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A REVIEW OF HISTORICAL EPO YFT STOCK ASSESSMENT SENSITIVITY ANALYSES

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CONTENTS

The following summarizes the results of previous sensitivity analyses conducted for the yellowfin tuna stock assessment in the eastern Pacific Ocean (EPO). The review covers different types of sensitivity analyses presented in the IATTC annual Stock Assessment Reports (SAR) from assessment year 2004 to 2012. Table 1 provides a summary of the sensitivity analyses conducted to date.

1. ASSESSMENT YEAR 2003 (SAR4 - ASCALA)

Several sensitivity analyses were carried out, including: (1) incorporation of a Beverton-Holt stock recruitment relationship with a steepness of 0.75, (2) iterative reweighting of the length-frequency sample size, (3) species-composition catch estimates, and (4) selectivity smoothness penalty weights used in previous assessments. The sensitivities do not differ much from those of the base case except for the stock-recruitment relationship sensitivity. We discuss this sensitivity and the iterative reweighting of the length-frequency sample size sensitivity below.

Stock assessment results

A sensitivity analysis was carried out to determine the effect of the stock-recruitment relationship. The base case analysis was carried out with an assumption of no stock-recruitment relationship (steepness parameter fixed at 1). An alternative analysis was carried out with the steepness of the Beverton-Holt stock-recruitment relationship fixed at 0.75. This implies that when the population is reduced to 20% of its unexploited level, the expected recruitment is 75% of the recruitment from an unexploited population. Previous results (Maunder and Watters 2002) suggest that the analysis with a stock-recruitment relationship fits the data better than the analysis without the stock-recruitment relationship, but, given the amount of data used in the analysis, the difference is probably not statistically significant (see Maunder and Watters 2002). The preference for lower values of steepness is probably a consequence of the regime shift in recruitment. When a Beverton-Holt stock recruitment relationship (steepness = 0.75) is included, the estimated biomass and recruitment are almost identical to those of the base case.

A sensitivity analysis was carried out to determine the influence of the length-frequency sample size. McAllister and Ianelli (1997) used an analytical method to determine the effective sample size for catchat- age data based on the observed and predicted proportional catch at age. They used a method of iteratively modifying the sample size based on this calculation until the change in sample size was small. We use this method to determine new sample sizes for each set (fishery and time period) of length-frequency data. The original sample size for the surface gears used in the base case was based on number of wells sampled. For the longline gears we modified the sample size so that the average sample size for the southern longline fishery was equal to the average sample size for the surface fishery that had the maximum average sample size (Fishery 7). This involved dividing the longline sample size by 25,143 (scaling factor) for each length-frequency time-fishery data set. The reweighting sensitivity has, on average, greater sample sizes than the base case for all fisheries. The sample size is increased, on average, between about 5 and 15 times for all fisheries except for the northern longline fishery, which increased by 88 times. This indicates that the purse-seine effective sample size is still less than the number of fish measured (about 50 per well) and that the longline effective sample size is still substantially less than the number of fish measured. The results from the reweighting sensitivity are similar to those of the base case, but the confidence intervals are much narrower. The average CV for the recruitment, biomass, and spawning biomass are 0.08, 0.02, and 0.02, respectively.

Reference points

When the Beverton-Holt stock-recruitment relationship is included in the analysis with a steepness of 0.75, the spawning biomass ratio (SBR) which consists of the ratio between the current and virgin spawning biomasses, is reduced and the SBR level that produces MSY1 (maximum sustainable yield) is increased. The SBR is estimated to be less than that at MSY for most of the model period, except for most of 1999-2002. The current effort level is estimated to be above the level required to produce MSY (Fmult < 12), but, due to the recent large recruitment, current catch is greater than MSY. In contrast to the analysis without a stock-recruitment relationship, the addition of this relationship may cause catch to be moderately reduced if effort is increased beyond the level required for MSY. The analysis without a stock-recruitment relationship has a relative yield curve equal to the relative yield-per-recruit curve because recruitment is constant. The yield curve bends over slightly more rapidly when the stock-recruitment relationship is included. The equilibrium catch under the current effort levels is estimated to be only slightly less than MSY, indicating that reducing effort will not greatly increase the catch.

