9.2 BFTW - Bluefin Tuna - West

BFTW-2. Fishery indicators

The total catch for the West Atlantic peaked at 18,608 t in 1964, mostly due to the Japanese longline fishery for large fish off Brazil (that started in 1962) and the U.S. purse seine fishery for juvenile fish (**BFT-Table 1**, **BFTW-Figure 1**). Catches dropped sharply thereafter to slightly above 3,000 t in 1969 with declines in longline catches off Brazil in 1967 and in purse seines. Catches increased to over 5,000 t in the 1970s due to the expansion of the Japanese longline fleet into the Northwest Atlantic and Gulf of Mexico and an increase in purse seine effort targeting larger fish for the sashimi market. Catches declined abruptly in 1982 from close to 6,000 t in the late 1970s and early 1980s with the imposition of a catch limit. The total catch for the West Atlantic, including discards, fluctuated without trend after 1982, reaching 3,319 t in 2002 (the highest since 1981, with all three major fishing nations indicating higher catches). Total catch in the West Atlantic subsequently declined steadily to 1,638 t in 2007 and then fluctuated without pronounced trend. The catch in 2018 was 2,027 t, 2,306 t in 2019 and 2,179 t in 2020 (as of 18 August 2020) (**BFTW-Figure 1**).

The Committee notes that ongoing work conducted as part of the MSE process is evaluating the sensitivity to assumed stock of origin of the large historical catches from the South Atlantic. Future modelling considerations of these catches should consider that while these catches are currently assumed to be of western stock origin the true stock of origin remains unknown.

The Committee notes that the TAC in the West has not been caught for the last 7 years. Based on information received, the Committee considers that this is not due to low stock abundance but rather to market and operational conditions.

The most recent (2021) stock assessment used 10 CPUE and two survey indices up to and including the year 2020 (**BFTW-Figure 2**). Several indices were modified from the previous year, based on recommendations by the BFT Technical Subgroup on Abundance Indices, which conducted a series of data workshops to critically evaluate data treatments and recommend best practices. In particular, the indices of juvenile fish based on the US Rod and Reel fishery experienced substantial modifications. Previously they were two separate indices but have been combined into a single index that better accounts for the dynamics of the fishery. The modified indices are denoted with an asterisk in **BFTW-Figure 2**, and those not denoted represent strict updates.

Several indices exhibit trends that may be indicative of environmentally driven changes in availability. As in 2017 and 2020, the Stock Synthesis assessment reconciled the conflicting trends in some Canadian and United States indices under a hypothesis of environmentally mediated availability of fish to the two regions. The Canada Acoustic index experienced a very low value for 2018 and subsequently also for 2019; it appears that the index is in a state of transition, possibly due to environmentally driven changes in the spatial distribution of the fish or of their prey. For modelling the Committee chose to split the index and, as two years of data would be uninformative for the models, the years 2018 and 2019 were removed from the assessment until such time as the differences between the time periods can be reconciled.

BFTW-3. State of the stock

The SCRS cautions that conclusions from the latest assessment (Anon., 2021d), using data through to 2020, do not capture the full degree of uncertainty in the assessments and projections and an independent review recommended against using it for management advice. The various major contributing factors to uncertainties include mixing between the stocks, recruitment, age composition, age at maturity, the possibility of regime shifts, assumptions regarding selectivity, and indices of abundance. As in 2020 the 2021 assessment also applied two stock assessment methods (VPA and Stock Synthesis) but only Stock Synthesis was deemed suitable at this time for projections and specific management advice for the western stock. While the Committee is not recommending this iteration of the VPA for projection and quantitative management advice, it provides time series as a qualitative comparison. The models used in 2021 underwent substantial changes compared to strict updates of the 2020 models, including: revised indices; alternative assumptions about fleet selectivity; and, the addition of two years of data (2019 and 2020).

Estimates of the absolute biomass scale of the stock have fluctuated between the 2017, 2020 update and the 2021 Stock Synthesis assessment models highlighting one of the key unquantified uncertainties regarding absolute size of the population (**BFTW-Figure 3**). These absolute biomass estimates factor directly into the yield estimates under the $F_{0.1}$ strategy, which therefore contribute to that underlying uncertainty.

Previous stock assessments determined stock status based on MSY-related reference points using two alternative recruitment potential scenarios: a 'low recruitment' scenario and a 'high recruitment' scenario. Since 2017, assessments have not provided management advice based on MSY reference points. To deal with this recruitment uncertainty, the focus has been on giving short-term advice based on an $F_{0.1}$ reference point (taken to be a proxy for F_{MSY}) assuming that near term recruitment will be similar to the recent past recruitment. As in the 2020 assessment, two spawning fraction scenarios (a young age at spawning, consistent with the eastern stock and older age of spawning with 100% spawning contribution at age 15) were considered in the assessment methods. Rather than presenting two series of spawning stock biomass (SSB) based on these two spawning fraction scenarios, total biomass is presented as this does not depend on which of these scenarios is selected.

Estimates from the Stock Synthesis model give a longer time series view of the population, (**BFTW-Figure 4**), capturing the higher recruitments estimated in the 1960s (although this is dependent on the assumption that the catches in the West were primarily of western rather than eastern origin fish). In 2017 the Stock Synthesis models estimated higher biomass than the VPA, but in 2020 the updated Stock Synthesis model and VPA estimates were similar in magnitude for the overlapping period 1979 – 2015. The 2021 Stock Synthesis models now estimate higher biomass than the VPA (**BFTW-Figure 4**), but quite similar biomass to the 2017 Stock Synthesis model (**BFTW-Figure 3**). In the 2021 Stock Synthesis model, total biomass in 2020 was 18% of biomass in 1950 and 46% of biomass in 1974. In contrast to the 2017 and 2020 assessments, the revised assessment did not estimate a long-term declining trend in recruitment since 2003 (**BFTW-Figures 3** and **4**). Additionally, the estimates for the most recent years indicated an increase in recruitment, informed by the revised juvenile index, as well as catch data. VPA gives qualitatively similar time series of recruitment and biomass, as well as improvement to stock status, as Stock Synthesis (**BFTW-Figure 4**).

