REPORT OF THE 2021 WESTERN BLUEFIN STOCK ASSESSMENT MEETING
(Online, 30 August-1 September 2021)

1. Opening, adoption of Agenda and meeting arrangements and assignment of rapporteurs

The 2021 Western Bluefin Stock Assessment Meeting of the Bluefin Tuna Species Group ("the Group") was held online from 30 August to 1 September 2021. Dr. John Walter (USA), the Rapporteur for the western Atlantic bluefin tuna stock (WBFT), opened the meeting and served as Chair. On behalf of the Executive Secretary, the Assistant Executive Secretary welcomed the participants to the meeting. According, the Commission request for an independent review of the WBFT assessment and according to the terms of reference for the external review (Anon. 2021a), the Group also had the participation of the invited expert, Dr. Mark Maunder. The Group Chair proceeded to review the Agenda which was adopted after some changes (**Appendix 1**).

The List of Participants is included in **Appendix 2**. The List of Documents presented at the meeting is attached as **Appendix 3**. The abstracts of all SCRS documents and presentations provided at the meeting are included in **Appendix 4**. The following served as rapporteurs:

Sections	*Rapporteur*
Items 1, 6	A. Kimoto
Items 2.1, 3.1	K. Gillespie
Items 2.2, 3.2	H. Fukuda
Item 4	M. Lauretta, J. Walter, A. Kimoto
Item 5	N. Taylor

2. Model diagnostics

2.1 VPA

SCRS/2021/139 documented the 2021 assessment of the West Atlantic bluefin tuna using virtual population analysis (VPA). The paper summarized the VPA data inputs, assumptions, provisional results, diagnostics and time series estimates of spawning stock biomass (both early and late maturity scenarios) for the period 1974 to 2020, and recruitment for the period 1974 to 2017. The model incorporated revisions to key indices, particularly an index for small fish (US Rod & Reel (USRR) 66-144). Relative to the 2020 WBFT VPA, model results were heavily influenced by addition of recent data. Model diagnostics indicate some problems with the updated model including a severe trend in the residuals for some indices and a strong retrospective bias.

The Group noted the substantial effort of Sub-groups in revising the indices considered in this model and the exploration of data related to shifts in recruitment. Significant discussion was dedicated to several of the poor VPA diagnostic results. It was noted that 2021 continuity runs, when compared to the 2020 VPA base case, showed a strong difference in scale in recruitment and spawning stock biomass estimates from 2005 onwards (**Figure 1** and **2**). The Group further noted the striking effect of the jackknife removal of the USRR 66-144 index (**Figure 3**), leading to substantial increases in recruitment in recent years (i.e. USRR 66-144 essentially constraining a strongly positive recruitment trend). Similarly, removal of recent data in retrospective analysis (**Figure 4**) provided an altered representation of both recruitment and biomass patterns, resulting in lower recent values for both. Noting the poor residuals associated with the USRR 66-144 index, it was suggested that a base case run could exclude this index. The author noted that this could be problematic for two reasons: i) this is only available small fish index and ii) a retrospective run on the USRR 66-144 jackknife (**Figure 3**) showed an even more amplified recent recruitment estimate and even more severe retrospective patterns. There was brief discussion on the positive bias observed in the bootstraps of both recruitment and biomass relative to the deterministic runs. It was suggested that this could be a result of poor residuals in juvenile fish fits.

The Group discussed exclusion of some data sources. Previous VPA assessment models (2017 and 2020) excluded US greater than 177 and two Canadian handline indices in the southwestern Nova Scotia and in the Gulf of St. Lawrence (CAN SWNS and CAN GSL). This was, again, the case for this assessment model due to large residuals and conflicting residual patterns in US and Canadian indices (**Figure 5**). This led to discussion on how selectivity, catchability, and vulnerability were considered in the both the indices and VPA. The author clarified that selectivity and catchability were held constant for each fleet and indicator across the various time series. These assumptions were largely driven by analyses conducted during the WBFT indices review in early 2021 (Anon., 2021b) which indicated that due to permitting rules (e.g. size class bag limits) and fishery spatial dynamics, targeting and catch size for each fleet is conserved among years. The author noted that in years where there is a high abundance of a particular cohort (potentially 2020 where large number of 2-3 years old were observed), these permitting rules may negatively bias estimation of the Kobe apical F.

Noting several potentially problematic features of the model performance, there was discussion on whether the VPA would be suitable for providing management advice. Before making a final decision, the Group suggested that the following sensitivity runs be tested and presented: i) halving of the catch-at-age for small fish (i.e. reduce absolute amount of catch for ages 2-3) in 2019 and 2020 to test the influence on recruitment versus influence of catch-at-age for older fish; ii) allowing the standard deviation on the vulnerability link parameter to increase up to 1.2; iii) walking the selectivity and catchability on the USRR 66-144; iv) conducting a bootstrap without 2020 data.

The Group was presented with these additional diagnostics (SCRS/2021/139) which indicated that i) halving the catch-at-age for 2-3 years old in 2020 and alternatively in both 2019 and 2020 had little impact on the problematic residual and retrospective patterns; ii) increasing the standard deviation of vulnerability had no discernable impact; iii) allowing selectivity and catchability on USRR 66-144 to walk resulted in slightly better fits and residuals, however, did not improve poor retrospectives; iv) bootstraps that excluded 2020 data still showed a substantial positive bias relative to the deterministic runs. In general, none of these tests improved retrospective and residual patterns. The author also tested the model's sensitivity to age 1 fish in the catch data. The relatively small catch of age 1 fish was further reduced to a catch of a single age 1 fish in each year since 1995. Surprisingly, this resulted in recruitment from 2007 and onward being significantly reduced. Notably, the positive recent recruitment pattern disappeared. This would seem to indicate that poorly informed data are having an inappropriately large effect on recruitment estimates even while selectivity for this age group is zero or near zero (the minimum size limit is 67 cm). After some discussion, the Group agreed that these unusual diagnostic results should preclude this model, in its current form, from further development and provisioning of management advice. It was suggested, however, that qualitative information for this model could be used to provide narrative to management advice from this Group.

2.2 Stock Synthesis

Documents SCRS/2021/140 and SCRS/2021/141 presented the input data and model configuration of the candidate base-case model embedded to the Stock Synthesis version 3.30.14 for the 2021 stock assessment of the western Atlantic bluefin tuna. The catch and composition data over the historical period (1950-2018) were nearly identical whereas those for the years 2019-2020 were updated. Most of the indices of abundance were simply updated using the same standardization method with up-to-date data. Four out of 12 indices of abundance were the subjects of major updates to revise the method for the data curation and standardization based on the thorough review and following agreement by the Technical Sub-group on Abundance indices as well as the BFT Species Group.

Given the data set, the authors noted that the continuity-like runs (2021 Continuity and Prototype runs; **Table 1**), which conformed to the 2020 stock assessment model configuration as close as possible with the 2 additional years of data (2019 and 2020), experienced difficulties in model convergence as well as a notable conflict of information among the data for the population scale estimates. To solve the issues, a modification, which changed the selectivity shape from asymptotic selectivity to dome-shape selectivity for all fleets except the CAN GSL index, was proposed. This modification reduced the data conflict on the population scale estimates and allowed the model to better achieve convergence criteria to a smaller final gradient than the continuity-like model. The Group agreed to some minor changes mainly to avoid allowing likely outlier data to have overly influential impact on the likelihoods, such as 1) removing one CPUE data point (year 1986) from the historical Japanese longline CPUE (JPN LL early); 2) aggregating the last five bins of size composition data (above 300 cm) for the USA and Mexican longline (MEX-USA LL) in the Gulf of Mexico (GOM); 3) not fixing but estimating the initial equilibrium fishing mortality for the Canadian and USA Harpoon (CAN USA HP) based on the initial equilibrium catch data.

The proposed base case model showed some improvements in the model convergence (diagnosed by randomly perturbations of the starting values of all parameters) and the model consistency (diagnosed by the likelihood profile over the fixed population scale parameter and the retrospective analysis for the spawning stock biomass estimates) from the previous assessments. The goodness-of-fit analysis did not indicate the critical misfit of the proposed base case model to the aggregated size composition data. Although the model fit to the JPN LL early index was improved in terms of its likelihood penalty, overall model fits to the indices of abundance remain as an issue as in several previous assessments. The authors also introduced the results of the diagnostics using the Age Structured Production Models (ASPMs) and the Catch Curve Analysis (CCA). ASPMs elucidated the production relationship in the model under the assumed biological and removal processes and a consistency in some of the input data with this relationship. CCA indicated some contributions of the size composition data to the estimation of the absolute biomass, although it was not consistent with the production relationship elucidated by the ASPMs.

The Group discussed about the changes in shapes of the selectivity from asymptotic to dome shape as this is a significant change of the model assumption. Recent research (Sampson and Scott, 2011; as well as modeling practice by Waterhouse *et al*., 2014) indicate that the asymptotic length-based selectivity should be chosen carefully because the asymptotic selectivity in the model, which fitted to the size composition data, is a strong assumption that implies an upper bound to population size along with the other biological assumptions (e.g. natural mortality and growth) (Minte-vera *et al*., 2017). Alternatively, there is also often a confounding between depletion and doming of the descending limb. For this reason, there is a general modeling practice that it is convenient and desirable if one fleet can be reasonably assumed to be asymptotic, which helps the model to interpret the descending limb of the catch curve. In this case modeling the Gulf of St Lawrence handline fishery from years 1950-1987 as asymptotic provided that single asymptotic fleet.

There was a suggestion that the constant asymptotic selectivity for the MEX-USA LL would be appropriate given the biological knowledge about the spawning migration of the large sized fish and a historical stability of the longline fleets in the Gulf of Mexico (GOM). However, there were also counterarguments that the fishery could be dome-shaped given the spatial and temporal distributions of the largest sized fish as well as the fishery operation. One observation was highlighted that there is a clear descending limb estimated in the selectivity of the JPN LL in the GOM although this fleet had been a predominant fleet during mid-1970's to early 1980's with targeting a large spawner cohort. As a response to this observation, the possible cohort-targeting effect that could make the selectivity to be domed is suggested with another observation that larger sized fish were caught by the CAN GSL in the same decade. After the lengthy discussion regarding the selectivity of JPN LL in GOM, which considered the reliability of the data and the lack of age composition data, the Group agreed that suggested changes in selectivity were reasonable as long as it did not lead to model instability or unrealistic scaling.

The decision to allow the CAN GSL 2010-2020 fleet to be domed was motivated by the marked change in mean length (**Figure 6**) in the fishery subsequent to 2008 when there was a change in the fleet operations. It was also noted that there has been a substantial increase in fraction of eastern migrants in this fishery, particularly at the younger ages (Puncher *et al.*, 2021).

The Group also discussed about the other minor changes applied to the model as well as the general results of the Stock Synthesis model. One suggestion was made to estimate the selectivity of the CAN GSL fishery between 1988 and 2009, since the size composition data of this fleet would be a better representative of their removals than that of CAN GSL since 1988, which was used to estimate the selectivity of CAN GSL before 1987 in the proposed base case. The authors showed the results of the model, which include the size composition data from CAN GSL fishery since 1988 and indicates the model performance was not degraded by this modification. The Group agreed the 2021 Final model (**Table 1**) which assumed the asymptotic selectivity fleet as the early period (1988-2009) of the CAN GSL since 1988.

3. Assessment results

3.1 VPA

Due to poor model diagnostics, the VPA was not further developed or used to provide stock status and projections. The following model trends are highly uncertain and should be interpreted with a large degree of caution. Notwithstanding these problems, the Group accepted that the VPA indicated an improved status of the resources compared to that estimated in the 2020 assessment (**Figure 2**).

VPA estimates of recent fishing mortality trended steadily downward and were lower during the terminal year than historically for most ages. Apical fishing mortality (maximum annual F-at-age) showed the lowest rates currently, relative to the entire time series and qualitatively indicated that fishing mortality was below $F_{0.1}$. Recruitment estimates showed relatively high inter-annual variability over the last 15 years, with terminal year estimates notably higher than the preceding years. The increase in spawning biomass during the last two decades reflected the several high recruitment events since 2003 and in the recent 17 years.

3.2 Stock Synthesis

The final recommended models are as follows in **Table 2** with the following parameter estimates (**Tables 3-4**), derived quantities (**Tables 5**) and benchmarks (**Table 6**). **Table 5** and **6** also list the likelihoods and benchmarks across each of the models presented to the Group. Model diagnostics, fits to indices and length composition, and estimated selectivities are provided in **Figures 7-21**. The estimated spawning stock biomass, recruitment, biomass ratio to unfished levels, and fishing mortality for the 2021 Final model are shown in **Figure 22**.

The Group carefully looked and discussed about the recruitment estimates (age 0), particularly for a couple of recent recruitments that occurred in 2017-2018 which were estimated to be higher than the other recent years. The authors recalled that those recruitments were primarily informed by the year 2020 data from juvenile abundance index (USRR 66-144) and its size composition data, and the reliability of the recruitment information from those data were confirmed by the ASPM-R analysis. There is also a suggestion that because those recruitments were estimated based on the observation of large amounts of smaller fish and there are numerous reasons that this could be the case. This might have occurred due to a strong cohort, possibly due to eastern origin fish migrants, slower growth of fish, or change in the fishery selectivity as we assume time-invariant length-based selectivity. As with any early sign of recruitment, the strength and magnitude will be further confirmed with additional years of data giving a repeated signal in the later age composition and indices. The Group also noted that the 95% confidence interval of the recruitment deviation for 2018 overlapped zero, indicating that this recruitment was not well estimated.

4. Projections and management advice

Stock Synthesis was deemed suitable for projection advice and passed diagnostic performance criteria. In contrast, diagnostic evaluation of the VPA indicated problematic performance, notably very high retrospective bias and bias between deterministic and stochastic results that could not be satisfactorily addressed in the time available. Given this, Group did not recommend the VPA for projections or quantitative stock status determinations at this time, though we do not rule out its utility in the future.

The Group also received a paper (SCRS/2021/143) where the reconditioned MSE Operating Models (OMs) for the Atlantic bluefin stocks are used to provide estimates of the trend in spawning biomasses of the two stocks of origin under a continuation of the current west area TAC of 2,350 t for 2022. The result is a median (across the OMs) increase in the spawning biomass of the western stock of 6% from 2022 to 2023, with a 21% probability of a decrease. The purpose was to complement results under preparation from refined and updated conventional assessment methods. The Group noted the results of this paper.

Projections were conducted using Stock Synthesis, based on estimates from the 2021 Final model. Biological and fisheries parameters used for projections, e.g. growth and fleet selectivities, were derived from the deterministic run. The fishing mortality status (i.e. the probability that the stock is currently undergoing overfishing relative to $F_{0.1}$) was calculated for the terminal model year (2020; therefore

$F_{2020}/F_{0.1}$), based on the average F of ages 10 to 20. The F reference point, $F_{0.1}$, was calculated in Stock Synthesis from the yield-per-recruit curve. Uncertainty in current fishing mortality relative to $F_{0.1}$ was determined by the multivariate lognormal approximation approach (Walter *et al.*, 2018; Winker *et al.*, 2019).

Future recruitment was assumed equal to the average of estimates over the period 2012 to 2017 (approximately 330,000 age-0 recruits per year). The recent three-year (2018 to 2020) recruitment estimates were also replaced with the projected average, as there were few data to inform those estimates and highly uncertain. Selectivity was assumed constant in the future, equal to the mean of 2018 to 2020 estimates (**Figure 23**). A fixed catch in 2021 equal to the TAC (2350t) was assumed, followed by three years (2022 to 2024) of alternative constant catches ranging from 2000 to 5000 by 100 t increments, as well as 2350 t (current TAC) scenarios. Fleet catch allocations varied across scenarios according to the allocation table outlined in Rec. 17-06, and the recent three-year (2018 to 2020) average catch ratio among CPCs (**Table 7**).

Changes in selectivity assumptions in Stock Synthesis improved performance of the models and rectified some model misspecification but did not rectify all of the conflicts in the models such as conflicts in the indices. The resulting changes to the model specifications show a substantial higher total biomass scale relative to the 2020 models (**Figure 24**) as well as a 30% increase in $F_{0.1}$ (going from 0.091 to 0.118). Furthermore, the variability in absolute scale differences between the 2017, the 2020 and now the 2021 models (**Figure 25**) is potentially indicative of a common issue of stock assessment models that are particularly challenged in the ability to estimate absolute scale (Deroba *et al.*, 2015). This has certainly been a concern with the VPA for the East and Mediterranean stock and, given the increasing influence of eastern origin fish in western fisheries (Puncher *et al.*, 2021), it is possible that the western-area assessments face similar challenges.

Recent assessments of both the eastern and western stocks developed catch advice based on the maintaining the status of the stock as not undergoing overfishing, measured as the current average fishing mortality rate relative to a $F_{0.1}$ reference point. The choice of $F_{0.1}$ was selected due to uncertainty in long-term recruitment potential while accounting for changes in recent recruitment and fishery selectivity dynamics over time. Accordingly, the Group has elected to focus on fishing-mortality based reference points that do not require knowledge of long-term recruitment potential, but nevertheless can be implemented in a manner that will lead to rebuilding. The reference point of choice for both the eastern and western stocks has been $F_{0.1}$ (Anon., 2017).

The fishery status for 2020 ($F_{2020}/F_{0.1}$) was determined to be not overfishing with greater than 95% probability. The estimates of fishing mortality relative to $F_{0.1}$ ($F_{2020}/F_{0.1}$) in 2020 are 0.530 (80% confidence interval = 0.474 - 0.589) and 0.520 (0.467 - 0.575) for late and early maturity scenarios, respectively (**Table 6**). Biomass projections at constant fixed TACs and $F_{0.1}$ are shown in **Figure 26.**

Recent higher recruitment (both in the catch-at-size and juvenile index of abundance), and a change in the selectivity assumptions of the fleets in Stock Synthesis both resulted in higher predicted yields. The addition of data and revised indices included since 2020 were responsible for ~50% increases in deterministic yield at $F_{0.1}$ for the 2022-2024 (**Tables 8** and **9**), while further changes in assumptions were responsible in ~50% of the changes.

5. Other matters

There were no additional matters discussed.

6. Adoption of the report

The Report of the 2021 Western Bluefin Stock Assessment Meeting was adopted, except for the first paragraph of section 3.2 and except for the fifth and seventh paragraphs of section 4. The Group adopted the pending paragraphs by correspondence by 18 September 2021. Dr. Walter thanked the participants and the Secretariat for their hard work and collaboration to finalize the report on time. The meeting was adjourned.

References

Anon. 2018. Report for biennial period, 2016-17, Part II – Vol. 2. 427 pp.

Anon. 2021a. *In press*. Report of the first 2021 intersessional meeting of the Bluefin Tuna Species Group (including W-BFT data preparatory) (Online, 5-13 April 2021). ICCAT Collect. Vol. Sci. Pap. 78(3): 1-145.

Anon. 2021b. Recommendation of the BFT Technical Sub-group on Abundance Indices for West Atlantic bluefin tuna. SCRS/2021/044

Deroba J.J., Butterworth D.S., Methot R.D., De Oliveira Jr, J.A.A., Fernandez C., Nielsen A., Cadrin S.X., Dickey-Collas M., Legault C.M., Ianelli J., Valero J.L., Needle C.L., O'Malley J.M., Chang Y-J., Thompson G.G., Canales C., Swain D.P., Miller D.C.M., Hintzen N.T., Bertignac M., Ibaibarriaga L., Silva A., Murta A., Kell L.T., de Moor C.L., Parma A.M., Dichmont C.M., Restrepo V.R., Ye Y., Jardim E., Spencer P.D., Hanselman D.H., Blaylock J., Mood M., and Hulson P.-J. F. 2015. Simulation testing the robustness of stock assessment models to error: some results from the ICES strategic initiative on stock assessment methods. ICES Journal of Marine Science 72(1): 19-30. https://doi.org/10.1093/icesjms/fst237

Minte-Vera C. V., Maunder M.N., Aires-da-Silva A. M., Satoh K., and Uosaki K. 2017. Get the biology right, or use size-composition data at your own risk. Fisheries Research 192:114-125. https://doi.org/10.1016/j.fishres.2017.01.014

Puncher G. N., Hanke A., Busawon D., Sylvester E., Golet W., Hamilton L. C., and Scott A. P. 2021. Individual assignment of Atlantic bluefin tuna in the northwestern Atlantic Ocean using single nucleotide polymorphisms reveals an increasing proportion of migrants from the eastern Atlantic Ocean. Canadian Journal of Fisheries and Aquatic Sciences. https://doi.org/10.1139/cjfas-2020-0336

Sampson D.B. and Scott R. D. 2011. A spatial model for fishery age-selection at the population level. Canadian Journal of Fisheries and Aquatic Sciences 68(6). https://doi.org/10.1139/f2011-044

Walter J., Hiroki Y., Satoh K., Matsumoto T., Winker H., Urtizberea Ijurco A., and Schirripa M. 2018. Atlantic bigeye tuna stock synthesis projections and Kobe 2 matrices. ICCAT Collect. Vol. Sci. Pap. 75(7): 2283-2300.

