INTER-AMERICAN TROPICAL TUNA COMMISSION

SCIENTIFIC ADVISORY COMMITTEE

FIFTH MEETING

La Jolla, California (USA)

12-16 May 2014

DOCUMENT SAC-05-10a

STOCK STATUS OF PACIFIC BLUEFIN TUNA AND THE URGENT NEED FOR MANAGEMENT ACTION

Mark N. Maunder[1], Kevin, R. Piner[2], and Alexandre Aires-da-Silva[1]

ABSTRACT

The stock assessment of Pacific bluefin tuna (PBF) by the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) is unsatisfactory because the model does not adequately fit the data, and this problem is only compounded in the updated assessment model. The lack of fit to the main indices of spawning abundance is particularly concerning. Despite these flaws, the model results are robust to a large number of alternative assumptions. Analysis of the data external to the model supports the management advice based on the model. The stock is highly depleted and experiencing overfishing. Although not discussed in the consensus assessment report, our independent analysis of the data shows that the spawning biomass is supported by a single cohort that is nearing the end of its life. Future projections predict that the population will not increase under the low recruitment scenario, which is consistent with recent recruitment estimates, unless catches of juveniles are reduced by 25-50%. Similar cuts are needed to ensure a high probability of reaching 10% of the unexploited biomass in 10 years, assuming average recruitment. In conclusion, urgent management action is needed to ensure the sustainability of the Pacific bluefin fisheries.

1. INTRODUCTION

There is considerable concern about the adequacy of the current Pacific bluefin tuna (PBF) stock assessment model. The model developed by the ISC working group on Pacific bluefin does not produce reasonable fits to the main indices of relative abundance and composition data (Figure 1). Despite inconsistencies in the data, a large number of sensitivity analyses all produced the same stock status designations (overfished and overfishing occurring). This consistency in stock status was used as the basis for management advice.

An update of the model with recent data continues to show a poor fit to the data and conflicts among data sets. In particular, the estimates of current spawning biomass were sensitive to the inclusion of Japanese and Chinese Taipei longline catch-per-unit-of-effort (CPUE) data, which have different trends.

For management advice to be accurate, it is important that the stock assessment model used adequately fit the main data components. Therefore, we conducted an exploratory analysis of the length-composition data for Pacific bluefin from the Japanese and Chinese Taipei longline fisheries to obtain insights into why the ISC model does not fit the data. In the process we developed a method to estimate spawning biomass outside the stock assessment model, and these external estimates are compared with those from

[1] Inter-American Tropical Tuna Commission, 8901 La Jolla Shores Drive, La Jolla, CA 92037-1508, USA

[2] NOAA National Marine Fisheries Service, Southwest Fisheries Science Center, 8901 La Jolla Shores Drive, La Jolla, CA 92037-1508, USA

the model. Finally, we conclude with advice to improve the stock assessment and for managing the stock.

2. COMPOSITION DATA

Length-composition data on the catch of Pacific bluefin are available for a variety of fisheries. These data provide information on the age/length selectivity/availability to the fishery and cohort strength (recruitment), and can also provide information on fishing mortality and abundance (Maunder and Piner in press). However, this latter information can be highly sensitive to model misspecification in processes such as selectivity (Lee *et al*. in press). It is therefore important that the composition data are modelled correctly. We conducted an exploratory analysis of the Pacific bluefin Japanese and Chinese Taipei longline length-composition data to obtain insights into why the assessment model does not fit the data.

2.1. Japanese longline length-composition data

Starting in 2000, a clear mode, likely representing a single very strong cohort, can be seen traversing through the Japanese longline length-composition data (Figure 2). The modal progression can be seen more clearly by truncating the length axis and looking at the last 7 years only (Figure 3). The mode may represent more than one consecutive cohort that are all above average due to correlated environmental conditions; however, the very low coefficient of variation (5%) for the variation of lengths in this mode and a subsequent smaller mode suggests that it is a single cohort (Figure 4). The length-composition data suggest that there is a single strong cohort that is supporting the spawning biomass, although there are some years of composition data that suggest more than one cohort (Figure 5). There are also differences in the sizes of fish caught in different seasons (Figure 6), although the data are scarce. Smaller fish are caught outside the main fishing season, but they do not appear to enter the composition data of the main fishing season as strong modes. It is not clear if the fishery is able to efficiently catch smaller tuna or if there are two different growth patterns. The catch in the off season is small, so the composition data from these seasons may not represent strong cohorts.

The recent large (200-250 cm) Pacific bluefin seen in the Japanese longline length-composition data have not been seen at high proportions in any of the data available for this fishery, which date back to the 1950s (Figure 7). This suggests that the Japanese longline fleet has been targeting the strong cohort and therefore its effective selectivity has changed over time. The clear mode of this strong cohort in the composition data can be used to estimate the growth of the fish in the cohort. They did not appear to grow much between 2008 and 2009 (Figure 8), but in general grew faster, particularly at older ages, than assumed in the ISC stock assessment model (Figure 8) or estimated for males and females by Shimose and Takeuchi (2012) (Figure 9).

The strong cohort seen in the length-composition data is consistent with the CPUE (Figure 10). The CPUE increased starting in 2001 as the strong cohort started to enter the fishery and declined starting in 2005 once the cohort was fully vulnerable to the fishery and there were no other strong cohorts to support the fishery. There appears to be a cohort entering the fishery 2-3 years later (Figure 3) that causes an increase in CPUE, but its effect is short-lived (Figure 10).

2.2. Chinese Taipei

The Chinese Taipei longline length composition data also show some modal progression (Figure 11), but the pattern is not as clear as it is for the Japanese data. Unlike the Japanese fishery, the Chinese Taipei fishery caught large (220-250 cm) Pacific bluefin in the past before the recent strong cohort (Figure 7), but the fish caught in 2005-2007, before the strong cohort moved through the Chinese Taipei fishery, were smaller. It is not clear if the strong cohort is faster-growing due to environmental conditions, if it is from a population with a different growth pattern, or if the Chinese Taipei fishery is also targeting the cohort.

The correspondence between the Chinese Taipei CPUE and its composition data is not clear. The CPUE increases after 2009 (Figure 13), but this is several years after the strong cohort entered the fishery.

3. ESTIMATING SPAWNING BIOMASS

The observation that the abundance of Pacific bluefin in the longline fisheries, which also corresponds to the spawning biomass, is mainly represented by a single cohort provides a unique opportunity to estimate spawning biomass, because the Japanese CPUE-based index of abundance represents this single cohort. Therefore, without additions due to new cohorts, the recent CPUE represents a decline in abundance of the strong cohort that can be used in a catch-curve type of analysis to estimate the total mortality rate (Z) (Figure 14). Given an assumed value of natural mortality (M), the fishing mortality (F) can be calculated ($F = Z - M$). Consequently, given catch (C) in weight from both the Japanese and Chinese Taipei longline fisheries, the spawning biomass (SB) can be calculated from the Baranov catch equation, making the assumption that all spawning Pacific bluefin, essentially one cohort, are fully vulnerable to the longline fisheries.

$$SB = \frac{Z}{F(1 - \exp(-Z))} C$$

The estimate of Z, based on the CPUE data from 2004 to 2010 only (to avoid the early years when the cohort may not have been fully selected, and later years that may have been more influenced by new cohorts as the abundance of the strong cohort decreased), is 0.35. The ISC assessment assumes $M = 0.25$, resulting in an estimate of $F = 0.1$ for this cohort by the longline fisheries. The consequent estimates of spawning biomass, in metric tons (t), are as follows:.

Year	Catch (t)	Spawning biomass
2004	3281	38882
2005	3072	36414
2006	2099	24875
2007	3302	39136
2008	1794	21260
2009	2082	24674
2010	1139	13493

Spawning biomass for the years prior to 2004 and after 2010 can be estimated by using the estimates of spawning biomass to scale the Japanese longline CPUE index of relative abundance to absolute abundance. The estimates of abundance for the 2004-2010 period are very similar to those estimated by the stock assessment model (Figure 15). However, the scaled Japanese CPUE index for the other years is not, which is not surprising given the assessment model provides a poor fit to this index. The estimates of spawning biomass are insensitive to the value assumed for natural mortality, but highly sensitive to the value of fishing mortality (Figure 16).

4. CONCLUSIONS

4.1. A plausible story of recent Pacific bluefin dynamics

Our analysis suggests that the recent spawning biomass levels have been mainly comprised of a single strong cohort. The strength of this cohort is supported by an index of recruitment based on the CPUE of the Japanese troll fishery for bluefin (Figure 17). The previous two cohorts were very weak. Subsequent cohorts were of moderate strength, but they failed to persist in the data. About the time that the strong cohort was spawned, a purse-seine fishery for small pelagics developed in the western Pacific that caught large amounts of very young Pacific bluefin (Figure 18). The high exploitation rate of this fishery, in addition to the other fisheries taking small to intermediate-sized Pacific bluefin, may not allow any new cohorts to enter the spawning biomass.

4.2. Stock assessment advice

The relatively poor performance of the current stock assessment model should be considered when providing detailed management advice based on the model results. However, the general conclusion – that the current spawning biomass is very low and substantial cuts in fishing mortality of juveniles are required – is robust to the assessment uncertainties.

4.3. Future research

A substantial effort is needed to improve the stock assessment in a way that would result in a better fit to the data. Our investigations of the data revealed that many, if not all, fisheries target strong cohorts. Therefore, additional time-varying selectivity should be considered for all fisheries, as static model process are responsible for much of the model misfit. The CPUE data for the Chinese Taipei longline fishery do not appear to be consistent with its composition data or with the Japanese longline CPUE data, which is considered a more reliable index of abundance, and therefore should be omitted from the analysis until the reasons for the inconsistencies are identified.

The following changes should be implemented immediately:

1. Model time-varying selectivity for all fleets catching juveniles of more than one age-class. One possible approach could be the McCall and Teo (2013) hybrid VPA.
2. Create a time block for Japanese longline selectivity starting in 2000 and force the selectivity to be asymptotic, to ensure that information on the strong cohort and the lack of other cohorts is maintained in the analysis.
3. Estimate the parameter that determines maximum length, to ensure that the growth is consistent with the length composition modes of the strong cohort.

Longer-term changes include

1. Split the Japanese longline fishery data into areas that catch small fish and areas that catch large fish
2. Investigate the possibility of time-varying growth or different sub-populations with different growth rates.
3. Consider allowing natural mortality to change by seasonal ages rather than annual ages.

4.4. Management advice

The Pacific bluefin stock is at very low levels, and the spawning population is mostly comprised of a single cohort that is coming to the end of its life. This is consistent with the stock assessment results that estimate the population is at a extremely low fraction of its unexploited level (2-5%). The current spawning biomass could be less than 10,000 t, which is about a quarter of the lowest level reached by southern bluefin tuna, and the depletion level is also lower than for southern bluefin tuna (Ana Parma pers. com.). The most recent recruitments appear to have fallen below the historical average. It is unclear if the recent drop in recruitment is related to low spawning abundance, environmental conditions, or is simply variability without trend. The prospects of stock recovery will depend on the level of future recruitment.