The Committee notes that further work is being conducted as part of the GBYP to collect more data on mixing, movement and stock of origin. These data are being incorporated into the Management Strategy Evaluation whereby they should help refine understanding of stock mixing.

Summary

Stock Synthesis was projected to formulate advice using recent (2012-2017) mean recruitment with alternative spawning-at-age scenarios equally weighted across model scenarios. Current F (average of 2018-2020) relative to the $F_{0.1}$ reference point was 0.53 (0.49-0.58, 80% confidence interval), indicating that overfishing was not occurring (**BFTW-Figure 5**). Under the updated model, the current TAC (Rec. 20-06) is not likely to lead to overfishing relative to $F_{0.1}$ with 100% probability.

Management advice is based on a fishing mortality reference point to project short-term catches based on recent recruitments. $F_{0.1}$ was considered a reasonable proxy for F_{MSY}, although F_{MSY} can be higher or lower than $F_{0.1}$ depending on the stock recruitment relationship, which in this case is poorly determined. $F_{0.1}$, while not dependent on the stock recruitment relationship, is sensitive to the assumptions regarding selectivity. In the 2021 assessment the overall selectivity was characterized as being substantially more dome-shaped than in previous assessments and this resulted in an approximately a 35% higher estimate of the value of $F_{0.1}$. A key element of the change towards a higher $F_{0.1}$ may also be the change in assumed selectivity towards smaller fish in the Gulf of St. Lawrence fishery in Canada.

BFTW-4. Outlook

In 1998, the Commission initiated a 20-year rebuilding plan designed to achieve SSB_{MSY} with at least 50% probability. As indicated above, the Committee did not use biomass-based reference points in formulating 2017, 2020 update, or 2021 revised models. The Committee is not evaluating if the stock is rebuilt because it has been unable to resolve the long-term recruitment potential. If an $F_{0.1}$ strategy were to continue to be applied, over the longer term the resource would fluctuate around the true, but unknown, value of $B_{0.1}$ whatever the future recruitment level. The $F_{0.1}$ strategy compensates for the effect of recruitment changes on biomass by allowing higher catches when recent recruitment is higher and reducing catches when recent recruitments are lower. Under this strategy, biomass may decrease at times because the stock is above $B_{0.1}$ or following lower recruitments.

The 2021 assessment indicates that recent (2012-2017) recruitments were higher than those estimated for the same period in the 2020 assessment and the averages assumed for the 2020 projections. In 2017 the population was projected to decline by ~7.5% from 2017 to 2020 at the current (2020) TAC of 2,350 t and in 2020 the population estimated to have experienced an 11.7% decline over the same time period. The current assessment estimates that the total biomass has actually experienced a 9% increase from 2017-2020.

With two additional years added to the 2020 assessment (2019-2020), substantial modifications made to the indices of abundance and to the model specifications, the assessment indicates that the overall biomass has increased. In contrast to previous assessments that have noted the passing of the peak biomass of the 2003-year class and below average recruitment in recent years, this assessment shows clear signs of several strong subsequent recruitment years. In particular, the 2017 recruitment appears to be high as evidenced by the index as well as catches, yet it would not have been evident in the 2020 model data.

The base model now assumes that most fleets have dome-shaped selectivity, whereas previously asymptotic selectivity was assumed. This change resulted in improvements in model diagnostics. It also had a major impact on TAC advice. The addition of data and revised indices included in the 2021 assessment were responsible for approximately 36% increases in deterministic yield at $F_{0.1}$ for the years 2022-2024 compared to the 2020 assessment results, while a combination of changes in model assumptions (in particular the change to an assumption of dome-shaped selectivity) and data were responsible 64% of the change. The Committee noted that the VPA, which had somewhat lower biomass scale, was excluded from projections as the Committee considered the VPA not suitable for projections. The impacts on yield advice from excluding the VPA are unknown but may have resulted in the now higher yields given that only Stock Synthesis is used for projections.

The time series of $F/F_{0.1}$ shows the fishing status over time relative to the year-specific estimate of $F_{0.1}$ (**BFTW-Figure 5**). Projections of total biomass and percent change in biomass at various fixed TACs and $F_{0.1}$ are provided in **BFTW-Table 2** and **BFTW-Figure 6**.

During discussions, it was suggested that dome-shaped selectivities might be warranted for some, but maybe not all of the fleets for which a change was imposed, and that additional approaches (e.g. improvements to abundance indices, assumption of senescence) might also have addressed model diagnostic issues, with differing implications for yield. Time constraints precluded examination of these alternatives during this assessment, just as the compressed assessment schedule in 2021 limited the Committee's ability to thoroughly review changes to the models and results.

The Committee reiterates that the effects of mixing and management measures on the eastern stock remain a considerable source of uncertainty for the outlook of the western stock. Consequently, changes to assessment and management approaches that take explicit account of mixing are a high priority.

Following receipt of the expert review which noted that the indices of abundance and composition data suggest that the current catch levels are sustainable and increases in catch may be possible, an empirical approach (SCRS/2021/177) and an MSE based approach (SCRS/2021/143) also showed that both the western area and the western stock biomass are increasing and could support a moderate TAC increase in the western area in 2022. The empirical approach to evaluating the indices examined the annual percent change in the indices over years 2017-2020, noting that the Gulf of Mexico index values for the year 2020 were not available. The MSE based approach examined changes to SSB over the next five-year period at fixed TAC values.

In the current Kobe 2 matrix (K2SM), the difference in tons between a wide range of probabilities of overfishing is small (**BFTW-Table 1**). This is a result of not capturing the full scientific uncertainty in the K2SM. A practical solution applied in other management fora is to replace the model-estimated uncertainty with values derived from the variability in absolute biomass estimated by repeated assessments. In the current situation this would better account for the variability in absolute scale noted between the 2017, the 2020 and the 2021 Stock Synthesis models. While the SCRS did not employ this approach, at this time, the practical implications are that improved accounting for true scientific uncertainty would increase the buffer between the 50% probability of not overfishing and higher probabilities.