Waterhouse L., Sampson D.B., Maunder M., and Semmens B. X. 2014. Using areas-as-fleets selectivity to model spatial fishing: Asymptotic curves are unlikely under equilibrium conditions. Fisheries Research 158: 15-25. https://doi.org/10.1016/j.fishres.2014.01.009.

Winker H., Kell L., Fu D., Sharma R., Courtney D., Carvalho F., Schirripa M., and Walter J. 2019. A rapid approach to approximate Kobe posteriors from Stock Synthesis assessment models with applications to north Atlantic shortfin mako. SCRS/2019/093 (Withdrawn).

Table 1. Descriptions of Stock Synthesis models considered by the Group.

Runs	***Descriptions***
2020 Base	The final stock assessment results in 2020. The terminal year is 2018.
2021 Continuity	Based on the 2020 Base run, the model incorporated the updated data up to 2020 for catch and some indices in the 2021 assessment exercise. This model includes CAN-HL combined index, US RR 66-114 cm, and US RR 115-144 cm.
2021 Prototype	Based on the 2021 Continuity run, the model further incorporated the changes on the indices: MEX-USA LL, CAN HL in SWNS, CAN HL in GSL, and combined US RR 66-155cm in a new fleet structure.
2021 Proposed base case	Proposed base case by SCRS/2021/141 to the Group. Several changes were made based on the 2021 Prototype run: selectivity was parameterized as length-based, and selectivity shapes were modified from asymptotic selectivity to double normal selectivity for all fleets except the CAN HL GSL index to allow for either doming or asymptotic.
2021 Final model	Based on the 2021 Proposed base case run, the following changes were made: 1) remove 1986 data point from JPN LL early index since 1976 2) aggregate length bins over 300cm for the MEX-USA LL size composition data 3) estimate the initial equilibrium fishing mortality for the CAN USA HP index based on the initial equilibrium catch data. 4) assumed asymptotic selectivity for the CAN GSL fleet for early period (1988-2008), allow free estimation of selectivity using double normal approximation for 2009-2020.

Table 2. Names and fishery definitions of the fleets used in the Stock Synthesis final model.

No.	*use*	*Fleet/Index*	*Selectivity (all length based except fleet 15)*	*Time block Selectivity*	*start*	*end*
1	Y	JAPAN_LL	Double Normal	Y (1950-2009)	1957	2020
2	Y	OTHER_ATL_LL	Double Normal	N	1957	2020
3	Y	GOM_LL_US_MEX	Double Normal	N	1971	2020
4	Y	JLL_GOM	Double Normal	N	1974	1981
5	Y	USA_CAN_PSFS	Double Normal	N	1950	1984
6	Y	USA_CAN_PSFB	Double Normal	N	1950	2015
7	Y	USA_TRAP	Double Normal	Y (1950-1992)	1950*	1974
8	Y	CAN_TRAP	Double Normal	N	1950*	2020
9	Y	USA_CAN_HARPOON	Double Normal	N	1950	2018
10	N	USA_HARPOON	Double Normal	N	1950	2020
11	Y	USA_RRFS	Double Normal	N	1950	1920
12	Y	USA_RRFB	Double Normal	N	1950	2020
13	N	CAN_CombinedHL	Double Normal	N	1988	2020
14	Y	CAN_SWNS_HLnoHP	Double Normal	N	1988	2020
15	N	CAN_SWNS_HLwithHP	Double Normal	N	1988	2020
16	Y	CAN_GSL_HL	Double Normal***	Y (1950-2008)	1988	2020
17	Y	CAN_GSL_old	Logistic	N	1950	1987
18	Y**	IND1_JAPAN_LL early	mirror JAPAN_LL	N	1976	2009
19	Y	IDX2_JAPAN_LL2	mirror JAPAN_LL	N	2010	2020
20	N	IDX3_USPLL_GOM	mirror GOM_LL	N	1987	1991
21	N	IDX4_USPLL_GOM2	mirror GOM_LL	N	1992	2020
22	Y	IDX5_MEXUSALL_GOM_LL2	mirror GOM_LL	N	1994	2019
23	Y	IDX6_JPNLL_GOM	mirror JLL_GOM	N	1974	1981
24	N	IDX7_US_RR_66_114	Double normal	N	1995	2020
25	N	IDX8_US_RR_115_144	Double normal	N	1995	2020
26	Y	IDX9_US_RR_66_144	Mirror USRRFS	N	1995	2020
27	Y	IDX10_US_RR_LT145	Mirror USRRFS	N	1980	1992
28	Y	IDX11_US_RR_GT177	Mirror USRRFB	N	1993	2020
29	Y	IDX12_US_RR_GT195	Mirror USRRFB	N	1983	1992
30	N	IDX13_CAN_combinedHL	Mirror Can combined HL	N	1984	2018
31	Y	IDX14_CAN_SWNS	mirror Can_SWNS_HLnoHP	N	1996	2020
32	Y	IDX15_CAN_GSL	mirror Can_GSL_HL	N	1988	2020
33	Y	IDX16_CAN_ACOUSTIC	mirror Can_GSL_HL	N	1994	2017
34	Y	IDX17_GOMlarval	mirror GOM_LL	N	1977	2019
35	N	IDX19_oceanographic	Exp(rec_dev)	N	1993	2011

* Fishery starts with equilibrium catch.
** The estimate for 1986 was removed.
*** Selectivity in early time block until 2008 mimic asymptotic shape with fixed high ending of double normal.

Table 3. Parameter estimates, phases initial values and standard deviations for the final model for late maturity scenario.

Label	*Value*	*Phase*	*Min*	*Max*	*Init*	*StDev*
L_at_Amax_Fem_GP_1	273.506	3	240	350	273.504	0.696301
VonBert_K_Fem_GP_1	0.297944	3	0.2	0.4	0.297306	0.0080385
Richards_Fem_GP_1	-1.01657	3	-2	0	-1.011	0.0669735
CV_young_Fem_GP_1	0.091835	4	0.03	0.15	0.09102	0.00566797
CV_old_Fem_GP_1	0.0643568	4	0.03	0.15	0.066024	0.00148668
SR_LN(R0)	6.63388	1	5	10	6.63736	0.041349
SR_BH_steep	0.559016	2	0.5	0.99	0.562091	0.0278948
SR_sigmaR	0.670471	3	0.2	1.2	0.679511	0.0807214
InitF_seas_1_flt_7USA_TRAP	0.0126395	1	1E-05	0.1	0.0125549	0.00213186
InitF_seas_1_flt_9USA_CAN_HARPOON	0.00231061	1	1E-05	0.1	0.0022942	0.000172621
LnQ_base_IDX11_US_RR_GT177(28)	-4.25942	1	-10	-2	-4.26025	0.0916597
LnQ_base_IDX14_CAN_SWNS(31)	-4.13428	1	-10	-2	-4.13578	0.101609
LnQ_base_IDX15_CAN_GSL(32)	-6.12873	1	-10	-2	-6.10122	0.108886
LnQ_base_IDX16_CAN_ACOUSTIC(33)	-6.57783	1	-10	-2	-6.55174	0.12191
LnQ_base_IDX11_US_RR_GT177(28)_ENV_mult	0.174096	3	-2	2	0.173377	0.0491642
LnQ_base_IDX14_CAN_SWNS(31)_ENV_mult	-0.134142	3	-2	2	-0.135056	0.0691958
LnQ_base_IDX15_CAN_GSL(32)_ENV_mult	-0.21859	3	-2	2	-0.215487	0.0307471
LnQ_base_IDX16_CAN_ACOUSTIC(33)_ENV_mult	-0.039187	3	-2	2	0.0366599	0.0376157
Size_DblN_peak_JAPAN_LL(1)	223.854	2	120	250	223.829	2.76439
Size_DblN_top_logit_JAPAN_LL(1)	-11.6732	2	-15	3	-11.6798	55.2614
Size_DblN_ascend_se_JAPAN_LL(1)	7.10026	3	-5	9	7.09927	0.120809
Size_DblN_descend_se_JAPAN_LL(1)	5.73913	5	-5	9	5.74841	0.352753
Size_DblN_end_logit_JAPAN_LL(1)	-3.18697	6	-20	10	-3.18679	0.541482
Size_DblN_peak_OTHER_ATL_LL(2)	214.336	2	120	285	214.211	2.38854
Size_DblN_top_logit_OTHER_ATL_LL(2)	-11.6184	2	-15	3	-11.6409	55.9487
Size_DblN_ascend_se_OTHER_ATL_LL(2)	8.03662	3	-5	9	8.0343	0.0570092
Size_DblN_descend_se_OTHER_ATL_LL(2)	7.09271	5	-5	9	7.11862	0.196028
Size_DblN_end_logit_OTHER_ATL_LL(2)	-2.49195	6	-20	10	-2.52811	0.392425
Size_DblN_peak_GOM_US_MEX_LL(3)	247.247	2	120	285	242.584	3.94879
Size_DblN_top_logit_GOM_US_MEX_LL(3)	-6.28462	2	-15	3	-11.9856	21.9657
Size_DblN_ascend_se_GOM_US_MEX_LL(3)	7.59258	3	-5	9	7.46492	0.108774
Size_DblN_end_logit_GOM_US_MEX_LL(3)	0.207353	6	-20	10	0.463658	0.206949
Size_DblN_peak_JPNLL_GOM(4)	232.863	2	120	285	232.976	2.48322
Size_DblN_top_logit_JPNLL_GOM(4)	-11.8788	2	-15	3	-11.8237	52.6778
Size_DblN_ascend_se_JPNLL_GOM(4)	6.60046	3	-5	9	6.62472	0.169863
Size_DblN_descend_se_JPNLL_GOM(4)	6.18961	5	-5	9	6.21873	0.193538
Size_DblN_end_logit_JPNLL_GOM(4)	-3.63153	6	-20	10	-3.66616	0.431098
Size_DblN_peak_USA_CAN_PSFS(5)	74.4773	3	50	200	74.3773	4.01654
Size_DblN_ascend_se_USA_CAN_PSFS(5)	4.74988	4	-4	12	4.72797	0.707638
Size_DblN_peak_USA_CAN_PSFB(6)	212.316	2	150	285	212.229	3.17388
Size_DblN_top_logit_USA_CAN_PSFB(6)	-2.1987	2	-5	3	-2.18515	0.328659
Size_DblN_ascend_se_USA_CAN_PSFB(6)	6.85495	3	-4	8	6.85257	0.14211

Table 3. Continued.

Label	*Value*	*Phase*	*Min*	*Max*	*Init*	*StDev*
Size_DblN_end_logit_USA_CAN_PSFB(6)	-4.03976	6	-15	5	-4.038	0.754815
Size_DblN_peak_USA_TRAP(7)	124.84	3	80	150	124.726	6.76268
Size_DblN_top_logit_USA_TRAP(7)	-2.28684	3	-5	3	-2.27338	0.846659
Size_DblN_descend_se_USA_TRAP(7)	7.41493	5	-2	10	7.41112	0.553005
Size_DblN_peak_CAN_TRAP(8)	270.623	2	120	285	270.933	2.64143
Size_DblN_top_logit_CAN_TRAP(8)	-12.1105	2	-15	3	-12.1142	49.7491
Size_DblN_ascend_se_CAN_TRAP(8)	7.82065	3	-5	9	7.82217	0.0777027
Size_DblN_descend_se_CAN_TRAP(8)	4.82551	5	-5	9	4.78631	0.492164
Size_DblN_end_logit_CAN_TRAP(8)	-2.53238	6	-20	10	-2.61201	0.705197
Size_DblN_peak_USA_CAN_HARPOON(9)	192.21	2	120	285	192.194	1.51961
Size_DblN_top_logit_USA_CAN_HARPOON(9)	-1.22563	2	-15	3	-1.22254	0.201147
Size_DblN_ascend_se_USA_CAN_HARPOON(9)	5.73187	3	-5	9	5.7307	0.133497
Size_DblN_descend_se_USA_CAN_HARPOON(9)	7.30874	5	-5	9	7.33835	0.324797
Size_DblN_end_logit_USA_CAN_HARPOON(9)	-2.99281	6	-20	10	-3.18928	1.04736
Size_DblN_peak_USA_RRFS(11)	111.921	2	80	120	111.905	1.2812
Size_DblN_top_logit_USA_RRFS(11)	-1.91565	3	-5	3	-1.91511	0.102809
Size_DblN_descend_se_USA_RRFS(11)	-3.07789	5	-5	4	-3.07737	15.1268
Size_DblN_peak_USA_RRFB(12)	195.389	2	140	220	195.425	2.03423
Size_DblN_top_logit_USA_RRFB(12)	-0.263249	3	-5	1	-0.262777	0.032703
Size_DblN_ascend_se_USA_RRFB(12)	6.68361	4	-4	8	6.68412	0.102545
Size_DblN_end_logit_USA_RRFB(12)	-1.7057	6	-15	5	-1.70827	0.160483
Size_DblN_peak_CAN_SWNS_HLnoHP(14)	210.336	2	120	285	210.265	1.83709
Size_DblN_top_logit_CAN_SWNS_HLnoHP(14)	-2.93387	2	-15	3	-2.85716	0.94721
Size_DblN_ascend_se_CAN_SWNS_HLnoHP(14)	6.60589	3	-5	9	6.60317	0.0914231
Size_DblN_descend_se_CAN_SWNS_HLnoHP(14)	7.72773	5	-5	9	7.73094	0.244617
Size_DblN_end_logit_CAN_SWNS_HLnoHP(14)	-3.65769	6	-20	10	-3.8286	1.42222
Size_DblN_peak_CAN_GSL_HL(16)	249.136	3	120	330	249.713	2.96243
Size_DblN_top_logit_CAN_GSL_HL(16)	-11.3865	3	-15	3	-11.4704	58.8581
Size_DblN_ascend_se_CAN_GSL_HL(16)	7.31676	4	-5	9	7.32814	0.109233
Size_DblN_descend_se_CAN_GSL_HL(16)	6.38678	5	-5	9	6.33812	0.336688
Size_DblN_end_logit_CAN_GSL_HL(16)	-3.07468	6	-20	10	-3.14319	1.34688
Size_inflection_CAN_GSL_old(17)	244.867	2	210	330	245.057	2.29169
Size_95%width_CAN_GSL_old(17)	14.5415	2	5	30	14.5234	3.18797
Size_DblN_peak_JAPAN_LL(1)_BLK1repl_1950	165.619	5	120	285	165.61	1.08181
Size_DblN_top_logit_JAPAN_LL(1)_BLK1repl_1950	-3.34263	5	-10	1	-3.33571	0.675059
Size_DblN_descend_se_JAPAN_LL(1)_BLK1repl_1950	7.48491	5	-1	9	7.47779	0.128895
Size_DblN_end_logit_JAPAN_LL(1)_BLK1repl_1950	-6.21961	5	-20	1	-6.17582	1.32257
Size_DblN_peak_USA_RRFS(11)_BLK2repl_1950	84.25	5	60	110	83.5143	1.46813
Size_DblN_top_logit_USA_RRFS(11)_BLK2repl_1950	-1.27713	5	-5	3	-1.11914	1.52211
Size_DblN_peak_CAN_GSL_HL(16)_BLK3repl_1950	297.475	5	120	330	297.856	1.35366
Size_DblN_top_logit_CAN_GSL_HL(16)_BLK3repl_1950	-6.02378	5	-15	3	-7.14244	198.477
Size_DblN_descend_se_CAN_GSL_HL(16)_BLK3repl_1950	1.67428	5	-5	9	9	106.744

Table 4. Parameter estimates, phases initial values and standard deviations for the final model for early maturity scenario.

Label	*Value*	*Phase*	*Min*	*Max*	*Init*	*StDev*
L_at_Amax_Fem_GP_1	273.646	3	240	350	273.646	0.709688
VonBert_K_Fem_GP_1	0.297462	3	0.2	0.4	0.297462	0.008032
Richards_Fem_GP_1	-1.01313	3	-2	0	-1.01313	0.066825
CV_young_Fem_GP_1	0.091813	4	0.03	0.15	0.091813	0.00565
CV_old_Fem_GP_1	0.064296	4	0.03	0.15	0.064296	0.00148
SR_LN(R0)	6.64991	1	5	10	6.64991	0.041245
SR_BH_steep	0.49618	2	0.4	0.99	0.49618	0.02504
SR_sigmaR	0.642304	3	0.2	1.2	0.642304	0.078601
InitF_seas_1_flt_7USA_TRAP	0.01242	1	1.E-05	0.1	0.01242	0.002094
InitF_seas_1_flt_9USA_CAN_HARPOON	0.002289	1	1E-05	0.1	0.002289	0.000171
LnQ_base_IDX11_US_RR_GT177(28)	-4.26822	1	-10	-2	-4.26822	0.091914
LnQ_base_IDX14_CAN_SWNS(31)	-4.1446	1	-10	-2	-4.1446	0.101885
LnQ_base_IDX15_CAN_GSL(32)	-6.15514	1	-10	-2	-6.15514	0.106874
LnQ_base_IDX16_CAN_ACOUSTIC(33)	-6.60374	1	-10	-2	-6.60374	0.120057
LnQ_base_IDX11_US_RR_GT177(28)_ENV_mult	0.175615	3	-2	2	0.175615	0.049052
LnQ_base_IDX14_CAN_SWNS(31)_ENV_mult	-0.13252	3	-2	2	-0.13252	0.068989
LnQ_base_IDX15_CAN_GSL(32)_ENV_mult	-0.21988	3	-2	2	-0.21988	0.030577
LnQ_base_IDX16_CAN_ACOUSTIC(33)_ENV_mult	-0.04046	3	-2	2	-0.04046	0.037478
Size_DblN_peak_JAPAN_LL(1)	223.833	2	120	250	223.833	2.77472
Size_DblN_top_logit_JAPAN_LL(1)	-11.6762	2	-15	3	-11.6762	55.225
Size_DblN_ascend_se_JAPAN_LL(1)	7.09993	3	-5	9	7.09993	0.121351
Size_DblN_descend_se_JAPAN_LL(1)	5.74034	5	-5	9	5.74034	0.352958
Size_DblN_end_logit_JAPAN_LL(1)	-3.20277	6	-20	10	-3.20277	0.542062
Size_DblN_peak_OTHER_ATL_LL(2)	214.322	2	120	285	214.322	2.37978
Size_DblN_top_logit_OTHER_ATL_LL(2)	-11.6208	2	-15	3	-11.6208	55.9187
Size_DblN_ascend_se_OTHER_ATL_LL(2)	8.03667	3	-5	9	8.03667	0.056911
Size_DblN_descend_se_OTHER_ATL_LL(2)	7.09073	5	-5	9	7.09073	0.193497
Size_DblN_end_logit_OTHER_ATL_LL(2)	-2.52785	6	-20	10	-2.52785	0.393558
Size_DblN_peak_GOM_US_MEX_LL(3)	243.742	2	120	285	243.742	2.31836
Size_DblN_top_logit_GOM_US_MEX_LL(3)	-11.4698	2	-15	3	-11.4698	57.811
Size_DblN_ascend_se_GOM_US_MEX_LL(3)	7.50742	3	-5	9	7.50742	0.081157
Size_DblN_descend_se_GOM_US_MEX_LL(3)	4.01861	5	-5	9	4.01861	1.09705
Size_DblN_end_logit_GOM_US_MEX_LL(3)	0.192318	6	-20	10	0.192318	0.203173
Size_DblN_peak_JPNLL_GOM(4)	232.702	2	120	285	232.702	2.4745
Size_DblN_top_logit_JPNLL_GOM(4)	-11.89	2	-15	3	-11.89	52.537
Size_DblN_ascend_se_JPNLL_GOM(4)	6.59391	3	-5	9	6.59391	0.169955
Size_DblN_descend_se_JPNLL_GOM(4)	6.1907	5	-5	9	6.1907	0.191646
Size_DblN_end_logit_JPNLL_GOM(4)	-3.66414	6	-20	10	-3.66414	0.430631
Size_DblN_peak_USA_CAN_PSFS(5)	75.0409	3	50	200	75.0409	4.06569
Size_DblN_ascend_se_USA_CAN_PSFS(5)	4.79962	4	-4	12	4.79962	0.692192
Size_DblN_peak_USA_CAN_PSFB(6)	212.315	2	150	285	212.315	3.17392
Size_DblN_top_logit_USA_CAN_PSFB(6)	-2.20203	2	-5	3	-2.20203	0.328411

Table 4. Continued.

