JOINT SOUTHWEST FISHERIES SCIENCE CENTER AND WEST COAST REGION NATIONAL MARINE FISHERIES SERVICE (NMFS) REPORT: Proxies for Maximum Fishing Mortality Threshold (MFMT) and Options for Minimum Stock Size Threshold (MSST)

During the November 2020 meeting, the Pacific Fishery Management Council (Council) requested that the Scientific and Statistical Committee (SSC): (1) review National Marine Fisheries Service (NMFS)-selected proxies for maximum fishing mortality threshold (MFMT) from the 2020 eastern Pacific Ocean (EPO) yellowfin and bigeye tuna (collectively, tropical tuna) stock assessments, and (2) consider options for using probabilistic framework assessments for highly migratory species (HMS) stock status determinations more generally. It may not be feasible to derive estimates or proxies for minimum stock size threshold (MSST) from the 2020 tropical tuna assessments, which employ probabilistic frameworks, before the Inter-American Tropical Tuna Committee's (IATTC) scientific staff complete the next assessments for these stocks--a situation that may lead to partial status determinations in the interim. However, the second task is important because it is likely that the probabilistic frameworks used in these recent IATTC assessments will continue to be used going forward, and because it is possible these frameworks could be used in other international assessments at some point.

Background. The Fishery Management Plan for U.S. West Coast Fisheries for Highly Migratory Species (HMS FMP) describes that proxies from internationally-produced assessments may be used for status determination criteria (SDC) (i.e., MSST=(1-M)B_{MSY} when M (natural mortality) ≤ 0.5, or $= 0.5B_{MSY}$ when $M > 0.5$, and MFMT=F_{MSY}). In 2018, the Council and its SSC reviewed and approved NMFS proxy selections from IATTC assessments for stocks of management unit species in the plan and noted that future review was not necessary. However, the new methods in the 2020 tropical tuna benchmark assessments, including use of probabilistic frameworks, present new challenges in relating these assessment results to the SDCs of the HMS FMP.

Following completion of the IATTC's Scientific Advisory Committee's (SAC) review of the assessments during the 26th through 28th in October 2020, NMFS determined that the 2020 EPO tropical tuna stock assessments represent the best scientific information available (BSIA) for the purposes of National Standard 2 (note: BSIA memo is included in SSC briefing materials). However, stock status determinations have not been completed based on that information. Rather, that process hinges on consideration and approval of MFMT proxies by the Council and a path forward for determining an appropriate estimate or proxy for MSST.

MFMT Proxies. The new 2020 tropical tuna assessments are based on 'risk analysis' methodologies, which use several reference models to represent various plausible states of nature (assumptions) about the biology of the fish, the productivity of the stocks, the operation of the fisheries, and take into account the different results, thus incorporating uncertainty into the formulation of management advice. This change also allows the IATTC staff to explicitly evaluate the probability statements specified in the IATTC harvest control rule for tropical tunas established in Resolution C-16-02.

NMFS proposes the following as proxies for MFMT from the recent assessments: If $P(F_{CUR}>F_{MSY})$ is more than 50 percent, then overfishing is occurring. That is, if the median of the probability distribution of F_{CUR}/F_{MSY} exceeds 1, then overfishing is occurring. NMFS views this as consistent with the HMS FMP which describes overfishing as occurring at a level "above" MFMT. Further, using a probability statement is also consistent with the manner in which IATTC determines stock status.

- ***EPO yellowfin tuna:*** The 2020 assessment indicates a nine percent probability that 2017-19 fishing mortality exceeds the MSY level (i.e., $P(F_{CUR}>F_{MSY}) = 9\%$). Because the IATTC's target fishing mortality threshold (F_{MSY}) is the same reference level as MFMT, the assessment results suggest it is highly unlikely that the stock is subject to overfishing. Based on NMFS-suggested proxy for MFMT, EPO yellowfin tuna would not be subject to overfishing. It may also be worth consideration that the recent assessment indicated approximately zero probability that the IATTC's F limit reference point has been exceeded ($P(F_{CUR}>F_{LIMIT}) = 0\%$) (See Appendix A for more detail on IATTC reference points). To obtain these probabilities, the posterior distributions from individual models were weighted and combined.

- ***EPO bigeye tuna:*** In addition to the added complexity of interpreting the results of the probabilistic framework used in the 2020 benchmark assessment, the posterior distributions of $P(F_{CUR}>F_{MSY})$ and $P(F_{CUR}>F_{LIMIT})$ were also bimodal (i.e., one set of model results exceeds the reference point while another does not). For bigeye, there is a 50 percent probability that 2017-19 fishing mortality exceeds the MSY level ($P(F_{CUR}>F_{MSY}) = 50\%$). Based on NMFS-suggested proxy for MFMT, EPO bigeye tuna would not be subject to overfishing. It may also be worth consideration that the recent assessment indicated a 5 percent probability that the IATTC's F limit reference point has been exceeded ($P(F_{CUR}>F_{LIMIT}) = 5\%$) (See Appendix A for more detail). To obtain these probabilities, the posterior distributions from individual models were weighted and combined.

