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**STATUS OF BIGEYE TUNA IN THE EASTERN PACIFIC OCEAN IN 2011  
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 Version 3.23b) was used in the assessment. This model is the same as the base case model used in the previous full assessment ([IATTC Stock Assessment Report 11](#)).

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 (150°W) of the EPO; the longline catches are more continuous, but relatively low between 160°W and 180W°. Bigeye are not often caught by purse seiners in the EPO north of 10°N, but a substantial portion of the longline catches of bigeye in the EPO is made north of that parallel. Bigeye tuna do not move long distances (95% of tagged bigeye showed net movements of less than 1000 nautical miles), and current information indicates minimal net movement between the EPO and the western and central Pacific Ocean. This is consistent with the fact that longline catch-per-unit-of-effort (CPUE) trends differ among areas. 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 in the EPO, and there is limited exchange of fish between the EPO and the western and central Pacific Ocean. Its results are consistent with results of other analyses of bigeye tuna on a Pacific-wide basis. In addition, analyses have shown that the results are insensitive to the spatial structure of the analysis. Currently, there are not enough tagging data to provide adequate estimates of movement between the EPO and the western and central Pacific Ocean.

The stock assessment requires a substantial amount of information. Data on retained catch, discards, catch per unit of effort (CPUE), and age-at-length data 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 (see [IATTC Stock Assessment Report 11](#)). Catch and CPUE for the surface fisheries have been updated to include new data for 2011. New or updated longline catch data are available for China (2010), Chinese Taipei (2008-2010), French Polynesia (2010), Japan (2007-2010), the Republic of Korea (2009-2011) and the United States (2009-2010). Longline catch data for 2011 are available for China, Chinese Taipei and Japan from the monthly reporting statistics. New or updated CPUE data are available for the Japanese longline fleet (2007-2010). New purse-seine length-frequency data are available for 2011. New or updated length-frequency data are not available for the Japanese longline fleet.

There are several important features in the estimated time series of bigeye recruitment (Figure 1). The most obvious pattern is a period of below-average recruitment prior to 1994, which may be a model artifact caused by the expansion of the floating-object fisheries in 1994. Estimates of recruitment before 1993 are more uncertain, as the floating-object fisheries were not catching significant amounts of small

bigeye. There was a period of above-average annual recruitment in 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 high in 2005 and 2006. The 2008 and 2010 recruitments were above average, but the recruitment in 2011 appears to have been below average. However, this recent estimate is very uncertain and should be regarded with caution, due to the fact that recently-recruited bigeye are represented in only a few length-frequency samples.

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 (Figures 2 and 3). 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. 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 population is far greater than that of the longline fishery (Figure 4). 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, when the spawning biomass ratio (the ratio of the spawning biomass at that time to that of the unfished stock; SBR) was at its historic low level of 0.16, the bigeye stock has shown a recovery trend, to an SBR of 0.24 at the end of 2010. This recent recovery trend is subsequent to the IATTC tuna conservation resolutions initiated in 2004. The SBR is estimated to have declined slightly since the beginning of 2011 to a level of 0.23 at the start of 2012 (Figure 5). According to the base case model, this most recent SBR is about 12% higher than the maximum sustainable yield (MSY) level (Table 1).

Recent catches are estimated to have been 8% less than those corresponding to the MSY levels (Table 1). If fishing mortality ( $F$ ) is proportional to fishing effort, and the current patterns of age-specific selectivity are maintained, the level of fishing effort corresponding to the MSY is about 95% of the current (2009-2011) level of effort (Table 1).

According to the base case results, the two most recent estimates indicate that the bigeye stock in the EPO is probably not overfished ( $S > S_{MSY}$ ), but that fishing mortality slightly exceeds the level corresponding to the MSY (overfishing is taking place,  $F > F_{MSY}$ ) (Figure 6). This interpretation, however, is subject to uncertainty, as indicated by the approximated confidence intervals around the most recent estimate in the Kobe plot (Figure 6).