BFTW-5. Effect of current regulations

The 2021 assessment estimates that the biomass has increased by 9% over the time period 2017-2020. The current TAC recommendation (Rec. 20-06) is set to end in 2021 with new TAC advice requested by the Commission. Under the revised models. The current TAC is not likely to have led to overfishing relative to $F_{0.1}$ (**BFTW-Figure 5**). Rollover of the 2021 TAC in Rec. 20-06 is also expected to have not led to overfishing with high probability.

BFTW-6. Management recommendations

The Commission recommended total allowable catches (TAC) of 2,350 t in 2018, 2019 and 2020 (Rec. 17-06) and a rollover of the previous TAC for 2021 (Rec. 20-06). The Committee provides management options including the constant TAC scenarios shown in the Kobe II strategy matrix. The TAC for each year, and associated probability of not overfishing associated with each scenario are shown in **BFTW-Table 1**.

Variability in the estimation of the absolute scale of the population is an inherent property of stock assessment models. Uncertainty related to variability around the absolute scale of the population estimates has a direct impact on yield advice under an $F_{0.1}$ management strategy, yet it is not quantified within the K2SM.

The Committee has long highlighted the uncertainty in western BFT management advice given the varying fraction of eastern migrants in the western management area. The 2021 assessment advice is also subject to this uncertainty. Considering this, the additional sources of uncertainty noted previously, and the conclusions of the external review, the current advice should be used with caution (Note: the Committee re-iterates that the MSE does take mixing into account and addresses some key associated uncertainty concerns that arise if mixing is ignored).

Given these considerations, only 2 years have been included in the Kobe 2 Strategy Matrix (**BFTW-Table 1**), and the Committee advises that the Commission could implement a moderate increase to the current W-BFT TAC of 2,350 t. In determining this moderate increase, in addition to the K2SM, the Committee also draws the attention of the Commission to the results from the alternative approaches to evaluate the current change in the western biomass and its response to future harvests. Namely, the empirical approach indicated a 4% increase of the western area relative abundance and a 16% increase of the western spawning stock relative abundance, and the MSE approach indicated a 28% increase based on the TAC that maintains annual increases in the Western stock SSB in the near term.

TAC should be reviewed annually by the Commission on the advice of the SCRS (which would be based on consideration of updates of the fishery indicators). This would permit the SCRS to, on any of those occasions, recommend that the next TAC be amended given sufficiently strong signals in the indicators. Notwithstanding the 2 years of catch levels provided in the Kobe matrix, the Committee reiterates the intention to provide a Candidate Management Procedure for the Commission to transition to a management procedure to set the TAC starting for 2023.

SUMMARY TABLE

Estimated mean of the Stock Synthesis models (two maturity specifications) for recent fishing mortality rate for each model was calculated the geometric mean of F over 2018 to 2020 relative to the F reference point, $F_{0.1}$ (a proxy for F_{MSY}). The values in parenthesis represent the approximate 80% confidence intervals from the hessian-based standard errors or multivariate lognormal approximation approach.

WEST ATLANTIC BLUEFIN TUNA SUMMARY	
Current Catch including discards (2020)	2,179*
$F_{current\ (2018\text{-}2020)}$	0.063 (0.059-0.067)[2]
$F_{0.1}$	0.118 (0.113-0.123)[3]
$F_{current\ (2018\text{-}2020)}/F_{0.1}$	0.53 (0.49-0.58)[2]
Estimated probability of overfishing ($F_{current\ (2018\text{-}2020)}$)/$F_{0.1}$)	<1%
Stock status[1]	Overfishing: No
Management Measures:	[Rec. 20-06] TAC of 2,350 t in 2021, including dead discards.

* As of 20 September 2021.

[1] Biomass reference points to determine stock status were not estimated in the 2021 assessment due to uncertainty in recruitment potential.

[2] Mean and approximate 80% confidence interval from the multivariate lognormal approximation approach from the assessment.

[3] Mean and approximate 80% confidence interval from the hessian-based standard errors.

BFT - Table 1. Estimated and reported catches (t) of bluefin tuna (*Thunnus thynnus*) by area, gear and flag.

