INTER-AMERICAN TROPICAL TUNA COMMISSION

87TH MEETING (RESUMED)

La Jolla, California (USA)
27-29 October 2014

DOCUMENT IATTC-87 INF-B

DEVELOPING CONSERVATION MEASURES FOR BLUEFIN TUNA IN THE EASTERN AND WESTERN REGIONS OF THE PACIFIC OCEAN: FACTORS TO CONSIDER AND FISHERY IMPACT ANALYSIS

Mark N. Maunder and Alexandre Aires-da-Silva

1. ABSTRACT

Pacific bluefin tuna is highly depleted and, due to its highly migratory nature, catches need to be restricted on both sides of the Pacific Ocean to ensure sustainability of the population. The stock is exploited by several countries using a diverse range of methods that catch bluefin of different ages, which complicates the management of this stock. This document discusses several factors to consider when developing conservation measures for bluefin tuna in the eastern and western regions of the Pacific Ocean. It also evaluates the impact on the spawning biomass of different catch reduction scenarios.

2. INTRODUCTION

Catches of Pacific bluefin tuna (PBF) need to be restricted on both sides of the Pacific Ocean to ensure the sustainability of the population. The current stock assessment conducted by the International Scientific Committee (ISC) using Stock Synthesis (Methot and Wetzel 2013), and additional supplementary analyses by Maunder *et al*. (2014), concluded that the stock is highly depleted and fishing mortality rates are very high. Proposed limit reference points, based on fishing mortality and on biomass, have been exceeded. A portion of the population migrates from the western Pacific Ocean (WPO) to the eastern Pacific Ocean (EPO) and back again. Therefore, fisheries on both sides of the Pacific Ocean can impact the spawning population. This document discusses several factors to consider when developing conservation measures for Pacific bluefin in both the eastern and western regions of the Pacific Ocean. It also evaluates the impact on the spawning biomass of different catch reduction scenarios.

3. ISSUES TO CONSIDER

3.1. Migration

A portion of the Pacific bluefin in the WPO migrate over to the EPO at about age 1 or 2; they stay in the EPO for one or more years and then at about age 4 or 5 migrate back to the WPO, where they begin to spawn. The proportion of the population that migrates to the EPO probably changes from year to year and may be related to environmental conditions. This migration pattern means that catch of young Pacific bluefin in the WPO influence the catch of Pacific bluefin in the EPO and vice versa, and catches on either side of the Pacific Ocean will impact the spawning biomass; therefore, any conservation measure needs to take this pattern into consideration. Conservation measures taken on one side of the Pacific Ocean should not be negated by lack of conservation measures on the other side. Reducing the catch of juvenile Pacific bluefin[1] on one side of the Pacific Ocean will increase the number of juveniles migrating to the other side, and will increase catches unless effort is reduced on that side.

3.2. Recruitment variability

Several fisheries for Pacific bluefin target only one or two age classes. This means that the catch in these fisheries will fluctuate depending on the strength of the cohort (year class). Pacific bluefin show a moderate amount of recruitment variability, which will influence catch correspondingly, given relatively constant effort levels. With constant catch quotas, this may mean that reaching the quota will take more or less time (or effort) depending on the recruitment strength. Recruitment variability also makes it difficult to evaluate the impact of management measures. For example, reduction in catch may not be due to a reduction in fishing mortality; it may simply be due to a reduction in the abundance. Estimates of fishing mortality may be a better indicator of the impact of management action.

3.3. Stock-recruitment relationship

The impact of management action is dependent on many factors. One factor is the strength of the stock-recruitment relationship. If recruitment is strongly dependent on spawning stock size (*i.e.* low steepness (h) of the Beverton-Holt stock-recruitment relationship) then, as the spawning stock rebuilds, the average recruitment will also increase. However, except for perhaps the most recent few years, there is little indication that there is a strong relationship between recruitment and spawning stock size for Pacific bluefin (Figure 1); therefore, it is possible that when the spawning stock rebuilds, recruitment, on average, will remain the same. Therefore, any increase in catches will be due to improved yield per recruit (*i.e.* taking advantage of individual growth). If allocation of effort among the fisheries is not changed, then there may not be much gain in long-term catches from the fishery. However, there should be less risk and higher catch per unit of effort (CPUE) due to higher stock sizes, which are beneficial in themselves.

The lack of a stock-recruitment relationship also means that, despite reductions in adult abundance, catch rates in the fisheries on juveniles have not declined. Therefore, if only juvenile catch rates are used as a measure of stock status, the results will be misleading.

There must be some dependence of recruitment on spawning stock size, even if only when the spawning stock is reduced to very low levels. Since Pacific bluefin spawning biomass is estimated to be at only 3-5% of virgin biomass, there is concern that exploitation is approaching a previously unobserved 'cliff" of the stock-recruitment relationship. For example, the spatial or temporal extent of spawning may be reduced, which could substantially reduce recruitment. If that is the case, following the precautionary principle, it is critical that the remaining spawners be protected and the spawning stock size increased as quickly as possible.

A scenario that includes a stock-recruitment relationship may cause the population to rebuild to a larger biomass than the scenarios without such a relationship, and may also change the impact of fisheries that catch adult Pacific bluefin.

3.4. Effort or catch control

Due to recruitment variability and variations in the proportion of Pacific bluefin moving across to the EPO, effort and catch controls will have different impacts. In a catch-based system, the fishing mortality for fisheries that catch a limited number of age classes will increase or decrease depending on the recruitment strength. This can be particularly dangerous for valuable easy-to-catch species, like Pacific

[1] The WCPFC's Northern Committee has defined juvenile Pacific bluefin in a management context for the Western and Central Pacific as fish less than 30 kg. This definition is inconsistent with the maturity curve used in the stock assessment model and with the fact that all Pacific bluefin in the EPO are juveniles (*i.e.* not sexually mature). There are a substantial number of juveniles above 30 kg on both sides of the Pacific Ocean; therefore, 30 kg should be considered only as a reference based on previous management recommendations, and not a definition of juveniles.

bluefin, when recruitment is low for consecutive years. An effort control system might be preferable to ensure that fishing mortality is kept at a reasonable level as catch fluctuates with abundance. However, the relationship between catch and effort is not fully understood for these fisheries, and, in addition, effort may be more difficult to measure and control than catch.

3.5. Comparison years

When multiple fisheries are involved, there will always be uncertainty and controversy about how much to limit each fishery. Frequently, a set of years is chosen as a reference, and catch limits are reduced in proportion to the average catch (or effort) in those years. A different set of years will result in different catch levels for each fishery. The Northern Committee (NC) of the Western and Central Pacific Fisheries Commission has used 2002-2004 as a reference in past assessments and management advice. The trends in catches in recent years for the WPO and the EPO are quite different, so using 2010-2012, for example, as a reference instead of 2002-2004 would have an effect on the relative catch levels between the two sides of the Pacific Ocean (Figure 2).

3.6. Low spawning biomass

The current spawning biomass of Pacific bluefin is very low, and made up of only a few cohorts. The immediate need is to increase the spawning biomass to reduce the risk of recruitment collapse. This can be achieved by reducing the amount of spawning biomass caught or increasing the number of fish recruited to the spawning population, or a combination of both. Reducing the catch of age-0 and age-1 fish can increase the spawning biomass, but it will take several years before these fish enter the spawning population. Although the fisheries for juvenile Pacific bluefin are estimated to have the greatest impact on spawning biomass, the urgent need to increase the spawning biomass means that limiting the catch of spawners as much as possible may be the best short-term management action.

3.7. Yield per recruit

The maximum sustainable yield (MSY) obtainable from a stock is a function of the yield per recruit (YPR; the average yield (catch) obtained from a single recruit (fish)) and the stock-recruitment relationship (see Maunder 2008 for a detailed description). Given the lack of evidence of a stock-recruitment relationship for Pacific bluefin, MSY is essentially a function of YPR. YPR is a tradeoff between natural mortality and growth: at young ages, the growth rate of individual fish is higher than the rate of natural mortality, so the total weight of all the fish alive in a cohort increases, but as fish age, growth slows down and is less than natural mortality, so that the total weight of all the fish alive in a cohort decreases. At some intermediate age (the critical age) the cohort reaches its maximum total weight, and catching all the fish at this age would maximize the YPR. However, it is generally not possible to catch all the fish at a given age, and the YPR has to be calculated based on a selectivity schedule and a fishing mortality rate. In general, maximum YPR, which equals MSY when recruitment is independent of stock size, is calculated by finding the fishing mortality rate that maximizes YPR for a given selectivity pattern.

