INTER-AMERICAN TROPICAL TUNA COMMISSION

SCIENTIFIC ADVISORY COMMITTEE

TENTH MEETING

San Diego, California (USA)
13-17 May 2019

DOCUMENT SAC-10-07

STATUS OF YELLOWFIN TUNA IN THE EASTERN PACIFIC OCEAN IN 2018 AND OUTLOOK FOR THE FUTURE

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EXECUTIVE SUMMARY

1. The assessment of yellowfin tuna in the eastern Pacific Ocean in 2018 uses the same model and assumptions as the previous assessment; the sole difference is that it includes new and updated data.
2. There is uncertainty about recent and future levels of recruitment and biomass. The annual recruitments have been about or below average since 2003. Both the spawning biomass (*S*) and the biomass of fish aged 3 quarters and older (*B*) were estimated to be below the maximum sustainable yield (MSY) level at the beginning of 2019 ($S_{\text{recent}}/S_{\text{MSY}}$ = 0.76; $B_{\text{recent}}/B_{\text{MSY}}$ = 0.84). As noted in previous full assessments (*e.g.* SAC-07-05b), these interpretations are uncertain, and highly sensitive to the model assumptions. With current (2016-2018 average) fishing mortality, the spawning biomass ratio (SBR[1]) is predicted to level off below the MSY level if recruitment is average, while purse-seine catches are predicted to stabilize around the MSY, due to the flat yield curve estimated for this stock (SAC-08-04b).
3. The highest fishing mortality (*F*) has been on fish aged 11-20 quarters (2.75-5 years). The average annual *F* has been increasing for all age classes since 2009.
4. The recent fishing mortality (*F*) is estimated to be above the MSY level (F_{MSY}; *F* multiplier = 0.89). This is a substantial change from the previous assessment, which estimated recent fishing mortality rates around the level corresponding to MSY ($F \approx F_{\text{MSY}}$). These interpretations are subject to uncertainty, but do not exceed the limit reference points; however, they are highly sensitive to the assumptions made about the relationship between stock size and recruitment (steepness; *h*), the weighting assigned to the different data sets (in particular to the longline index of abundance), the growth curve, and the assumed rates of natural mortality (*M*), as shown in previous assessments.
5. The recent results from Project H.1.a, part of the work plan to improve the bigeye assessment, are shedding light on similar issues that have now been identified in the current yellowfin assessment. An investigation of the reasons for the change in F/F_{MSY} in the yellowfin assessment is described in Document SAC-10 INF-F.
6. In preparation for the 2020 benchmark assessment of yellowfin, the staff developed a workplan (SAC-10-01) that addresses key uncertainties that are of concern, in particular the longline data used for the indices of abundance. Indicators have also been developed and are presented in a companion document (SAC-10-08).

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[1] Ratio of the current spawning biomass to that of the unfished population

UPDATE ASSESSMENT

This report presents the key results of an update stock assessment of yellowfin tuna (*Thunnus albacares*) in the eastern Pacific Ocean (EPO), conducted using an integrated statistical age-structured stock assessment model (Stock Synthesis Version 3.23b). "Update" stock assessment means that the base case model used in this assessment is the same as that used in the previous assessment, conducted in 2018 (Document SAC-09-06), the sole difference is that it includes new and updated data. Improvements will be made for the 2020 benchmark assessment, following the workplan to address key uncertainties (SAC-10-01). Stock Synthesis produces an extensive series of model output results and fit diagnostics. These are available for the base case model in html and pdf formats.

Yellowfin are distributed across the Pacific Ocean, but the bulk of the catch is made in the eastern and western regions. Purse-seine catches of yellowfin are relatively low near the western boundary of the EPO at 150ºW. Most of the catch in the EPO is taken by purse-seiners. Tagging studies of yellowfin throughout the Pacific indicate that the fish tend to stay within 1,800 km of their release positions. This regional fidelity, along with the geographic variation in phenotypic and genotypic characteristics of yellowfin shown in some studies, suggests that there might be multiple stocks of yellowfin in the EPO and throughout the Pacific Ocean. This is consistent with the fact that longline catch-per-unit-of-effort (CPUE) trends differ among areas in the EPO. However, movement rates between these putative stocks, as well as across the 150°W meridian, cannot be estimated with currently-available tagging data. This assessment assumes a single stock of yellowfin in the EPO.

The stock assessment requires a substantial amount of information. Data on retained catch, discards, CPUE, and size compositions of the catches from several different fisheries have been analyzed. Several assumptions regarding processes such as growth, recruitment, movement, natural mortality (*M*), and fishing mortality (*F*), have also been made. The catch data for the surface fisheries[2] have been updated and new data added for 2018. New or updated longline catch data were available for China (2017), Japan (2017-2018), Korea (2017), Chinese Taipei (2015-2017), the United States (2009, 2017), French Polynesia (2017), Vanuatu (2017), and other nations (2016-2017). For longline fisheries with missing catch data, catches were assumed to be the same as in the most recent year with available data. Surface-fishery CPUE data were updated, and new CPUE data added for 2018. New or updated CPUE data were available for the Japanese longline fleet for 2017-2018. New surface-fishery size-composition data for 2018 were added, and data for the last quarter of 2017 were updated. New or updated length-frequency data for the Japanese commercial longline fleet were available for 2011-2017.