Label	*Value*	*Phase*	*Min*	*Max*	*Init*	*StDev*
Size_DblN_ascend_se_USA_CAN_PSFB(6)	6.85506	3	-4	8	6.85506	0.142131
Size_DblN_end_logit_USA_CAN_PSFB(6)	-4.07876	6	-15	5	-4.07876	0.761193
Size_DblN_peak_USA_TRAP(7)	124.784	3	80	150	124.784	6.77348
Size_DblN_top_logit_USA_TRAP(7)	-2.28276	3	-5	3	-2.28276	0.844391
Size_DblN_descend_se_USA_TRAP(7)	7.41668	5	-2	10	7.41668	0.553747
Size_DblN_peak_CAN_TRAP(8)	270.278	2	120	285	270.278	2.45493
Size_DblN_top_logit_CAN_TRAP(8)	-12.1264	2	-15	3	-12.1264	49.5463
Size_DblN_ascend_se_CAN_TRAP(8)	7.81716	3	-5	9	7.81716	0.07498
Size_DblN_descend_se_CAN_TRAP(8)	4.86562	5	-5	9	4.86562	0.456826
Size_DblN_end_logit_CAN_TRAP(8)	-2.56203	6	-20	10	-2.56203	0.708459
Size_DblN_peak_USA_CAN_HARPOON(9)	192.205	2	120	285	192.205	1.51967
Size_DblN_top_logit_USA_CAN_HARPOON(9)	-1.23038	2	-15	3	-1.23038	0.199337
Size_DblN_ascend_se_USA_CAN_HARPOON(9)	5.73172	3	-5	9	5.73172	0.133526
Size_DblN_descend_se_USA_CAN_HARPOON(9)	7.30118	5	-5	9	7.30118	0.319235
Size_DblN_end_logit_USA_CAN_HARPOON(9)	-3.02546	6	-20	10	-3.02546	1.03825
Size_DblN_peak_USA_RRFS(11)	111.89	2	80	120	111.89	1.282
Size_DblN_top_logit_USA_RRFS(11)	-1.91459	3	-5	3	-1.91459	0.102826
Size_DblN_descend_se_USA_RRFS(11)	-3.07738	5	-5	4	-3.07738	15.1316
Size_DblN_peak_USA_RRFB(12)	195.314	2	140	220	195.314	2.02984
Size_DblN_top_logit_USA_RRFB(12)	-0.2626	3	-5	1	-0.2626	0.032607
Size_DblN_ascend_se_USA_RRFB(12)	6.68153	4	-4	8	6.68153	0.102598
Size_DblN_end_logit_USA_RRFB(12)	-1.73024	6	-15	5	-1.73024	0.160118
Size_DblN_peak_CAN_SWNS_HLnoHP(14)	210.322	2	120	285	210.322	1.83769
Size_DblN_top_logit_CAN_SWNS_HLnoHP(14)	-2.9299	2	-15	3	-2.9299	0.933607
Size_DblN_ascend_se_CAN_SWNS_HLnoHP(14)	6.60555	3	-5	9	6.60555	0.091501
Size_DblN_descend_se_CAN_SWNS_HLnoHP(14)	7.71536	5	-5	9	7.71536	0.241229
Size_DblN_end_logit_CAN_SWNS_HLnoHP(14)	-3.6835	6	-20	10	-3.6835	1.40693
Size_DblN_peak_CAN_GSL_HL(16)	249.119	3	120	330	249.119	1.79141
Size_DblN_top_logit_CAN_GSL_HL(16)	-11.2402	3	-15	3	-11.2403	60.6916
Size_DblN_ascend_se_CAN_GSL_HL(16)	7.32121	4	-5	9	7.32121	0.081251
Size_DblN_end_logit_CAN_GSL_HL(16)	-3.02189	6	-20	10	-3.02189	1.025
Size_inflection_CAN_GSL_old(17)	244.632	2	210	330	244.632	2.30942
Size_95%width_CAN_GSL_old(17)	14.4434	2	5	30	14.4434	3.20932
Size_DblN_peak_JAPAN_LL(1)_BLK1repl_1950	165.638	5	120	285	165.638	1.08165
Size_DblN_top_logit_JAPAN_LL(1)_BLK1repl_1950	-3.33405	5	-10	1	-3.33405	0.666973
Size_DblN_descend_se_JAPAN_LL(1)_BLK1repl_1950	7.48113	5	-1	9	7.48113	0.127964
Size_DblN_end_logit_JAPAN_LL(1)_BLK1repl_1950	-6.2675	5	-20	1	-6.2675	1.33638
Size_DblN_peak_USA_RRFS(11)_BLK2repl_1950	84.3623	5	60	110	84.3623	1.4753
Size_DblN_top_logit_USA_RRFS(11)_BLK2repl_1950	-1.36222	5	-5	3	-1.36222	0.02857
Size_DblN_peak_CAN_GSL_HL(16)_BLK3repl_1950	297.276	5	120	330	297.276	1.33862
Size_DblN_top_logit_CAN_GSL_HL(16)_BLK3repl_1950	-6.03852	5	-15	3	-6.03847	199.129
Size_DblN_descend_se_CAN_GSL_HL(16)_BLK3repl_1950	1.70858	5	-5	9	1.70853	108.781

Table 5. Table of key information for the final models and continuity and prototype runs for late and early maturity scenarios.

	2021 Continuity		***2021 Prototype***		***2021 Final model***	
Maturity scenario	***late***	***early***	***late***	***early***	***late***	***early***
Run time	39 min	34 min	7 min	21 min	15 min	9 min
Total negative log-likelihood	6850.37	6850.57	7004.53	7004.85	6672.16	6669.16
Catch	2.35E-11	2.35E-11	7.29E-11	7.32E-11	1.66E-11	1.65E-11
Equil_catch	4.26219	4.01917	0.01716	0.015894	0.004417	0.004084
Survey	671.205	670.929	677.745	677.175	485.128	484.549
Length_comp	4.29E+03	4.29E+03	4434.66	4435.33	4312.5	4311.99
Age_comp	1873.29	1873.72	1885.79	1886.35	1869.93	1869.58
Recruitment	1.05E+01	1.03E+01	5.26472	4.92631	3.58862	2.03592
InitEQ_Regime	0	0	0	0	0	0
Forecast_Recruitment	0	0	0	0	0	0
Parm_priors	0.487353	0.4872	0.463245	0.46176	0.513135	0.510209
Parm_softbounds	0.021162	0.021205	0.010956	0.011599	0.023137	0.02299
Parm_devs	0.565872	0.566744	0.579149	0.580297	0.464682	0.464693
Crash_Pen	0	0	0	0	0	0
Parameter that hit bound	0	0	0	0	0	0
The number of estimated parameter	125	125	125	125	146	146
Akaike Information Criteria (AIC)	13950.74	13951.14	14259.06	14259.7	13636.32	13630.32

Table 6. Benchmarks and relative stock status for the final models with 80% confidence intervals, continuity and prototype runs for late and early maturity scenarios.

Item	*maturity schedule*	*2020 Base*	*2021 Continuity*	*2021 Prototype*	*2021 Final model*		
		Value	*Value*	*Value*	*Value*	*80LCI***	*80UCI***
SSB Unfished	late	181690	183210	164990	230876	218802	242950
	early	224062	224181	204428	282480	267806	297154
Total Biomass Unfished	late	227902	226925	207057	284044	269217	298871
	early	224062	228987	209005	288594	194021	303578
Recruitment (age0) Unfished (1000s)	late	591	594	532	760	720	801
	early	594	599	537	773	732	814
F_{cur}*	late	0.076	0.085	0.092	0.063	0.060	0.067
	early	0.076	0.085	0.091	0.062	0.059	0.066
	average	0.076	0.085	0.091	0.063	0.059	0.067
$F_{0.1}$	late	0.091	0.083	0.082	0.118	0.113	0.122
	early	0.091	0.083	0.082	0.118	0.113	0.123
	average	0.091	0.083	0.082	0.118	0.113	0.123
$F_{cur}/F_{0.1}$	late	0.831	1.025	1.119	0.538	0.508	0.570
	early	0.831	1.024	1.116	0.529	0.500	0.564
	average	0.831	1.024	1.117	0.534	0.500	0.570
$F_{2020}/F_{0.1}$	late	-	1.020	1.129	0.530	0.474	0.589
	early	-	1.019	1.125	0.520	0.467	0.575
	average	-	1.019	1.127	0.525	0.467	0.589

* Average fishing mortality in the most recent 3 years: 2018 -2020 for the 2021 models, and 2016-2018 for the 2020 Base case.
** Confidence intervals for each maturity scenario were determined by the multivariate lognormal approximation approach.

Table 7. The allocated catch by Fleet in Stock Synthesis model in the short-term projection by TAC (2000 – 5000 t).

	TAC															
Fleet	2000	2100	2200	2300	2350	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300	3400
JAPAN_LL # 1	346	363	381	399	407	416	473	573	658	683	708	732	757	782	807	831
OTHER_ATL_LL # 2	192	199	207	215	219	223	227	227	227	234	241	248	255	263	270	277
GOM_US_MEX_LL # 3	116	122	128	134	137	140	143	143	156	162	168	174	180	186	191	197
JPNLL_GOM # 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
USA_CAN_PSFS # 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
USA_CAN_PSFB # 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
USA_TRAP # 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CAN_TRAP # 8	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4
USA_CAN_HARPOON (op1)	103	109	114	119	122	125	127	127	127	132	137	142	147	151	156	161
USA_RRFS # 11	150	158	166	173	177	181	185	185	185	192	199	206	213	220	227	234
USA_RRFB # 12	762	801	840	879	898	918	938	938	939	975	1,010	1,045	1,081	1,116	1,151	1,187
CAN_SWNS_HLnoHP # 14 (op1)	76	80	84	88	90	91	94	94	93	97	100	104	108	111	115	118
CAN_GSL_HL # 16	252	264	277	290	296	303	310	310	310	321	333	344	356	368	379	391
CAN_acoustic_GSL # 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	TAC															
Fleet	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500	4600	4700	4800	4900	5000
JAPAN_LL # 1	856	881	905	930	955	980	1,004	1,029	1,054	1,079	1,103	1,128	1,153	1,178	1,202	1,227
OTHER_ATL_LL # 2	284	291	298	305	312	319	326	334	341	348	355	362	369	376	383	390
GOM_US_MEX_LL # 3	203	209	215	220	226	232	238	244	250	255	261	267	273	279	284	290
JPNLL_GOM # 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
USA_CAN_PSFS # 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
USA_CAN_PSFB # 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
USA_TRAP # 7	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
CAN_TRAP # 8	4	4	4	4	5	5	5	5	5	5	5	5	6	6	6	6
USA_CAN_HARPOON (op1)	166	170	175	180	185	190	194	199	204	209	214	218	223	228	233	238
USA_RRFS # 11	241	248	255	262	269	276	283	290	297	304	311	318	324	331	338	345
USA_RRFB # 12	1,222	1,257	1,292	1,328	1,363	1,398	1,434	1,469	1,504	1,540	1,575	1,610	1,646	1,681	1,716	1,752
CAN_SWNS_HLnoHP # 14 (op1)	122	125	129	132	136	139	143	146	150	153	157	160	164	167	171	174
CAN_GSL_HL # 16	403	414	426	438	449	461	472	484	496	507	519	531	542	554	566	577
CAN_acoustic_GSL # 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 8. Projected yield at $F_{0.1}$ for the period between 2022 and 2024 based on the 2020 base case, 2021 continuity run, 2021 prototype and the 2021 final model, using several assumptions on selectivity.

Models	maturity scenario	Yeild at F0.1 2022	2023	2024	Slectivity for calculation the F0.1
2020 Base Case	late	1761.6	1669.28	1611.95	
2020 Base Case	early	1756.1	1663.77	1606.43	2016-2018
2020 Base Case	average	1758.85	1666.525	1609.19	
2021 continuity	late	2539.74	2480.69	2447.54	
2021 continuity	early	2540.69	2481.39	2448.16	2018-2020
2021 continuity	average	2540.215	2481.04	2447.85	
2021 prototype	late	2461.87	2502.74	2604.21	
2021 prototype	early	2465.87	2505.94	2606.09	2005-2008
2021 prototype	average	2463.87	2504.34	2605.15	
2021 Final model	late	3797.04	3765.91	3812.32	
2021 Final model	early	3623	3599.37	3649.17	2005-2008
2021 Final model	average	3710.02	3682.64	3730.745	
2021 prototype	late	2514.2	2455.03	2511.13	
2021 prototype	early	2520.28	2461.11	2516.12	2018-2020
2021 prototype	average	2517.24	2458.07	2513.625	
2021 Final model	late	4036.97	3792.36	3750.54	
2021 Final model	early	3855.16	3632.61	3599.3	2018-2020
2021 Final model	average	3946.065	3712.485	3674.92	

Table 9. Comparisons of projected yield at $F_{0.1}$ for the period between 2022 and 2024 among models.

Effects	Comparisons: Model and selectivity		Model and selectivity		Year 2022	2023	2024
Change due to additional year (2020)	2020 Base Case	2016-2018	2021 continuity	2018-2020	144%	149%	152%
Change due to new Indices	2021 prototype*	2018-2020	2021 continuity	2018-2020	99%	99%	103%
Change due to new data and model assumptions	2021 Final model	2005-2008	2021 prototype*	2005-2008	151%	147%	143%
Change in selectivity impact due to F0.1	2021 Final model	2018-2020	2021 Final model	2005-2008	106%	101%	99%

*noted diagnostic issues with protoype

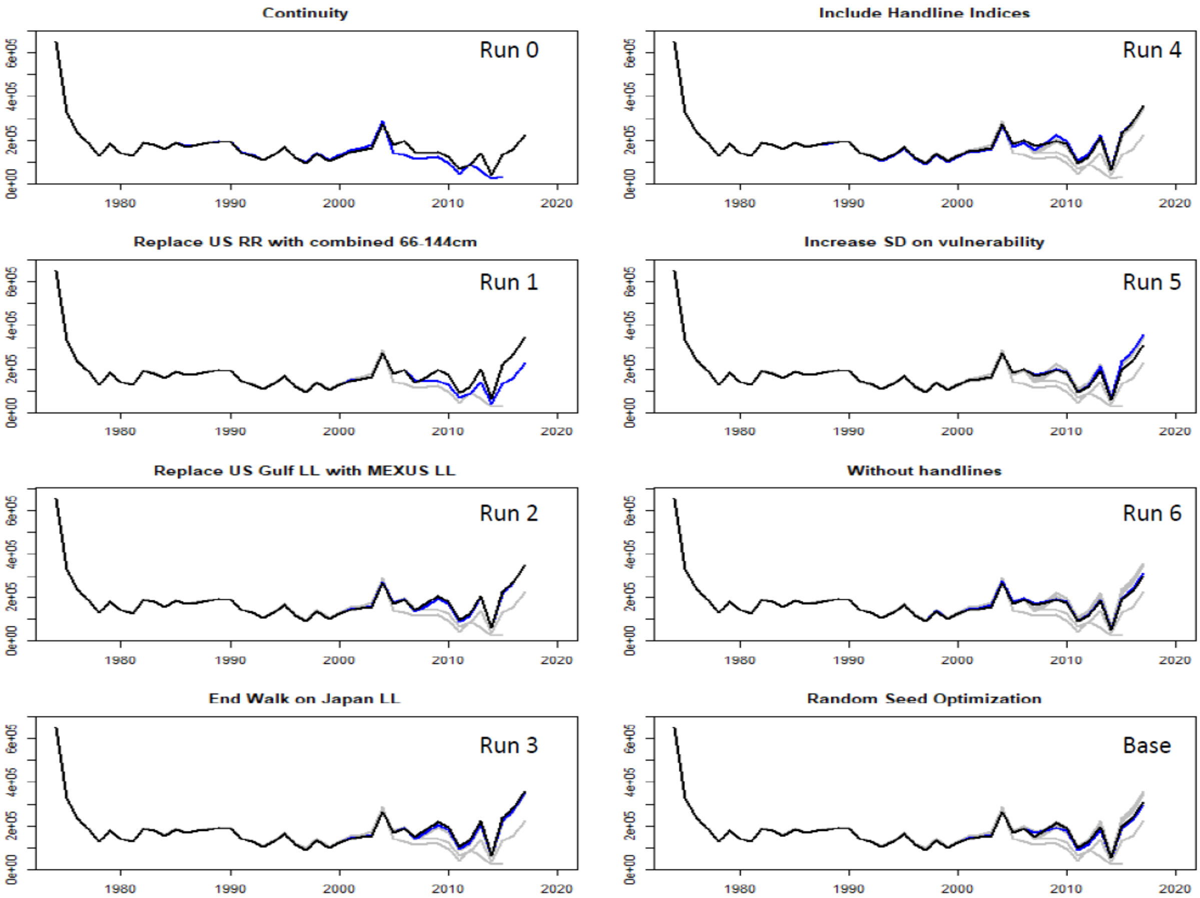


Figure 1. VPA. Estimates of bluefin tuna recruitment in the West Atlantic by stepwise model iteration (moving down by column in each step) from the continuity to the proposed base model. The black line shows the updated run in each step, the blue lines shows the run from the previous step, and the gray lines show all other prior runs.

