INTER-AMERICAN TROPICAL TUNA COMMISSION

SCIENTIFIC ADVISORY COMMITTEE

FIFTH MEETING

La Jolla, California (USA)
12-16 May 2014

DOCUMENT SAC-05-08a

STATUS OF BIGEYE TUNA IN THE EASTERN PACIFIC OCEAN IN 2013 AND OUTLOOK FOR THE FUTURE

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This report presents the most current stock assessment of bigeye tuna (*Thunnus obesus*) in the eastern Pacific Ocean (EPO). An integrated statistical age-structured stock assessment model (Stock Synthesis 3.23b) was used in the assessment.

Bigeye tuna are distributed across the Pacific Ocean, but the bulk of the catch is made to the east and to the west. The purse-seine catches of bigeye are substantially lower close to the western boundary (150ºW) of the EPO; the longline catches are more continuous, but relatively low between 160ºW and 180º. Bigeye are not often caught by purse seiners in the EPO north of 10ºN, but a substantial portion of the longline catches of bigeye in the EPO is made north of that parallel. It is likely that there is a continuous stock throughout the Pacific Ocean, with exchange of individuals at local levels. The assessment is conducted as if there were a single stock of bigeye in the EPO, and there is minimal net movement of fish between the EPO and the western and central Pacific Ocean. Its results are consistent with the results of other analyses of bigeye tuna on a Pacific-wide basis. Data from recent tagging programs, which will help to provide estimates of movement between the EPO and the western and central Pacific Ocean, are being collected and analyzed, and will help to improve the spatial structure assumptions in the next full assessment of bigeye.

This model is the same as that used in the previous full assessment conducted in 2013 (IATTC Stock Assessment Report 14) which included several improvements. First of all, a new Richards growth curve estimated externally from an integrated analysis of otolith age-readings and tag-recapture observations was introduced. This curve reduced the uncertainty about the average size of the oldest fish (L_2 parameter). In addition, the parameters which determine the variance of the length-at-age were also taken from the new externally-derived growth estimates. Diagnostic analyses with the previous base case model configuration indicated a dominant influence of the size-composition data in determining the productivity (the R_0 parameter) of the bigeye stock, and conflicts among datasets were also found. As a result, improvements were made in the previous full assessment on the weighting assigned to the different datasets. Specifically, the size-composition data of all fisheries were down-weighted. In addition, the number of catch per unit of effort (CPUE) data series used as indices of abundance was reduced in order to minimize conflict trends among data sets. Rather than fitting to a total of ten CPUE series (two purse-seine indices and eight longline indices), a reduced set of indices of abundance was chosen to best represent the bigeye stock trends (the early and late periods of the Central and Southern longline fisheries).

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, and fishing mortality, have also been made. Catch and CPUE data for the surface fisheries have been updated, and include new data for 2013. New or updated longline catch data are available for China (2012), Japan

(2010-2012), Korea (2012), Chinese Taipei (2010-2012), the United States (2011-2012), French Polynesia (2012) and Vanuatu (2012). Longline catch data for 2013 are available for China, Japan, Chinese Taipei, and Korea from the monthly report statistics. New or updated CPUE data are available for the Japanese longline fleet (2010-2012). New purse-seine length-frequency data are available for 2013 and updates are available for 2012. New or updated length-frequency data are available for the Japanese longline fleet (2011-2012).

A prominent feature in the time series of estimated bigeye recruitment is that the highest recruitment peaks of 1983 and 1998 coincide with the strongest El Niño events during the historic period of the assessment (Figure 1). There was a period of above-average annual recruitment during 1994-1998, followed by a period of below-average recruitment in 1999-2000. The recruitments were above average from 2001 to 2006, and were particularly strong in 2005. More recently, the recruitments were below average during 2007-2009, and have fluctuated around average during 2010-2013. The most recent annual recruitment estimate (2013) is at about average levels. However, this estimate is highly uncertain, and should be regarded with caution, due to the fact that recently-recruited bigeye are represented in only a few length-frequency data sets.

There have been important changes in the amount of fishing mortality caused by the fisheries that catch bigeye tuna in the EPO. On average, since 1993 the fishing mortality of bigeye less than about 15 quarters old has increased substantially, and that of fish more than about 15 quarters old has also increased, but to a lesser extent) (Figure 2). The increase in the fishing mortality of the younger fish was caused by the expansion of the purse-seine fisheries that catch tuna in association with floating objects. The fishing mortality of juvenile bigeye, particularly of fish 9-12 quarters of age, declined in 2013, mainly due to the 27% reduction in the catches of juvenile bigeye by the surface fisheries. It is clear that the longline fishery had the greatest impact on the stock prior to 1995, but with the decrease in longline effort and the expansion of the floating-object fishery, at present the impact of the purse-seine fishery on the bigeye stock is far greater than that of the longline fishery (Figure 3). The discarding of small bigeye has a small, but detectable, impact on the depletion of the stock.

Over the range of spawning biomasses estimated by the base case assessment, the abundance of bigeye recruits appears to be unrelated to the spawning potential of adult females at the time of hatching.