In general, recruitment of yellowfin to the fisheries in the EPO is both annually and seasonally variable. This analysis and previous analyses indicate that the yellowfin population may have experienced three different recruitment productivity regimes: below average (1975-1982), mostly above average (1983-2002), and mostly below average (2003-2014) (Figure 1). The 2015 recruitment was estimated to be above average, coinciding with the 2015-2016 El Niño event, while the 2016 recruitment was estimated to be below average. The recruitments of 2017 and 2018 were estimated with high uncertainty, and it is not possible to ascertain at this time whether they were below or above average. In addition, the recruitment point estimate for 2018 might be upwardly biased, because of a retrospective pattern already noticed in previous assessments. The productivity regimes correspond to regimes in biomass, with higher-productivity regimes producing greater biomasses (Figure 2). The existence of a stock-recruitment relationship is also supported by the data from these regimes, but the evidence is weak, and this is probably an artifact of the apparent regime shifts.

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[2] Purse-seine and pole-and-line

The different productivity regimes may support different MSY levels and associated SBRs[3]. The SBR of yellowfin in the EPO was below the level corresponding to the maximum sustainable yield (SBR_{MSY}) during 1977-1983, coinciding with the low-productivity regime, but above that level during most of the following years until 2005 (Figure 2). Since 2005, the SBR has been below the MSY level, except during 2008-2010, following the above-average recruitment of 2006. The increase in the SBR in 1984 is attributed to the regime change, and the recent decrease may be a reversion to an intermediate productivity regime. Since 2011, when the SBR fell as a result of the series of low recruitments that coincided with a series of strong La Niña events, it has been estimated to be at, or slightly below, the MSY level; at the start of 2019 it was estimated to be 0.21, below the MSY level (0.27). With the current (2016-2018) fishing mortality and the current estimate of recent recruitment, the SBR is predicted to increase for two years, and then decline and stabilize below the MSY level (Figure 2), assuming average recruitment in the future.

Substantial levels of fishing mortality (F) have been estimated for the yellowfin fishery in the EPO (Figure 3). These levels are highest for yellowfin aged 11-20 quarters (2.75-5 years), and lowest for the younger fish (< 10 quarters or 2.5 years). The average annual F has been increasing for all age classes since 2009. A slight decrease was estimated for 2017, followed by a new increase in 2018.

Historically, the dolphin-associated and unassociated purse-seine fisheries have had the greatest impact on the spawning biomass of yellowfin, followed by the floating-object fisheries (Figure 4). In more recent years, the impact of the floating-object fisheries has been greater than that of the unassociated fisheries, and in 2018 it was estimated that the impact of the floating-object fisheries surpassed that of the dolphin-associated fisheries. The impacts of the longline and purse-seine discard fisheries are much less, and have decreased in recent years.

The SBR is substantially below the MSY level ($S_{recent}/S_{MSY} = 0.76$), as is the biomass of fish aged 3 quarters and older ($B_{recent}/B_{MSY} = 0.84$; Figure 5). It is estimated that current $F > F_{MSY}$, based on the current distribution of effort among the different fisheries (F multiplier = 0.89, approximate confidence interval CI = (0.79,0.99), Figure 5), and catches in 2018 were at that level (Table 1). This is a substantial change from the previous assessment, which estimated $F \approx F_{MSY}$ (F multiplier = 0.99; CI = (0.88, 1.10)). These interpretations are subject to uncertainty, but do not exceed the limit reference points; however, they are highly sensitive to the assumptions made about the relationship between stock size and recruitment (steepness; h), the weighting assigned to the different data sets (in particular to the longline CPUE), the growth curve, and the assumed rates of natural mortality (M) for yellowfin, as shown in previous assessments.

It is important to note that the curve relating the average sustainable yield to the long-term fishing mortality is flat around the MSY level (SAC-08-04b); therefore, moderate changes in the long-term levels of effort will change the long-term catches only marginally, as can be seen in the projected catches with current F and F_{MSY}, while changing the spawning biomass considerably. Maintaining the fishing mortality below the MSY level would result in only a marginal decrease in the long-term average yield, with the benefit of a relatively large increase in the spawning biomass. In addition, if management is based on the base case assessment, which assumes that there is no stock-recruitment relationship, but in fact there is such a relationship, the loss in yield would be greater than if management is based on assuming a stock-recruitment relationship when in fact there is none (SAC-08-04b).

The average weights of yellowfin taken from the fishery have in general been consistent over time, but vary substantially among the different fisheries. The OBJ, NOA-N, and pole-and-line fisheries capture younger, smaller yellowfin than do the NOA-S, DEL, and LL fisheries. The LL fisheries and the DEL-S fishery catch older, larger yellowfin than the DEL-N and DEL-C fisheries. In recent years, however, the average

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[3] spawning biomass ratio: the ratio of the current spawning biomass to that of the unfished population

length of some fisheries that select for larger fish has increased (SAC-10 INF-F).

The MSY calculations indicate that, theoretically at least, catches could be increased if the fishing effort were directed toward longlining and purse-seine sets on yellowfin associated with dolphins. This would also increase the SBR_{MSY}.

The MSY has been stable during the assessment period (1975-2018) (Figure 6), which suggests that the overall pattern of selectivity has not varied a great deal over time. However, the overall level of fishing effort relative to the MSY level has varied over time, as shown by the variation of the F multiplier over time.

