Projections based on the 2016 Pacific Bluefin tuna assessment

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Summary

This paper provides a description of the deterministic forward projections undertaken using the reference case model of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean's (ISC)2016 stock assessment for Pacific bluefin tuna. Projections were run using SSFUTURES (Akita et al. 2015) as described in the 2016 assessment (ISC, 2016). Projections included modifications made to the harvest levels found in the ISC assessment in order to compare the effect of alternative catch limits. The alternative catch limits and description of the projection scenarios are listed in Table 1.

Introduction

Projections from the 2016 stock assessment suggest that the spawning stock is 56% likely to recover to the interim target spawning biomass of 43,000 mt by 2024, even if recruitment continues to be low, if the WCPFC CMM 2015-04 and IATTC resolution C-14-06 are fully implemented. This interim target spawning biomass is significantly higher than the 2014 spawning biomass (estimated in the 2016 assessment), but equates to just 6.4% of the unfished biomass (SB₀). Additionally, the probability of success falls short of the required 60% or greater likelihood contained in WCPFC CMM 2015-04, Therefore, additional projections that would help illuminate alternative management strategies were conducted.

The results from forward projections of stock status can be one of the pieces of information used by the various management forums to inform management decisions. This paper presents projection results based on the 2016 stock assessment of Pacific bluefin tuna. A general overview of the basic methodology employed, key assumptions made, and the results of the projections are provided here. Detailed documentation of the assessment model, the underlying modeling framework (SS3) and projection software are provided in the assessment report (ISC 2016 and references therein).

Methods

Projections were completed using SSFUTURES, (Akita et al. 2015, 2016) a modeling framework designed to simplify projections from a completed Stock Synthesis (SS, Methot and Wetzel, 2013) model. All projections were based on the results of the base-case model, and for projections 2, 3, 4, 6, and 7 the catch limits are based on Scenario 2 as illustrated in Table 2 and 4.2 of the assessment report (ISC, 2016). Each projection was completed using 20 simulations for each of 300 bootstrap replicates. The assessment report notes that the base-case model replicates were derived by estimating parameters using SS and fishery data generated with parametric resampling of residuals from the expected values.

Therefore, these projections are considered to include parameter uncertainty of the stock assessment model because of the bootstrap runs, which included estimation of model parameters using the same error distributions assumed with the stock assessment. All scenarios used a future recruitment level randomly resampled from the relatively low recruitment period (1980-1989) for the assumed low recruitment scenario as per Scenario 2.

Results and Discussion

The results of the projections (Figure 1, Table 2) are compared with SSB_{MED}, as per the assessment report (ISC 2016). SSB_{MED} is defined by the WCPFC as the historical median spawning stock biomass and is currently used by the Commission as the interim rebuilding target of 43,000 t². Due to a downward revision of the biomass estimates in the 2016 assessment, the projections reported in this document use a value of SSB_{MED} =38,000 t, as is done in the 2016 assessment report. This is the median of the 300 individual SSB_{MED} calculated for each bootstrap simulation. As noted in the assessment document, the projection SSB_{MED} of 38,000 MT is less than the base-case model SSB_{MED}(41,000 t), which is used as a potential biological reference point, and less than the recovery target in the WCPFC CMM (43,000 t). Therefore, probabilities of rebuilding to both 38,000 and 43,000 MT are also reported (Table 2).

The United States of America has proposed a rebuilding plan for Pacific bluefin tuna to the last two Northern Committee meetings of the WCPFC that is based on the idea that "For overfished stocks, the biomass which would produce maximum sustainable yield [B_{MSY}] can serve as a rebuilding target."³ The proposed rebuilding plan submitted by the United States of America uses twenty percent of the unfished spawning stock size (20%SSB_{CURRENT,F=0}) as a proxy for B_{MSY} (Mace, 1994). The WCPFC has adopted 20%SSB_{CURRENT,F=0} as the limit reference point—as a proxy for B_{MSY}—for the three tropical tuna stocks and for North Pacific and South Pacific albacore. At the 2016 meeting of the WCPFC, the Commission suggested that the Northern Committee develop conservation and management measures that will rebuild the Pacific bluefin stock to 20%SSB_{CURRENT,F=0} levels by 2034 This value is widely used in the tuna-RFMO setting, for example, it is being used by the Commission for the Conservation of Southern Bluefin Tuna as an interim rebuilding target (to be achieved by 2035). Probabilities of 20%SSB_{CURRENT,F=0} are reported in Table 2, along with the probabilities of reaching 10%SSB_{CURRENT,F=0}.

