SCRS/2017/176 Collect. Vol. Sci. Pap. ICCAT, 74(6): 3305-3404 (2018)

WESTERN ATLANTIC BLUEFIN TUNA STOCK ASSESSMENT 1950-2015 USING STOCK SYNTHESIS

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SUMMARY

This document describes a stock assessment model using Stock Synthesis for the Western Atlantic population of Bluefin tuna. This document describes initial model set up, fleet definitions, selectivity and parameterizations. The model runs from 1950 to 2015 and was fit to length composition data, conditional length at age (otolith age-length pairs input as an age-length key), 13 indices and 13 fishing fleets. Growth was internally estimated in the model and natural mortality was scaled with a Lorenzen function. Two models with late spawning (100% at age 13) and early age spawning (100% at 5) are presented. Model diagnostics indicate some conflict between length and index data but generally robust diagnostic performance. A Beverton-Holt stock recruitment relationship was estimated in the model with steepness, sigmaR and R0 freely estimated. Overall fits to length composition were fairly good and 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.

RÉSUMÉ

Ce document décrit un modèle d'évaluation des stocks utilisant Stock synthèse pour la population de thon rouge de l'Atlantique Ouest. Ce document décrit la mise en place du modèle initial, les définitions des flottilles, la sélectivité et les paramétrages. Le modèle s'étend de 1950 à 2015 et a été ajusté aux données de composition de taille, à la longueur conditionnelle à l'âge (paires âge-longueur d'otolithes saisies comme une clé âge-taille), 13 indices et 13 flottilles de pêche. La croissance a été estimée en interne dans le modèle et la mortalité naturelle a été mise à l'échelle avec une fonction de Lorenzen. Deux modèles avec frai tardif (100 % à l'âge 13) et avec frai précoce (100 % à l'âge 5) sont présentés. Les diagnostics du modèle indiquent certains conflits entre les données de taille et les données de l'indice mais généralement des performances de diagnostics robustes. Une relation stock-recrutement de Beverton-Holt a été estimée dans le modèle avec steepness, sigmaR et R0 estimés librement. Dans l'ensemble, les ajustements à la composition des tailles ont été assez bons, et les deux scénarios du modèle ont montré un comportement très similaire, le stock diminuant dans les années 70, demeurant relativement faible durant la période 1980-2000 et faisant apparaître un schéma de croissance constante de la population depuis 2000.

RESUMEN

Este documento describe un modelo de evaluación de stock utilizando Stock Synthesis para la población de atún rojo del Atlántico occidental. Este documento describe la configuración inicial del modelo, las definiciones de flota, la selectividad y las parametrizaciones. El modelo abarca desde 1950 hasta 2015, y se ajustó a los datos de composición por tallas, la talla por edad condicional (pares de otolitos edad-talla introducidos como clave de edad-talla), 13 índices y 13 flotas. El crecimiento se estimó internamente en el modelo y la mortalidad natural se escaló con una función Lorenzen. Se presentan dos modelos con una reproducción tardía (100% en la edad 13) y una reproducción temprana (100% en la edad 5). Los diagnósticos del modelo indican algún conflicto entre los datos de talla y del índice, pero un rendimiento de los diagnósticos por lo general robusto. Se estimó en el modelo una relación stock reclutamiento de Beverton y Holt con inclinación, y SigmaR y R0 se estimaron libremente. Los ajustes globales a la composición por tallas eran bastante buenos, y los dos ensayos del modelo mostraban un comportamiento similar, el stock descendía durante los 70, permanecía en un nivel relativamente bajo durante el periodo 1980-2000 y mostraba un patrón constante de crecimiento de la población desde 2000.

KEYWORDS

Stock assessment, bluefin tuna

Introduction

Stock Synthesis (SS) is an integrated statistical catch-at-age model which is widely used for many stock assessments in the United States and throughout the world (Methot and Wetzel 2013 http://nft.nefsc.noaa.gov/Stock_Synthesis_3.htm). SS takes relatively unprocessed input data and incorporates many of the important processes (mortality, selectivity, growth, etc.) that operate in conjunction to produce observed catch, size and age composition and CPUE indices. Because many of these inputs are correlated, the concept behind SS is that they should be modeled together, which helps to ensure that uncertainties in the input data are properly accounted for in the assessment. SS is comprised of three subcomponents: 1) a population subcomponent that recreates an estimate of the numbers/biomass at age using estimates of natural mortality, growth, fecundity, etc.; 2) an observational sub-component that consists of observed (measured) quantities such as CPUE or proportion at length/age; and 3) a statistical sub-component that uses likelihoods to quantify the fit of the observations to the recreated population.

Overall the WBFT SS model uses size composition information, conditional age at length data (essentially an age-length key using the age-length pair data available for WBFT), 11 indices and landings going back to 1950 (**Figure 1**). Catch at age for the Japan longline, as derived from cohort slicing is input in the model but not used in fitting for the purposes of evaluating the predicted CAA from SS with the assumed CAA for the VPA.

Basic equations and technical specifications underlying Stock Synthesis can be found in Methot and Wetzel (2011). In these models we use SS version 3.24P.

Model Spatial Structure

The model assumed the Western Atlantic Bluefin tuna stock structure (West of 45º longitude) with no spatial structure otherwise. Fleet structure was designed to generally alias spatial/temporal structure with fleets were separated according to whether they occurred in the Gulf of Mexico or the Atlantic and when there was a clear separation in size structure due to either selectivity or availability.

Temporal domain and initial conditions

The model starts in 1950 and runs to 2015. Conditions were assumed to be near-virgin in 1950 with two fleets, USA_CAN_TRAP and USA_CAN_HARPOON, assumed to have equilibrium catches equal to the average of 1950-1955, respectively, 434.5 and 310 t. An annual time step was assumed for the model with all fleets assumed to take catch out continuously over the year. Individual indices were adjusted to account for the timing within the year when the index occurs. In the current iteration no time blocks on selectivity or catchability are imposed.

Biology

A single sex was assumed for the model and spawning biomass was assumed to be the summed mass of all mature fish. Fish are born at age 0 and the model uses a plus group age of 35. Maturity at age was modeled with two vectors representing either early or late spawning (**Figure 56**). Natural mortality was modeled with a Lorenzen function scaled according to the growth model with a reference M of 0.1 applied to a reference age of 20 according to decisions made intersessionally. Growth was modeled with a Richards 3 parameter formulation and initially input as the Ailloud *et al.* (2017) growth parameters but then all growth parameters (length at age 0.5, Linf, K, Richards parameter and the CV on young and old fish) were freely estimated in the model. Fecundity was modeled as proportional to weight (eggs=a*Wt^b) and the overall Western Atlantic length weight relationship was used to convert size to weight (1.52E 05* length^3.05305). Biological vectors input or estimated in SS (italics) are shown below:

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	…	35
Early spawning	0	0	0	0.25	0.5	1	1	1	1	1	1	1	1	1	1	…	1
Late spawning	0	0	0	0	0	0	0	0.01	0.04	0.19	0.56	0.88	0.98	1	1	…	1
M (Lorenzen scaled)	0.40	0.33	0.27	0.23	0.20	0.18	0.16	0.14	0.13	0.12	0.12	0.11	0.11	0.11	0.11	…	0.10
Growth (mid-year size)	43	58	75	93	113	133	152	170	186	200	212	222	231	238	243	….	266

Stock-recruitment relationship

A Beverton-Holt stock recruit relationship was assumed and that spawning biomass was equal to the biomass of the mature population according to the two maturity vectors outlined in the biology section. Parameters of the stock recruitment relationship (steepness and R0) were freely estimated as well as the variance in interannual recruitment deviations (sigmaR).

Deviations from the stock-recruitment relationship were assumed to follow a lognormal distribution estimated on a logscale as N(0, sigmaR) variates with a min and max of -5 and 5, respectively. Zero recruitment deviations were assumed until the start of informative data on age structure, i.e. annual deviates were only estimated from 1961-2015. The lognormal bias correction ($-0.5\sigma^2$) for the mean of the stock recruit relationship was applied during the period 1961-2014 with a bias correction ramp applied prior to 1961 and after 2011 according to the Methot and Taylor (2011) recommended bias correction ramping.

Fleet and index definitions

Overall the model consists of 12 fleets (**Table 1**):
1. JAPAN_LL 2. USA_CAN_PSFS 3. USA_CAN_PSFB 4. USA_TRAP 5.
USA_CAN_HARPOON 6. USA_RRFB 7. USA_RRFS 8. OTHER_ATL_LL 9. CAN_HOOKLINE 10.
GOM_LL_US_MEX 11. JLL_GOM 12. CAN_TRAP

and 13 indices, though two (tagging and the oceanographic index were not used)
1. IND1_JAPAN_LL 2. IDX2_US_RR_66_114 3. IDX3_US_RR_115_144 4.
IDX4_US_RR_LT145 5. IDX5_US_RR_GT177 6. IDX6_US_RR_GT195 7. IDX7_USPLL_GOM 8.
IDX8_JLL_GOM
9. IDX9_CAN_NS 10. IDX10_GOM larval 11. IDX11_tagging (not used) 12.
IDX12_CAN_ACOUSTIC
13. IDX13_oceanographic (not used)

Modifications to fleet structure

Originally the SS fleet structure was determined at the data workshop; subsequent evaluation of fleets necessitated some restructuring to avoid having 'mixed' fleets or to have to model time-varying selectivity. These changes are documented below for each fleet.

Purse seine

Modifications to US_CAN_PS, split into two fleets, large purse seine and small purse seine were conducted to separate the bimodality observed in the original fleet designation (**Figure 2**). Task I data is split into PSFB and PSFS for the years 1969-1979 allowing for an average fraction of PSFB/PSFS to be calculated (15% big/small) to partition the historical purse seine prior to 1969. After 1985 the size frequency data indicates that the PS is entirely composed of fish >145 so the fishery can be assumed to be PSFB for 1985-2016. The years 1980-1984 are a transition period from small fish to large fish which for which a linear interpolation of the fraction of big/small was used between 15% (in 1969) and 100% (in 1985) giving a linear ramp on the increase in the PSFB and a commensurate decrease in PSFS. The small fraction of large fish (15%) in the purse seine prior to 1970 reflects the general tendency of this fishery to capture primarily age 1, 2 and 3-year old fish for canning (Sakagawa 1975).

Similarly, the size frequency data only indicates a bimodality of large and small fish for 1979 and 1984 (**Figure 2**). Splitting these records at 145 cm allows for the smaller size range to be assigned to PSFS and the larger fish to PSFB, allowing for more homogenous PS fleet designations and clear separation of small fish and large fish. Two records (1979 and 1984) were split and the large 'clump' of fish (for 1984, fish greater than 145 were placed in placed in US_CAN_PSFB) and fish less than these sizes were placed in US_CAN_PSFS.