If fishing effort continues at recent levels, and future recruitment is about average, the spawning biomass (S) (Figure 2) and the catches of the surface fisheries (Figure 7) are predicted to increase slightly in the near future. However, S is predicted to stabilize below S_{MSY}. The confidence intervals are wide, and there is a moderate probability that the SBR will be substantially above or below the SBR at MSY. The catches are predicted to stabilize around the MSY, because the yield curve is flat around current F and F_{MSY} (see Figure 8 in SAC-08-04b), assuming the base-case model is a good approximation of the dynamics of the population (see SAC-10 INF-F).

If a stock-recruitment relationship is assumed, the outlook is more pessimistic: current effort is estimated to be substantially above the MSY level (Table 1), and the spawning biomass is substantially below the MSY level (Figure 2). Previous assessments (SAC-07-05b) and other research (SAC-10 INF-F) have indicated that the status of the stock is sensitive to the value assumed for the average size of the oldest fish (L_2), and more pessimistic results are obtained when higher values are assumed for this parameter. Results are also more pessimistic if the weighting assigned to the length-frequency data is decreased or if the CPUE of the DEL-N and DEL-I fisheries, standardized using a spatial-temporal methods, are used as indices of abundance instead of its nominal CPUE , and more optimistic if the nominal CPUE of the DEL-N fishery is used as the main index of abundance instead of that of the LL-S fishery.

The recent findings from Project H.1.a, part of the work plan to improve the bigeye assessment, are shedding light on similar issues that have now been identified in the current yellowfin assessment. An investigation of the reasons for the change in F/F_{MSY} in the yellowfin assessment is described in Document SAC-10 INF-F.

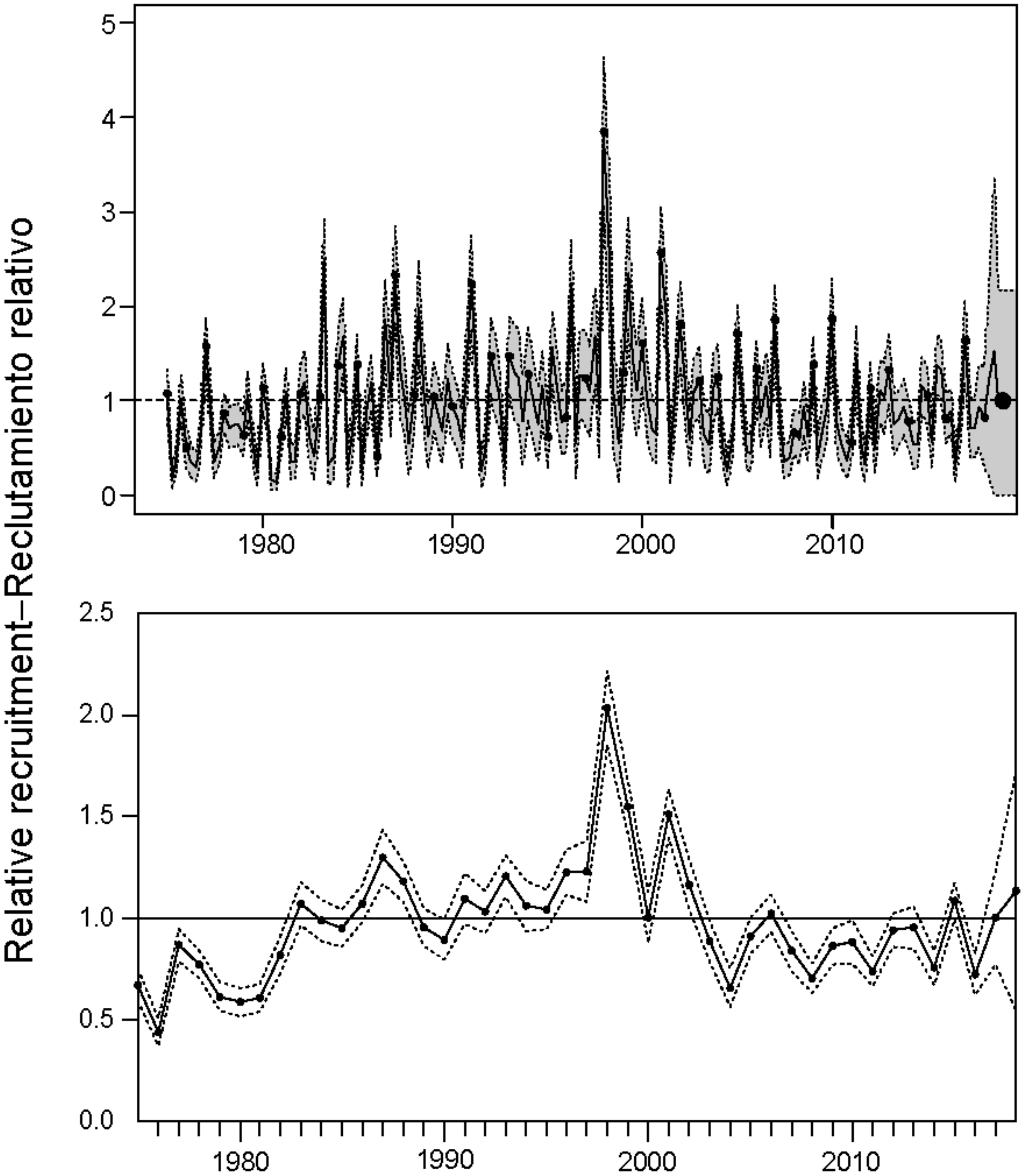

FIGURE 1. Estimated quarterly (top panel) and annual (bottom panel) recruitment at age zero of yellowfin tuna to the fisheries of the EPO. The estimates are scaled so that the average recruitment is equal to 1.0 (dashed horizontal line). The solid line illustrates the maximum likelihood estimates of recruitment, and the shaded area indicates the approximate 95% confidence intervals around those estimates.