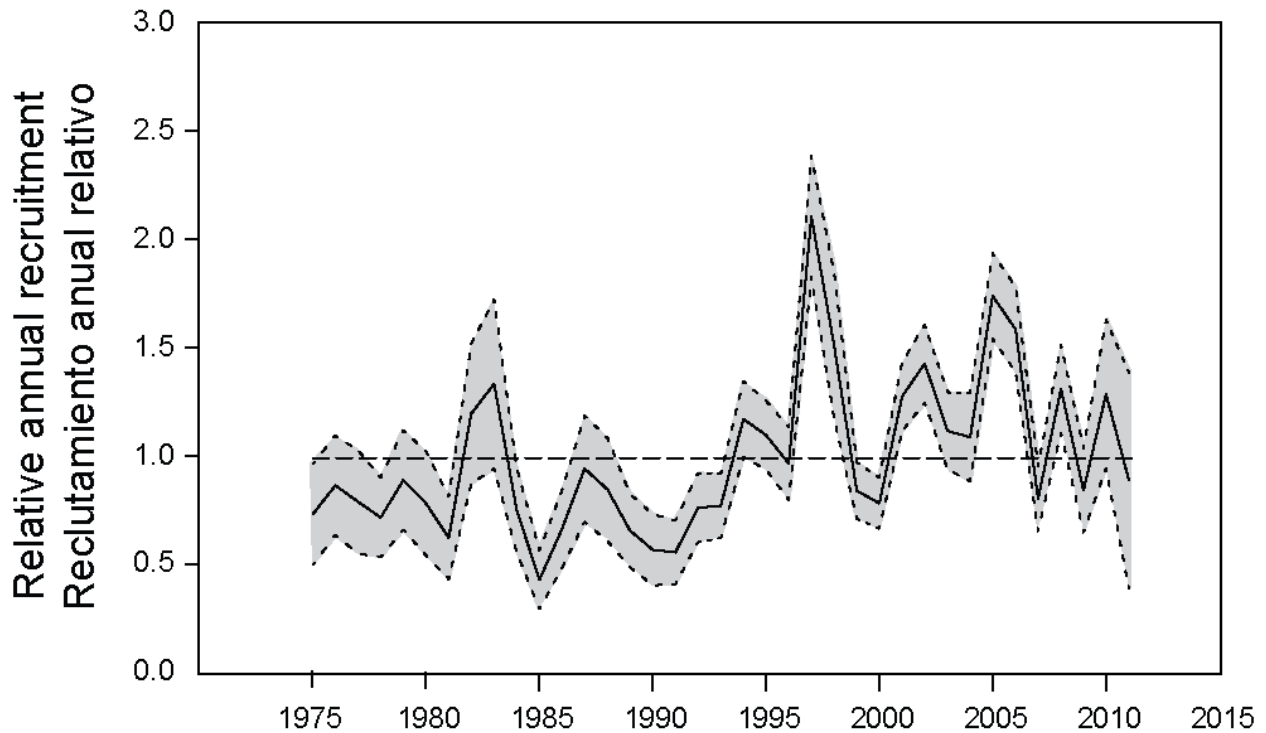
The MSY of bigeye in the EPO could be maximized if the age-specific selectivity pattern were similar to that of the longline fisheries, because they catch larger individuals that are close to the critical weight. Before the expansion of the floating-object fishery that began in 1993, the MSY was greater than the current MSY and the fishing mortality was less than  $F_{MSY}$  (Figure 7).

Under the current levels of fishing mortality, recent spikes in recruitment are predicted not to sustain the increasing trend observed for SBR since 2004. Both the base case and the assessment assuming a stock-recruitment relationship indicate a slight decline of the SBR since the start of 2011 and predict that the population is likely to further drop below the level corresponding to MSY under average recruitment conditions (Figure 5). It is estimated that catches will be lower in the future at current levels of fishing effort if a stock-recruitment relationship is assumed, particularly for the surface fisheries (Figure 8).