US handline and rod and reel

The US handline and rod and reel fishery consists of two distinct modes: commercial and recreational which are clearly evident in the bimodality of the size frequency (**Figure 3)**. It has been separated as such in the Task I database but also separated into RRFS (small <145 cm) and RRFB (big >145 cm) which almost exactly separates the commercial and recreational landings for the years 1990-2014. After 2014 the RRFS and RRFB designations have been dropped and only separated according to recreational or commercial. Hence it possible to separate the two fleets for much of the time series based on the reported size category. For years where landings were reported only as RR we use a ratio of RRFB/sum(RRFB+RRFS) to partition out RR fish. The average ratio of RRFB/total for the years 1960-1968 was calculated from the average for the years 1950-1959 and 1969-1970 and was 0.61. For the years 1980 to 1989 the average was taken from years 1969-1970 and then the years 1990-2000 (0.71). This provided a ratio to split the undifferentiated RR landings. We also assume that all handline is RRFB and assume that all RR commercial is also RRFB. For the size frequency data we separated the composition data at 145 cm assigning all fish below this to RRFS and all fish above to RRFB, allowing for a complete separation of the task I and the size frequency information. The Canada handline fleet consists of handline, rod and reel and, with the revised placement of the tended line fish from the "other" fleet, also tended line.

Trap fisheries

Much (70%) of the early US landings from 1950-1959 came from traps in and around Cape Cod Bay with the size composition appearing to be fish between 100-160 cm (Mather *et al.* 1995) and the size composition from 1955-1961 indicates this to be the case (**Figure 4**). This size composition for the Canada trap fisheries which operated primarily around St. Margarets Bay (Mather *et al.* 1995) indicate a generally larger size composition. Furthermore, the US trap fishery ended in 1975 while the Canada trap fishery has continued until the present, albeit at a low level. Hence it makes sense to split the two fleets and the two size compositions to ensure an adequate characterization of the two fisheries. This split was simple as the trap data could be split by Flag and the composition data has no overlap in years.

Other fleet

Originally a catch-all 'other' fleet was created, however 98% of this fleet landings were from Canada tended line which was added to the Canada Handline fleet. The remainder of the 'other' fleet (223 t over the 65-year time series) was some gill net, trawl or unclassified fish from US, some rod and reel fish from UK territories which were added to USA_RRFB as it was likely larger fish, similar to the large RR fish. A very small amount of landings from Argentina TW were added to the Japanese longline (11 t between 1985-1990) as this fleet was the greatest amount of catch in this time period and no composition data was available. This removed the need to model an 'other' fleet entirely.

Total catch (Task I)

The total catches were calculated by the Secretariat (**Table 2, Figure 5**) with some modifications as noted to the fleets, above. Catch in mass was used in the model for all fleets, and was assumed to be known essentially without error. Initial equilibrium catch was input for USA_trap and USA_CAN_Harpoon that had non-neglible catches in 1950. Initial F was estimated for these fleets but was assumed to be zero for all other fleets. To provide initial equilibrium catches for USA_TRAP and USA_CAN_HARPOON the average for 1950-1955 was input (434.5 and 310 t, respectively). In initial model fitting the initial F for the USA_CAN_Harpoon fleet hit a minimum bound at 0.001476 and in subsequent models was fixed at this value.

Conditional age at length inputs

Age-length data was available from the same dataset used to fit the Ailloud *et al.* (2017) growth curve and for modeling the age-length key. These data were aged otoliths read according to standardized protocols read by five different labs. The total number of age-length pairs available were 4298 from years 1974-2015. Following protocols from Ailloud *et al.* outlier age-length pairs were flagged as ones for which the mean size at age was +/- 3 times the estimated standard deviation in size at age and were removed (**Figure 6**).

For several age composition datasets some decisions were required to be made to assign gear type. Fish less than 145 cm SFL were assigned to PSFS or RRFS (small fish) and greater than 145 to PFSB or RRFB (big) fish for each gear type. Canada "TL" (tended line) and "RR" fish were assigned to CAN_HL. Canada "UN" fish were assigned to "CAN_HL". Some fish were recorded as "HP/RR" and were assigned to USA_RRFB for convenience due to the larger samples size for this gear.

For several fish, gear types were not recorded so expert opinion was necessary to assign gear based on landing port. For ports which were primarily recreational (Montauk, Great Kills and Babylon, NY) gear was assumed to be USA_RRFS. Ten fish captured off of Cape Hatteras, NC in winter of 2013 could have been either OTHER_ATL_LL or USA_RRFB and were assigned to USA_RRFB. Four fish landed in Gloucester, MA in 1975-1976 could have been either USA_RRFB, USA_CAN_HARPOON or USA_CAN_PSFB but were assigned to USA_RRFB, USA_CAN_HARPOON based on similarity to adjacent samples. Lastly four fish captured on Japan longliners in the Gulf of Mexico were assigned to OTHER_LL_GOM as these would have been the only 4 fish for this fleet.

Age-length data was assigned to 9 different fleets (**Figure 7**). Age information was originally input with an aging error vector assuming a CV of 0.1 (SCRS/2014/038). Subsequently it was determined that otolith derived ages might have overestimated the true age and an ageing bias vector was produced using data from paired otolith-spine samples collected in the past by assuming spines readings are correct for fish up to age 7. This provided an aging bias and updated aging error vector for otoliths:

	Otoliths		*Spines*	
Age class	*Age*	*Standard error*	*Age*	*Standard error*
0	0.58	0.14	0.5	0.13
1	1.86	0.41	1.5	0.38
2	2.79	0.54	2.5	0.38
3	3.82	0.62	3.5	0.38
4	5.1	0.73	4.5	0.49
5	5.93	0.75	5.5	0.57
6	7.31	0.89	6.5	0.75
7	8.83	1.07	7.5	0.83
8	8.5	1.09	8.5	0.88
9	9.5	1.14	9.5	0.91
10	10.5	1.22	10.5	0.93
11	11.5	1.34	11.5	1.05
12	12.5	1.52	12.5	1.27
13	13.5	1.85	13.5	1.42
14	14.5	2.04	14.5	1.85
15	15.5	1.76	15.5	2.12
16	16.5	1.66	16.5	2.35
17	17.5	1.44	17.5	2.83
18	18.5	1.53	18.5	2.99
19	19.5	2.2	19.5	3.16
20	20.5	2.31	20.5	3.32

Catch at age input

Catch at age was input for the Japan longline fleet which did not have conditional age at length data. Catch at age data was not fit in the likelihood component but was input for diagnostic purposes to evaluate the consistency of decisions used to construct the CAA with internal modeling of growth and selectivity in SS.

Size frequency information

Development of the raw size frequency input to SS are outlined in SCRS/2017/166. Some data cleaning was conducted (removing outliers, etc) but the size composition information was used in its most raw format as provided by individual CPCs (**Figures 8 & 9**). Data was input is straight fork length in centimeters and modeled with 5 cm length bins between 30 and 350 cm in the model.

Two slight departures or conversions from initial size composition definitions were made to several data sources. First the OTHER_ATL_LL composition data consisted of U.S. and Canadian observers on Japan longline vessels. Originally this was assigned to OTHER_ATL_LL, however these sizes were much different that the Canadian and U.S. lengths that composed the majority of OTHER_ATL_LL in other years (**Figure 8**) and much more closely resembled the lengths of the Japan_LL. Hence it appeared that moving these lengths to JAPAN_LL was warranted. An initial sensitivity run comparing moving these lengths to JAPAN_LL versus keeping them in OTHER_ATL_LL found that there was little practical impact on the results but a substantial improvement in fit to the OTHER_ATL_LL as these outlier lengths were moved to a more similar fleet.

Second, the United States longline data for years 1996 and 2000-2010 showed some clear outliers indicative of being reported in different units (**Figure 10**) and also for the Gulf of Mexico (not shown). Further exploration of the dataset indicated that they were reported for those years in Pectoral fin curved fork length which explains the much smaller fish in these years. It was fairly straightforward to convert all length for these years to CFL (using the conversion (CFL=1.35*PFCFL) and then to SFL using the ICCAT CFL to SFL conversion which resulted in these lengths then resembling very closely the lengths for adjacent years (**Figure 10**). An initial sensitivity run was conducted to explore the result of converting these lengths indicated that the practical result was neglible but the model fit was greatly improved as converting the lengths reduced these outliers.

Size frequencies for the remainder of the 12 fleets indicate relatively consistent size structure over time with the exception of several fleets with sparse data (**Figures 8 and 9**). Length composition data is modeled assuming a multinomial distribution.

Catch per unit effort data

The current version of the SS models do not use the Gulf of Mexico oceanographic index or the historic tagging index. Use of the tagging index would have required reconfiguring the SS model to estimate individual F as parameters, vastly increasing the number of parameters (single parameter for each year and each fleet) for limited gain. Hence this index was not fit. For the Canada handline index the original index recommended by the data workshop was smoothed over years, resulting in very poor residual patterns. Subsequently it was determined intersessionally to replace this index with the GLM formulation that better preserves interannual variability. All indices were input with a CV of 0.2 for each year (input as a log scale standard error in model) and each index. This decision was similar to the decisions made for the VPA and other models. CPUE indices were assumed to have a lognormal error structure. No timeblocks on indices were modeled as indices that required splits were input as separate indices with unique catchabilities. CPUE input data are not shown here but fits to CPUE data are shown in Results.

Selectivity

Selectivity was parameterized (**Table 1**) as length-based for most fleets/surveys as either 6 parameter double normal which could take on either dome or asymptotic shape or as logistic on the basis of visual examination of the length composition data. Several surveys had a special selectivity parameterization with the larval survey assumed to have selectivity of the spawning biomass. The oceanographic index was not used in the likelihood but was retained to evaluate the potential fit and was modeled with a selectivity equal to exp(rec devs). For the US_RR_115_144 index ages 4 was assumed to be fully selected and selectivity for age 5 was estimated as a random walk from age 4. In several cases of when the double normal selectivity showed either a steady increasing or decreasing limb these were modeled to allow for either a smooth increase or decrease to avoid sharp and unrealistic breaks. For one selectivity parameter (SizeSel_4P_2_USA_TRAP) a symmetric beta prior was used with a mean of -4 and a standard deviation of 0.05 to avoid the model hitting bounds on this parameter.

Data weighting

Francis and Hilborn (2011) indicates that often in complex integrated models there is conflicting sources of information, stemming from fitting to either the length composition data, or abundance index data and often the numerically abundant length composition information dominates the likelihood. Length composition data was initially input with a sample size of 100 and conditional age at length data was input with the actual sample size. In most cases, the effective N was much higher than the input N indicating that that the effective sample should be reduced for most fleets. Input sample size for length and age data input was iteratively adjusted so that the harmonic mean effective N equaled the input N using variance adjustments. Input weights, as follow, generally substantially downweighted the length composition as well as the conditional length at age data. Age composition data input for the Japan_LL was not fit in the model likelihood and removed using the lambda emphasis factors.

Fleet	1	2	3	4	5	6	7	8	9	10	11	12
Length input	0.326	0.066	0.171	0.112	0.445	0.436	0.141	0.414	0.479	0.359	0.203	0.331
Age input	NA	0.275	0.81	NA	0.488	0.249	0.164	0.87	0.337	0.463	NA	0.783

No adjustment to index weighting was performed in the current iterations of the models.