FIGURA 1. Reclutamiento trimestral (recuadro superior) y anual (recuadro inferior) estimado de atún aleta amarilla de edad cero a las pesquerías del OPO. Se ajusta la escala de las estimaciones para que el reclutamiento medio equivalga a 1.0 (línea de trazos horizontal). La línea sólida ilustra las estimaciones de verosimilitud máxima del reclutamiento, y la zona sombreada los límites de confianza de 95% aproximados de las estimaciones.

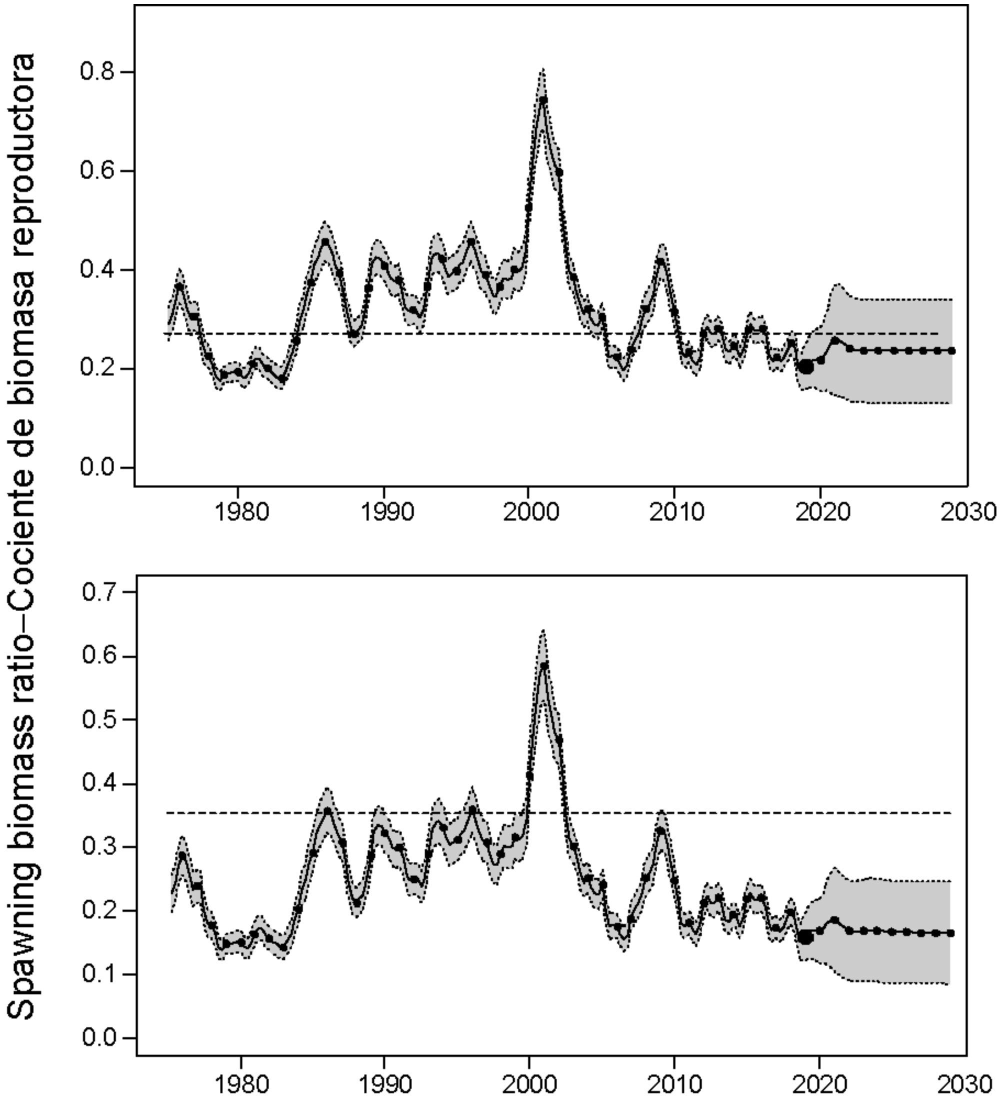

FIGURE 2. Spawning biomass ratios (SBRs) for yellowfin tuna in the EPO, including projections for 2019-2029 based on average fishing mortality rates during 2016-2018, from the base case (top) and the sensitivity analysis that assumes a stock-recruitment relationship (*h* = 0.75, bottom). The dashed horizontal line (at 0.27 and 0.35, respectively) identifies the SBR at MSY. The solid curve illustrates the maximum likelihood estimates, and the estimates after 2019 (the large dot) indicate the SBR predicted to occur if fishing mortality rates continue at the average of that observed during 2016-2018, and average environmental conditions occur during the next 10 years. The shaded area indicates the approximate 95% confidence intervals around those estimates.

FIGURA 2. Cocientes de biomasa reproductora (SBR) de atún aleta amarilla en el OPO, con proyecciones para 2019-2029 basadas en las tasas de mortalidad por pesca medias durante 2016-2018, del caso base (arriba) y el análisis de sensibilidad que supone una relación población-reclutamiento (*h* = 0.75, abajo). La línea de trazos horizontal (en 0.27 y 0.35, respectivamente) identifica el SBR correspondiente al RMS. La curva sólida ilustra las estimaciones de verosimilitud máxima, y las estimaciones a partir de 2018 (punto grande) indican el SBR que se predice ocurrirá con tasas de mortalidad por pesca en el promedio de aquellas observadas durante 2016-2018, y con condiciones ambientales medias durante los 10 años próximos. El área sombreada indica los intervalos de confianza de 95% aproximados alrededor de esas estimaciones.

