2016 Pacific Bluefin Tuna Stock Assessment

ISC PBFWG

EXECUTIVE SUMMARY

1. Stock Identification and Distribution

Pacific bluefin tuna (*Thunnus orientalis*) has a single Pacific-wide stock managed by both the Western and Central Pacific Fisheries Commission (WCPFC) and the Inter-American Tropical Tuna Commission (IATTC). Although found throughout the North Pacific Ocean, spawning grounds are recognized only in the western North Pacific Ocean (WPO). A portion of each cohort makes trans-Pacific migrations from the WPO to the eastern North Pacific Ocean (EPO), spending up to several years of its juvenile life stage in the EPO before returning to the WPO.

2. Catch History

While Pacific bluefin tuna (PBF) catch records prior to 1952 are scant, there are some PBF landings records dating back to 1804 from coastal Japan and to the early 1900s for U.S. fisheries operating in the EPO. Catch of PBF was estimated to be high from 1929 to 1940, with a peak catch of approximately 47,635 t (36,217 t in the WPO and 11,418 t in the EPO) in 1935; thereafter catches of PBF dropped precipitously due to World War II. PBF catches increased significantly in 1949 as Japanese fishing activities expanded across the North Pacific Ocean. By 1952, a more consistent catch reporting process was adopted by most fishing nations. Estimates indicate that annual catches of PBF fluctuated widely from 1952-2014 (Figure 1). During this period reported catches peaked at 40,383 t in 1956 and reached a low of 8,653 t in 1990. While a suite of fishing gears have been used to catch PBF, the majority is currently caught in purse seine fisheries (Figure 2). Catches during 1952-2014 were predominately composed of juvenile PBF, but since the early 1990s, the catch of age 0 PBF has increased significantly (Figure 3).

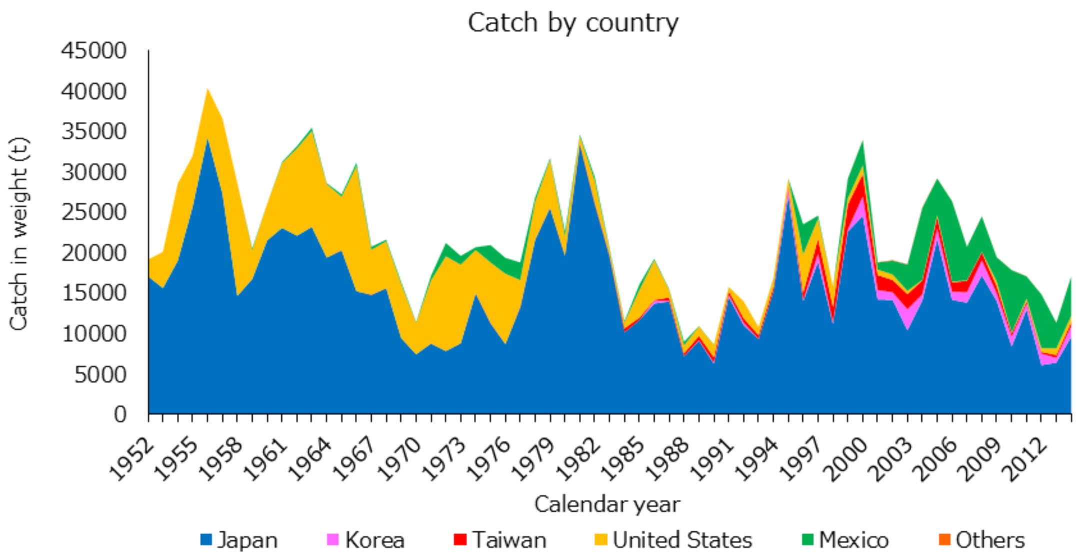


Figure 1. Annual catch of Pacific bluefin tuna (*Thunnus orientalis*) by country from 1952 through 2014 (calendar year).

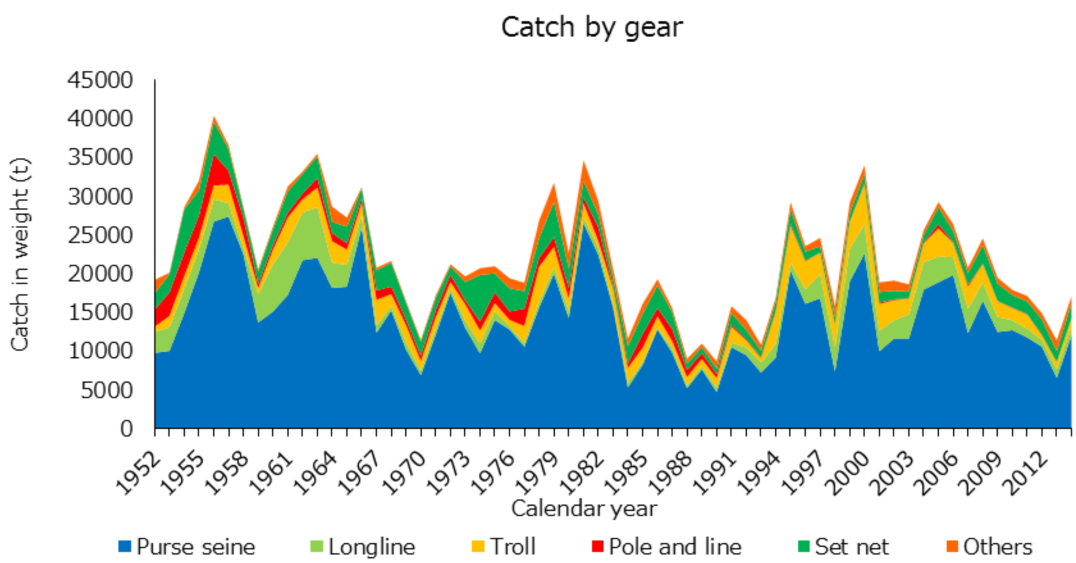


Figure 2. Annual catch of Pacific bluefin tuna (*Thunnus orientalis*) by gear type from 1952 through 2014 (calendar year).