Options for Using Probabilistic Framework Assessments for HMS Stock Status Determinations: NMFS and Council staff engaged in some preliminary discussions on this topic with the SSC during their November 2020 meeting. Those discussions considered potential options for situations when reference levels consistent with domestic SDCs are not reported in assessment results, like is the case for MSST with the recent tropical tuna assessments from the IATTC. One potential option raised was whether international assessment authors could report domestic SDCs when producing assessment results. Another option was whether NMFS' Science Center staff could produce a secondary analysis for review by the SSC. Below NMFS evaluates the pros and cons of these two options, Fs and suggests another (third option) for further discussion.

1. Request that international assessment results include reference levels consistent with domestic SDCs in the future.

    - PRO: Reporting of domestic SDCs, determining whether they constitute BSIA, and resulting status determinations would be an efficient and timely process. If SDCs were reported as results in the assessment and subject to international review, this

would serve the purpose of making a BSIA determination under National Standard 2. NMFS would not need to duplicate any of the analytical effort of the IATTC staff, nor would the Council need to concern itself with conducting another review in addition to that of the IATTC's SAC.

- CON: This will be a significant addition to the IATTC's scientific staff work-load, and the request would have to be made through the U.S. delegation to IATTC. In addition, NMFS conjectures that the IATTC scientific staff may not find it feasible to meet such a request out of concern that doing so may spur other countries to make additional requests, adding to the already high workload to produce an assessment.

2. NMFS Science Center conducts a secondary analysis to produce reference levels consistent with domestic SDCs, and the Council conducts a review of that analysis for purposes of determining whether their results constitute BSIA.

    - PRO: Analyses to produce the domestic SDCs will be based on the models and risk analyses developed by IATTC and will not be affected by the IATTC scientific staff's ability to accommodate the extra work needed for the analyses.

    - CON: (1) The SWFSC estimates that producing secondary analyses of this type would require additional resources, which it does not currently have to support this approach. The need for additional resources to conduct these analyses may grow should other international stock assessments present similar challenges. Stock Synthesis model files are publicly available but will likely need to be checked and adjusted. Methods to weight and combine model results for the domestic SDCs would have to be developed, documented, and reviewed. For example, different levels of natural mortality (M) are used or estimated within different models of the risk analysis, resulting in different MSST proxies for different models. In addition, if the M parameters are estimated, the covariances between the M and MSY values from different models would have to be incorporated into the calculation of the MSST proxies. After calculating the distributions of MSST proxies from the various models in the risk analysis, these distributions would have to be weighted according to the weights estimated by the IATTC and combined into a single distribution. One check would be to calculate the distributions for the IATTC reference points using this weighting procedure and compare with the results from IATTC. 2) The Council may also be required to make additional investments of resources to ensure the secondary analysis produced by NMFS satisfies BSIA standards under National Standard 2, meaning a STAR panel review or similar. While future iterations of these secondary analyses could be less time consuming, that would only be the case if there were no changes to the assessments. (3) Given that domestic management of commercial fishing on these stocks is primarily based on international management responses to stock status relative to international target reference points, the value added for the extra investment would likely be marginal.

3. In the absence of additional analysis or international assessments reporting reference levels consistent with MSST, the Council could determine an MSY-based proxy as suitable for MSST. One example might be to use the probability of exceeding biomass at a MSY level (e.g., B_{MSY} or S_{MSY}) since this reference level is reported in most international assessments. A way to deal with the fact that B_{MSY} is more a conservative reference level than the current MSST is to identify a higher probability of current biomass exceeding B_{MSY} as a suitable proxy (e.g., a stock is overfished if the probability of current biomass being below biomass at MSY is greater than, for example, 75 percent [e.g., $P(B_{CUR}<B_{MSY})>0.75$)]. Another example might be to use the median of the reported adult female annualized M values of the reference models as the M value used to calculate the MSST. If M > 0.5, the MSST is calculated as $S_{CUR}/0.5*S_{MSY}$. Therefore, if all the models have M > 0.5, as is the case for the IATTC risk analysis, all the S_{CUR}/S_{MSY} distributions are scaled by the same value (i.e., 0.5). That same value can then be applied to the overall S_{CUR}/S_{MSY} distribution reported by IATTC instead of calculating the MSST distribution for each model and combining the models with the appropriate weights. For the models with estimated M, the medians of the M posterior distributions are all > 0.5, which means that the majority of the MSST distributions of these models are calculated as $S_{CUR}/0.5*S_{MSY}$ and the covariance between M and S_{MSY} can therefore be ignored. For the IATTC risk analysis, the reported adult female annualized M values of the reference models for both yellowfin and bigeye are currently all >0.5. Therefore, the MSST proxy would currently be calculated as $S_{CUR}/0.5*S_{MSY}$. These are two of possibly many options.

