INTER-AMERICAN TROPICAL TUNA COMMISSION

SCIENTIFIC ADVISORY COMMITTEE

SEVENTH MEETING

La Jolla, California (USA)
09-13 May 2016

DOCUMENT SAC-07-05d
UPDATED ASSESSMENT AND MANAGEMENT OF PACIFIC BLUEFIN TUNA

Mark N. Maunder

1. ABSTRACT

A new assessment has been developed for Pacific bluefin tuna by the ISC bluefin tuna working group. The assessment is a substantial improvement over previous assessments, but the management implications are generally the same: the stock is at very low levels, and the fishing mortality is higher than any reasonable reference point. Substantial management action has already been taken on both sides of the Pacific Ocean to rebuild the population, and the assessment indicates that these actions are adequate. However, there are still some issues with respect to the adequacy of the model fit to the data and uncertainty about the relationship between recruitment and spawning stock size. Here we investigate the robustness of the assessment model results to these issues and discuss the management implications of the assessment results. Our alternative analysis, which starts in 1980, estimates growth, and has time-varying selectivity for the Japanese longline fishery, is more optimistic than the base case assessment but supports the general conclusion that the stock is at very low levels and the fishing mortality is higher than any reasonable reference point. The main concerns about the stock are (1) the extremely low levels of spawning biomass, (2) uncertainty about how recruitment is related to the spawning biomass, and (3) two out of the last three recruitments are at the lowest levels observed since 1980 according to the index of recruitment based on troll CPUE, which has been shown to be reliable. Therefore, it is recommended that further action be taken to protect the spawning population.

2. INTRODUCTION

Recent stock assessments of Pacific bluefin tuna (*Thunnus orientalis*) clearly indicate that the stock is at very low levels and the fishing mortality is higher than any reasonable reference point (ISC 2012, 2014; Maunder *et al.* 2014). Severe management action has been taken on both sides of the Pacific Ocean to rebuild the population. The previous assessments have been problematic and cannot be relied upon to predict rebuilding rates under the current management. However, all alternative models that were investigated also indicated that the stock is highly depleted. Therefore, the International Scientific Committee (ISC) working group produced an improved assessment model (ISC 2016, executive summary), which is much better than the previous models, but still has some problems that might impact the rebuilding predictions. Here we investigate the robustness of the assessment model results to these issues. We also discuss the management implications of the current assessment.

3. ASSESSMENT

The Pacific bluefin tuna assessment is conducted using the Stock Synthesis software (Methot and Wetzel 2013), which implements the integrated modelling approach (Maunder and Punt 2013) and fits to indices of relative abundance based on catch-per-unit-of-effort (CPUE) and length-composition data from various fisheries. Previous assessments produced poor fits to many of the data sets, but a large range of model assumptions produced similar results, indicating that the stock is at very low levels and the fishing mortality is higher than any reasonable reference points (ISC 2012, 2014; Maunder *et al.* 2014). The new assessment (ISC 2016, executive summary) improved the fits to many of the data sets, but fits to some of the key data sets were still problematic. In particular, the base case assessment model is unable to fit the increase in CPUE of the Japanese longline fishery starting in 2002 (Figure 1) nor the recent length-composition data (Figure 2) from this fishery.

We first investigate the stock assessment by looking at the longline length-composition data. This analysis updates that of Maunder *et al.* (2014). Interpretation of length-frequency data is problematic because of temporal variation in growth and selectivity, and the fact that the length compositions from consecutive cohorts merge together as the fish age. Therefore, the observations below are only an indication of what might be occurring in the fishery. Despite these limitations, the observations might provide insight into how the stock should be modelled for assessment purposes. Figures 3 and 4 show the length-composition data from the Japanese and Chinese Taipei longline fisheries, respectively. The Japanese fleet generally catches smaller fish than the Chinese Taipei fleet, and multiple modes, presumably representing cohorts of same-age fish, can be seen in the Japanese data. The Chinese Taipei data are generally only comprised of a single mode, except in the last few years, when a second mode can be seen entering the fishery. A strong cohort can be seen entering the Japanese fishery, starting in 2000 and growing through the fishery. However, after 2002 the peak of the mode representing this cohort no longer grows, indicating that either the cohort stops growing, or is no longer selected by the fishery, or is overwhelmed by younger cohorts. From 2002 to 2005, the standard deviation of the normal distribution representing the cohort increases from 8.8 cm to 15.0 cm, indicating that the normal distribution may be representing an increasing number of cohorts. A cohort can be seen moving through the Chinese Taipei longline data starting in 2002, at a size slightly larger than that seen in the Japanese longline data in the same year. However, the mean of the normal distribution representing this cohort does not increase after 2004. A second strong cohort appears to enter the Japanese longline fishery starting in 2002, with a mode at about 176 cm, and may be accompanied by another cohort in 2003, recruited at about the same size of 176 cm. These cohorts appear to grow through the fishery all the way until the last year of data in 2012, with a mode at about 235 cm. A strong cohort can be seen moving through the Chinese Taipei fishery, starting in 2006 at a slightly larger size (217 cm) than seen in the Japanese fishery (207 cm) in the same year. However, the mode in 2012 is about the same for both fisheries. Other cohorts can be seen entering the Japanese fishery in recent years, including 2007 and 2010. A strong cohort can be seen in the Chinese Taipei fishery in 2014, but it is not clear whether this is the same cohort seen entering the Japanese fishery in 2010.

The large cohorts enter the Japanese longline fishery at around 176 cm, or about six years of age. Mapping the fish back to their year of birth, the strong cohorts of 2000, 2002, and 2003 relate to years of birth of 1994, 1996, and 1997, respectively. The recruitment index shows strong recruitments in 1994 and 1996, but not in 1997 (Figure 5). Interestingly, the 1996 cohort that is most strongly seen in the longline composition data is not estimated to be as high as the recruitment index indicates.