[1] AMSY (average maximum sustainable yield) and MSY have been used interchangeably in the stock assessments
[2] Fmult is the ratio of the fishing mortality at MSY (FMSY) to the current fishing mortality and indicates how much the fishing effort would have to be changed to produce MSY. This quantity is used as the basis for making management decisions for tunas in the EPO.

TABLE 5.1. AMSY and related quantities for the base case and the stock-recruitment relationship sensitivity analysis.
TABLA 5.1. RMSP y cantidades relacionadas para el caso base y los análisis de sensibilidad a la relación población-reclutamiento.

	Base case	h = 0.75	Iterative reweighting
	Caso base	h = 0.75	Reponderación iterativa
AMSY–RMSP	254,723	266,371	250,750
B_{ms2} –B_{rm2}	381,775	502,129	377,686
S_{ms2}—S_{rm2}	6,010	7,946	5,990
C_{2002}/AMSY—C_{2002}/RMSP	1.72	1.64	1.76
B_{2003}/B_{AMSY} –B_{2003}/B_{RMSP}	0.89	0.70	0.74
S_{2003}/S_{AMSY} –S_{2003}/S_{RMSP}	0.89	0.70	0.74
$S_{AMSY}/S_{F=0}$ –$S_{RMSP}/S_{F=0}$	0.37	0.41	0.38
F multiplier—Multiplicador de *F*	1.20	0.89	1.36

	Last year's selectivity smoothness weighting factors	Species composition-based catches
	Factores de ponderación por suavidad de selectividad del año pasado	Capturas basadas en composición por especie
AMSY–RMSP	254,334	253,594
B_{ms2} –B_{rm2}	379,826	379,913
S_{ms2}—S_{rm2}	5,965	5,983
C_{2002}/AMSY—C_{2002}/RMSP	1.72	1.63
B_{2003}/B_{AMSY} –B_{2003}/B_{RMSP}	0.86	0.87
S_{2003}/S_{AMSY} –S_{2003}/S_{RMSP}	0.87	0.87
$S_{AMSY}/S_{F=0}$ –$S_{RMSP}/S_{F=0}$	0.37	0.38
F multiplier—Multiplicador de *F*	1.18	1.20

2. ASSESSMENT YEAR 2006 (SAR7 - ASCALA)

Sensitivity analyses were carried out to investigate the incorporation of a Beverton-Holt (1957) stock-recruitment relationship, the assumed value for the asymptotic length parameter of the Richards growth curve, and changing the longline CPUE standardization method from using a delta-gamma model to using a delta-lognormal model.

Stock assessment results

The base case analysis assumed no stock-recruitment relationship, and an alternative analysis was carried out with the steepness of the Beverton-Holt stock-recruitment relationship fixed at 0.75. This implies that when the population is reduced to 20% of its unexploited level, the expected recruitment is 75% of the recruitment from an unexploited population. As in previous assessments, the analysis with a stock-recruitment relationship fits the data better than the analysis without the stock-recruitment relationship. However, the regime shift in recruitment could also explain the result, since the period of high recruitment is associated with high spawning biomass, and vice versa. When a Beverton-Holt stock recruitment relationship (steepness = 0.75) is included, the estimated biomass and recruitment are almost identical to those of the base case assessment. However, when the stock-recruitment relationship is included, the recent spawning biomass is below the level corresponding to the MSY.

The assumed value for the asymptotic length parameter of the Richards growth curve was fixed at a lower value of 170 cm, and an upper value of 200 cm, bracketing the base case value of 185 cm estimated from the otolith data. The value of 154 cm estimated by stock assessments for the western and central Pacific Ocean (Adam Langley, Secretariat of the Pacific Community, pers. com.) was not consistent with the otolith data. Unlike the EPO bigeye assessment (Harley and Maunder 2005), the estimated biomass and recruitment are not very sensitive to values of the asymptotic length parameter in the range investigated. There are very few individuals larger than 160 cm in the length-frequency data, and the maximum length seen is between 175 and 190 cm in most years. There are estimated to be comparatively few large fish in the population throughout the period of the assessment, given the fishing mortality applied by the purse-seine fisheries and the high natural mortality. The longline fishery selectivities are able to adjust to fit the expected numbers at length, such that when asymptotic length is greater, selectivity at older ages is increased to eliminate the older, larger fish. This flows through into greater fishing mortality at greater ages, to an extent that may not be realistic. The SBR is also insensitive to the asymptotic length parameter, which can be explained by the low proportion of females in the population in the older age classes. The best fit to the data is from the model with the low value for the asymptotic length parameter, with most of the improvement coming from a better fit to the length-frequency data.

