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UPDATED INDICATORS OF STOCK STATUS FOR SKIPJACK TUNA IN THE EASTERN PACIFIC OCEAN

Mark Maunder

A major management objective for tunas in the eastern Pacific Ocean (EPO) is to keep stocks at levels capable of producing maximum sustainable yields (MSYs). Management objectives based on MSY or related reference points (*e.g.* fishing mortality that produces MSY (F_{MSY}); spawner-per-recruit proxies) are in use for many species and stocks worldwide. However, these objectives require that reference points and quantities to which they are compared be available. The various reference points require different amounts and types of information, ranging from biological information (*e.g.* natural mortality, growth, and stock-recruitment relationship) and fisheries characteristics (*e.g.* age-specific selectivity), to absolute estimates of biomass and exploitation rates. These absolute estimates generally require a formal stock assessment model. For many species, the information required to estimate these quantities is not available, and alternative approaches are needed. Even more data are required if catch quotas are to be used as the management tool.

Skipjack tuna is a notoriously difficult species to assess. Due to its high and variable productivity (*i.e.* annual recruitment is a large proportion of total biomass), it is difficult to detect the effect of fishing on the population with standard fisheries data and stock assessment methods. This is particularly true for the stock of the EPO, due to the lack of age-composition data, and especially tagging data, without which a conventional stock assessment of skipjack is not possible. The continuous recruitment and rapid growth of skipjack mean that the temporal stratification needed to observe modes in length-frequency data make the current sample sizes inadequate. Previous assessments have had difficulty in estimating the absolute levels of biomass and exploitation rates, due to the possibility of a dome-shaped selectivity curve (Maunder 2002; Maunder and Harley 2005), which would mean that there is a cryptic biomass of large skipjack that cannot be estimated. The most recent assessment of skipjack in the EPO (Maunder and Harley 2005) is considered preliminary because it is not known whether the catch per day fished for purse-seine fisheries is proportional to abundance. Analysis of currently available tagging data is unlikely to improve the skipjack stock assessment (Maunder 2012a) and a fully length-structured model produced unrealistic estimates (Maunder 2012b). In addition to the problems listed above, the levels of age-specific natural mortality are uncertain, if not unknown, and current yield-per-recruit (YPR) calculations indicate that the YPR would be maximized by catching the youngest skipjack in the model (Maunder and Harley 2005). Therefore, neither the biomass- nor fishing mortality-based reference points, nor the indicators to which they are compared, are available for skipjack in the EPO.

One of the major problems mentioned above is the uncertainty as to whether the catch per unit of effort (CPUE) of the purse-seine fisheries is an appropriate index of abundance for skipjack, particularly when the fish are associated with fish-aggregating devices (FADs). Purse-seine CPUE data are particularly problematic, because it is difficult to identify the appropriate unit of effort. In the current analysis, effort is defined as the amount of searching time required to find a school of fish on which to set the purse seine, and this is approximated by number of days fished. Few skipjack are caught in the longline fisheries or dolphin-associated purse-seine fisheries, so these fisheries cannot be used to develop reliable indices of abundance for skipjack. Within a single trip, purse-seine sets on unassociated schools are generally intermingled with floating-object or dolphin-associated sets, complicating the CPUE calculations. Maunder and Hoyle (2007) developed a novel method to generate an index of abundance, using data from the floating-object fisheries. This method used the ratio of skipjack to bigeye in the catch and the "known" abundance of bigeye based on stock assessment results. Unfortunately, the method was of limited usefulness, and more research is needed to improve it. Currently, there is no reliable index of relative abundance for skipjack in the EPO. Therefore, other indicators of stock status, such as the average weight of the fish in the catch, should be investigated.