The stock assessment model does not fit a consecutive series of years with increasing Japanese CPUE (Figure 1). This increase starts in 2002, at about the time that the second strong cohort enters the Japanese fishery, and the mode of the first strong cohort does not appear to increase. Japanese CPUE fell sharply in 2006, and the CPUE generally declines after that. The drop occurs when the large cohort reaches the 206 cm size, which is the upper range of the sizes observed in the data from 1993[1] to 2006. This may indicate a complete change in the way the fishery operates. It appears that the Japanese fleet targets

[1] Length-composition data for 1969-1992 from the Japanese longline fleet were not used in the model

strong cohorts, and will switch from one strong cohort to another, presumably due to economic considerations (*e.g*., catch rates and distance to port). The length composition suggests that the Japanese fleet initially targeted the strong cohort that entered the fishery in 2000, but then changed to target the next one (or two) strong cohort(s) that entered the fishery in 2002 (and 2003), but since there were no subsequent strong cohorts, they continued targeting that cohort until 2011. Cohort targeting implies that the stock assessment model selectivity (a combination of gear selectivity and availability) changes over time, and therefore these observations suggest that the stock assessment model should include temporal variation in selectivity for the Japanese longline fishery. This is problematic, because the selectivity is associated with the main index of abundance, and adding temporal variation in selectivity will reduce the information content of the index. The ISC Working Group did conduct an assessment with time varying selectivity for the Japanese longline fishery, but it did not choose it as its base case assessment model, but rather chose to present it as a sensitivity analysis. This analysis provided better fits to the Japanese longline CPUE based index of abundance.

There are several other issues with the base case assessment. First, several changes occurred around 1980: the proportion of the bluefin catch that was taken in the EPO fell, the recruitment index based on the CPUE of the troll fishery started, the Japanese longline-CPUE-based index of abundance used in the assessment was split in 1975, and there are few reliable length-composition data available from the 1970s and 1980s. Therefore, a model starting in 1980 might be more reliable. Second, the model still has trouble fitting the Japanese longline length-composition data, even with time-varying selectivity, and this may be due to misspecified growth in the model. Therefore, estimating the growth parameters and the variation of length-at-age parameters might improve the model fit. We ran a model (the "alternative" model) that includes these changes and also models temporal variation in the Japanese longline fishery selectivity and compares it with the "base case" model results to evaluate the robustness of the management advice. The alternative model is able to fit the increase in Japanese longline CPUE that starts in 2002 (Figure 6) and generally fits the Japanese longline length composition better (Figure 7). The general trend in spawning biomass is about the same as the base case, except for a larger initial decline starting in 1980, but the depletion level is less, although the stock is estimated to still be highly depleted (Figure 8). The recruitment estimates are very similar, with the alternative assessment estimating slightly higher recruitment in some years (Figure 5). The age structure in 2014 differs somewhat from the base case, with higher abundance for all fish 6 years or more of age (Figure 9). The final age structure is important, because those ages will contribute to future spawning biomass.

4. MANAGEMENT

The IATTC does not have any management reference points for Pacific bluefin tuna, but the Northern Committee of the Western and Central Pacific Fisheries Commission (WCPFC) does have a rebuilding target (interpreted by the ISC bluefin working group as a 60% probability of reaching the medium spawning biomass over the period covered by the assessment model (SSB_{MED}), as estimated in the current assessment, by 2024). The new base case assessment projects that the population will rebuild to the Northern Committee's target level within the required probability level even with low recruitments. However, the estimates of biomass in the early years used to calculate the rebuilding targetare uncertain and may be biased. The alternative assessment has higher abundance for 2014 and higher recruitment and, if projections are conducted, they are expected to be more optimistic in terms of future absolute biomass. The alternative assessment starts in 1980, so the SSB_{MED} reference point refers to a different range of years, and since biomass prior to 1980 was higher, SSB_{MED} for the alternative model is expected to be lower than the base case, resulting in a high probability of recovering to SSB_{MED}.

The low recruitment projection scenario is the most pessimistic, more so than even the stock-recruitment scenario. However, there is little information about the stock-recruitment relationship; in fact, there is little evidence for such a relationship for any highly fecund pelagic spawner. Even if a stock-recruitment relationship exists, it is probably more complex than represented by the commonly-used Beverton-Holt and Ricker models. The spatial and temporal range of spawning is probably more important than the absolute abundance of spawners, as argued by Maunder and Deriso (2013). Therefore, it is uncertain at what spawning population level the recruitment of north Pacific bluefin might decline, and it may vary depending on the environmental conditions.

The troll-CPUE-based index of recruitment used in the model appears to represent recruitment strength well. Even when it is not included in the fitting procedure (*i.e*. not included in the total likelihood function used to estimate the model parameters), the estimates of recruitment generally follow it (Figure 10). This indicates that the index is consistent with information in the other data used in the assessment model. Two of the last three recruitment index values are at the lowest levels seen since the index started in 1980. There are some differences in the most recent years for which the assessment model may be less accurate because they are based on less years (ages) of data. If we consider the recruit estimate by the model, 2014 would be the lowest and 2012 will be the 5th lowest since 1980. This low recruitment is a concern, and suggests that the spawning biomass and the spatial and temporal range of spawning should be further protected.

Management has focused on reducing the catches by fisheries for juveniles because they are estimated to have the greatest impact on the stock. However, including a stock-recruitment relationship in the model increases the impact of the fisheries on spawners (Maunder and Aires-da-Silva 2014). This is further evidence that protecting the spawning stock is important. However, the projections using a stock-recruitment relationship, with a steepness of 0.9, were not necessarily more pessimistic than the low-recruitment scenario.

5. CONCLUSION

The finding that the north Pacific bluefin stock is at very low levels and the fishing mortality is higher than any reasonable reference point is robust to model assumptions, and support previous findings (ISC 2012, 2014; Maunder *et al.* 2014). The stock is projected to rebuild under current management actions (ISC 2016, Executive summary). However, due to uncertainty in how recruitment is related to the spawning stock size and when recruitment might be impacted by the low spawning abundance level, there is concern over the low abundance of spawners. This is exacerbated by the limited number of cohorts that comprise the spawning biomass. Therefore, it is recommended that further action be taken to protect the spawning population, as recommended by Maunder and Aires-da-Silva (2014).

The interpretation of the Japanese longline length-composition data presented here differs somewhat from that described in Maunder *et al.* (2014), who identified a single cohort entering the fishery in 2000 and moving through the fishery. Here, we identify not only that cohort but also one (or two) cohort(s) entering the fishery in 2002 (and 2003) that comprise most of the Japanese longline catch in subsequent years. However, the interpretation that the spawning biomass is supported by one or a few cohorts remains, and protecting the spawners should be a priority.

Further work needs to be done to improve the stock assessment. A priority is evaluating the targeting of specific cohorts by the longline fisheries. This may involve analyzing the data at finer spatial scales; for example, spatial separation of Chinese Taipei longline data made them more compatible with the other data. Temporal variation in growth may be another important area for further research, particularly since cohorts seen in the Chinese Taipei longline length-composition data appear to reach different maximum lengths, although this also could be caused by targeting specific cohorts.

6. 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. Shuya Nakatsuka provided comments that improved the report.