				1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
TOTAL				29318	34128	36642	48881	49751	54009	53545	52657	52772	52775	52784	53319	52305	52125	51756	51812	62638	26460	21798	13195	11781	12688	14725	14887	18042	21033	25466	29794	33516	37144
BFT-E				26389	31831	34258	46769	47303	51497	51211	50000	50000	50000	50000	50000	50000	50000	50000	50000	61000	24460	19818	11338	9774	10934	13243	13261	16201	19132	23616	27767	31211	34965
	ATE			6543	7396	9317	7054	9780	12098	16379	11630	10247	10061	10086	10347	7394	7402	9023	7529	8441	8243	6684	4379	3984	3834	4163	3918	4841	5969	7216	8157	9452	11308
	MED			19846	24435	24941	39715	37523	39399	34831	38370	39753	39939	39914	39653	42606	42598	40977	42471	52559	16217	13133	6959	5790	7100	9080	9343	11360	13163	16401	19610	21759	23657
BFT-W	ATW			2929	2296	2384	2113	2448	2512	2334	2657	2772	2775	2784	3319	2305	2125	1756	1811	1638	2000	1980	1857	2007	1754	1482	1627	1842	1901	1850	2027	2306	2179
Landings	ATW		Longline	903	689	712	539	491	545	382	764	915	858	610	729	186	644	425	565	420	606	366	529	743	478	470	498	553	562	559	664	675	571
			Other surf.	578	509	406	307	384	429	293	342	279	283	201	107	139	97	89	85	63	78	121	107	147	117	121	119	138	93	123	77	168	132
			Purse seine	237	300	295	301	249	245	250	249	248	275	196	208	265	32	178	4	28	0	11	0	0	2	29	38	34	0	0	0	0	
			Sport (HL+RR)	1083	586	854	804	1114	1032	1181	1108	1125	1121	1650	2036	1399	1139	924	1005	1023	1134	1251	1009	888	917	692	810	1085	1204	1144	1263	1450	1460
			Traps	0	1	29	79	72	90	59	68	44	16	16	28	84	32	8	3	4	23	23	39	26	17	11	20	6	10	13	3	4	4
Discards	ATW		Longline	128	211	88	83	138	167	155	123	160	222	105	211	232	181	131	149	100	159	207	174	202	224	145	139	19	29	10	17	7	6
			Other surf.	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	1	2	2	4
			Purse seine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	4	5	0	0	0	0	
			Sport (HL+RR)	0	0	0	0	0	0	14	3	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Landings	ATW	CP	Brazil	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	**0**
			Canada	485	443	459	392	576	597	503	595	576	549	524	604	557	537	600	733	491	575	530	505	474	477	480	463	531	466	472	508	666	553
			FR-St Pierre et Miquelon	0	0	0	0	0	0	0	0	1	0	0	3	1	10	5	0	4	3	2	8	0	0	0	0	9	0	0	0	0	**0**
			Japan	688	512	581	427	387	436	322	691	365	492	506	575	57	470	265	376	277	492	162	353	578	289	317	302	347	345	346	406	406	407
			Korea Rep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	52	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
			Mexico	9	15	17	4	23	19	2	8	14	29	10	12	22	9	10	14	7	7	10	14	14	51	23	51	53	55	34	80	39	28
			Panama	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
			Trinidad and Tobago	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
			UK-Bermuda	0	0	0	0	0	1	2	2	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
			UK-British Virgin Islands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
			UK-Turks and Caicos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
			USA	1582	1085	1237	1163	1311	1285	1334	1235	1213	1212	1583	1840	1426	899	717	468	758	764	1068	803	738	713	502	667	877	1002	986	1013	1185	1178
		NCC	Chinese Taipei	0	0	0	0	4	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		NCO	Argentina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
			Cuba	0	0	0	0	0	0	0	0	0	0	0	74	11	19	27	19	0	0	0	0	0	0	0	0	0	0	0	0	0	
			Dominica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
			ICCAT (RMA)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
			NEI (ETRO)	23	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
			NEI (Flag related)	0	0	0	0	0	0	0	0	429	270	49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
			Sta Lucia	14	14	2	43	9	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Discards	ATW	CP	Canada	0	0	0	0	0	0	6	16	11	46	13	37	14	15	0	2	0	1	3	25	36	17	0	0	3	8	1	3	3	5
			Japan	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
			Mexico	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	
			USA	128	211	88	83	138	171	155	110	149	176	98	174	218	167	131	147	100	158	204	150	166	206	159	143	22	24	10	15	6	6

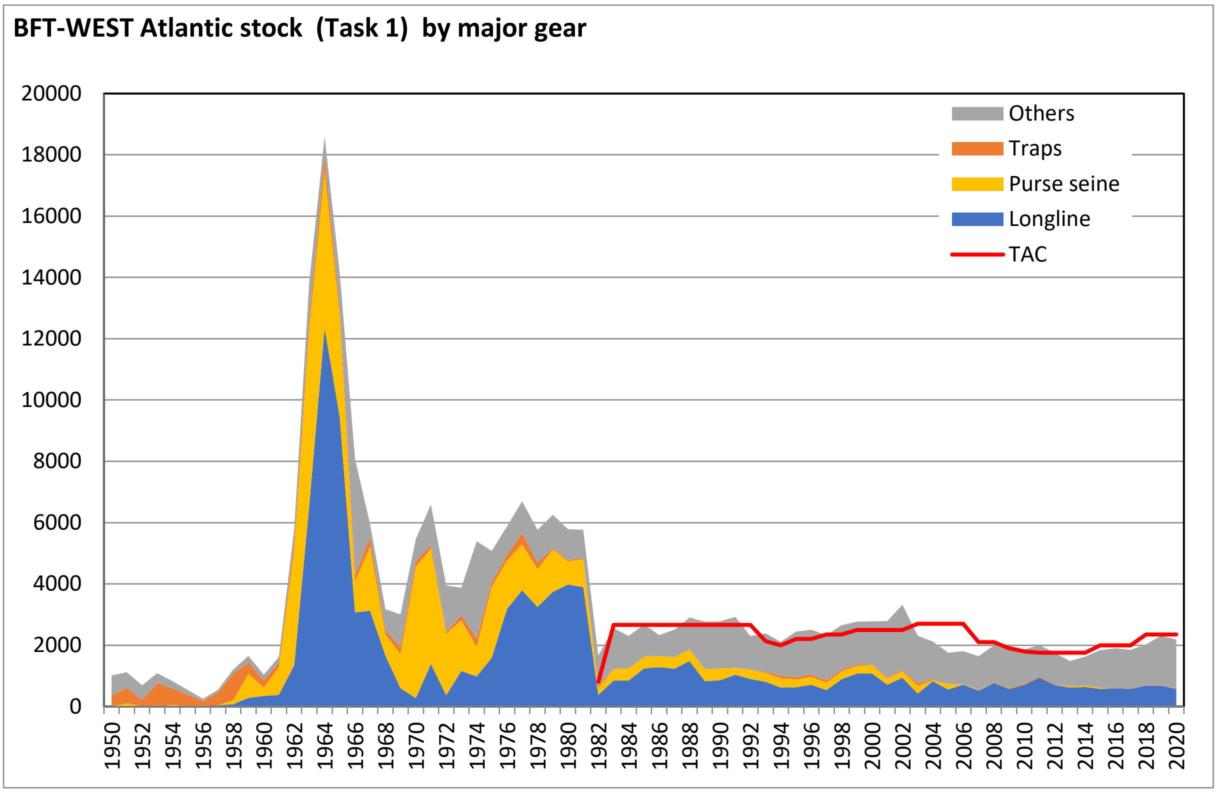
BFTW-Table 1. Kobe II matrix giving the probability that the fishing mortality rate (F) will be less than the F reference point ($F \leq F_{0.1}$, overfishing not occurring) over the next three years for alternative constant annual catches, based on results from the 2021 Stock Synthesis (combined two maturity specifications). Considering the uncertainties noted above and in previous sections, as well as the conclusions of the independent peer review, the Commission should interpret the results reflected in the Kobe strategy matrix with caution

