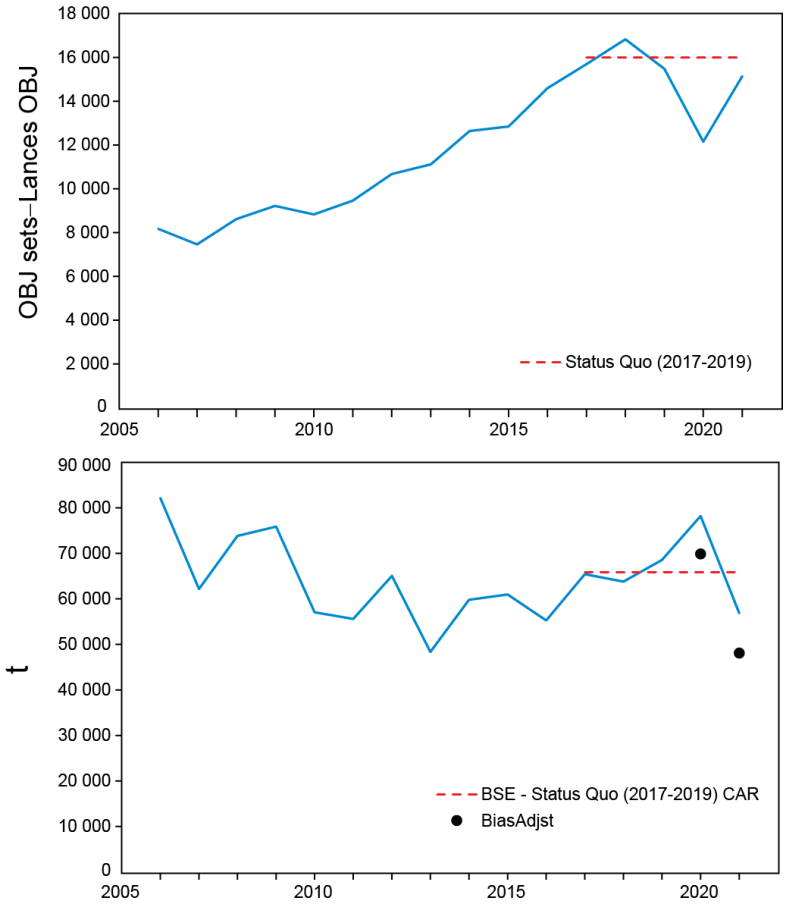

FIGURE 2. Number of sets on floating objects (top) and retained purse-seine catches for bigeye tuna (metric tons). The *status quo* conditions (average in 2017-2019) are shown. Estimates for bigeye catches adjusted for bias (BiasAdjst) caused by the effect of the COVID-19 pandemic during 2020 and 2021 are shown (SAC-13-05).

1.1.2.c Data improvements: enhanced species composition port-sampling program

At its 98th Meeting of the IATTC, the Commission established an Individual Vessel Limit (IVL) program for bigeye tuna catches. Beginning in 2023, this program will include enhanced port-sampling of the wells of trips that are considered to have caught a substantial amount of bigeye tuna. In order to prepare for this enhanced port-sampling component of the IVL program, an IVL pilot study was funded by the Commission, to take place in July–December 2022. As planned (SAC-13 INF-F), the pilot study will have two phases. The first phase will focus on collection of extensive well sampling data to be used in simulations to test sampling designs for estimation of well-level and trip-level catch composition. This will be followed by a second phase that will focus on field testing of the best sampling design from the first phase, to identify and resolve any potential logistical issues. Although the data collection protocols of the pilot study have been designed to try to minimize delays on the normal unloading of the catch, while still providing high-quality scientific data, the pilot study will not be without any impact and will be more time consuming than the regular IATTC port-sampling protocol to which facilities and unloaders have become accustomed. In particular, for the first phase of the pilot study, it will be essential that: a) space be provided for the sampling team near the well head of a well that is being sampled so that species and size composition data can be collected in an efficient manner; and, b) that vessel crew and unloaders assist the sampling team in transporting groups of fish to be sampled to the sampling location, as well as assist with the return of the sampled fish into the next step of the unloading process (e.g., onto a conveyor belt). Details of the study protocol for the first phase are provided in SAC-13 INF-F.

1.1.3. Management advice

Based on the rationale presented above, in 2022 the staff makes the following recommendations for the conservation of tropical tunas:

RECOMMENDATIONS:

1. Maintain the provisions of the current resolution (C-21-04).
2. Assist the staff in the implementation of the Individual Vessel Limit Pilot Study (SAC-13 INF-F) during July–December 2022.

1.1.4. Future research

Future research should focus on: 1) continuing to improve the risk analysis and the stock assessment models for bigeye and yellowfin, which also involves their data inputs, 2) continue to improve the assessment for skipjack tuna based on recently collected tagging data, and 3) evaluate management strategies that are shown to be robust to the main uncertainties, including the bigeye bimodality, using MSE.

1.1.4.a Improving the risk analysis and the stock assessment models

Matters that require investigation and/or improvement include the bimodal pattern in the risk analysis of bigeye, more objective and transparent scoring in the risk analysis, continuing the collaborative work to improve the longline indices of abundance, the ability to estimate yellowfin absolute abundance, the two-stock hypothesis for yellowfin, estimates of growth, selectivity, and natural mortality through tagging data, and a stronger involvement of industry stakeholders in the tagging program (*e.g.* facilitating access to tagging operations in offshore areas, aggregations on FADs, etc.). Implementation of Close-Kin Mark-Recapture should be evaluated as a way of resolving uncertainties in the stock assessments and be implemented as soon as practical if appropriate.

1.1.4.b Integrate information from the tagging into the interim stock assessment

The interim stock assessment developed for skipjack tuna successfully estimated the status of the skipjack stock in the EPO. However, the interim stock assessment does not make full use of the available tagging

data. These data are currently being analyzed as outlined in SAC-12-06 and will be used in 2023 to improve the assessment. The exact details of the analysis and how the tagging information will be used in the assessment will be part of the ongoing research.

1.1.4.c Management Strategy Evaluation

The staff acknowledges that there may always be unresolved issues in knowledge, their impact on taking appropriate management action, and the inherent limits of modelling complex and changing natural systems and their fisheries. Management Strategy Evaluation for tropical tunas is focusing on including additional sources of uncertainty (implementation uncertainty, management/institutional uncertainty, sampling uncertainty, projection uncertainty) and refining elements of the current strategy, along with alternatives (types and estimation of reference points, specificity of the current HCR, performance metrics, etc.), that are important for evaluating the robustness of the management advice and the likelihood of strategies achieving desired management objectives. The models developed in the risk analysis will be used to inform the development of operating (simulation) models for MSE. The MSE process is being developed to evaluate setting management actions based on simpler models or empirical HCRs that rely on trends in data, as an alternative or complement to the recent model-based approaches while both data and stock assessments are improved. An MSE workplan for tropical tunas (SAC-13 INF-C) is ongoing at IATTC (see recent Workshops), with an initial focus on bigeye and moving to the other tropical tuna towards the end of the current plan in 2024 (funding is available from 2021 to 2023; funding for 2024 and beyond has not been secured yet).