There are several fisheries that catch Pacific bluefin, and each catches a different range of ages. Therefore, the maximum YPR changes depending on the effort allocation among fisheries (*e.g.* Maunder 2002). In general, fisheries that catch young fish will produce a lower YPR than those that catch intermediate-age or old fish. Depending on the objectives of management, the allocation of effort among fisheries and the consequent YPR may be an important factor to consider.

3.8. Minimum legal size

Minimum legal size (MLS) has been used as a management tool for many stocks, and is often used in recreational fisheries due to the ease of enforcement. It is often designed to either allow fish to spawn at least once, and hence protect the spawning biomass, or to avoid harvesting small fish and thus improve the YPR.

A strict MLS has not been applied to Pacific bluefin, but restricting management actions to fish less than

30 kg has similar problems to a MLS. First, unless a fishery can completely control its selectivity, or unless discarded fish have a high survival rate, it is very difficult to implement and evaluate a MLS: it is more practical to limit catches by fisheries that generally catch juveniles. This is how management for juveniles is implemented on the EPO, since the fishery catches only juveniles, even if they are above 30 kg. Since Pacific bluefin of the same size tend to school together, it is possible to target fish of roughly a certain size using some fishing methods (*e.g*. purse seine), but it is not clear if it is possible to avoid fish less than 30 kg in all fisheries. It is also unclear how easy it would be to enforce such a MLS, or what the survival rate of any discards would be from the different fisheries. Furthermore, it is unlikely that discards will be reported by those fisheries with low or non-existent observer coverage, thus increasing the uncertainty about the total mortality from the fishery and degrading the quality of the stock assessments. A MLS is also contrary to Resolution C-13-01, which requires that all bigeye, skipjack, and yellowfin tuna caught in the purse-seine fishery be retained (except fish considered unfit for human consumption for reasons other than size).

3.9. Fishery impacts

Evaluation of the impact of management actions applied to the Pacific bluefin stock is complicated by the number and diversity of fisheries that exploit the stock. Many of these fisheries capture only a few age classes, and therefore the selectivity of the gear needs to be taken into consideration when evaluating management actions (Wang *et al*. 2009). Given the complex nature life history of Pacific bluefin (*e.g*. migration across the Pacific Ocean) and the wide range of fisheries, and with increasing the spawning biomass as the management goal, it is difficult to conceptualize how management actions will impact the spawning biomass. For example, will the same percentage reduction in catch for each fishery result in the same relative reduction in the impact on the spawning biomass? The fishery impact will be dependent on the rate of natural mortality, which is difficult to estimate and uncertain for most species. Natural mortality is typically high and particularly difficult to estimate for young individuals, and may show substantial temporal variation. Some of the fisheries catch very young Pacific bluefin and estimates of their relative impact are likely to be uncertain.

4. METHODS

IATTC Members requested several projections to evaluate the influence of different catch levels in the WPO and the EPO. The 2014 ISC reference case stock assessment model developed in Stock Synthesis (Methot and Wetzel 2013) was used to carry out these projections. The model was extended 50 years into the future, following the method of Maunder *et al*. (2006) to ensure that equilibrium was achieved, and the catch for these years was set at the assumed level for each fishery. Note that the management measures were implemented starting in the second half of 2013, which differs from how the management will be implemented in practice.

The first scenario (0) was set up to approximate NC scenario 6 as described in the ISC 2014 stock assessment report, which reduces the catch of fish <30 kg in the WPO and total catch in the EPO. To approximate the reduction we reduced catch in the fisheries that mainly catch fish <30kg (all WPO fisheries except the longline fisheries and the purse-seine fisheries that target tunas and not small pelagics). All EPO fisheries are assumed to catch juveniles. The scenarios tested were:

Scenario	Reduction	Reference level	Fisheries
0 (a)	50%	WPO: 2002-2004 average EPO all: 5,500 t EPO sport: 2002-2004 average	WPO: < 30 kg EPO: all
0 (b)	WPO: 50% EPO: 10, 20, 30%[2]	WPO: 2002-2004 average EPO: 2010-2012 average	WPO: < 30 kg EPO: all
1	10, 20, 30%	2002-2004 average	< 30 kg

[2] equivalent to 6%, 16%, and 27% from the 5,500 t level, respectively

Scenario	Reduction	Reference level	Fisheries
2	10, 20, 30%	2010-2012 average	< 30 kg
3	10, 20, 30%	2002-2004 average	all
4	10, 20, 30%	2010-2012 average	all

Several of the scenarios were repeated with recruitment reduced to the 1980-1989 average, a reduction of about 33%, and using a steepness (*h*) of the stock-recruitment relationship of 0.85.

The NC specified a rebuilding plan for Pacific bluefin tuna starting in 2015, with the initial goal of rebuilding the spawning stock biomass to the historical median of about 42,500 t within 10 years with a probability of at least 60%. Therefore, we use this spawning biomass level as a reference when presenting results.

A fishery impact analysis (Wang *et al*. 2009) was carried out to determine the relative change in impact attributed to each type of fishery and to the EPO and the WPO. This analysis takes into consideration the age of the fish caught by each fishery, and measures the impact on the spawning biomass.

5. RESULTS AND DISCUSSION

The catch for each scenario is shown in Figure 3. The scenarios based on 2010-2012 catches have lower adult catch, while the juvenile catch is more similar across the scenarios. In fact, in all cases, the scenarios based on 2002-2004 catches have higher adult catch than those based on 2010-2012 catches. It should be noted that the NC conservation recommendation also restricts fishing mortality to the 2002-2004 level so the actual adult catch in the western Pacific Ocean may be below the 2002-2004 average in the first few years of the projection period as the adult population increases. The projections presented here did not account for the fishing mortality restrictions and assumed that the catch limits would be taken in full.

Rebuilding is fastest, except for the first few years, and to a higher equilibrium level for scenario 0a (Tables 1 and 2; Figures 4 and 5). Scenarios 0b with 10% and 20% reduction rebuilt to higher spawning biomass levels than the corresponding scenarios 2 and 4, but with 30% reduction scenarios 2 and 4 rebuilt to higher levels. Scenarios 1 and 3 had the lowest rebuilding levels. There was not much difference between scenarios 1 and 3 and between scenarios 2 and 4, indicating that reducing the catch of adults does not influence the final rebuilding level. However, the scenarios that do not reduce the catch of spawners have slower rebuilding rates in the first few years (Figure 6). With average recruitment, all scenarios rebuild deterministically to above the historical median in 10 years, except scenario 1 with a 10% reduction (Table 1).

As expected, rebuilding is slower under the low recruitment scenario (Figure 7). Scenarios 1 and 3, which are based on 2002-2004 catches, predict that the stock will collapse. The other scenarios rebuild deterministically to above the historical median in 10 years. Of the scenarios tested, only scenario 4 with a 30% reduction rebuilds when the steepness of the stock-recruitment relationship is 0.85 (Figure 8). The stock initially rebuilds slower than in scenarios without a stock-recruitment relationship, but eventually rebuilds to a higher level.

The relative equilibrium impact on the spawning biomass of the different fisheries groups under the various scenarios is shown in Table 3. There is some variability among scenarios. The impact of the EPO fisheries has varied over time (Figure 9) ranging from just over 40% in the mid-1970s to under 15% in the early 2000s and the current impact is just under 20%. A recent change in the impact starting in the late 1990s is attributed to the western Pacific purse seine juvenile fisheries that increased in the 1990s (Figure 10). The relative equilibrium impact among fisheries is insensitive to the size of the reduction or whether the adult catch is reduced, but is moderately sensitive to the reference years for the reduction. The historical impact is substantially different if a stock-recruitment relationship is assumed (compare Figures 10 and 11): the impact of the fisheries that catch large Pacific bluefin is increased at low stock sizes when there is a stock-recruitment relationship.