Since the start of 2005, the spawning biomass ratio (SBR; the ratio of the spawning biomass at that time to that of the unfished stock) gradually increased, to a level of 0.30 at the start of 2010. This may be attributed to a combined effect of a series of above-average recruitments since 2001, the IATTC tuna conservation resolutions during 2004-2009, and decreased longline fishing effort in the EPO. However, although the resolutions have continued to date, the rebuilding trend was not sustained, and the SBR gradually declined to a low historic level of 0.19 at the start of 2014 (Figure 4). This decline could be related to a period dominated by below-average recruitments that began in late 2007 and coincides with a series of particularly strong La Niña events.

At the beginning of 2014, the spawning biomass of bigeye tuna in the EPO appears to have been about 5% below S_{MSY}, and the recent catches are estimated to have been about 24% lower than the maximum sustainable yield (MSY). If fishing mortality is proportional to fishing effort, and the current patterns of age-specific selectivity are maintained, F_{MSY} is about 4% higher than the current level of effort (Table 1).

According to the base case results, the most recent estimate indicates that the bigeye stock in the EPO is slightly overfished ($S<S_{\mathrm{MSY}}$) but that overfishing is not taking place ($F<F_{\mathrm{MSY}}$) (Figure 5a). In fact, the current exploitation is very close to the MSY target reference points. Likewise, the current base case model indicates that the proposed limit reference points of 0.38 S_{MSY} and 1.6 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, have not been exceeded (Figure 5b). These interpretations, however, are subject to uncertainty, as indicated by the approximate confidence intervals around the most recent estimate in the phase plots. Also, they are strongly dependent on the

assumptions made about the steepness parameter of the stock-recruitment relationship, the assumed levels of adult natural mortality, the growth curve, and the weighting assigned to the size-composition data.

The MSY of bigeye in the EPO could be maximized if the age-specific selectivity pattern were similar to that of the longline fisheries, because they catch larger individuals that are close to the critical weight. Before the expansion of the floating-object fishery that began in 1993, the MSY was greater than the current MSY and the fishing mortality was much less than F_{MSY} (Figure 6).

At current levels of fishing mortality, and if recent levels of effort and catchability continue and average recruitment levels persist, the SBR is predicted to remain stable at about 0.19 until 2017. After that, the SBR is predicted to gradually increase, and stabilize at about 0.21 around 2019, slightly above to the level corresponding to MSY (0.20) (Figure 4). If a stock-recruitment relationship is assumed, it is estimated that catches will be lower in the future at current levels of fishing effort, particularly for the surface fisheries (Figure 7).

These simulations are based on the assumption that selectivity and catchability patterns will not change in the future. Changes in targeting practices or increased catchability of bigeye as abundance declines (*e.g.* density-dependent catchability) could result in differences from the outcomes predicted here.

Key Results

1. The results of this assessment indicate a recovery trend for bigeye tuna in the EPO during 2005-2009, subsequent to IATTC tuna conservation resolutions initiated in 2004. However, the decline of the spawning biomass that began at the start of 2010 persisted through 2013, and reduced both summary and spawning biomasses to their lowest historic levels at the start of 2014. This decline may be related to a series of recent below-average recruitments which coincide with a series of strong la Niña events. However, at current levels of fishing mortality, and if recent levels of effort and catchability continue and average recruitment levels persist, the SBR is predicted to stabilize at about 0.21, very close to the level corresponding to MSY.
2. There is uncertainty about recent and future recruitment and biomass levels.
3. The fishing mortality of juvenile bigeye, particularly of fish 9-12 quarters of age, declined in 2013, due to the 27% reduction in the catches of juvenile bigeye by the surface fisheries.

Both the recent fishing mortality rates and levels of spawning biomass are estimated to be slightly below the level corresponding to MSY. These interpretations are uncertain and highly sensitive to the assumptions made about the steepness parameter of the stock-recruitment relationship, the assumed rates of natural mortality for adult bigeye, the growth curve, and the weighting assigned to the size-composition data, in particular to the longline size-composition data. The results are more pessimistic if a stock-recruitment relationship is assumed, if lower rates of natural mortality are assumed for adult bigeye, if the length of the oldest fish is assumed to be greater, and if a greater weight is assigned to the size-composition data, in particular for the longline fisheries.