RECOMMENDATIONS:

In collaboration with CPCs and relevant stakeholders:

1. Continue improving stock assessments and risk analysis for tropical tunas.
2. Continue improving the stock assessment for skipjack, particularly making use of the recently collected tagging data following SAC-12-08.
3. Continue support for MSE for tropical tunas, following guidelines from C-16-02 and C-19-07.

1.2. Pacific bluefin tuna

The Pacific bluefin tuna working group of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) completed an update assessment of the species in 2022. The 2020 SSB was above the initial rebuilding target. While it is still below the second rebuilding target adopted by the WCPFC and IATTC, the stock recovery is faster than scheduled.

Resolution C-21-05 establishes management of Pacific bluefin tuna in the EPO for the period 2021-2024 defining total commercial catches and biennial catch limits for each CPC. No changes are needed to the provisions under Resolution C-21-05 for conservation and management of the stock.

The assessment includes several catch scenarios, with different increases in catch and different distributions of the catch between small and large fish. Catching larger fish increases the total catch in weight for a given level of rebuilding. Under all examined catch scenarios, the second rebuilding target will be met by 2029. If one of the alternative scenarios is chosen as the basis for future catch limits, the choice should take into account both the desired rebuilding rate and the distribution of catch between small and large bluefin.

RECOMMENDATIONS:

1. No changes are needed to the provisions under Resolution C-21-05.
2. Increased catches based on the scenarios analyzed are possible under the harvest strategy prepared by the joint tRFMO working group. The choice of catch scenario should take into account the desired rebuilding rate and the distribution of catch between small and large bluefin.

1.3. North Pacific albacore tuna

The last benchmark stock assessment was completed in 2020 by the Albacore Working Group (ALBWG) of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC), and the next is planned for 2023. The spawning biomass was at 46% of the dynamic virgin spawning biomass in 2018, the last year in the assessment, and the fishing mortality during 2015-2017 ($F_{2015\text{-}2017}$) is below the level corresponding to the maximum sustainable yield ($F_{2015\text{-}2017}/F_{MSY}$ = 0.60). Ten-year projections with either constant catch (2013-2017 average, 69,000 t) or constant fishing mortality (at the $F_{2015\text{-}2017}$ level) predicted an increase in the female spawning biomass. The Working Group noted that there was no evidence that fishing had reduced the spawning stock biomass below thresholds associated with most potential biomass-based reference points. The Working Group concluded that the north Pacific albacore stock is healthy, and that the productivity was sufficient to sustain recent exploitation levels, assuming average historical recruitment in both the short and the long term.

The Working Group finished the Management Strategy Evaluation (MSE) for the North Pacific albacore stock. The first round of the MSE was reported in March 2019 (ISC/19/ANNEX/06), and a second round was completed during 2020 and the final report was finalized in 2021 (ISC/21/ANNEX/11). In the context of the MSE process, management and conservation objectives were agreed[6] and endorsed by the Commission in 2020. During 2021, several regional workshops took place to present and discuss the results of the MSE to stakeholders.

The MSE process included input from managers and stakeholders and extensive simulation work. Candidate harvest control rules (HCRs) were suggested by managers and stakeholders. All HRCs are based on inputs from the assessment model and included target, limit, and threshold reference points, all based on dynamic quantities that take into consideration temporal variation in selectivity and recruitment. Based on the estimated status of the stock, the HRC specifies whether a management action to control fishing is needed. The management actions tested were mixed control or Total Allowable Catch (TAC). Under mixed control, surface fisheries (EPO troll and pole-and-line, and Japanese pole-and-line) are managed via effort control, while longline fisheries are managed via a TAC.

Sixteen HCRs were tested (Figure 3) under several scenarios ranging from low to high productivity of the stock, of which four (which were deemed a good representation of the plausible mechanisms operating in the population) were retained to present the results. The performance of the HCRs under those scenarios was measured through indicators consisting of quantitative representations of the overall management objectives adopted for the fishery.

[6] The following management objectives for North Pacific albacore tuna were developed in the context of the MSE process, given the overarching objective of maintaining the viability and sustainability of the current North Pacific albacore stock and fisheries, agreed upon in the process:

- Maintain spawning biomass above the limit reference point.
- Maintain total biomass, with reasonable variability, around the historical average depletion of total biomass.
- Maintain harvest ratios by fishery (fraction of fishing impact with respect to SSB) at historical average.
- Maintain catches by fishery above average historical catch.
- If a change in total allowable effort and/or total allowable catch occurs, the rate of change should be relatively gradual.
- Maintain *F* at the target value with reasonable variability.

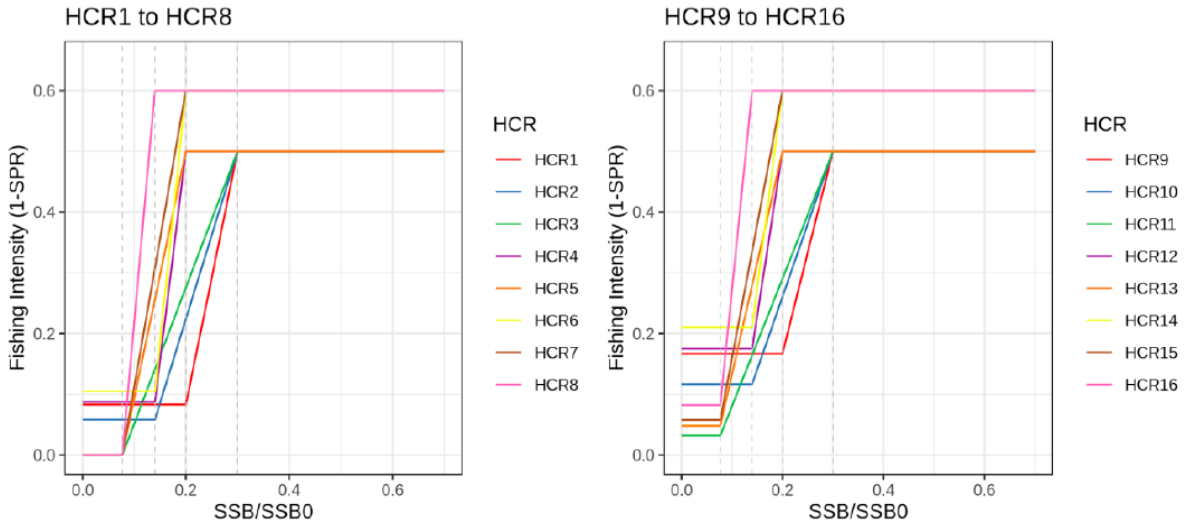

FIGURE 3. Harvest control rules tested in the Management Strategy Evaluation for the North Pacific albacore tuna stock. The upper horizontal lines indicate target reference points (TRP) (lines at 0.6 or $F_{40\%SSB}$ and 0.5 or $F_{50\%SSB}$), the vertical dashed lines indicate threshold or limit reference points (LRP) (which are all based on the dynamic SSB). Threshold reference points, when breached, trigger management action to avoid further declines that could result in breaching the limit reference points.