7. REFERENCES

ISC (International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean) 2012. Stock assessment of Pacific bluefin tuna in 2012. Pacific Bluefin Tuna Working Group. http://isc.fra.go.jp/pdf/Stock_assessment/PBF_stock_assessment_report_2012.pdf

ISC (International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean) 2014. Stock assessment of bluefin tuna in the Pacific Ocean in 2014. Report of the Pacific Bluefin Tuna Working Group http://isc.fra.go.jp/pdf/2014_Intercessional/Annex4_Pacific%20Bluefin%20Assmt%20Report%202014-%20June1-Final-Posting.pdf

Maunder, M.N. and Aires-da-Silva, A. 2014. Developing conservation measures for bluefin tuna in the eastern and western regions of the Pacific Ocean: factors to consider and fishery impact analysis. IATTC Stock Assessment Report 15: 74-99.

Maunder, M.N. and Deriso, R.B (2013) A stock–recruitment model for highly fecund species based on temporal and spatial extent of spawning. Fisheries Research, 146: 96–101.

Maunder, M.N. Piner, K.R., and Aires-da-Silva, A. 2014. Stock status of Pacific bluefin tuna and the urgent need for management action. IATTC Stock Assessment Report 15: 47-73.

Maunder, M.N. and Punt A.E. (2013) A review of integrated analysis in fisheries stock assessment. Fisheries Research 142: 61– 74.

Methot, R. D., and Wetzel, C. 2013. Stock Synthesis: a biological and statistical framework for fish stock assessment and fishery management. Fisheries Research, 142: 86–99.

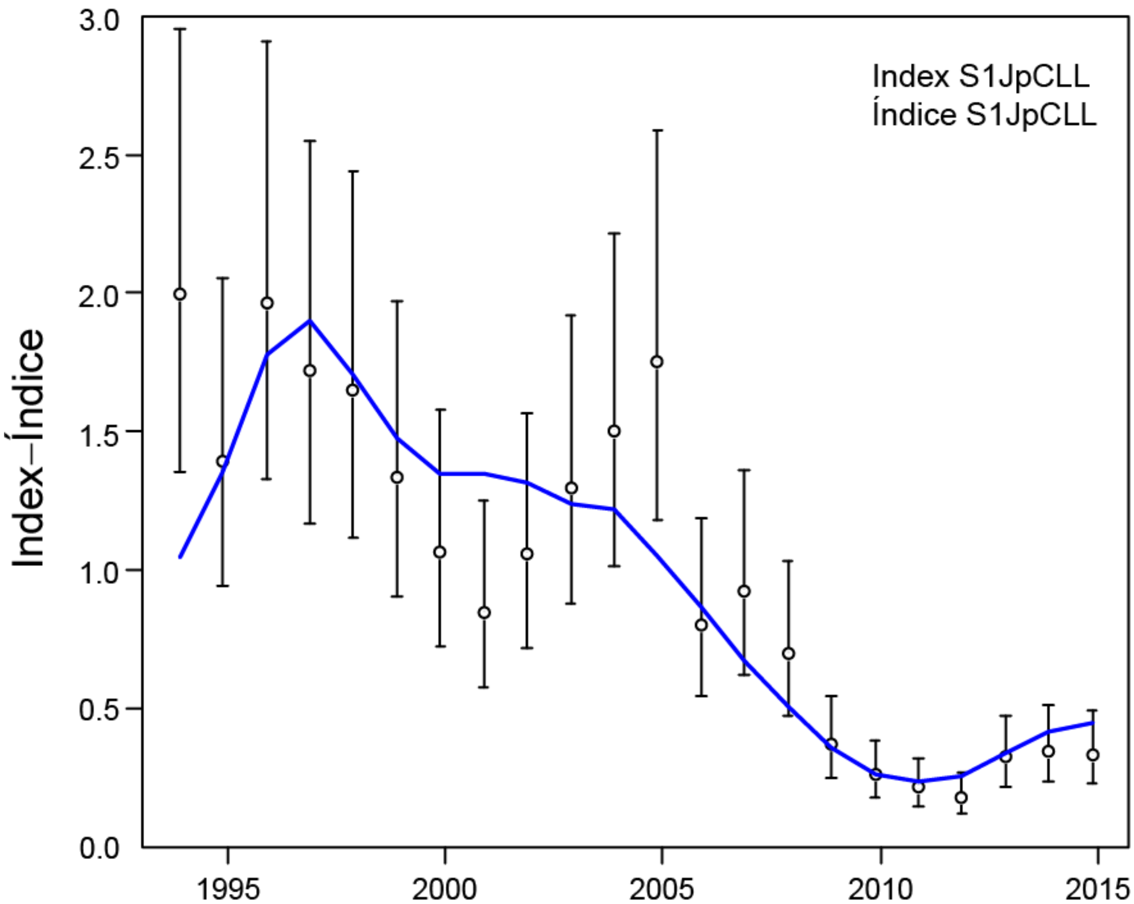

FIGURE 1. Fit of the base-case model to the index of abundance based on Japanese longline CPUE, 1994-2015.
FIGURA 1. Ajuste del modelo de caso base al índice de abundancia basado en la CPUE palangrera japonesa, 1994-2015.