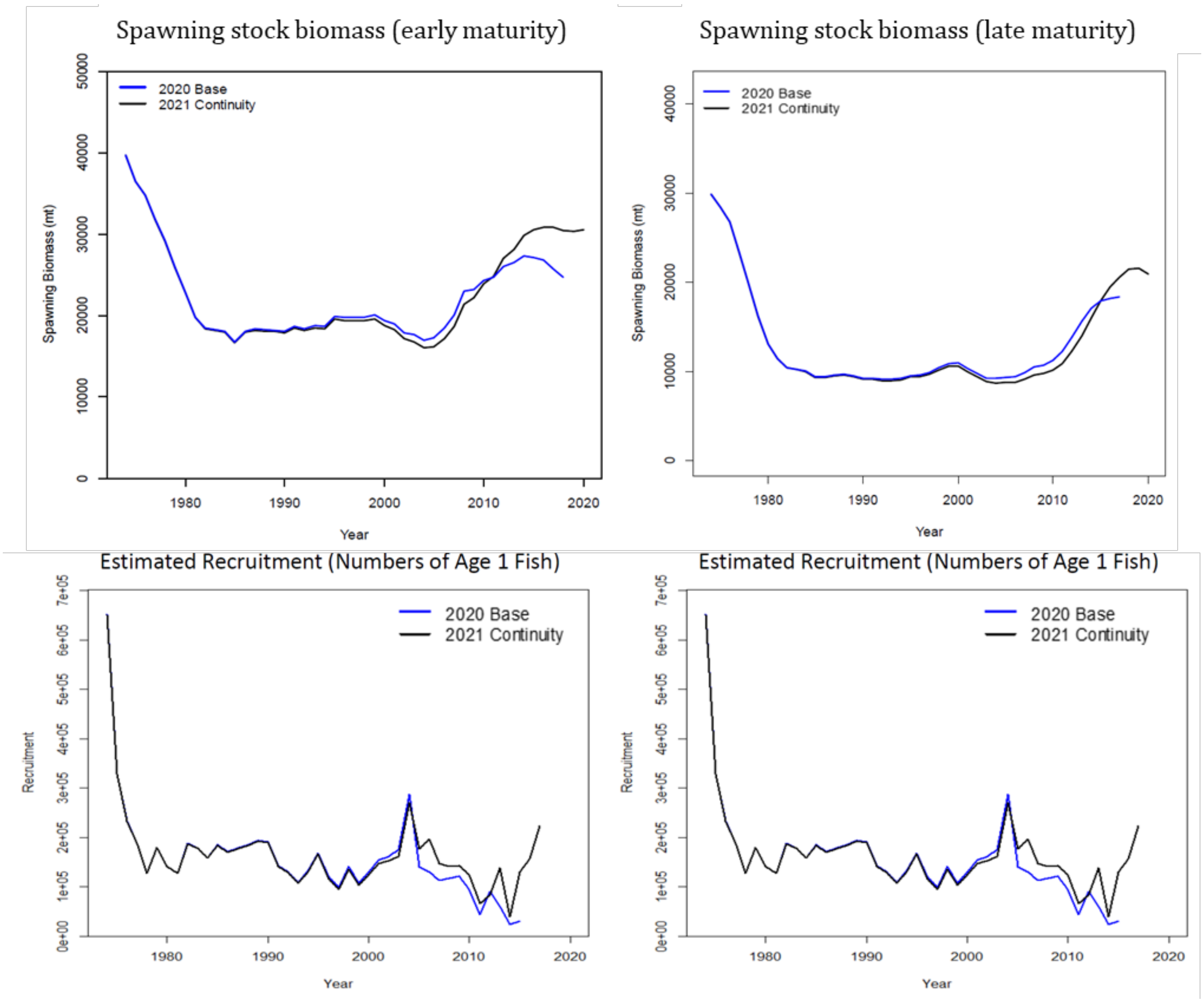


Figure 2. VPA Spawning stock biomass (upper panels) and recruitment estimates (age 1, lower panels) by the 2021 Continuity runs (black lines) for late (left panels) and early maturity (right panels) scenarios of bluefin tuna in the West Atlantic compared to the 2020 assessment (blue lines)

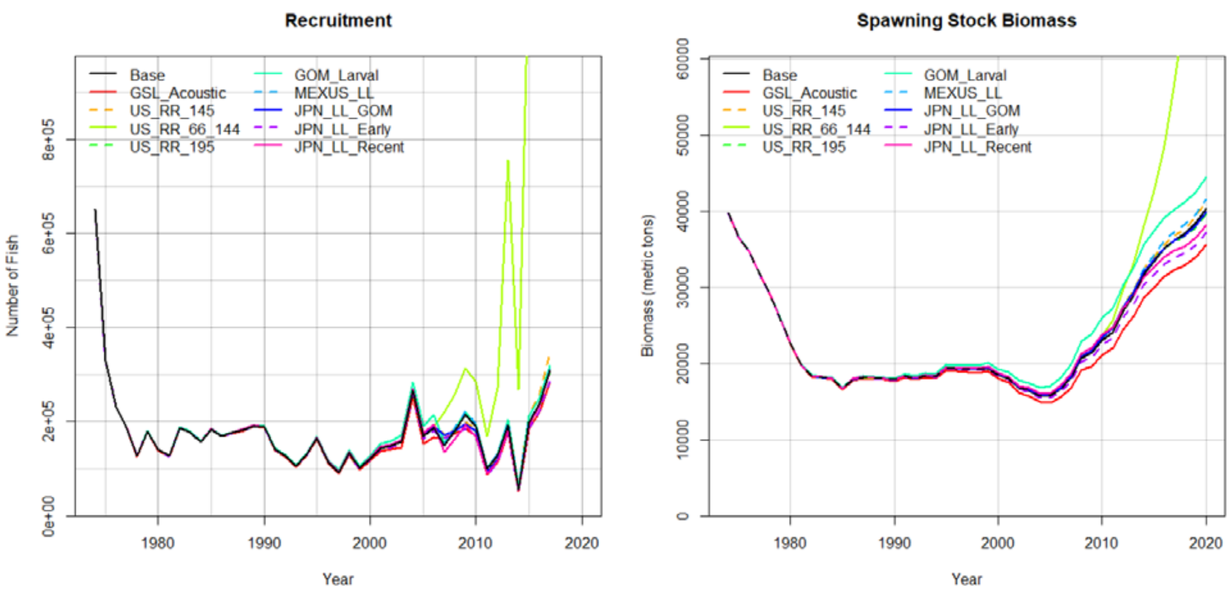


Figure 3. VPA. Index jackknife effects on estimates of bluefin tuna in the West Atlantic by the 2021 base case. Recruitment (left panel) and spawning stock biomass (right panel, early maturity scenario).

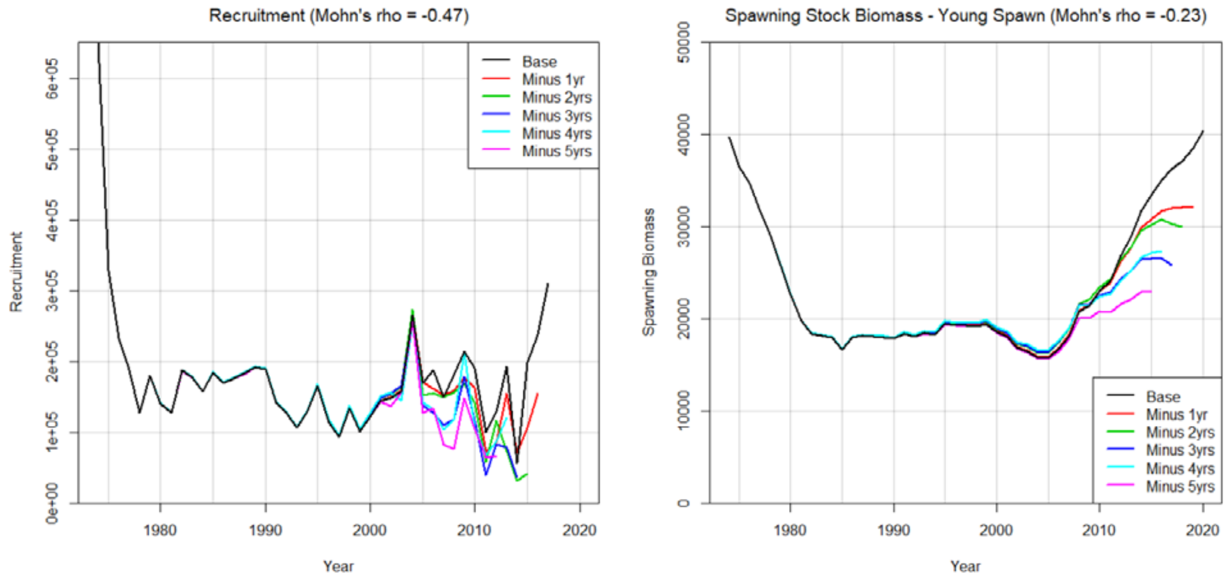


Figure 4. VPA. Retrospective estimates of bluefin tuna in the West Atlantic by the 2021 base case. Recruitment (left panel) and spawning stock biomass (early maturity scenario, right panel).

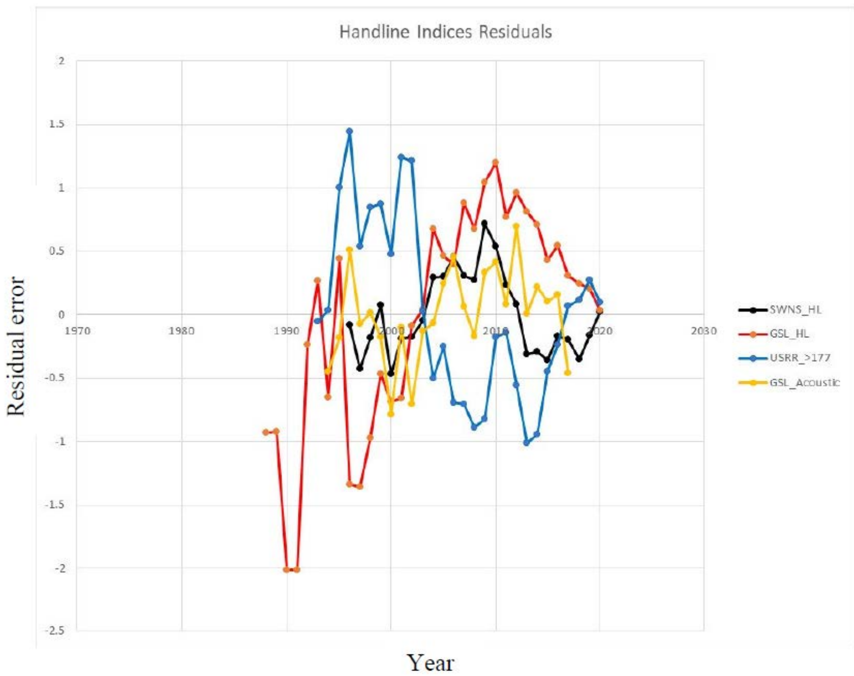


Figure 5. VPA. Residual error to handline (Canada GSL, Canada SWNS, and US RR>177cm) indices and the GSL acoustic index.

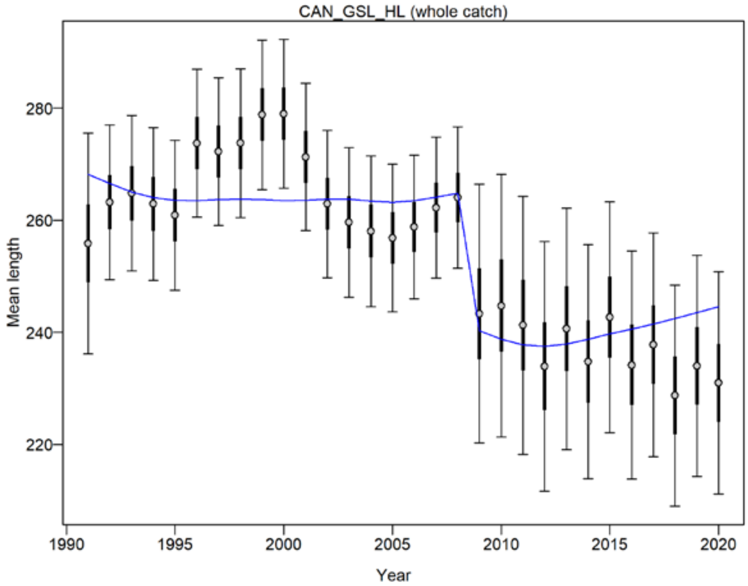


Figure 6 Stock Synthesis. Observed length composition since 1990 by Canadian handline in the GSL, and estimated mean length (blue line) in the model.

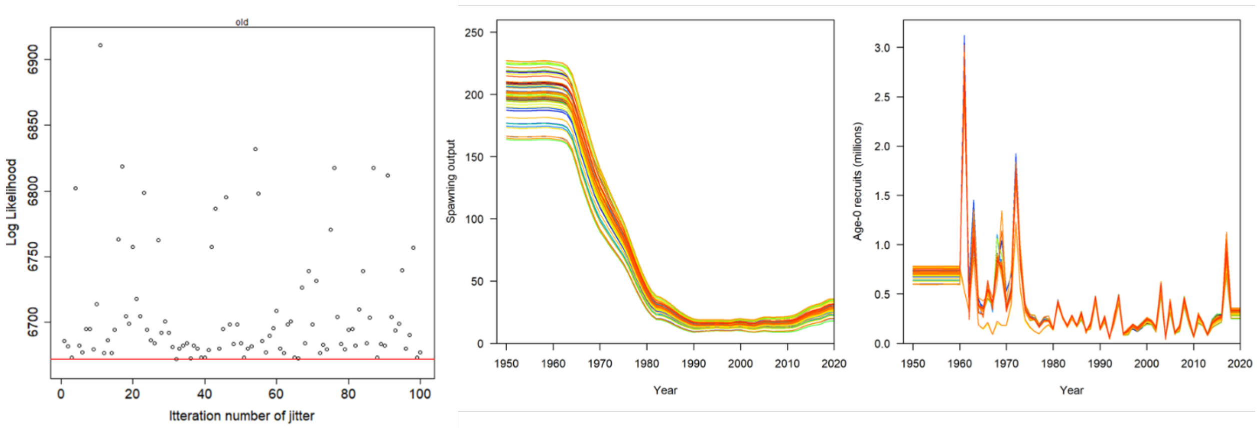


Figure 7. Results of log-likelihood (Left), SSB (center), and recruitment (age0, Right) by the jitter analysis for the final models for late maturity scenario.

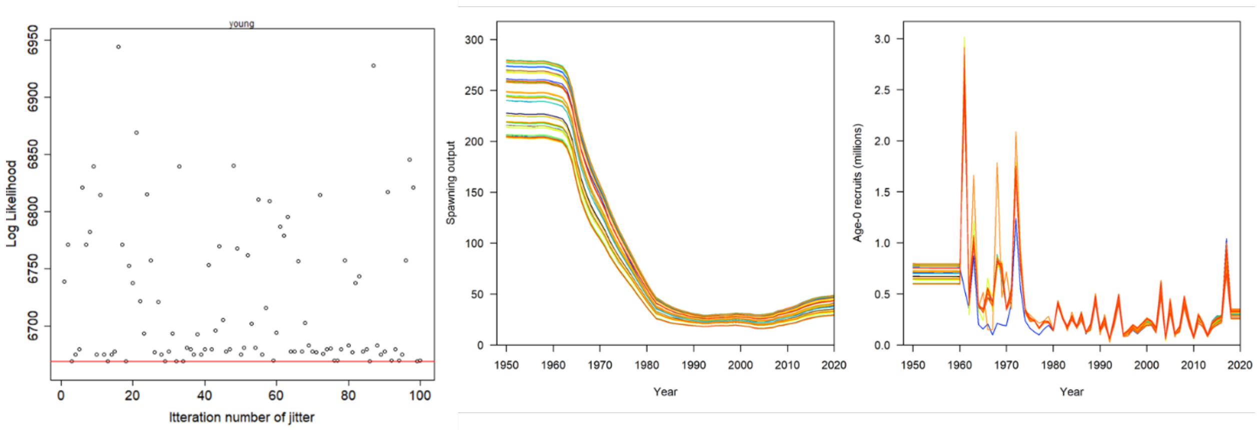


Figure 8. Results of log-likelihood (Left), SSB (center), and recruitment (age0, Right) by the jitter analysis for the final models for early maturity scenario.

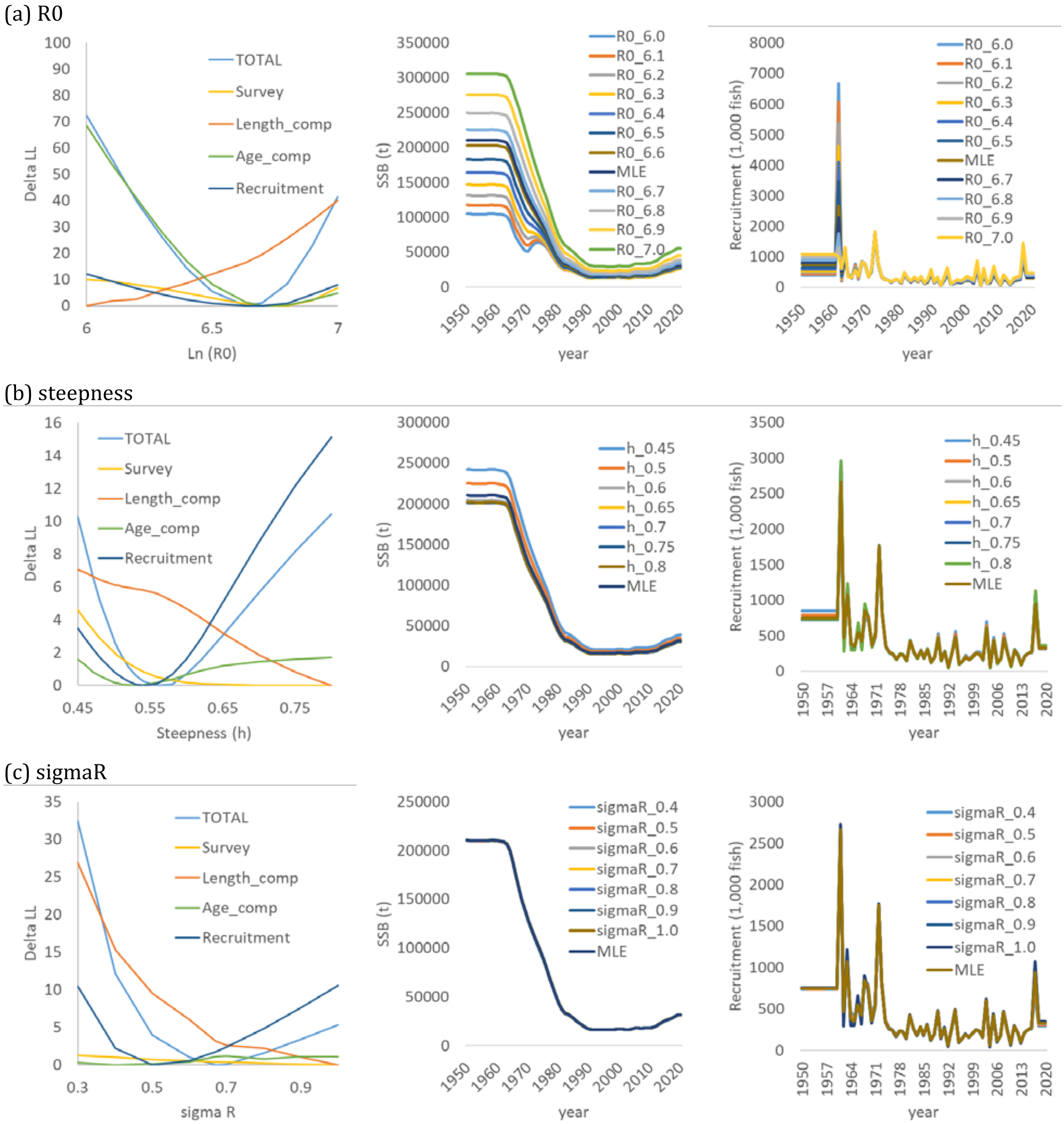


Figure 9. Likelihood profiles (Left) by (a) R0, (b) steepness and (c) sigmaR and resulting SSB (Center) and recruitment (Right) trends for the final model for late maturity scenario.

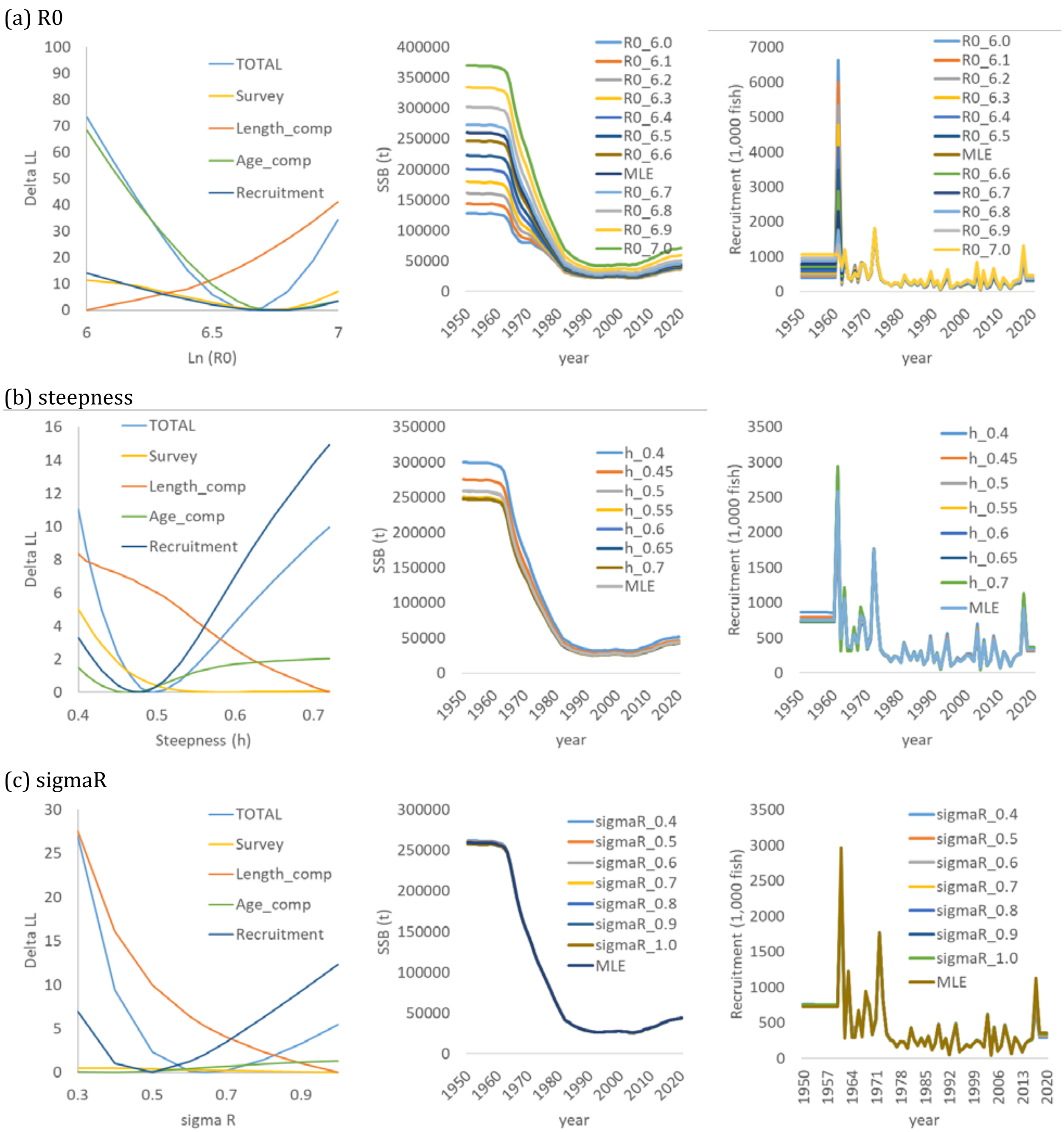


Figure 10. Likelihood profiles (Left) by (a) R0, (b) steepness and (c) sigmaR and resulting SSB (Center) and recruitment (Right) trends for the final model for early maturity scenario.