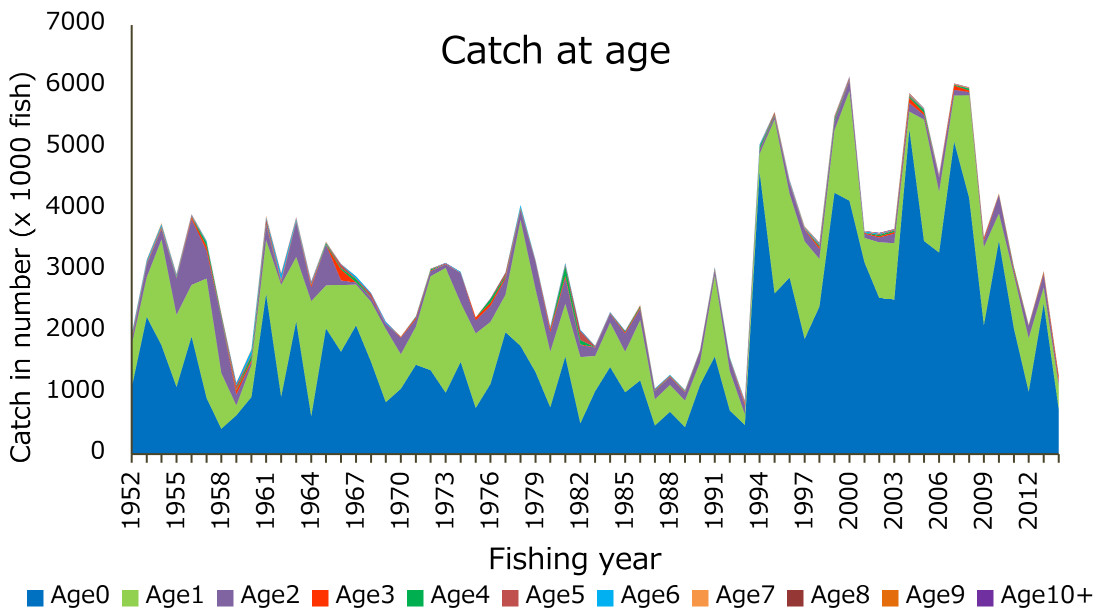


Figure 3. Annual catch-at-age of Pacific bluefin tuna (*Thunnus orientalis*) by fishing year (1952-2014).

3. Data and Assessment

Population dynamics were estimated using a fully integrated age-structured model (Stock Synthesis (SS) v3.24f) fitted to catch, size-composition and catch-per-unit of effort (CPUE) data from 1952 to 2015, provided by Members of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC), Pacific Bluefin Tuna Working Group (PBFWG) and non-ISC countries. Life history parameters included a length-at-age relationship from otolith-derived ages, and natural mortality estimates from a tag-recapture study and empirical-life history methods.

A total of 19 Fleets were defined for use in the stock assessment model based on country/gear/season/region stratification. Quarterly observations of catch and size compositions, when available, were used as inputs to the model to describe the removal processes. Annual estimates of standardized CPUE from the Japanese distant water, off-shore and coastal longline, the Taiwanese longline and the Japanese troll fleets were used as measures of the relative abundance of the population. The assessment model was fitted to the input data in a likelihood-based statistical framework. Maximum likelihood estimates of model parameters, derived outputs and their variances were used to characterize stock status and to develop stock projections.

In the previous assessments, it was found that conflicts existed among data in the model. However, stock biomass trends were consistent among tested model runs and conservation advice based on those results was provided. The 2016 assessment model was developed and refined in the intervening three years based on improvements made by PBFWG scientists. The improvements include: more accurate historical catch data, a better estimate of size composition by fleet, improved standardization of abundance indices, a revised growth curve based on additional otolith information and standardization of aging techniques, and improved model settings to represent the best input data.

4. Stock Status and Conservation Advice accepted at ISC16 Plenary

<u>Stock Status</u>

The PBFWG conducted a benchmark assessment (base-case model) using the best available fisheries and biological information. For data considered reliable, the base-case model fits the data well and is internally consistent among most of the other sources of data. The model is a substantially improved from the 2014 assessment. The base-case model indicates: (1) spawning stock biomass (SSB) fluctuated throughout the assessment period (fishing years 1952-2014) and (2) the SSB steadily declined from 1996 to 2010; and (3) the decline appears to have ceased since 2010, although the stock remains near the historic low. The model diagnostics suggest that the estimated biomass trend for the last 30 years is considered robust although SSB prior to the 1980s is uncertain due to data limitations.

Using the base-case model in the 2016 assessment, the 2014 (terminal year) SSB was estimated to be around 17,000 t (Figure 7-4), which is about 9,000 t below the terminal year estimated in the 2014 assessment (26,000 in 2012). This is because of improvements to the input data and refinements to the assessment model which scaled down the estimated value of SSB, and not because the SSB declined from 2012 to 2014.