A new method was used to standardize the longline CPUE data in 2006: a delta-lognormal model was used instead of a delta-gamma model. This resulted in slightly different CPUE indices for the northern and southern longline fisheries. The biomass was insensitive to this change, as were the SBR and SBR associated with MSY.

Reference points

When the Beverton-Holt stock-recruitment relationship is included in the analysis with a steepness of 0.75, the SBR is reduced and the SBR level corresponding to the MSY is increased. The SBR is estimated to be less than that at MSY for most of the model period, except for the 2000- 2002 period. The current effort level is estimated to be above the MSY level, and current catch very close to the MSY. In contrast to the analysis without a stock-recruitment relationship, the addition of this relationship implies that catch may be moderately reduced if effort is increased beyond the level required for MSY. The analysis without a stock-recruitment relationship has a relative yield curve equal to the relative yield-per-recruit curve because recruitment is constant. The yield curve bends over slightly more rapidly when the stock-recruitment relationship is included than when it is not included. The equilibrium catch under the current effort levels is estimated to be 96% of MSY, indicating that reducing effort would not greatly increase the catch.

When the asymptotic length is adjusted to either 170 cm or 200 cm, the SBR does not change significantly; the SBR level corresponding to the MSY is reduced slightly for asymptotic length of 170 cm. The current effort level is estimated to be either slightly below (L_∞ = 170 cm) or very close to (L_∞ = 200 cm) the MSY level (Table 5.1 in SAR 7), and the current catch very close to the MSY (Table 5.1 in SAR 7). The implications of increasing effort are very similar to the base case. The equilibrium catch under the current effort levels for asymptotic length of 170 cm is estimated to be 100% of MSY, indicating that increasing effort would not increase the equilibrium catch.

TABLE 5.1. AMSY and related quantities for the base case and the stock-recruitment relationship sensitivity analysis. All analyses are based on average fishing mortality for 2003 and 2004. B_{recent} and B_{AMSY} are defined as the biomass of fish 2+ quarters old at the start of 2006 and at AMSY, respectively, and S_{recent} and S_{AMSY} are defined as indices of spawning biomass (therefore, they are not in metric tons). C_{recent} is the estimated total catch in 2005.

TABLA 5.1. RMSP y cantidades relacionadas para el caso base y los análisis de sensibilidad a la relación población-reclutamiento. Todos los análisis se basan en la mortalidad por pesca media de 2003 y 2004. Se definen B_{recent} y B_{RMSP} como la biomas de peces de 2+ trimestres de edad al principio de 2006 y en RMSP, respectivamente, y S_{recent} y S_{RMSP} como los índices de biomasa reproductora (por lo tanto, no se expresan en toneladas métricas). C_{recent} es la captura total estimada en 2005.

	Base case Caso base	**h = 0.75**	**L_∞ = 170 cm**	**L_∞ = 200 cm**
AMSY–RMSP	287,519	300,282	288,809	287,695
B_{AMSY}–B_{RMSP}	416,379	546,213	409,895	419,322
S_{AMSY}—S_{RMSP}	4,677	6,444	4,662	4,661
C_{recent}/AMSY—C_{recent}/RMSP	1.06	1.01	1.05	1.06
B_{recent}/B_{AMSY}–B_{recent}/B_{RMSP}	1.00	0.77	1.02	1.02
S_{recent}/S_{AMSY}–S_{recent}/S_{RMSP}	1.14	0.83	1.16	1.15
$S_{AMSY}/S_{F=0}$–$S_{RMSP}/S_{F=0}$	0.37	0.43	0.36	0.37
F multiplier—Multiplicador de *F*	1.02	0.68	1.04	1.04

3. ASSESSMENT YEAR 2009 (SAR10 – Stock Synthesis)

The stock assessment was conducted using Stock Synthesis for the first time. Seven sensitivity analyses were carried out to investigate the incorporation of a Beverton-Holt stock-recruitment relationship, inclusion of CPUE and length composition data from all fisheries, natural mortality, selectivity, growth, exclusion of the floating-object size-composition data, and a change in the floating-object fisheries selectivity starting in 2001.