One of the main features of the scenarios is that scenario 0 (NC scenario 6) as implemented implies that, in the WPO, the adult catch increases while the juvenile catch diminishes; therefore, although the total catch is similar to other scenarios, the equilibrium impact on the spawning biomass is less. However, the short-term impact is greater than in some scenarios (Figure 6). The historical impact of fisheries that catch large Pacific bluefin is increased if a stock-recruitment relationship is assumed. In our analysis we assume that all Pacific bluefin caught in the western Pacific tuna purse-seine fishery were considered adults for quota-setting purposes; however, this is only an approximation, since some of these fish are less than 30 kg or less that the age of maturity assumed in the stock assessment model. A concern is whether these fish are actually adults and contribute to the spawning biomass. If they are not, the tuna purse-seine fisheries may be catching fish that were not caught by the juvenile fisheries because of the restrictions but which have still not spawned. Therefore, it is imperative that better maturity information is collected to ensure that these fisheries are not having more of an impact on the spawning biomass than is currently estimated.

It should be noted that the current Pacific bluefin tuna stock assessment model that this analysis is based on is considered unreliable (Maunder *et al.* 2014), and therefore the results presented here should be considered with caution. In addition, the management was implemented earlier than it would be in practice, and restrictions on fishing mortality in the western Pacific Ocean were not modelled. The relative differences among scenarios should be more reliable than the absolute estimates of rebuilding levels and fishery impacts.

6. CONCLUSION

Pacific bluefin tuna is highly depleted and management is urgently needed to ensure sustainability (Maunder *et al*. 2014). Management action is needed on both sides of the Pacific Ocean. Any management actions on one side of the Pacific will influence the abundance on the other side of the Pacific. Catch allocation among fisheries is complicated because they catch different aged fish, which influences their impact, and the relative impacts have changed over time. Current management actions in the western Pacific Ocean imply increased catch of spawning adults, which is contrary to the urgent need to protect the spawning biomass. The catch restrictions for the EPO outlined in the IATTC staff recommendations (45% reduction in commercial catch from the 2010-2012 levels) should be adopted, and the catch restrictions recommended by the NC should be augmented by reductions in the catch of spawning adults to avoid immediate threats to the population[3].

ACKNOWLEDGEMENTS

Rick Deriso provided advice on the manuscript.

REFERENCES

Maunder, M.N. 2002. The relationship between fishing methods, fisheries management and the estimation of MSY. Fish and Fisheries, 3: 251-260.

Maunder, M.N. 2008. Maximum Sustainable Yield. *In* Sven Erik Jørgensen and Brian D. Fath (Editor-in-Chief), General Ecology. Vol. 3 of Encyclopedia of Ecology, 5 vols. pp. 2292-2296 Oxford: Elsevier.

[3] **NC recommendations**:

- Total fishing effort by vessels fishing for Pacific bluefin tuna in the area north of 20°N shall stay below the 2002-2004 annual average levels.
- All catches of Pacific bluefin tuna less than 30 kg shall be reduced to 50% of the 2002-2004 annual average levels. Any overage of the catch limit shall be deducted from the catch limit for the following year.
- CCMs shall take every possible measure not to increase catches of Pacific bluefin tuna 30 kg or larger from the 2002-2004 annual average levels.

IATTC staff recommendations:

- Limit commercial catches in 2014 below 3,154 t, which was the estimated commercial catch in 2013, and non-commercial catches in 2014 below 221 t, which is based on the same method that was applied to commercial catch to determine that recommended limit.

Maunder M.N., Harley, S.J., and Hampton, J. 2006. Including parameter uncertainty in forward projections of computationally intensive statistical population dynamic models. ICES Journal of Marine Science 63: 969-979.

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 SAC-05-10a.

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.

Wang, S-.P., Maunder, M.N., Aires-da-Silva, A., and Bayliff, W.H. 2009. Evaluating fishery impacts: application to bigeye tuna (*Thunnus obesus*) in the eastern Pacific Ocean. Fisheries Research 99: 106-111.

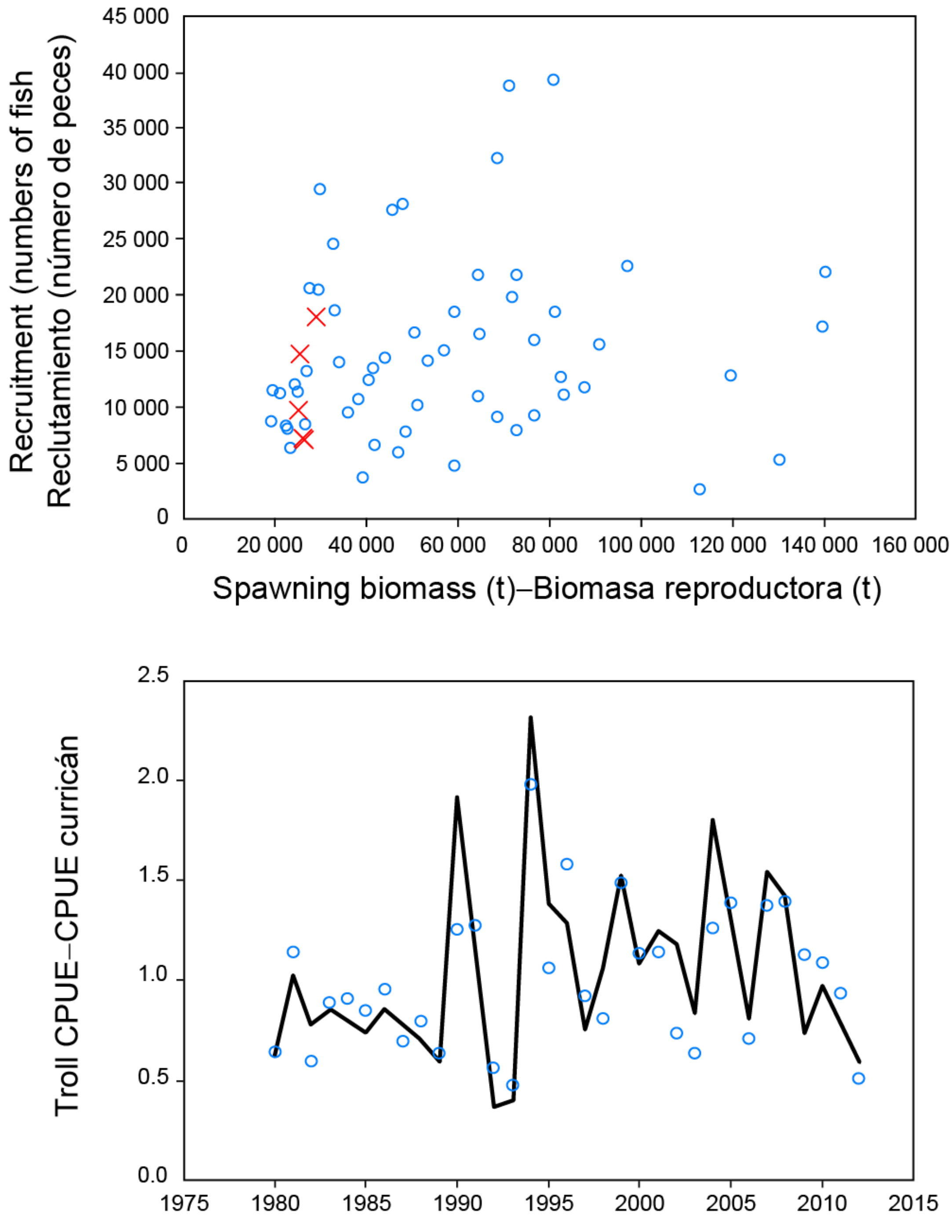

FIGURE 1. Stock-recruitment relationship (upper panel; years 2008-2012 are represented by x's) and the time series of the observed (circles) and predicted (solid line) recruitment index based on the troll fishery (lower panel).