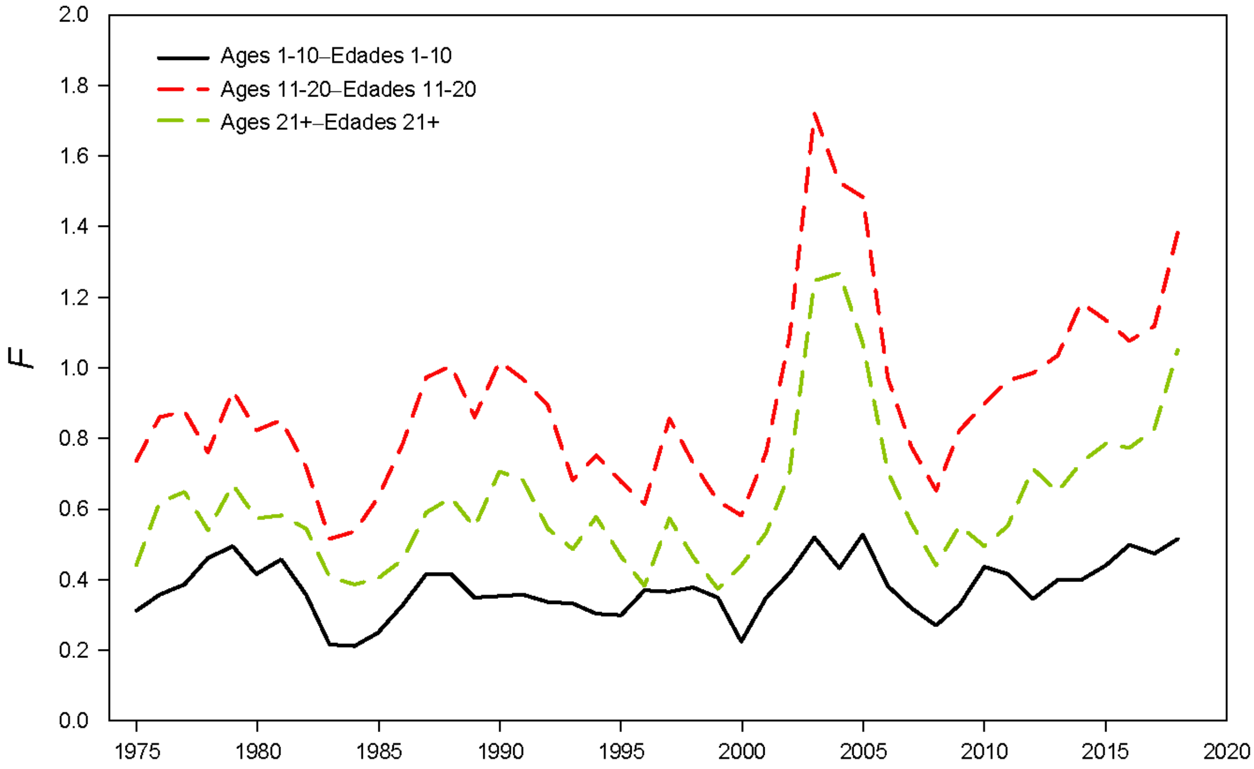

FIGURE 3. Average annual fishing mortality (*F*) by age groups, by all gears, of yellowfin tuna recruited to the fisheries of the EPO. The age groups are defined by age in quarters.

FIGURA 3. Mortalidad por pesca (*F*) anual media, por grupo de edad, por todas las artes, de atún aleta amarilla reclutado a las pesquerías del OPO. Se definen los grupos de edad por edad en trimestres.