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

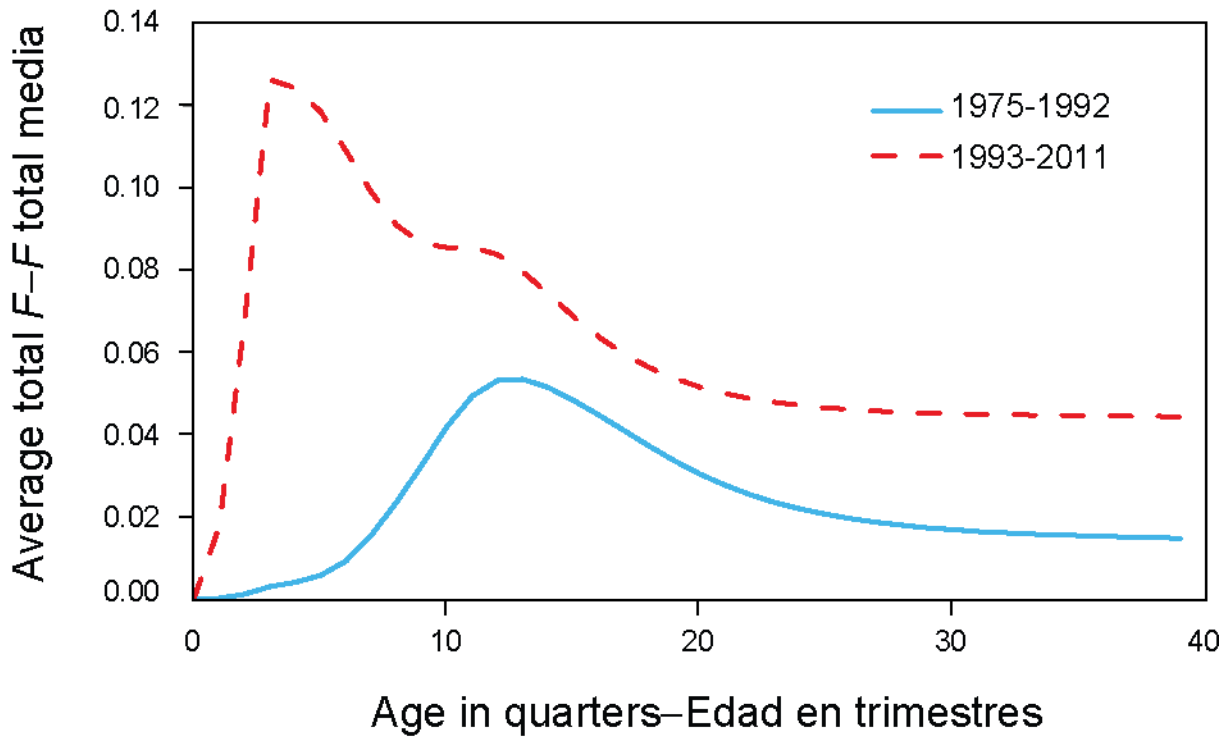
## **Key results**

1. The results of this assessment indicate a recent recovery trend for bigeye tuna in the EPO (2005-2010), subsequent to IATTC tuna conservation resolutions initiated in 2004. However, an apparent slight decline of the spawning biomass has begun at the start of 2011 and, under the current levels of fishing mortality and average recruitment, recent spikes in recruitment are predicted not to sustain the early observed population rebuilding trend.
2. There is uncertainty about recent and future recruitment and biomass levels;
3. The recent fishing mortality rates are estimated to be slightly above the level corresponding to MSY, and the recent levels of spawning biomass are estimated to be above that level. As described in [IATTC Stock Assessment Report 11](#), these interpretations are uncertain and highly sensitive to the assumptions made about the steepness parameter of the stock-recruitment relationship, the average size of the older fish, the assumed levels of natural mortality for adult bigeye, and the historic period of the bigeye exploitation used in the assessment. The results are more pessimistic if a stock-recruitment relationship is assumed, if a higher value is assumed for the average size of the older fish, if lower rates of natural mortality are assumed for adult bigeye, and if only the late period of the fishery (1995-2009) is included in the assessment;
4. The results are more optimistic if a lower value is assumed for the average size of the older fish, and if higher levels of natural mortality are assumed for adult bigeye.



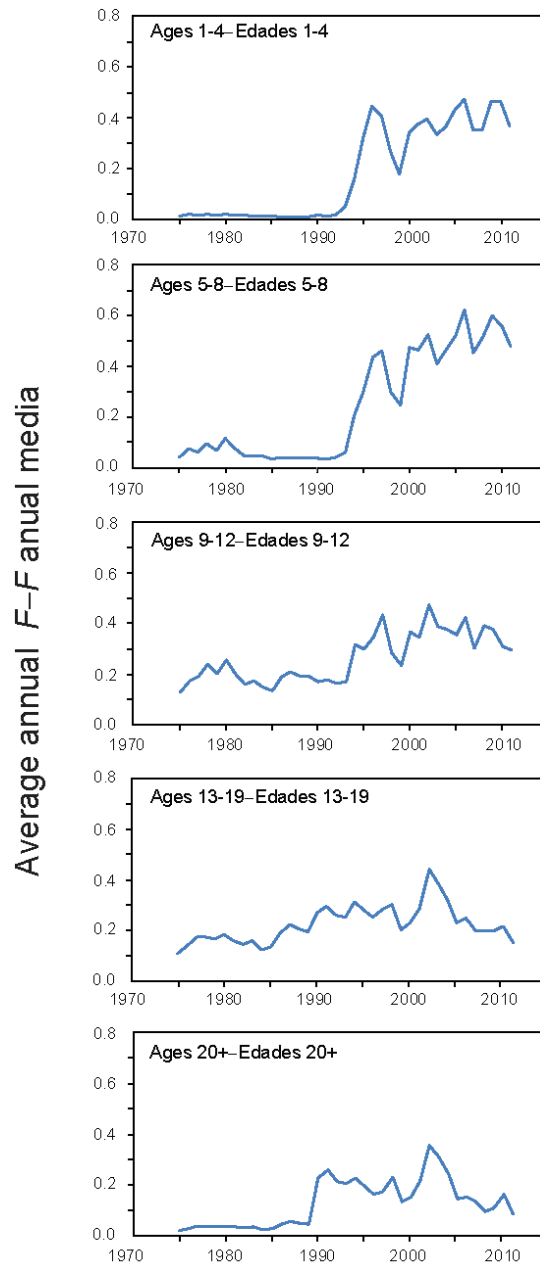
**FIGURE 1.** Estimated annual recruitment of bigeye tuna to the fisheries of the EPO. The estimates are scaled so that the estimate of virgin recruitment is equal to 1.0 (dashed horizontal line). The solid line shows the maximum likelihood estimates of recruitment, and the shaded area indicates the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