Future projections conducted by the ISC PBF working group predict that the population will not increase if future recruitment falls below the historical mean (low recruitment scenario), unless catches of juveniles are reduced by 25-50%. Similar cuts are needed to ensure a high probability of reaching 10% of the unexploited biomass in 10 years, even with recruitment at the historical average. Substantial and immediate cuts in fishing mortality of juveniles are most likely required to ensure the viability of the Pacific bluefin fisheries.

The longline fisheries, which target spawning adults, are estimate to have a very limited impact on the spawning stock biomass (Figure 19), so the greatest benefit can be obtained by restricting the other fisheries, which target juveniles. However, the longline fleets should not be allowed to increase their catches, to avoid losing the benefits from the reduction in the catch of juveniles. One caveat to the low impact of adult fishing mortality is the extremely low levels of current spawning biomass. At these low levels of spawning abundance, it may be that recruitment will be adversely affected. Some consideration of protecting the limited spawner population may be necessary until cuts in juvenile *F* allow more bluefin to become spawners.

The eastern Pacific Ocean (EPO) fleets are estimated to contribute only about 20% of the fishery impact on the population (Figure 19), despite recent catches of Pacific bluefin in the EPO being of similar magnitude to those in the western Pacific Ocean (Figure 18). This is primarily for two reasons. First, the analysis evaluates the impact of fishing on the spawning biomass, and the impact of any catch reductions will take several years to appear in the analysis. Second, the impact of a fishery is related to both the amount of catch and the age of the fish caught. The EPO fisheries catch fish older than the WPO small pelagic purse-seine fishery. The relative impact on the spawning biomass of catching a ton of fish of a given age can be calculated by the inverse of the average weight at that age and adjusting for natural mortality between that age and when the fish becomes mature. These calculations were carried out relative to age 5, the age at about which all fish are mature (Figure 20). For example, a ton of age-1 fish has about twice the impact of a ton of age-2 fish, so simply catching the same tonnage a year older could halve the impact. These calculations can help interpret the impact of each fishery based on their estimated selectivity curves (Figure 21). The goal of management for Pacific bluefin should be to reduce the fishing mortality so that juveniles can make it through to the spawning biomass without being caught. It is important that any reduction in fishing mortality on the very young fish is not offset by these fish being caught in the other fisheries that catch them at an older age and hence there should be reductions in all fisheries. It also should be noted that reduced catch does not necessarily mean reduced fishing mortality. If the abundance has decreased, reduced catches may just be a consequence of reduced biomass and not reduced fishing mortality. This is particularly important to consider given the recent low estimates of recruitment (Figure 17).

ACKNOWLEDGEMENTS

We thank the ISC Pacific bluefin working group, who put together all the data for the stock assessment model and provided feedback on the analyses contained in this report.

REFERENCES

Lee, H-H., Piner, K. R., Methot, R. D., and Maunder, M. N. (in press). Use of likelihood profiling over a global scaling parameter to structure the population dynamics model: an example using blue marlin in the Pacific Ocean. Fisheries Research.

MacCall, A.D. and Teo, S.L.H. 2013. A hybrid stock synthesis-Virtual population analysis model of Pacific bluefin tuna. Fisheries Research, 142: 22-26.

Maunder, M.N. and Piner, K. R. (in press) Contemporary fisheries stock assessment: many issues still remain. ICES Journal of Marine Science

Shimose, T. and Takeuchi, Y. 2012. Updated sex specific growth parameters for Pacific bluefin tuna *Thunnus orientalis*. ISC/12-1/PBFWG/12.

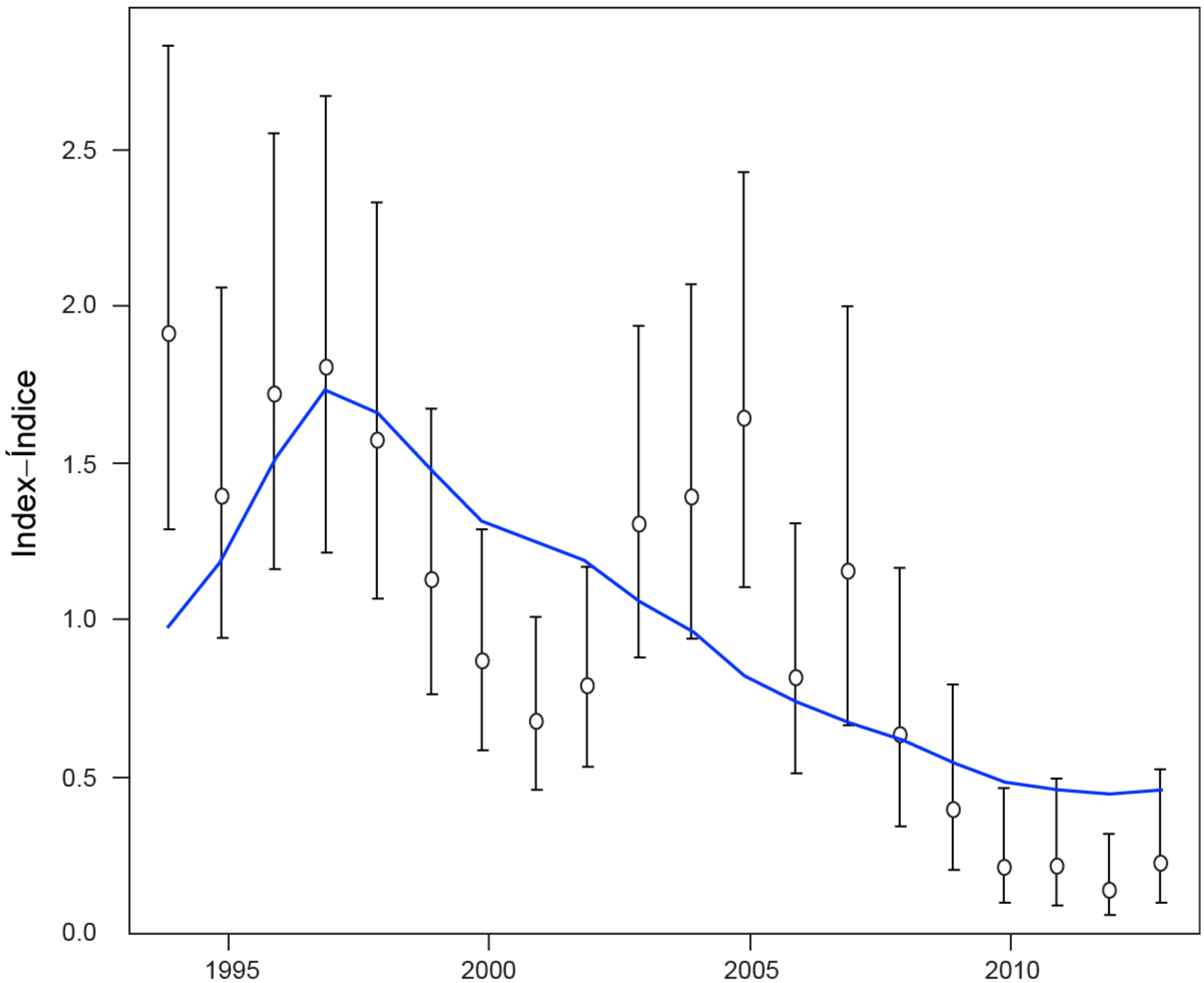

FIGURE 1a. Fit of the ISC stock assessment model to the Japanese longline CPUE indices of abundance.

FIGURA 1a. Ajuste del modelo de evaluación del ISC a los índices de abundancia basados en la CPUE de la pesquería palangrera japonesa.

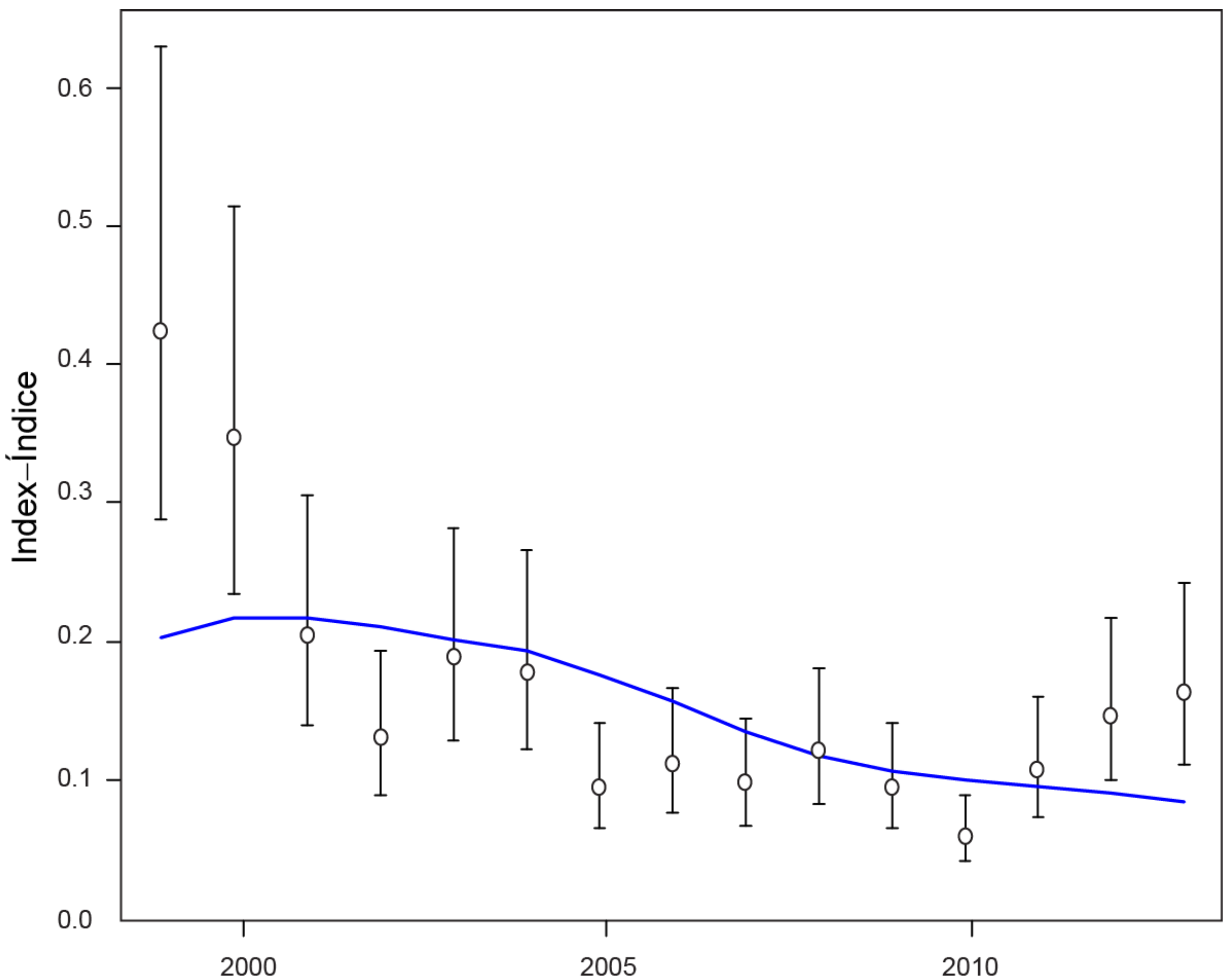

FIGURE 1b. Fit of the ISC stock assessment model to the Chinese Taipei longline CPUE indices of abundance.