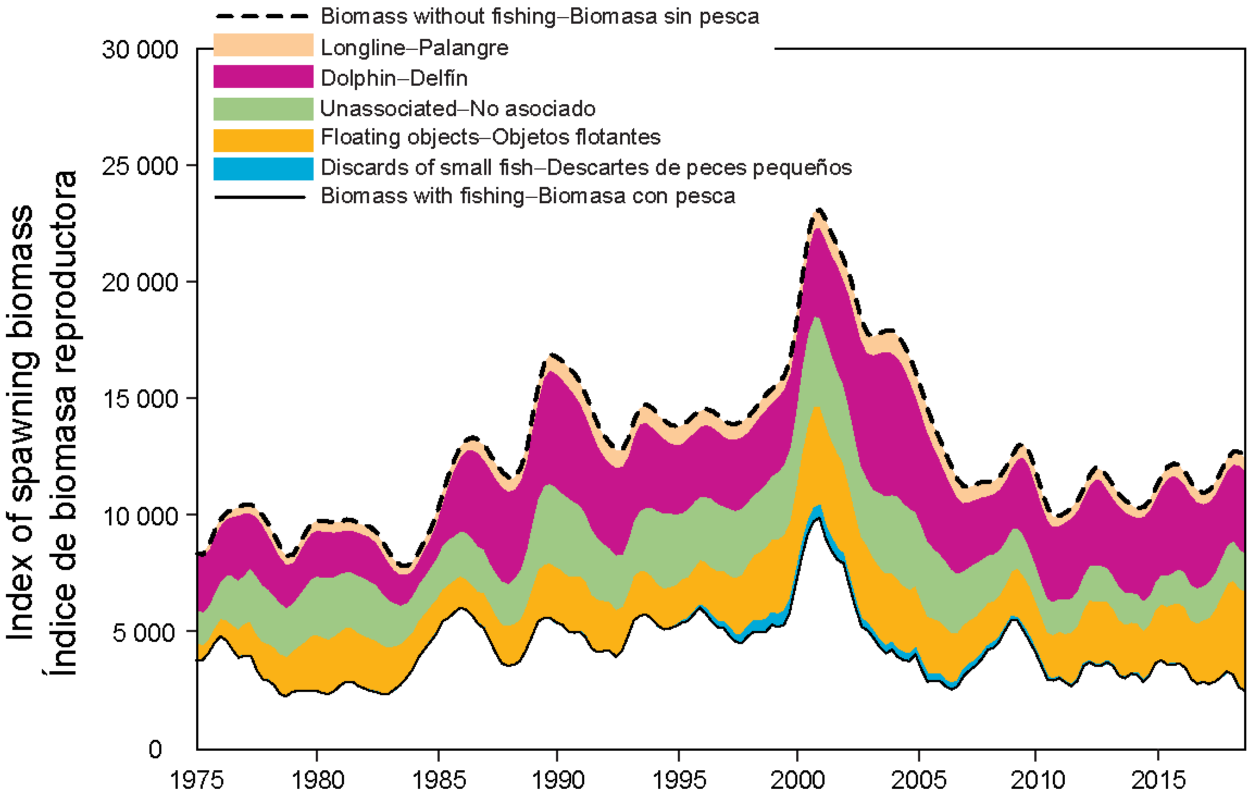

FIGURE 4. Biomass trajectory of a simulated population of yellowfin tuna that was never exploited (dashed line) and that predicted by the stock assessment model (solid line). The shaded areas between the two lines show the portions of the fishery impact attributed to each fishing method.

FIGURA 4. Trayectoria de la biomasa de una población simulada de atún aleta amarilla que nunca fue explotada (línea de trazos) y aquella predicha por el modelo de evaluación de la población (línea sólida). Las áreas sombreadas entre las dos líneas representan la porción del impacto de la pesca atribuida a cada método de pesca.

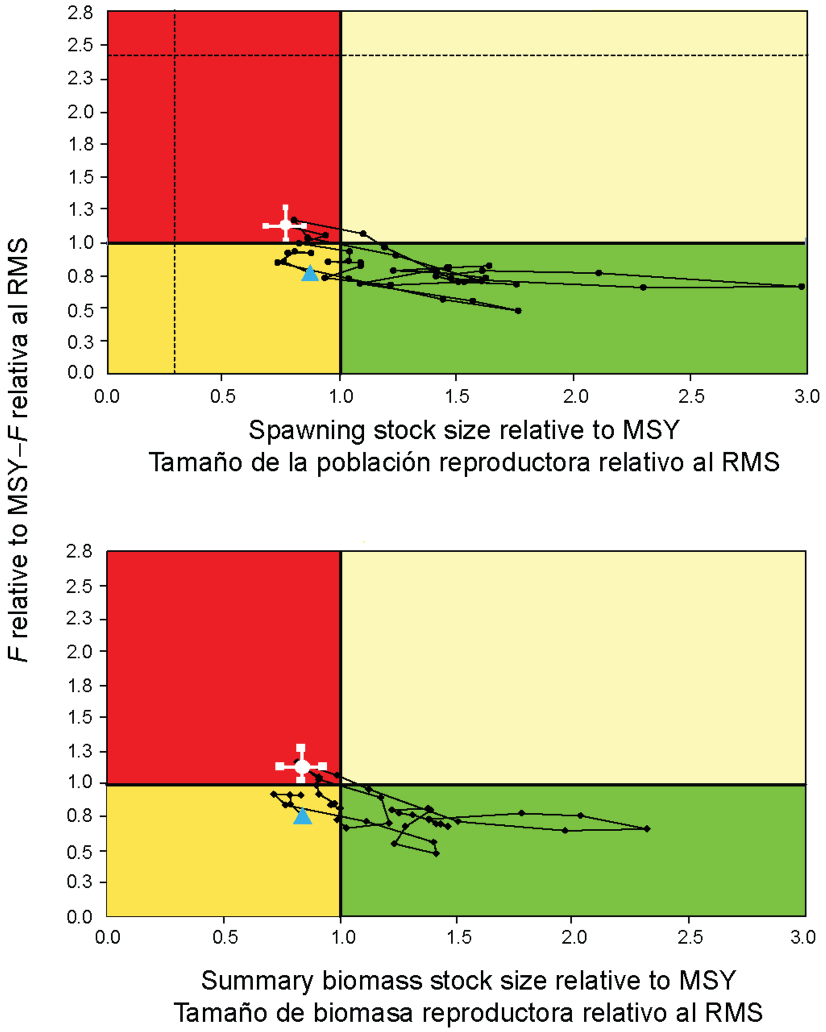

FIGURE 5. Kobe (phase) plot of the time series of estimates of stock size (top: spawning biomass; bottom: total biomass of fish aged 3 quarters and older) and fishing mortality relative to their MSY reference points. The panels represent target reference points (S_{MSY} and F_{MSY}). The dashed lines represent the interim limit reference points of 0.28 *S_{MSY} and 2.42*F_{MSY}, which correspond to a 50% reduction in recruitment from its average unexploited level based on a conservative steepness value (h = 0.75) for the Beverton-Holt stock-recruitment relationship. Each dot is based on the average exploitation rate over three years; the large red dot indicates the most recent estimate. The squares around the most recent estimate represent its approximate 95% confidence interval. The triangle represents the first 3-year period (1975-1977).