The main results of the MSE were (ISC/21/ANNEX/11):

- All HCRs were able to maintain the stock above the level considered undesirable (*i.e.,* above WCPFC's limit reference point (20% SSB0), the IATTC limit reference point used for tropical tunas (7.7% SSB0)), with more than 92% probability (for mixed controls) or 86% probability (for TAC control), even in the event of undeclared catches from an unknown fleet.
- For all HCRs, mixed control maintained higher and less variable stock biomass than TAC control as the catches of surface fleets under effort control responded quickly to changes in biomass and their catch levels were not impacted by assessment errors in biomass estimates. Mixed control performs better under all indicators in the scenario of low productivity than TAC controls.
- HCRs with the LRP and $SSB_{threshold}$ reference points closer to the SSB associated with TRP resulted in a higher frequency of management interventions (that is, HCRs with 30% SSB0 as threshold and $F_{50\%SSB}$ as target, and HCRs 20% SSB0 as threshold and $F_{40\%SSB}$ as target).
- HCRs that used $F_{40\%SSB}$ as TRP produced more variable catches (but higher median catches) than HCRs that used $F_{50\%SSB}$ under TAC control.

In the spirit of the MSE process in which the choice of an HCR is a product of the dialogue process among stakeholders, the staff is not recommending a particular HCR. The staff, however, notes that while all HCRs maintain the stock above undesirable levels, the HCRs with mixed control do so with higher probability, are more robust under low productive regimes and maintain a less variable stock biomass. In addition, current management measures in the IATTC for tropical tunas are based on mixed controls: effort control (temporal closures) for the purse-seine fleet and TACs for the longline fleet, with the recent introduction of IVLs for bigeye caught in the purse-seine fleet.

The current conservation and management measures for North Pacific albacore (IATTC Resolutions C-05-02, C-13-03 and C-18-03; also WCPFC CMM 2005-03) are based on maintaining the fishing effort below the 2002-2004 levels. The effort levels in eastern Pacific Ocean for 2018-2020 are 63% and 65% of those in 2002-2004, for vessel-days and number of vessels, respectively (IATTC-98a-01).

Given the relative stability in the biomass and fishing mortality in recent years, the staff considers that the current

resolutions should be continued; however, given the results of the MSE, there are multiple options of HCRs that fulfill the sustainability requirements. The staff recommends that CPCs use the results of the concluded MSE process to consider choosing a suitable HCR given the trade-offs among catches, management interventions and avoidance of undesirable stock levels.

RECOMMENDATIONS:

1. CPCs should continue to implement Resolutions C-05-02, C-13-03, C-18-03, presently in force.
2. CPCs should use the results of the concluded MSE process to establish reference points and a harvest control rule (HCR) for North Pacific albacore tuna.

1.4. South Pacific albacore tuna

In collaboration with the IATTC, the Pacific Community (SPC) conducted a benchmark stock assessment for South Pacific albacore tuna in 2021. It is based on a spatially-explicit stock assessment model in which the South EPO is considered as a single area due to the lack of tagging data. Several axes of the structural uncertainties were explored in this benchmark assessment, including steepness, movement, size data weighting, recruitment distribution, and the combination of growth and natural mortality. The final structural uncertainty grid for this assessment consisted of 72 models. Results suggest that the movement scenario (tagging vs. SEAPODYM informed movement rates) is the major source of uncertainty among those uncertainty axes.

Based on the weighted grid of the 72 models, the estimated reference points for albacore tuna in the South Pacific are:

- The median value of relative recent (2016-2019) spawning biomass depletion ($SB_{2016\text{-}2019}/SB_{F=0}$) was 0.52 with a 10th to 90th percentile interval of 0.41 to 0.57.
- There was a 0% probability (0 out of 72 models) that the recent (2016-2019) spawning biomass had breached the limit reference point (0.2) adopted by the WCPFC.
- The median of relative recent fishing mortality as a ratio of that corresponding the MSY ($F_{2015\text{-}2018}/F_{MSY}$) was 0.24 with a 10th to 90th percentile interval of 0.15 to 0.37.
- There was a 0% probability (0 out of 72 models) that the recent (2015-2018) fishing mortality was above F_{MSY}.

In summary, the benchmark assessment suggests that the South Pacific albacore stock is healthy and the recent fishing mortality is much lower than the fishing mortality at MSY. Nevertheless, it should be noted that the spawning biomass of South Pacific albacore was estimated to have decreased sharply since 2017 due likely to the continuing increase in the amount of longline catch in recent years (see SAC-13-03). For albacore in the south EPO, the spawning biomass ratio (spawning biomass divided by spawning biomass in an unfished condition) is estimated to have decreased from above 0.9 in 1960 to less than 0.5 in 2019 (Figure 4).