Since the stock assessments and reference points for skipjack in the EPO are so uncertain, developing alternative methods to assess and manage the species that are robust to these uncertainties would be beneficial. Full management strategy evaluation (MSE) for skipjack would be the most comprehensive method to develop and test alternative assessment methods and management strategies; however, developing MSE is time-consuming, and has not yet been conducted for skipjack. In addition, higher priority for MSE is given to yellowfin and bigeye tuna, as available data indicate that these species are more susceptible to overfishing than skipjack. Therefore, Maunder and Deriso (2007) investigated some simple indicators of stock status based on relative quantities. Rather than using reference points based on MSY, they compared current values of indicators to the distribution of indicators observed historically. They also developed a simple stock assessment model to generate indicators for biomass, recruitment, and exploitation rate. We update their results to include data up to 2018. To evaluate the current values of the indicators in comparison to historical values, we use reference levels based on the 5th and 95th percentiles, as the distributions of the indicators are somewhat asymmetric. Indicators of number of sets and catch-per-set are also presented. Additional relevant indicators are also presented in SAC-10-06.

Eight data- and model-based indicators are shown in Figure 1. The standardized effort, which is a measure of exploitation rate, is calculated as the sum of the effort, in days fished, for the floating-object (OBJ) and unassociated (NOA) fisheries. The floating-object effort is standardized to be equivalent to the unassociated effort by multiplying by the ratio of the average floating-object CPUE to the average unassociated CPUE. The purse-seine catch started increasing substantially in the mid-1990s, and has been above average since 2003; during 2015-2017 it was above the upper reference level, but fell below it in 2018. The floating-object CPUE has generally been above average since the early 1990s, and was above the upper reference level in 2016. The unassociated CPUE has been increasing since the early 2000s; it has been above average since about 2003, and was above the upper reference level in 2017, but fell below it in 2018. The standardized effort indicator of exploitation rate increased starting in the early 1990s, and has been above the average level since about 2000. The average weight of skipjack has been declining since 2000, and in 2015 and 2016 was below the lower reference level, but increased slightly to above that level in 2017, then fell back to the reference level in 2018. Both biomass and recruitment have been increasing over the past 20 years, and were above their respective upper reference levels in 2015 and 2016. The exploitation rate started increasing in the mid-1980s, and has fluctuated around the average since the mid-1990s.

The number of sets by both large and small purse-seine vessels in the floating-object fishery has increased consistently for at least the past 15 years (Figure 3), and at the same time the catch per set has fallen. The number of days fished has not increased at the same rate, and the increased number of sets is therefore likely the cause of the increased catch and catch per day fished (CPDF). The CPDF is used to create the model-based indicators and therefore the estimated increases in recruitment and abundance are probably an artifact caused by the increased number of sets.

The data- and model-based indicators have yet to detect any adverse impacts of the fishery. However, the model-based indicators are probably biased and should not be considered reliable. The average weight was at or below its lower reference level during 2015-2017, which can be a consequence of overexploitation, but can also be caused by recent recruitments being greater than past recruitments or expansion of the fishery into areas occupied by smaller skipjack. The average length is less in the western part of the EPO, but it has been declining in all areas (Figure 3). The long-term pattern in reduced average weight is probably due to increasing fishing mortality resulting from the increasing number of sets. However, it is unknown if the current fishing mortality levels are appropriate because there are no reference points for skipjack tuna in the EPO; however, any continued decline in average length is a concern. Neither analyses of tagging data, nor various previous models (length-structured, A-SCALA, and SEAPODYM), indicate a credible risk to the skipjack stock(s) (Document SAC-07-05c).

Productivity and susceptibility analysis (PSA; see IATTC Fishery Status Report 12, Figure L-4) shows that skipjack has substantially higher productivity than bigeye. Biomass (B) and the fishing mortality that corresponds to MSY (F_{MSY}) are, respectively, negatively and positively correlated with productivity. Therefore, since skipjack and bigeye have about the same susceptibility, and susceptibility is related to fishing mortality, the status of skipjack can be inferred from the status of bigeye, but only if the fishing mortality of bigeye is below the MSY level (*i.e.*, $F<F_{MSY}$). Since an assessment of bigeye is not available, no inferences can be made at this stage about the status of skipjack. A conventional assessment of skipjack is necessary to ascertain the status of the stock, but, as noted above, this is not possible without much more extensive tagging data. The large-scale tagging program (Project E.4.a) that commenced in 2019 is therefore critical.