FIGURA 1. Relación población-reclutamiento (panel superior; años 2008-2012 representados por x) y la serie de tiempo del índice de reclutamiento observado (círculos) y predicho (línea sólida) basado en la pesquería de curricán (panel inferior).

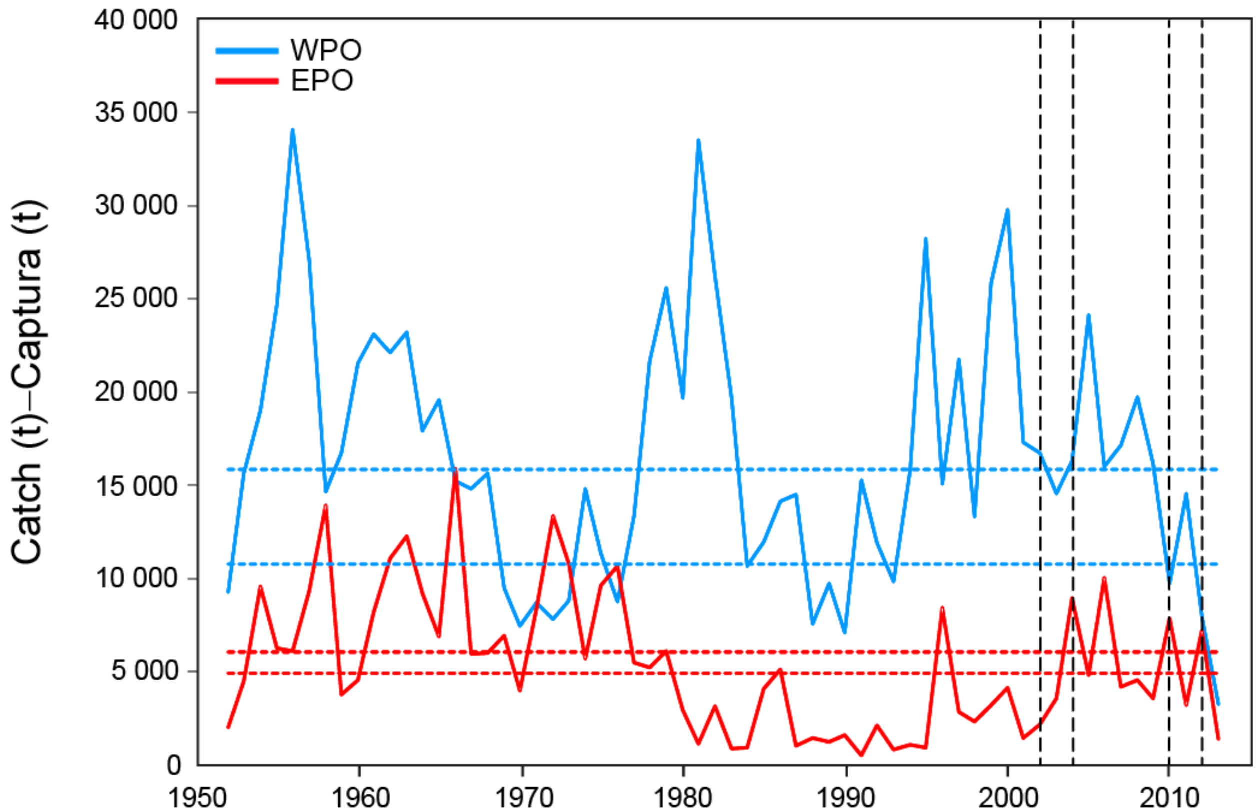

FIGURE 2. Catch of Pacific bluefin in the western (WPO) and eastern (EPO) Pacific Ocean. The horizontal dotted lines indicate the average catch during 2002-2004 and 2010-2012 (indicated by vertical dotted lines).

FIGURA 2. Captura de aleta azul del Pacífico en el Océano Pacífico occidental (WPO) y oriental (EPO). Las líneas de trazos horizontales indican la captura media durante 2002-2004 y 2010-2012 (indicada por líneas de trazos verticales).

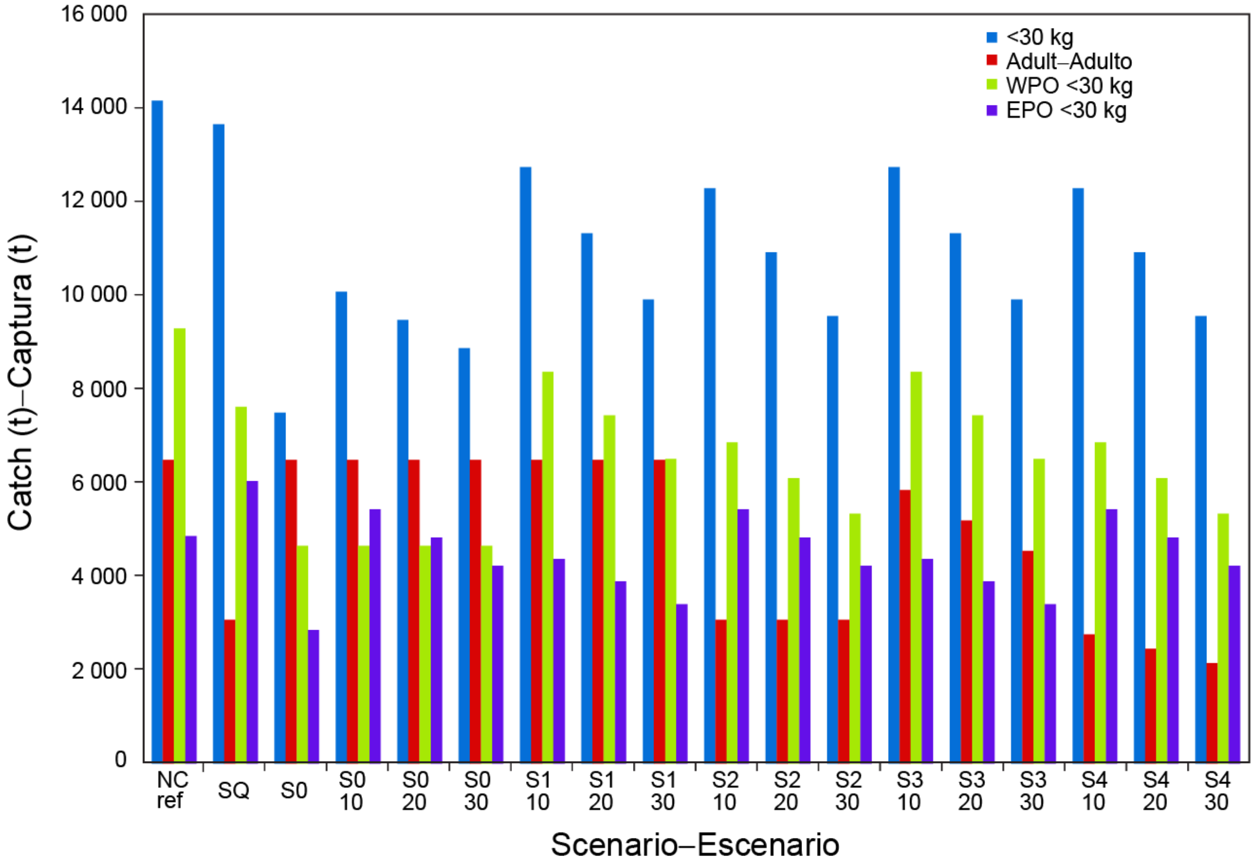

FIGURE 3. Future catch for each scenario, by category.
FIGURA 3. Captura future para cada escenario, por categoría.