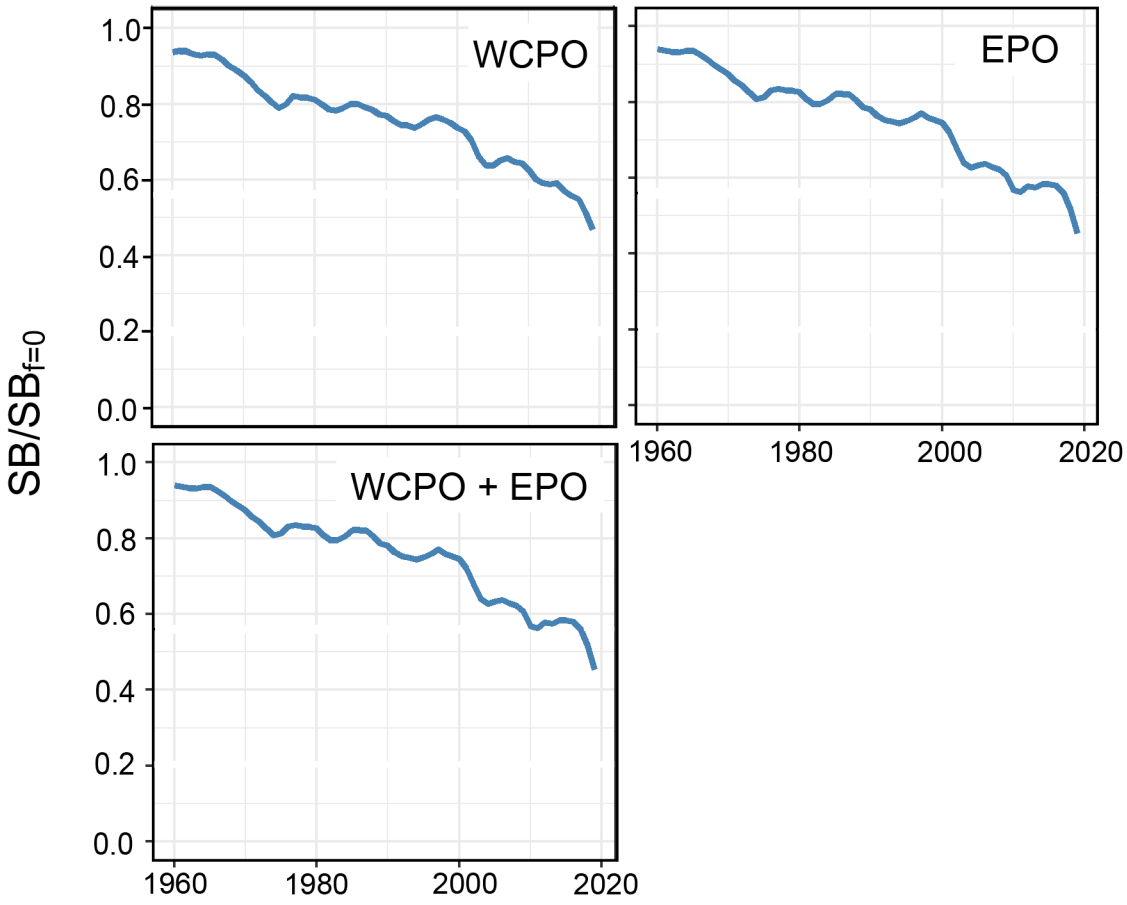

FIGURE 4. Estimated spawning biomass ratio for south Pacific albacore by management regions. This figure is modified from Figure 32 in SAC-13 INF-S.

RECOMMENDATION:

1. Continue collaborating with the Pacific Community (SPC) to monitor the stock status of South Pacific albacore tuna (*e.g.*, using sock status indicators and conducting another benchmark assessment in 3-4 years).

2. NON-TARGET SPECIES

2.1. Silky sharks

The indices for large silky sharks, based on data from the purse-seine fishery on floating objects, have been updated through 2021 for the north and south EPO (BYC-11 INF-B). Previous analyses (SAC-08-08a(i)) identified a correlation between north EPO indices, particularly those for small and medium silky sharks, and interannual variability in oceanographic conditions, and thus the indices for those size categories, and for all silky sharks, were not updated because of concerns about bias. Because of recent increases in the live release of silky sharks, two sets of indices for large silky sharks were computed, one including live release data and the other not. Taken together, the two sets of indices likely bracket the trend that would have resulted in both the north and south EPO if "finning"[7], shark handling, and data recording practices had continued unchanged since 1994. The real trend is considered to be closer to the index based on dead + live releases because sharks recorded as released alive in recent years would probably have been recorded as dead previously, and thus the dead + live release is likely a more consistent indicator. The terminal point of these indices suggests a relatively stable abundance level for over a decade, with the 2021 values similar to, or slightly above, the 2020 values, and thus no changes to management measures are recommended.

[7] Cutting the fins off sharks and discarding the carcass.

However, the stock status is uncertain, and an assessment has not been possible due to the paucity of data, especially for the longline fleets of the EPO coastal nations, which are believed to have the greatest impact on the stock (SAC-05 INF-F). Insufficient data for stock assessment is also a common problem for almost all shark species with which EPO fisheries interact. Therefore, in 2022 the staff used the ecological risk assessment method EASI-Fish to conduct the first comprehensive quantitative vulnerability assessment for 32 shark species caught in industrial and artisanal fisheries in the EPO (SAC-13-11). The assessment showed silky shark to be classified as "most vulnerable", having the second highest vulnerable rank among the 32 shark species assessed. As a result of handicapped stock assessment attempts and EASI-Fish outcomes, the staff has made recommendations for data collection as part of its work plan for addressing the stock assessments of sharks (see Section 4.1).

Paragraph 7 of Resolution C-21-06, which extends Resolution C-19-05 for another biennial period (2022-2023), requires CPCs to implement a three-month prohibition on the use of steel leaders in certain longline fisheries, and paragraph 8 requires the IATTC staff to present, at the SAC meeting in 2022, an analysis of the available data, including the shark fishery sampling program in Central America, with recommendations for improvement of the resolution, including adjustment of the prohibition period in paragraph 7. Resolution C-21-06 also directs the staff to consider the efficacy of the limits established by the resolution and if necessary, recommend revisions. However, the improved species-level catch and composition data required for this analysis are not yet fully available, so it remains a challenge for the staff to evaluate the efficacy of the limits.

Such persisting data limitations, among others, which apply to both target and non-target species, motivated the staff to review current Resolutions pertaining to data provision that underpin all of its research, in particular, the Resolution on data provision, C-03-05. To this end, the staff has prepared Document SAC-12-09 (see Section 3) with the overarching goal of creating a revised Resolution C-03-05, which will improve the scope and quality of data provided for science, conservation and management, of both target and non-target species.

As part of additional steps taken by the staff to address data limitations, significant progress has been made in recent years in developing the foundations for a sampling program for shark fisheries in Central America (see Section 4.1, SAC-11-13). Made possible through recent funds provided by the European Union, the sampling program in Central America has reached its completion in December 2021. The results supported a proposal that was presented at the 2021 98th Meeting (resumed) meeting of the Commission to establish a long term sampling program in Central America (IATTC-98-02c). Unfortunately, the necessary funds to implement the program are not available yet. If the sampling design of the current sampling program is expanded to other regions in the EPO (*e.g.,* South America, Mexico), both data collection and stock assessments for sharks in the EPO should improve. Resources to expand the Central American shark data collection improvements into other EPO coastal nations will soon be available under a phase 2 of the ABNJ project (SAC-13-12).