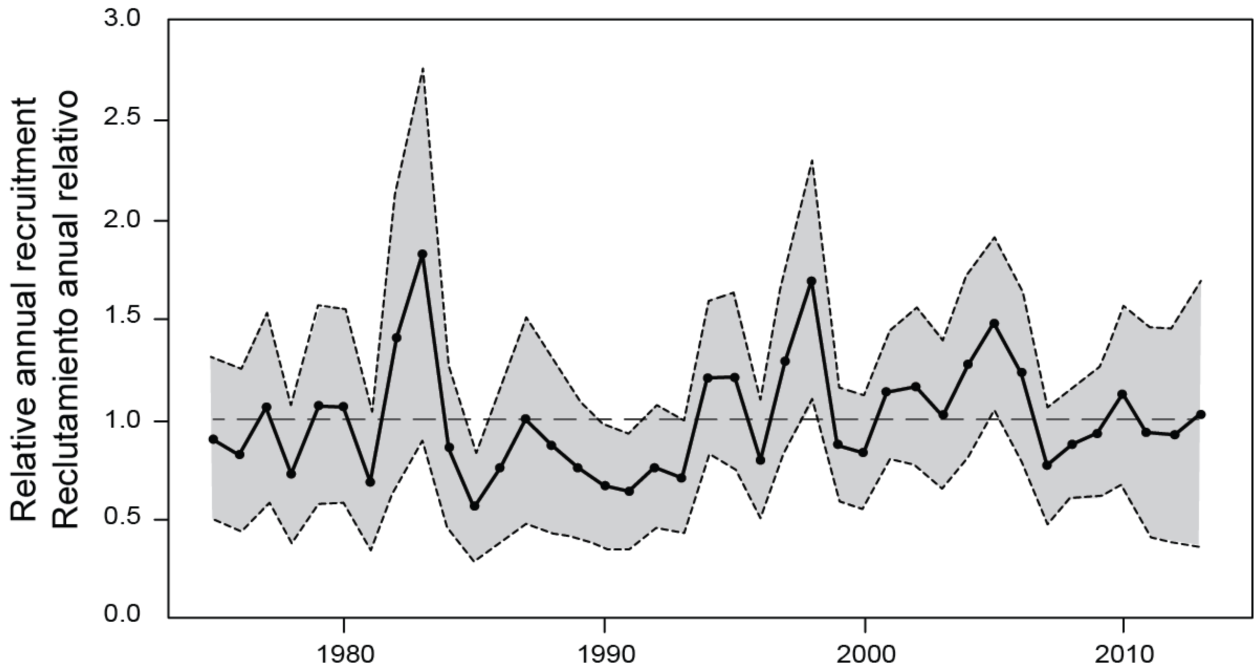

FIGURE 1. Estimated annual recruitment of bigeye tuna to the fisheries of the EPO. The estimates are scaled so that the estimate of virgin recruitment is equal to 1.0 (dashed horizontal line). The solid line shows the maximum likelihood estimates of recruitment, and the shaded area indicates the approximate 95% intervals around those estimates.

FIGURA 1. Reclutamiento estimado de atún patudo a las pesquerías del OPO. Se escalan las estimaciones para que la estimación de reclutamiento virgen equivalga a 1,0 (línea de trazos horizontal). La línea sólida indica las estimaciones de reclutamiento de verosimilitud máxima, y el área sombreada indica los intervalos de confianza de 95% aproximados de esas estimaciones.

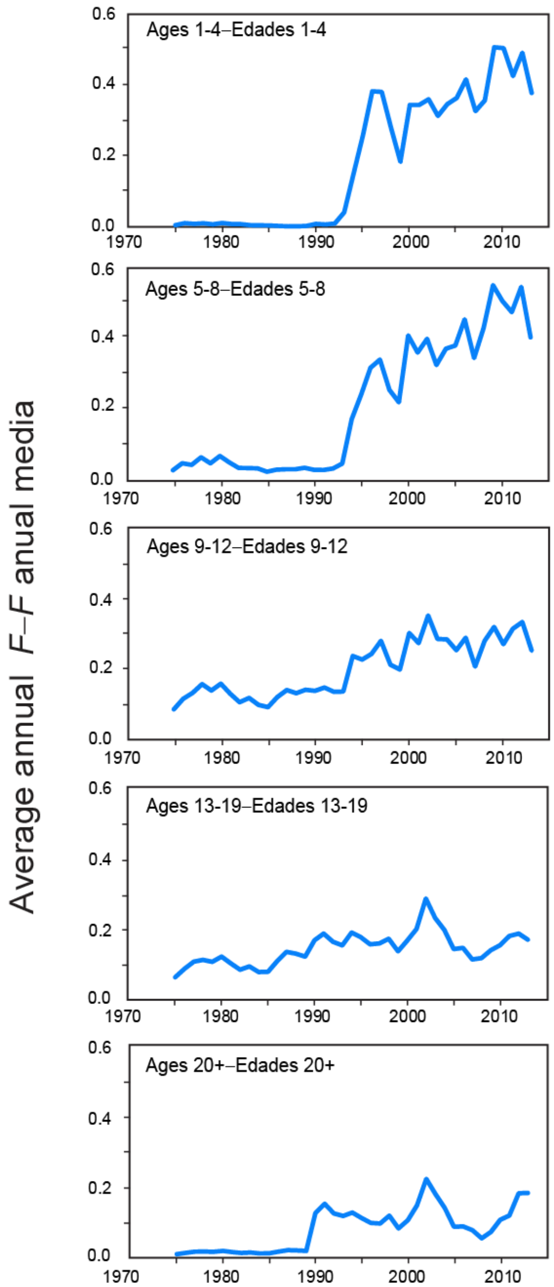

FIGURE 2. Average annual fishing mortality, by all gears, of bigeye tuna recruited to the fisheries of the EPO. Each panel illustrates the average fishing mortality rates that affected the fish within the range of ages indicated in the title of each panel. For example, the trend illustrated in the top panel is an average of the fishing mortalities that affected the fish that were 1-4 quarters old.