Stock assessment results

The base case analysis assumed no stock-recruitment relationship, and an alternative analysis was carried out with the steepness of the Beverton-Holt stock-recruitment relationship fixed at 0.75. This implies that when the population is reduced to 20% of its unexploited level, the expected recruitment is 75% of that from an unexploited population. As in previous assessments, the analysis with a stock-recruitment relationship fits the data better than the analysis without the stock-recruitment relationship. However, as stated previously, the regime shift could also explain the result, since the period of high recruitment is associated with high spawning biomass, and vice versa. When a Beverton-Holt stock-recruitment relationship (steepness = 0.75) is included, the estimated biomass and recruitment are almost identical to those of the base case assessment.

The estimated biomass and the relative recruitment from the sensitivity analysis that includes all the data (i.e. size composition and CPUE data for all fisheries except the discard fisheries and the CPUE for the pole and line fishery) in the model are similar to those for the base case.

The model that estimates the natural mortality for mature yellowfin produces a substantially better fit to the data with a reduction in the negative log likelihood of 46 units for two additional parameters. The estimated biomass is much greater than for the base case. The relative recruitment is similar to that for the base case. The natural mortality was estimated to be slightly higher for adult females, but was also estimated to increase substantially for males.

When age-specific selectivity is used, the estimated abundance and recruitment are similar to the base case, but the SBR corresponding to MSY is substantially higher. The estimated age-specific selectivity curves show peaks at around 10-15 quarters similar to the length-based selectivities estimated in the previous assessment.

The model that fixes the length at the maximum age to 175 cm produces a better fit to the length-frequency data, but a worse fit to the CPUE data. However, the total negative log likelihood cannot be compared because of the additional sex ratio data. Nevertheless, removing the otolith data component of the negative log likelihood indicates that the lower length at the maximum age fits the other data better. The estimated biomass is moderately greater than that for the base case and the relative recruitment is similar to that for the base case.

Excluding the size-composition data for the floating object fishery from the analysis has very little impact on the results, except for lowering the most recent recruitment and biomass estimates. However, it does remove the retrospective pattern of recent recruitment and biomass being estimated higher when recent data are excluded from the analysis.

Including a change in selectivity for the floating-object fisheries starting in 2001 has negligible impact on the results, despite the improved fit to the data as represented by a reduction in the negative log likelihood. The selectivities for three of the four floating-object fisheries catch more smaller yellowfin after the adoption of the resolution, as would be expected due to the ban on discards of small tuna.

Reference points

Including a stock-recruitment relationship in the stock assessment produces more pessimistic results, with the current spawning biomass being below that corresponding to MSY and fishing effort being higher than that corresponding to MSY (Table 5.1 SAR10). However, it increases the level of MSY that can be achieved. Including all the data has only a small impact on the results. Estimating the adult natural mortality produces more optimistic results, with the spawning biomass being substantially greater than that corresponding to MSY, current effort being substantially below that corresponding to MSY, and increases the level of MSY that can be obtained. Estimating age-specific selectivity increases the SBR corresponding to MSY, and therefore the spawning biomass is less than that corresponding to MSY and the effort levels are greater than those corresponding to MSY. Fixing the length at the maximum age to 175 cm produces more optimistic results, with the spawning biomass being substantially greater than that corresponding to MSY and current effort being substantially below that corresponding to MSY, but the level of MSY that can be obtained is about the same. The sensitivity analyses showed that excluding the floating object size composition data or including a change in the selectivities for the floating-object fisheries caused negligible changes in the management quantities (results not presented).

TABLE 5.1. MSY and related quantitie s for the base case and the stock-recru itment relationship sensitivity analysis, ba sed on average fis hing mortality (F) for 2006-2008. The quantities are also given based on average F for 2006-2007. B_{recent} and B_{MSY} are defined as the biomass of fish 3+ quarters old at the start of the first quarter of 2009 and at MSY, respectively, and S_{recent} and S_{MSY} are defined as indices of spawning bioma ss (therefore, they are not in metric tons). C_{recent} is the estimated total catch for 2008.

TABLA 5.1. RMS y cantidades relacionadas para el caso base y los análisis de sensibilidad a la relación población-reclutamiento, basados en la mortalidad por pesca (F) media de 2006-2008. Se presentan también las ca ntidades basadas en la F media de 200 6-2007. Se definen B_{recent} y B_{RMS} como la biomasa de peces de 3+ t rimestres de edad al princi pio del primer trimestr e de 2009 y en RMS, respecti vamente, y S_{recent} y S_{RMS} como índices de biomasa reproductora (por lo tanto, no se expresan en toneladas métricas). C_{recent} es la captura total estimada de 2008.