Table 2 summarizes the results of the future projections for each additional projection listed in Table 1 along with the probabilities from Scenario 2 as reported in the assessment document. Within the first ten-year simulation period (2015 to 2024), the projection results indicated that the probability of SSB recovering to both the interim rebuilding targets (38,000 t and 41,000 t) at 2024 is nearly 100% for all projections. All projections had a 98% chance or higher of meeting 10% of SSB₀ by 2024 except the Projection 2, which had a 94.5% probability of reaching 10% of SSB₀. Aside from Projection 1 (fishery

 $^{^{2}}$ Note that the SSB_{MED} calculated for the projections and used to evaluate rebuilding strategy is not the same as the one used as one of the potential biological reference points, further explanation is provided in section 6.0 of the assessment report (ISC 2016).

³ Article 6.1 of the WCPF Convention, by reference to Annex II of the UN Fish Stocks Agreement.

closure), the only projections that had a greater than 75% probability that SSB is more than 20%SSB₀ in 2024 were Projection 6 (100% transfer of WPO <30kg catch to >30kg, 98.4%), Projection 5 (50% of 2013-2014 average catch, 83.4%), and Projection 4 (50% of Scenario 2, 94.9%).

Closing the fishery (Projection 1, TAC=0) is the only projection that resulted in a 100% probability of reaching all rebuilding points by 2024. Aside from this scenario, a range of options exist to achieve a high probability that SSB is more than 20%SSB₀ in 2024. The most ambitious (highest probability of reaching 20%SSB₀ in 2024) rebuilding plan was Projection 6 (100% transfer of WPO <30kg catch to >30kg). This suggests that the catch of fish less than 30kg in the western Pacific Ocean is highly impacting the stock as a whole. In comparison to Projection 6, the assessment estimated a 0% probability that SSB is more than 20%SSB₀ in 2024 under Scenario 2. If only 50% of the catch of fish less than 30kg is transferred to the greater than 30kg category (Projection 7), then the probability falls from 98.4% (Projection 6) to 23.5%. All projections considered in this modeling exercise resulted in greater than 75% probabilities that SSB is more than 20%SSB₀ in 2034.

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Tables

Table 1. Descriptions of the projection scenarios.

		Catch Limits (MT)		
Projection #	Scenario Description	EPO	WPO>30K	WPO<30K
1	Fishery closure (TAC=0)	0	0	0
2	70% of Scenario 2	2310	4607	3308
3	60% of Scenario 2	1980	3949	2835
4	50% of Scenario 2	1650	3291	2363
5	50% of 2013-2014 average catch	1675	3341	2398
6	100% transfer of WPO <30kg catch to >30kg	3300	11307	0
7	50% transfer of WPO <30kg catch to >30kg	3300	8945	2362

Table 2. Future projection scenarios for Pacific bluefin tuna (*Thunnus orientalis*) and their probability of achieving various target levels by various time schedules based on the base-case model.

		Cat	ch Limits (M	T)	Probabili than SSB (ity that SSE median (38	is more .000tons)	Probabil than 43,00	ity that SSB 0 tons (SSB ssessment	is more med@last	Probabil th	ity that SSB an 10% SSB	is more 0	Probability	that SSB is 20%SSB0	morethan	Average	e Catch
			WPO	WPO									-					
Projection	Scenario Description	EPO	>30KG	<30KG	2024	2029	2034	2024	2029	2034	2024	2029	2034	2024	2029	2034	2019	2024
	SCENARIO 2	3300	6,582	4,725	69.3%	83.7%	86.6%	56.1%	73.9%	79.0%	13.6%	29.3%	35.4%	0.1%	0.4%	0.6%	11750	12994
1	Fishery closure (TAC=0)	0	0	0	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	295	292
2	70% of Scenario 2	2310	4607	3308	99.7%	100.0%	100.0%	99.5%	100.0%	100.0%	94.5%	99.7%	99.8%	17.1%	65.8%	81.3%	9818	10411
3	60% of Scenario 2	1980	3949	2835	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	99.3%	100.0%	100.0%	50.4%	94.6%	98.5%	8626	8992
4	50% of Scenario 2	1650	3291	2363	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	94.9%	100.0%	100.0%	7290	7628
5	50% of 2013-2014 average catch	1675	3341	2398	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	83.4%	99.7%	99.8%	7510	7685
6	100% transfer of WPO <30kg catch to >30kg	3300	11307	0	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	98.4%	100.0%	100.0%	11312	14249
7	50% transfer of WPO <30kg catch to >30kg	3300	8945	2362	99.9%	100.0%	100.0%	99.9%	100.0%	100.0%	98.2%	99.9%	100.0%	23.5%	79.5%	91.9%	11204	14351

Figures



Figure 1. Comparisons of various projection results for Pacific bluefin as listed in Table 1. The solid lines indicate median of bootstrapped projection results.