FIGURA 1b. Ajuste del modelo de evaluación del ISC a los índices de abundancia basados en la CPUE de la pesquería palangrera de Taipei Chino.

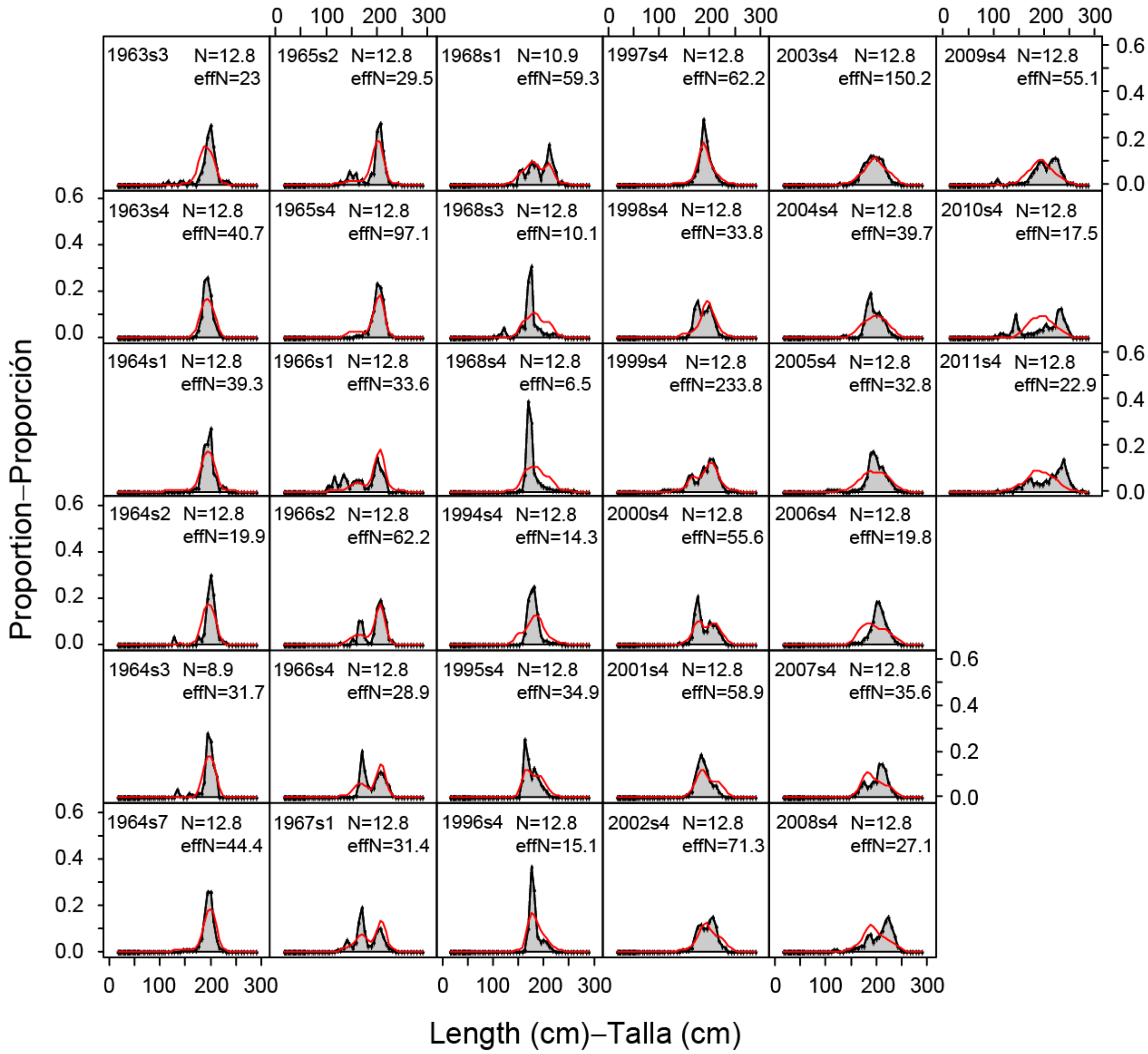

FIGURE 1c. Fit of the ISC stock assessment model to the Japanese longline length-composition data.

FIGURA 1c. Ajuste del modelo de evaluación del ISC a los datos de composición por talla de la pesquería palangrera japonesa.

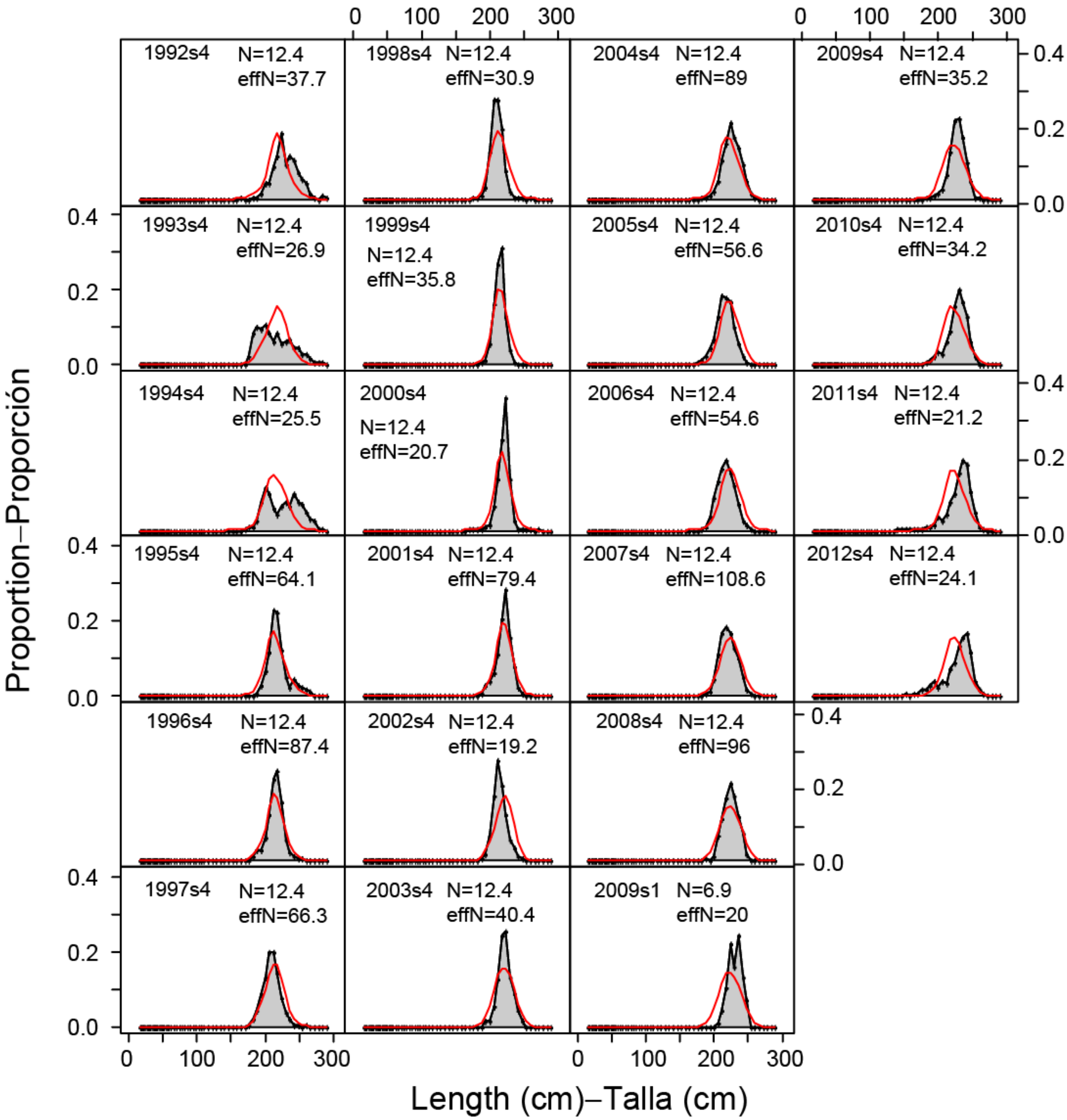

FIGURE 1d. Fit of the ISC stock assessment model to the Chinese Taipei longline length-composition data.

FIGURA 1d. Ajuste del modelo de evaluación del ISC a los datos de composición por talla de la pesquería palangrera de Taipei Chino.

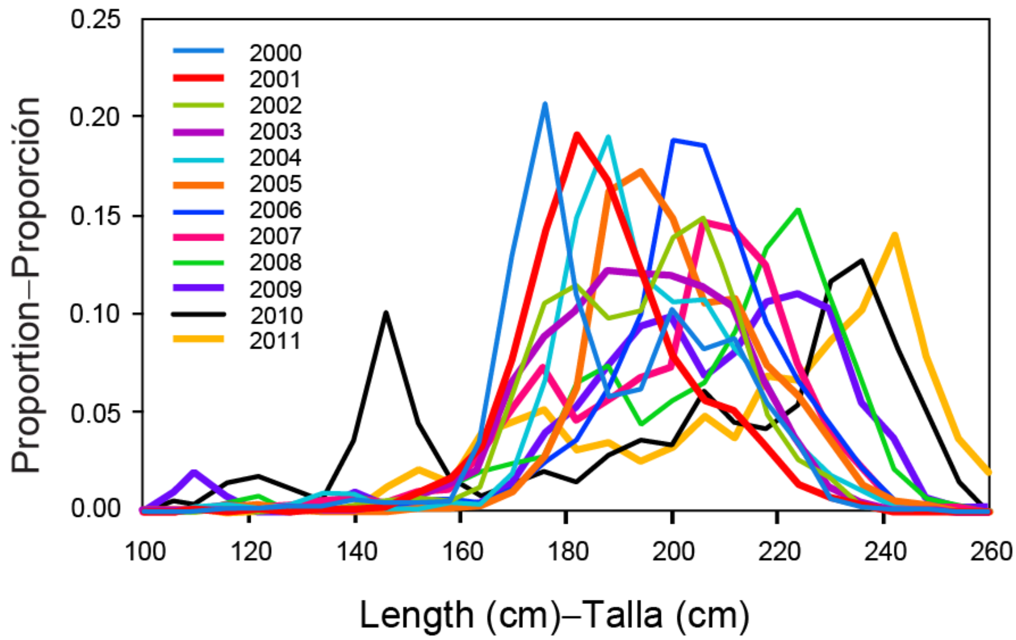

FIGURE 2. Japanese longline length-composition data, 2000-2011
FIGURA 2. Datos de composición por talla de la pesquería palangrera japonesa, 2000-2011.