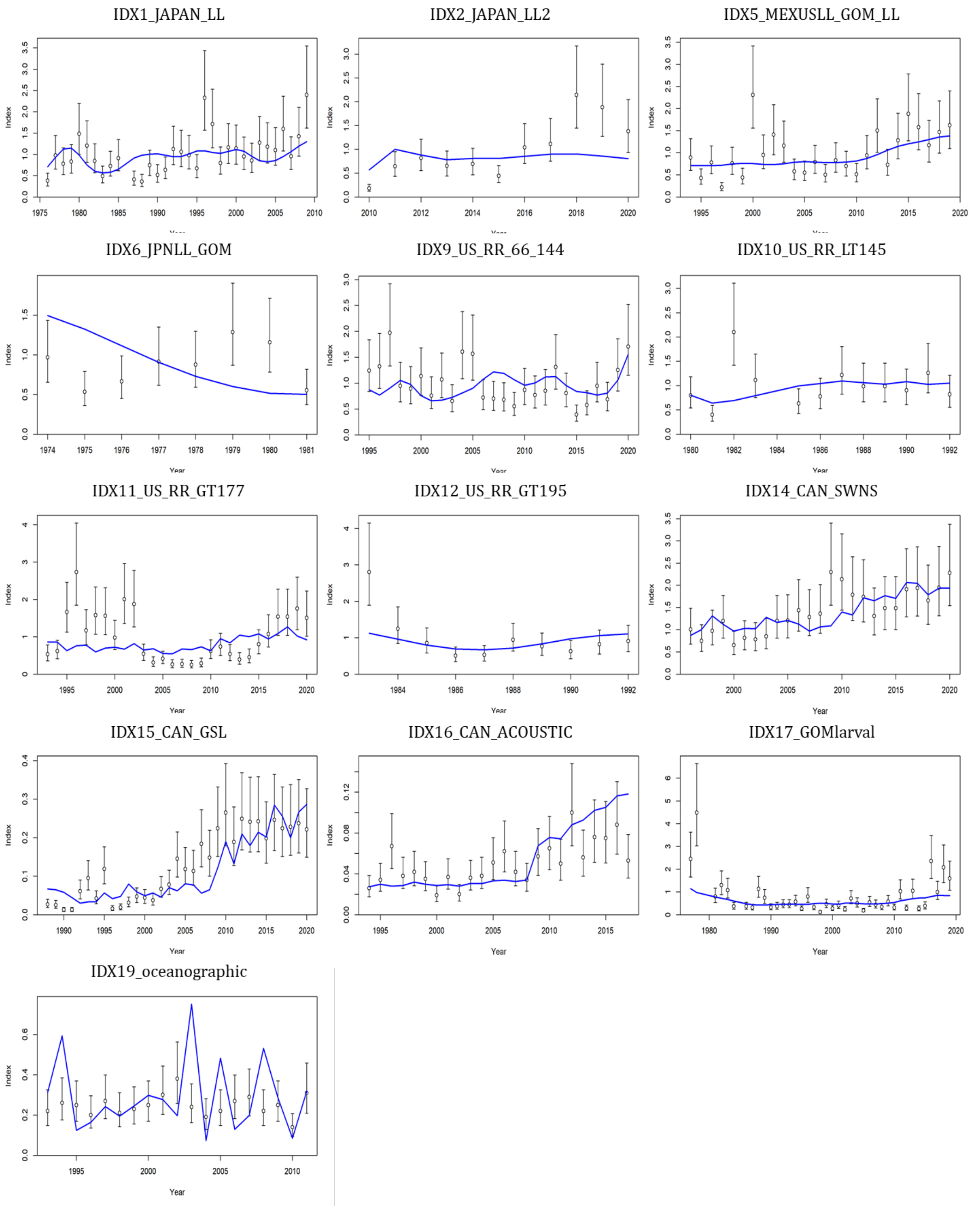


Figure 11. Fits to each CPUE index for the final model for late maturity scenario.

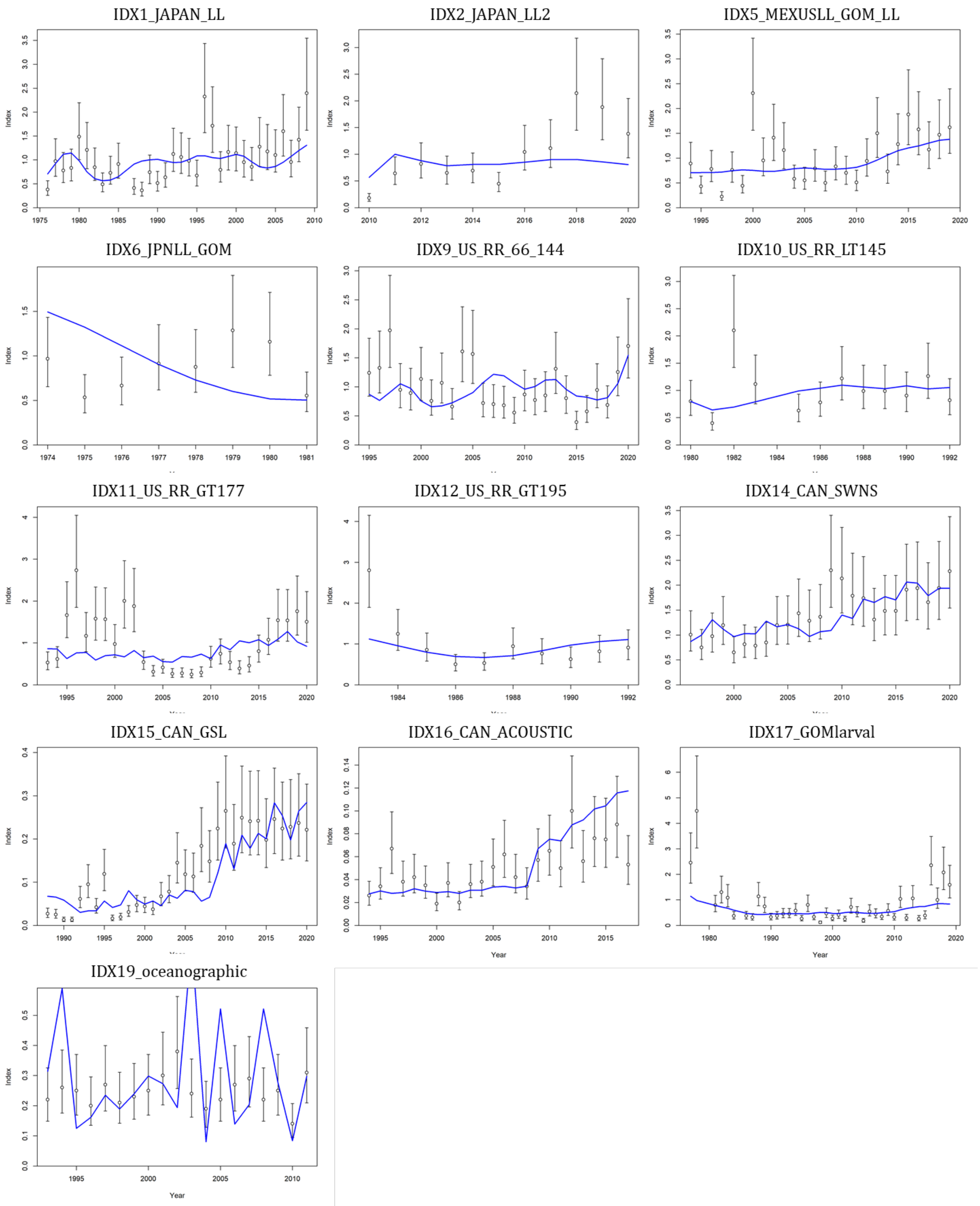


Figure 12. Fits to each CPUE index for the final model for early maturity scenario.

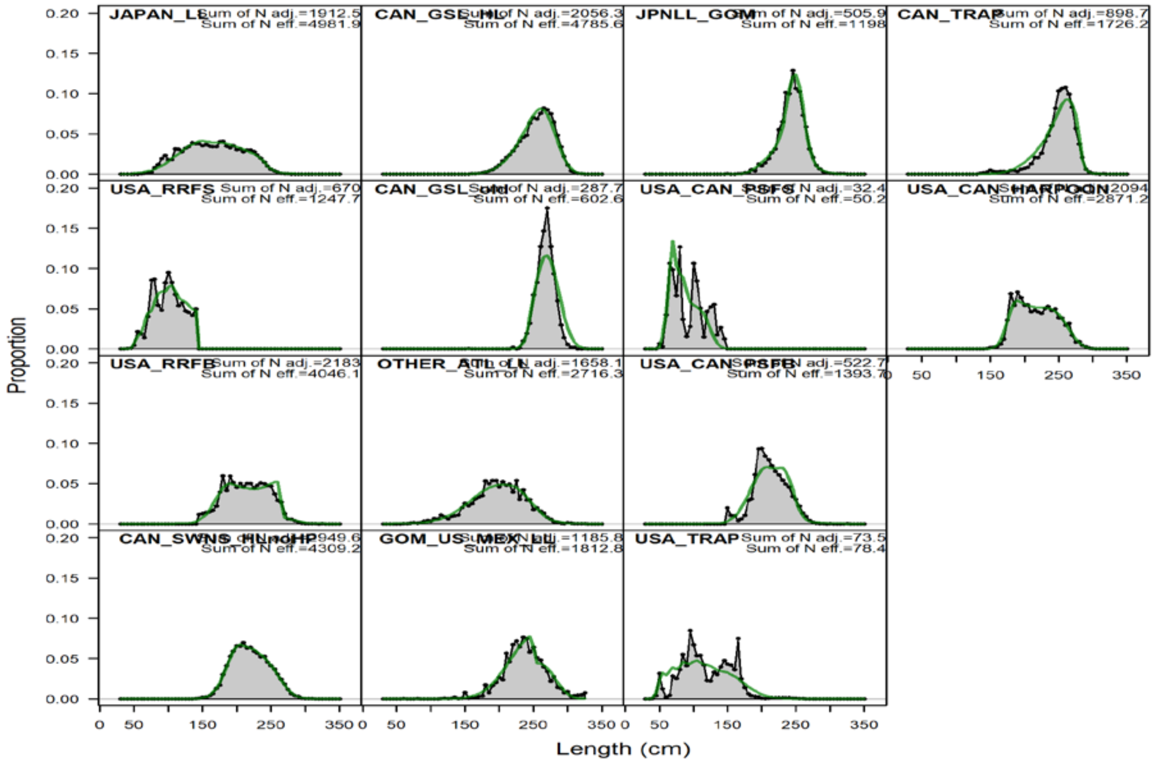


Figure 13. Fits to length composition data over all years for the final model for late maturity scenario.

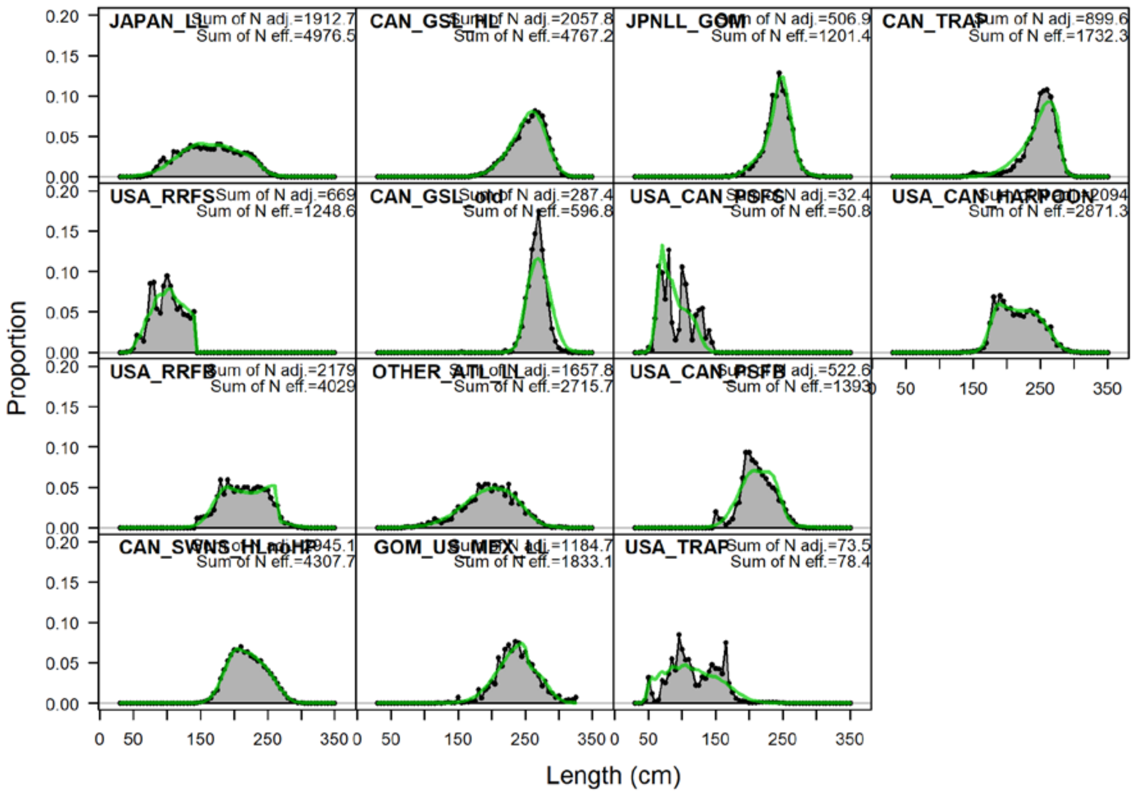


Figure 14. Fits to length composition data over all years for the final model for early maturity scenario.

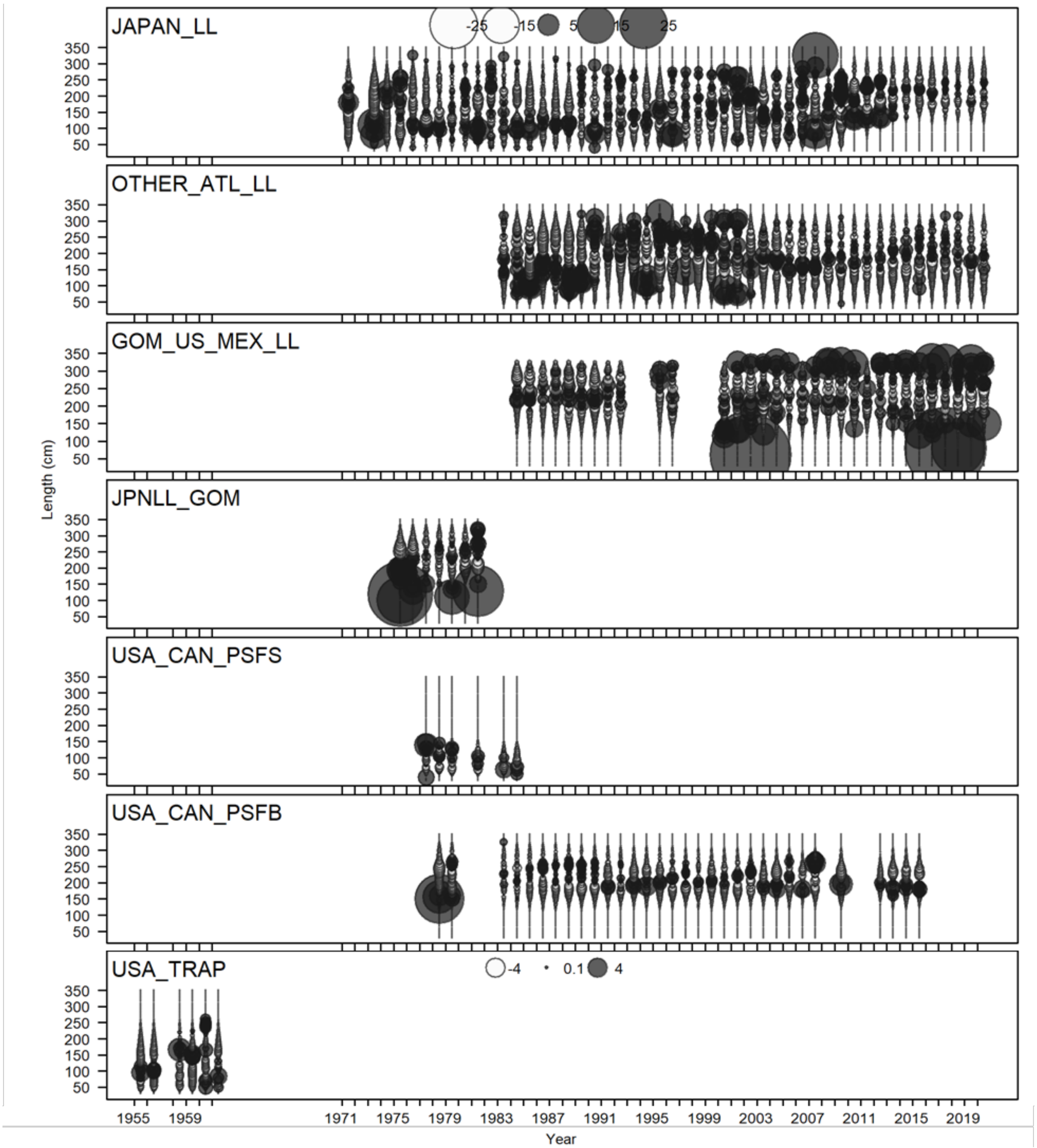


Figure 15. Time series of Pearson residuals on the length composition data by fleets for the final model for late maturity scenario.