Annex 1 Detailed Results

A.1. Projection 1 Fishery closure (TAC=0)

Annex Figure 1. Results of Projection #1 (Fishery closure, TAC=0) for Pacific bluefin as listed in Table 2 of the report. The solid line indicates the median of bootstrapped projection results, the shaded area indicates the area between the 5th and 95th quantiles.

Annex Table 1. Estimated quantiles of SSB from Projectio						
Year	Median	95 th Quantile	5 th Quantile			
2015	23,306	31,887	16,816			
2016	33,755	44,267	23,794			
2017	41,586	54,415	29,591			
2018	54,052	69,067	40,276			
2019	74,217	92,072	57,586			
2020	111,673	137,748	88,573			
2021	152,357	184,109	123,652			
2022	189,703	226,374	156,413			
2023	223,231	264,160	186,824			
2024	252,074	295,509	213,565			
2025	277,055	320,539	235,923			
2026	298,336	342,315	255,267			
2027	315,479	360,967	271,978			
2028	329,545	374,567	285,111			
2029	340,774	386,585	295,448			
2030	349,850	395,839	304,506			
2031	357,382	403,182	311,628			
2032	363,238	410,675	317,079			
2033	367,787	414,568	320,788			
2034	371,426	418,784	325,181			
2035	374.088	422.340	327.696			



A.2. Projection 2, 70% of Scenario 2

Annex Table 2. Estimated quantiles of SSB from Projection 2

Year	Median	95 th Quantile	5 th Quantile
2015	23,617	32,209	17,165
2016	30,759	41,086	21,416
2017	34,548	47,237	23,213
2018	39,110	53,603	26,264
2019	44,295	62,043	29,436
2020	54,264	79,759	34,448
2021	66,162	98,499	41,066
2022	78,520	116,920	47,905
2023	90,951	134,306	55,478
2024	101,875	148,586	62 <i>,</i> 658
2025	112,276	159,440	69,528
2026	121,518	169,761	75,963
2027	128,997	178,106	81,953
2028	135,950	184,093	87,359
2029	141,341	190,513	91,622
2030	145,089	195,126	95 <i>,</i> 563
2031	148,875	199,123	98,227
2032	152,100	202,669	101,341
2033	154,409	204,933	103,646
2034	156,495	207,078	104,870
2035	157,840	208,644	106,010

Annex Figure 2. Results of Projection #2 (70% of Scenario 2) for Pacific bluefin as listed in Table 2 of the report. The solid line indicates the median of bootstrapped projection results, the shaded area indicates the area between the 5th and 95th quantiles.



A.3. Projection #3. 60% of Scenario 2

Annex Figure 3. Results of Projection #3 (60% of Scenario 2) for Pacific bluefin as listed in Table 2 of the report. The solid line indicates the median of bootstrapped projection results, the shaded area indicates the area between the 5th and 95th quantiles.

Year	Median	95 th Quantile	5 th Quantile
2015	23,751	32,327	17,308
2016	31,359	42,043	21,849
2017	36,091	48,985	24,330
2018	42,531	57,569	28,710
2019	50,445	69,300	34,023
2020	64,745	91,618	42,156
2021	81,402	114,503	52,661
2022	98,282	136,420	63,668
2023	114,412	156,667	75,240
2024	128,247	172,865	87,086
2025	140,997	185,297	97,206
2026	152,039	197,379	106,301
2027	161,288	207,455	114,626
2028	169,312	214,151	121,532
2029	175,300	220,640	127,047
2030	180,173	226,212	132,498
2031	184,229	231,130	136,913
2032	188,001	235,235	140,148
2033	190,672	237,279	142,276
2034	192,635	240,031	144,403
2035	194,177	241,624	145,647

Annex Table 3. Estimated quantiles of SSB from Projection 3

A.4. Projection #4. 50% of Scenario 2



Annex Figure 4. Results of Projection #4 (50% of Scenario 2) for Pacific bluefin as listed in Table 2 of the report. The solid line indicates the median of bootstrapped projection results, the shaded area indicates the area between the 5th and 95th quantiles.