The management of silky sharks is hindered by the lack of a reliable stock assessment due to the absence of reliable time series of data typically used in stock assessment (catch, CPUE, and sex/size composition). Management of silky sharks could therefore be greatly improved by implementing a close-kin mark-recapture study that would provide estimates of absolute adult abundance and adult natural mortality (SAC-12-14). Until a reliable stock assessment can be undertaken, the staff plans to use data-limited assessment methods, such as EASI-Fish, to explore the potential efficacy of CMMs to guide managers in the intervening period (*e.g.,* CMMs specified under Resolution C-21-06).

RECOMMENDATIONS:

Considering the recent improvements in shark fishery data collection in Central America (SAC-11-13), as well as the upcoming expansion of these data collection improvement efforts into other coastal states (SAC-13-12):

CPCs should enhance their compliance with the following provisions of Resolution C-21-06 (to be extended in the new resolution):

1. Paragraph 7, prohibiting the use of steel leaders during a period of three consecutive months of each year for the relevant portions of their national fleets.
2. Paragraphs 11 and 12, which require notifying the Commission of the period of the prohibition, the number of vessels subject to the prohibition, and how compliance with the prohibition will be monitored.

Considering the potential benefits of Close-Kin Mark-Recapture:

3. Fund a workplan for Close-Kin Mark-Recapture starting with Project H.7.e: Feasibility and sampling design for close-kin mark-recapture analysis of stocks in the EPO.

2.2. Seabirds

Resolution C-11-02 should be revised to be consistent with the current state of knowledge regarding seabird mitigation techniques, as described in document SAC-08-INF-D. The two-column menu approach in C-11-02 should be replaced by a requirement to use at least two of three mitigation methods (line weighting, night setting, and bird-scaring lines) in combination, in a way that will meet the minimum standards recommended by ACAP and BirdLife International. Other mitigation methods should not be approved until their effectiveness is proven. Following Resolution C-19-04, the IATTC organized a workshop to discuss the minimum hook size that would reduce sea turtle mortality. The workshop also addressed the ecosystem-level concerns and potential trade-offs regarding the expanded use of circle hooks in longline fisheries and discussed the potential impacts of gear types on various taxa, including seabirds. However, the data are inconclusive to comment on any conservation value of circle hooks over other hook shapes or sizes to seabirds given a lack of empirical studies (WSHKS-01).

RECOMMENDATION:

Revise Resolution C-11-02 consistent with the current and future state of knowledge regarding seabird mitigation techniques.

2.3. Sea turtles

A revised resolution on sea turtles (C-19-04) entered into force on 1 January 2021 requiring EPO tuna fisheries to implement various measures designed to reduce the bycatch of sea turtles, in particular the use of circle hooks and finfish baits in shallow longline sets. The low encounter rates of sea turtles by fishing vessels make these 'rare event' data difficult to analyze using conventional approaches for assessing the status of sea turtle populations. Therefore, a collaborative research project (BYC-11-01) between the IATTC, the Inter-American Convention on the Protection and Conservation of Sea Turtles (IAC), and international sea turtle experts employed the EASI-Fish approach as an alternative means to assess vulnerability status and to simulate conservation and management measures (CMMs) that may mitigate fishery-imposed risks to the critically endangered East Pacific population of leatherback sea turtle. This project was extended in 2021-2022 with several model improvements (*e.g.,* a new species distribution model and updated fishing effort data for artisanal fisheries) (BYC-11-02). Proxies for fishing mortality ($\tilde{F}_{2019}$) and the breeding stock biomass per recruit (BSR_{2019}) exceeded precautionary biological reference points ($F_{80\%}$ and $BSR_{80\%}$), classifying the EP leatherback turtle stock as "most vulnerable" in the reference year (2019). Of the 70 CMM scenarios, use of circle hooks, finfish bait, and to a lesser extent best handling and release practices were each predicted to decrease vulnerability when examined individually, by far the most effective scenarios involved using these three measures in concert, followed by using circle hooks with either finfish bait or best practices.

RECOMMENDATION:

Revise Resolution C-19-04 consistent with the simulated efficacy of CMMs assessed in BYC-11-02.

B. DATA COLLECTION

3. DATA FOR LARGE LONGLINERS

Recent challenges with the assessments of the target tuna fisheries demanded the use of sophisticated analyses that required fine-scale spatial and temporal resolution catch, effort and size data (SAC-11-06; SAC-11-07; IATTC-95-05) from the longline fleets operating far from the coasts and particularly in the high-seas, which in some cases, are not routinely available to the staff. Challenges are also encountered by the staff when producing assessments for tuna-like species, such as swordfish (SWO-01), due to a lack of data. CPUE data from Japan forms the basis for the index of abundance used in the current assessments of bigeye, yellowfin, and for the first time skipjack (SAC-13-07), and it is key to address hypotheses of spatial structure for yellowfin tuna in the EPO. However, the magnitude and spatial extent of effort by the Japanese fleet has decreased markedly in the EPO, thereby deteriorating the quality of the indices of abundance. Recent collaborative work with Japan, Korea, Chinese Taipei and China has improved the understanding of their logbook data for developing new indices of abundance. Data for this work were only made available to the staff via multiple MoUs between the IATTC and each CPC, which are renewed annually. The data regularly submitted by the CPCs related to the Resolution C-03-05 on data provision are aggregated spatially (1° x 1° or 5° x 5°) and contain little or no gear configuration information, and no vessel identifiers, which are important factors for better understanding changes in catchability and species targeting (OTM-30), both of which influence abundance indices. Operational-level data (high resolution 'level 1' catch and effort data as defined in C-03-05) with corresponding size information are necessary to improve the indices of abundance routinely used in the stock assessments for bigeye and yellowfin tuna, and will become increasingly important for other commercially important species such as swordfish, other billfish and sharks. These data already exist for most, if not all, large longline fleets (and for some coastal longline fleets), and are currently submitted to other t-RFMOs by IATTC CPCs (WCPFC13), and are similar to the data available to the staff for the purse-seine fishery. Therefore, these equivalent longline data should be expected to be made available to staff on an annual basis for the purposes of improving the quality of data reporting and research to facilitate fulfillment of mandates by the Antigua Convention.

The staff has prepared an extensive workplan to address several uncertainties in the stock assessment of yellowfin, bigeye tuna and other species that will require high-resolution CPUE data with corresponding size information. The staff has routine access to high-resolution data for most of the purse-seine fleet, but not for the longline fleet from which indices of abundance are mostly derived. The quality of stock assessments of tuna and tuna-like species undertaken by the staff will therefore continue to be severely compromised without access to these high-quality existing data.