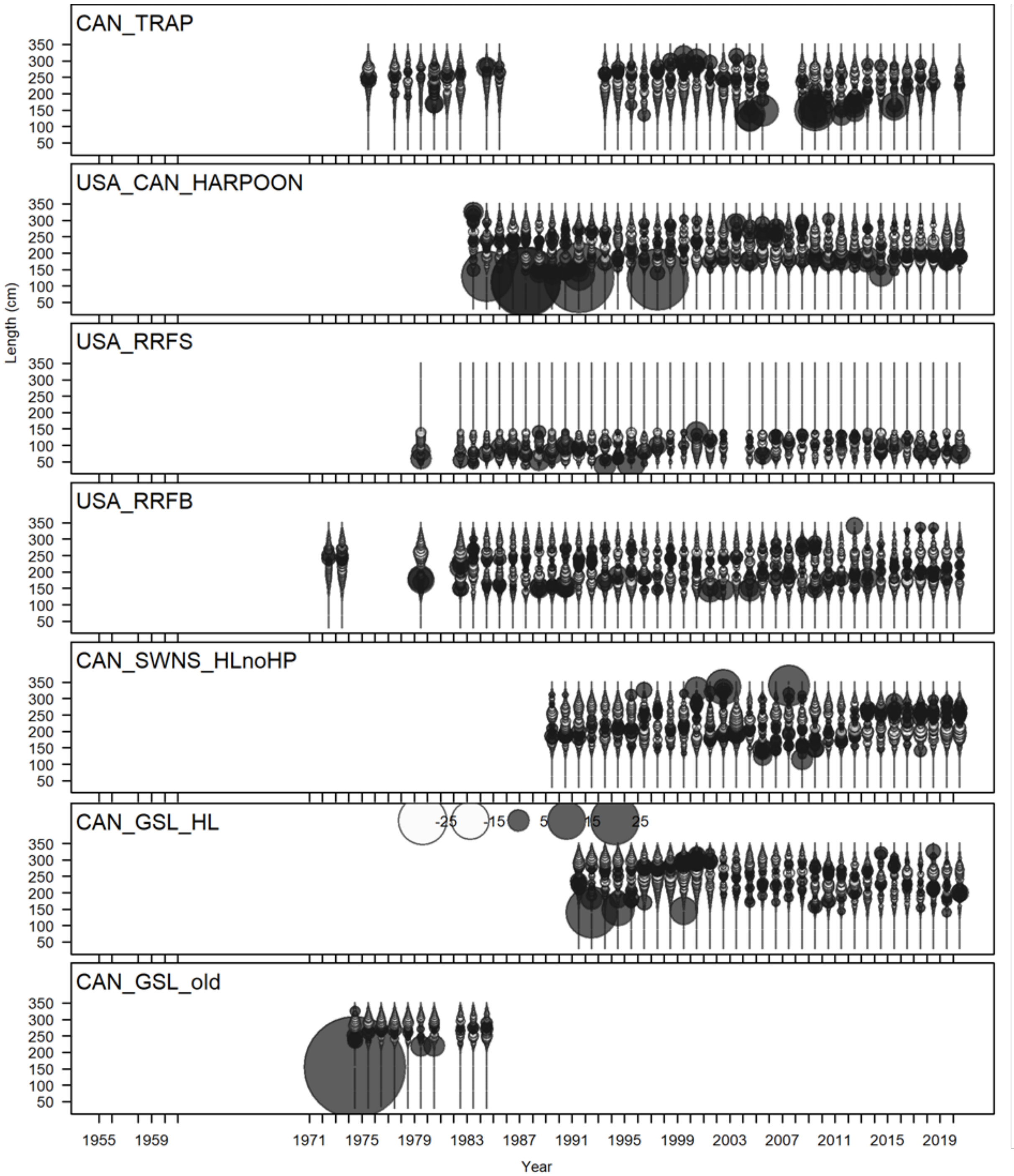


Figure 15. Continued.

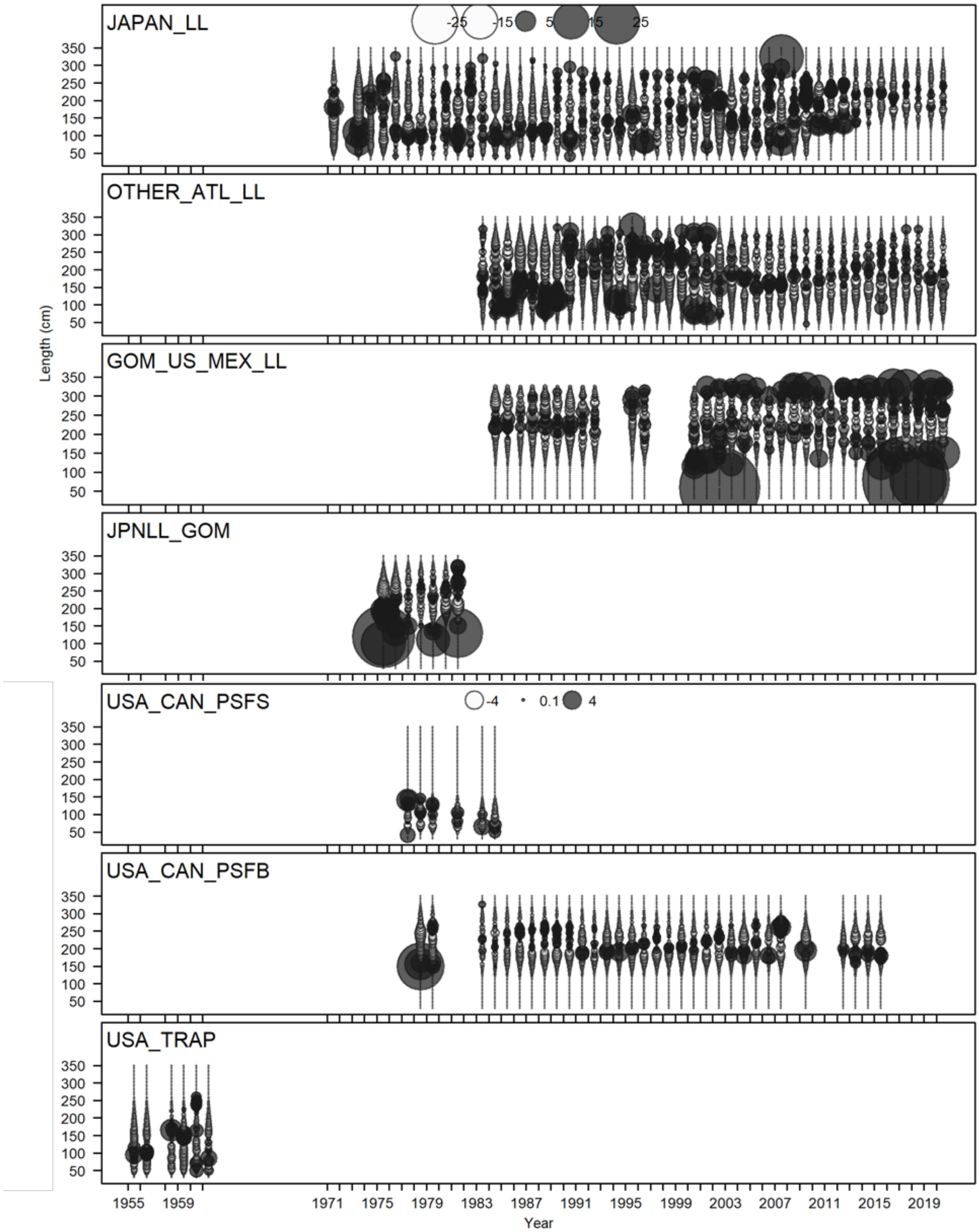


Figure 16. Time series of Pearson residuals on the length composition data by fleets for the final model for early maturity scenario.

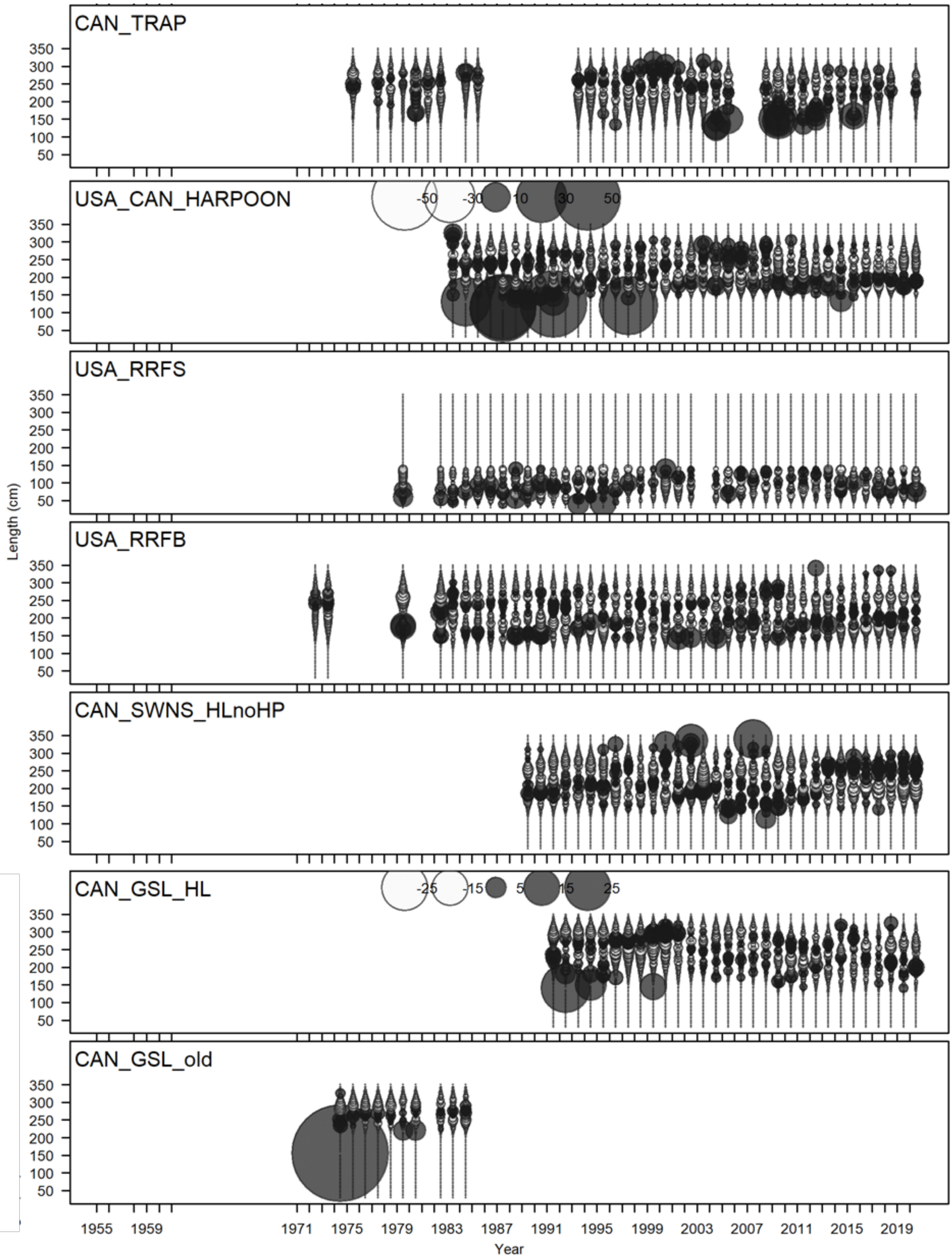
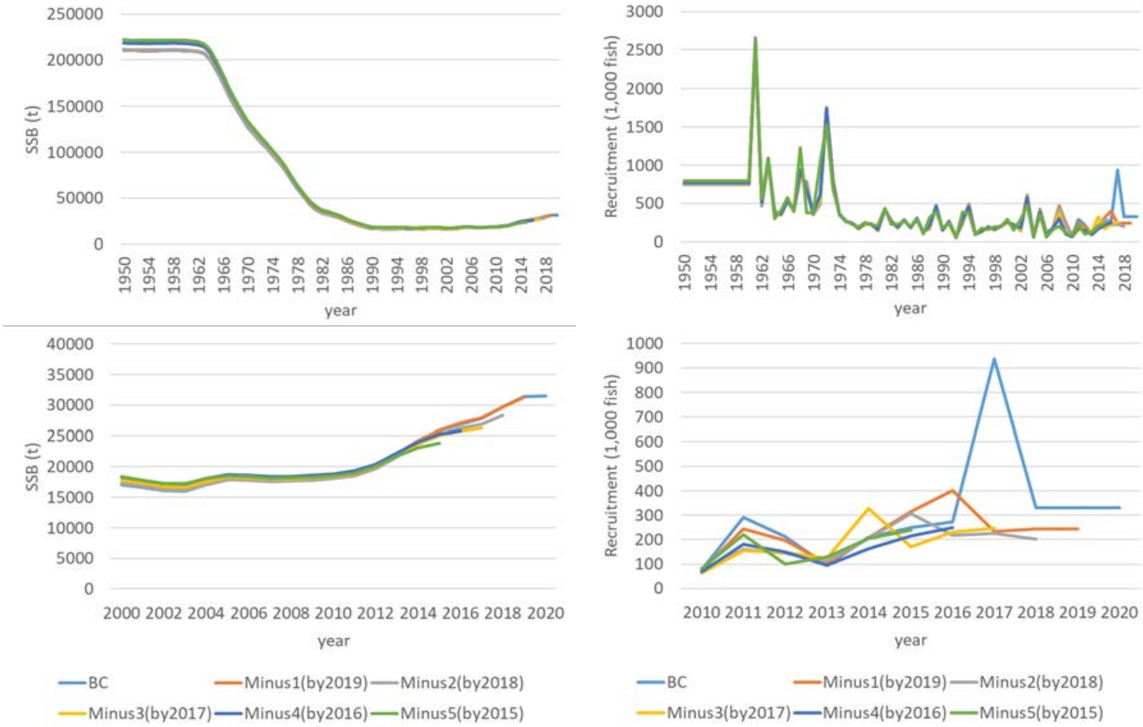


Figure 16. Continued.

(a) late maturity scenario



(b) early maturity scenario

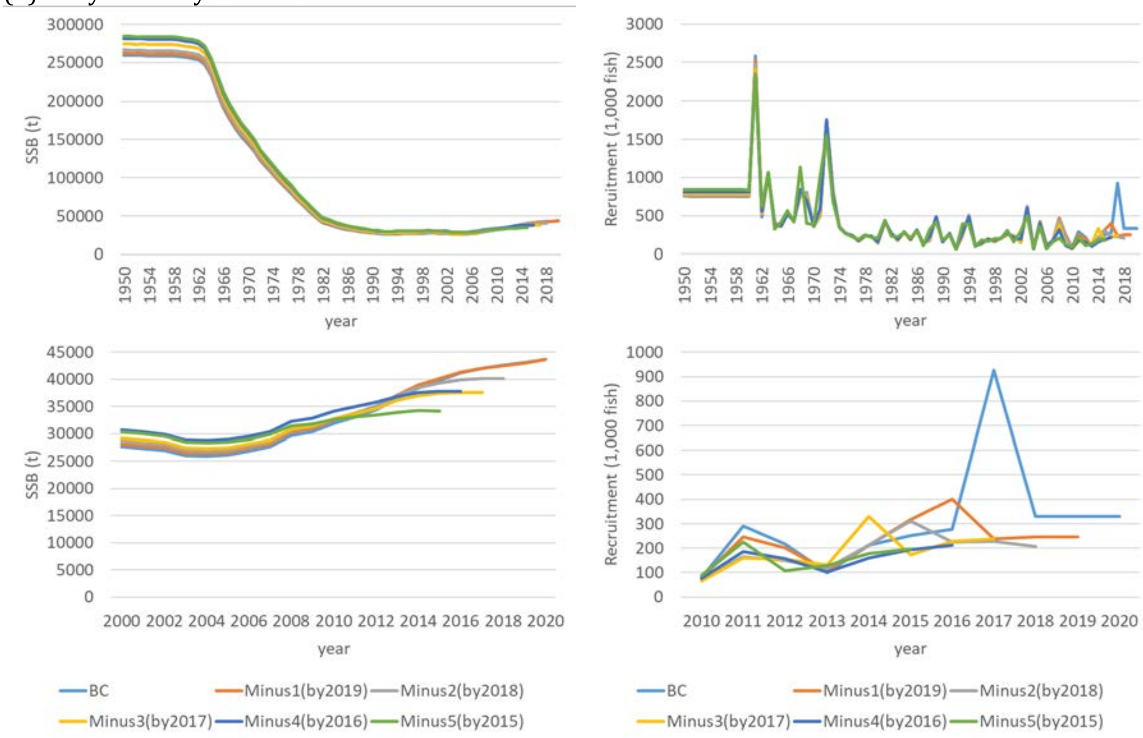
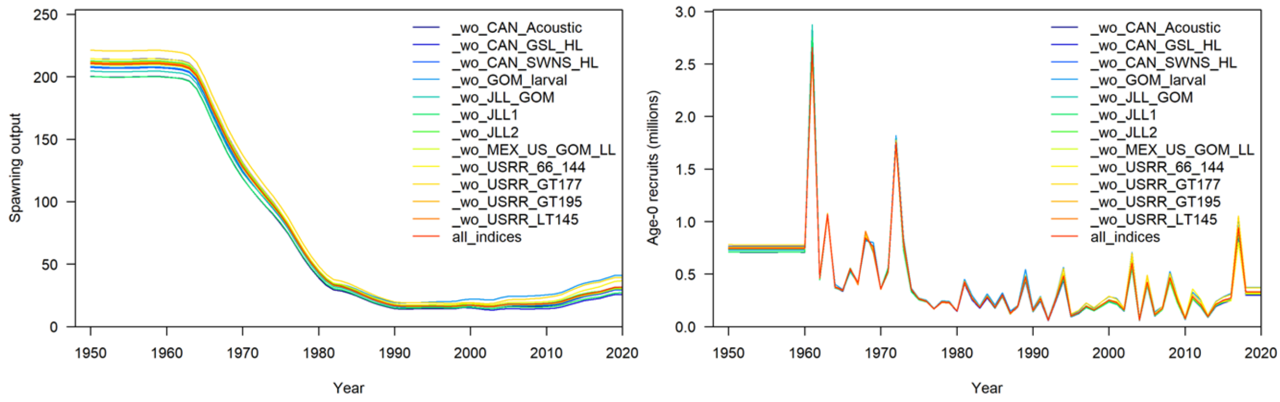


Figure 17. Retrospective plots of SSB (t) and recruitment (age 0, thousand fish) trends for the final models for (a) late and (b) early maturity scenarios. Upper panels are for the whole assessment period between 1950 and 2020, and lower panels show the period after 2000.

(a) late maturity



(b) early maturity

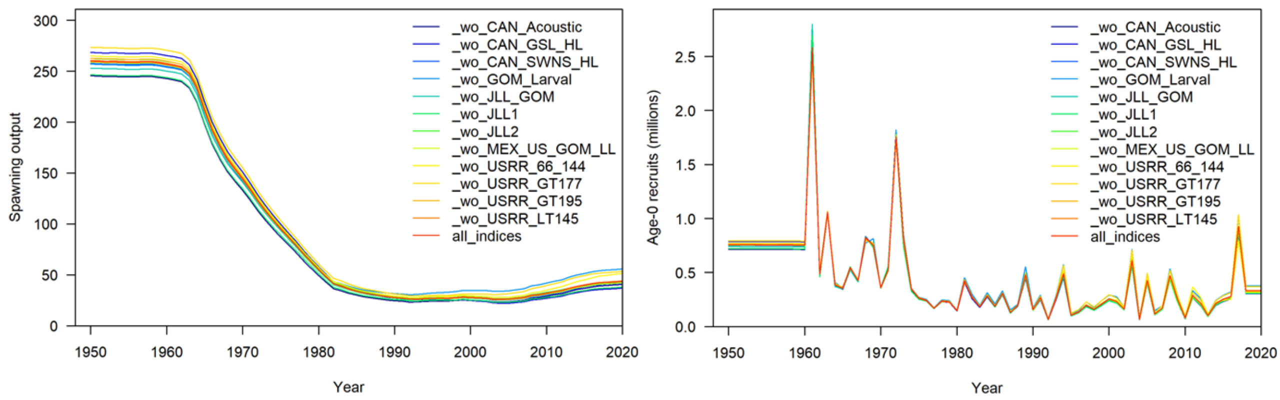
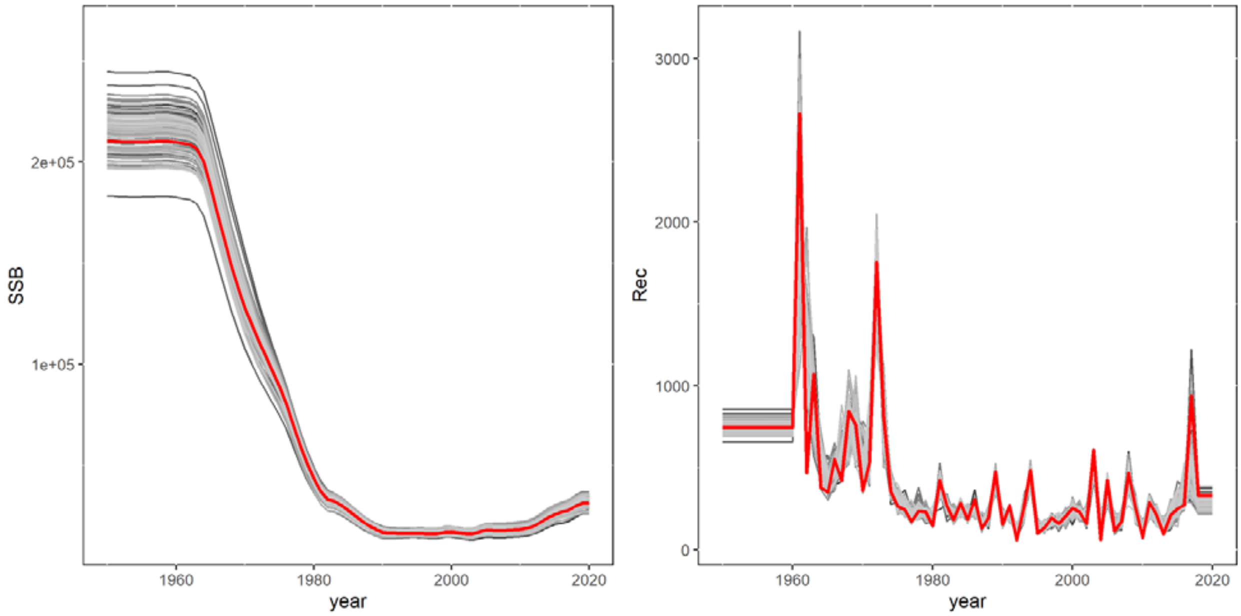


Figure 18. SSB (Left) and recruitment (age0, Right) by jackknife analysis regarding abundance indices for the final models for (a) late and (b) early maturity scenarios.