    - PRO: (1) The first example in this approach would be an efficient way to use the results of probabilistic assessments in that the Council and NMFS would not need to commit additional resources to the process of making stock status determinations consistent with the FMP. This approach removes natural mortality (M) from the formulation of the proxy, and would make the proxy more consistent over time, because the M parameter changes between assessments, and between models within the risk analysis framework. The proxy would represent a fixed probabilistic statement, which is also consistent with the manner the IATTC determines stock status. (2) While the second example is also an efficient way to determine stock status because it also would not require significant resources for a secondary analysis to produce the proxy or for conducting a secondary review to consider whether the proxy satisfies BSIA, although it may involve some additional calculations beyond what may be reported as assessment results. This example will produce a proxy that is likely closer to MSST than the first example. (3) Further, because both examples set MSST at a reference level below biomass at MSY, both could allow the IATTC the opportunity to take corrective action when biomass drops below the IATTC's target reference level at MSY before the Council is obligated to make recommendations to address an overfished stock status.[1].
    - CON: (1) This approach of using a proxy to determine whether a stock is overfished relative to MSST is not as precise as the other options discussed above. In the case

[1] Because the IATTC uses spawning biomass at MSY as a target reference point (see Appendix A), spawning biomass is likely to hover around the MSY level. Additionally, when biomass drops below the MSY level, the IATTC typically takes action aimed at increasing biomass above that level, which may negate the need for additional action by the Council.

of the first example, using a probability statement for exceeding biomass at MSY as a proxy for MSST introduces an additional source of uncertainty as to whether biomass has in fact exceeded MSST. (2) The closer a probability statement is to 50 percent (i.e., $P(S_{CUR}<S_{MSY})=0.5)$), the closer the MSST proxy is to biomass at MSY. Using such a precautionary approach could lead to increased, and potentially unnecessary workload for the Council. (3) If the Council would like to evaluate the management strategy of using a proxy with a probability statement and compare that to the current MSST, it would require substantial resources to do so, which the SWFSC does not currently have. (4) The second example in this approach may involve additional, but not significant, workload. This is the case as long as M is above 0.5 (because MSST uses either 1-M or 0.5, whichever is lower, and the M values are currently above 0.5; therefore 0.5 would be used in the calculation of MSST). If and when the majority of M values in the models are below 0.5, a different approach would be needed because the covariance and model weighting would have to be considered.

APPENDIX A: Discussion of IATTC's Target and Interim Limit Reference Points

For EPO stocks of yellowfin and bigeye tuna, the IATTC manages to target biomass and fishing mortality reference points (S_{MSY} and F_{MSY}, respectively). In stock assessments, IATTC scientific staff typically refer to stocks being subject to overfishing or overfished relative to these target reference points. The IATTC uses that information to determine management measures with the intent of maintaining biomass and fishing mortality at MSY levels.

In addition to reporting target reference points for EPO yellowfin and bigeye stocks, the IATTC scientific staff also report interim limit reference points, which were adopted by the IATTC in 2014. The interim spawning biomass limit reference point (S_{LIMIT}) is the threshold of S that should be avoided because further depletion could endanger the sustainability of the stock. The interim S_{LIMIT} is the spawning biomass that produces 50 percent of the virgin recruitment (R_0) if the stock-recruitment relationship follows the Beverton-Holt function with a steepness (h) of 0.75. This spawning biomass is equal to 0.077 of the equilibrium virgin spawning biomass (S_0).
The interim fishing mortality limit reference point (F_{LIMIT}) is the threshold of fishing mortality that should be avoided because fishing more intensively could endanger the sustainability of the stock. The interim F_{LIMIT} is the fishing mortality rate that, under equilibrium conditions, maintains the spawning population at S_{LIMIT}.

The IATTC's harvest control rule (HCR) requires action be taken if the probability (P) of the current spawning biomass ($S_{CURRENT}$) being below S_{LIMIT} is greater than 10 percent. Thus, to provide management advice, $S_{CURRENT}/S_{LIMIT}$ and the probability of $S_{CURRENT} < S_{LIMIT}$ (or $P(S_{CURRENT}/S_{LIMIT} <1)$, which is computed by assuming the probability distribution function for the ratio is normal), are reported. The HCR also requires action to be taken if the probability of the average fishing mortality during the terminal years of the assessment period ($F_{CURRENT}$) being above F_{LIMIT} is greater than 10 percent. Therefore, $F_{CURRENT}/F_{LIMIT}$, and the probability of this ratio being > 1 (by assuming the probability distribution function for the ratio is normal), are also reported (Minte-Vera et al. 2020, Xu et al. 2020).

PFMC
02/09/21