The staff proposes that current and historic high-resolution, operational-level catch, effort and size ("TASK II") data, by sex, be required for the high-seas longline to improve stock assessments of tuna and tuna-like species be made available to the staff on a continuous basis. This will allow the scientific staff to fulfil its mission detailed in the SSP to "*undertake state-of-the-art scientific research to inform sound management advice, aiming at the conservation and sustainable use of the marine species and ecosystems covered by the Antigua Convention*" additional to completing the proposed workplan (SAC-12-01) on a timely manner. The staff will continue to be mindful of data confidentiality as demonstrated by the handling of the purse-seine data in strict accordance with Resolutions C-04-10, C-15-07 and IATTC Rule of Procedure XIII. The staff commends the CPCs that have already signed MOUs for the purposes of making longline data available to the staff.

RECOMMENDATIONS:

Each CPC to make available in 2022 to the IATTC set-by-set catch and effort (TASK II 'level 1' data) and ancillary operational information, from longline logbooks for both historical and current periods, and updates thereafter. All data fields requested are listed in SAC-12-09 Annex 1, Appendix 2 TASK II. However, at a minimum, the following fields must be provided (unless unavailable): Vessel unique identifier, date and time of start and end of set, latitude and longitude of start and end of set, number of hooks used, number of floats used, maximum fishing depth of the hooks, number of light sticks used, length of the mainline, material of the mainline, length of the branchline, material of the branch line, length of the float line, material of the floatline, bait, species caught (all), number of fish (by species).

Each CPC to make available to the IATTC size composition data by sex with date of collection and fine-resolution location information, both historical and current periods.

4. SHARKS AND RAYS

4.1. Improving data collection and stock assessments for sharks

Paragraph 1 of Resolution C-16-05 requires the IATTC staff to develop a workplan for completing full stock assessments for silky and hammerhead sharks. As noted in SAC-05 INF-F, SAC-05-11a, and SAC-07-06b(iii), improving shark fishery data collection in the EPO is an essential prerequisite.

The first comprehensive quantitative ecological risk assessment for sharks in the EPO was completed in 2022 (SAC-13-11) using the EASI-Fish approach, which identified 20 of the 32 species assessed exceeding biological reference points, thus rendering these species "most vulnerable". Of the 20 most vulnerable species, silky shark and three species of hammerheads were ranked highest. The EASI-Fish assessment and previous shark research undertaken by the staff have identified significant data deficiencies for vulnerable shark species, including silky and/or hammerhead sharks, in the EPO: 1) reliable catch and size composition data for coastal (*i.e.* 'artisanal') longline and gillnet fisheries (SAC-07-06b(iii); SAC-08-07e), high-seas longline fisheries (SAC-08-07b; SAC-08-07e) and small[8] purse-seine vessels (SAC-08-06a), 2) basic biological information to parameterize EASI-Fish and stock assessments, such as length-weight and length-length relationships, maturity ogives and growth curves, and 3) species-specific and fishery-specific estimates of post-release survival. In particular, without data from a properly designed long-term sampling program for artisanal fisheries across EPO coastal States (a significant part of component (1)), the IATTC staff will not be able to meet this requirement of Resolution C-16-05.

As a first step toward developing sampling designs for catch and size composition in artisanal fisheries, and for size composition in industrial longline fisheries, a wealth of information has been collected in five Central American countries under Project C.4.a, funded by FAO-GEF through March 2019, and through March 2020 by the IATTC capacity-building fund (SAC-11-13). Made possible through recent funds provided by the European Union, the sampling program in Central America has reached its completion in December 2021. The results supported a proposal that was presented at the 2021 98th Meeting (resumed) meeting of the Commission to establish a long term sampling program in Central America (IATTC-98-02c). Unfortunately, the necessary funds to implement such long-term program are not available to date. If these funds to initiate the long-term sampling program in Central America are secured and these efforts are expanded to other regions in the EPO (*e.g.,* South America, Mexico), both data collection and stock assessments for sharks in the EPO could improve. Resources to expand the Central American shark data collection improvements into other EPO coastal nations will soon be available under a phase 2 of the ABNJ project (SAC-13-12).

[8] IATTC classes 1-5; carrying capacity ≤ 363 t.

RECOMMENDATIONS:

1. Establish, or strengthen, data collection programs for artisanal fisheries in EPO coastal States to obtain reliable catch and size composition data and biological information for assessments of vulnerability and stock status.

2. Electronic tagging studies be conducted to obtain species-specific and fishery-specific estimates of post-release survival for prioritized vulnerable bycatch species, including sharks and rays.

Given the scale and importance of the shark fisheries in Central America and the lack of fishery/biological sampling data from shark landings in that region (SAC-07-06b(iii)), the staff reiterates the following recommendation:

RECOMMENDATION:

Establish an IATTC field office in Central America near the port or ports where most shark landings occur.

As regards fishery component (2), Resolution C-12-07 requires that vessel captains record all shark catches transshipped, but not by species. Species data are needed for accurate estimates of species-specific catches, so the staff recommends that vessel captains record transshipments of sharks by species.

RECOMMENDATION:

Require all vessel captains to complete the transshipment declaration forms of Resolution C-12-07 by species, for all shark catches.

Previous recommendations by the staff on data collection by observers on longline vessels and Class 1-5 purse-seine vessels are reiterated in Section 7.

5. ECOSYSTEM CONSIDERATIONS

5.1. Feasibility study to develop a sampling program for updating morphometric relationships and collecting biological samples for priority species in EPO tuna fisheries

Length-weight (L-W) relationships are the foundation to a variety of research projects including stock assessments, ecological risk assessments (*e.g.,* EASI-Fish) and for converting catch reported in numbers to weights, and vice versa. These relationships can vary markedly in space and time and can greatly influence stock and risk assessment model outcomes. Despite this, L-W relationships for tunas are outdated (*e.g.,* yellowfin: 1986, bigeye: 1966 and skipjack: 1959) or inadequate for many priority species (see SAC-13-11, SAC-09-12). Catch estimations are also affected by imprecise and/or outdated L-W relationships. Furthermore, species and size composition of the catch and fishing strategies differ significantly between longline (LL) and purse-seine (PS) fisheries (*e.g.,* see IATTC-98-01). Additionally, basic life history data for assessment models are absent or inadequate for most bycatch species. A proposed feasibility study (Project F.3.a) addresses these issues and seeks to develop a plan to update morphometric and biological sampling at large-scale in the future, through the collaboration of staff, CPCs, industry and other relevant stakeholders.

RECOMMENDATION:

In collaboration with CPCs and relevant stakeholders, develop a feasibility study (Project F.3.a) for a fishery-dependent sampling program to develop morphometric relationships and collect biological samples from prioritized species to improve catch estimations and assessment models.