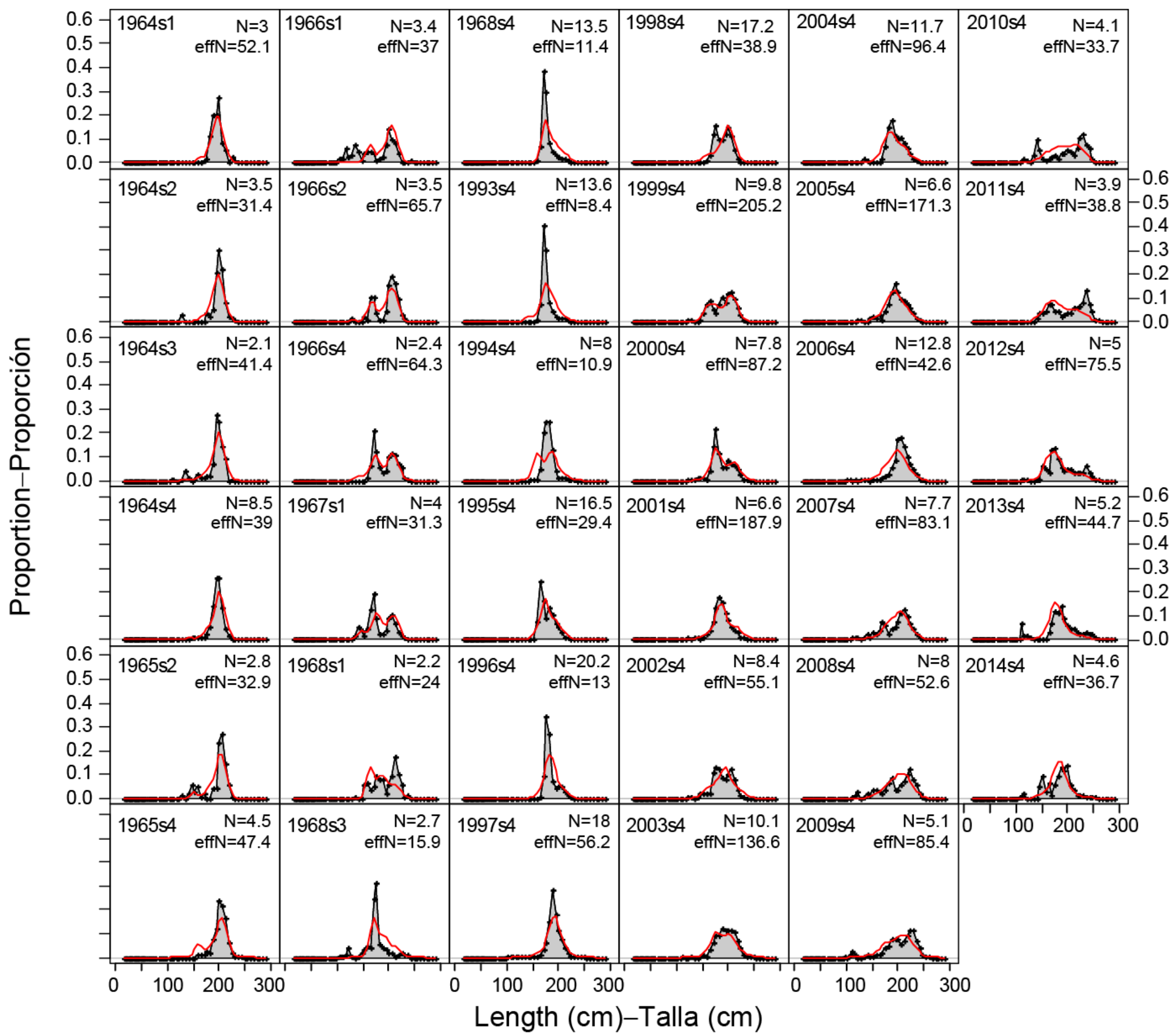

FIGURE 2. Fit of the base-case model to the Japanese longline length-composition data for selected years. s = quarter.

FIGURA 2. Ajuste del modelo de caso base a los datos de composición por talla de la pesquería palangrera japonesa, en años seleccionadas. s = trimestre.

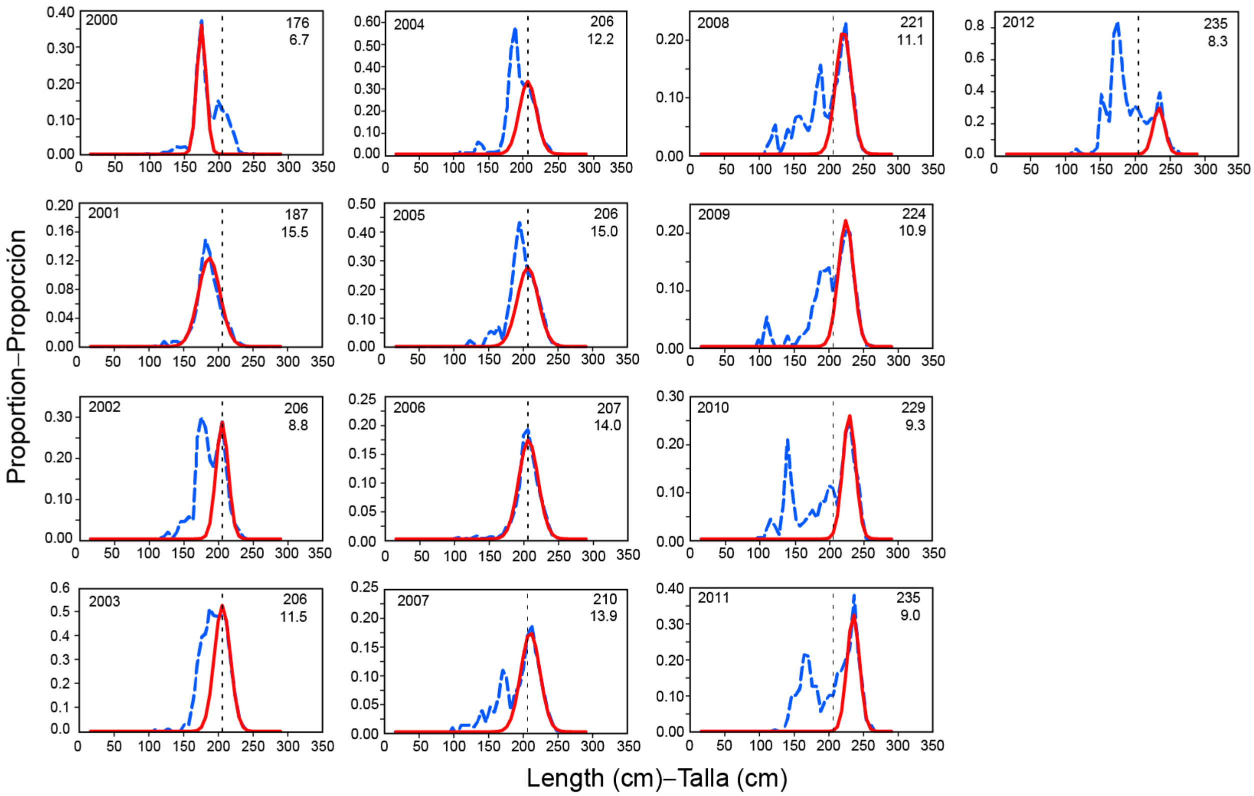

FIGURE 3. Japanese longline length-composition data for 2000-2012. The dashed line represents the observed length compositions; the solid line is a normal distribution fitted to a component of the data; and the numbers in the top right corner are the mean and standard deviation of the normal distribution. The vertical dashed line is at 206 cm.

FIGURA 3. Datos de composición por talla de la pesquería palangrera japonesa, 2000-2012. La línea de trazos representa las composiciones por talla observadas; la línea sólida es una distribución normal ajustada a un componente de los datos; y los números en la esquina superior derecha son el promedio y la desviación estándar de la distribución normal. Ea línea de trazos vertical se encuentra en 206 cm.