ACKNOWLEDGEMENTS

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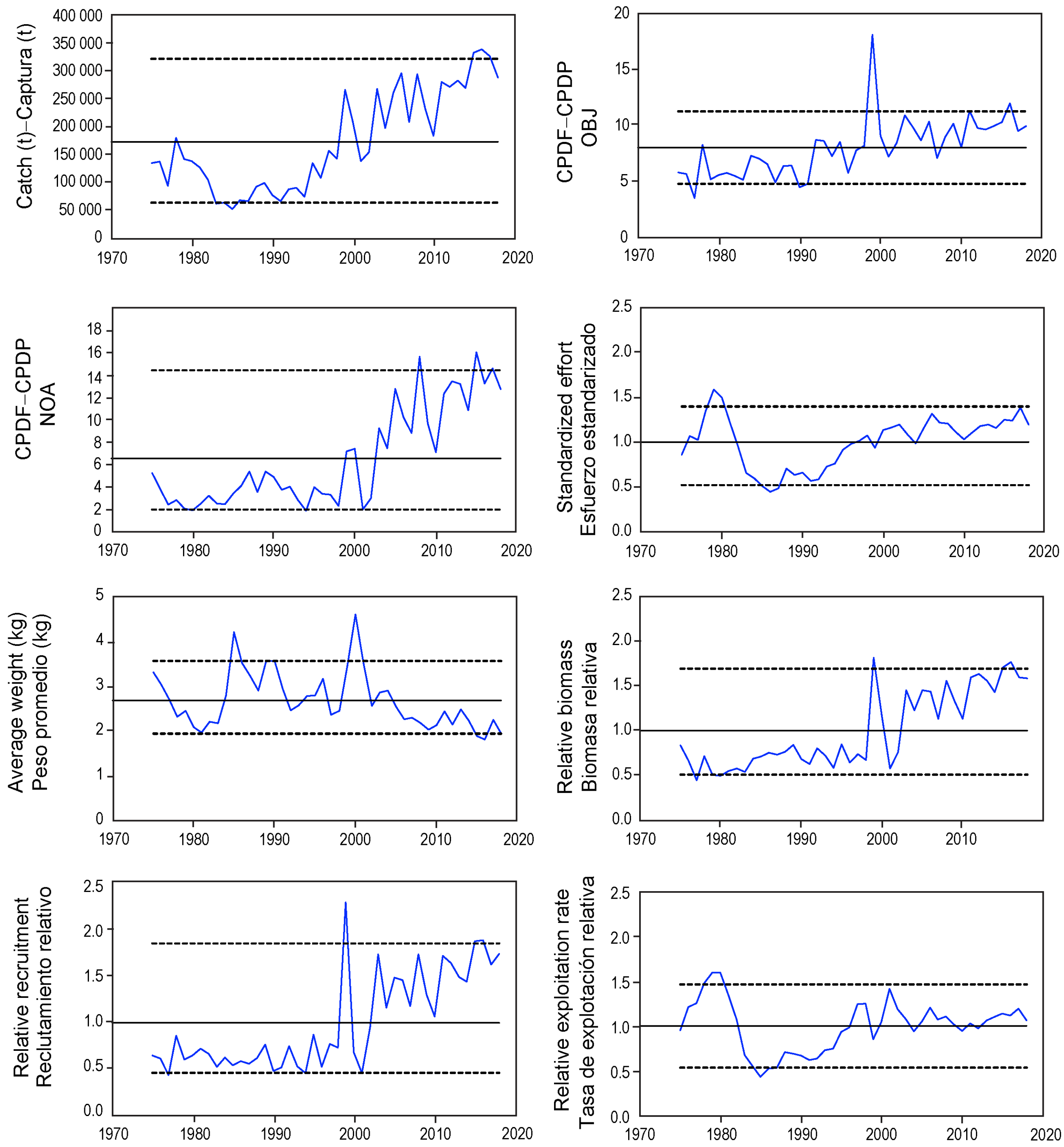

FIGURE 1. Indicators of stock status for skipjack tuna in the eastern Pacific Ocean. OBJ: floating-object fishery; NOA: unassociated fishery; CPDF: catch per day fished. All indicators are scaled so that their average equals one.