FIGURA 2. Mortalidad por pesca anual media, por todas las artes, de atún patudo reclutado a las pesquerías del OPO. Cada recuadro ilustra las tasas medias de mortalidad por pesca que afectaron a los peces de la edad indicada en el título de cada recuadro. Por ejemplo, la tendencia ilustrada en el recuadro superior es un promedio de las mortalidades por pesca que afectaron a los peces de entre 1 y 4 trimestres de edad.

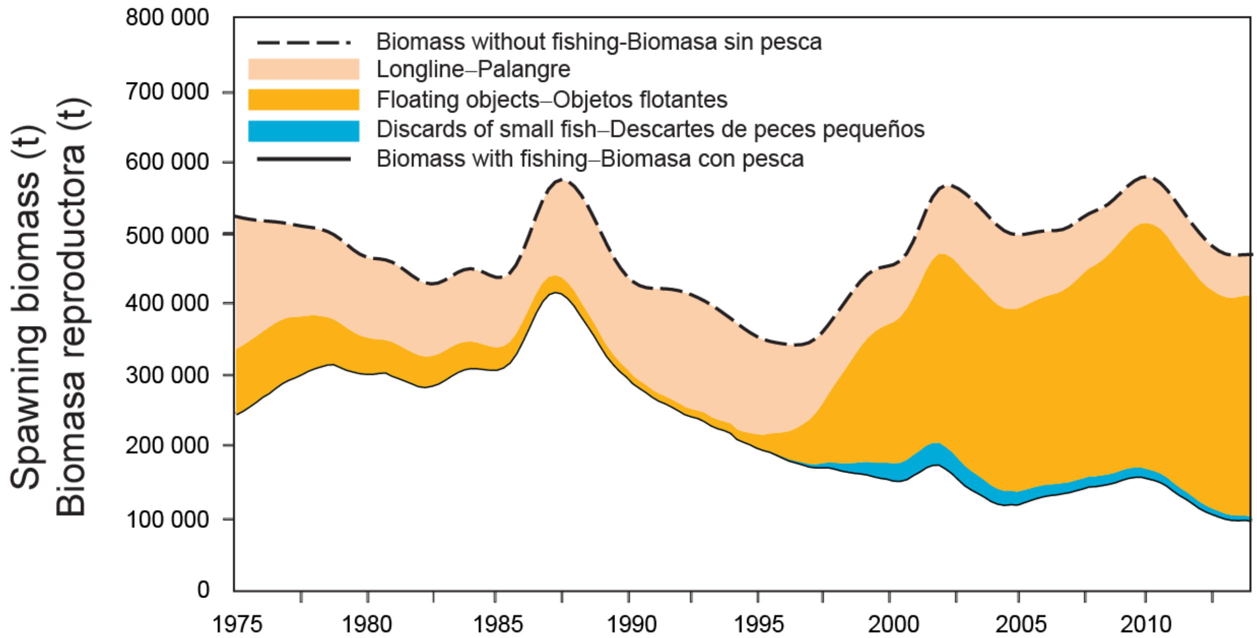

FIGURE 3. Trajectory of the spawning biomass of a simulated population of bigeye tuna that was not exploited (top line) and that predicted by the stock assessment model (bottom line). The shaded areas between the two lines show the portions of the impact attributed to each fishing method. t = metric tons.
FIGURA 3. Trayectoria de la biomasa reproductora de una población simulada de atún patudo no explotada (línea superior) y la que predice el modelo de evaluación (línea inferior). Las áreas sombreadas entre las dos líneas señalan la porción del efecto atribuida a cada método de pesca. t = toneladas métricas.