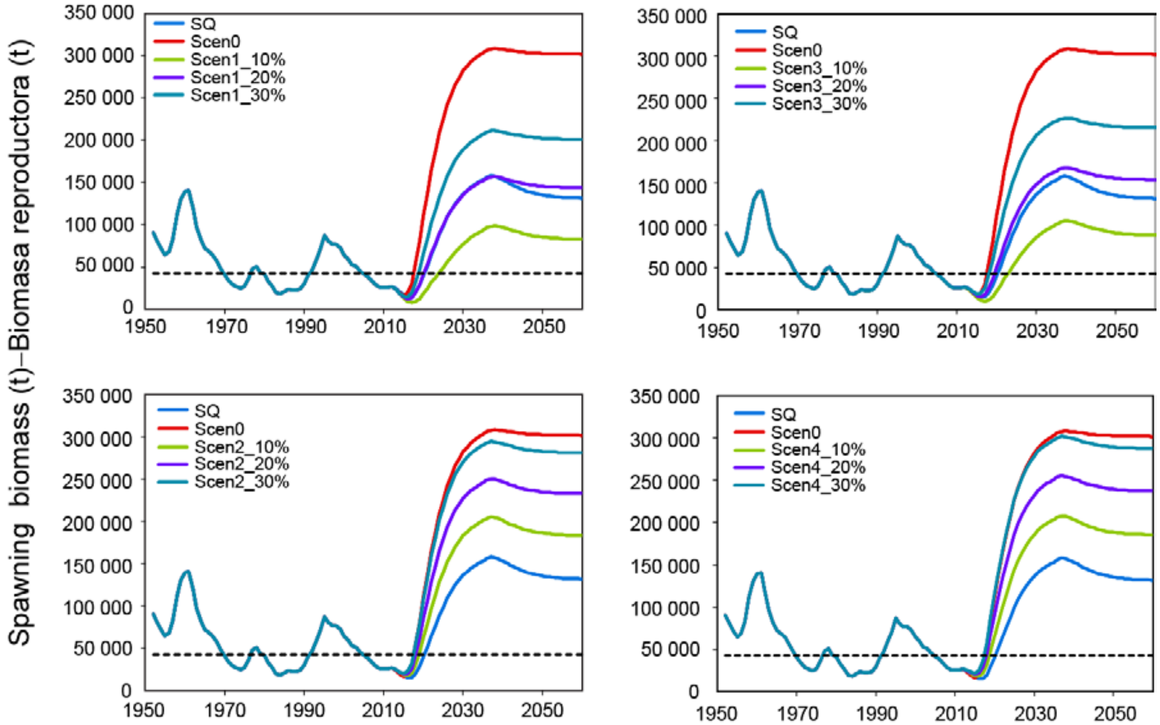

FIGURE 4. Projections of spawning biomass under different future catch scenarios. The horizontal dashed line is the spawning biomass rebuilding reference level used by the NC.

FIGURA 4. Proyecciones de la biomasa reproductora en distintos escenarios de captura futura. La línea de trazos horizontal representa el nivel de referencia de recuperación de la biomasa reproductora usado por el NC.

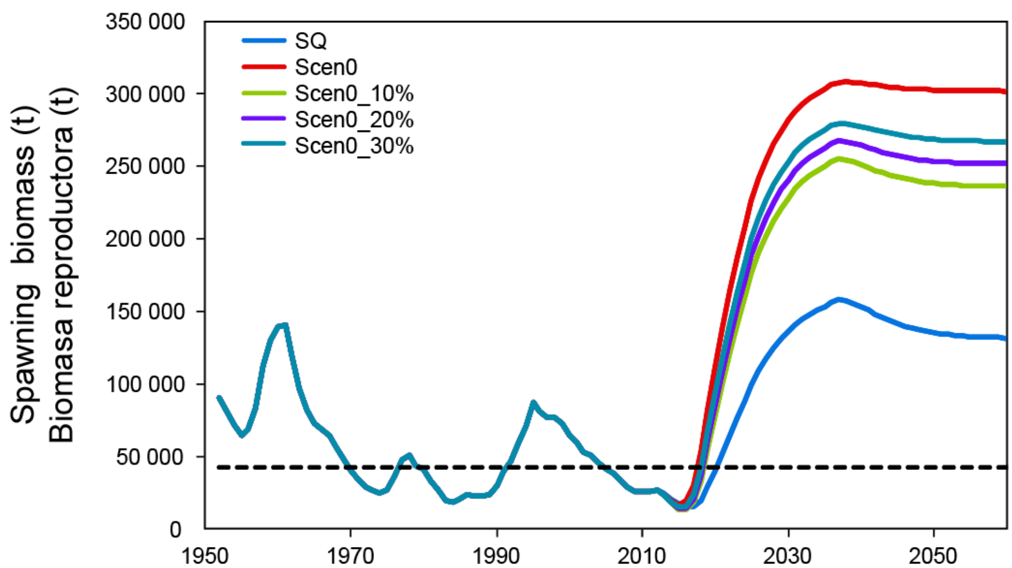

FIGURE 5. Projections of spawning biomass under different future EPO catch scenarios with WPO catch based on NC scenario 6. The horizontal dashed line is the spawning biomass rebuilding reference level used by the NC.

FIGURA 5. Proyecciones de la biomasa reproductora en distintos escenarios de captura futura en el OPO con captura del Pacífico occidental basada en el escenario 6 del NC. La línea de trazos horizontal representa el nivel de referencia de recuperación de la biomasa reproductora usado por el NC.

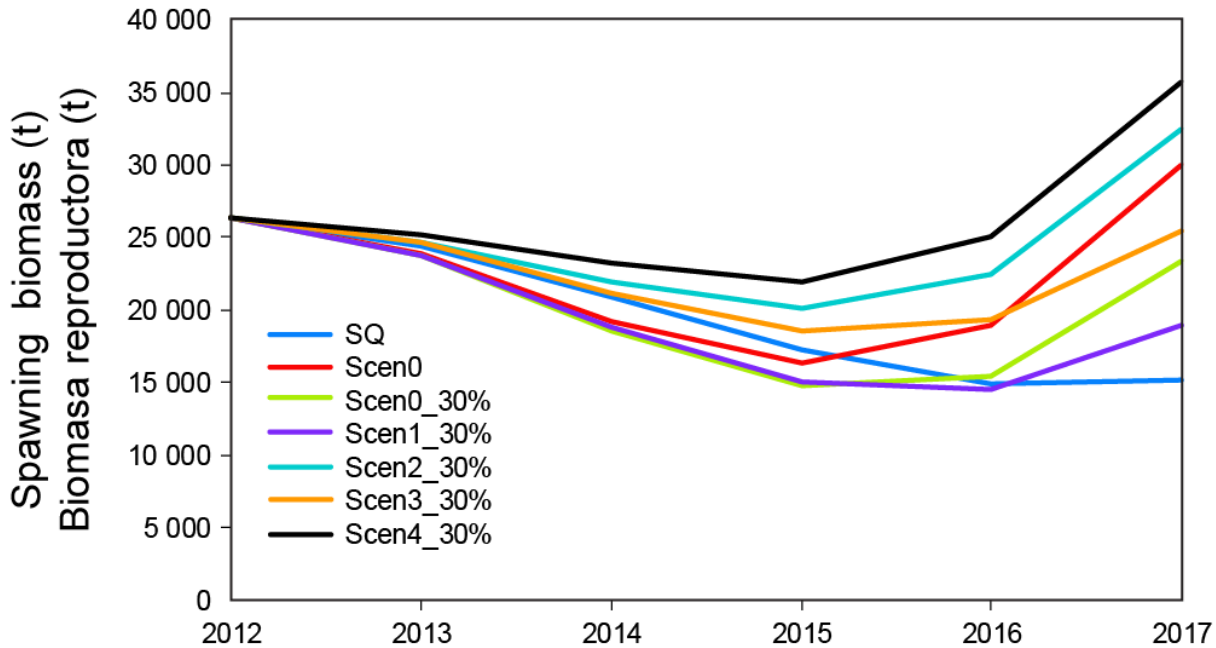

FIGURE 6. Projections of spawning biomass under different future catch scenarios, 2013-2017.
FIGURA 6. Proyecciones de la biomasa reproductora en distintos escenarios de captura futura, 2013-2017.