FIGURA 1. Indicadores de condición de la población de atún barrilete en el Océano Pacífico oriental. OBJ: pesquería sobre objetos flotantes; NOA: pesquería no asociada; CPDP: captura por día de pesca. Se ajusta la escala de todos los indicadores para que su promedio equivalga a uno.

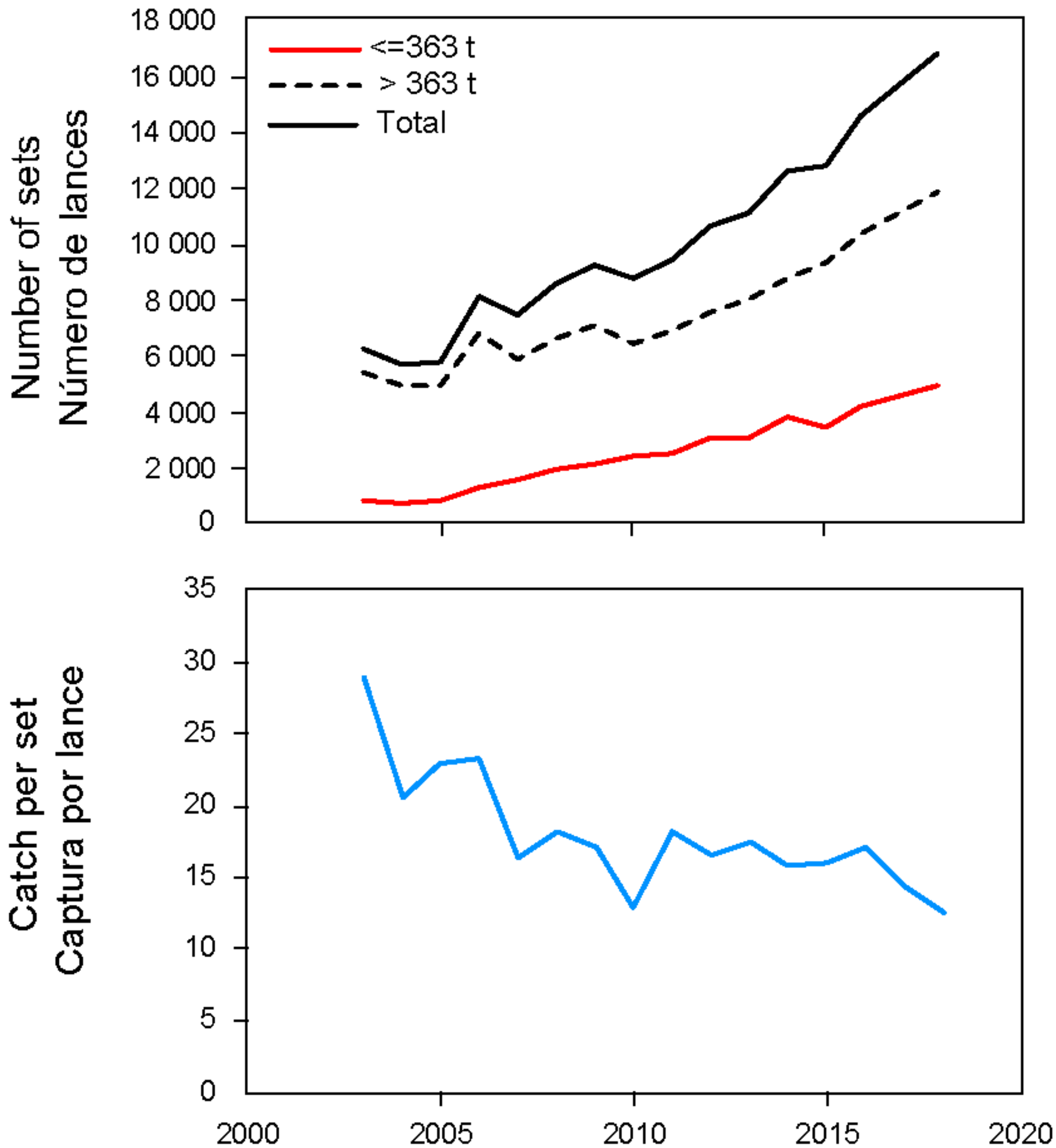

FIGURE 2. Number of floating-object sets, by vessel carrying capacity and total (top panel), and catch per set in the floatingzobject fishery (bottom panel).