Annex Table 4. Estimated quantiles of SSB from Projection								
	Year	Median	95 th Quantile	5 th Quantile				
	2015	23,940	32,484	17,517				
	2016	32,218	42,727	22,640				
	2017	38,185	51,181	26,249				
	2018	48,017	63,218	33,417				
	2019	61,184	80,988	43,359				
	2020	83,383	111,039	58,620				
	2021	106,671	139,914	76,840				
	2022	128,914	166,302	94,636				
	2023	148,971	190,770	111,932				
	2024	165,991	209,874	127,798				
	2025	181,363	224,884	140,433				
	2026	194,276	238,800	151,823				
	2027	205,448	250,273	162,356				
	2028	214,241	258,549	170,353				
	2029	221,225	266,483	176,499				
	2030	226,797	272,077	182,216				
	2031	231,315	277,487	186,752				
	2032	235,452	282,158	190,816				
	2033	238,534	284,422	192,620				
	2034	240,683	287,628	195,824				
	2035	242,334	289,442	197,150				





Annex Tak	ole 5. Estimated o	quantiles of SSB fro	m Projection 5
Year	Median	95 th Quantile	5 th Quantile
2015	23,903	32,560	17,441
2016	32,194	43,035	22,376
2017	37,908	50,971	25,569
2018	46,383	61,773	31,587
2019	57,133	76,769	39,489
2020	75,829	103,460	51,606
2021	96,557	129,682	66,719
2022	116,821	154,398	82,011
2023	135,330	177,259	97,163
2024	151,241	195,280	111,937
2025	165,546	209,226	124,075
2026	177,768	222,337	134,486
2027	188,154	233,213	144,447
2028	196,608	240,896	151,961
2029	203,143	248,002	157,998
2030	208,544	253,735	163,525
2031	212,744	258,703	167,840
2032	216,712	263,278	171,711
2033	219,585	265,517	173,446
2034	221,843	268,274	176,211
2035	223,312	270,133	177,821

Annex Figure 5. Results of Projection #5 (50% of 2013-2014 average catch). The solid line indicates the median of bootstrapped projection results, the shaded area indicates the area between the 5th and 95th quantiles.





Annex Figure 6. Results of Projection #6 (100% transfer of WPO <30kg catch to >30kg) for Pacific bluefin as listed in Table 2 of the report. The solid line indicates the median of bootstrapped projection results, the shaded area indicates the area between the 5th and 95th quantiles.

Year	Median	95 th Quantile	5 th Quantile
2015	23,243	31,796	16,866
2016	30,177	40,367	21,202
2017	35,518	47,084	24,680
2018	46,277	59,869	33,779
2019	63,709	81,191	48,353
2020	89,555	114,849	67,998
2021	115,056	145,689	88,401
2022	138,503	173,742	107,295
2023	159,499	199,421	125,226
2024	177,944	220,081	140,804
2025	193,966	236,933	154,263
2026	207,900	251,411	166,242
2027	219,549	263,750	176,997
2028	229,161	273,458	185,915
2029	236,679	282,021	192,536
2030	243,222	288,615	198,912
2031	248,125	294,173	203,878
2032	252,820	299,533	207,871
2033	256,300	302,841	211,051
2034	259,225	305,978	214,128
2035	261,188	308,594	216,180

Annex Table 6. Estimated quantiles of SSB from Projection 6

A.7. Projection #7. 50% transfer of WPO <30kg catch to >30kg



Annex Figure 7. Results of Projection #7 (100% transfer of WPO <30kg catch to >30kg) for Pacific bluefin as listed in Table 2 of the report. The solid line indicates the median of bootstrapped projection results, the shaded area indicates the area between the 5th and 95th quantiles.

Annex	able 7. Estimated	quantiles of SSB	from Projection 7
Year	Median	95 th Quantile	5 th Quantile
2015	23,165	31,736	16,779
2016	29,603	39,762	20,545
2017	32,635	43,929	21,963
2018	37,215	50,543	25,353
2019	43,945	60,514	29,834
2020	56,723	80,856	37,337
2021	71,309	101,079	46,521
2022	85,635	120,096	55 <i>,</i> 973
2023	99,101	138,465	66,043
2024	110,987	152,713	75,390
2025	121,464	163,808	82,972
2026	130,819	173,870	90,362
2027	138,570	182,476	96,621
2028	145,280	189,301	101,932
2029	150,491	195,156	106,591
2030	155,034	199,985	110,968
2031	158,394	203,966	114,302
2032	161,868	207,942	116,934
2033	164,221	210,304	119,147
2034	166,302	212,272	121,115
2035	167,758	214,601	122,807