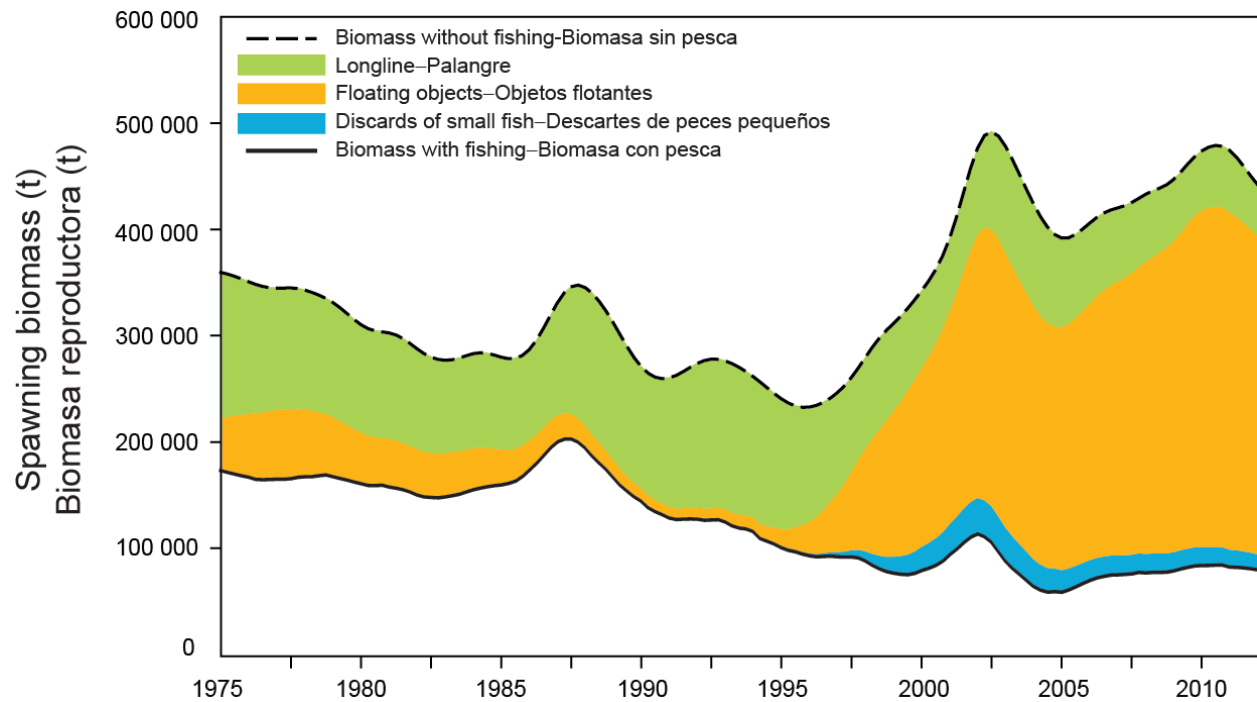
**FIGURE 2.** Average quarterly fishing mortality at age of bigeye tuna, by all gears, in the EPO. The curves for 1975-1992 and 1993-2011 display the averages for the periods before and after the expansion of the floating-object fisheries, respectively.

**FIGURA 2.** Mortalidad por pesca trimestral media por edad de atún patudo en el OPO, por todas las artes. Las curvas de 1975-1992 y 1993-2011 indican los promedios de los períodos antes y después de la expansión de las pesquerías sobre objetos flotantes, respectivamente.