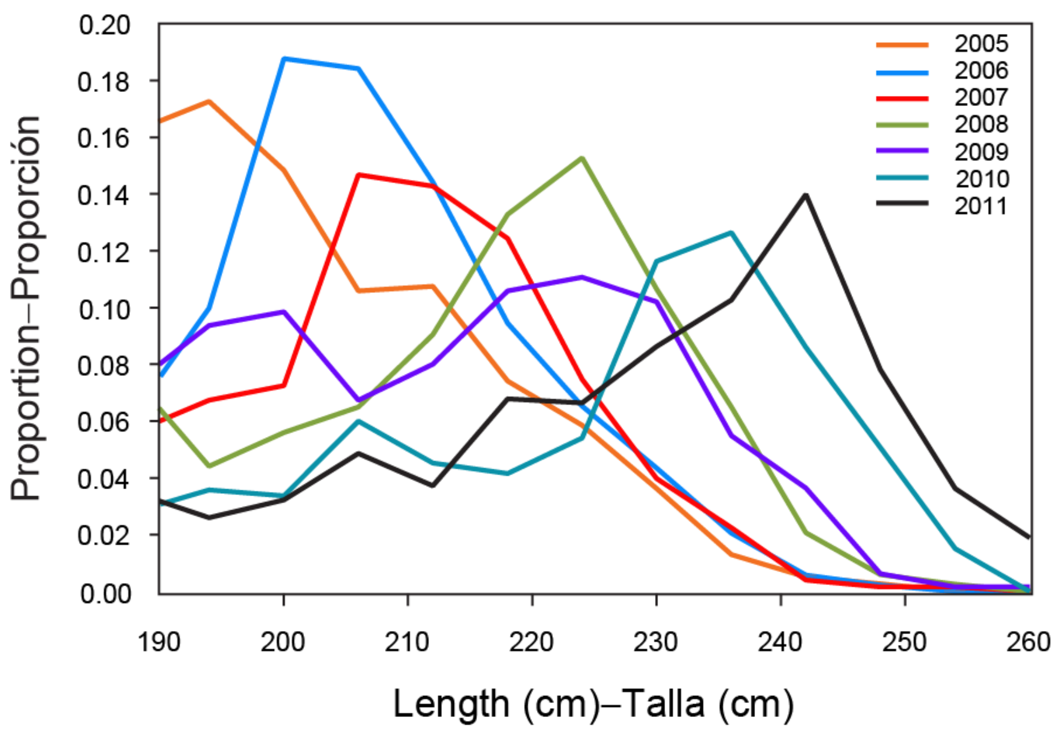

FIGURE 3. Japanese longline length-composition data, 2005-2011.
FIGURA 3. Datos de composición por talla de la pesquería palangrera japonesa, 2005-2011.

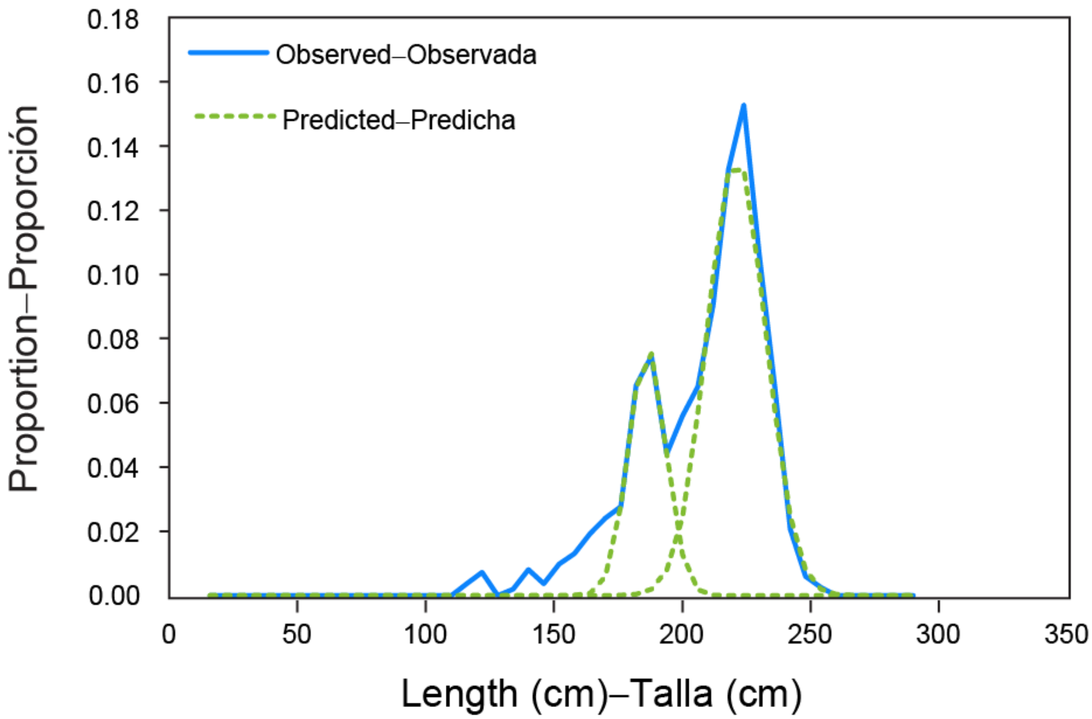

FIGURE 4. Fit of normal distributions to the 2008 Japanese longline length-composition data.
FIGURA 4. Ajuste de distribuciones normales a los datos de composición por talla de la pesquería palangrera japonesa de 2008.

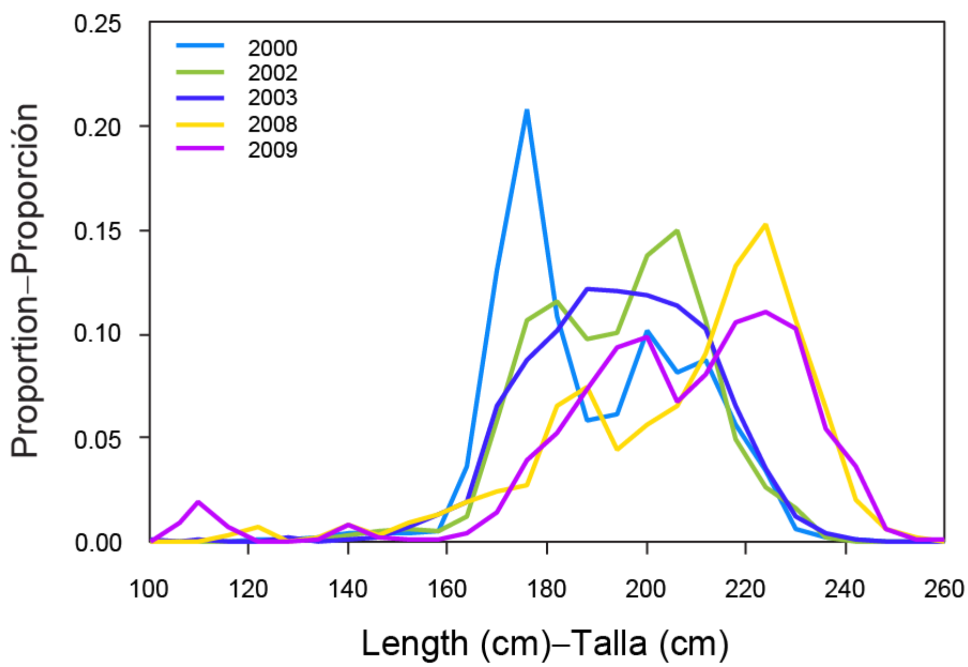

FIGURE 5. Japanese longline length-composition data that indicate multiple models.
FIGURA 5. Datos de composición por talla de la pesquería palangrera japonesa que indican modeles múltiples.

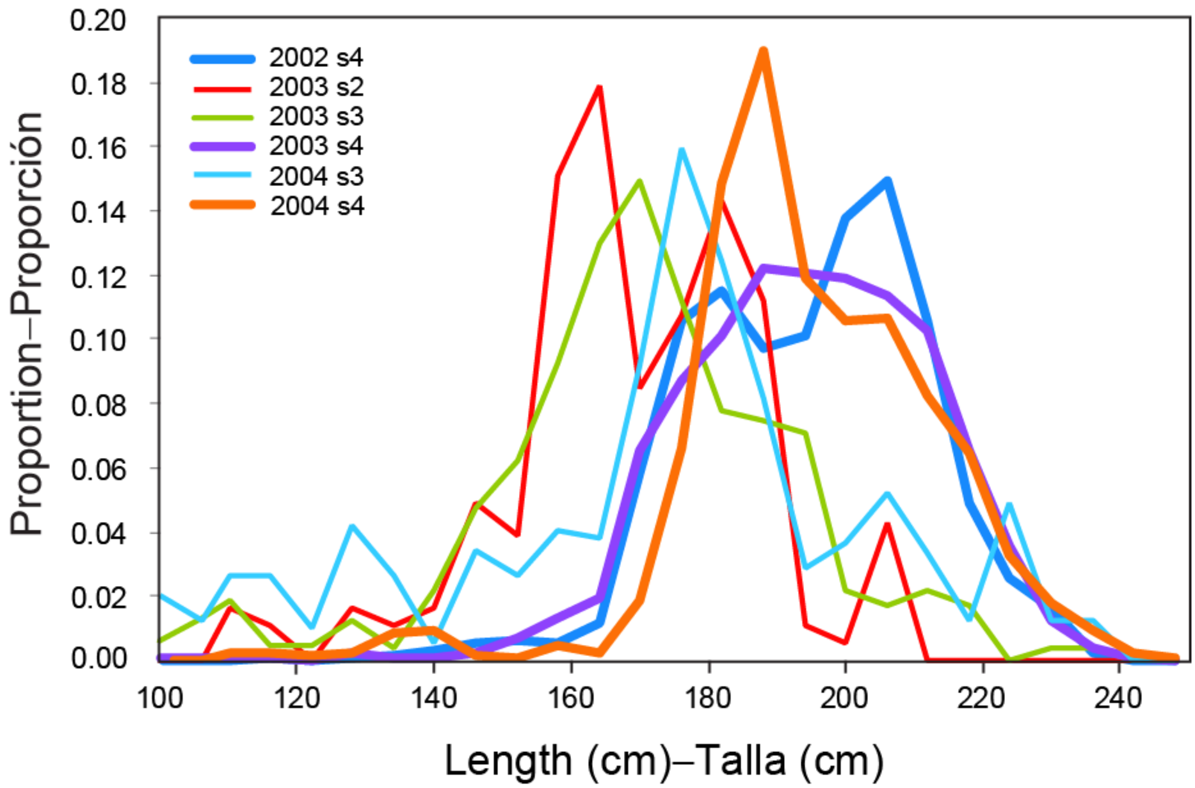

FIGURE 6. Japanese longline length-composition data for multiple seasons (s). The thick lines correspond to the the main fishing season (s4).