TAC	2022	2023
0 - 3000	100%	100%
3100	99%	99%
3200	98%	98%
3300	94%	95%
3400	91%	89%
3500	83%	81%
3600	71%	70%
3700	60%	56%
3800	45%	48%
3900	36%	34%
4000	25%	23%
4100	18%	18%
4200	11%	10%
4300	7%	6%
4400	5%	4%
4500	2%	2%
4600	1%	1%
4700	1%	1%
4800 - 5000	0%	0%

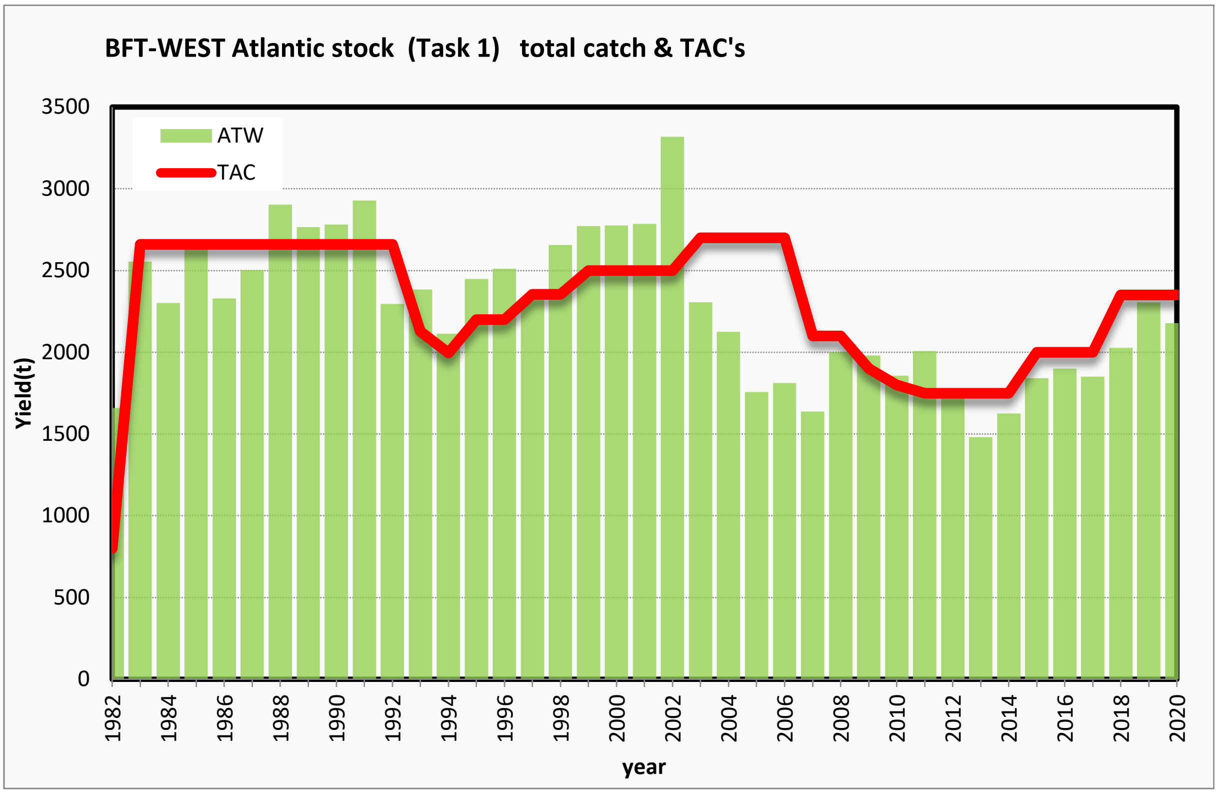
BFTW-Table 2. Percentage change in total stock biomass at the middle of the year relative to 2021 under alternative constant catch scenarios from the 2021 assessment, based on the projections from Stock Synthesis averaged across 2 maturity specifications. Stock Synthesis projections come from averaging the deterministic model runs. Values should be understood to have the same qualifications as the Kobe 2 strategy matrix since the projected biomass estimates are similarly uncertain.

Catch	2022	2023
0	5.9%	15.3%
2000	3.8%	8.9%
2200	3.6%	8.2%
2350	3.4%	7.7%
2400	3.4%	7.6%
2600	3.2%	6.9%
2800	2.9%	6.3%
3000	2.7%	5.6%
3200	2.5%	5.0%
3400	2.3%	4.4%
3600	2.1%	3.7%
3800	1.8%	3.1%
4000	1.6%	2.4%
4200	1.4%	1.8%
4400	1.2%	1.1%
4600	1.0%	0.5%
4800	0.7%	-0.2%
5000	0.5%	-0.8%