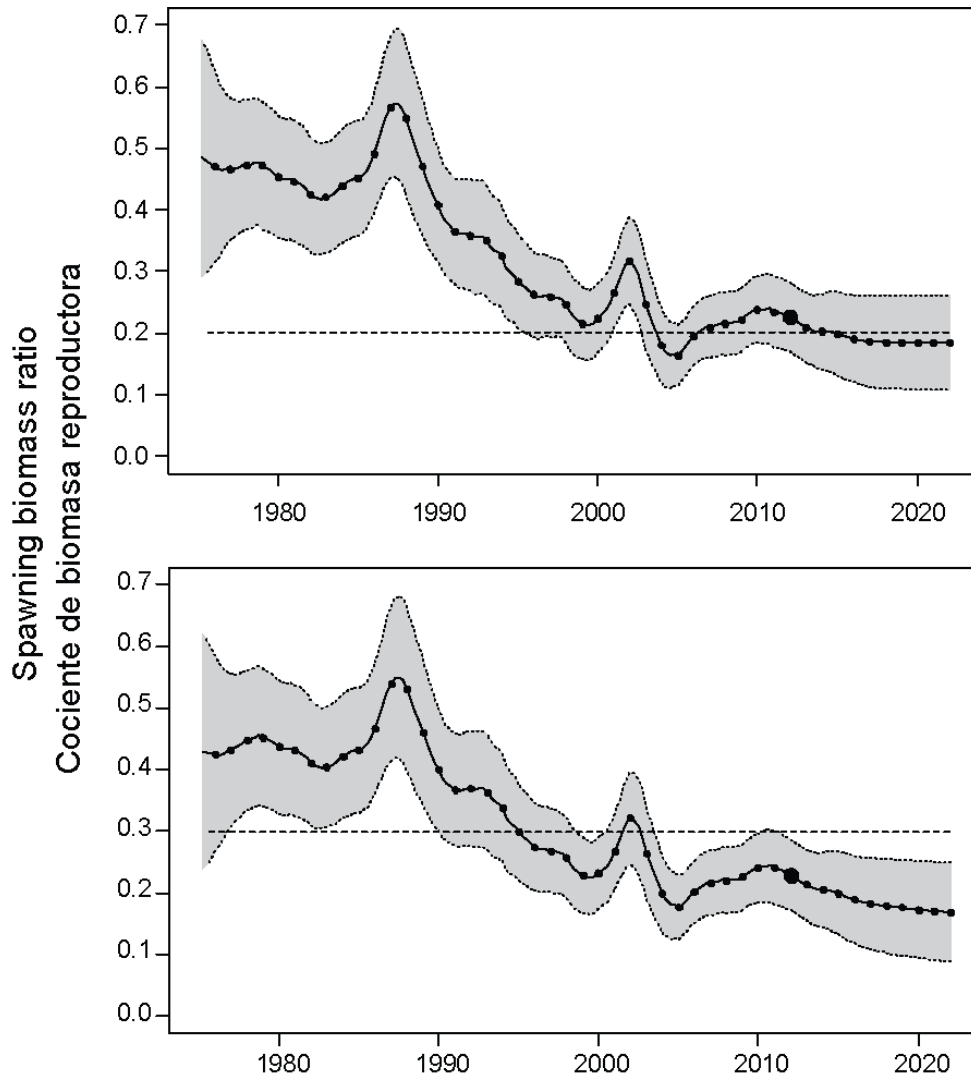
**FIGURE 3.** Average annual fishing mortality, by all gears, of bigeye tuna recruited to the fisheries of the EPO. Each panel illustrates the average fishing mortality rates that affected the fish within the range of ages indicated in the title of each panel. For example, the trend illustrated in the top panel is an average of the fishing mortalities that affected the fish that were 1-4 quarters old.

**FIGURA 3.** 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 de más arriba es un promedio de las mortalidades por pesca que afectaron a los peces de entre 1 y 4 trimestres de edad.