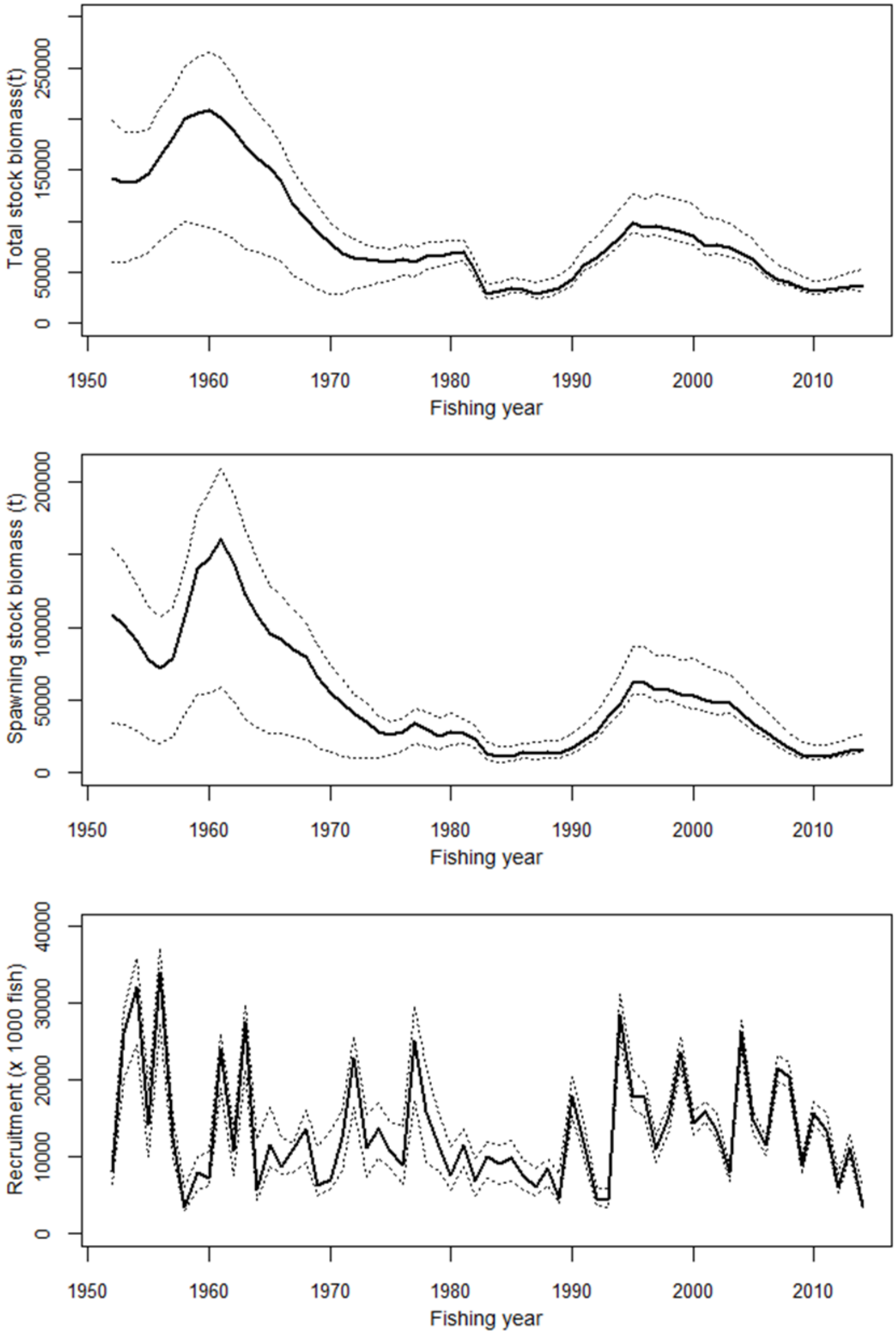


Figure 7-4 Total stock biomass (top), spawning stock biomass (middle) and recruitment (bottom) of PBF from the base-case model. The solid line indicates point estimate and dashed lines indicate the 90% confidence interval.

Recruitment estimates fluctuate widely without an apparent trend. The 2014 recruitment was relatively low, and the average recruitment for the last five years may have been below the historical average level (Figure 7-4). It should be noted that recruitment in terminal years of any assessment are highly uncertain due to limited information on the cohorts and this holds true for the 2016 assessment. However, two of the last three data points from the Japanese troll CPUE-based index of recruitment, which was consistent with other data in the model, are at their lowest level since the start of the index (1980). Estimated age-specific fishing mortalities on the stock during 2011-2013 and 2002-2004 (the base period for WCPFC CMM 2015-04) are presented in Figure 7-5. Most age-specific fishing mortalities (F) for intermediate ages (2-10 years) are substantially above F2002-2004 while those for age 0, as well as ages 11 and above are lower (Table 7-1).

Table 7-1. Percent change of estimated age-specific fishing mortalities of PBF from 2002-2004 to 2011-2013.

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
change from F2002-2004 to F2011-2013	−28%	−1%	+96%	+4%	+86%	+43%	−9%	+81%	+21%	+23%	+5%	−5%	−7%	−8%	−9%	−10%	−10%	−10%	−11%	−11%	−11%

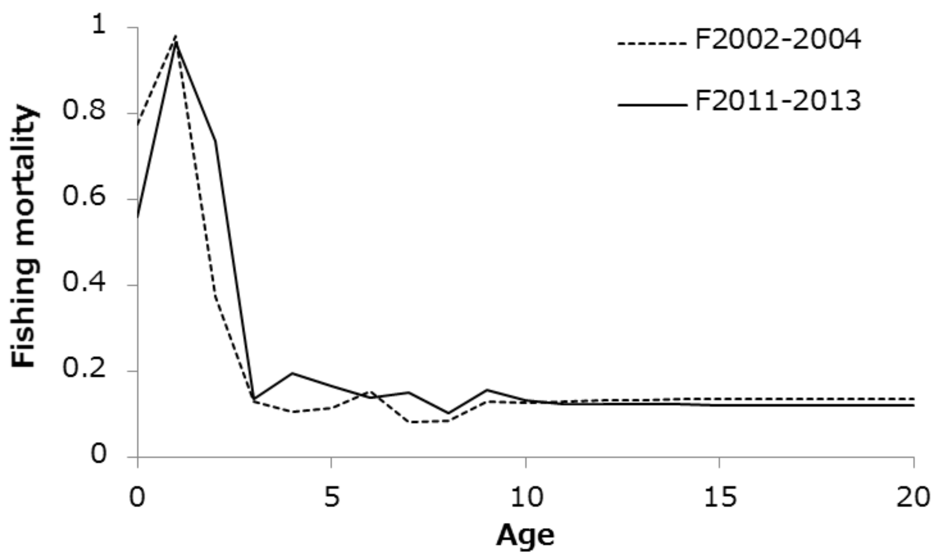


Figure 7-5. Geometric means of annual age-specific (years) fishing mortalities of PBF for 2002-2004 (dashed line) and 2011-2013 (solid line).