FIGURA 6. Datos de composición por talla de la pesquería palangrera japonesa de múltiples temporadas (s). Las líneas gruesas corresponden a la temporada principal de pesca (s4).

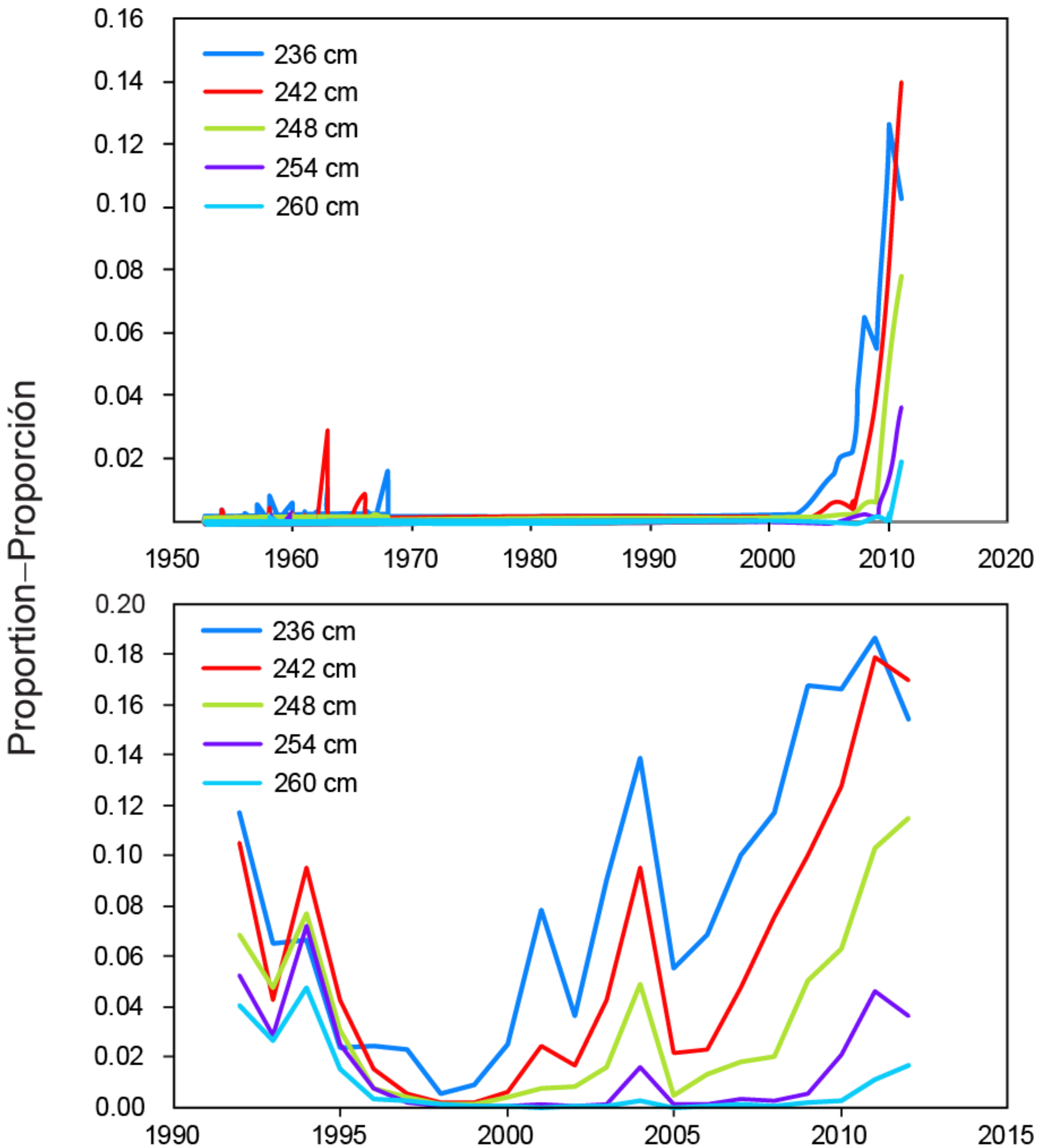

FIGURE 7. Proportions of the length-composition data at different lengths over time for the Japanese (upper panel) and Chinese Taipei (lower panel) longline fisheries.

FIGURA 7. Proporciones de los datos de composición por talla en distintas tallas a lo largo del tiempo correspondientes a las pesquerías palangreras de Japón (panel superior) y Taipei Chino (panel inferior).

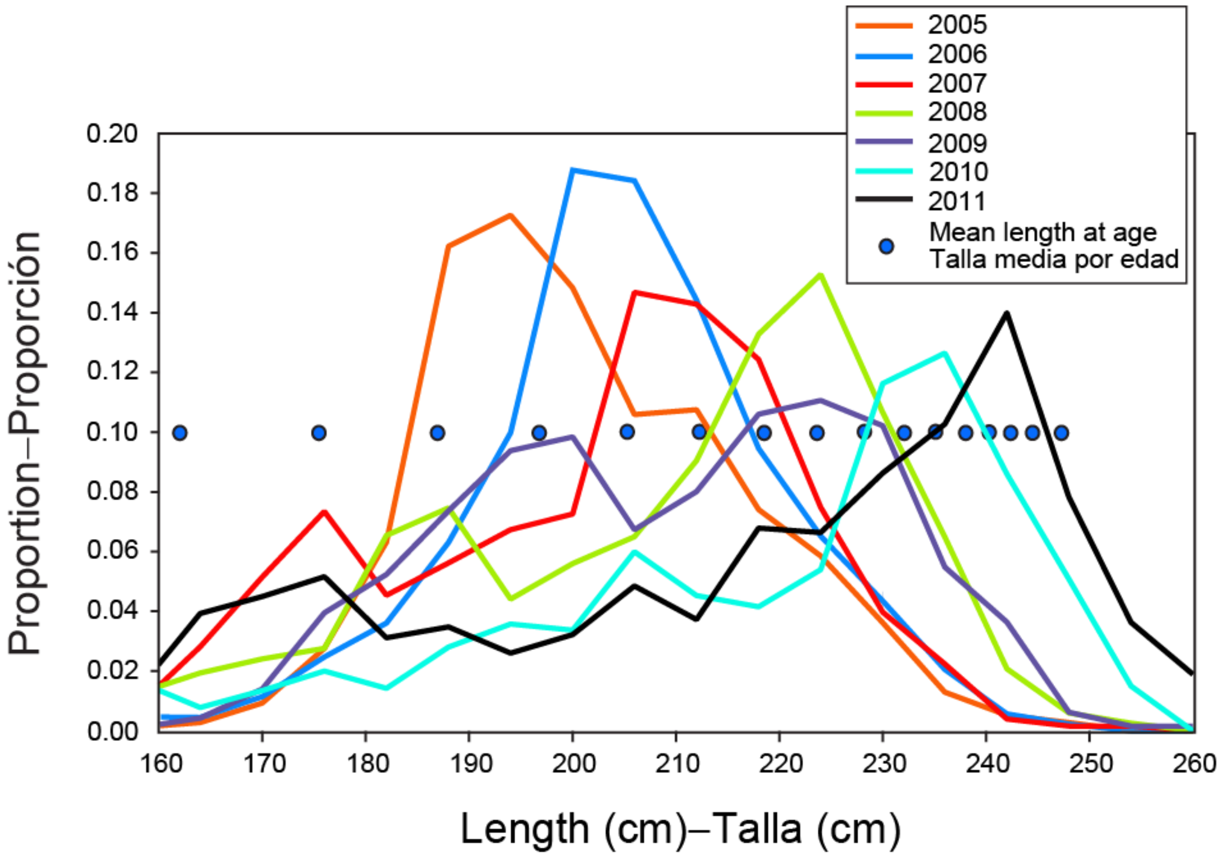

FIGURE 8. Comparison of mean length-at-age (dots) used in the ISC assessment model and the Japanese length-composition data.
FIGURA 8. Comparación de la talla media por edad (puntos) usada en el modelo de evaluación del ISC y los datos japoneses de composición por talla.

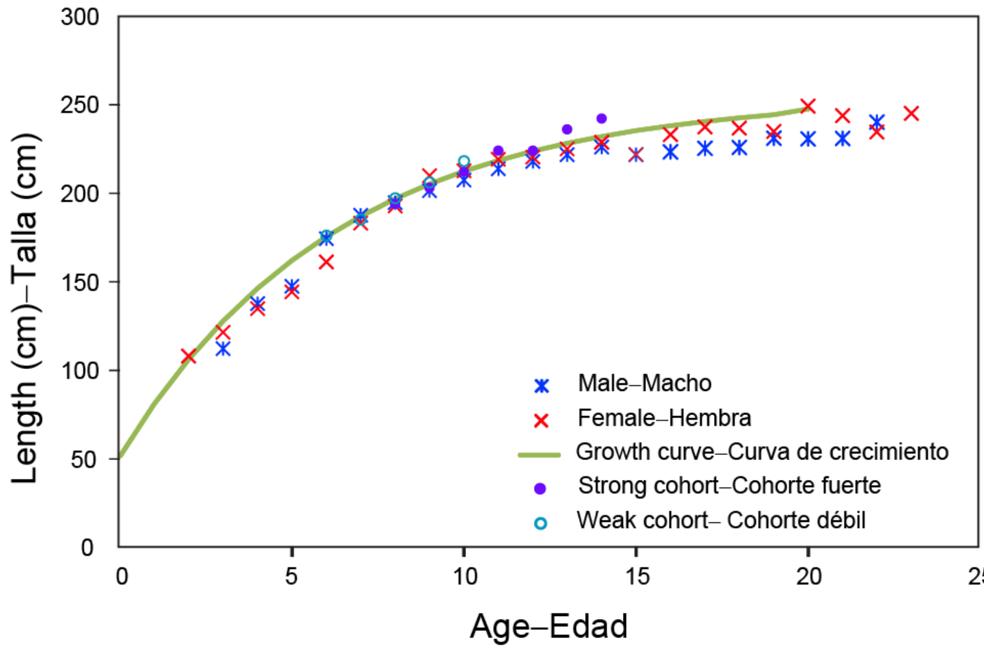

FIGURE 9. Comparison of mean length-at-age estimates for the strong and weak cohorts from the Japanese longline length-composition data, with the growth curve used in the ISC stock assessment model and sex-specific mean length-at-age from Shimose and Takeuchi (2012).
FIGURA 9. Comparación de las estimaciones de talla media por edad de las cohortes fuertes y débiles de los datos de composición por talla de la pesquería palangrera japonesa y la curva de crecimiento usada en el modelo de evaluación del ISC y la talla media por edad por sexo de Shimose y Takeuchi (2012).