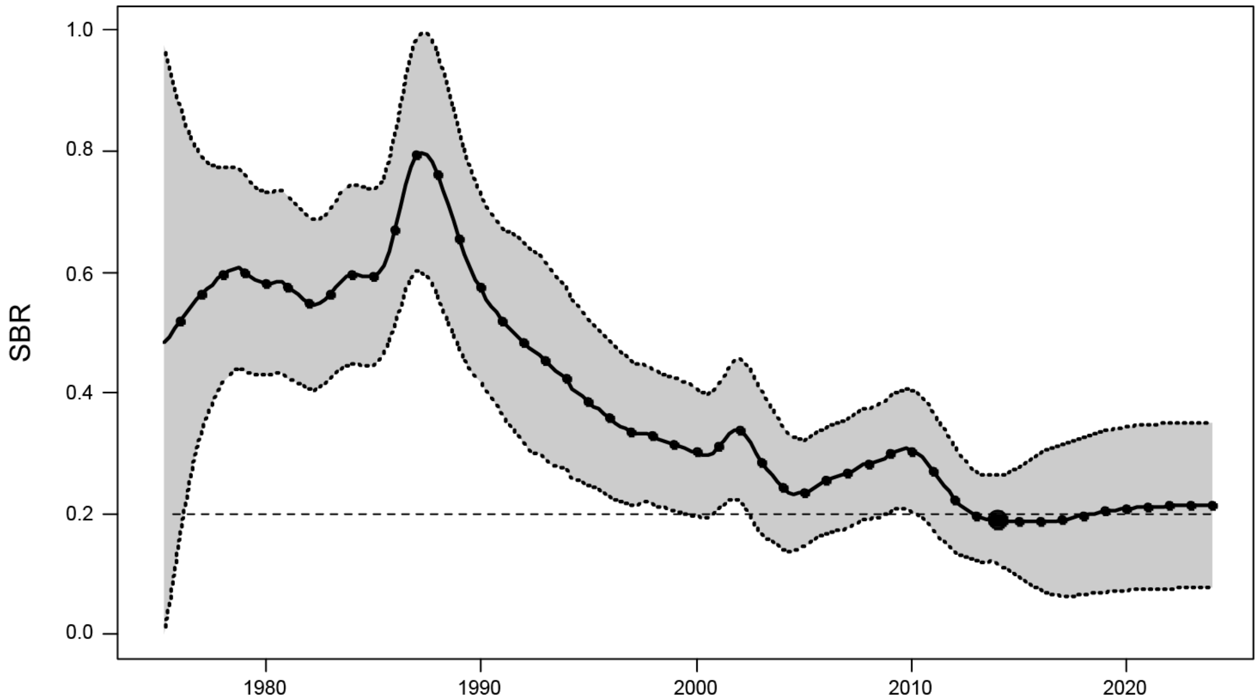

FIGURE 4. Estimated spawning biomass ratios (SBRs) of bigeye tuna in the EPO, including projections for 2014-2023 based on average fishing mortality rates during 2011-2013. The dashed horizontal line (at about 0.20) identifies the SBR at MSY. The solid line illustrates the maximum likelihood estimates, and the estimates after 2014 (the large dot) indicate the SBR predicted to occur if fishing mortality rates continue at the average of that observed during 2011-2013. The dashed lines are the 95-percent confidence intervals around these estimates.

FIGURA 4. Cocientes de biomasa reproductora (SBR) del atún patudo en el OPO, incluyendo proyecciones para 2014-2023 basadas en las tasas medias de mortalidad por pesca durante 2011-2013. La línea sólida ilustra las estimaciones de verosimilitud máxima, y las estimaciones a partir de 2014 (el punto grande) señalan el SBR predicho si las tasas de mortalidad por pesca continúan en el promedio observado durante 2011-2013. Las líneas de trazos representan los intervalos de confianza de 95% alrededor de esas estimaciones.