Model Diagnostics

Model convergence was assessed using several means. The first diagnostic was whether the Hessian, (i.e., the matrix of second derivatives of the likelihood with respect to the parameters) inverts. The second measure is the maximum gradient component which, ideally, should be low. The third diagnostic was a jitter analysis of parameter starting values to evaluate whether the model has converged to a global solution, rather than a local minimum. Starting values of all estimated parameters were randomly perturbed by 10% and 50 trials were run.

Other diagnostics performed included likelihood profiling of key parameters (steepness, R0 and sigmaR), evaluation of fits to residuals for indices and length composition, retrospective analyses and sensitivity to different indices and compositional data inputs. Likelihood profiles were completed for three key model parameters: steepness of the stock-recruit relationship (h) and the log of unexploited equilibrium recruitment (R_0) and sigma R. Likelihood profiles elucidate conflicting information among various data sources, determine asymmetry around the likelihood surface surrounding point estimates and evaluate the precision of parameter estimation. Retrospective analyses are also standard diagnostic practice and were conducted on models 1-2 with 5 year retrospective peels.

Another model diagnostic is parametric bootstrapping. Uncertainty in parameter estimates and derived quantities can as well bias between the maximum likelihood estimates and estimates obtained by bootstrapping were investigated using a parametric bootstrap approach. Bootstrapping is a standard technique used to estimate confidence intervals for model parameters or other quantities of interest. There is a built-in option to create bootstrapped data-sets using SS. This feature performs a parametric bootstrap using the error assumptions and sample sizes from the input data to generate new observations about the fitted model expectations. The model was refit to approximately 100 bootstrapped data-sets and the distribution of the parameter estimates was used to represent the uncertainty in the parameters and derived quantities of interest.

Parameters Estimated

Overall 93 parameters were estimated in the model, consisting of 7 growth parameters 1 initial F parameter, 29 selectivity parameters, 3 stock recruitment parameters and 54 recruitment deviations. Only a single selectivity parameter was input with a Bayesian prior to aid model stability.

Benchmark and fishing mortality calculations

For overall fishing mortality rate the exploitation rate in biomass was used. MSY, B_{MSY}, F_{MSY} and equilibrium yield estimates were calculated on the basis of the F_{age} distribution (selectivities) estimated for 2015. Proxy benchmarks of SPR30% are also provided. If an F0.1 proxy is desired this can be calculated from the yield per recruit curve and the SSB at F0.1 from running long-term projections fishing ag F0.1. Given the substantial changes in overall selectivity over time the F and Bmsy benchmarks will have to be estimated on a year-specific basis according to the flee*et al.*location in that year.

Uncertainty Quantification

Uncertainty in parameter estimates and derived quantities was evaluated using multiple approaches. First, uncertainty in parameter estimates was quantified by computing asymptotic standard errors for each parameter (**Tables 4 and 5**). Asymptotic standard errors are calculated by inverting the Hessian matrix after the model fitting process. Asymptotic standard errors are based upon the maximum likelihood estimates of parameter variances at the converged solution. A second method of quantifying uncertainty is to run parametric bootstraps. Bootstrap results of 100 models are shown for diagnostic purposes.

Sensitivity runs

Two models were conducted using early and late spawning. These represent two states of nature of fecundity at age. An additional suite of 'jackknife' sensitivity runs consisting of removing one index group (e.g. all Japan Longline indices, etc) from the model one at a time were conducted to determine the most influential indices in the models. At the assessment workshop a series of 11 additional runs were conducted and outlined below.

Additions to WBFT SS

During the 2017 assessment meeting several issues were identified that required some modifications to the initial WBFT assessment models. These changes are outlined below and are reflected in the final base models 12 and 13:

1. Switch the selectivity of the larval index to mirror the GOM_LL_US_MEX fishery.

2. Make IDX2_US_RR_66_114 and IDX3_US_RR_115_144 selectivities length based. Input size information for these fleets, downweight it by 0.0001 so that it is not double counted with the length composition data for the RR_FS and estimate selectivities. Many parameters of the double normal selectivity were fixed to achieve knife-edge selectivity at the size breaks.

3. Time block selectivity for JLL_GOM 1950-2009, 2010-2015

4. Split the CAN_HOOKLINE 1950 1987, 1988-2015 into two time periods and two fleets GSL1 only 1950-1987 and mixed GSL-SWNS starting in1988. This required removing some very small fish in the early GSL1 fishery.

5. Time block USRRFS and RR66_114 in 1992 2015 due to apparent changes in selectivity of the fishery.

6. Incorporate the Atlantic Multidecadal Oscillation (AMO) as an environmental factor to modulate catchability for the Canada GSL_NS index, the Canadian acoustic index and the USRR>177 index in a manner similar to Schirripa *et al.* (2016) and similar to the method used in the 2017 swordfish assessment. The environmental index used was the AMO for July, August, September. The AMO is a climate cycle affecting sea surface temperatures in the North Atlantic and linking this factor to catchability of several indices implicitly considers that this factor affects only the catchability and not productivity.

7. Sensitivity run with a baseline M of 0.07

8. Corrected the length-weight relationship to be the adopted ICCAT relationship (Rodriguez *et al.* 2015).

9. Incorporate otolith aging bias. During the meeting a concern was raised that the otoliths may give an age estimate biased high due to a false band for young ages. A revised aging error and aging bias vector was obtained based upon paired otolith-spine readings and was used to account for aging bias:

Age 0.58 1.86 2.79 3.82 5.10 5.93 7.31 8.83 8.50 9.50
10.50 11.50 12.50 13.50 14.50 15.50 16.50 17.50 18.50 19.50
20.50 21.50 22.50 23.50 24.50 25.50 26.50 27.50 28.50 29.50
30.50 31.50 32.50 33.50 34.50
SE 0.14 0.41 0.54 0.62 0.73 0.75 0.89 1.07 1.09 1.14 1.22 1.34
1.52 1.85 2.04 1.76 1.66 1.44 1.53 2.20 2.31 2.43 2.54
2.65 2.77 2.88 2.99 3.10 3.22 3.33 3.44 3.56 3.67 3.78
3.89

10. Size at age was initially input with a CV as a function of age but was switched to be a function of length during the meeting to more closely match growth assumptions of Ailloud *et al.* 2016.

11. After correcting the length-weight relationship, the model was somewhat unstable which required dealing with several parameters that were strongly (>+/- 0.85) correlated with similar parameters.

SizeSel_1P_3_JAPAN_LL_BLK1repl_1950	SizeSel_1P_1_JAPAN_LL_BLK1repl_1950	0.943402
SizeSel_3P_3_USA_CAN_PSFB	SizeSel_3P_1_USA_CAN_PSFB	0.863109
Richards_Fem_GP_1	L_at_Amin_Fem_GP_1	-0.8631
SizeSel_1P_2_JAPAN_LL_BLK1repl_1950	SizeSel_1P_1_JAPAN_LL_BLK1repl_1950	-0.93308
Richards_Fem_GP_1	VonBert_K_Fem_GP_1	-0.94663

This resulted in poor jitter performance as the correlated parameters varied back and forth. While not affecting the overall model estimates greatly it did make the model unstable. To address this, several values were fixed at their previous (Runs 10 and 11) values. The parameters that were fixed were:

SizeSel_3P_1_USA_CAN_PSFB, SizeSel_2P_1_USA_CAN_PSFS and SizeSel_1P_1_JAPAN_LL_BLK1repl_1950 and L_at_Amin_Fem_GP_1.

This resulted in a final set of 13 model runs of which models 12 (early) and 13 (early spawning) represented the base case models.

Projections

Preliminary projections were conducted for diagnostic purposes to confirm that the models provide reasonable projection advice. Initially deterministic projections were conducted in stock synthesis and stochastic projections were conducted intersessionally. Recruitment projections were done for years 2015-2021 as 2015 recruitment was not freely estimated in the model.

Projections were conducted for four recruitment scenarios: recruitment from the Beverton-Holt stock recruitment relationship with steepness = 0.55 (high age at maturity) - 0.47 (low age at maturity) and sigmaR (0.73 (high age at maturity) - 0.69 (low age at maturity) and constant recruitment from the geometric mean recruitment (1000s age 0) for three year periods:

Range	*Years*	*Late*	*Early*
3 years	2010-2012	121	120
6 years	2007-2012	132	132
10 years	2003-2012	170	172

To implement this in SS, the recruitment deviations were adjusted to achieve recruitment approximately equal to the geometric mean for the three time periods using the SSB in 2015. These recruitment deviations were then input as forecast deviations. This input constant recruitment deviations, however the resulting recruitment was close to but not exactly the geometric mean recruitment.

Further projections specifications follow:

Three fishing mortality rates ($F_{current}$ (avg 2013-2015), F0.1 and F_{msy}). F0.1 was obtained from the yield per recruit curves (**Figure 61**). Ten fixed TACs (1000, 1250, 1500, 1750, 2000, 2250, 2500, 3000, 3250, 3500) were run.

Selection patterns and relative fishing mortality patterns are the average of 2006-2009 (pre-changes in Japan longline selectivity).

Input preliminary reported catches for 2016 for each fleet in the model (total= 1912 t) and the quota (2000 t) for 2017 allocated according to 2016 proportions across fleets. Yields from 2018-2021 were then calculated or fixed according to the assumed fishing mortality rates or TACs. Projections were then conducted for 2016-2025.

Stochastic projections were conducted in a similar manner as for the deterministic projections using parametric bootstrap data sets created from each model run. The parametric bootstrap method creates new datasets according to the parametric assumptions of the data e.g. distributional form, mean and variance. For model runs 12 and 13, 100 individual bootstraps were conducted. This results in 100 bootstraps x 10 fixed TACs x 3 recruitment scenarios x 2 models= 6000 individual projections.

For the Kobe matrix the relative fishing mortality rate is calculated according to each bootstrap estimate of F0.1.

Results

Model diagnostics

Overall the models show relatively good diagnostic performance though the maximum gradient components are slightly higher than desired (usually less than 0.0001) (**Table 3**). The models run relatively fast (~15 mins) and show good convergence properties over many different scoping runs that have been required to obtain two candidate models presented her. Both models show nearly identical diagnostic performance, and very similar log-likelihoods so they can basically be discussed as a single model. No parameters hit bounds and most parameters show relatively low standard deviations relative to the estimated values indicating decent estimation (**Tables 4** and **5**). Derived quantities, benchmarks and standard errors indicate relatively well determined values (**Table 6**).

Both models show some instability in the loglikelihood with different starting values (**Figure 11**) however the practical result of this instability is negligible. Model run 12 did not achieve the lowest log likelihood of the jitters though model 13 did, however the practical result of this is neglible. Much of the instability is in the magnitude of the early recruitments estimated between 1961-1974, which is likely a function of the extremely sparse size frequency information from this time period.

Both models converge on estimates of steepness, sigmaR and R0 (**Figures 12 and 13**) though these there is some conflict among data sources for steepness and sigma R. Notably the length composition data diverges from other data sources.

Retrospective performance of the models is good (**Figure 14**) with no perceptible pattern in SSB. There some pattern in the terminal year estimate of recruitment due to the bias adjustment ramping.