FIGURA 2. Número de lances sobre objetos flotantes, por capacidad de acarreo del buque y total (recuadro superior), y captura por lance en la pesquería sobre objetos flotantes (recuadro inferior).

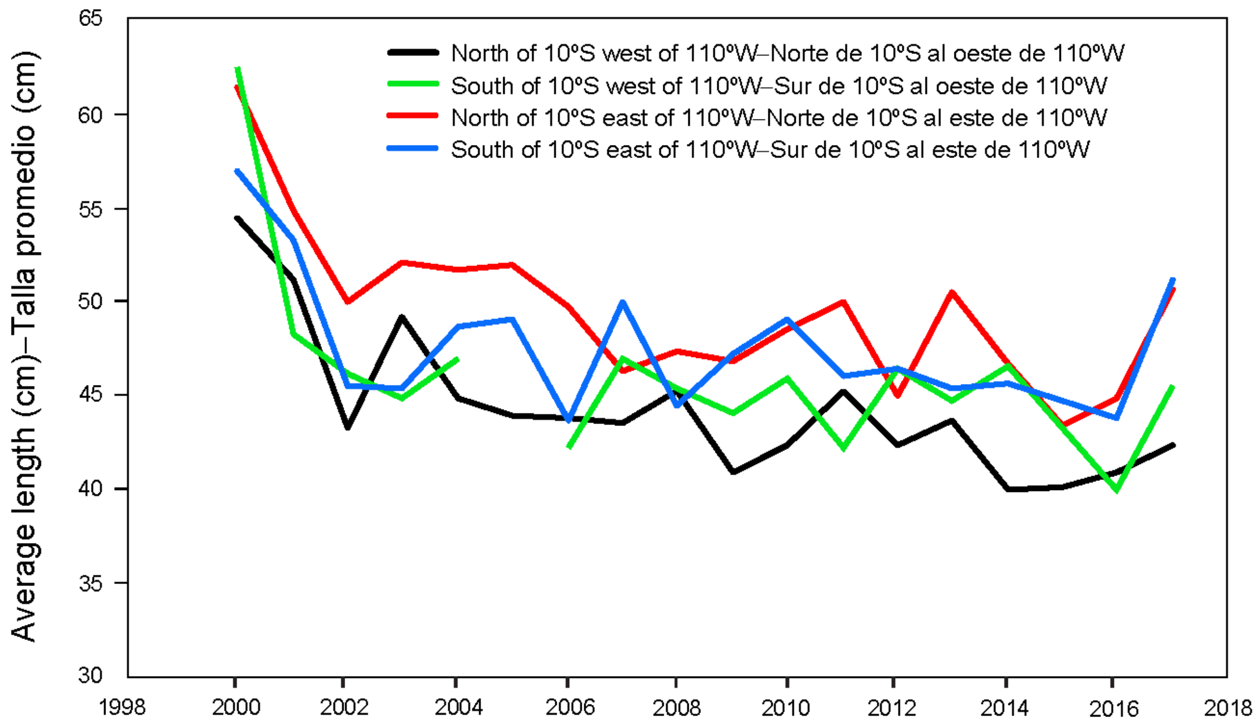

FIGURE 3. Mean length of skipjack tuna caught in the floating-object fishery in four areas in the EPO.
FIGURA 3. Talla promedio del atún barrilete capturado en la pesquería sobre objetos flotantes en cuatro zonas del OPO.