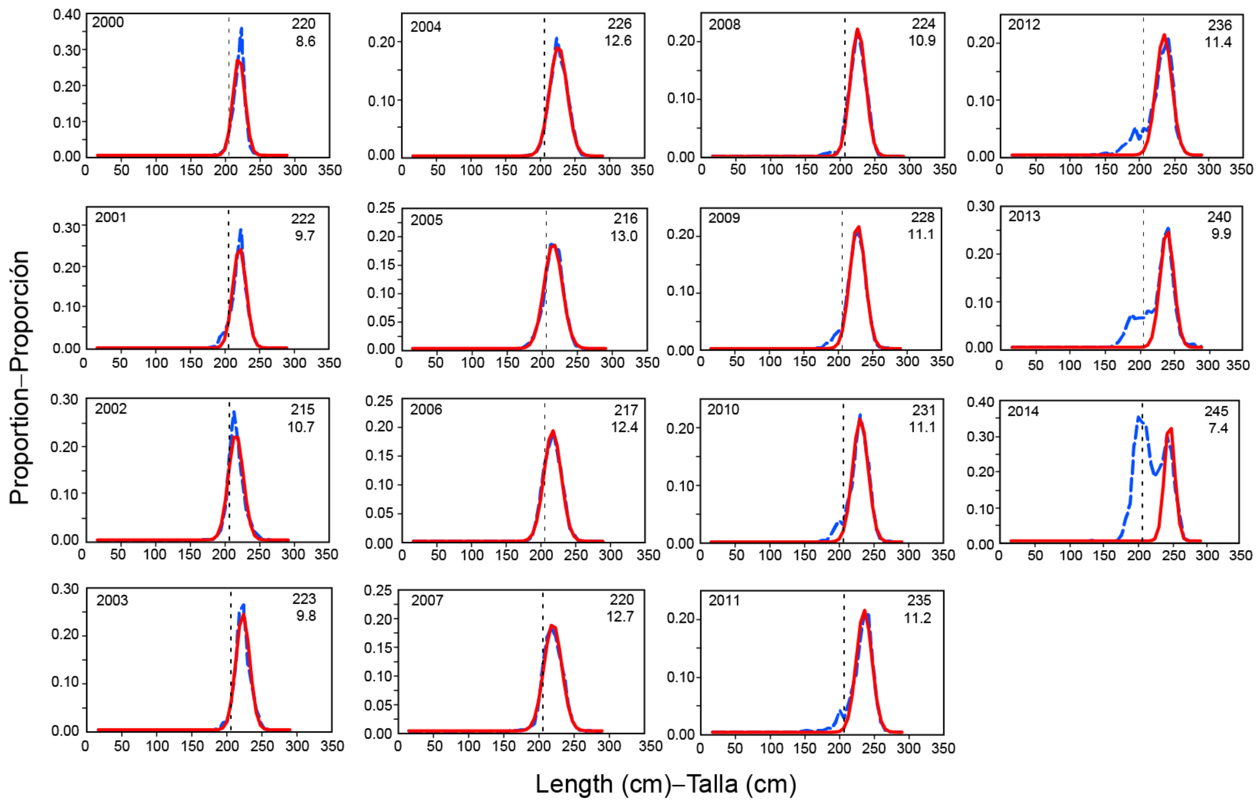

FIGURE 4. Chinese Taipei longline length composition data for 2000-2012. The dashed line represents the observed length compositions; the solid line is a normal distribution fitted to a component of the data; and the numbers in the top right corner are the mean and standard deviation of the normal distribution. The vertical dashed line is at 206 cm.

FIGURA 4. Datos de composición por talla de la pesquería palangrera de Taipei Chino, 2000-2012. La línea de trazos representa las composiciones por talla observadas; la línea sólida es una distribución normal ajustada a un componente de los datos; y los números en la esquina superior derecha son el promedio y la desviación estándar de la distribución normal. Ea línea de trazos vertical se encuentra en 206 cm.

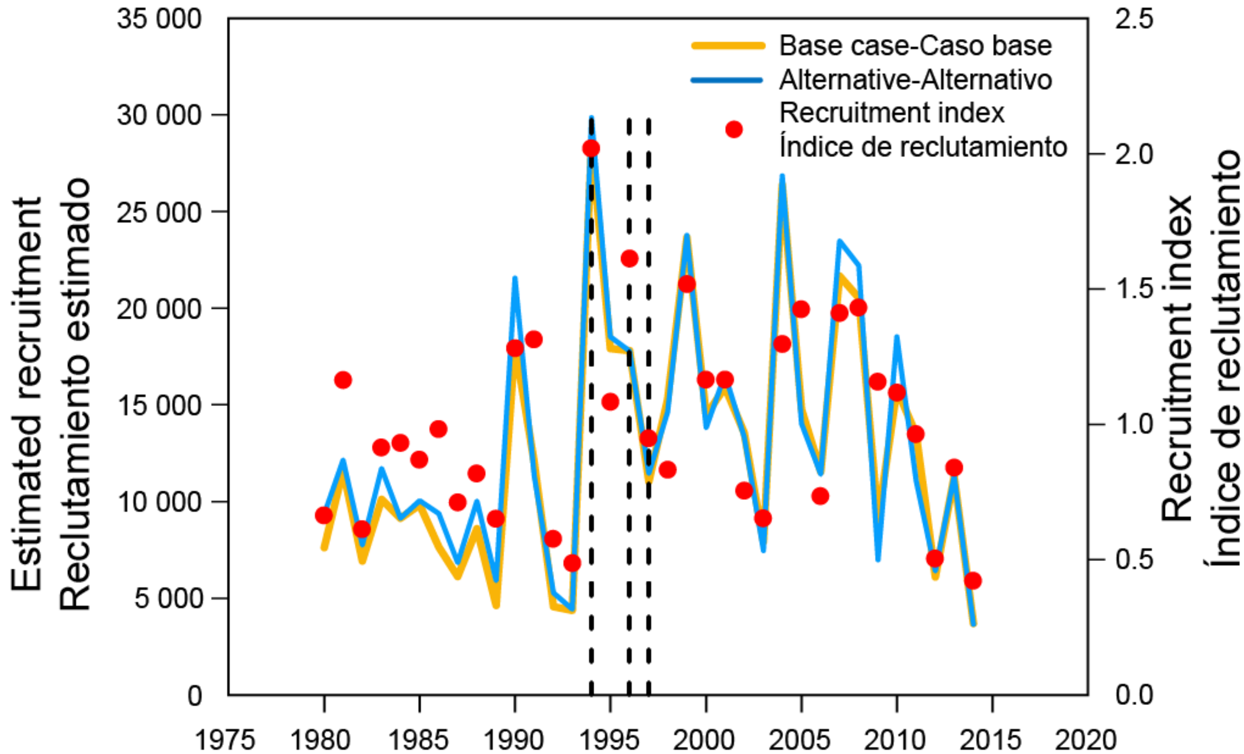

FIGURE 5. Comparison of the recruitment estimated by the alternative assessment model and the base case assessment model. The troll-CPUE-based recruitment index is provided for reference. The vertical dashed lines indicate 1994, 1996, and 1997, years of good recruitment to the longline fisheries.