**FIGURE 4.** 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.

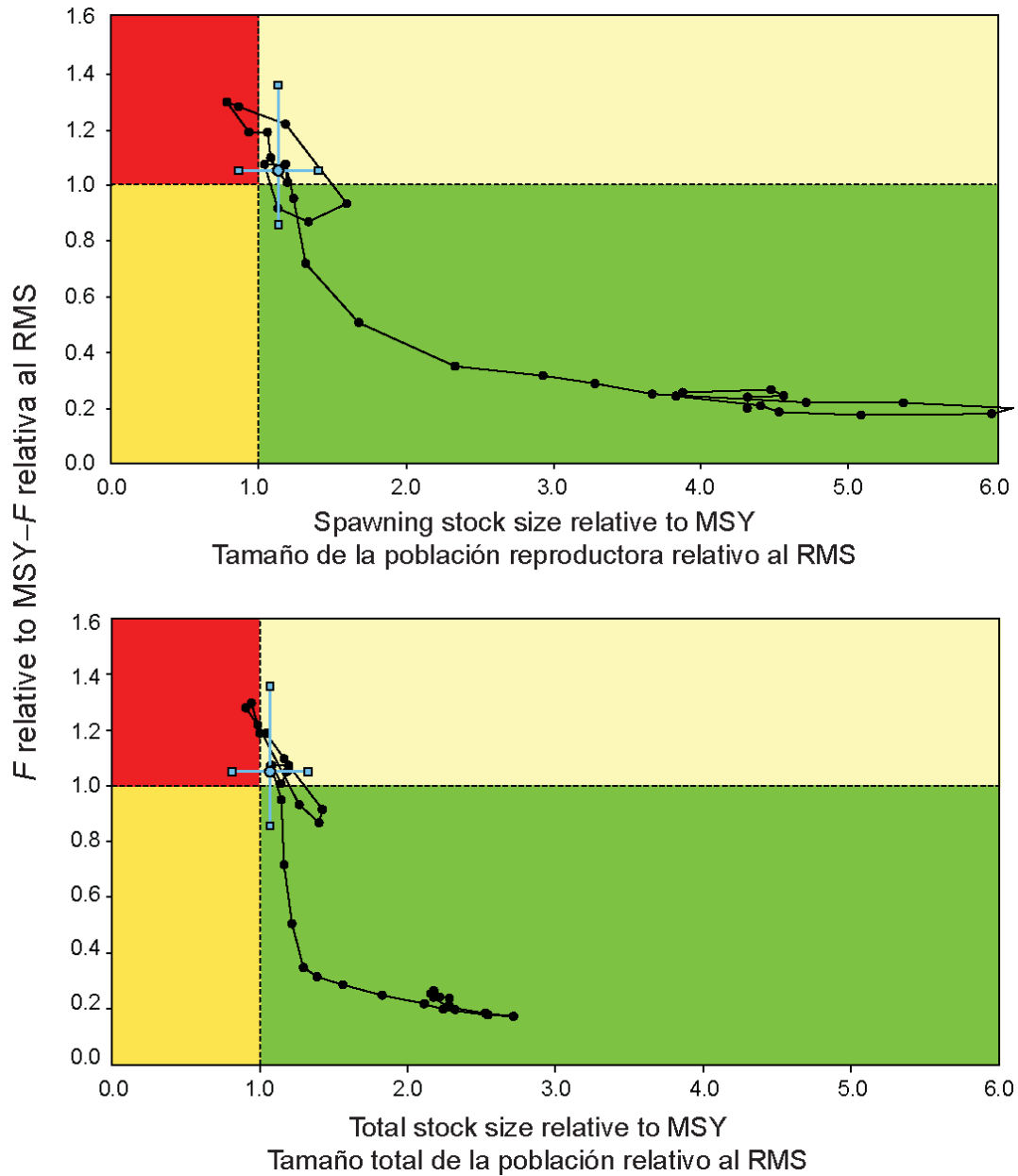
**FIGURA 4.** Trayectoria de la biomasa reproductora de una población simulada de atún patudo no explotada (línea superior) y la que predice el modelo de evaluación (línea inferior). Las áreas sombreadas entre las dos líneas señalan la porción del efecto atribuida a cada método de pesca. t = toneladas métricas.



**FIGURE 5.** Spawning biomass ratios (SBRs) of bigeye tuna in the EPO, including projections for 2012-2022 based on average fishing mortality rates during 2009-2011 from the base case (top) and the analysis of sensitivity to the steepness of the stock-recruitment relationship (bottom). The dashed horizontal line (at about 0.20 and 0.30, respectively) identifies the SBR at MSY. The solid line illustrates the maximum likelihood estimates, and the estimates after 2012 (the large dot) indicate the SBR predicted to occur if fishing mortality rates continue at the average of those observed during 2009-2011, and average environmental conditions occur during the next 10 years. The shaded area indicates the approximate 95% confidence intervals around those estimates.