(a) late maturity



(b) early maturity

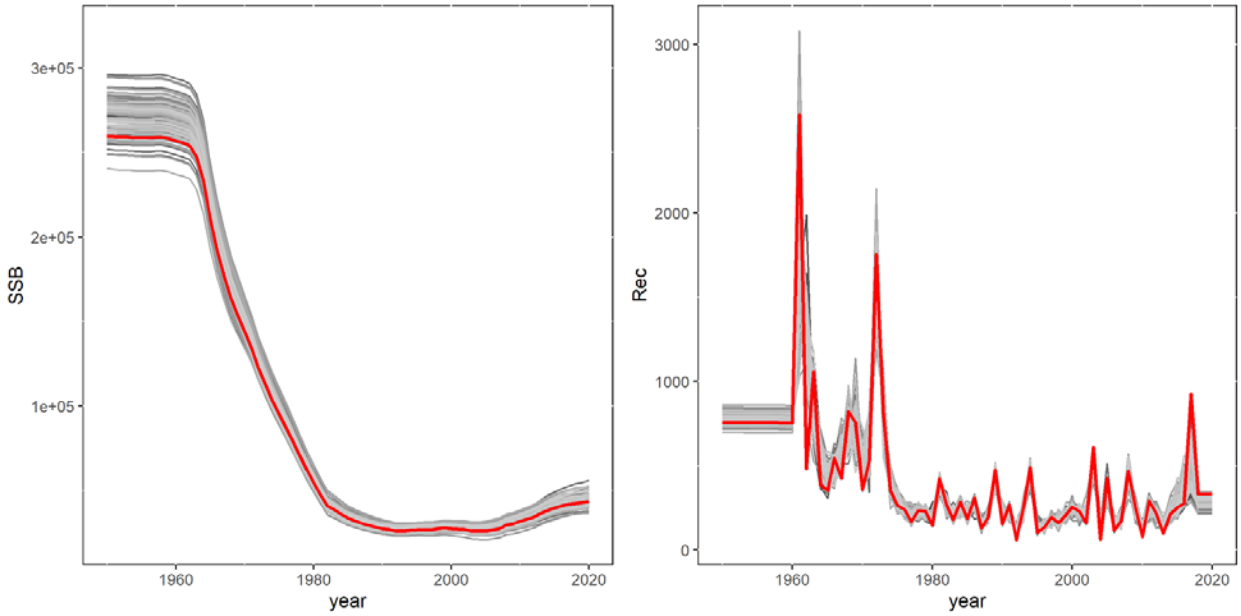


Figure 19. Results of SSB and recruitment trends came from original runs (red line) and 100 bootstrap replicates (gray line) for the final models for (a) late and (b) early maturity scenarios. (optional)

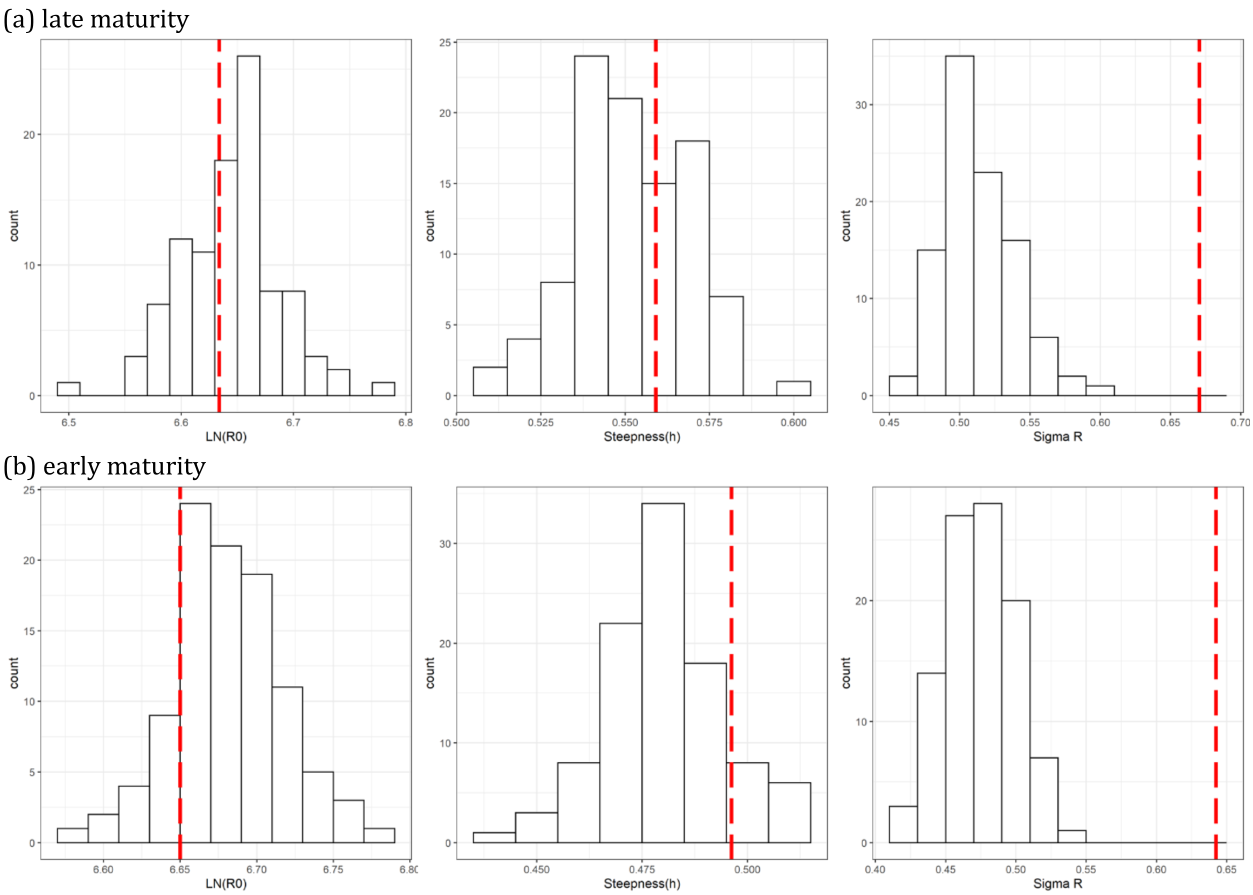


Figure 20. Results of the distribution of 3 parameter estimates related to Stock-Recruitment relationship came (optional) from 100 bootstraps replicates for the final models for (a) late and (b) early maturity scenarios, ln(R0) (left), steepness (middle) and sigmaR (Right). Red line shows the estimates in original run without data perturbation.

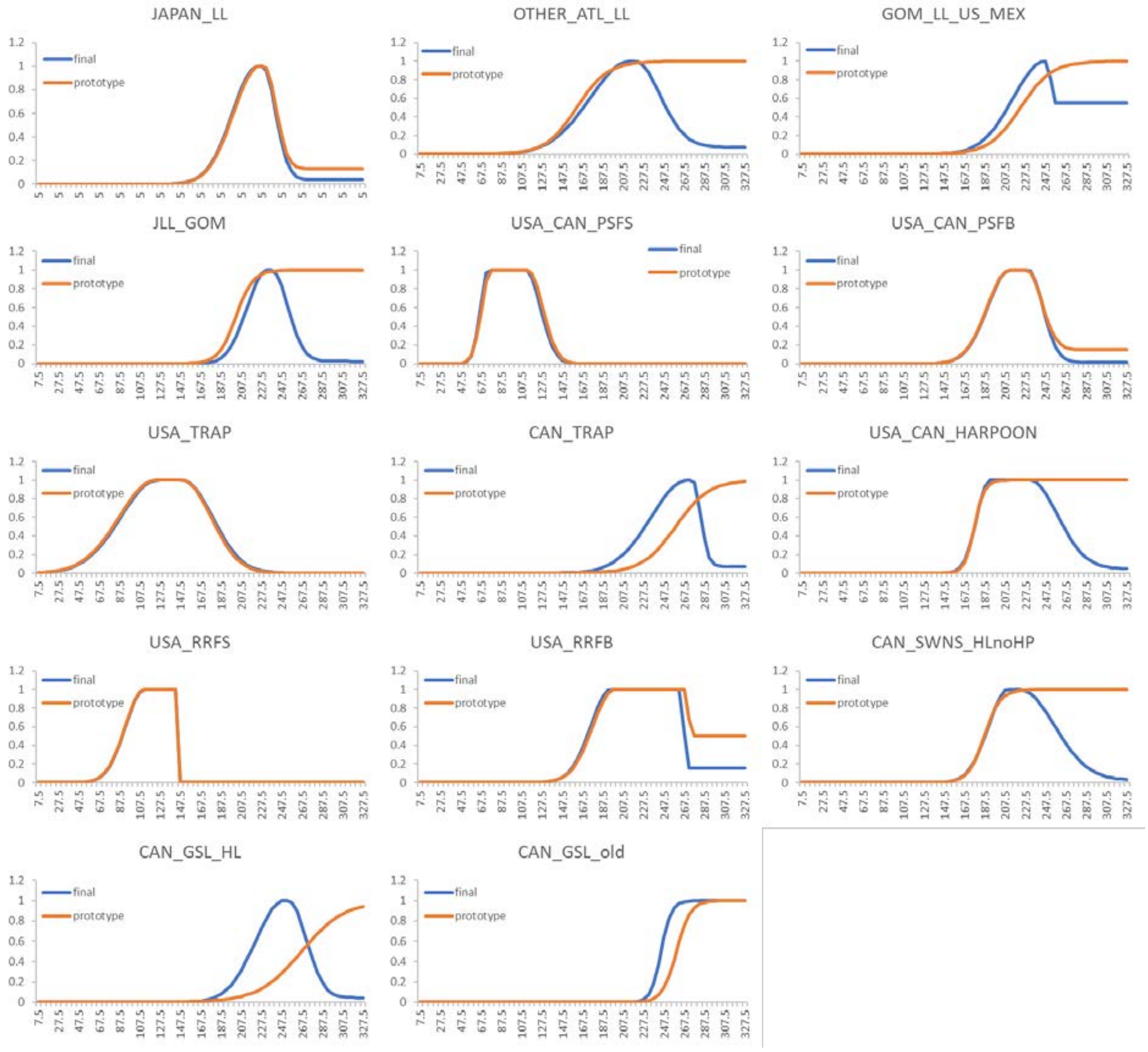


Figure 21. Estimated selectivity at end year by fleet for the final model for late maturity scenario.

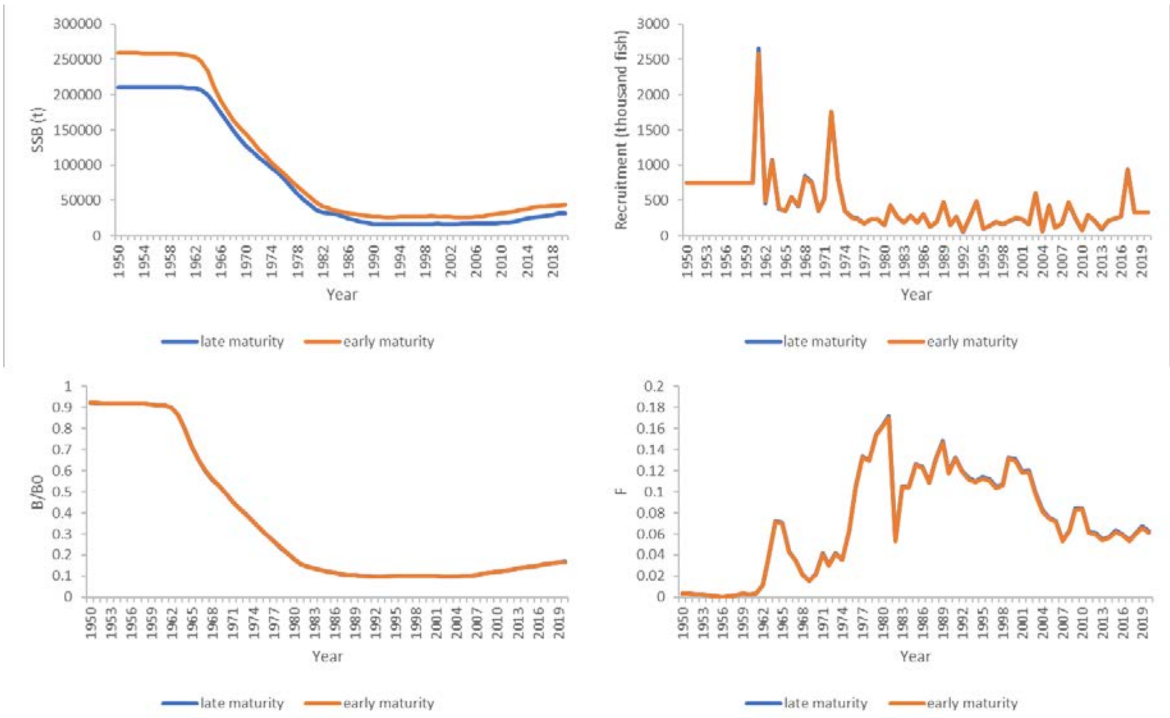


Figure 22. The comparison plots of time series of SSB (top left), recruitment (top right), biomass ratio to unfished levels (bottom left) and fishing mortality (bottom right) between the final models for late (blue) and early (orange) maturity scenarios.

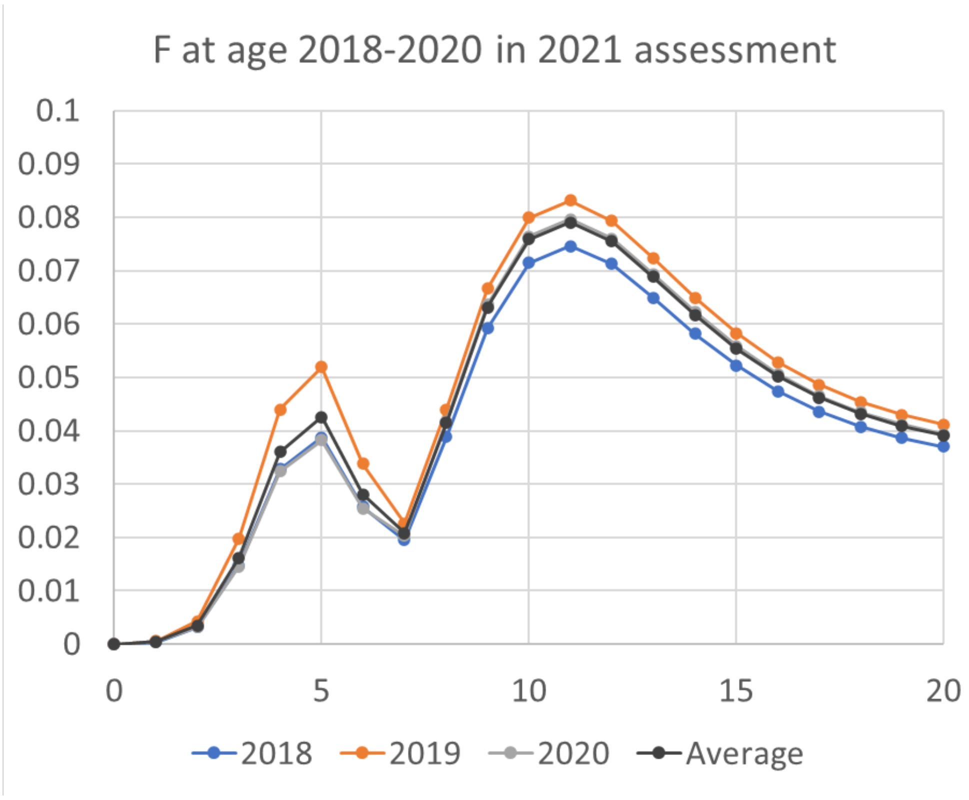


Figure 23. Estimated fishing mortality at age between 2018 and 2020, and its average (black line).

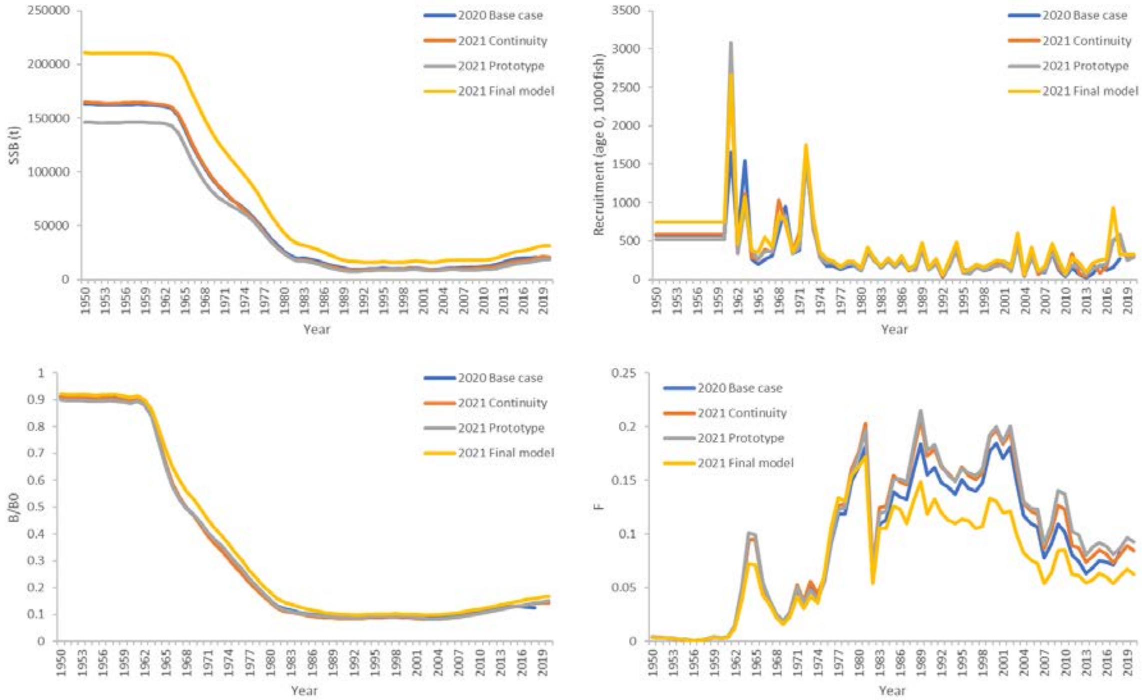


Figure 24. The comparison plot of time series of SSB (top left), recruitment (top right), biomass ratio to unfished levels (bottom left) and fishing mortality (bottom right) for the 2020 base case model, 2021 continuity run, 2021 prototype, and the 2021 final model for late maturity scenario.