Retrospective fits to the indices show some slight divergence in the fit to the Japan LL2 (**Figures 15 and 16**), which is the same for both models and likely a function of a very short time series. Overall the fits to the indices change very little retrospectively. An additional diagnostic plot is to estimate the dynamic B0- which basically indicates how much productivity the model has to create to fit the data. The red line is the biomass that would occur under no fishing, indicating the pattern of high recruitment deviations in the recent years would have moved SSB above virgin for both high and low age at maturity. This plot is also a potential indicator of potential changes in system productivity.

Bootstrapping results indicate that the MPD is relatively well aligned with the 100 bootstraps for SSB but not as well for recruitment (**Fig. 18**). Run 1 as projected forward at F_{MSY} using the stock recruitment curve indicating that the model does project and that the bootstraps give reasonable projection results (**Fig. 18**). The MPD estimate for the deterministic run for R0, steepness (red line on **Figure 19**) was generally near the center of the histogram of estimates from the bootstraps. However, for sigmaR the MPD was higher for both runs. This is a potential area of concern and may be a product of the bootstraps being created from an assumed multinomial distribution for the length composition information. Hence the composition data may be far less noisy then the real data, resulting in reduced estimates of recruitment variability, though this does not appear to affect the SSB estimates. Nonetheless this merits further exploration particularly because of the role that sigmaR has in the bias correction for the back transformation of recruitment estimated on the log scale to the arithmetic scale.

Model results

Estimated selectivities generally reflected assumed patterns of the fisheries (**Figure 20**). The doming of the Japan_LL is fairly steep but seems rather well determined by the fact that several fleets have asyptototic selectivity and capture much larger fish on average. Fixing the Japan_LL to logistic (not shown) results in a substantial lack of fit to this fleets length composition. Selectivity for the OTHER_ATL_LL was initially estimated as double normal allowing a doming but the estimated selectivity only showed a declining limb at around 250 cm and had some substantial parameter confounding. Hence, for model stability it was estimated at logistic. In either case the model results were almost imperceptibly different but model performance was improved with logistic selectivity for this fleet. Due to the fact that it is a mix of US and Canada, the relative distribution of samples (and catch) from these two fleets could mean that selectivity might need to be allowed to vary over time. Nonetheless this seems unlikely to alter the overall pattern in the model.

Fits to indices are generally fairly poor except for the CAN_acoustic index which is very well fit (**Figure 21**). The estimated stock recruitment relationship indicates a positive relationship between SSB and recruitment with high interannual variability in estimated recruitment deviations (**Figure 22**). Of note is the declining trend in recruitment deviations in recent years. Steepness was estimated to be 0.55 and 0.47, respectively, for runs 12 and 13, respectively, despite the differing spawning assumptions of late versus early spawning. This result might be counterintuitive but is a product of internally estimating the stock-recruitment relationship. In this case the higher age at maturity model estimates that there are more recruits per spawner than in the lower age at maturity. Nonetheless the stock-recruitment relationships are not strongly determined.

Overall the length composition data are fairly well fit with few systematic departures with only the JLL_GOM being systematically not fit (**Figure 23**). Fits for each year and each fleet (**Figures 24-35**) indicate that while overall most fits are good, there are many years with departures. Problematic departures can be seen in the Pearson residuals where one would look for strong patterned trends (**Fig. 36-47**).

Of particular note is the recent residual pattern in the JAPAN_LL where there remain strong positive residuals along a diagonal and a near absence of fish below this diagonal from about 2000 onward (**Fig 36**). This pattern was mitigated from early runs by allowing for time-varying selectivity (**Figure 39**). This pattern is somewhat evident in the OTHER_ATL_LL and the CAN_HL residuals (**Figures. 43, 44**) and can be seen in the raw data (**Figures 8, 9**). The model currently interprets- and attempts to account for the absence of these fish through a declining trend in recruitment deviations since 2005 and these patterns warrant further evaluation, particularly as the values in **Figure 43** and **44** are residuals and if the model were to actually fit these the declines in recruitment would be even greater. There is the possibility that the high 2002 and 2003 age 0 recruitments could be creating this type of pattern due to size/age specific schooling, or due them actually being of Eastern origin. In either case the declining recruitment estimated by the model appears to be a product of this pattern in the size composition and is not actually observed in the young fish indices US_RR_115_144 which the model estimates a substantial divergence in recent years (**Figure 21**). Hence this may be one of the clear areas of conflict between the length composition and the indices.

The lack of fit to the JLL_GOM could be reconciled by allowing for dome-shaped selectivity but this seems rather implausible for a fishery centered on the spawning area of the oldest fish. The size composition is extremely sharp indicating that it could be a product several cohorts and that due to the short time period of data the lack of fit may be due to the effect of a transient cohort. Given that this represents some of the earliest length composition in the model this could be one of the factors influencing some of the initial model instability in estimating the earliest recruitment deviations.

Early model versions showed some systematic lack of fit appear in the early CAN_HOOKLINE which was reconciled by splitting this fleet into an early GSL fleet and also in the time period after 1996 for the USA_RR FS. The lack of fit to the USA_RR_FS was substantially diminished by imposing a time block on the selectivity in 1992 due to the effect of size limits (**Figure 45**).

Fits to the JAPAN_LL catch at age estimated by cohort slicing are fairly good and resemble the fits to the length composition (**Figures. 54, 55**) except in the first 20 years when the CAA is not used for the VPA and in the recent years due to the aforementioned lack of fit. This indicates that, at least for the construction of the CAA for the Japan LL, the assumptions used for the cohort slicing are not at odds with the assumptions of growth in SS. Further evidence of this similarity can be seen in the nearly exact match of the growth curve estimated by Ailloud *et al.*

(2017) and the growth curve freely estimated in SS (**Figure. 56).** Note that in subsequent model runs (Runs 12 and 13) the length at Amin was fixed at the previous estimates to avoid parameter confounding with the von bertalanffy K. Note that there is a slight divergence at the youngest age which results in a slight divergence in the internally scaled natural mortality in SS versus the vector agreed upon at the DW (**Figure 56**).

Overall the times series of SSB and recruitment and other derived parameters are extremely similar between the two model runs (**Figure 57**) indicating the relatively limited effect of changing the age at maturity on model fit or model performance. While SSB is scaled higher or lower the resulting total biomass estimates and relative levels of depletion from virgin (**Figure 57**) are very similar. Both models indicate stock decreasing during the 1970s remaining relatively low during the 1980-2000 period and showing a pattern of steady population growth since 2000. Fishing mortality has generally decreased in the recent 20 years. The time series of SSB and recruitment also show less evidence of a 'regime change' in the longer time series and more indication recruitment declining due to a decline in SSB (**Figure. 58).**

The jackknife results indicate that greatest model tension is between the GOM larval index and the USRR>177 and the CAN_NS. Removing either the GOM larval or the USRR>177 results in more strongly increasing SSB, while removing the CAN_NS results in a much reduced SSB increase (**Figure 59**).

Model runs

Overall thirteen different model runs were conducted to evaluate different hypotheses or to deal with issues raised at the assessment workshop. Overall there was little major differences across model runs though except the model run with no stock-recruitment relationship was fairly divergent (**Figure 60**). The final model runs chosen for advice were models 12 and 13.

runs	LL	SSBinit	SSB2015	grad	comment
1	5992.9	184812	32012.5	0.000302	high age at mat
2	6004.56	226433	39372.5	0.001961	low age at mat
3	5602.95	154218	23752.6	2.59E-05	M=0.07
4	5710.05	192139	27354.6	0.000852	model growth with a cv as a function of length
5	5760	86110	41906	0.000504	free rec devs (e.g. no stock recruitment relationship)
6	5530.84	179472	32293.5	0.000164	no aging bias time blocks, GSL1 new fleet, CAN Acoustic mirror GSL1, JLLsplit and RW
7	5516.1	176726	33959.5	0.002382	like 6 but with aging bias
8	5431.17	177492	28388	0.000774	like 7 but with env effect
9	5433.35	224102	38682.4	0.000786	like 8 but with low age at maturity
10	5413.13	176169	27612.2	0.000913	Like 8 but with Rodriguez *et al.* LW
11	5411.89	223642	38466.5	0.000422	Like 9 but with Rodriguez *et al.* LW
12	5413.97	175941	28218.6	0.002541	BASE1. Like 10 but several correlated parms fixed at estimates
13	5408.97	224180	38828.1	0.00405	BASE2. Like 11 but several correlated parms fixed at estimates

Stock status

Stock status estimates from deterministic results indicate that the current fishing mortality rates (**Table 6**) are both below $F_{0.1}$ and F_{msy} indicating that overfishing is not occurring at either of these metrics. Given uncertainty in appropriate biomass reference points it is not clear what the current biomass status is at this point.

Projections

Projections were conducted for 10 TACs, three fishing mortality rates and four recruitment scenarios across both models 12 and 13. Fixed TAC projections across all recruitment scenarios indicate that the level of assumed recruitment has little influence on 2018 TACs (**Figure 62 and 63**) and that, across most recruitment and F scenarios the SSB will decline as the 2003 year class declines. Yields in the range of 1500-2000t would be necessary to avoid the stock declines in these projections.

Fixed F projections for yield in 2018 could be in the range of 2800 t for the F0.1 across the recruitment scenarios (**Table 7. Figure 64**). Much of these projected yields are due to the continued influx of the 2003 year class into the projected catch and these yields decline in the future. Projected yields at F_{msy} are lower (~1450 t) but also assume that recruitment will revert to the stock recruitment relationship which would assume higher recruitment than observed in the three geometric mean time periods (**Table 7**, **Figure 63**).

Discussion

Overall the model shows relatively good stability though there is some initial instability in the early rec dev estimation and the fit to the indices is rather low. Nonetheless the model is relatively stable across the two model runs and the various diagnostic. Fits to the composition data are relatively good, though there are some noticeable 'diagonal' patterns in the data where the composition data sees more fish than the model can estimate. This is a common pattern arising from really peaked length composition which could be the product of catches of a single year class. If there is year-class specific schooling this could manifest as higher selectivity on a particular year class, a phenomenon noted by several authors (Mather *et al.* 1995) and seen in fisheries such as the Norwegian purse seine which was focused on only a few cohorts that appeared in Norway waters. Alternatively, it could be a product of a strong 2002-2003 cohort of Eastern fish entering the Western fisheries.

This issue could be the reason for the systematic lack of fit to a) the JLL_GOM and b) the JAPAN_LL in the Atlantic in the most recent years, both of which are far more peaked than the estimated selectivity would allow. The model interprets the JAPAN_LL- and some of the other composition data as indicative of the presence of really only a single year class with little surrounding recruitment. This is evidenced by the residual 'triangle' of missing fish in this composition data and results in the model estimating a substantial recent declining recruitment. This could pose a problem for the projections in that they will likely show a decline in biomass in the near term due to the absence of recruitment and this issue should be further evaluated. Allowing the selectivity for the JAPAN_LL to vary in the recent years, improved this issue though the selectivity still does not fit the data well indicating that there are other signals in the models which might not allow this to fit. This could be that other fleets do not see such a strong 2003 cohort. Given that the JAPAN_LL fleet fishes on a very mixed East and West stock, if the strong 2003 cohort peak is due to substantial numbers of Eastern origin fish, this unaccounted for mixing could be part of the problem.