FIGURA 5. Gráfica de Kobe (fase) de la serie de tiempo de las estimaciones del tamaño de la población (arriba: biomasa reproductora; abajo: biomasa total de peces de 3 trimestres o más de edad) y la mortalidad por pesca en relación con sus puntos de referencia de RMS. Los paneles representan puntos de referencia objetivo (S_{RMS} y F_{RMS}). Las líneas de trazos representan los puntos de referencia límite de 0.28*S_{RMS} y 2.42*F_{RMS}, que corresponden a una reducción de 50% del reclutamiento de su nivel medio no explotado basada en un valor cauteloso de la inclinación de la relación población-reclutamiento de Beverton-Holt (h = 0.75). Cada punto se basa en la tasa de explotación media de tres años; el punto rojo grande indica la estimación más reciente. Los cuadrados alrededor de la estimación más reciente representan su intervalo de confianza de 95% aproximado. El triángulo representa el primer trienio (1975-1977).

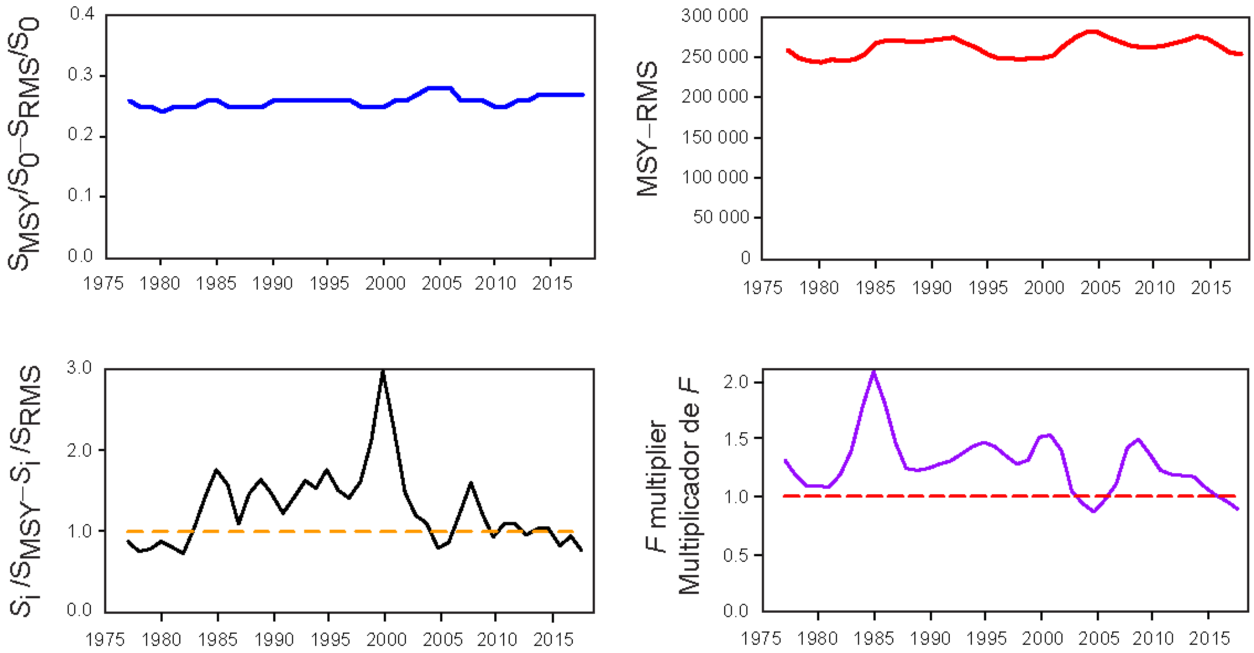

FIGURE 6. Estimates of MSY-related quantities calculated using the average age-specific fishing mortality for each year (S_i is the index of spawning biomass at the end of the last year in the assessment).

FIGURA 6. Estimaciones de cantidades relacionadas con el RMS calculadas a partir de la mortalidad por pesca media por edad para cada año. (S_i es el índice de la biomasa reproductora al fin del último año en la evaluación).