Although no limit reference points have been established for the PBF stock under the auspices of the WCPFC and IATTC, the F2011-2013 exceeds all calculated biological reference points except for FMED and FLOSS despite slight reductions to F in recent years

(Table 7-2). The ratio of SSB in 2014 relative to the theoretical unfished[2] SSB (SSB2014/SSBF=0, the depletion ratio) is 2.6%[3] and SSB2012/SSBF=0 is 2.1% indicating a slight increase from 2012 to 2014. Although the SSB2014/SSBF=0 for this assessment (2.6%) is lower than SSB2012/SSBF=0 from the 2014 assessment (4.2%), this difference is due to improvements in the input data and model structure rather than a decline in SSB from 2012 to 2014. Note that potential effects on Fs as a result of the measures of the WCPFC and IATTC starting in 2015 or by other voluntary measures are not yet reflected in the data used in this assessment.

Since no reference points for PBF have yet been agreed to at present, two examples of Kobe plots (Figure 7-6: plot A based on SSBMED and FMED, plot B based on SSB20% and SPR20%) are presented. These versions of the Kobe plot represent two interpretations of stock status in an effort to prompt further discussion. In summary, if these were the reference points, the stock would be approaching overfishing status in the case of FMED and the stock would be considered overfished. Plot B shows that the stock has remained in overfished and being-overfished status for the vast majority of the assessment period if F20% and SSB20% were chosen as reference points. The ISC notes that the SSB estimates before 1980 are more uncertain and that the reason why the fishing mortality is estimated to be so high right after the WWII is not well understood. The low biomass level at the beginning of the assessment period could potentially be the result of relatively high catches prior to the assessment period of PBF.

Table 7-2. Ratios of the estimated fishing mortalities F2002-2004, F2009-2011 and F2011-2013 relative to computed F-based biological reference points and SSB (t) and depletion ratio for the terminal year of the reference period for PBF.

	F_{max}	$F_{0.1}$	F_{med}	F_{loss}	$F_{10\%}$	$F_{20\%}$	$F_{30\%}$	$F_{40\%}$	Estiamted SSB for terminal year of each reference period	Depletion ratio for terminal year of each reference period
2002-2004	1.86	2.59	1.09	0.80	1.31	1.89	2.54	3.34	41,069	0.064
2009-2011	1.99	2.78	1.17	0.85	1.41	2.03	2.72	3.58	11,860	0.018
2011-2013	1.63	2.28	0.96	0.70	1.15	1.66	2.23	2.94	15,703	0.024

[2] “Unfished” refers to what SSB would be had there been no fishing.

[3] The unfished SSB is estimated based upon equilibrium assumptions of no environmental or density-dependent effects.

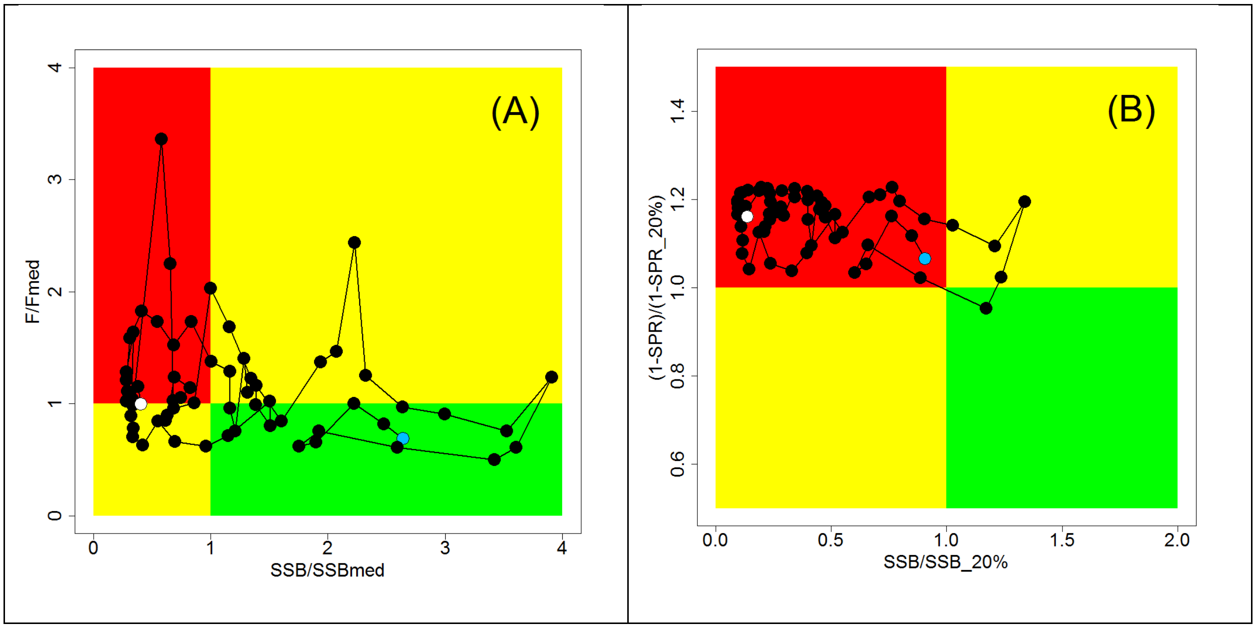


Figure 7-6 Kobe plots for PBF. (A) SSBMED and FMED; (B) SSB20% and SPR20%. Note that SSBMED is estimated as the median of estimated SSB over whole assessment period (40,944 t) and FMED is calculated as an F to provide SSBMED in long-term, while the plots are points of estimates. The blue and white points on the plot show the start (1952) and end (2014) year of the period modeled in the stock assessment, respectively.