The retrospective pattern on recruitment deserves some comment as there was a noticeable retrospective pattern. The pattern in recruitment is due to the parameterization of the recruitment deviation bias adjustment ramping where the last year of estimated recruitment deviations converges towards a deviation of zero, resulting in a prediction of recruitment from the stock-recruitment curve in the absence of informative data on recruitment. This could be over-ridden for projections or to improve these plots, but in general is not a strong concern and one might want to impose this reversion to the mean in the absence of data similar to the replacement of recruitments in the VPA.

Accounting for the divergent patterns in CPUE between the US rod and reel >177 and the two Canadian indices through the AMO resulted in a substantially improved model fit. Parameter estimates indicated a strongly positive effect of the AMO on the two Canadian indices and a strong negative effect on the US RR>177 indicating a plausible mechanism whereby the generally warming pattern in the Northwest Atlantic might shift BFT distribution away from U.S. waters and towards the Canadian fisheries. The plausibility of this hypothesis should be further tested with empirical movement data, more detailed exploration of the catch rate data and habitat modeling.

In general, the two model runs with early versus late spawning were almost imperceptibly different (though with different absolute magnitudes of SSB), with steepness and F_{msy} estimated to be very slightly higher in the later spawning. The similarity of the two runs is such that the early/late spawning is not really a major sensitivity on the model results which means that more time and effort should be focused on more critical sources of uncertainty such historical data resurrection, natural mortality, environmental effects on catchability, larval survival or stock mixing. One could further obviate the age at maturity debate altogether by calculating benchmarks according to total biomass as well.

Conclusions

The two model runs presented here represent a combination of the most data ever provided for a WBFT assessment. The integrated modeling framework also provides a strong platform for testing numerous hypothesis or for consideration as an operating model. To conclude we summarize the model strengths, weaknesses and concerns:

Strengths: long time series of information, makes the most of all available data with the limited assumptions regarding growth, shape of natural mortality, inherent productivity or catch or size at age.

Weaknesses: Creation of some data series required interpolations and splitting length composition data at size cut-offs that may not exactly fit the fisheries. Tagging index not used. Poor fit to CPUE indices, perhaps too much weight on length/age data. The lack of fit to the recent time series of Japan longline composition data. Poor composition data in early time period reflected in very high CVs on estimated recruitments. Poor stock recruitment relationship, albeit while still freely estimating steepness, R0 and sigmaR.

Concerns: Declining trend in recruitment in recent years may be due to changing selectivity of Japan longline to focus on the 2003 year class (born in 2002). If there is age-specific schooling this may be the case as the strongly peaked composition data suggests that almost all of the Japan longline catch is of this year class and the model does not fit this well. Conversely the lack of appearance of other year classes could be indicative of a decline in recruitment. SigmaR is for the maximum posterior density estimate is outside of the estimate for the bootstraps, which may be a function of the bootstraps not being as noisy as the comp data.

Acknowledgements

We are grateful for the contributions of the Secretariat, the combined efforts of a vast number of colleagues who, through GBYP, have resurrected age-length information, catches and other historical data that facilitate creating an integrated model that uses as much data as possible for WBFT. The first author thanks Matt Siskey who greatly facilitated assigning gears to the age composition data and Michael Schirripa who helped substantially in incorporating the AMO into modeling. The authors are extremely grateful to Rick Methot and Ian Taylor who have helped with understanding the *Stock Synthesis* software and supporting graphical routines in R4SS produced.

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Table 1. Names and fishery definitions of the fleets used in the SS model.

Num.	*Fleet/Index*	*Selectivity (all length based except fleet 15)*	*block*	*use*	*start*	*end*
1	JAPAN_LL	Double Normal	N	Y	1957	2015
2	USA_CAN_PSFS	Double Normal	N	Y	1950	1984
3	USA_CAN_PSFB	Double Normal	N	Y	1950	2015
4	USA_TRAP	Double Normal	N	Y	1950*	1974
5	USA_CAN_HARPOON	logistic	N	Y	1950*	2015
6	USA_RRFB	Double Normal	N	Y	1950	2015
7	USA_RRFS	Double Normal	N	Y	1950	2015
8	OTHER_ATL_LL	logistic	N	Y	1952	2015
9	CAN_HOOKLINE	logistic	N	Y	1950	2015
10	GOM_LL_US_MEX	logistic	N	Y	1972	2015
11	JLL_GOM	logistic	N	Y	1974	1981
12	CAN_TRAP	logistic	N	Y	1950	2015
13	CAN_GSL1	logistic	N	Y	1950	1987
14	IND1_JAPAN_LL	mirror JAPAN_LL	N	Y	1976	2015
15	IDX2_US_RR_66_114	mirror RRFS	N	Y	1993	2015
16	IDX3_US_RR_115_144	Ages 4-5	N	Y	1993	2015
17	IDX4_US_RR_LT145	mirror RRFS	N	Y	1980	1992
18	IDX5_US_RR_GT177	mirror RRFB	N	Y	1993	2015
19	IDX6_US_RR_GT195	mirror RRFB	N	Y	1983	1992
20	IDX7_USPLL_GOM	mirror GOM_LL	N	Y	1987	1992
21	IDX8_JLL_GOM	mirror JLL_GOM	N	Y	1974	1981
22	IDX9_CAN_NS	mimic CAN_HL	N	Y	1984	2015
23	IDX10_GOM larval	SSB	N	Y	1977	2015
24	IDX11_tagging	NA	N	N	1970	1981
25	IDX12_CAN_ACOUSTIC	mimic CAN_GSL1	N	Y	1994	2015
26	IDX13_oceanographic	exp(rec devs)	N	N	1993	2011
27	IND14_JAPAN_LL2	mirror JAPAN_LL	N	Y	2010	2015
28	IND15_USPLL_GOM_LL2	mirror GOM_LL	N	Y	1993	2015

*Fishery starts with equilibrium catch.

Table 2. Task I landings input for SS3.

year	USA CAN PSFS		USA CAN PSFB	USA TRAP	USA CAN HARP	USA RRFB	USA RRFS	OTHER ATL LL	CAN HL	GOM LL US MEX	JLL GOM	CAN TRAP
equ. Cat.	*0*	*0*	*435*	*310*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
1950	0	1	0	346	459	88	38	0	75	0	0	10
1951	0	85	15	491	263	155	1	0	86	0	0	27
1952	0	0	0	135	323	95	0	7	69	0	0	65
1953	0	0	0	766	197	86	5	1	29	0	0	0
1954	0	47	8	531	129	46	13	5	49	0	0	0
1955	0	0	0	377	135	14	4	16	9	0	0	0
1956	0	0	0	181	47	14	2	40	3	0	0	0
1957	30	0	0	404	58	19	15	16	4	0	0	0
1958	32	117	21	869	61	64	3	40	0	0	0	0
1959	200	664	117	302	125	58	7	83	14	0	0	79
1960	339	235	42	204	119	46	9	1	5	0	0	32
1961	373	768	135	79	78	44	23	0	41	0	0	79
1962	1219	3203	565	87	44	239	133	132	40	0	0	137
1963	6191	4905	866	74	22	677	418	367	90	0	0	229
1964	12044	4378	773	161	24	313	196	303	99	0	0	318
1965	9147	2831	500	166	55	597	378	318	94	0	0	81
1966	2471	855	151	134	46	2211	1410	604	111	0	0	87
1967	694	1770	312	139	53	198	112	2432	56	0	0	174
1968	272	584	103	25	61	286	171	1393	180	0	0	101
1969	116	1118	0	38	30	757	113	477	170	0	0	193
1970	66	3335	953	53	72	447	57	202	151	0	0	130
1971	1375	3166	603	47	166	949	123	15	88	0	0	59
1972	321	1549	462	29	160	1058	111	18	188	23	0	29
1973	1097	1387	269	13	86	546	31	30	239	29	0	144
1974	824	892	68	20	214	185	2361	41	409	39	81	256
1975	237	2009	311	0	0	694	122	49	206	24	1276	144
1976	790	1365	217	0	189	382	28	246	342	37	2112	172
1977	1033	1292	210	0	157	512	60	118	302	14	2625	372
1978	709	1117	113	0	158	645	51	80	208	28	2436	221
1979	1298	1012	369	0	143	647	95	101	214	22	2323	31
1980	1420	537	221	0	102	555	80	37	259	10	2516	47
1981	1759	516	394	0	109	462	71	37	279	90	2012	41
1982	292	101	136	0	86	370	89	68	436	14	0	68
1983	711	109	275	0	159	620	117	118	426	12	0	7
1984	696	57	344	0	115	561	116	73	261	75	0	3
1985	1092	0	377	0	166	614	135	50	122	98	0	20
1986	584	0	360	0	127	422	94	577	41	124	0	0
1987	960	0	367	0	122	569	156	136	33	142	0	17
1988	1109	0	383	0	151	475	125	197	275	173	0	14
1989	468	0	385	0	187	627	161	255	579	101	0	1
1990	550	0	384	0	129	501	476	151	432	156	0	2
1991	688	0	237	0	129	570	483	150	479	193	0	0
1992	512	0	300	0	105	441	116	261	433	127	0	1
1993	581	0	295	0	121	558	209	148	372	71	0	29
1994	427	0	301	0	102	642	93	139	274	56	0	79
1995	387	0	249	0	120	661	260	184	457	58	0	72
1996	436	0	245	0	128	529	355	221	453	55	0	90

1997	330	0	250	0	153	772	180	181	383	26	0	59
1998	691	0	249	0	169	642	167	170	475	26	0	68
1999	365	0	248	0	154	673	103	648	473	62	0	44
2000	492	0	275	0	202	638	50	516	514	72	0	16
2001	506	0	196	0	122	1010	245	179	481	30	0	16
2002	575	0	208	0	68	1008	519	320	547	45	0	28
2003	57	0	265	0	98	677	315	285	449	76	0	84
2004	470	0	32	0	48	389	329	195	470	160	0	32
2005	265	0	178	0	46	257	170	163	541	129	0	8
2006	376	0	4	0	50	218	158	236	664	102	0	3
2007	277	0	28	0	40	235	399	155	412	88	0	4
2008	492	0	0	0	54	307	352	154	499	119	0	23
2009	162	0	11	0	84	717	143	290	427	122	0	23
2010	353	0	0	0	66	573	111	280	364	70	0	39
2011	578	0	0	0	100	420	173	341	342	27	0	26
2012	289	0	2	0	83	421	149	260	381	153	0	17
2013	317	0	43	0	70	251	115	243	377	55	0	11
2014	302	0	42	0	79	379	100	242	371	92	0	20
2015	347	0	39	0	103	581	113	163	427	62	0	6

*gray shaded years are a product of an interpolated decline from PSFS to PSFB over 1980-1984.