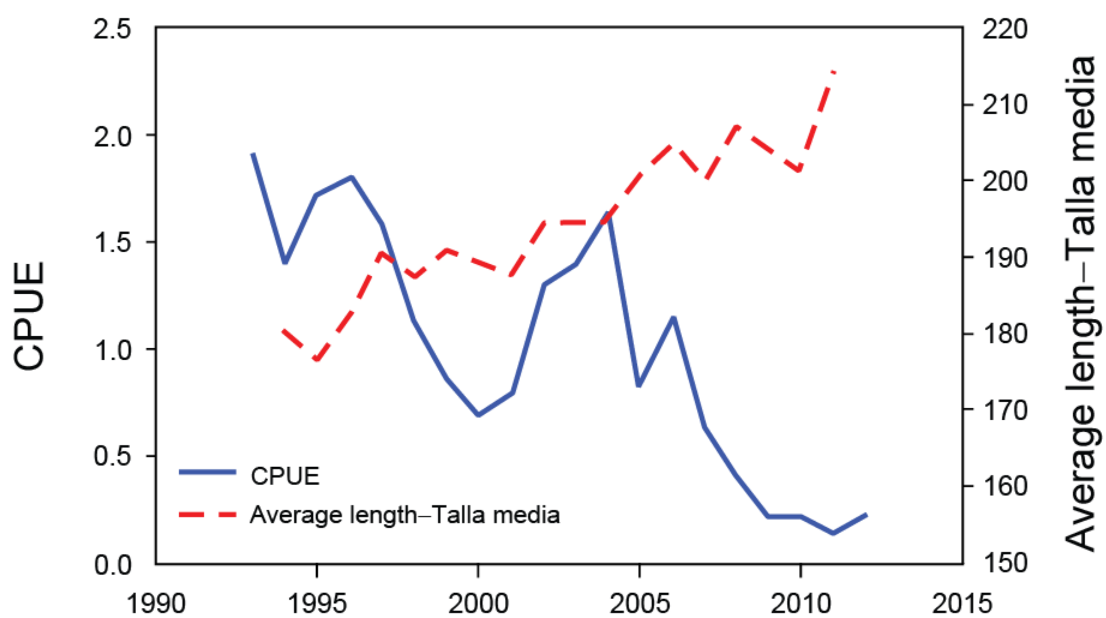

FIGURE 10. Comparison of mean length and CPUE from the Japanese longline fishery.
FIGURA 10. Comparación de talla media y CPUE de la pesquería palangrera japonesa.

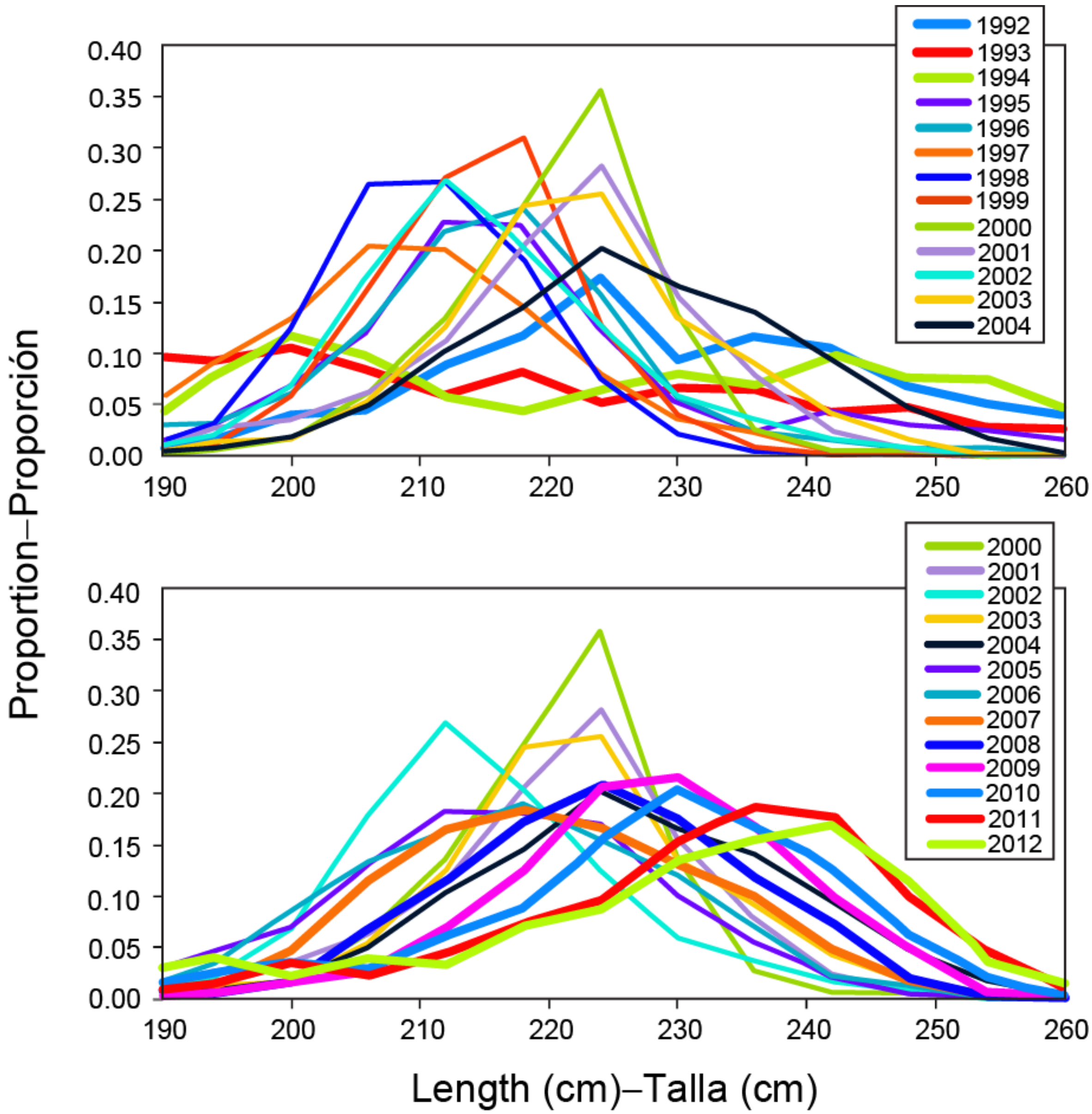

FIGURE 11. Length-composition data from the Chinese Taipei longline fishery. The thick lines represent early and late years that have large bluefin.

FIGURA 11 Datos de composición por talla de la pesquería palangrera de Taipei Chino. Las líneas gruesas representan años tempranos y tardíos que incluyen aleta azul grande.

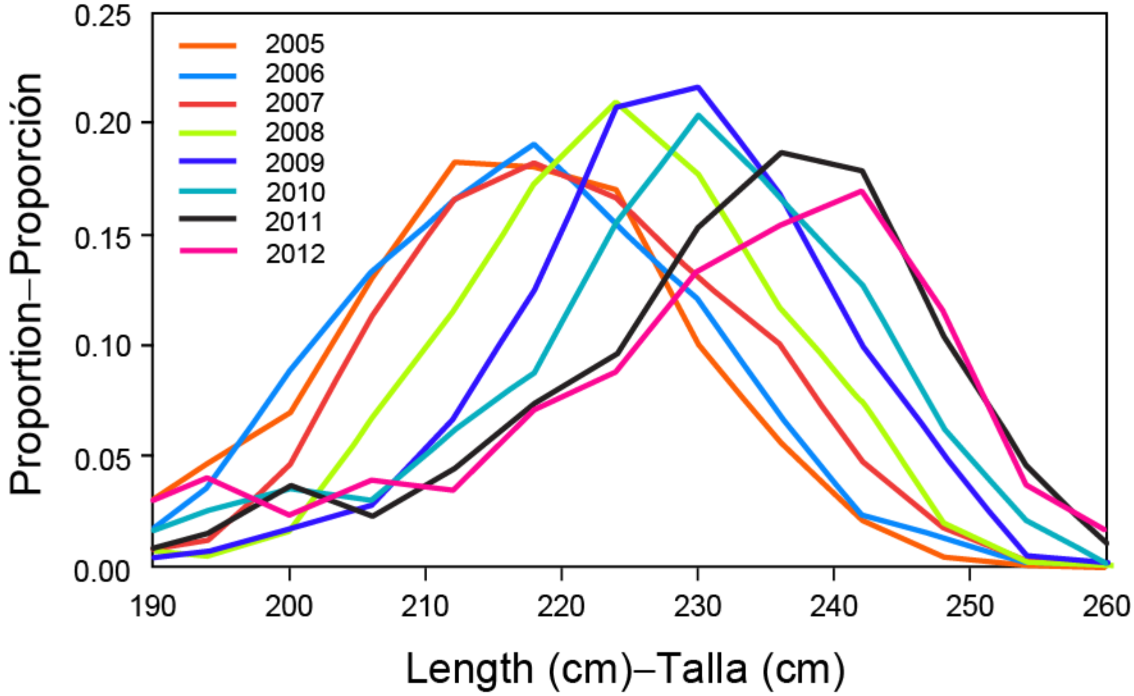

FIGURE 12. Chinese Taipei longline length-composition data, 2005-2012.
FIGURA 12. Datos de composición por talla de la pesquería palangrera de Taipei Chino, 2005-2011.

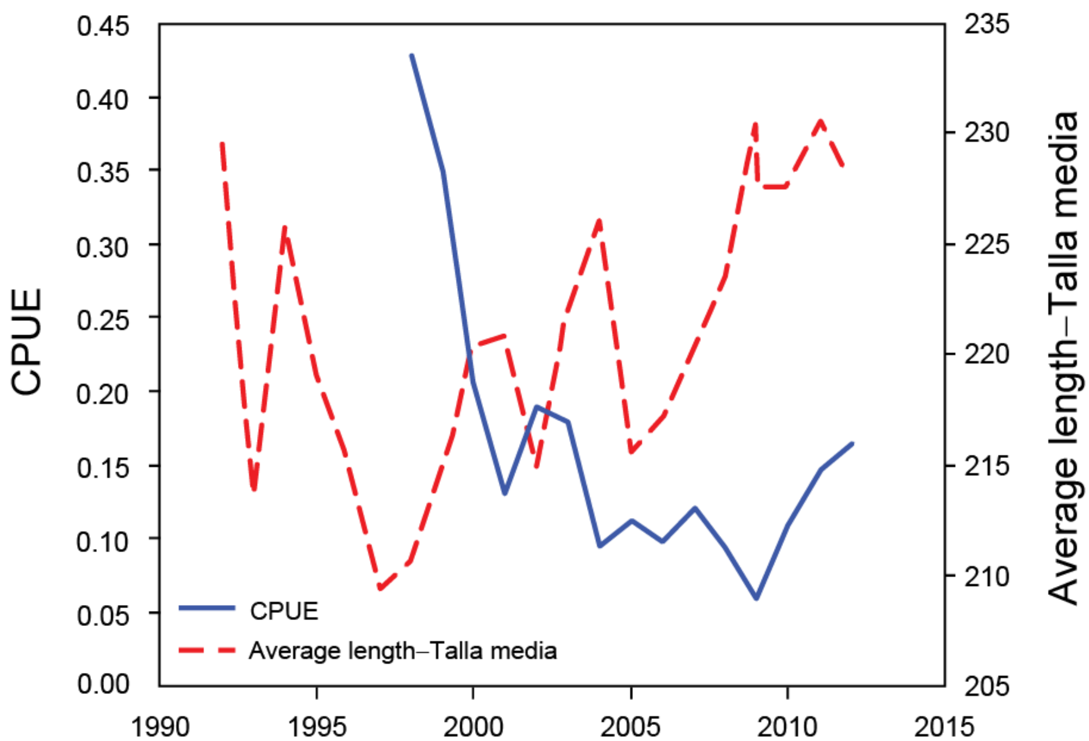

FIGURE 13. Comparison of mean length and CPUE from the Chinese Taipei longline fishery.
FIGURA 13. Comparación de talla media y CPUE de la pesquería palangrera de Taipei Chino.