Historically, the WPO coastal fisheries group has had the greatest impact on the PBF stock, but since about the early 1990s the WPO purse seine fleets, in particular those targeting small fish (age 0-1), have had a greater impact, and the effect of these fleets in 2014 was greater than any of the other fishery groups. The impact of the EPO fishery was large before the mid-1980s, decreasing significantly thereafter. The WPO longline fleet has had a limited effect on the stock throughout the analysis period (Figure 7-7). This is because the impact of a fishery on a stock depends on both the number and size of the fish caught by each fleet; i.e., catching a high number of smaller juvenile fish can have a greater impact on future spawning stock biomass than catching the same weight of larger mature fish.

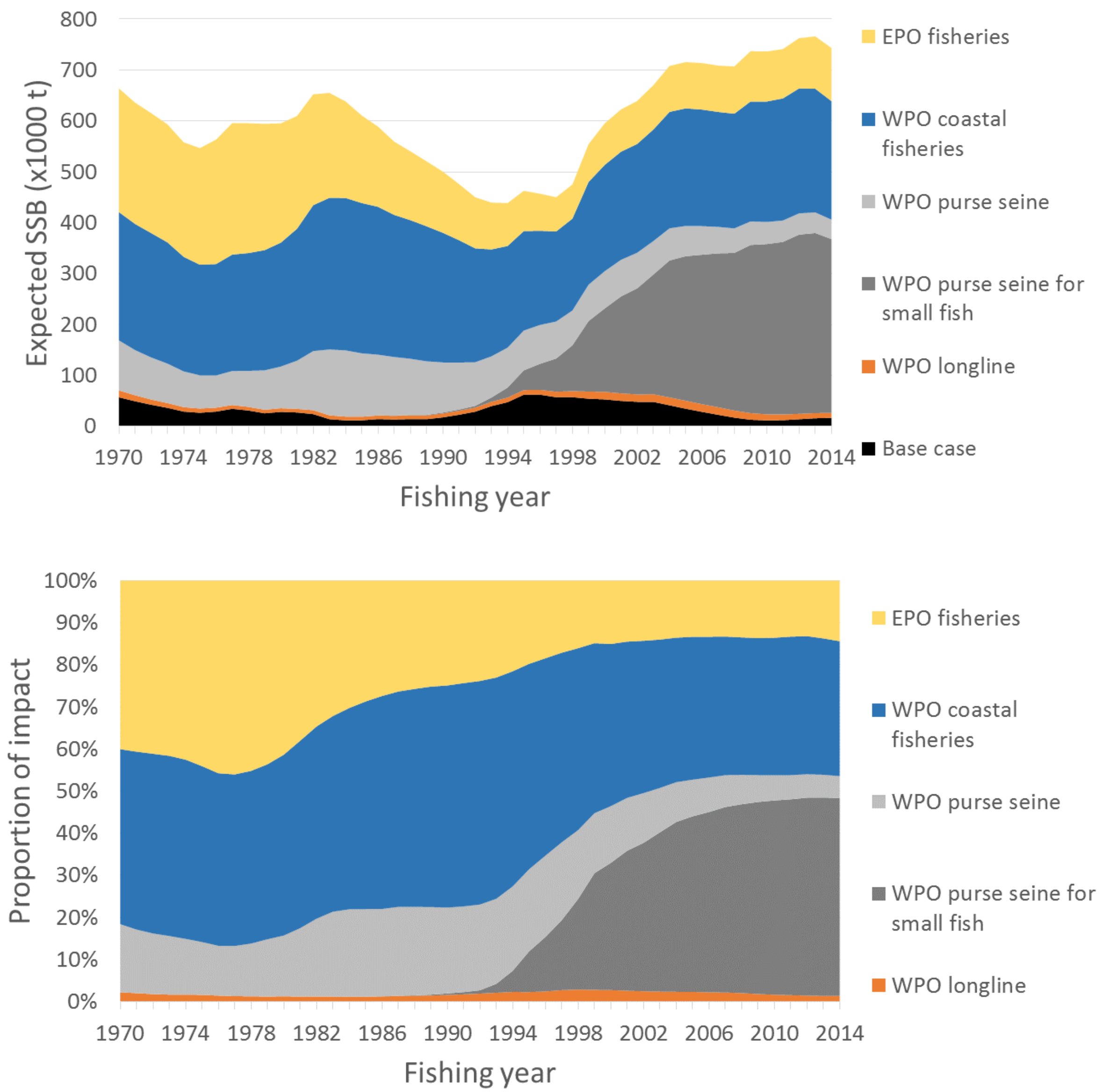


Figure 7-7. Trajectory of the spawning stock biomass of a simulated population of PBF when zero fishing mortality is assumed and recruitment series at F=0 is the same as estimated in the assessment, estimated by the base-case model. (top: absolute impact, bottom: relative impact). Fleet definition; WPO longline: F1, F12, F17. WPO purse seine for small fish: F2, F3, F18. WPO purse seine: F4, F5. WPO coastal fisheries: F6-11, F16, F19. EPO fisheries: F13, F14, F15.

<u>Conservation Advice</u>

The steady decline in SSB from 1996 to 2010 appears to have ceased, although SSB2014 is near the historic low and the stock is experiencing exploitation rates above all calculated biological reference points except for FMED and FLOSS.

The projection results based on the base-case model under several harvest and recruitment scenarios and time schedules are shown in Table 7-3 and Figure 7-8. Under all examined scenarios the initial goal of WCPFC, rebuilding to SSBMED by 2024 with at least 60% probability, is reached and the risk of SSB falling below SSBLOSS at least once in 10 years was low.

The projection results indicate that the probability of SSB recovering to the initial WCPFC target (SSBMED by 2024, 38,000 t, calculated in the same manner as the previous assessment) is 69% or above the level prescribed in the WCPFC CMM if low recruitment scenario is assumed and WCPFC CMM 2015-04 and IATTC Resolution C-14-06 continue in force and are fully implemented (Table 4: Scenario 2 with low recruitment).