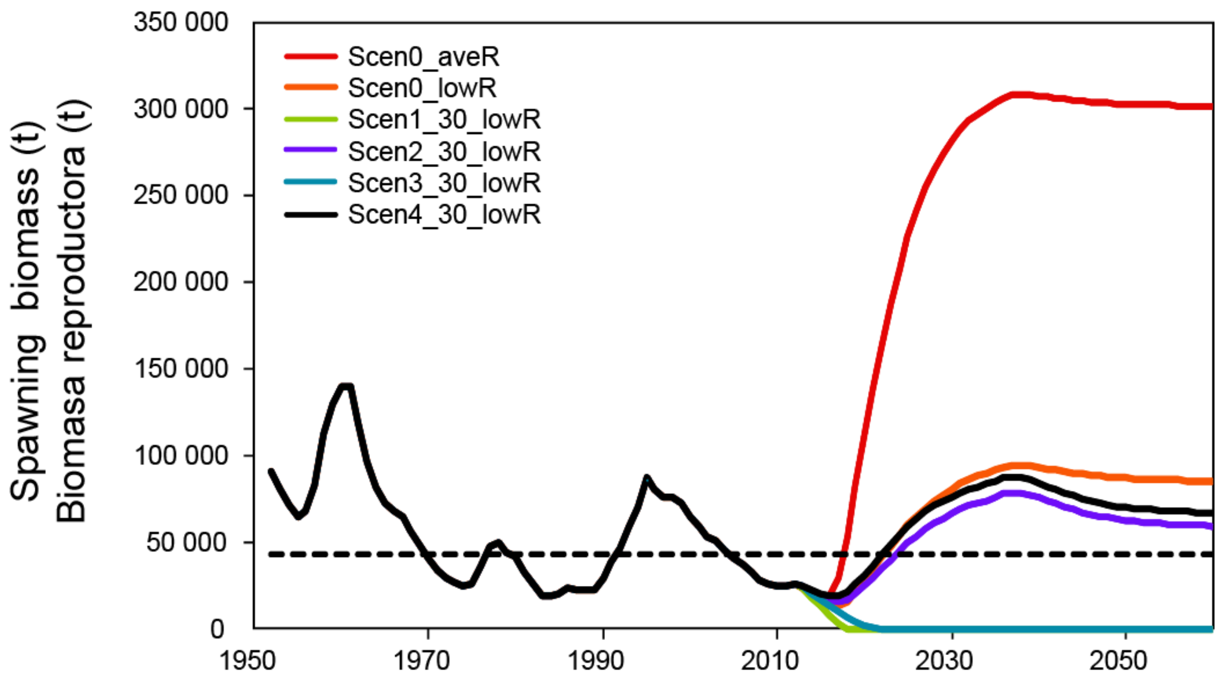

FIGURE 7. Projections of spawning biomass under different future EPO catch scenarios that assume low recruitment (except Scen0_aveR, which has average recruitment). The horizontal dashed line is the spawning biomass rebuilding reference level used by the NC.
FIGURE 7. Proyecciones de la biomasa reproductora en distintos escenarios de captura futura en el OPO que suponen reclutamiento bajo (excepto Scen0_aveR, que supone reclutamiento medio). La línea de trazos horizontal representa el nivel de referencia de recuperación de la biomasa reproductora usado por el NC.

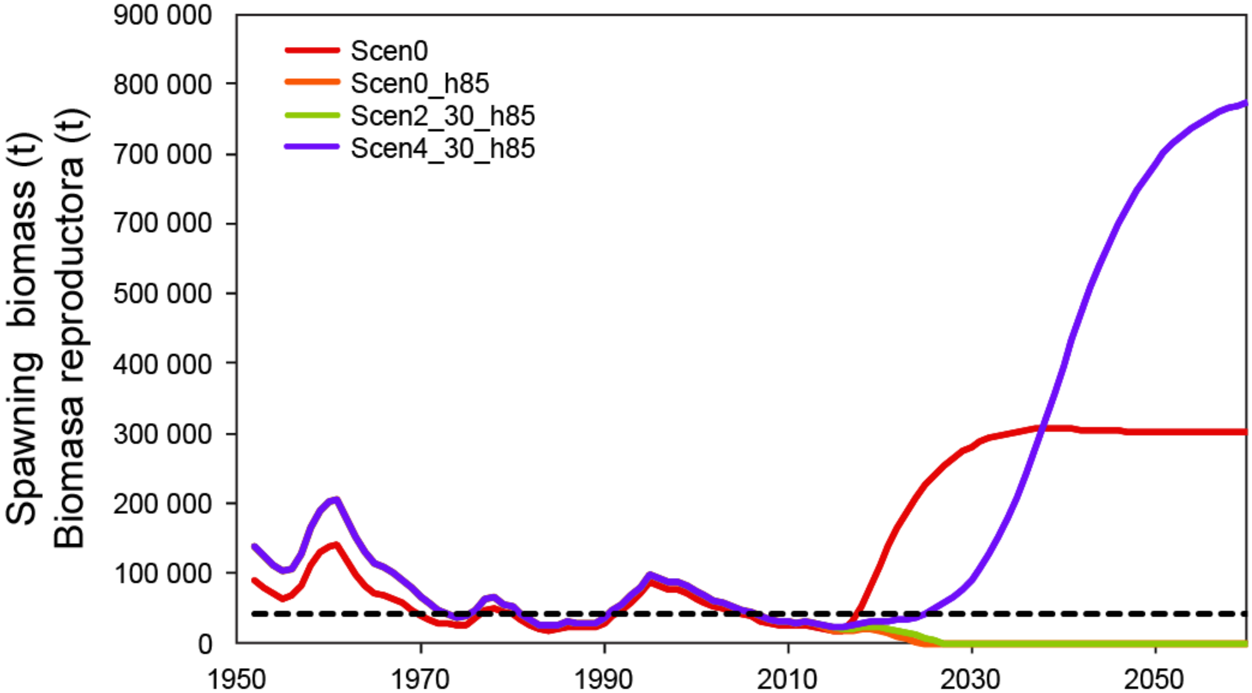

FIGURE 8. Projections of spawning biomass under different future EPO catch scenarios that assume a stock-recruitment steepness (*h*) of 0.85 (except Scen0, which has average recruitment (*h* ≈ 1)). The horizontal dashed line is the spawning biomass rebuilding reference level used by the NC.

FIGURE 8. Proyecciones de la biomasa reproductora en distintos escenarios de captura futura en el OPO que suponen una inclinación de la relación población-reclutamiento (*h*) de 0.85 (excepto Scen0, que supone reclutamiento medio (*h* ≈ 1)). La línea de trazos horizontal representa el nivel de referencia de recuperación de la biomasa reproductora usado por el NC.