** blue shaded years are a product of splitting PSFS

*** very minor “other” task I allocated to similar or most abundant fishery (usually US RRFB)

Table 3. Table of key information for models 12 and 13, noting the specifications, log-likelihoods, run time, and parameters that hit bounds.

model	Run12, later spawning	Run13, early spawning
max gradient component	0.002541	0.00405
run time	17	17
total loglikelihood	5413.97	5408.97
Catch	1.16E-11	1.17E-11
Equil_catch	0.831404	0.595269
Survey	616.722	616.565
Length_comp	3450.58	3448.05
Age_comp	1334.85	1334.28
Recruitment	5.94366	4.42335
Forecast_Recruitment	0	0
Parm_priors	0.710684	0.710534
Parm_softbounds	0.012731	0.012746
Parm_devs	4.32179	4.33238
Crash_Pen	0	0
bounded parms	0	0

Table 4. Parameter estimates, phases initial values and standard deviations for run 12. Rec devs not shown.

Num	Label	Value	active num	Phase	Min	Max	Init	Status	SD	prior	Prior	Pr_SD	type
1	NatM_p_1_Fem_GP_1	0.1	_	-3	0.05	0.3	0.1	NA	_	No_prior	0	0	biology
2	L_at_Amin_Fem_GP_1	42.9753	_	-2	0	50	42.975	NA	_	No_prior	0	0	growth
3	L_at_Amax_Fem_GP_1	263.326	1	4	200	400	266.91	OK	0.7875	No_prior	0	0	growth
4	VonBert_K_Fem_GP_1	0.2539	2	4	0.05	0.4	0.2577	OK	0.0066	No_prior	0	0	growth
5	Richards_Fem_GP_1	-0.4742	3	4	-3	3	-0.655	OK	0.0565	No_prior	0	0	growth
6	CV_young_Fem_GP_1	0.1041	4	3	0.05	0.25	0.1073	OK	0.0061	No_prior	0	0	growth
7	CV_old_Fem_GP_1	0.06708	5	3	0.02	0.25	0.0481	OK	0.0016	No_prior	0	0	growth
8	Wtlen_1_Fem	1.8E-05	_	-3	1E-08	0.01	2E-05	NA	_	No_prior	0	0	
9	Wtlen_2_Fem	3.00125	_	-3	2	4	3.0013	NA	_	No_prior	0	0	
10	Mat50%_Fem	8.8	_	-3	4	15	8.8	NA	_	No_prior	0	0	
11	Mat_slope_Fem	-50	_	-3	-100	-1	-50	NA	_	No_prior	0	0	
12	Eggs_scalar_Fem	1	_	-3	1	1	1	NA	_	No_prior	0	0	
13	Eggs_exp_wt_Fem	1	_	-3	1	1	1	NA	_	No_prior	0	0	
14	RecrDist_GP_1	0	_	-4	0	0	0	NA	_	No_prior	0	0	
15	RecrDist_Area_1	0	_	-4	0	0	0	NA	_	No_prior	0	0	
16	RecrDist_Seas_1	0	_	-4	0	0	0	NA	_	No_prior	0	0	
17	CohortGrowDev	0	_	-4	0	0	0	NA	_	No_prior	0	0	
18	SR_LN(R0)	6.46259	6	2	3	18	6.4903	OK	0.0381	No_prior	0	0	SRR
19	SR_BH_steep	0.54547	7	2	0.2	0.99	0.552	OK	0.0274	No_prior	0	0	SRR
20	SR_sigmaR	0.71368	8	6	0	2	0.7405	OK	0.0876	No_prior	0	0	SRR
21	SR_envlink	0	_	-3	-5	5	0	NA	_	No_prior	0	0	
22	SR_R1_offset	0	_	-4	-5	5	0	NA	_	No_prior	0	0	
23	SR_autocorr	0	_	-99	0	0	0	NA	_	No_prior	0	0	
99	InitF_1JAPAN_LL	0	_	-1	0	1	0	NA	_	No_prior	0	0	initF
100	InitF_2USA_CAN_PSFS	0	_	-1	0	1	0	NA	_	No_prior	0	0	initF
101	InitF_3USA_CAN_PSFB	0	_	-1	0	1	0	NA	_	No_prior	0	0	initF
102	InitF_4USA_TRAP	0.01306	63	5	1E-05	1	0.0126	OK	0.002	No_prior	0	0	initF
103	InitF_5USA_CAN_HARPOON	0.00147	_	-5	1E-05	1	0.0015	NA	_	No_prior	0	0	initF

104	InitF_6USA_RRFB	0	_	-1	0	1	0	NA	_	No_prior	0	0	initF
105	InitF_7USA_RRFS	0	_	-1	0	1	0	NA	_	No_prior	0	0	initF
106	InitF_8OTHER_ATL_LL	0	_	-1	0	1	0	NA	_	No_prior	0	0	initF
107	InitF_9CAN_HOOKLINE	0	_	-1	0	1	0	NA	_	No_prior	0	0	initF
108	InitF_10GOM_LL_US_MEX	0	_	-1	0	1	0	NA	_	No_prior	0	0	initF
109	InitF_11JLL_GOM	0	_	-1	0	1	0	NA	_	No_prior	0	0	initF
110	InitF_12CAN_TRAP	0	_	-1	0	1	0	NA	_	No_prior	0	0	initF
111	InitF_13CAN_GSL1	0	_	-1	0	1	0	NA	_	No_prior	0	0	initF
112	Q_envlink_18_IDX5_US_RR_GT177	-0.8279	64	4	-5	5	0	OK	0.2251	No_prior	0	0	qenv
113	Q_envlink_22_IDX9_CAN_GSLNS	2.00681	65	4	-5	5	0	OK	0.1674	No_prior	0	0	qenv
114	Q_envlink_25_IDX12_CAN_ACOUSTIC	0.88043	66	4	-5	5	0	OK	0.2556	No_prior	0	0	qenv
115	LnQ_base_18_IDX5_US_RR_GT177	-4.8205	67	1	-15	1E-06	-4.735	OK	0.0789	No_prior	0	0	q
116	LnQ_base_22_IDX9_CAN_GSLNS	-5.1155	68	1	-15	1E-06	-4.735	OK	0.072	No_prior	0	0	q
117	LnQ_base_25_IDX12_CAN_ACOUSTIC	-5.8079	69	1	-15	1E-06	-4.735	OK	0.1265	No_prior	0	0	q
118	SizeSel_1P_1_JAPAN_LL	207.529	70	2	40	250	155	OK	5.5829	No_prior	0	0	sel
119	SizeSel_1P_2_JAPAN_LL	-9.3634	71	2	-10	3	-1.788	OK	15.884	No_prior	0	0	sel
120	SizeSel_1P_3_JAPAN_LL	6.97326	72	3	-5	9	7.437	OK	0.2284	No_prior	0	0	sel
121	SizeSel_1P_4_JAPAN_LL	7.74345	_	-2	-5	9	7.7435	NA	_	No_prior	0	0	sel
122	SizeSel_1P_5_JAPAN_LL	-999	_	-3	-99	15	-999	NA	_	No_prior	0	0	sel
123	SizeSel_1P_6_JAPAN_LL	-5.6885	73	4	-20	10	-13.58	OK	19.732	No_prior	0	0	sel
124	SizeSel_2P_1_USA_CAN_PSFS	68.4973	_	-2	40	100	68.497	NA	_	No_prior	0	0	sel
125	SizeSel_2P_2_USA_CAN_PSFS	-1	_	-3	-5	3	-1	NA	_	No_prior	0	0	sel
126	SizeSel_2P_3_USA_CAN_PSFS	3.87105	74	4	-4	12	3.9104	OK	0.4647	Sym_Beta	0.5	0.1	sel
127	SizeSel_2P_4_USA_CAN_PSFS	-5	_	-3	-5	6	-5	NA	_	No_prior	0	0	sel
128	SizeSel_2P_5_USA_CAN_PSFS	-999	_	-2	-15	5	-999	NA	_	No_prior	0	0	sel
129	SizeSel_2P_6_USA_CAN_PSFS	-999	_	-2	-15	10	-999	NA	_	No_prior	0	0	sel
130	SizeSel_3P_1_USA_CAN_PSFB	213.666	_	-1	40	250	213.67	NA	_	No_prior	0	0	sel
131	SizeSel_3P_2_USA_CAN_PSFB	-2.5273	75	2	-5	3	-2.160	OK	0.3512	No_prior	0	0	sel
132	SizeSel_3P_3_USA_CAN_PSFB	6.93862	76	3	-4	12	6.8998	OK	0.0745	Sym_Beta	0.5	0.1	sel
133	SizeSel_3P_4_USA_CAN_PSFB	6	_	-3	-2	6	6	NA	_	No_prior	0	0	sel
134	SizeSel_3P_5_USA_CAN_PSFB	-999	_	-2	-15	5	-999	NA	_	No_prior	0	0	sel
135	SizeSel_3P_6_USA_CAN_PSFB	-2.2311	77	4	-15	5	-3.136	OK	0.4521	No_prior	0	0	sel
136	SizeSel_4P_1_USA_TRAP	142.47	78	1	40	200	143.78	OK	11.9	No_prior	0	0	sel