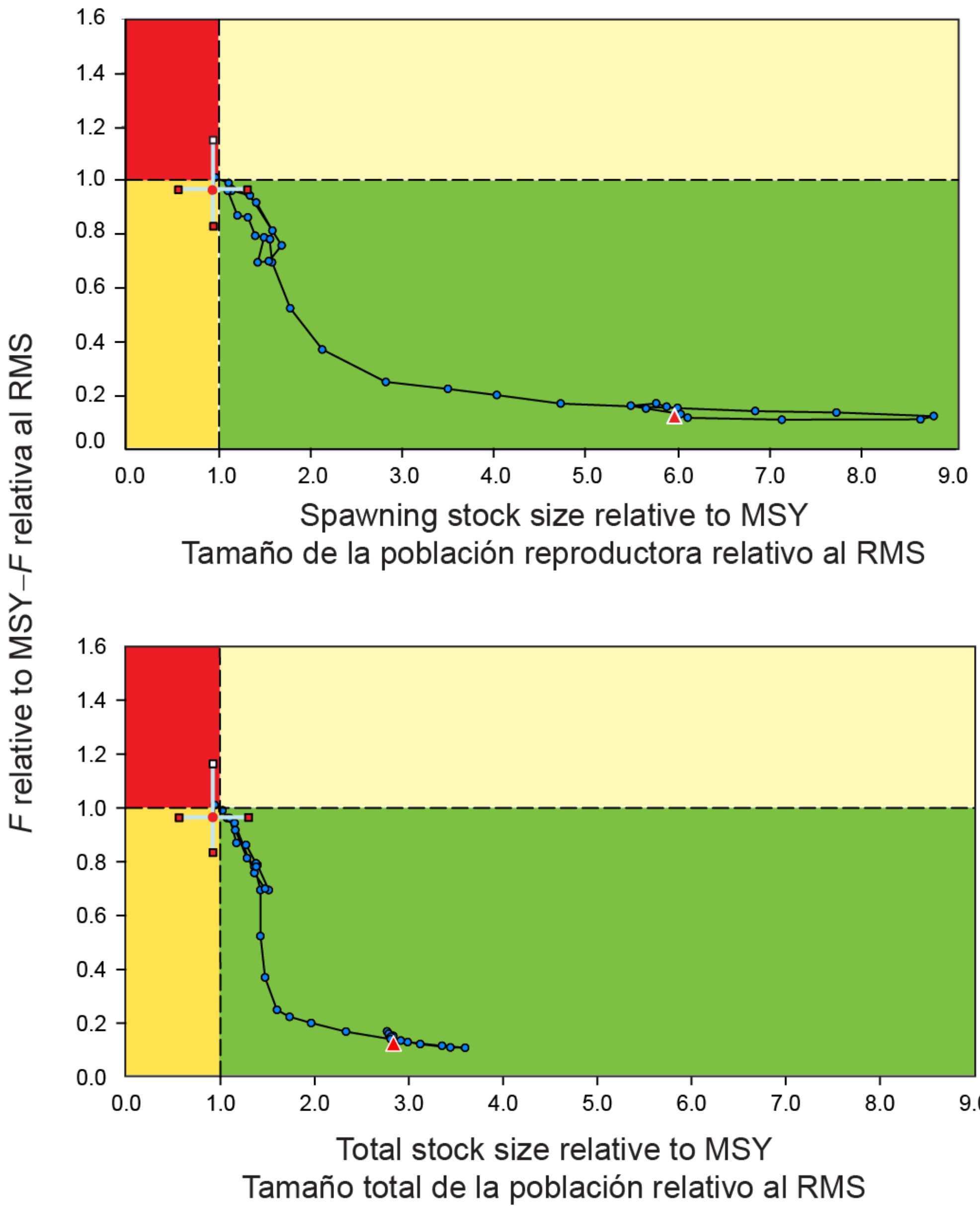

FIGURE 5a. Target Kobe (phase) plot of the time series of estimates of stock size (top: spawning biomass; bottom: total biomass) and fishing mortality relative to their MSY reference points. The panels represent proposed target reference points (S_{MSY} and F_{MSY}). Each dot is based on the average fishing mortality rate over three years; the large dot indicates the most recent estimate. The squares around the most recent estimate represent its approximate 95% confidence interval. The triangle is the first estimate (1975).

FIGURA 5a. Gráfica de Kobe (fase) objetivo de la serie de tiempo de las estimaciones del tamaño de la población (arriba: biomasa reproductora; abajo: biomasa total) y la mortalidad por pesca en relación con sus puntos de referencia de RMS. Los recuadros representan puntos de referencia objetivo propuestos (S_{RMS} and F_{RMS}). Cada punto se basa en la tasa de explotación media de un trienio; el punto grande indica la estimación más reciente. Los cuadros alrededor de la estimación más reciente representan el intervalo de confianza de 95% aproximado. El triángulo es la primera estimación (1975).

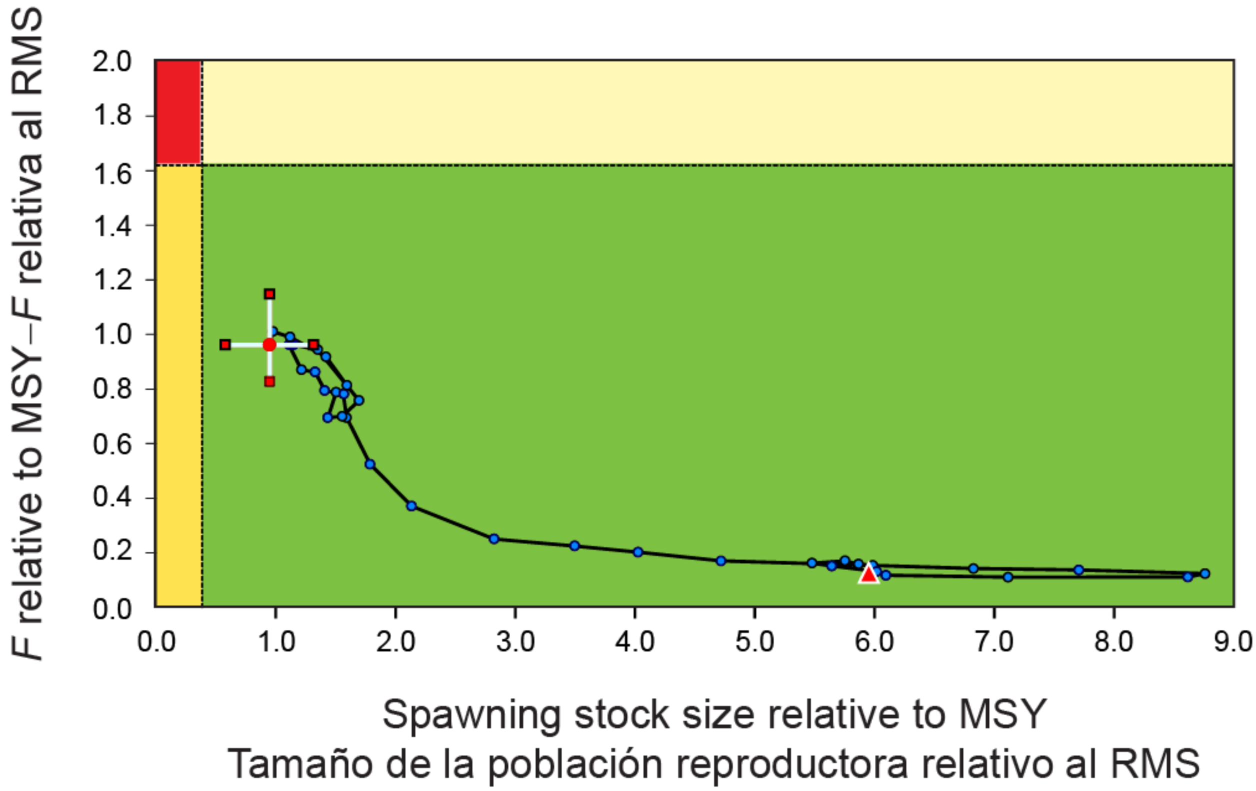

FIGURE 5b. Limit Kobe (phase) plot of the time series of estimates of spawning stock size and fishing mortality relative to their MSY reference points. The panels represent the proposed limit reference points of 0.38 S_{MSY} and 1.6 F_{MSY}, which correspond to a 50% reduction in recruitment from its 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 fishing mortality rate over three years; the large dot indicates the most recent estimate. The squares around the most recent estimate represent its approximate 95% confidence interval. The triangle is the first estimate (1975).