6. FISH-AGGREGATING DEVICES (FADs)

The recommendations in this section are based on documents FAD-06-02 and FAD-06-03; some of them were endorsed by the *ad-hoc* Working Group on FADs, SAC-09, SAC-10 and IATTC-97-01.

6.1. Timely provision of FAD data

Resolution C-19-01 requires that CPCs provide data on FADs recorded by captains of purse-seiners

without observers aboard for the previous calendar year "*no later than 90 days prior to each regular meeting of the SAC*", and that the IATTC staff present a preliminary analysis of that information to the SAC. However, given the many other tasks required of the staff in preparation for SAC meetings, this does not allow sufficient time for a thorough analysis of the data, and therefore more timely provision of data is desirable.

RECOMMENDATION:

CPCs should provide the FAD data from each fishing trip without an observer aboard to the IATTC staff as soon as possible after the trip terminates.

6.2. Provision of detailed buoy data

Under Resolution C-17-02 and C-20-06, CPCs were required to provide "daily information" on their active FADs, which was interpreted to mean a single data point per FAD per day, the selection criteria for which are unclear (*e.g.* no acoustic biomass information is required by the Resolution). This combination of low resolution and uncertain selection criteria meant that these data were of limited scientific utility. Also, CPCs were allowed to report data in different formats, sometimes highly summarized (without any information on FAD identification or trajectory), which again were of little use for science. Moreover, Resolution C-19-01 allows CPCs to use different methods for marking and identifying FADs. As a result, the data provided under C-17-02 and C-20-06 were inadequate even to allow connection of the various FAD-related IATTC. In recent years, the IATTC staff, the FAD-WG and even the SAC itself recommended the provision of raw buoy data as received by original users (*i.e.* vessels, fishing companies), including both trajectories and acoustic biomass information. Starting in 2022, under Resolution C-21-04, CPCs need to report this data following the format specified in Annex IV of C-21-04.

As noted by voluntary pilot studies using raw buoy data, including both trajectories and acoustic biomass information, at regional (*e.g.*, FAD-05-INF-E, FAD-06-03) and global (*e.g.*, IOTC-2020-WPTT20-14, SCRS/2019/075) level, scientific studies require high-resolution, standardized long-time series data. Therefore, the staff recommends that CPCs provide the historic raw buoy data in order to conduct the appropriate scientific analyses, and in particular, to continue improving the assessment of skipjack (SAC-13-07) and other tropical tuna species.

RECOMMENDATION:

CPCs should provide to the IATTC staff the historic raw buoy data received by original users (*i.e.* vessels, fishing companies), including both trajectories and acoustic biomass information.

6.3. Biodegradable FADs

The purse-seine effort on the fish-aggregating device (FAD) fishery in the EPO has progressively increased since the early 1990s due to its efficiency in capturing tropical tunas that aggregate under FADs. Resolutions C-19-01 and C-21-04 require the IATTC staff to present recommendations on the use of biodegradable materials to mitigate the entanglement of species and reduce marine debris. To this end, the staff, in collaboration with fishing organizations, has developed trials for testing biodegradable and non-entangling materials for the tuna FAD fishery (project M.5.a; document FAD-06-02). Moreover, the staff has engaged with other research and initiatives conducted by other t-RFMOs, and stakeholders with the intention of sharing experiences, and discussing common goals and harmonization. The implementation of biodegradable FADs in the region deserves the consideration of a number of aspects, ranging from identifying suitable materials and designs for FAD construction, the adoption of a definition and characteristics for a biodegradable FAD, and updating data collection forms and procedures, among others.

Hence, the IATTC staff's recommendations are as follows (FAD-06-02):

RECOMMENDATIONS:

1. Consider current prototypes 1 and 2 as potential examples for effective biodegradable FAD construction[9].
2. Harmonize across t-RFMOs and regional biodegradable FAD initiatives, to the extent possible, the definition of biodegradable FADs, the guidelines and timeline for their construction and implementation, as well as data collection priorities.
3. Consider the following definition for biodegradable FADs, simplified from Zudaire et al., (2021): "*A biodegradable FAD is composed of non-netting from organic materials and/or bio-based alternatives certified by international standards as biodegradable in marine environments*".
4. Require further trials at sea to refine important practical and technical aspects for the full implementation of biodegradable FADs (*e.g.,* durability, designs, material availability and acquisition). Ideally, these trials should be monitored and conducted in collaboration with scientists.
5. Request that the results of biodegradable trials at sea be made available to the FAD WG.
6. Consider a gradual/stepwise process, including a timeline for the implementation of fully biodegradable FADs based on the current state of material availability.
7. Reduce, to the extent possible and within the gradual process of biodegradable FAD implementation, the amount of material (*e.g.,* tail depth) and the non-biodegradable components of NED design and construction, provided that fishing efficiency is not compromised.

6.4. Traditional FADs

Purse seine fishers extensively deploy drifting FADs to aggregate and catch tropical tuna, with >20,000 FADs deployed in the eastern Pacific Ocean annually in recent years. Main concerns related to the loss and abandonment of FADs are i) marine pollution; ii) the potential risk of entanglement of marine megafauna in FAD netting while drifting at sea or stranded; and iii) the potential to cause ecological damage to vulnerable ecosystems via stranding events, including reefs, beaches, and other essential habitats. A series of recent simulation experiments undertaken based on possible FAD drifting behavior, identified potential corridors of connectivity between industrial FAD fishing grounds and zones of important habitats. Although these connectivity patterns appear to be somewhat mitigated against by the current deployment distribution of FADs in the EPO, additional research and analyses are desirable to better understand interactions between FADs and sensitive species' populations, their potential entanglements; and the likely changes in connectivity and distribution of FADs under proposed different FAD designs and use strategies.

Hence, the IATTC staff's recommendations are as follows (BYC-11-05):

RECOMMENDATION:

Given the overlap of FADs with oceanic and coastal habitats of sea turtles, consider no netting materials for FAD construction and eliminating potential entanglement.