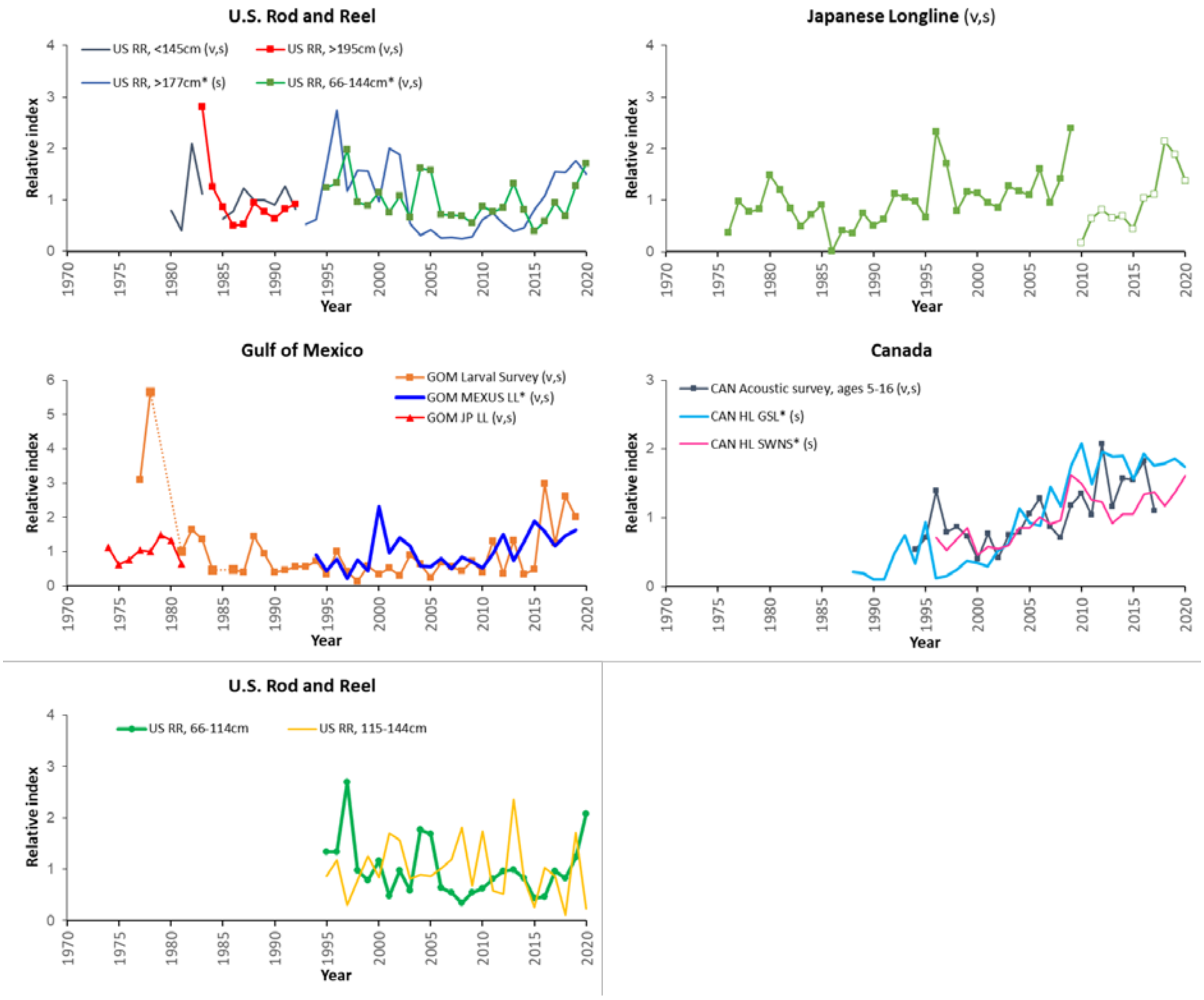
(a)



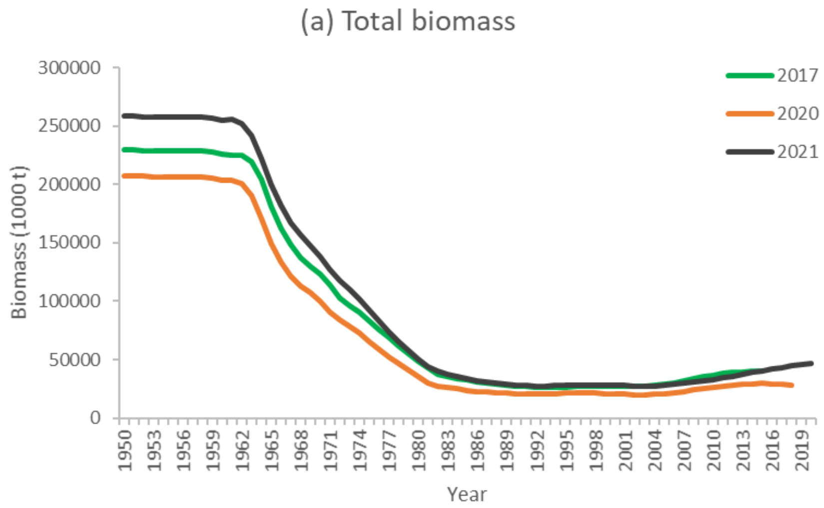
(b)

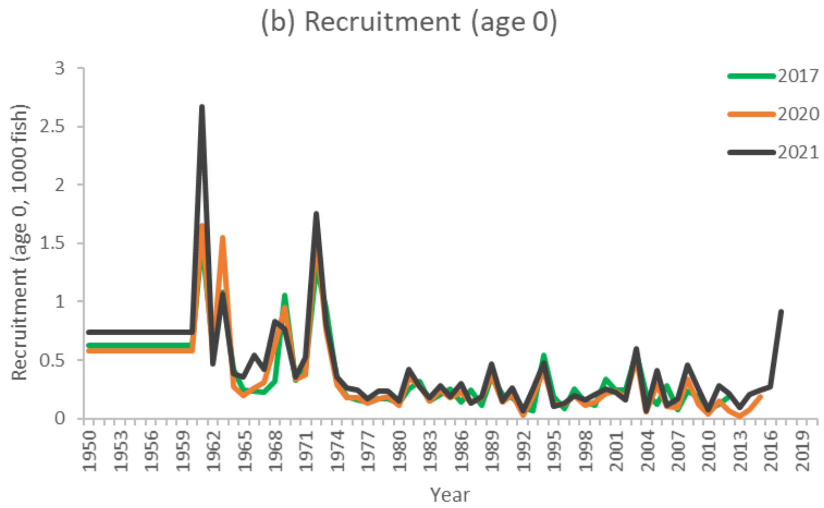


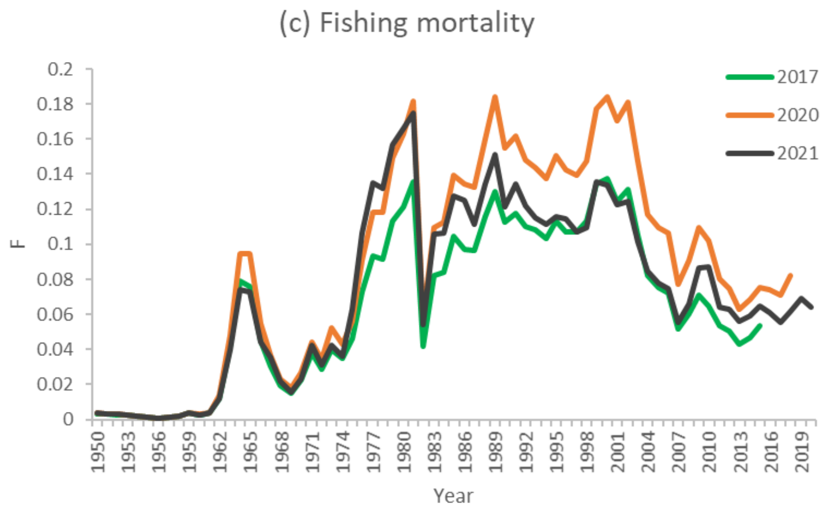
BFTW-Figure 1. Historical catches of western bluefin tuna: (a) by gear type and (b) TACs agreed by the Commission (which are shown for comparison).