	Base case Caso base	h = 0.75	Average F F promedio 2006-2007	All data Todos los datos	Natural mortality Mortalidad natural	Selectivity Selectividad	Growth Crecimiento
MSY–RMS	273,159	310,073	274,944	269,296	327,475	267,222	274,688
B_{MSY}–B_{RMS}	372,909	594,909	373,750	376,590	395,803	434,769	368,475
S_{MSY}–S_{RMS}	3,522	6,436	3,523	3,626	3,259	4,764	3,163
C_{recent}/MSY–C_{recent}/RMS	0.75	0.66	0.74	0.76	0.62	0.76	0.74
B_{recent}/B_{MSY}–B_{recent}/B_{RMS}	1.27	0.78	1.27	1.12	1.9	0.81	1.5
S_{recent}/S_{MSY}–S_{recent}/S_{RMS}	1.32	0.71	1.32	1.16	2.56	0.81	1.66
$S_{MSY}/S_{F=0}$–$S_{RMS}/S_{F=0}$	0.27	0.36	0.27	0.28	0.2	0.38	0.24
F multiplier—Multiplicador de F	1.09	0.68	1.00	1.06	2.27	0.68	1.39

4. ASSESSMENT YEAR 2011 (SAR12 – Stock Synthesis)

Three sensitivity analyses were carried out to investigate the incorporation of a Beverton-Holt stock-recruitment relationship, average size of the older fish, and fitting to the CPUE data of the northern dolphin-associated fishery as the main index of abundance.

Stock assessment results

The base case assessment assumed no stock-recruitment relationship, and an alternative analysis was carried out with the steepness of the Beverton-Holt stock-recruitment relationship fixed at 0.75. This implies that when the population is reduced to 20% of its unexploited level, the expected recruitment is 75% of that from an unexploited population. As in previous assessments, the analysis with a stock-recruitment relationship fits the data better than the analysis without the stock-recruitment relationship. However, as stated previously, the regime shift could also explain the result, since the period of high recruitment is associated with high spawning biomass, and vice versa. When a Beverton-Holt stock-recruitment relationship (steepness = 0.75) is included, the estimated biomass and recruitment are almost identical to those of the base case assessment. A likelihood profile on steepness confirms that the model fits better at lower fixed values for this parameter, with its maximum likelihood apparently occurring at about 0.7.

The base case model assumes a Richards (1959) growth function. The choice of the average size of the older fish – the L2 parameter – is somewhat arbitrary, since otolith readings are not available for larger (older) fish. In the base case, L2 is fixed at 182.3 cm, a value estimated in a previous assessment (Maunder and Aires-da-Silva 2010). A sensitivity analysis was done to study the effect of fixing L2 at different values (a lower and a higher value, 170 and 190 cm, respectively). The estimated biomass and recruitment time series are very sensitive to the assumed value of L2, they are greater for a lesser value of the parameter.

The base case model assumes the CPUE of the southern longline fishery (Fishery 12) to be the most reliable index of abundance (CV = 0.2). However, this fishery mainly targets bigeye tuna, not yellowfin. If instead the model is fitted more closely to the northern dolphin-associated fishery (Fishery 9, CV = 0.2), the biomass and recruitment trajectories are still very similar to those from the base case. This suggests that there is consistency in the information provided by the two CPUE indices. However, the recent decline in biomass levels estimated by the base case is not so strong in the sensitivity analysis, particularly for spawning biomass. This result is mainly due to the model fitting more closely to the recent CPUE trends of the northern dolphin-associated fishery, rather than the southern longline fishery. The model fit to the CPUE of the northern dolphin-associated fishery is not so indicative of the pronounced recent decline as indicated by the base case model which fits more closely to the CPUE of the southern longline fishery.