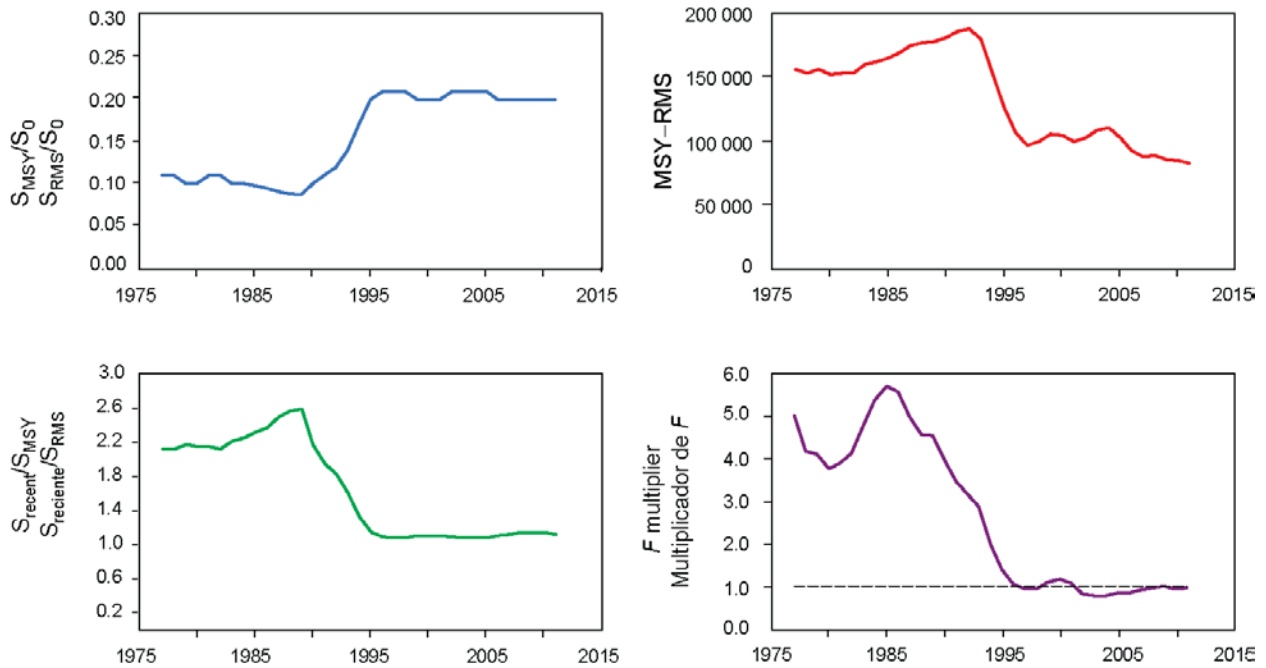
**FIGURA 5.** Cocientes de biomasa reproductora (SBR) del atún patudo en el OPO, incluyendo proyecciones para 2012-2022 basadas en las tasas medias de mortalidad por pesca durante 2009-2011 del caso base (arriba) y el análisis de sensibilidad a la inclinación de la relación población-reclutamiento (abajo). La línea de trazos horizontal (en aproximadamente 0.20 y 0.30, respectivamente) identifica el SBR en RMS. La línea sólida ilustra las estimaciones de verosimilitud máxima, y las estimaciones a partir de 2012 (el punto grande) señalan el SBR predicho si las tasas de mortalidad por pesca continúan en el promedio de aquéllas observadas durante 2009-2011, y ocurren condiciones ambientales medias durante la próxima década. El área sombreada representa los intervalos de confianza aproximados de 95% alrededor de esas estimaciones.





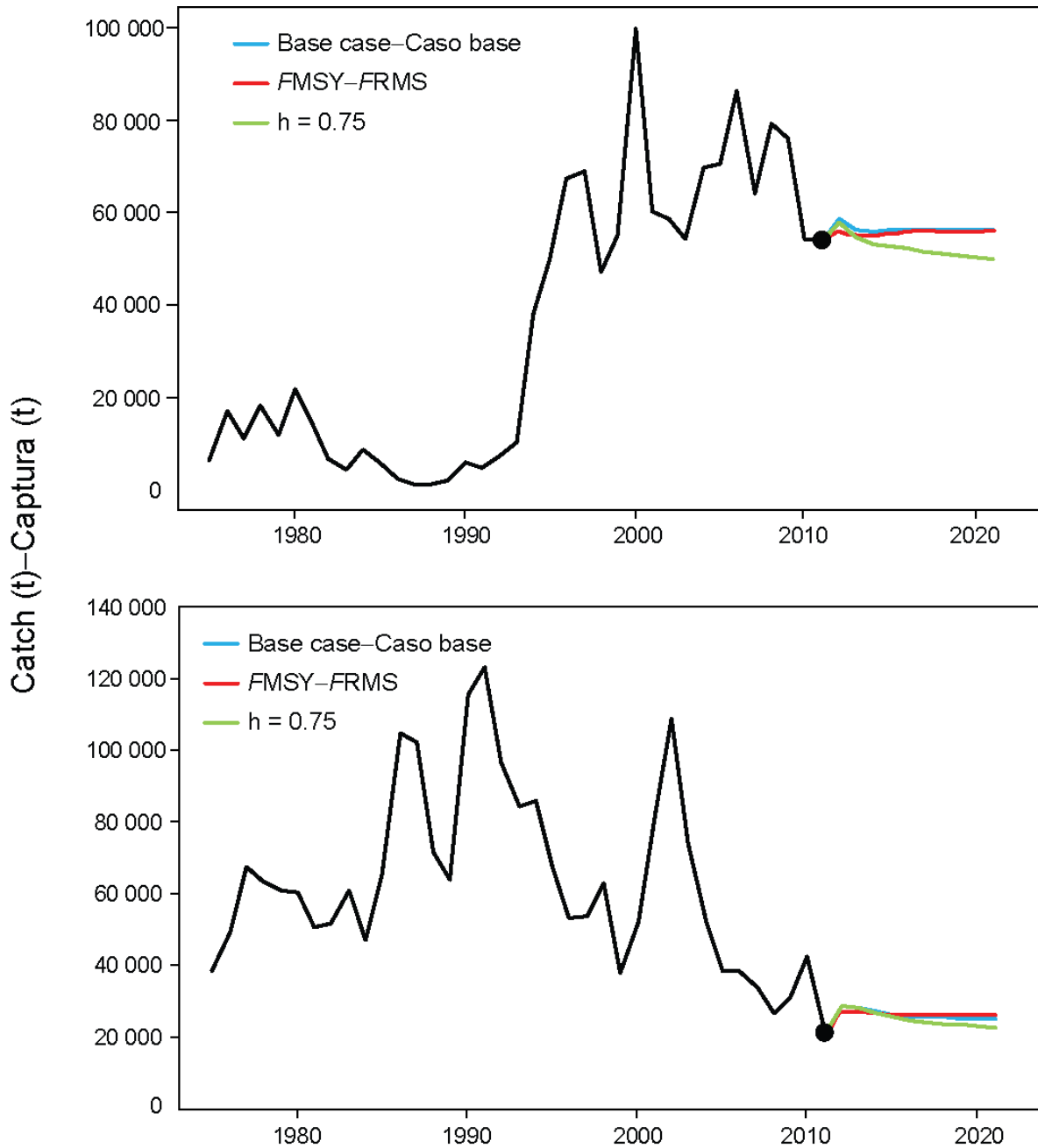
**FIGURE 6.** Kobe (phase) plot of the time series of estimates of stock size (top: spawning biomass; bottom: total biomass) and fishing mortality relative to their MSY reference points. Each dot is based on the average fishing mortality rate over three years; the large dot indicates the most recent estimate. The squares around the most recent estimate represent its approximate 95% confidence interval.