137	SizeSel_4P_2_USA_TRAP	-4.054	79	3	-5	3	-4.356	OK	2.1529	Sym_Beta	-4	0.1	sel
138	SizeSel_4P_3_USA_TRAP	8.59545	80	3	-4	12	8.496	OK	0.3993	No_prior	0	0	sel
139	SizeSel_4P_4_USA_TRAP	7.23267	81	3	-2	10	7.2499	OK	0.484	Sym_Beta	1.2	0.1	sel
140	SizeSel_4P_5_USA_TRAP	-999	_	-2	-15	5	-999	NA	_	No_prior	0	0	sel
141	SizeSel_4P_6_USA_TRAP	-999	_	-2	-15	10	-999	NA	_	No_prior	0	0	sel
142	SizeSel_5P_1_USA_CAN_HARPOON	176.286	82	2	30	250	176.93	OK	0.9176	No_prior	0	0	sel
143	SizeSel_5P_2_USA_CAN_HARPOON	17.5697	83	2	10	100	17.782	OK	1.3107	No_prior	0	0	sel
144	SizeSel_6P_1_USA_RRFB	190.38	84	1	40	200	191.23	OK	0.9951	No_prior	0	0	sel
145	SizeSel_6P_2_USA_RRFB	-0.5543	_	-3	-5	3	-0.554	NA	_	No_prior	0	0	sel
146	SizeSel_6P_3_USA_RRFB	6.56855	_	-3	-4	12	6.5686	NA	_	No_prior	0	0	sel
147	SizeSel_6P_4_USA_RRFB	6	_	-3	-2	6	6	NA	_	Sym_Beta	1.4	0.05	sel
148	SizeSel_6P_5_USA_RRFB	-999	_	-2	-15	5	-999	NA	_	No_prior	0	0	sel
149	SizeSel_6P_6_USA_RRFB	-0.5837	85	2	-15	5	-1.241	OK	0.3571	No_prior	0	0	sel
150	SizeSel_7P_1_USA_RRFS	89.6566	86	1	40	200	93.971	OK	0.6018	No_prior	0	0	sel
151	SizeSel_7P_2_USA_RRFS	-1.5	_	-2	-5	3	-1.5	NA	_	Sym_Beta	-5	5	sel
152	SizeSel_7P_3_USA_RRFS	6.48538	_	-3	-4	12	6.4854	NA	_	No_prior	0	0	sel
153	SizeSel_7P_4_USA_RRFS	0.9731	_	-3	-2	6	0.9731	NA	_	No_prior	0	0	sel
154	SizeSel_7P_5_USA_RRFS	-999	_	-2	-15	5	-999	NA	_	No_prior	0	0	sel
155	SizeSel_7P_6_USA_RRFS	-5	_	-2	-15	10	-5	NA	_	No_prior	0	0	sel
156	SizeSel_8P_1_OTHER_ATL_LL	154.633	87	2	30	250	176.93	OK	2.3965	No_prior	0	0	sel
157	SizeSel_8P_2_OTHER_ATL_LL	47.9283	88	2	10	100	17.782	OK	2.4189	No_prior	0	0	sel
158	SizeSel_9P_1_CAN_HOOKLINE	192.111	89	2	30	300	212.93	OK	1.8767	No_prior	0	0	sel
159	SizeSel_9P_2_CAN_HOOKLINE	31.9166	90	2	10	100	58.182	OK	2.255	No_prior	0	0	sel
160	SizeSel_10P_1_GOM_LL_US_MEX	214.856	91	2	30	300	208.86	OK	2.6588	No_prior	0	0	sel
161	SizeSel_10P_2_GOM_LL_US_MEX	39.733	92	2	10	100	34.111	OK	2.8512	No_prior	0	0	sel
162	SizeSel_11P_1_JLL_GOM	197.457	93	2	30	250	193.17	OK	5.4316	No_prior	0	0	sel
163	SizeSel_11P_2_JLL_GOM	22.8986	94	2	10	100	20.182	OK	6.7331	No_prior	0	0	sel
164	SizeSel_12P_1_CAN_TRAP	258.489	95	2	30	300	248.14	OK	4.4153	No_prior	0	0	sel
165	SizeSel_12P_2_CAN_TRAP	57.7566	96	2	10	100	55.264	OK	2.8224	No_prior	0	0	sel
166	SizeSel_13P_1_CAN_GSL1	259.622	97	2	30	320	212.93	OK	1.8792	No_prior	0	0	sel
167	SizeSel_13P_2_CAN_GSL1	21.6795	98	2	10	100	58.182	OK	2.2324	No_prior	0	0	sel
168	SizeSel_15P_1_IDX2_US_RR_66_114	65	_	-3	40	200	65	NA	_	No_prior	0	0	sel
169	SizeSel_15P_2_IDX2_US_RR_66_114	-1.7	_	-3	-5	3	-1.7	NA	_	No_prior	0	0	sel
170	SizeSel_15P_3_IDX2_US_RR_66_114	-4	_	-3	-4	12	-4	NA	_	No_prior	0	0	sel
171	SizeSel_15P_4_IDX2_US_RR_66_114	-2	_	-3	-2.5	6	-2	NA	_	No_prior	0	0	sel

172	SizeSel_15P_5_IDX2_US_RR_66_114	-999	_	-2	-15	5	-999	NA	_	No_prior	0	0	sel
173	SizeSel_15P_6_IDX2_US_RR_66_114	-5	_	-2	-15	10	-5	NA	_	No_prior	0	0	sel
174	SizeSel_16P_1_IDX3_US_RR_115_144	115	_	-3	40	200	115	NA	_	No_prior	0	0	sel
175	SizeSel_16P_2_IDX3_US_RR_115_144	-2.1	_	-3	-5	3	-2.1	NA	_	No_prior	0	0	sel
176	SizeSel_16P_3_IDX3_US_RR_115_144	-4	_	-3	-4	12	-4	NA	_	No_prior	0	0	sel
177	SizeSel_16P_4_IDX3_US_RR_115_144	-2	_	-3	-2.5	6	-2	NA	_	No_prior	0	0	sel
178	SizeSel_16P_5_IDX3_US_RR_115_144	-999	_	-2	-15	5	-999	NA	_	No_prior	0	0	sel
179	SizeSel_16P_6_IDX3_US_RR_115_144	-5	_	-2	-15	10	-5	NA	_	No_prior	0	0	sel
180	SizeSel_1P_1_JAPAN_LL_BLK1repl_1950	162	_	-5	40	250	162	NA	_	No_prior	0	0	sel
181	SizeSel_1P_2_JAPAN_LL_BLK1repl_1950	-4.3982	99	5	-10	3	-1.78	OK	1.048	No_prior	0	0	sel
182	SizeSel_1P_3_JAPAN_LL_BLK1repl_1950	7.66975	100	5	-5	9	7.43	OK	0.0387	No_prior	0	0	sel
183	SizeSel_1P_4_JAPAN_LL_BLK1repl_1950	7.74	_	-2	-5	9	7.74	NA	_	No_prior	0	0	sel
184	SizeSel_1P_5_JAPAN_LL_BLK1repl_1950	-999	_	-3	-999	15	-999	NA	_	No_prior	0	0	sel
185	SizeSel_1P_6_JAPAN_LL_BLK1repl_1950	-4.5884	101	5	-20	10	-13.58	OK	0.8021	No_prior	0	0	sel
186	SizeSel_7P_1_USA_RRFS_BLK3repl_1992	106.033	102	1	40	200	93.971	OK	0.7593	No_prior	0	0	sel
187	SizeSel_7P_2_USA_RRFS_BLK3repl_1992	-1.5	_	-2	-5	3	-1.5	NA	_	Sym_Beta	-5	0.05	sel
188	SizeSel_7P_3_USA_RRFS_BLK3repl_1992	6.48538	_	-3	-4	12	6.4854	NA	_	No_prior	0	0	sel
189	SizeSel_7P_4_USA_RRFS_BLK3repl_1992	0.9731	_	-3	-2	6	0.9731	NA	_	No_prior	0	0	sel
190	SizeSel_7P_5_USA_RRFS_BLK3repl_1992	-999	_	-2	-15	5	-999	NA	_	No_prior	0	0	sel
191	SizeSel_7P_6_USA_RRFS_BLK3repl_1992	-5	_	-2	-15	10	-5	NA	_	No_prior	0	0	sel

Table 5. Parameter estimates, phases initial values and standard deviations for run 13. Rec devs not shown.

Num	Label	Value	active num	Phase	Min	Max	Init	Status	SD	prior	Prior	Pr_SD	type
1	NatM_p_1_Fem_GP_1	0.1	_	-3	0.05	0.3	0.1	NA	_	No_prior	0	0	biology
2	L_at_Amin_Fem_GP_1	42.9753	_	-2	0	50	42.975	NA	_	No_prior	0	0	growth
3	L_at_Amax_Fem_GP_1	263.278	1	4	200	400	266.91	OK	0.7882	No_prior	0	0	growth
4	VonBert_K_Fem_GP_1	0.25189	2	4	0.05	0.4	0.2577	OK	0.0065	No_prior	0	0	growth
5	Richards_Fem_GP_1	-0.4526	3	4	-3	3	-0.6557	OK	0.0557	No_prior	0	0	growth
6	CV_young_Fem_GP_1	0.10381	4	3	0.05	0.25	0.1073	OK	0.006	No_prior	0	0	growth
7	CV_old_Fem_GP_1	0.0672	5	3	0.02	0.25	0.0481	OK	0.0016	No_prior	0	0	growth
8	Wtlen_1_Fem	1.8E-05	_	-3	1E-08	0.01	2E-05	NA	_	No_prior	0	0	
9	Wtlen_2_Fem	3.00125	_	-3	2	4	3.0013	NA	_	No_prior	0	0	
10	Mat50%_Fem	8.8	_	-3	4	15	8.8	NA	_	No_prior	0	0	
11	Mat_slope_Fem	-50	_	-3	-100	-1	-50	NA	_	No_prior	0	0	
12	Eggs_scalar_Fem	1	_	-3	1	1	1	NA	_	No_prior	0	0	
13	Eggs_exp_wt_Fem	1	_	-3	1	1	1	NA	_	No_prior	0	0	
14	RecrDist_GP_1	0	_	-4	0	0	0	NA	_	No_prior	0	0	
15	RecrDist_Area_1	0	_	-4	0	0	0	NA	_	No_prior	0	0	
16	RecrDist_Seas_1	0	_	-4	0	0	0	NA	_	No_prior	0	0	
17	CohortGrowDev	0	_	-4	0	0	0	NA	_	No_prior	0	0	
18	SR_LN(R0)	6.472	6	2	3	18	6.4903	OK	0.038	No_prior	0	0	SRR
19	SR_BH_steep	0.47086	7	2	0.2	0.99	0.552	OK	0.0239	No_prior	0	0	SRR
20	SR_sigmaR	0.67838	8	6	0	2	0.7405	OK	0.085	No_prior	0	0	SRR
21	SR_envlink	0	_	-3	-5	5	0	NA	_	No_prior	0	0	
22	SR_R1_offset	0	_	-4	-5	5	0	NA	_	No_prior	0	0	
23	SR_autocorr	0	_	-99	0	0	0	NA	_	No_prior	0	0	
78	Late_RecrDev_2015	0	_	_	_	_	_	NA	_	dev	0	0	
99	InitF_1JAPAN_LL	0	_	-1	0	1	0	NA	_	No_prior	0	0	initF
100	InitF_2USA_CAN_PSFS	0	_	-1	0	1	0	NA	_	No_prior	0	0	initF
101	InitF_3USA_CAN_PSFB	0	_	-1	0	1	0	NA	_	No_prior	0	0	initF
102	InitF_4USA_TRAP	0.01287	63	5	1E-05	1	0.0126	OK	0.0019	No_prior	0	0	initF
103	InitF_5USA_CAN_HARPOON	0.00147	_	-5	1E-05	1	0.0015	NA	_	No_prior	0	0	initF
104	InitF_6USA_RRFB	0	_	-1	0	1	0	NA	_	No_prior	0	0	initF
105	InitF_7USA_RRFS	0	_	-1	0	1	0	NA	_	No_prior	0	0	initF
106	InitF_8OTHER_ATL_LL	0	_	-1	0	1	0	NA	_	No_prior	0	0	initF