FIGURA 5. Comparación del reclutamiento estimado por el modelo de evaluación alternativo y la evaluación de caso base. Se incluye para referencia el índice de reclutamiento basado en la CPUE curricanera. Las líneas de trazos verticales señalan 1994, 1996, y 1997, años de buen reclutamiento a las pesquerías palangreras.

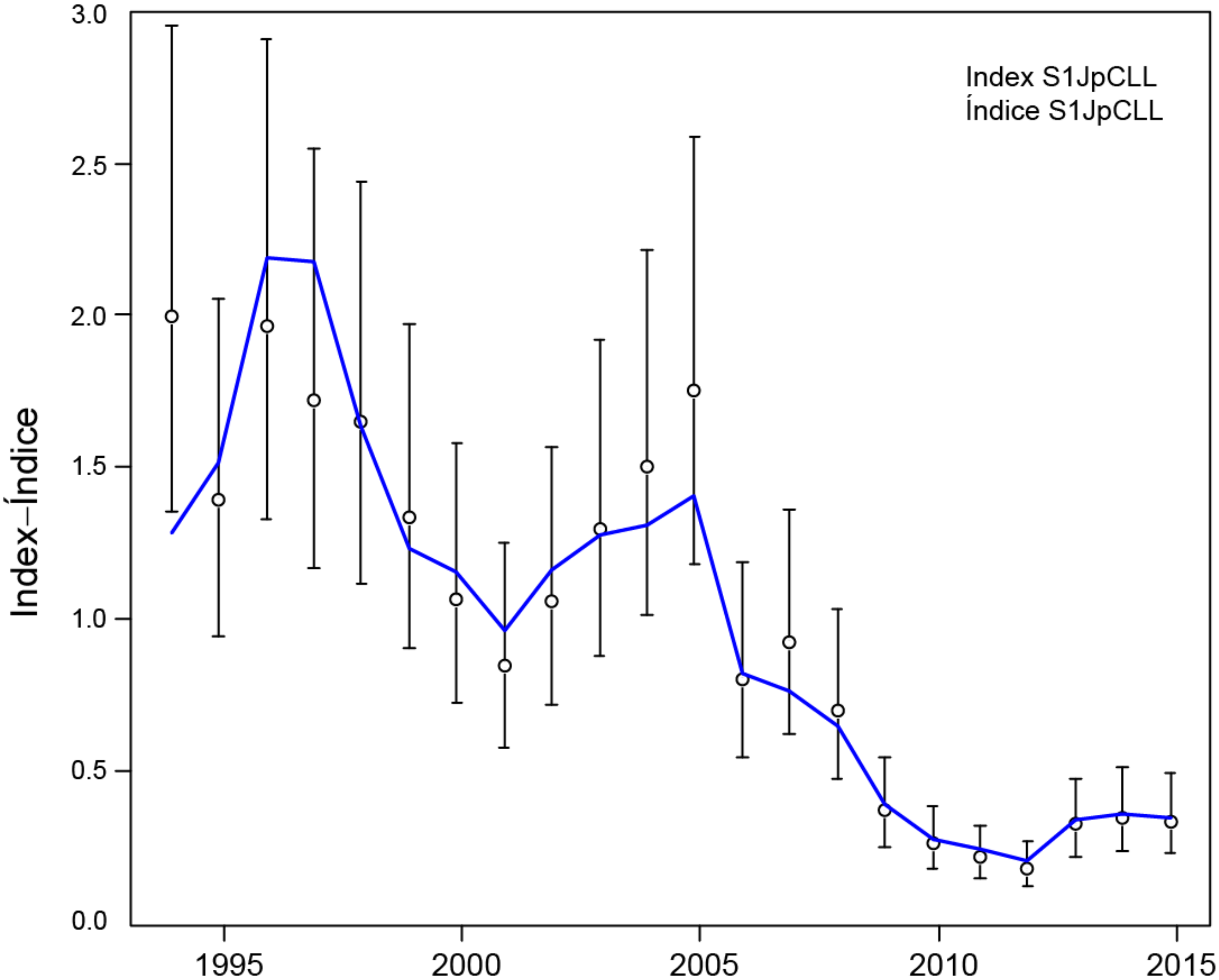

FIGURE 6. Fit of the alternative model to the Japanese longline CPUE based index of abundance, 1993-2015.

FIGURA 6. Ajuste del modelo alternativo al índice de abundancia basado en la CPUE palangrera japonesa, 1993-2015.