The ISC notes that there are technical inconsistencies in the calculation of SSBMED in the assessment and projection. The ISC also notes that the current calculation of SSBMED in the projection incorporates the most recent estimates of SSB and unless a fixed period of years is specified to calculate SSBMED, its calculation (SSBMED) could be influenced by future trends in spawning biomass. The ISC therefore recommends defining SSBMED as the median point estimate for a fixed period of time, either, 1952-2012 or 1952-2014. If 1952-2012 is chosen, then SSBMED is estimated to be 41,069 t, and if 1952-2014 is chosen, SSBMED is 40,994 t. The probabilities of achieving 41,000 t under various scenarios are provided in Table 7-3. The probabilities of achieving 43,000 t, where WCPFC CMM2015-04's initial rebuilding target is specified as 42,592 t, are also provided in Table 7 3, although this value is derived from the previous assessment and is higher than the SSBMED calculated in the current assessment. The ISC recommends that in the future absolute values should not be used for the initial rebuilding target, as the calculated values of reference points would change from assessment to assessment.

Scenario 2 with low recruitment has the lowest prospect of recovery among the examined harvest scenarios. The probability of achieving the WCPFC's initial target (SSBMED by 2024) would increase if more conservative management measures were implemented as shown in Table 7-3 and Figure 7-8. The projection results indicate that a 10% reduction in the catch limit for fish smaller than the weight threshold in CMM 2015-04 would have a larger effect on recovery than a 10% reduction in the catch limit for fish larger than the weight threshold. (Figure 7-8 (D)). The ISC further notes that the current assessment model uses a maturity ogive that assumes 20%, 50% and 100% maturity in age 3 (weight on July 1: 34kg), 4 (weight on July 1: 58kg) and 5 (weight on July 1: 85kg), respectively, while the WCPFC CMM 2015-04 specifies that catches of fish smaller than 30kg should be reduced. The weight threshold in the CMM needs to be increased to 85kg (weight of age 5) if the intent is to reduce catches on all juveniles according to the maturity ogive in the assessment.

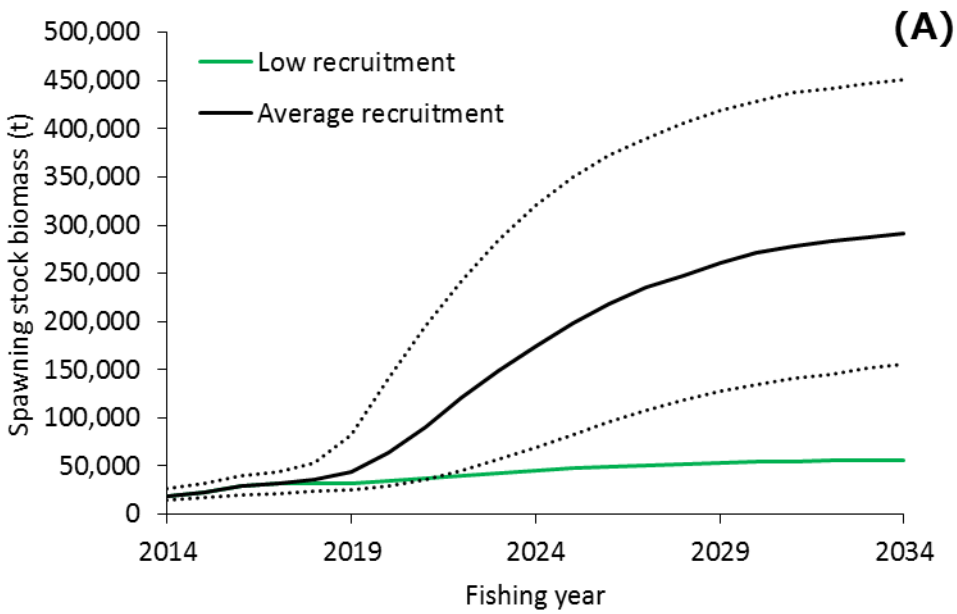
The projections results assuming a stronger stock-recruitment relationship (where h=0.9) than in the assessment model (0.999) are not necessarily more pessimistic than the low recruitment scenario.

The projection results assume that the CMMs are fully implemented and are based on certain biological or other assumptions. In particular, the ISC noted the implementation of size based management measures need to be monitored carefully. If conditions change, the projection results would be more uncertain. Given the low SSB, the uncertainty in future recruitment, and the influence of recruitment has on stock biomass, monitoring recruitment and SSB should be strengthened so that the recruitment trends can be understood in a timely manner.