Reference points

Including a stock-recruitment relationship in the stock assessment produces more pessimistic results, with the current spawning biomass being below that corresponding to MSY and fishing effort being higher than that corresponding to MSY MSY (Table 5.1 SAR12). However, it increases the level of MSY that can be achieved. Fixing the mean size of the oldest age class to a lower value than that assumed in the base case (e.g., 170 cm) produces more optimistic results, with the spawning biomass being at about the level corresponding to MSY and current effort being substantially below that level, but the level of MSY that can be obtained is about the same. In contrast, fixing the mean size of the oldest age class to a higher value than that assumed in the base case (e.g.,190 cm) produces more pessimistic results, with the spawning biomass being below that corresponding to MSY and current effort dropping below the level corresponding to MSY, but the level of MSY that can be obtained changes little. The sensitivity analyses showed that fitting more closely to the CPUE data of the northern dolphin-associated fishery (CV fixed at 0.2), rather than taking the CPUE of the southern longline fishery as the main index of abundance, produces a more optimistic assessment of the status of the stock. While the recent spawning biomass is estimated to be about the level corresponding to MSY, the recent levels of fishing effort are estimated to be well below those corresponding to MSY.

TABLE 5.1. Estimates of the MSY and its associated quantities for yellowfin tuna for the base case assessment and the sensitivity analyses. All analyses are based on average fishing mortality during 2008-2010. B_{recent} and B_{MSY} are defined as the biomass of fish 3+ quarters old (in metric tons) at the beginning of 2011 and at MSY, respectively. S_{recent} and S_{MSY} are in metric tons. C_{recent} is the estimated total catch in 2010. The F multiplier indicates how many times effort would have to be effectively increased to achieve the MSY in relation to the average fishing mortality during 2008-2010.

TABLA 5.1. Estimaciones del RMS y sus cantidades asociadas para el atún patudo para la evaluación del caso base y los análisis de sensibilidad. Todos los análisis se basan en la mortalidad por pesca promedio de 2008-2010. Se definen B_{recent} y B_{RMS} como la biomasa de peces de 3+ trimestres de edad (en toneladas métricas) al principio de 2011 y en RMS, respectivamente. Se expresan S_{recent} y S_{MSY} en toneladas métricas. C_{recent} es la captura total estimada en 2010. El multiplicador de F indica cuántas veces se tendría que incrementar el esfuerzo para lograr el RMS en relación con la mortalidad por pesca media durante 2008-2010.

Data – Datos	Base case Caso base	F (avg.-prom. 2008-2009)	h = 0.75	L_2		CPUE DEL-N
				170 cm	190 cm	
MSY-RMS	262,857	263,310	291,790	275,310	264,704	266,470
B_{MSY}- B_{RMS}	354,958	360,024	559,967	370,334	359,144	362,808
S_{MSY}- S_{RMS}	3,305	3,407	5,993	3,777	3,169	3,413
B_{MSY}/B_0- B_{RMS}/B_0	0.31	0.32	0.37	0.31	0.31	0.32
S_{MSY}/S_0- S_{RMS}/S_0	0.26	0.27	0.35	0.24	0.27	0.26
C_{recent}/MSY- C_{recent}/RMS	0.88	0.88	0.79	0.84	0.87	0.87
B_{recent}/B_{MSY}- B_{recent}/B_{RMS}	0.96	0.95	0.61	1.20	0.85	1.23
S_{recent}/S_{MSY}-S_{recent}/S_{RMS}	0.71	0.69	0.39	1.03	0.59	0.98
F multiplier-Multiplicador de F	1.13	1.29	0.71	1.65	0.94	1.29

5. SUMMARY

Several sensitivity analyses have been carried out for the EPO yellowfin tuna stock assessment since first application of integrated statistical age-structured models. Many of these sensitivities have had little impact on the results including: (a) iterative reweighting of the length-frequency sample size, (b) species-composition catch estimates, (c) selectivity smoothness penalty weights, (d) changing the longline CPUE standardization method from using a delta-gamma model to using a delta-lognormal model, (e) including size composition and CPUE data from all the fisheries, (f) Including a change in selectivity for the floating-object fisheries starting in 2001, g) and fitting to the CPUE data of the northern dolphin-associated fishert as the main index of abundance. The results were particularly sensitive to the steepness of the stock-recruitment relationship, natural mortality, the mean size of older individuals, and assumptions about selectivity curves. The recent recruitment and biomass estimates were sensitive to the exclusion of the floating object fishery size-composition and this eliminated the retrospective bias.

REFERENCES

See Table 1 for EPO yellowfin tuna stock assessment references. Additional references are provided below.

McAllister, M.K., Ianelli, J.N., 1997. Bayesian stock assessment using catch-at-age data and the sampling-importance resampling algorithm. Can. J. Fish. Aquat. Sci. 54, 284–300.