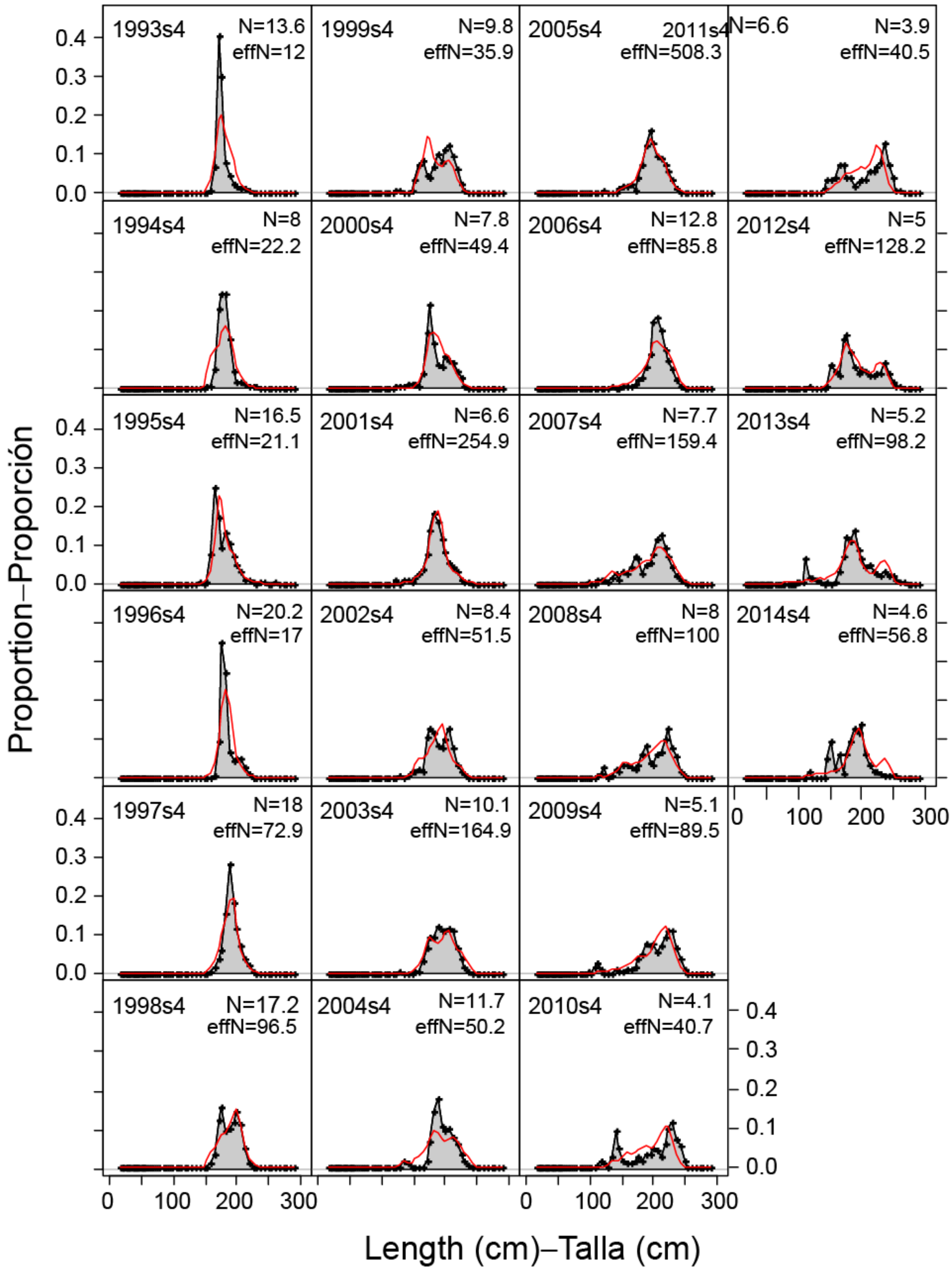

FIGURE 7. Fit of the alternative model to the Japanese longline length composition data, 1993-2014.
FIGURA 7. Ajuste del modelo alternativo de los datos de composición por talla de la pesquería palangrera japonesa, 1993-2014.

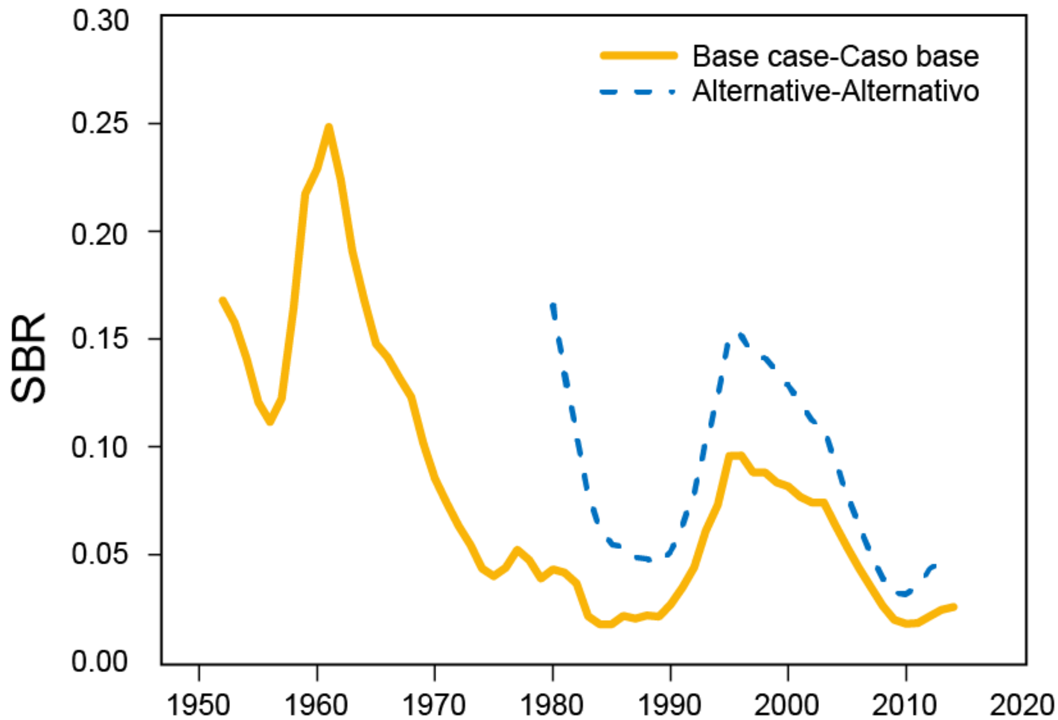

FIGURE 8. Comparison of the spawning biomass ratio (SBR) estimated by the alternative model and the base case model.
FIGURA 8. Comparación del cociente de biomasa reproductora (SBR) estimado por el modelo alternativo y el modelo de caso base.