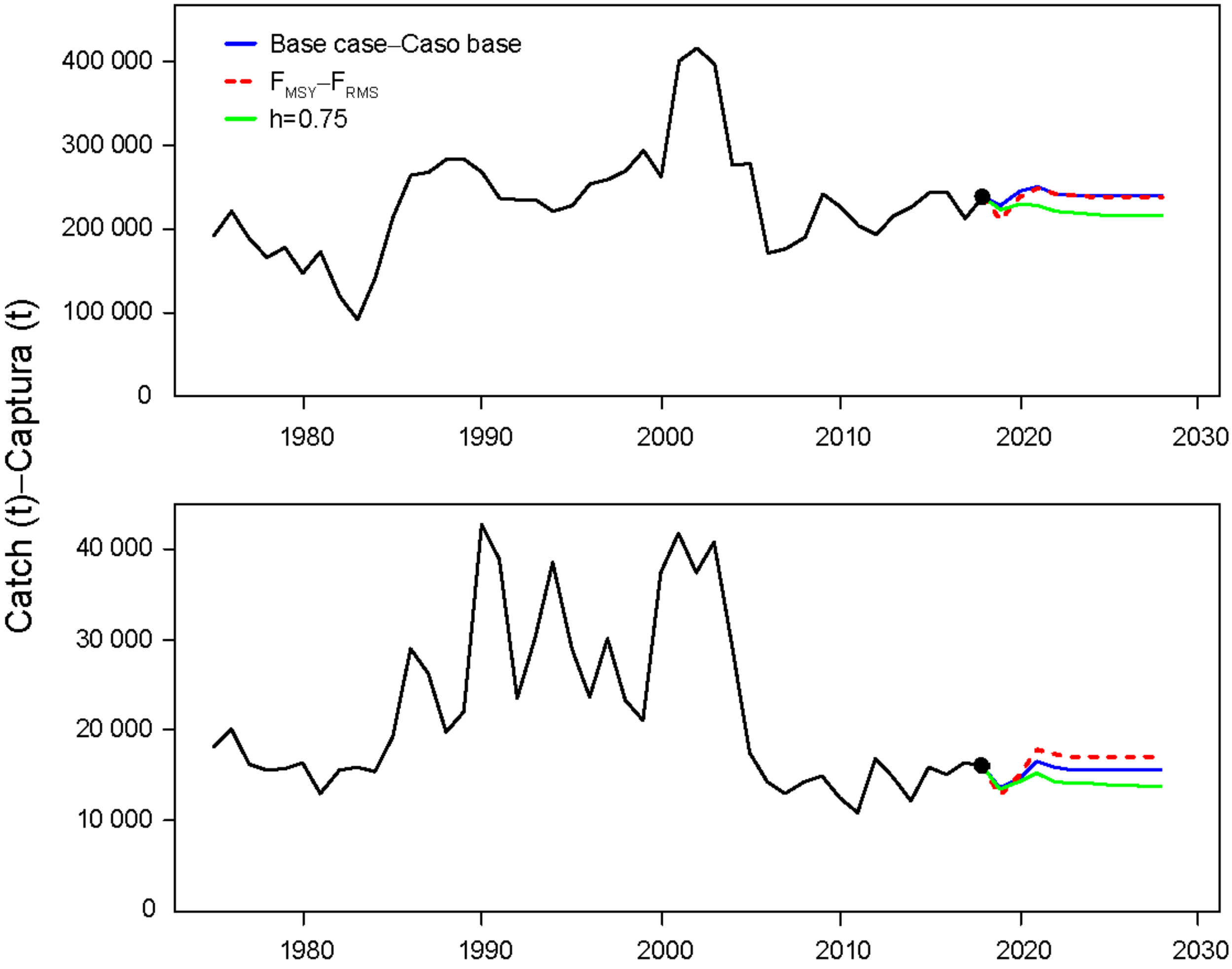

FIGURE 7. Historic and projected annual catches of yellowfin tuna by surface (top panel) and longline (bottom panel) fisheries from the base case while fishing with the current effort, the base case while fishing at the fishing mortality corresponding to MSY (F_{MSY}), and the analysis of sensitivity to steepness ($h = 0.75$) of the stock-recruitment relationship while fishing with the current effort. The large dot indicates the most recent catch (2018).

FIGURA 7. Capturas históricas y proyectadas de atún aleta amarilla de las pesquerías de superficie (panel superior) y palangre (panel inferior), del caso base con el nivel actual de esfuerzo, del caso base con la mortalidad por pesca correspondiente al RMS (F_{RMS}), y el análisis de sensibilidad a la inclinación ($h = 0.75$) de la relación población-reclutamiento con el nivel actual de esfuerzo. El punto grande indica la captura más reciente (2018).

TABLE 1. MSY and related quantities for the base case and the stock-recruitment relationship sensitivity analysis, based on average fishing mortality (*F*) for 2016-2018. B_{recent} and B_{MSY} are defined as the biomass, in metric tons, of fish 3+ quarters old at the start of the first quarter of 2019 and at MSY, respectively, and S_{recent} and S_{MSY} are defined as indices of spawning biomass (therefore, they are not in metric tons). C_{recent} is the estimated total catch for 2018.

TABLA 1. RMS y cantidades relacionadas para el caso base y el análisis de sensibilidad a la relación población-reclutamiento, basados en la mortalidad por pesca (*F*) media de 2016-2018. Se definen B_{reciente} y B_{RMS} como la biomasa, en toneladas, de peces de 3+ trimestres de edad al principio del primer trimestre de 2018 y en RMS, respectivamente, y S_{reciente} y S_{RMS} como índices de biomasa reproductora (por lo tanto, no se expresan en toneladas). C_{reciente} es la captura total estimada de 2018.

YFT	**Base case Caso base**	***h* = 0.75**
MSY-RMS	254,975	268,782
B_{MSY}- B_{RMS}	371,787	552,161
S_{MSY}- S_{RMS}	3,638	6,022
B_{MSY}/B_0- B_{RMS}/B_0	0.31	0.37
S_{MSY}/S_0- S_{RMS}/S_0	0.27	0.35
C_{recent}/MSY- C_{reciente}/RMS	1.00	0.95
$B_{\text{recent}}/B_{\text{MSY}}$- $B_{\text{reciente}}/B_{\text{RMS}}$	0.84	0.55
$S_{\text{recent}}/S_{\text{MSY}}$-$S_{\text{reciente}}/S_{\text{RMS}}$	0.76	0.45
F multiplier-Multiplicador de *F*	0.89	0.58