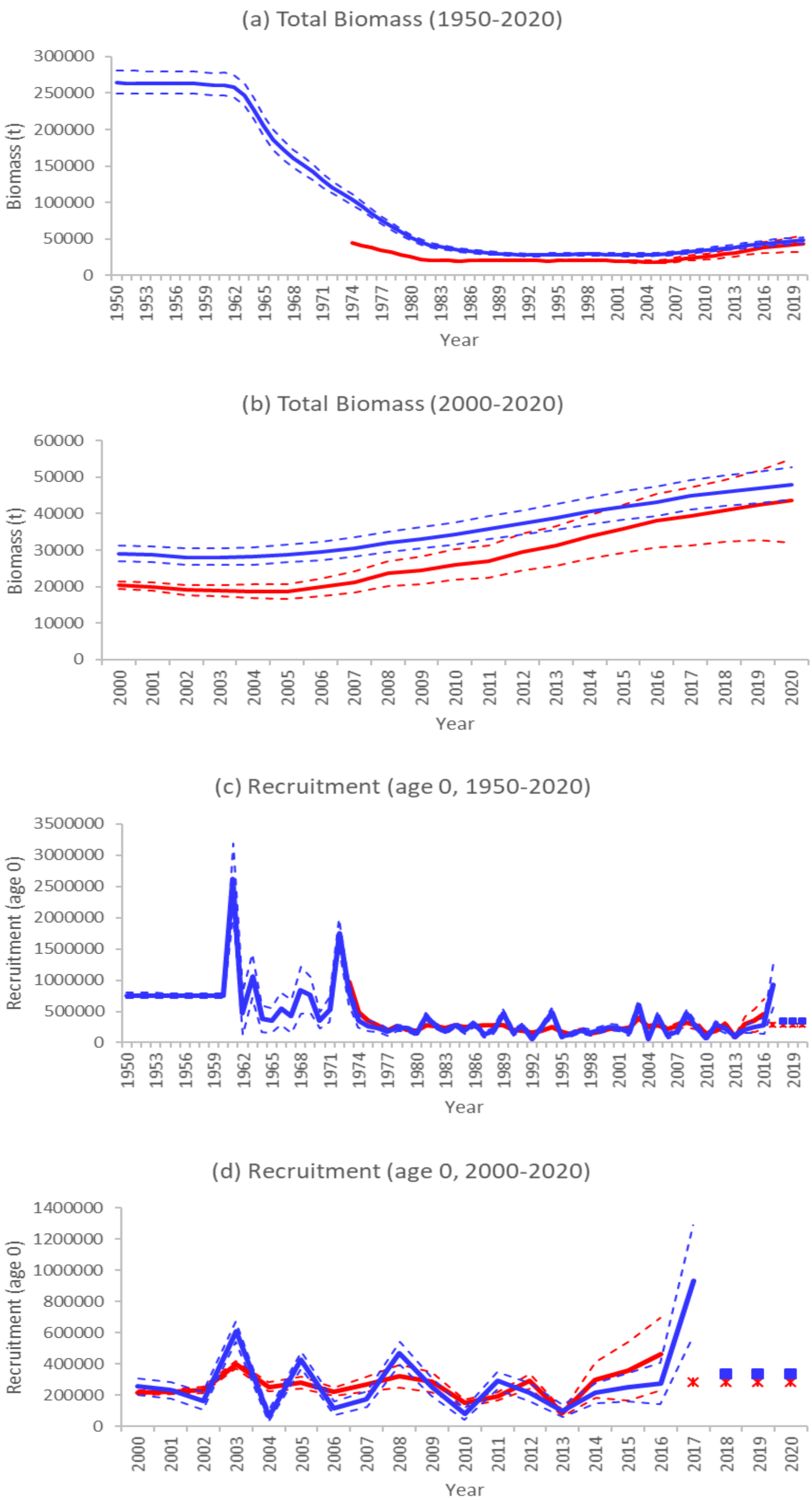
BFTW-Figure 2. Indices of relative abundance for western bluefin tuna. Indices denoted with "*" represent revised indices rather than strict updates of indices used in the 2020 stock assessment. Indices denoted with an "s" were used in Stock Synthesis and indices with a "v" were used in VPA. U.S. Rod and reel 66-114 and 115-144 indices are shown for illustrative purposes but were superseded by the combined 66-144 index. The 1986 low data point of the Japanese longline in the West Atlantic was removed in the Stock Synthesis models.



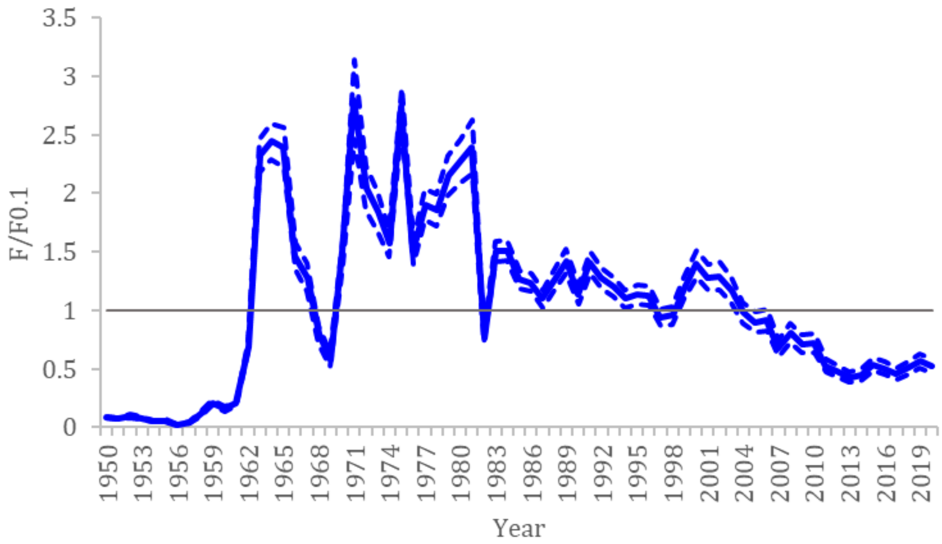




BFTW-Figure 3. Comparisons of (a) total biomass, (b)recruitment, and (c) fishing mortality by Stock Synthesis among 2017 (green), 2020 (orange), and 2021 (black) stock assessments for West bluefin tuna.