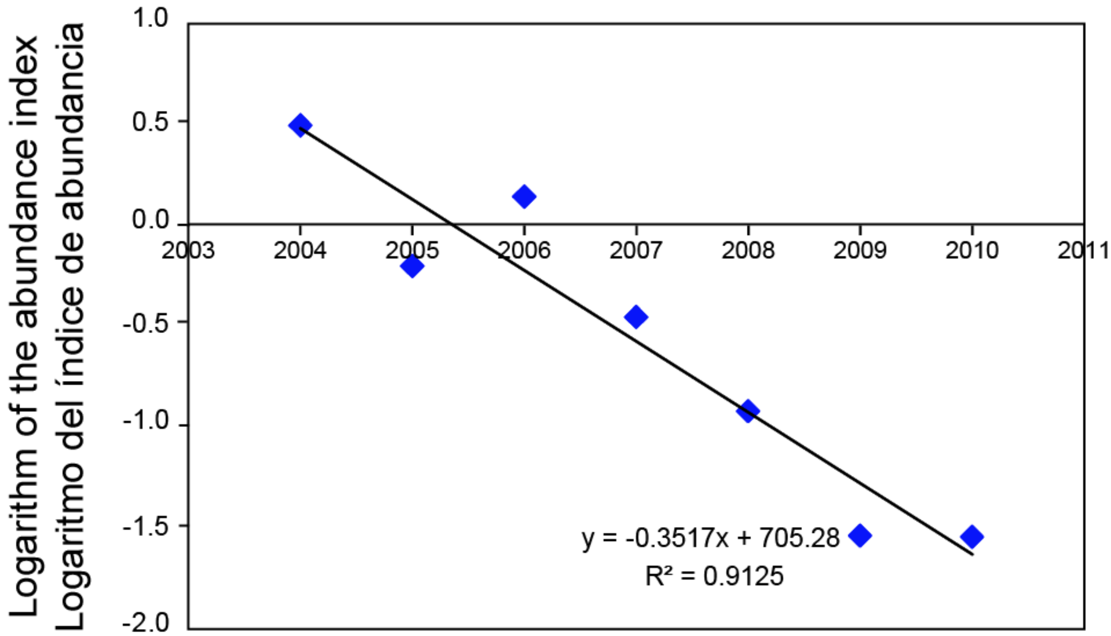

FIGURE 14. Catch curve analysis (log-linear regression) based on the Japanese longline CPUE index of relative abundance.
FIGURA 14. Análisis de curva de crecimiento (regresión logarítmica lineal) basado en el índice de abundancia relativa de la CPUE palangrera japonesa

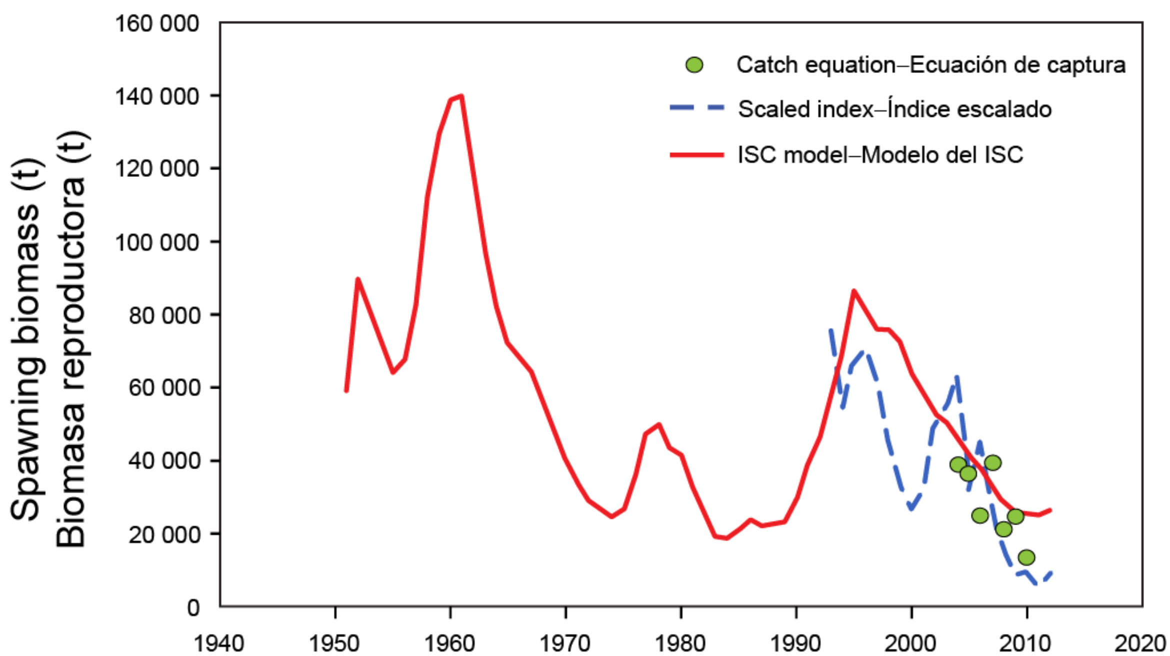

FIGURE 15. Comparison of the spawning biomass estimates from the catch equation with those of the scaled Japanese CPUE index and the estimates from the ISC stock assessment model.
FIGURA 15. Comparación de las estimaciones de biomasa reproductora de la ecuación de captura con aquellas de índice escalado de CPUE japonesa y las estimaciones del modelo de evaluación del ISC.

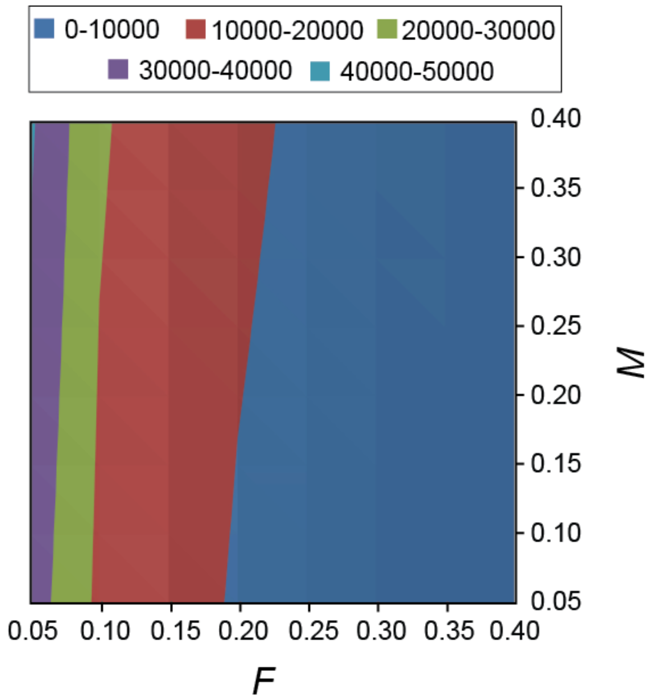

FIGURE 16. Contour plot of spawning biomass estimates, in metric tons, for different levels of longline fishing mortality (*F*) and natural mortality (*M*), based on average longline catch during 2008-2010.

FIGURA 16. Gráfica de contornos de estimaciones de biomasa reproductora, en toneladas, correspondientes a distintos niveles de mortalidad por pesca (*F*) palangrera y mortalidad natural (*M*), basadas en la captura palangrera media durante 2008-2010.

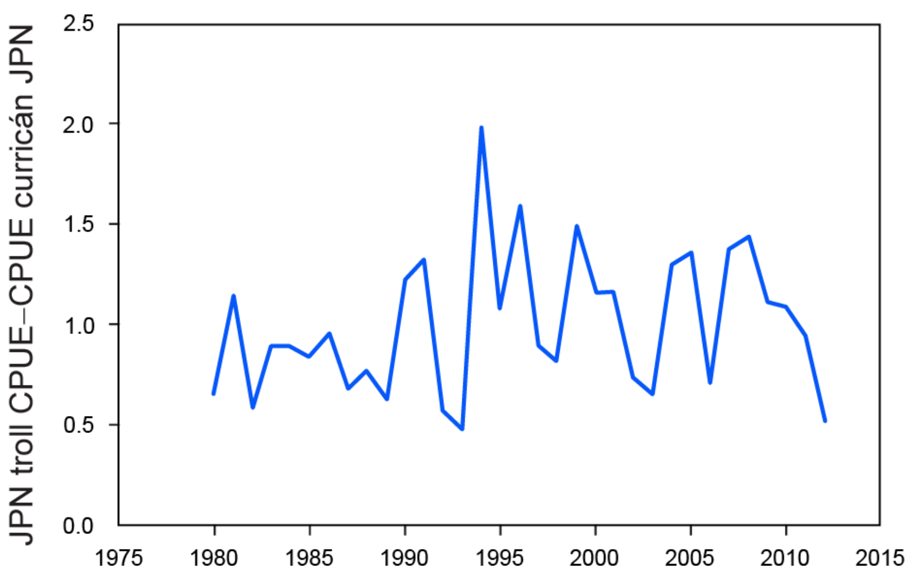

FIGURE 17. Index of relative recruitment of Pacific bluefin tuna based on the CPUE of the Japanese troll fishery.

FIGURA 17. Índice de reclutamiento relativo del atún aleta azul del Pacífico, basado en la CPUE de la pesquería japonesa con curricán.