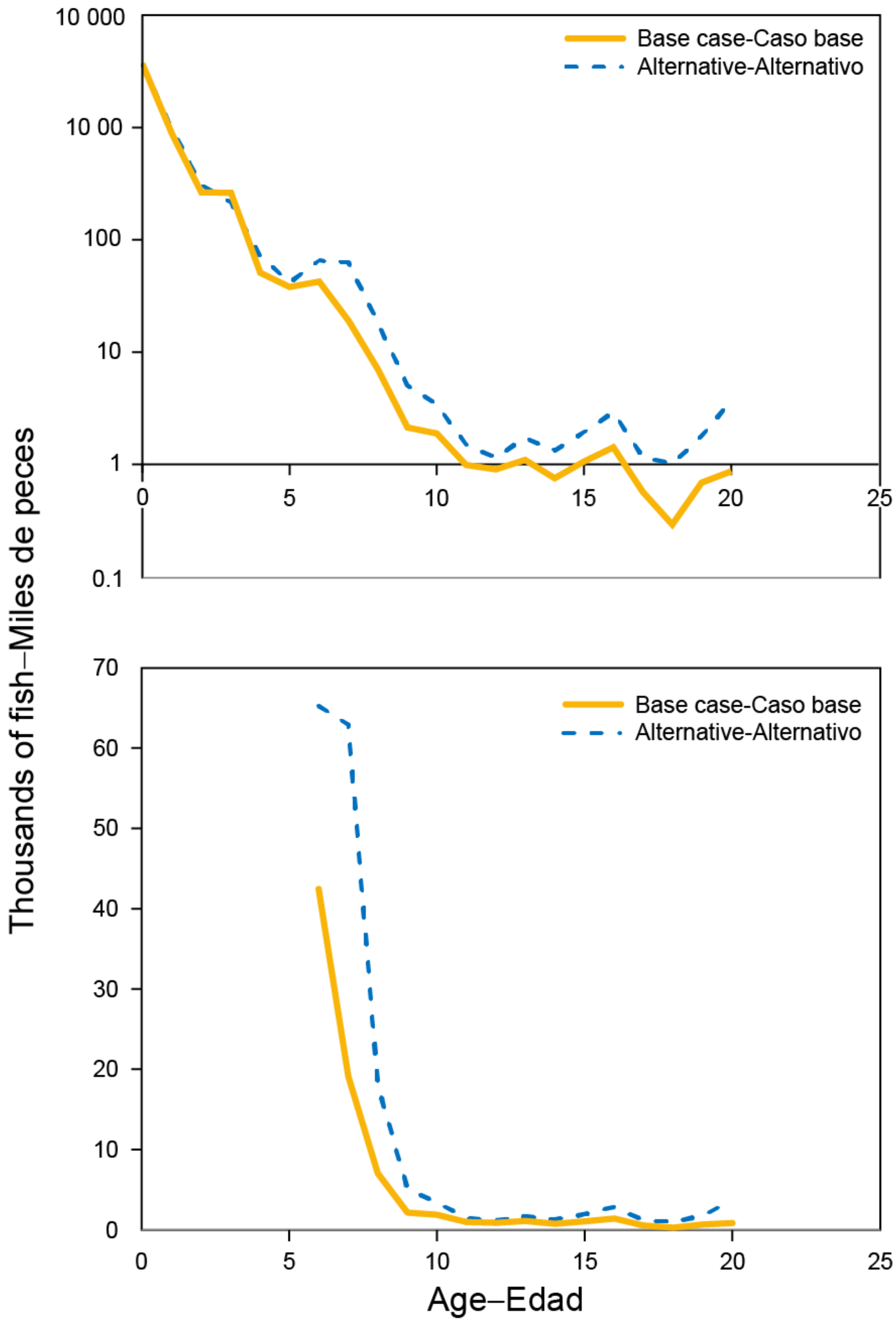

FIGURE 9. Comparison of the 2014 age structure estimated by the alternative model and the base case model. Che upper panel uses a logarithmic scale, and the lower panel ignores fish less than 6 years old, to allow easier comparisons.

FIGURE 9. Comparación de la estructura por edad de 2014 estimada por el modelo alternativo y el modelo de caso base. El panel superior usa una escala logarítmica, y el panel inferior omite peces de menos de 6 años de edad, para facilitar la comparación.

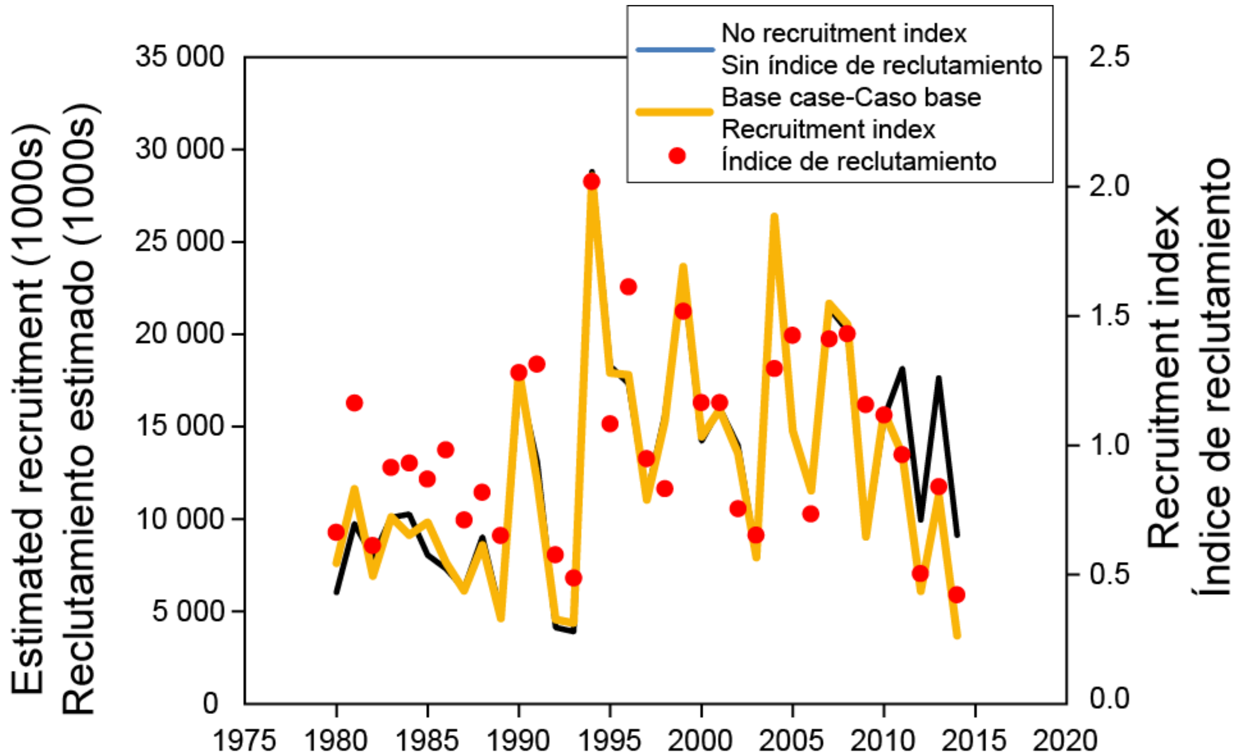

FIGURE 10. Comparison of the recruitment estimated by the base case model and the model that does not fit the troll-CPUE-based index of recruitment.

FIGURA 10. Comparación del reclutamiento estimado por el modelo de caso base y el modelo que no se ajusta al índice de reclutamiento basado en la CPUE curricanera.