**FIGURA 6.** Gráfica de Kobe (fase) 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. Cada punto se basa en la tasa de explotación media de un trienio; el punto grande indica la estimación más reciente. Los cuadrados alrededor de la estimación más reciente representan su intervalo de confianza de aproximadamente 95%.



**FIGURE 7.** Estimates of MSY-related quantities calculated using the average age-specific fishing mortality for each year. ( $S_{recent}$  is the spawning biomass at the end of the last year in the assessment.)

**FIGURA 7.** Estimaciones de cantidades relacionadas con el RMS calculadas usando la mortalidad por pesca por edad media para cada año. ( $S_{reciente}$  es la biomasa reproductora al fin del último año en la evaluación.)



**FIGURE 8.** Historic and projected annual catches of bigeye tuna by the 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 observed catch (2011).

**FIGURA 8.** Capturas anuales históricas y proyectadas de patudo por las pesquerías de superficie (arriba) y de palangre (abajo) del caso base con la pesca en el nivel actual de esfuerzo, del caso base con la pesca en 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 al pescar con el esfuerzo actual. El punto grande representa la captura observada más reciente (2011).

**TABLE 1.** MSY and related quantities for the base case and the stock-recruitment relationship sensitivity analysis, based on average fishing mortality ( $F$ ) for 2009-2011.  $B_{\text{recent}}$  and  $B_{\text{MSY}}$  are defined as the biomass, in metric tons, of fish 3+ quarters old at the start of the first quarter of 2012 and at MSY, respectively, and  $S_{\text{recent}}$  and  $S_{\text{MSY}}$  are defined as indices of spawning biomass (therefore, they are not in metric tons).  $C_{\text{recent}}$  is the estimated total catch for 2011.

**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 2009-2011. Se definen  $B_{\text{reciente}}$  y  $B_{\text{RMS}}$  como la biomasa, en toneladas, de peces de 3+ trimestres de edad al principio del primer trimestre de 2012 y en RMS, respectivamente, y  $S_{\text{reciente}}$  y  $S_{\text{RMS}}$  como índices de biomasa reproductora (por lo tanto, no se expresan en toneladas).  $C_{\text{reciente}}$  es la captura total estimada de 2011.

	Base case – Caso base	$h = 0.75$
MSY–RMS	82,246	78,879
$B_{\text{MSY}} - B_{\text{RMS}}$	320,818	559,384
$S_{\text{MSY}} - S_{\text{RMS}}$	72,902	140,995
$C_{\text{recent}}/\text{MSY} - C_{\text{reciente}}/\text{RMS}$	0.92	0.96
$B_{\text{recent}}/B_{\text{MSY}} - B_{\text{reciente}}/B_{\text{RMS}}$	1.06	0.76
$S_{\text{recent}}/S_{\text{MSY}} - S_{\text{reciente}}/S_{\text{RMS}}$	1.12	0.77
$B_{\text{MSY}}/B_{F=0} - B_{\text{RMS}}/B_{F=0}$	0.25	0.34
$S_{\text{MSY}}/S_{F=0} - S_{\text{RMS}}/S_{F=0}$	0.20	0.30
$F$ multiplier—Multiplicador de $F$	0.95	0.70