FIGURA 5b. Gráfica de Kobe (fase) límite de la serie de tiempo de las estimaciones del tamaño de la población reproductora y la mortalidad por pesca relativas a sus puntos de referencia de RMS. Los recuadros representan los puntos de referencia límite propuestos de 0,38 S_{RMS} y 1,6 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 un trienio; el punto grande indica la estimación más reciente. Los cuadros alrededor de la estimación más reciente representan el intervalo de confianza de 95% aproximado. El triángulo es la primera estimación (1975).

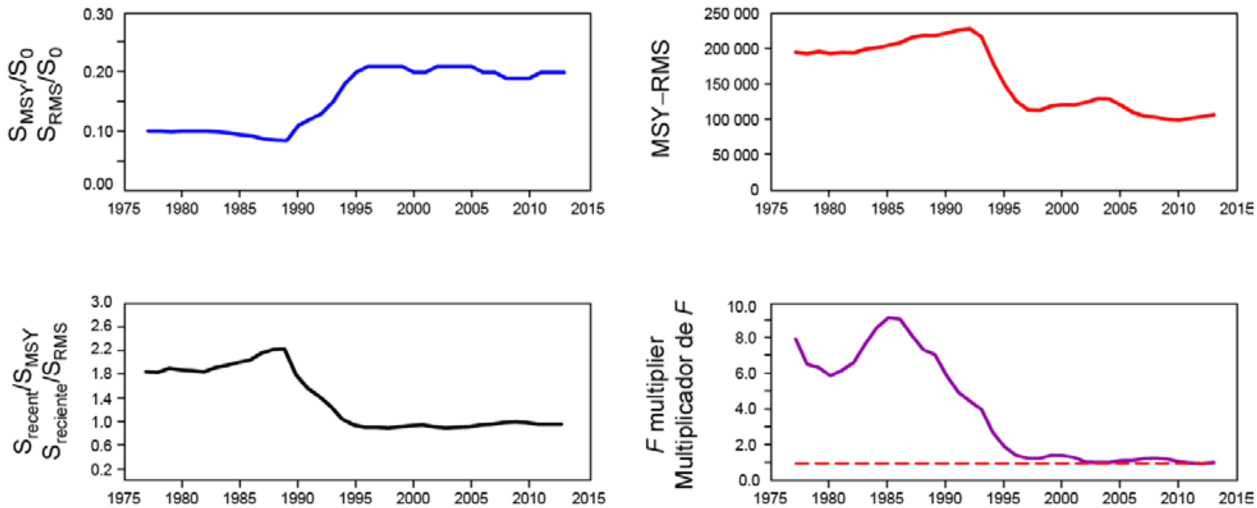

FIGURE 6. Estimates of MSY-related quantities calculated using the average age-specific fishing mortality for each year. (S_{recent} is the spawning biomass at the beginning of 2014.)

FIGURA 6. Estimaciones de cantidades relacionadas con el RMS calculadas usando la mortalidad por pesca por edad para cada año. ($S_{reciente}$ es la biomasa reproductora al principio de 2014.)