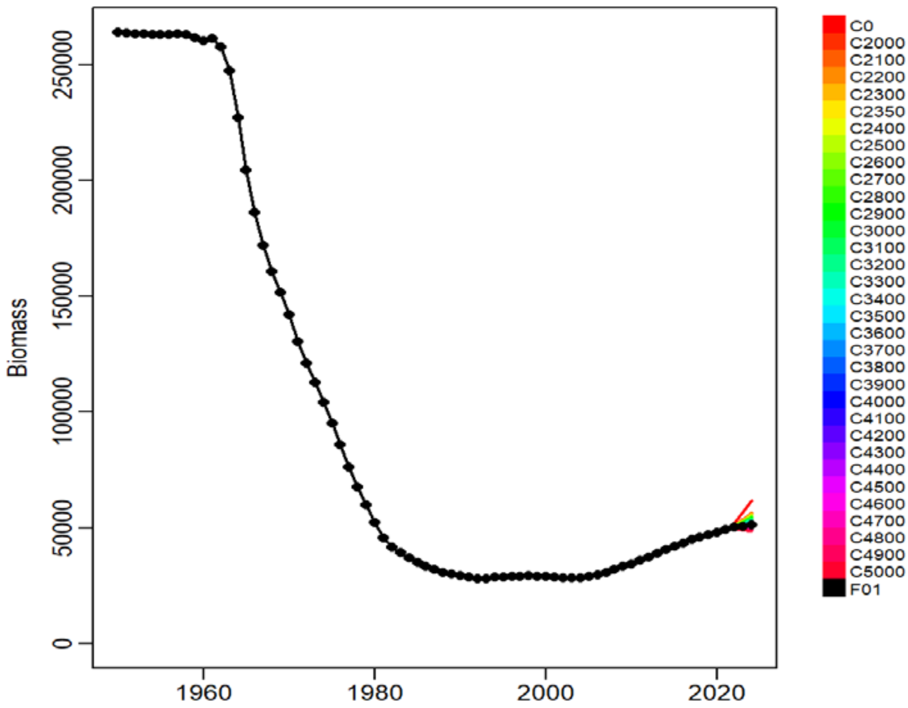


BFTW-Figure 4. Estimates of (a) total stock biomass for 1950-2020 and (b) for 2000-2020, and (c) recruitment (age 0) for 1950-2020 and (d) for 2000-2020 for the base VPA (red) and Stock Synthesis (blue) models from the 2021 assessment. The 80% confidence intervals are indicated with dashed lines. Recruitment estimates for the recent years (2017-2020 for VPA; 2018-2020 for Stock Synthesis) have been replaced by the average recruitment in the recent 6 years (2012-2017).

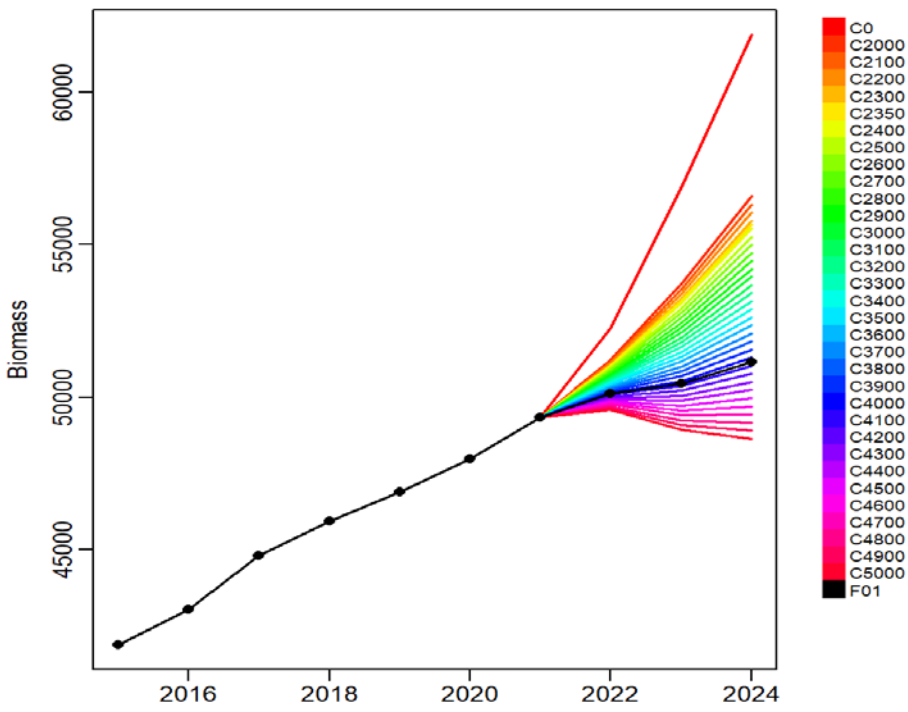


BFTW-Figure 5. Fishing mortality relative to the $F_{0.1}$ reference point as estimated by Stock Synthesis for the 2021 assessment. The 80% confidence intervals are indicated with dashed lines.

a)



b)



BFTW-Figure 6. Projected total stock biomass (mt) of bluefin tuna in the West Atlantic under alternative constant catch scenarios, averaged across maturity specifications for Stock Synthesis. The deterministic model runs are averaged across both maturity specifications. (a) Upper panel: 1950-2024, (b) lower panel: zoomed in to 2015 to 2024.