Harvesting Scenario #	Fishing mortality	Catch limit *		Threshold of Small/Large	Recruitment scenario **	Probability that SSB exceeds 38,000 tons (SSB median of Bootstrap analysis runs)			Probability that SSB exceeds 41,000 tons (SSB median of Basecase model) ***			Probability that SSB is more than 43,000 tons (SSBmed@last assessment)			Probability that SSB is more than 10%SSB0			Probability that SSB is more than 20%SSB0			Average Catch	
		Small	Large			2024	2029	2034	2024	2029	2034	2024	2029	2034	2024	2029	2034	2024	2029	2034	2019	2024
Scenario1	F2002-2004	scenario 6 in 2014 assessment		30 kg	Low recruitment	77.0%	88.8%	89.9%	69.7%	83.3%	85.2%	64.3%	79.3%	81.9%	14.7%	28.0%	31.8%	0.0%	0.0%	0.1%	11619.2	13574.9
Scenario2		50% of 2002-2004 average catch for WPO fisheries 3,300 tons for EPO commercial fisheries	2002-2004 average catch for WPO fisheries		Low recruitment	69.3%	83.7%	86.6%	61.5%	77.8%	82.3%	56.1%	73.9%	79.0%	13.6%	29.3%	35.4%	0.1%	0.4%	0.6%	11749.7	12994.2
					Average recruitment	99.6%	100%	100%	99.3%	100%	100%	99.3%	100%	100%	96.3%	99.8%	100%	73.8%	95.0%	98.0%	12958.4	14750.8
					Stock Recruit Relationship w/ h=0.9	98.2%	99.8%	99.9%	97.7%	99.8%	99.9%	97.5%	99.7%	99.9%	93.5%	99.4%	99.9%	72.0%	97.3%	99.6%	13087.3	15020.1
Scenario3		50% of 2002-2004 average catch		50 kg	Low recruitment	80.5%	91.5%	94.0%	73.8%	87.9%	90.7%	69.1%	85.1%	88.5%	22.2%	43.6%	51.7%	0.2%	0.9%	1.3%	11404.4	12672.3
Scenario4				80 kg	Low recruitment	86.4%	94.6%	96.5%	80.6%	91.9%	94.7%	76.6%	90.0%	93.0%	27.8%	51.8%	61.3%	0.2%	1.1%	1.6%	11292.6	12542.7
Scenario5		90% of scenario 2	same as Scenario 2	30 kg	Low recruitment	90.0%	96.5%	98.1%	85.3%	94.8%	97.0%	81.5%	93.4%	95.9%	35.0%	61.7%	70.4%	0.3%	2.5%	3.7%	11306.4	12881.3
					Average recruitment	99.9%	100%	100%	99.9%	100%	100%	99.9%	100%	100%	98.4%	100%	100%	82.2%	97.8%	99.3%	12442.0	14126.3
					Stock Recruit Relationship w/ h=0.9	99.4%	100%	100%	99.2%	100%	100%	99.1%	100%	100%	97.0%	99.8%	100%	81.8%	99.0%	99.9%	12576.4	14448.2
Scenario6		same as Scenario 2	90% of scenario 2		Low recruitment	75.3%	88.2%	90.2%	67.2%	82.9%	86.5%	61.7%	78.6%	83.4%	15.7%	32.5%	38.7%	0.1%	0.5%	0.7%	11496.2	12632.4
					Average recruitment	99.7%	100%	100%	99.6%	100%	100%	99.5%	100%	100%	96.8%	99.9%	100%	75.1%	95.2%	98.1%	12686.3	14071.5
					Stock Recruit Relationship w/ h=0.9	98.9%	99.9%	100%	98.6%	99.9%	100%	98.4%	99.9%	100%	95.0%	99.7%	100%	75.5%	98.0%	99.9%	12761.0	14379.7
Scenario7		90% of scenario 2			Low recruitment	90.3%	96.8%	98.3%	86.2%	95.4%	97.6%	82.7%	94.2%	96.8%	39.4%	68.0%	77.4%	0.5%	3.5%	5.6%	11231.0	12607.1
					Average recruitment	99.9%	100%	100%	99.9%	100%	100%	99.9%	100%	100%	98.5%	100%	100%	83.5%	98.1%	99.6%	12139.4	13461.7
					Stock Recruit Relationship w/ h=0.9	99.2%	100%	100%	99.1%	100%	100%	99.0%	99.9%	100%	96.9%	99.8%	100%	81.6%	99.0%	99.9%	11227.3	12461.8
Scenario8		80% of scenario 2	same as Scenario 2		Low recruitment	97.5%	99.6%	99.9%	96.1%	99.3%	99.7%	94.8%	98.9%	99.5%	65.4%	89.2%	94.0%	1.9%	14.5%	22.8%	10922.8	12688.4
Scenario9		same as Scenario 2	80% of scenario 2		Low recruitment	78.1%	89.9%	92.5%	70.4%	85.6%	88.8%	65.0%	81.9%	86.3%	18.4%	37.1%	44.7%	0.2%	0.6%	0.9%	11327.0	12329.9
Scenario10		80% of scenario 2			Low recruitment	98.3%	99.8%	99.9%	97.4%	99.6%	99.9%	96.3%	99.5%	99.8%	73.2%	93.8%	97.5%	3.1%	22.4%	34.1%	10585.9	11586.4
					Average recruitment	100%	100%	100%	100%	100%	100%	100%	100%	100%	99.7%	100%	100%	91.0%	99.5%	100%	11194.1	12104.9
					Stock Recruit Relationship w/ h=0.9	99.8%	100%	100%	99.7%	100%	100%	99.7%	100%	100%	98.7%	100%	100%	90.0%	99.7%	100%	11227.3	12461.8
Scenario11	F2011-2013	same as Scenario 2	same as Scenario 2		Low recruitment	82.6%	93.0%	95.0%	75.9%	89.9%	92.1%	71.3%	86.4%	89.9%	23.6%	46.2%	56.0%	0.1%	1.2%	1.6%	12266.8	13587.4

Table 7 3. Future projection scenarios for PBF and their probability of achieving various target levels by various time schedules based on the base-case model.

* Catch limits for EPO commercial fisheries is applied for all the catch (small and large fish) made by the Fleets.
** Average recruitment refers to the recruitment for the whole assessment period while low recruitment refers to that of 1980-1989.
*** Probability that SSB exceeds 41,000 tons (SSB median of Basecase model) developed by PBFWG at ISC16 Plenary.