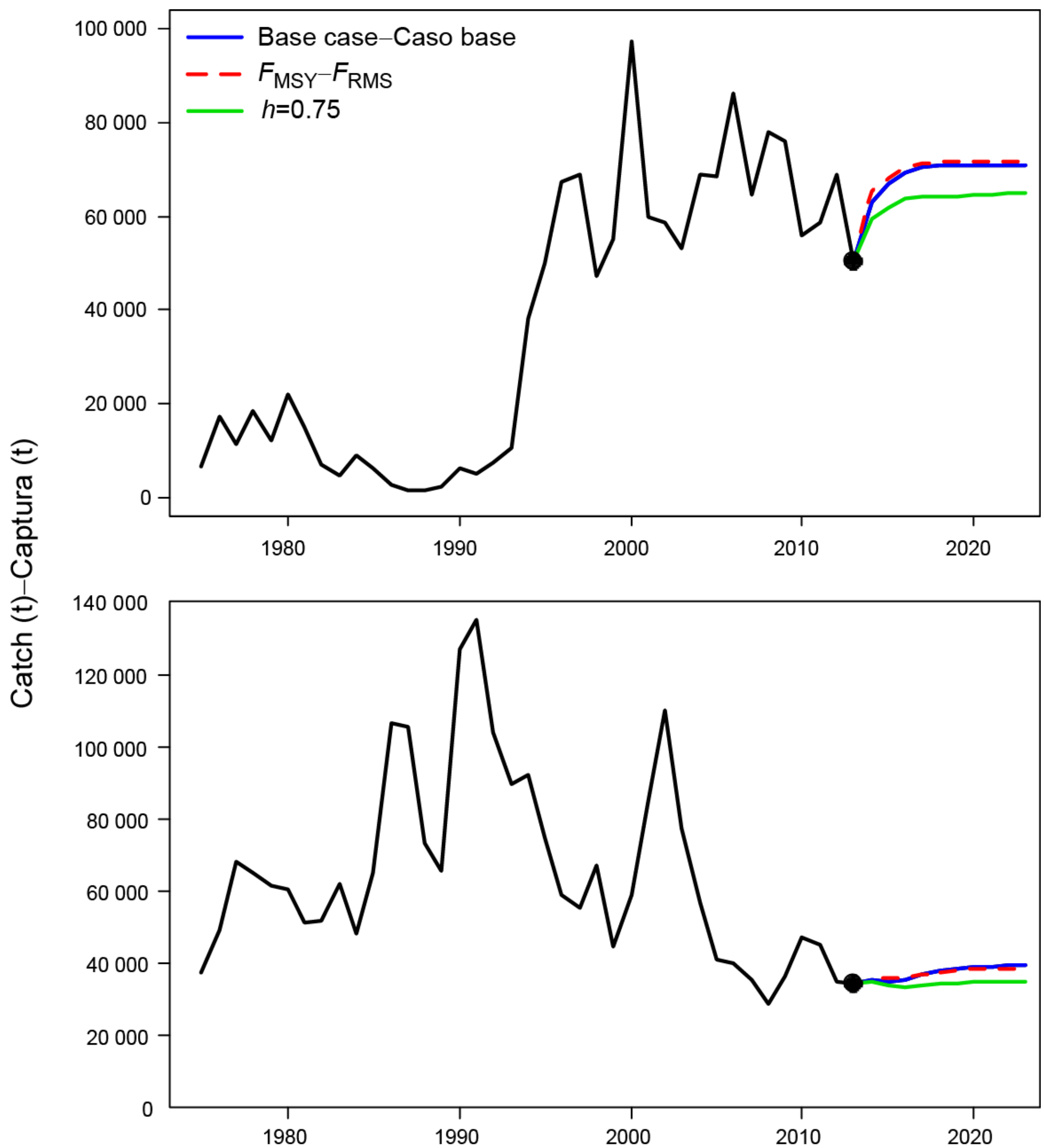

FIGURE 7. Historic and predicted annual catches of bigeye tuna during 2014-2023 for the surface (top panel) and longline (bottom panel) fisheries, based on fishing mortality rates during 2011-2013. Predicted catches are compared between the base case, the analysis assuming F_{MSY} and the analysis in which a stock-recruitment relationship (h = 0.75) was used. t = metric tons.

FIGURA 7. Capturas anuales históricas y predichas de atún patudo durante 2014-2023 en las pesquerías de superficie (recuadro superior) y de palangre (recuadro inferior), basadas en las tasas de mortalidad por pesca durante 2011-2013. Se comparan las capturas predichas entre el caso base, el análisis que supone F_{MSY} y el análisis en el que se usa una relación población-reclutamiento (h = 0.75). t = toneladas métricas.

TABLE 1. Estimates of the MSY and its associated quantities for bigeye tuna for the base case assessment and the sensitivity analyses. All analyses are based on average fishing mortality during 2011-2013. B_{recent} and B_{MSY} are defined as the biomass of fish 3+ quarters old (in metric tons) at the beginning of 2014 and at MSY, respectively. S_{recent} and S_{MSY} are in metric tons. C_{recent} is the estimated total catch in 2013. The F multiplier indicates how many times effort would have to be effectively increased to achieve the MSY in relation to the average fishing mortality during 2011-2013.

TABLA 1. Estimaciones del RMS y sus cantidades asociadas para el atún patudo para la evaluación del caso base y los análisis de sensibilidad. Todos los análisis se basan en la mortalidad por pesca promedio de 2011-2013. Se definen B_{recent} y B_{RMS} como la biomasa de peces de 3+ trimestres de edad (en toneladas métricas) al principio de 2014 y en RMS, respectivamente. Se expresan S_{recent} y S_{MSY} en toneladas métricas. C_{recent} es la captura total estimada en 2013. El multiplicador de F indica cuántas veces se tendría que incrementar el esfuerzo para lograr el RMS en relación con la mortalidad por pesca media durante 2011-2013.

	Base case- Caso base	***h* = 0.75**
MSY-RMS	110,458	104,773
B_{MSY}- B_{RMS}	420,280	746,794
S_{MSY}- S_{RMS}	105,164	207,160
B_{MSY}/B_0- B_{RMS}/B_0	0.25	0.33
S_{MSY}/S_0- S_{RMS}/S_0	0.20	0.30
C_{recent}/MSY- C_{recent}/RMS	0.76	0.80
$B_{\text{recent}}/B_{\text{MSY}}$- $B_{\text{recent}}/B_{\text{RMS}}$	0.95	0.73
$S_{\text{recent}}/S_{\text{MSY}}$-$S_{\text{recent}}/S_{\text{RMS}}$	0.95	0.71
F multiplier- Multiplicador de F	1.04	0.81