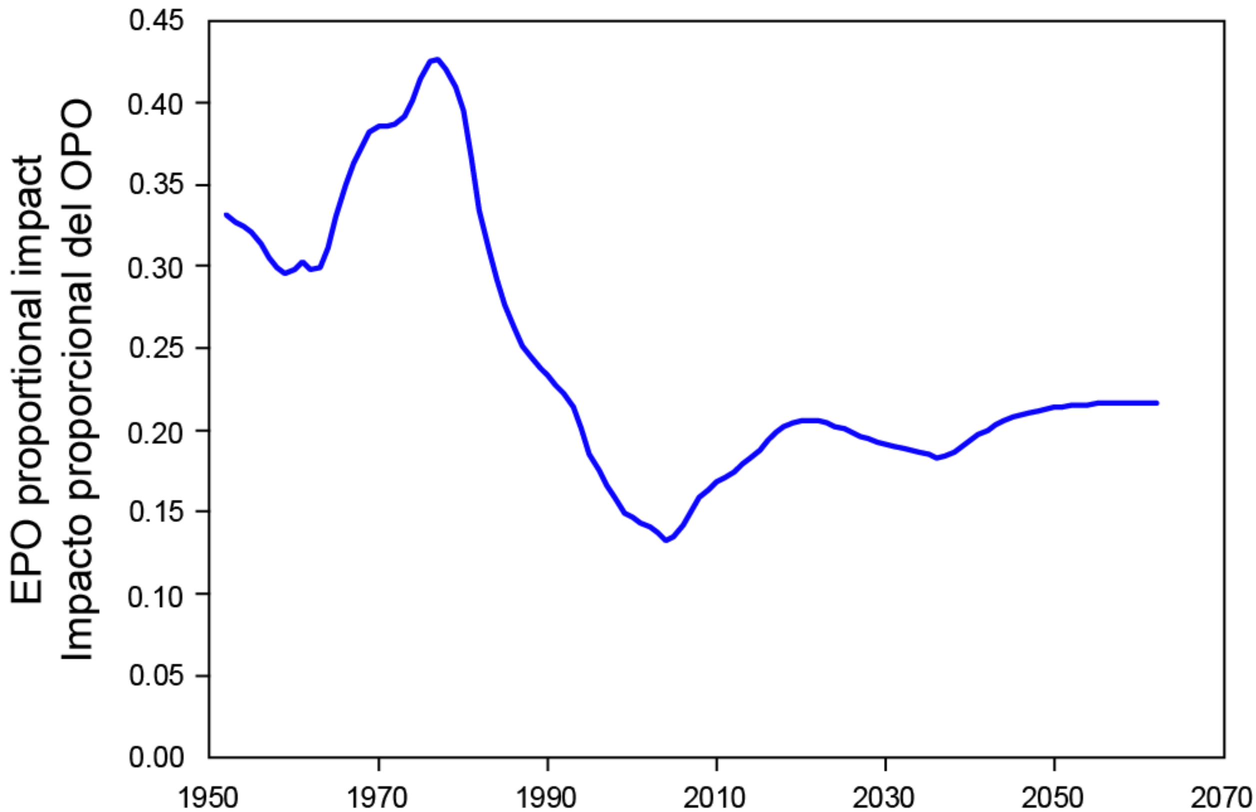

FIGURE 9. Proportion of the total fishery impact, historically and from scenario 0, attributed to the EPO fisheries.

FIGURA 9. Proporción del impacto total de la pesca, históricamente y del escenario 0, atribuida a las pesquerías del EPO.

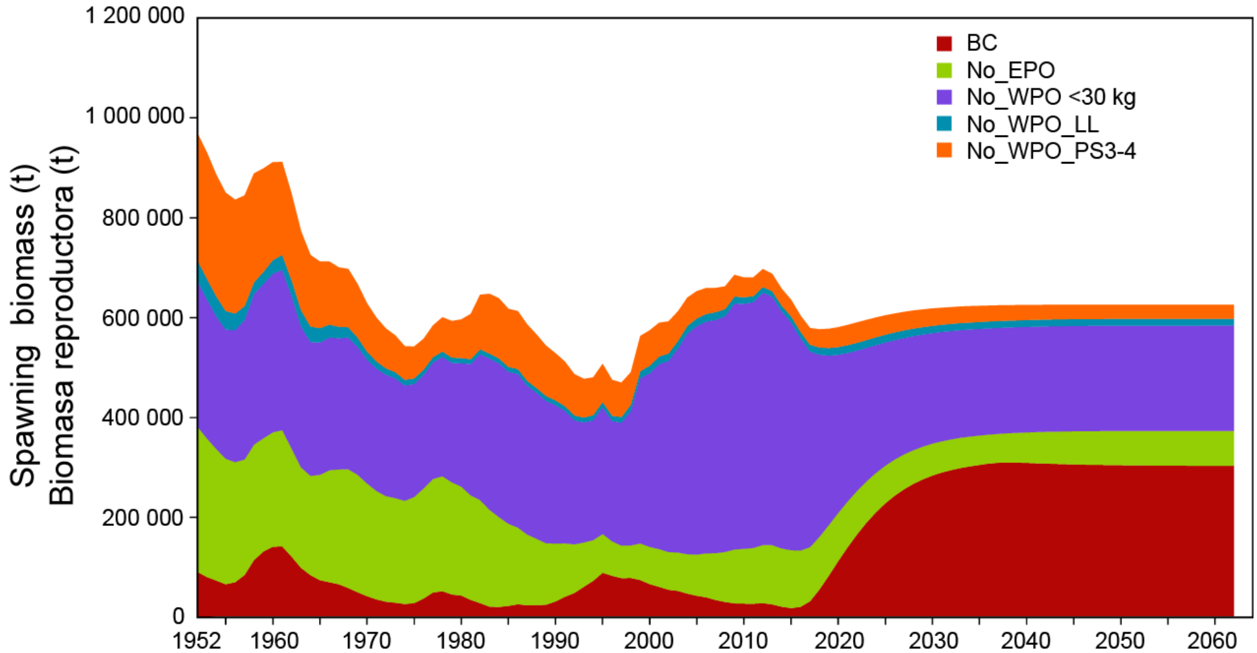

FIGURE 10. Fishery impact from scenario 0 (NC scenario 6 approximation).
FIGURA 10. Impacto de la pesca del escenario 0 (aproximación del escenario 6 del NC).

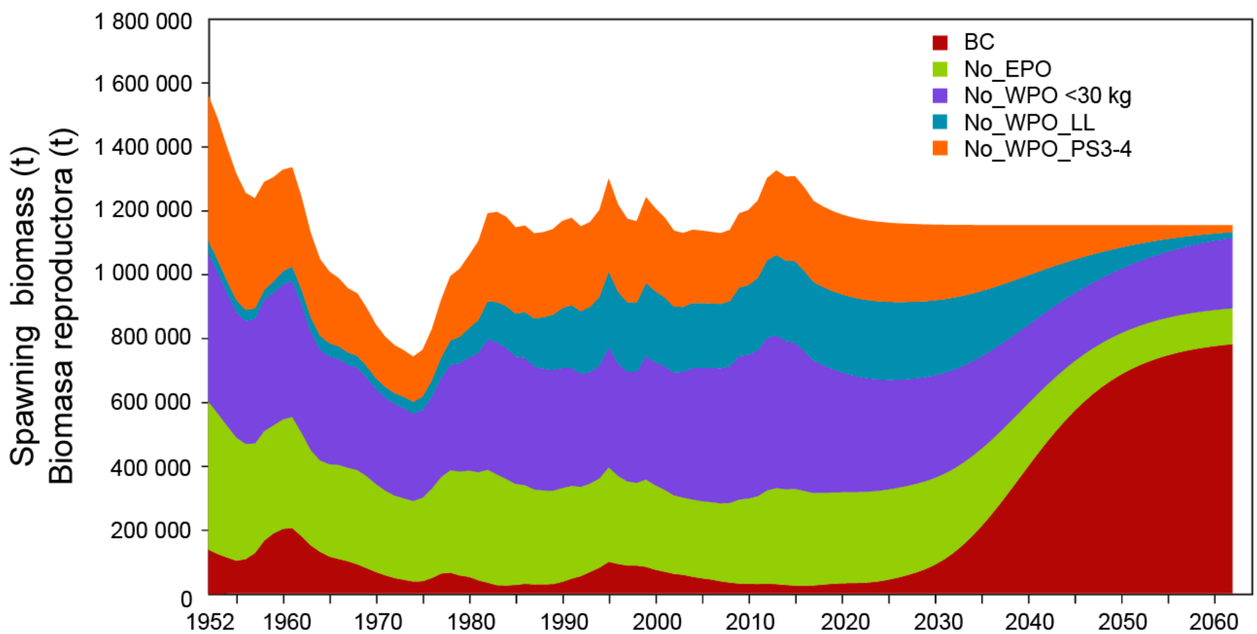

FIGURE 11. Fishery impact from scenario 4 with 30% reduction in catch and stock-recruitment steepness (h) of 0.85.
FIGURA 11. Impacto de la pesca del escenario 4 con una reducción de 30% de la captura y una inclinación (h) de la relación población-reclutamiento de 0.85.

TABLE 1. Spawning biomass (t) for various years under each scenario. Also included for reference purposes are the proposals of Mexico (Scen0_MEX) and Japan (Scen0_JPN).
TABLA 1. Biomasa reproductora (t) en varios años para cada escenario. Se incluyen también para referencia las propuestas de México (Scen0_MEX) y Japón (Scen0_JPN).