7. OBSERVER COVERAGE

7.1. Purse-seine fishery

7.1.1. Observer coverage of purse-seine vessels of less than 364 t carrying capacity

No formal, fleet-wide on-board observer program exists for Class 1-5 purse-seine vessels, and as a result, trips by many small[10] purse-seine vessels are never sampled by observer programs (SAC-08-06a; SAC-12-09). Vessel logbooks and cannery unloading records are the principal sources of data on the activities of these vessels. However, they generally do not contain information on tuna discards, and the data are less complete and detailed

[9] Prototype 3 results will need to be updated, and its suitability considered, once all deployments are finalized
[10] Carrying capacity ≤ 363 t.

than those collected by observers. In addition, bycatch information is only rarely recorded in logbooks, which hampers efforts to conduct assessments for such species. Electronic monitoring (EM) for this fleet component is currently being explored (Project D.2.a; SAC-10-12), and some capabilities of EM detected in the pilot study are detailed in Appendix 2 of SAC-11-11; however, EM data collection is not likely to begin at any significant level prior to January 2025, given the steps that need to be completed for implementation of an EM System in the EPO (SAC-12-10; SAC-12-11). Therefore, a fleet-wide observer program is needed to obtain the data necessary for estimating the quantity and species composition of bycatches by these vessels and to understand the strategies and dynamics of their operations. Based on a previous study of EPO data for Class-6 vessels fishing on floating objects (IOTC Proceedings WPDCS-01-09, 4: 48–53), an initial sampling coverage of 20% of all trips of the small-vessel fleet component is recommended.

RECOMMENDATION:

Establish a fleet-wide observer program for purse-seine vessels of less than 364 t carrying capacity, with a sampling coverage of 20%.

7.2. Longline fishery

7.2.1. Observer coverage

Resolution C-19-08 requires that at least 5% of the fishing effort by longline vessels greater than 20 m length overall (LOA) carry a scientific observer. However, recent analyses undertaken by IATTC staff with the new operational-level data collected by observers onboard large longline vessels showed that, at such a low level of coverage, the data are not representative of the fishing activities of the entire fleet and cannot even be used to produce accurate estimates of total catch of target species such as bigeye tuna and yellowfin tuna (BYC-10 INF-D). Therefore, the staff concludes that 5% coverage is too low for calculating accurate estimates of the total catches of bycatch species caught by these vessels, particularly those species caught infrequently, such as sea turtles, seabirds and some sharks of conservation concern. In fact, several studies of sampling coverage for other longline fisheries have shown that 20% coverage is considered the minimum level required for estimating total catch of bycatch species. Both the staff and the SAC have recommended that this level of coverage be adopted for longline vessels over 20 m LOA (SAC-10 INF-H).

RECOMMENDATION:

The staff maintains its recommendation of at least 20% observer coverage of longline vessels over 20 m length overall.

7.2.2. Data standards and reporting

In 2019, the Commission replaced Resolution C-11-08 on scientific observers on longline vessels with Resolution C-19-08. Annex B to C-19-08 formalizes the minimum data standards for longline observer data collection approved by SAC-08 in 2017. Under these measures, all CPCs with qualifying longline vessels fishing in the EPO are required to report all operational data collected by their respective observer programs since 2013. However, several CPCs have not yet reported data for all relevant years.

RECOMMENDATION:

CPCs should submit all operational longline observer data collected from 1 January 2013 to present, consistent with the minimum data standards contained in Annex B of C-19-08 or provide a clear and complete explanation as to why the missing datasets have not been submitted.

8. ELECTRONIC MONITORING

8.1. Implementing an electronic monitoring system for the tuna fisheries

Electronic monitoring (EM) is increasingly being used worldwide to record the activities of fishing vessels, to complement human observer programs, and where on-board observer coverage is too low or non-existent. Accordingly, per request of the Scientific Advisory Committee during its 10th meeting in 2019, and pursuant to paragraphs 9 and 10 of Resolution C-19-08, the IATTC staff, at the 11th meeting of the SAC in

2020, presented the document SAC-11-10, containing information on the potential of an Electronic Monitoring System (EMS), a description and evaluation of the minimum standards of its components, and the actions that would be required for its implementation. To further discuss the elements contained in document SAC-11-10, the *1st Workshop on Implementation of an EMS in the EPO* was held in April 2021. Presented at this workshop, the document EMS-01-01 recommended several actions for endorsement by the Commission. Among these was a workplan formulated by IATTC staff (EMS-01-02-Rev), which proposed a series of workshops to consider and analyze the EMS components and subcomponents in a hierarchical and chronological order. The associated Terms of Reference of these EMS workshops and a set of definitions were adopted through the Resolutions C-21-02 and C-21-03, respectively, during the 98th Meeting of the IATTC. In observance of Resolution C-21-02, and according with the workplan adopted for the implementation of an EMS in the EPO, the staff organized in fall 2021 the 2nd Workshop of an EMS in the EPO to discuss aspects on the institutional structure, goals and scope of the EMS (see EMS-02-01 and EMS-02-02 Rev.). A 3rd Workshop was organized in spring 2022 to discuss considerations related to the management of an EMS for the EPO (see EMS-03-01). The staff has compiled all the comments and concerns of the workshop participants and revised its preliminary recommendations as necessary (SAC-13-INF-D).

RECOMMENDATION:

See document SAC-13-INF-D for a compilation of all staff recommendations on EM, which were presented and discussed with the workshop participants. Where appropriate, the staff preliminary recommendations were revised.

9. WORKING GROUPS

9.1. Establish a working group on Ecosystem and Bycatch

The current Working Group on Bycatch was established by the IATTC in 1997. Its role was further elaborated, two years later, through the adoption of Resolution C-99-11 on bycatch. In April 2000, the IATTC Director gave a verbal account of its terms of reference, as recorded in the report of the meeting, as follows: 1. To define the relationships between bycatch and objectives; 2. To develop gear technologies for bycatch reduction; 3. To formulate and evaluate management schemes for reducing bycatch. Since then, the negotiations leading to the adoption of the Antigua Convention in 2003 and the entry into force of the convention in 2010 significantly expanded the mandate of the IATTC, through the incorporation of an ecosystem approach to fisheries management, in line with the principles and standards contained in the international instruments adopted at the global level, particularly within FAO. That evolution is still not reflected appropriately in the current terms of reference of the Working Group on Bycatch. There is in addition an increasing disparity between the original mandate of the Working Group, on the one hand, and, on the other, the Strategic Science Plan and program of work that were endorsed by the Commission. Accordingly, the Co-Chairs of the Working Group, in coordination with the staff of the Commission, considered necessary to prepare a draft of terms of reference that would be more precise, comprehensive, and detailed, as well as reflecting appropriately the broadening of the mandate of the Commission under the Antigua Convention (BYC-11-03). It is also proposed to modify that its name be modified to "Working Group on Ecosystem and Bycatch".

RECOMMENDATION:

The SAC should consider and endorse the terms of reference (BYC-11-03) for the creation of a new "Working Group on Ecosystem and Bycatch," which would replace and expand the functions of the current Working Group on Bycatch through broadening its mandate to include ecosystem considerations and others, consistent with the Antigua Convention.