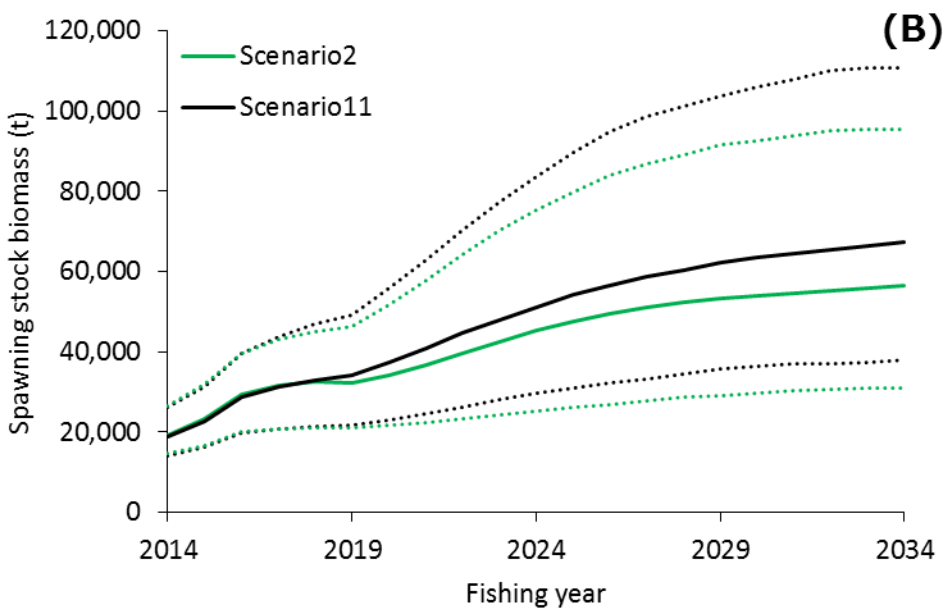


Figure 7-8. Comparisons of various projection results for PBF. (A) low recruitment vs. historical average recruitment (Scenario 2). (B) current CMMs (Scenario 2) vs. current F (Scenario 11) (low recruitment). The solid lines indicate median of bootstrapped projection results and dotted lines indicate 90% confidence interval.

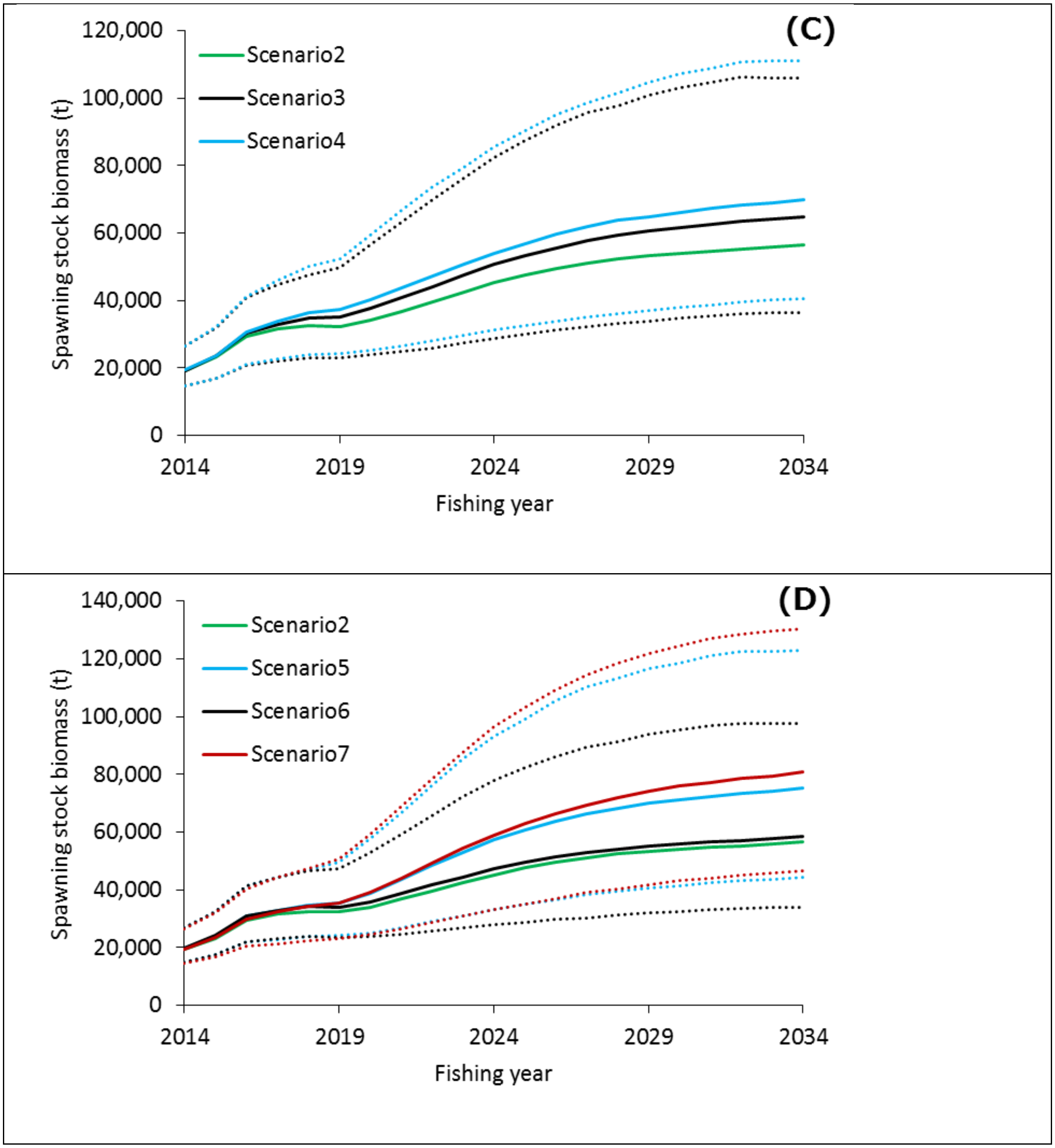


Figure 7-8 (cont.) Comparisons of various projection results for PBF. (C) different definition of small fish (30kg (Scenario 2) vs. 50kg (Scenario 3) vs. 80kg (Scenario 4)) (low recruitment). (D) current CMMs (Scenario 2) vs. additional 10% catch limit reduction for small fish (Scenario 5), for large fish (Scenario 6) and for all fish (Scenario 7) (low recruitment). The solid lines indicate median of bootstrapped projection results and dotted lines indicate 90% confidence interval.