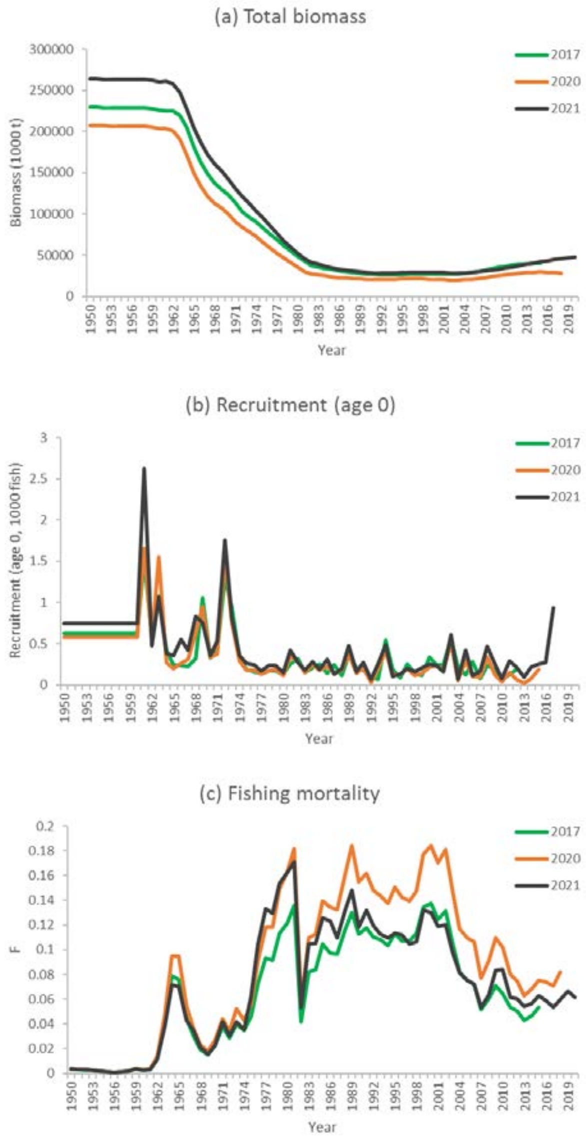
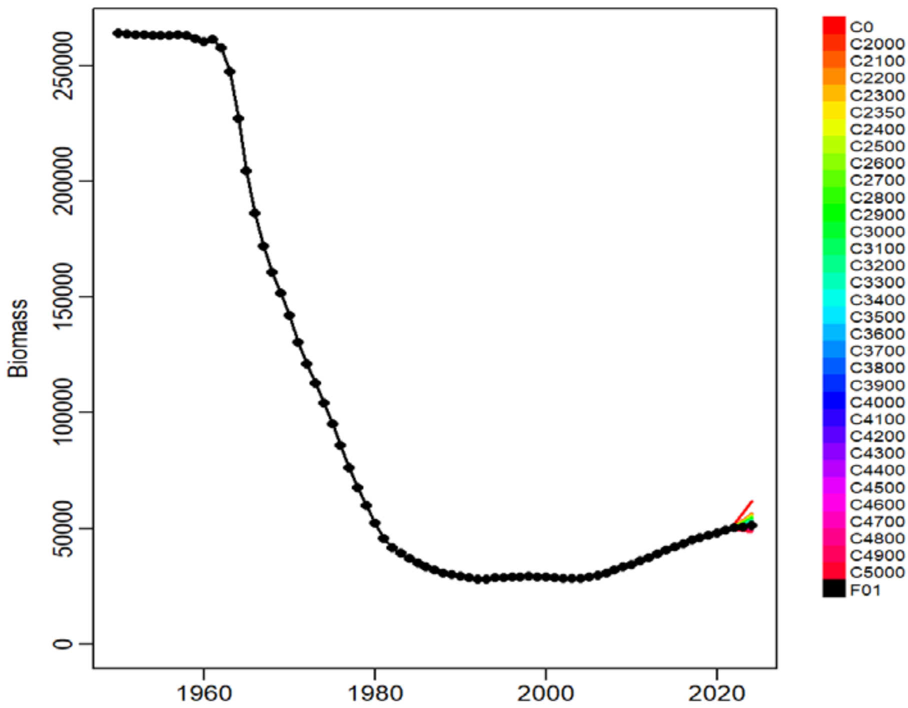


Figure 25. Comparisons of (a) total biomass, (b)recruitment, and (c) fishing mortality by Stock Synthesis among 2017 (green), 2020 (orange), and 2021 (black) stock assessments for West bluefin tuna. The combined results for both maturity scenarios are shown.
(a) 1950-2024



(b) 2015-2024

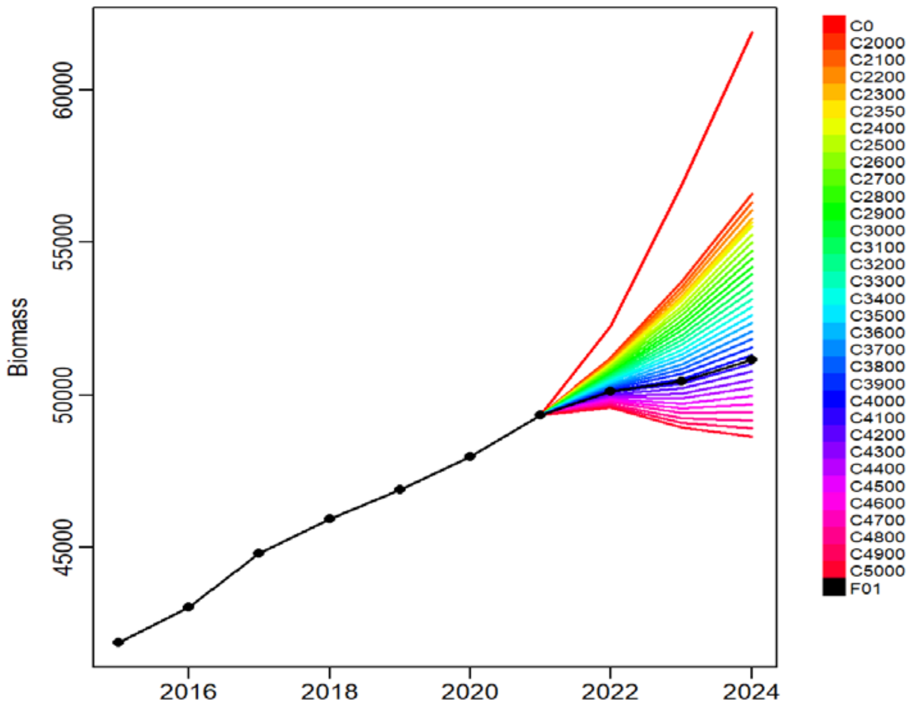


Figure 26. Projected total stock biomass (mt) of bluefin tuna in the West Atlantic under alternative constant catch scenarios, averaged across maturity specifications for Stock Synthesis. The deterministic model runs are averaged across both maturity specifications. (a) Upper panel: 1950-2024, (b) lower panel: zoomed in to 2015 to 2024.

Appendix 1

Agenda

1. Opening, adoption of agenda and meeting arrangements

2. Model diagnostics

   2.1 VPA

   2.2 Stock Synthesis

3. Assessment results

   3.1 VPA

   3.2 Stock Synthesis

4. Projections and management advice

5. Other matters

6. Adoption of the report and closure

Appendix 2

List of Participants

CONTRACTING PARTIES

CANADA

Duprey, Nicholas
Senior Science Advisor, Fisheries and Oceans Canada - Fish Population Science, Government of Canada, 200-401 Burrard Street, Vancouver, BC V6C 3R2
Tel: +1 604 499 0469; +1 250 816 9709, E-Mail: nicholas.duprey@dfo-mpo.gc.ca

Gillespie, Kyle
Fisheries and Oceans Canada, St. Andrews Biological Station, Population Ecology Division, 125 Marine Science Drive, St. Andrews, New Brunswick, E5B 0E4
Tel: +1 506 529 5725, Fax: +1 506 529 5862, E-Mail: kyle.gillespie@dfo-mpo.gc.ca

Hanke, Alexander
Scientist, St. Andrews Biological Station, Fisheries and Oceans Canada, 531 Brandy Cove Road, St. Andrews, New Brunswick E5B 2L9
Tel: +1 506 529 5912, Fax: +1 506 529 5862, E-Mail: alex.hanke@dfo-mpo.gc.ca

EUROPEAN UNION

Arrizabalaga, Haritz
Principal Investigator, AZTI Marine Research Basque Research and Technology Alliance (BRTA), Herrera Kaia Portualde z/g, 20110 Pasaia, Gipuzkoa, España
Tel: +34 94 657 40 00; +34 667 174 477, Fax: +34 94 300 48 01, E-Mail: harri@azti.es

Di Natale, Antonio
Director, Aquastudio Research Institute, Via Trapani 6, 98121 Messina, Italy
Tel: +39 336 333 366, E-Mail: adinatale@costaedutainment.it; adinatale@acquariodigenova.it

Gordoa, Ana
Senior scientist, Centro de Estudios Avanzados de Blanes (CEAB - CSIC), Acc. Cala St. Francesc, 14, 17300 Blanes, Girona, España
Tel: +34 972 336101; +34 666 094 459, E-Mail: gordoa@ceab.csic.es

Pierucci, Andrea
University of Cagliari, 09126 Cagliari, Italy
Tel: +39 328 651 6025, E-Mail: andrea.pierucci@hotmail.it

Rodríguez-Marín, Enrique
Ministerio de Ciencia, Innovación y Universidades, Instituto Español de Oceanografía, C.O. de Santander, Promontorio de San Martín s/n, 39004 Santander, Cantabria, España
Tel: +34 942 291 716, Fax: +34 942 27 50 72, E-Mail: enrique.rmarin@ieo.es

Rouyer, Tristan
Ifremer - Dept Recherche Halieutique, B.P. 171 - Bd. Jean Monnet, 34200 Sète, Languedoc Rousillon, France
Tel: +33 782 995 237, E-Mail: tristan.rouyer@ifremer.fr

JAPAN
Butterworth, Douglas S.
Emeritus Professor, Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch, 7701 Cape Town, South Africa
Tel: +27 21 650 2343, E-Mail: doug.butterworth@uct.ac.za

Daito, Jun
Chief, Japan Tuna Fisheries Co-operative Association, 31-1, Eitai 2-Chome, Koto-ku, Tokyo 135-0034
Tel: +81 356 462 382, Fax: +81 356 462 652, E-Mail: daito@japantuna.or.jp

Fukuda, Hiromu
Head of Group, Highly Migratory Resources Division, Fisheries Stock Assessment Center, Fisheries Resources Institute, Japan Fisheries Research and Education Agency, 2-12-4 Fukuura, Kanazawa, Yokohama, 234-8648
Tel: +81 45 788 7936, E-Mail: fukudahiromu@affrc.go.jp

Miura, Nozomu
Assistant Director, International Division, Japan Tuna Fisheries Co-operative Association, 2-31-1 Eitai Koto-ku, Tokyo 135-0034
Tel: +81 3 5646 2382, Fax: +81 3 5646 2652, E-Mail: miura@japantuna.or.jp; gyojyo@japantuna.or.jp

Nakatsuka, Shuya
Deputy Director, Highly Migratory Resources Division, Fisheries Resources Institute, Japan Fisheries Research and Education Agency, 2-12-4, Fukuura, Kanazawa Kanagawa, 236-8648
Tel: +81 45 788 7950, E-Mail: snakatsuka@affrc.go.jp

Rademeyer, Rebecca
Marine Resource Assessment and Management Group, Department of Mathematics and Applied Mathematic - University of Cape Town, Private Bag, 7700 Rondebosch, South Africa
Tel: +651 300 442, E-Mail: rebecca.rademeyer@gmail.com

Tsukahara, Yohei
ScientistHighly Migratory Resources Division, Fisheries Stock Assessment Center, Fisheries Resources Institute, Highly Migratory Resources Division, Fisheries Stock Assessment Center, Fisheries Resources Institute, Japan Fisheries Research and Education Agency, 2-12-4, Fukuura, Kanagawa, Yokohama, Shizuoka Shimizu-ku 236-8648
Tel: +81 45 788 7937, Fax: +81 54 335 9642, E-Mail: tsukahara_y@affrc.go.jp

Uozumi, Yuji
Adviser, Japan Tuna Fisheries Co-operation Association, Japan Fisheries Research and Education Agency, 31-1 Eitai Chiyodaku, Tokyo Koutou ku Eitai 135-0034
Tel: +81 3 5646 2380, Fax: +81 3 5646 2652, E-Mail: uozumi@japantuna.or.jp

MEXICO
Ramírez López, Karina
Instituto Nacional de Pesca y Acuacultura, Centro Regional de Investigación Acuícola y Pesquera - Veracruz, Av. Ejército Mexicano No.106 - Colonia Exhacienda, Ylang Ylang, C.P. 94298 Boca de Río, Veracruz
Tel: +52 5538719500, Ext. 55756, E-Mail: kramirez_inp@yahoo.com

MOROCCO
Abid, Noureddine
Chercheur et ingénieur halieute au Centre Régional de recherche Halieutique de Tanger, Responsable du programme de suivi et d'étude des ressources des grands pélagiques, Centre régional de l'INRH à Tanger/M'dig, B.P. 5268, 90000 Drabed, Tanger
Tel: +212 53932 5134; +212 663 708 819, Fax: +212 53932 5139, E-Mail: noureddine.abid65@gmail.com

UNITED STATES

Brown, Craig A.
Chief, Highly Migratory Species Branch, Sustainable Fisheries Division, NOAA Fisheries Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, Florida 33149
Tel: +1 305 586 6589, Fax: +1 305 361 4562, E-Mail: craig.brown@noaa.gov

Cadrin, Steven Xavier
Associate Professor, SMAST - University of Massachusetts, School for Marine Science & Technology, Department of Fisheries Oceanography, 836 South Rodney French Blvd, Fairhaven, MA 02744
Tel: +1 508 910 6358, Fax: +1 508 910 6374, E-Mail: scadrin@umassd.edu

Hansell, Alexander
Postdoctoral Researcher, Gulf of Maine Research Institute, 350 Commercial St, Portland ME 04101
Tel: +1 (207) 772-2321 Ext. 1620; +1 617 640 0895, E-Mail: alex.hansell@noaa.gov; ahansell@gmri.org

Kerr, Lisa
Gulf of Maine Research Institute, 350 Commercial Street, Portland ME 04101
Tel: +1 301 204 3385; +1 207 228 1639, E-Mail: lkerr@gmri.org

Lauretta, Matthew
Fisheries Biologist, NOAA Fisheries Southeast Fisheries Center, 75 Virginia Beach Drive, Miami, Florida 33149
Tel: +1 305 361 4481, E-Mail: matthew.lauretta@noaa.gov

Schalit, David
President, American Bluefin Tuna Association, 176 Mulberry Street - 4th floor, New York 10013
Tel: +1 917 573 7922, E-Mail: dschalit@gmail.com

Walter, John
Research Fishery Biologist, NOAA Fisheries, Southeast Fisheries Center, Sustainable Fisheries Division, 75 Virginia Beach Drive, Miami, Florida 33149
Tel: +305 365 4114; +1 804 815 0881, Fax: +1 305 361 4562, E-Mail: john.f.walter@noaa.gov

Weiner, Chris
33 Park Street, #4, Portland, Maine 04101
Tel: +1 978 886 0204, E-Mail: chrisweiner14@gmail.com

Weiner, Stephen
PO Box 465, Maine Ogunquit 03907
Tel: +1 978 764 3637, E-Mail: weinersb@gmail.com

OBSERVERS FROM NON-GOVERNMENTAL ORGANIZATIONS

PEW CHARITABLE TRUSTS - PEW

Galland, Grantly
Officer, Pew Charitable Trusts, 901 E Street, NW, Washington, DC 20004, United States
Tel: +1 202 540 6953; +1 202 494 7741, Fax: +1 202 552 2299, E-Mail: ggalland@pewtrusts.org

THE OCEAN FOUNDATION

Miller, Shana
The Ocean Foundation, 1320 19th St., NW, 5th Floor, Washington, DC 20036, United States
Tel: +1 631 671 1530, E-Mail: smiller@oceanfdn.org

SCRS CHAIRMAN

Melvin, Gary
SCRS Chairman, St. Andrews Biological Station - Fisheries and Oceans Canada, Department of Fisheries and Oceans, 285 Water Street, St. Andrews, New Brunswick E5B 1B8, Canada
Tel: +1 506 652 95783, E-Mail: gary.d.melvin@gmail.com; gary.melvin@dfo-mpo.gc.ca

SCRS VICE-CHAIRMAN

Coelho, Rui
Researcher, SCRS Vice-Chairman, Portuguese Institute for the Ocean and Atmosphere, I.P. (IPMA), Avenida 5 de Outubro, s/n, 8700-305 Olhão, Portugal
Tel: +351 289 700 504, E-Mail: rpcoelho@ipma.pt

INVITED EXPERT

Maunder, Mark
Inter-American Tropical Tuna Commission - IATTC, 8901, La Jolla 92037-1509, United States
Tel: +1 858 546 7100, E-Mail: mmaunder@iattc.org

*****

ICCAT Secretariat

C/ Corazón de María 8 – 6th floor, 28002 Madrid – Spain
Tel: +34 91 416 56 00; Fax: +34 91 415 26 12; E-mail: info@iccat.int

Manel, Camille Jean Pierre
Neves dos Santos, Miguel
Ortiz, Mauricio
Taylor, Nathan
Kimoto, Ai

Appendix 3

List of Papers and Presentations

Number	Title	Authors
SCRS/2021/139	West Atlantic bluefin tuna Virtual Population Analysis	Lauretta M., Kimoto A., Rouyer T., Ortiz M., and Walter J.
SCRS/2021/140	Western Atlantic bluefin tuna stock assessment 1950-2020 using Stock Synthesis: part I. model specification and input data	Tsukahara Y., Walter J., Fukuda H., Kimoto A., and Ortiz M.
SCRS/2021/141	Western Atlantic bluefin tuna stock assessment 1950-2020 using Stock Synthesis: part II. model diagnostics, results and projection	Tsukahara Y., Walter J., Fukuda H., Kimoto A., and Ortiz M.
SCRS/2021/143	Short-term constant catch projections for the Atlantic bluefin stocks based on the reconditioned MSE Operating Models	Butterworth D.S., and Rademeyer R.A.

Appendix 4

SCRS Document and Presentations Abstracts as provided by the authors

SCRS/2021/139 This report documents the 2021 assessment of the West Atlantic bluefin tuna using virtual population analysis. The SCRS Bluefin Tuna Species Group reviewed the assessment data inputs and work plan via webinar during April 5-13, 2021. We present the base model diagnostics and results, including time series estimates of spawning stock biomass (both young and older spawning scenarios) for the period 1974 to 2020, and recruitment for the period 1974 to 2017. Model diagnostics indicate some problems with the updated model including a severe trend in the residuals for some indices and a strong retrospective bias.

SCRS/2021/140 This document describes a stock assessment model using Stock Synthesis (version 3.30) for the Western Atlantic population of Bluefin tuna. The model runs from 1950 to 2020 and was fit to length composition data, conditional length at age (otolith age-length pairs input as an age-length key), 12 indices and 13 fishing fleets. Growth was internally estimated in the model and natural mortality was scaled with a Lorenzen function. These input and model settings were slightly changed from those used in 2020 except relative abundance indices in accordance with the request from ICCAT Commission. Two models (early and late maturity) were used for advice in 2017 and the same are retained here. The shapes of most selectivity were changed from asymptotic to dome shape to improve the convergence of the models and to reduce the conflict among the data sources, which was mainly due to the conflict among the indices. The trend of spawning stock biomass and recruitment are similar to previous one, while the biomass level was obviously different. These results will combine with those came from VPA analysis for the management recommendation in this year.

SCRS/2021/141 This document describes a stock assessment model using Stock Synthesis (version 3.30.14) for the Western Atlantic population of Bluefin tuna. This document describes model diagnostics and initial results derived from proposed settings for 2021 assessment. The diagnostics result showed relatively better performance with some negative signs that those in 2020 assessment, while some problems remained as it was in the last assessment. The two model runs showed very similar behavior with the stock decreasing during the 1970s, remaining relatively low during the 1980-2000 period and showing a pattern of steady population growth since 2000. This document also describes projection settings and stock status based on F based reference point, F0.1, which is estimated from the YPR curve in assessment result. Current F during 2018-2020 was below the F0.1, hence the stock was not subject to be overfishing. It is also showed that the probability which is that F<F0.1 under several constant catch scenarios for management advice.

SCRS/2021/143 The reconditioned MSE Operating Models (OMs) for the Atlantic bluefin stocks are used to provide estimates of the trend in spawning biomasses of the two stocks of origin under a continuation of the current west area TAC of 2350 t for 2022 (and also for the next three years under this and two lower TAC levels). The purpose is to complement results under preparation from refined and updated conventional assessment methods. The result is a median (across the OMs) increase in the spawning biomass of the western stock of 6% from 2022 to 2023, with a 21% probability of a decrease. The median for the eastern stock also increases, and results are similar for the next few years. The advantages and disadvantages of this approach compared to the conventional area-based assessment methods are discussed briefly.