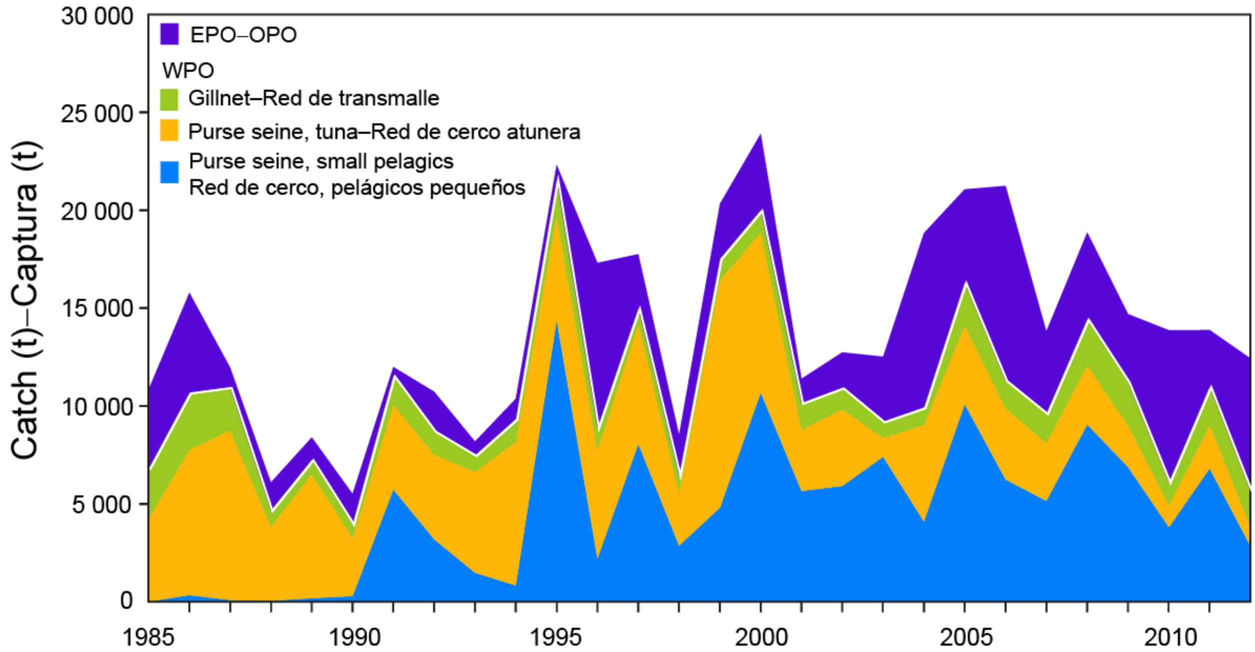

FIGURE 18. Catches by the main fisheries that catch juvenile Pacific bluefin tuna, 1985-2012.
FIGURA 18. Capturas de las las pesquerías principales que capturan atún aleta azul del Pacífico juvenil, 1985-2012.

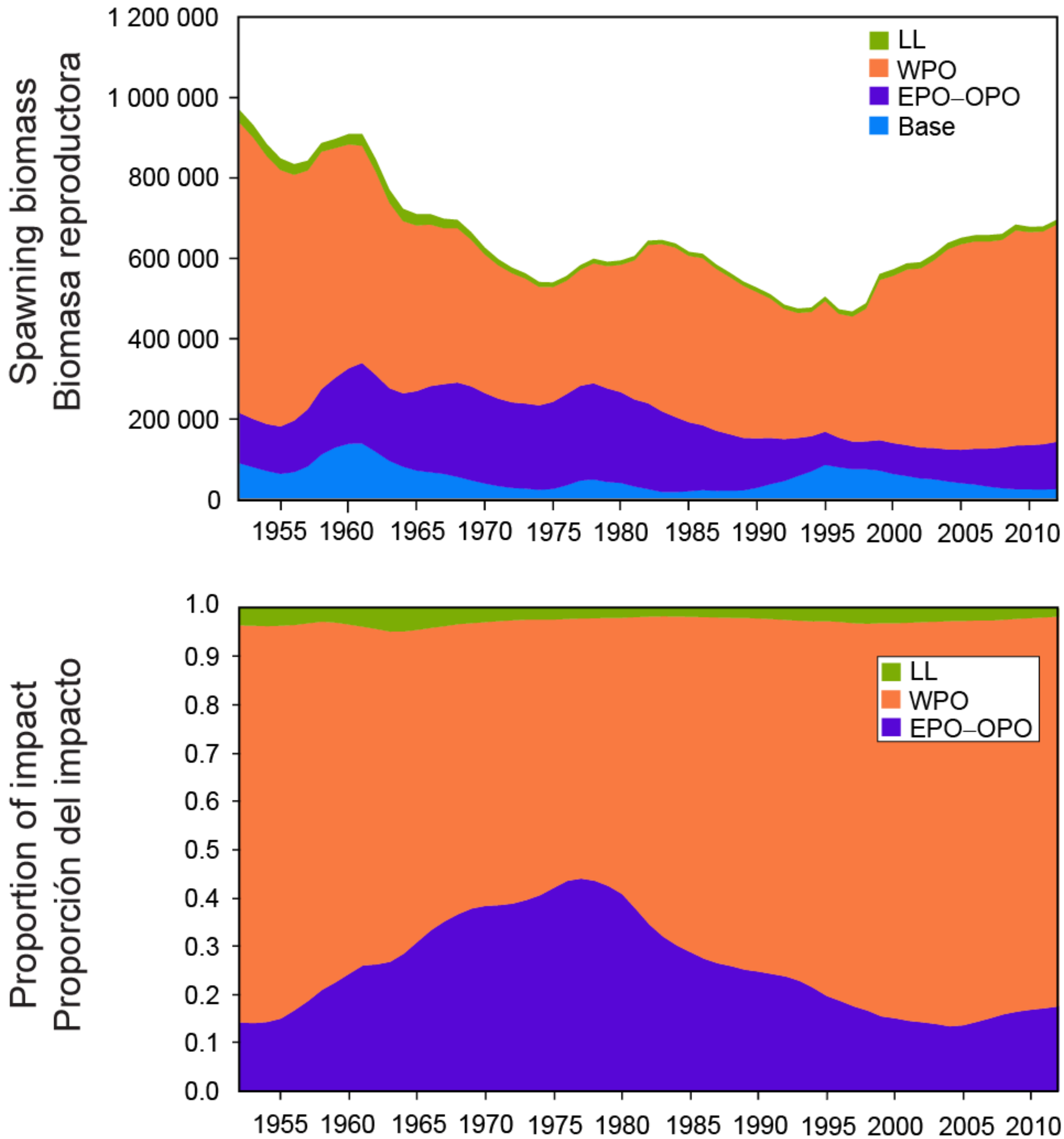

FIGURE 19. Impact of the longline (LL) fisheries, the WPO non-longline fisheries, and the EPO purse-seine and sport fisheries on the spawning biomass of Pacific bluefin tuna (upper panel), and their relative contribution to the fishery impact (lower panel), 1950-2013.

FIGURA 19. Impacto de las pesquerías palangreras (LL), las pesquerías no palangreras del Pacífico occidental (WPO), y las pesquerías de cerco y deportivas del OPO sobre la biomasa reproductora del atún aleta azul del Pacífico (panel superior), y su contribución relativa al impacto de la pesca (panel inferior), 1950-2013.

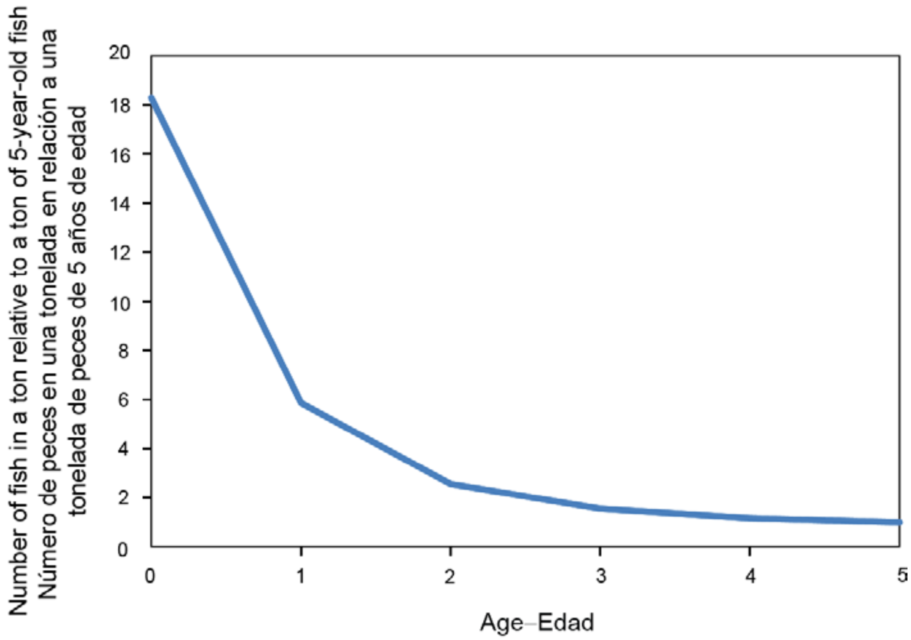

FIGURE 20. Relative impact on the spawning biomass of a catch of a ton of fish, by age.
FIGURA 20. Impacto relativo sobre la biomasa reproductora de la captura de una tonelada de pescado, por edad.

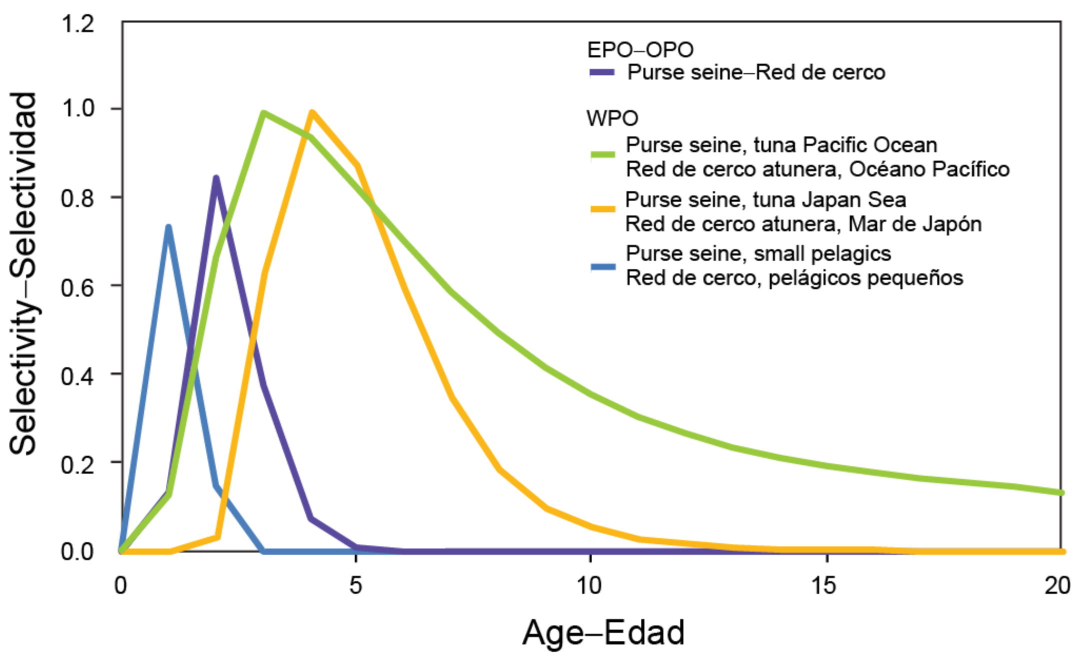

FIGURE 21. Estimated selectivity curves for the main fisheries that catch juvenile Pacific bluefin tuna.
FIGURA 21. Curvas de selectividad estimadas para las pesquerías principales que capturan atún aleta azul del Pacífico juvenil.