Harley and Maunder (2005)

http://iattc.org/PDFFiles2/StockAssessmentReports/SAR5%20_BET_%20ENG.pdf

Table 1. Summary of historical sensitivity analyses for the EPO yellowfin tuna stock assessment.

SAR	Assessment Year	Model	Reference	Sensitivities	Change in S/S_{MSY}	Change in Fmultiplier
1	2000	ASCALA	Maunder and Watters (2001) http://www.iattc.org/PDFFiles2/StockAssessmentReports/SAR1_yelllowfin_ENG.pdf	None		
2	2001	ASCALA	Maunder and Watters (2002) http://www.iattc.org/PDFFiles2/StockAssessmentReports/SAR2_yellowfin_ENG.pdf	h=0.75		
3	2002	ASCALA	Maunder (2002) http://www.iattc.org/PDFFiles/SAR3_YFT_ENG.pdf	h=0.75		
4	2003	ASCALA	Maunder and Harley (2004) http://www.iattc.org/PDFFiles2/StockAssessmentReports/SAR4_YFT_ENG.pdf	a) h=0.7 b) Iterative reweighting of the length-frequency sample size c) Species-composition catch estimates d) Selectivity smoothness penalty weights used in previous assessments.	-21% -17% -2% -2%	-26% 13% 0% -2%
5	2004	ASCALA	Maunder and Harley (2005) http://www.iattc.org/PDFFiles2/StockAssessmentReports/SAR5%20_YFT_ENG.pdf	h=0.75		
6	2005	ASCALA	Hoyle and Maunder (2006) http://www.iattc.org/PDFFiles2/Sto	h=0.75		

			ckAssessmentReports/SAR6-YFT-ENG.pdf			

7	2006	ASCALA	Hoyle and Maunder (2007) http://www.iattc.org/PDFFiles2/StockAssessmentReports/SAR7-YFT-ENG.pdf	a) h=0.75;
				b) Linf = 170 cm
				c) Linf = 200 cm;
				d) Delta-lognormal standardized CPUE;
					-27%
					2%
					1%
					Small
						-33%
						2%
						2%
						Small

8	2007	ASCALA	Maunder (2008) http://www.iattc.org/PDFFiles2/StockAssessmentReports/SAR8-YFT-ENG.pdf	h=0.75;		
9	2008	ASCALA	Maunder (2009) http://www.iattc.org/PDFFiles2/StockAssessmentReports/SAR9-YFT-ENG.pdf	h=0.75;		
10	2009	SS3	Maunder and Aires-da-Silva (2010) http://www.iattc.org/PDFFiles2/StockAssessmentReports/SAR10a-YFT-ENG.pdf	a) h=0.75; b) CPUE sds estimated; c) M for mature females and for mature males estimated and data on sex ratio included; d) Penalized age-specific parameters used for some selectivities; e) The maximum length is fixed at 175 cm, and the remaining three parameters of the Richards growth equation are estimated. The model is fit to age data from otoliths conditioned on length. f) Excluding the size-composition data for the floating-object fisheries from the analysis	-46% -12% 94% -39% 26% Small	-38% -3% 108% -38% 28% Small

				g) Change in selectivity for the floating-object fisheries starting in 2001 due to Resolution C-00-08, which prohibited the discarding of yellowfin tuna resulting from sorting by size	Small	Small
11	2010	SS3	Maunder and Aires-da-Silva (2011) http://www.iattc.org/PDFFiles2/StockAssessmentReports/SAR-11-YFT-ENG.pdf	h=0.75		
12	2011	SS3	Aires-da-Silva and Maunder (2012) http://www.iattc.org/PDFFiles2/StockAssessmentReports/SAR-12-YFTENG.pdf	a) h=0.75 b) L2 is fixed 170 cm c) L2 is fixed at 190 cm. d) Fitting to the CPUE of the northern dolphin-associated fishery as the main index of abundance, rather than the CPUE of the southern longline fishery. For this purpose, the CV fixed at 0.2, and the CVs of other fisheries are estimated.	-45% 45% -17% 38%	-37% 46% -17% 14%
13	2012	SS3	Aires-da-Silva and Maunder (2012) http://www.iattc.org/PDFFiles2/StockAssessmentReports/SAR-12-YFTENG.pdf	h=0.75		