	SQ	Scen0	Scen0_MEX	Scen0_JPN
2013	24479	23868	23728	23834
2015	17290	16383	14537	15898
2017	15251	30018	22040	27930
2019	28362	81366	63205	76781
2021	51940	138193	112994	131920
2023	76891	187487	157764	180133
2031	140650	287813	253203	279265
2061	131364	301478	259150	290715
	Scen0_10%	Scen0_20%		Scen0_30%
2013	23643	23699		23752
2015	13609	14214		14845
2017	18049	20669		23404
2019	53420	59932		66453
2021	99453	108516		117572
2023	141499	152404		163190
2031	234259	246958		259502
2061	235893	251466		266881
	Scen1_10%	Scen1_20%		Scen1_30%
2013	23732	23781		23828
2015	12971	13997		15003
2017	7607	12911		18921
2019	12514	29013		47346
2021	24890	54082		83827
2023	37574	78239		117627
2031	81042	140025		193652
2061	82423	143388		200983
	Scen2_10%	Scen2_20%	Scen2_25%	Scen2_30%
2013	24540	24597	24624	24651
2015	18190	19126	19606	20094
2017	20406	26179	29243	32404
2019	45014	62357	71165	80031
2021	79726	107118	120679	134163
2023	112855	147455	164415	181201
2031	187488	232196	254078	275732
2061	183126	232710	256980	280988
	Scen3_10%	Scen3_20%		Scen3_30%
2013	24004	24323		24636
2015	14188	16395		18562
2017	9540	17048		25398

2019	15328	36268		58722	
2021	29302	63641		98953	
2023	43835	90122		134952	
2031	89047	152369		210578	
2061	87815	153141		215056	
	Scen4_10%	Scen4_20%	Scen4_25%	Scen4_30%	
2013	24723	24961	25079	25195	
2015	18830	20389	21177	21970	
2017	21456	28358	32009	35768	
2019	46885	66189	75992	85858	
2021	82293	112181	126970	141670	
2023	99651	153175	171459	189549	
2031	190425	237769	260921	283825	
2061	185401	237148	262482	287544	
	Scen0_lowR	Scen1_30_lowR	Scen2_30_lowR	Scen3_30_lowR	Scen4_30_lowR
2013	23853	23811	24632	24624	25181
2015	15169	13216	18924	17066	20913
2017	13418	3696	16277	9838	19585
2019	21436	1	20585	4297	25703
2021	35089	0	29829	914	36866
2023	48139	0	40127	1	48654
2031	83735	0	69110	0	78877
2061	85505	0	59477	0	67192
	Scen0_h85	Scen2_30_h85	Scen4_30_h85		
2013	27625	28417	29001		
2015	18307	22366	24404		
2017	17795	21358	24913		
2019	20884	23373	30053		
2021	15132	20310	32245		
2023	6857	14366	34482		
2031	0	0	105941		
2061	0	0	777322		

TABLE 2. Spawning biomass for various years under each scenario as a ratio of the average catch in 2010-2012. Also included for reference purposes are the proposals of Mexico (Scen0_MEX) and Japan (Scen0_JPN).

TABLA 2. Biomasa reproductora en varios años en cada scenario como proporción de la captura media de 2010-2012. Se incluyen también para referencia las propuestas de México (Scen0_MEX) y Japón (Scen0_JPN).

	SQ	Scen0_ISC	Scen0_MEX	Scen0_JPN
2013	1.00	0.98	0.97	0.97
2015	1.00	0.95	0.84	0.92
2017	1.00	1.97	1.45	1.83
2019	1.00	2.87	2.23	2.71
2021	1.00	2.66	2.18	2.54
2023	1.00	2.44	2.05	2.34
2031	1.00	2.05	1.80	1.99
2061	1.00	2.29	1.97	2.21
	Scen0_10%	Scen0_20%		Scen0_30%
2013	0.97	0.97		0.97
2015	0.79	0.82		0.86
2017	1.18	1.36		1.53
2019	1.88	2.11		2.34
2021	1.91	2.09		2.26
2023	1.84	1.98		2.12
2031	1.67	1.76		1.85
2061	1.80	1.91		2.03
	Scen1_10%	Scen1_20%		Scen1_30%
2013	0.97	0.97		0.97
2015	0.75	0.81		0.87
2017	0.50	0.85		1.24
2019	0.44	1.02		1.67
2021	0.48	1.04		1.61
2023	0.49	1.02		1.53
2031	0.58	1.00		1.38
2061	0.63	1.09		1.53
	Scen2_10%	Scen2_20%	Scen2_25%	Scen2_30%
2013	1.00	1.00	1.01	1.01
2015	1.05	1.11	1.13	1.16
2017	1.34	1.72	1.92	2.12
2019	1.59	2.20	2.51	2.82
2021	1.53	2.06	2.32	2.58
2023	1.47	1.92	2.14	2.36
2031	1.33	1.65	1.81	1.96
2061	1.39	1.77	1.96	2.14
	Scen3_10%	Scen3_20%		Scen3_30%
2013	0.98	0.99		1.01

2015	0.82	0.95		1.07	
2017	0.63	1.12		1.67	
2019	0.54	1.28		2.07	
2021	0.56	1.23		1.91	
2023	0.57	1.17		1.76	
2031	0.63	1.08		1.50	
2061	0.67	1.17		1.64	
	Scen4_10%	Scen4_20%	Scen4_25%	Scen4_30%	
2013	1.01	1.02	1.02	1.03	
2015	1.09	1.18	1.22	1.27	
2017	1.41	1.86	2.10	2.35	
2019	1.65	2.33	2.68	3.03	
2021	1.58	2.16	2.44	2.73	
2023	1.30	1.99	2.23	2.47	
2031	1.35	1.69	1.86	2.02	
2061	1.41	1.81	2.00	2.19	
	Scen0_ISC_lowR	Scen1_30_lowR	Scen2_30_lowR	Scen3_30_lowR	Scen4_30_lowR
2013	0.97	0.97	1.01	1.01	1.03
2015	0.88	0.76	1.09	0.99	1.21
2017	0.88	0.24	1.07	0.65	1.28
2019	0.76	0.00	0.73	0.15	0.91
2021	0.68	0.00	0.57	0.02	0.71
2023	0.63	0.00	0.52	0.00	0.63
2031	0.60	0.00	0.49	0.00	0.56
2061	0.65	0.00	0.45	0.00	0.51
	Scen0_h85	Scen2_30_h85	Scen4_30_h85		
2013	1.13	1.16	1.18		
2015	1.06	1.29	1.41		
2017	1.17	1.40	1.63		
2019	0.74	0.82	1.06		
2021	0.29	0.39	0.62		
2023	0.09	0.19	0.45		
2031	0.00	0.00	0.75		
2061	0.00	0.00	5.92		

TABLE 3. Equilibrium (after 50 years) percentage impact on the spawning biomass, by fishery group.
TABLA 3. Impacto porcentual de equilibrio (al cabo de 50 años) sobre la biomasa reproductora, por grupo de pesquerías.

			No_EPO	No_WPO<30 kg	No_WPO_LL	No_WPO_PS3-4
2010-2012		SQ	0.32	0.65	0.01	0.02
Scenario 0	(52%)	S0	0.65	0.04	0.09	0.09
	10%	S0 10	0.55	0.03	0.07	0.07
	20%	S0 20	0.57	0.04	0.08	0.08
	30%	S0 30	0.59	0.04	0.08	0.08
	40%	S0 40	0.62	0.04	0.08	0.08
Scenario 1	10%	S1 10	0.70	0.03	0.06	0.06
	20%	S1 20	0.70	0.03	0.06	0.06
	30%	S1 30	0.70	0.03	0.07	0.07
Scenario 2	10%	S2 10	0.65	0.01	0.03	0.03
	20%	S2 20	0.65	0.01	0.03	0.03
	30%	S2 30	0.65	0.01	0.03	0.03
Scenario 3	10%	S3 10	0.71	0.02	0.05	0.05
	20%	S3 20	0.72	0.02	0.05	0.05
	30%	S3 30	0.72	0.02	0.05	0.05
Scenario 4	10%	S4 10	0.65	0.01	0.02	0.02
	20%	S4 20	0.66	0.01	0.02	0.02
	30%	S4 30	0.66	0.01	0.02	0.02
Scenario 4	30%	S2_30_h85	0.59	0.05	0.06	0.06