107	InitF_9CAN_HOOKLINE	0	_	-1	0	1	0	NA	_	No_prior	0	0	initF
108	InitF_10GOM_LL_US_MEX	0	_	-1	0	1	0	NA	_	No_prior	0	0	initF
109	InitF_11JLL_GOM	0	_	-1	0	1	0	NA	_	No_prior	0	0	initF
110	InitF_12CAN_TRAP	0	_	-1	0	1	0	NA	_	No_prior	0	0	initF
111	InitF_13CAN_GSL1	0	_	-1	0	1	0	NA	_	No_prior	0	0	initF
112	Q_envlink_18_IDX5_US_RR_GT177	-0.8318	64	4	-5	5	0	OK	0.2251	No_prior	0	0	qenv
113	Q_envlink_22_IDX9_CAN_GSLNS	2.00367	65	4	-5	5	0	OK	0.1674	No_prior	0	0	qenv
114	Q_envlink_25_IDX12_CAN_ACOUSTIC	0.88113	66	4	-5	5	0	OK	0.2556	No_prior	0	0	qenv
115	LnQ_base_18_IDX5_US_RR_GT177	-4.8313	67	1	-15	1E-06	-4.7353	OK	0.0791	No_prior	0	0	q
116	LnQ_base_22_IDX9_CAN_GSLNS	-5.1256	68	1	-15	1E-06	-4.7353	OK	0.0722	No_prior	0	0	q
117	LnQ_base_25_IDX12_CAN_ACOUSTIC	-5.8166	69	1	-15	1E-06	-4.7353	OK	0.1266	No_prior	0	0	q
118	SizeSel_1P_1_JAPAN_LL	207.494	70	2	40	250	155	OK	5.5854	No_prior	0	0	
119	SizeSel_1P_2_JAPAN_LL	-9.3602	71	2	-10	3	-1.7888	OK	15.949	No_prior	0	0	
120	SizeSel_1P_3_JAPAN_LL	6.97455	72	3	-5	9	7.437	OK	0.2286	No_prior	0	0	
121	SizeSel_1P_4_JAPAN_LL	7.74345	_	-2	-5	9	7.7435	NA	_	No_prior	0	0	sel
122	SizeSel_1P_5_JAPAN_LL	-999	_	-3	-999	15	-999	NA	_	No_prior	0	0	sel
123	SizeSel_1P_6_JAPAN_LL	-5.5131	73	4	-20	10	-13.586	OK	16.796	No_prior	0	0	
124	SizeSel_2P_1_USA_CAN_PSFS	68.4973	_	-2	40	100	68.497	NA	_	No_prior	0	0	
125	SizeSel_2P_2_USA_CAN_PSFS	-1	_	-3	-5	3	-1	NA	_	No_prior	0	0	
126	SizeSel_2P_3_USA_CAN_PSFS	3.83953	74	4	-4	12	3.9104	OK	0.456	Sym_Beta	0.5	0.1	
127	SizeSel_2P_4_USA_CAN_PSFS	-5	_	-3	-5	6	-5	NA	_	No_prior	0	0	
128	SizeSel_2P_5_USA_CAN_PSFS	-999	_	-2	-15	5	-999	NA	_	No_prior	0	0	sel
129	SizeSel_2P_6_USA_CAN_PSFS	-999	_	-2	-15	10	-999	NA	_	No_prior	0	0	sel
130	SizeSel_3P_1_USA_CAN_PSFB	213.666	_	-1	40	250	213.67	NA	_	No_prior	0	0	sel
131	SizeSel_3P_2_USA_CAN_PSFB	-2.5238	75	2	-5	3	-2.1602	OK	0.3508	No_prior	0	0	sel
132	SizeSel_3P_3_USA_CAN_PSFB	6.94011	76	3	-4	12	6.8998	OK	0.0746	Sym_Beta	0.5	0.1	sel
133	SizeSel_3P_4_USA_CAN_PSFB	6	_	-3	-2	6	6	NA	_	No_prior	0	0	sel
134	SizeSel_3P_5_USA_CAN_PSFB	-999	_	-2	-15	5	-999	NA	_	No_prior	0	0	sel
135	SizeSel_3P_6_USA_CAN_PSFB	-2.2325	77	4	-15	5	-3.1367	OK	0.4534	No_prior	0	0	sel

136	SizeSel_4P_1_USA_TRAP	142.4	78	1	40	200	143.78	OK	11.965	No_prior	0	0	sel
137	SizeSel_4P_2_USA_TRAP	-4.0517	79	3	-5	3	-4.3568	OK	2.1581	Sym_Beta	-4	0.1	sel
138	SizeSel_4P_3_USA_TRAP	8.60472	80	3	-4	12	8.496	OK	0.4032	No_prior	0	0	sel
139	SizeSel_4P_4_USA_TRAP	7.23391	81	3	-2	10	7.2499	OK	0.4848	Sym_Beta	1.2	0.1	sel
140	SizeSel_4P_5_USA_TRAP	-999	_	-2	-15	5	-999	NA	_	No_prior	0	0	sel
141	SizeSel_4P_6_USA_TRAP	-999	_	-2	-15	10	-999	NA	_	No_prior	0	0	sel
142	SizeSel_5P_1_USA_CAN_HARPOON	176.284	82	2	30	250	176.93	OK	0.919	No_prior	0	0	sel
143	SizeSel_5P_2_USA_CAN_HARPOON	17.592	83	2	10	100	17.782	OK	1.3143	No_prior	0	0	sel
144	SizeSel_6P_1_USA_RRFB	190.349	84	1	40	200	191.23	OK	0.9967	No_prior	0	0	sel
145	SizeSel_6P_2_USA_RRFB	-0.5543	_	-3	-5	3	-0.5543	NA	_	No_prior	0	0	sel
146	SizeSel_6P_3_USA_RRFB	6.56855	_	-3	-4	12	6.5686	NA	_	No_prior	0	0	sel
147	SizeSel_6P_4_USA_RRFB	6	_	-3	-2	6	6	NA	_	Sym_Beta	1.4	0.05	sel
148	SizeSel_6P_5_USA_RRFB	-999	_	-2	-15	5	-999	NA	_	No_prior	0	0	sel
149	SizeSel_6P_6_USA_RRFB	-0.5817	85	2	-15	5	-1.2419	OK	0.3571	No_prior	0	0	sel
150	SizeSel_7P_1_USA_RRFS	89.6448	86	1	40	200	93.971	OK	0.6013	No_prior	0	0	sel
151	SizeSel_7P_2_USA_RRFS	-1.5	_	-2	-5	3	-1.5	NA	_	Sym_Beta	-5	5	sel
152	SizeSel_7P_3_USA_RRFS	6.48538	_	-3	-4	12	6.4854	NA	_	No_prior	0	0	sel
153	SizeSel_7P_4_USA_RRFS	0.9731	_	-3	-2	6	0.9731	NA	_	No_prior	0	0	sel
154	SizeSel_7P_5_USA_RRFS	-999	_	-2	-15	5	-999	NA	_	No_prior	0	0	sel
155	SizeSel_7P_6_USA_RRFS	-5	_	-2	-15	10	-5	NA	_	No_prior	0	0	sel
156	SizeSel_8P_1_OTHER_ATL_LL	154.514	87	2	30	250	176.93	OK	2.4025	No_prior	0	0	sel
157	SizeSel_8P_2_OTHER_ATL_LL	47.9632	88	2	10	100	17.782	OK	2.4283	No_prior	0	0	sel
158	SizeSel_9P_1_CAN_HOOKLINE	192.157	89	2	30	300	212.93	OK	1.8853	No_prior	0	0	sel
159	SizeSel_9P_2_CAN_HOOKLINE	32.002	90	2	10	100	58.182	OK	2.2659	No_prior	0	0	sel
160	SizeSel_10P_1_GOM_LL_US_MEX	214.956	91	2	30	300	208.86	OK	2.6674	No_prior	0	0	sel
161	SizeSel_10P_2_GOM_LL_US_MEX	39.8211	92	2	10	100	34.111	OK	2.8594	No_prior	0	0	sel
162	SizeSel_11P_1_JLL_GOM	197.47	93	2	30	250	193.17	OK	5.4388	No_prior	0	0	sel
163	SizeSel_11P_2_JLL_GOM	22.924	94	2	10	100	20.182	OK	6.7414	No_prior	0	0	sel
164	SizeSel_12P_1_CAN_TRAP	258.563	95	2	30	300	248.14	OK	4.4166	No_prior	0	0	sel
165	SizeSel_12P_2_CAN_TRAP	57.7693	96	2	10	100	55.264	OK	2.824	No_prior	0	0	sel
166	SizeSel_13P_1_CAN_GSL1	259.62	97	2	30	320	212.93	OK	1.8761	No_prior	0	0	sel
167	SizeSel_13P_2_CAN_GSL1	21.6691	98	2	10	100	58.182	OK	2.2302	No_prior	0	0	sel
168	SizeSel_15P_1_IDX2_US_RR_66_114	65	_	-3	40	200	65	NA	_	No_prior	0	0	sel

169	SizeSel_15P_2_IDX2_US_RR_66_114	-1.7	_	-3	-5	3	-1.7	NA	_	No_prior	0	0	sel
170	SizeSel_15P_3_IDX2_US_RR_66_114	-4	_	-3	-4	12	-4	NA	_	No_prior	0	0	sel
171	SizeSel_15P_4_IDX2_US_RR_66_114	-2	_	-3	-2.5	6	-2	NA	_	No_prior	0	0	sel
172	SizeSel_15P_5_IDX2_US_RR_66_114	-999	_	-2	-15	5	-999	NA	_	No_prior	0	0	sel
173	SizeSel_15P_6_IDX2_US_RR_66_114	-5	_	-2	-15	10	-5	NA	_	No_prior	0	0	sel
174	SizeSel_16P_1_IDX3_US_RR_115_144	115	_	-3	40	200	115	NA	_	No_prior	0	0	sel
175	SizeSel_16P_2_IDX3_US_RR_115_144	-2.1	_	-3	-5	3	-2.1	NA	_	No_prior	0	0	sel
176	SizeSel_16P_3_IDX3_US_RR_115_144	-4	_	-3	-4	12	-4	NA	_	No_prior	0	0	sel
177	SizeSel_16P_4_IDX3_US_RR_115_144	-2	_	-3	-2.5	6	-2	NA	_	No_prior	0	0	sel
178	SizeSel_16P_5_IDX3_US_RR_115_144	-999	_	-2	-15	5	-999	NA	_	No_prior	0	0	sel
179	SizeSel_16P_6_IDX3_US_RR_115_144	-5	_	-2	-15	10	-5	NA	_	No_prior	0	0	sel
180	SizeSel_1P_1_JAPAN_LL_BLK1repl_1950	162	_	-5	40	250	162	NA	_	No_prior	0	0	sel
181	SizeSel_1P_2_JAPAN_LL_BLK1repl_1950	-4.4019	99	5	-10	3	-1.78	OK	1.0515	No_prior	0	0	sel
182	SizeSel_1P_3_JAPAN_LL_BLK1repl_1950	7.67213	100	5	-5	9	7.43	OK	0.0388	No_prior	0	0	sel
183	SizeSel_1P_4_JAPAN_LL_BLK1repl_1950	7.74	_	-2	-5	9	7.74	NA	_	No_prior	0	0	sel
184	SizeSel_1P_5_JAPAN_LL_BLK1repl_1950	-999	_	-3	-999	15	-999	NA	_	No_prior	0	0	sel
185	SizeSel_1P_6_JAPAN_LL_BLK1repl_1950	-4.5906	101	5	-20	10	-13.58	OK	0.8027	No_prior	0	0	sel
186	SizeSel_7P_1_USA_RRFS_BLK3repl_1992	100.853	102	1	40	200	93.971	OK	0.5534	No_prior	0	0	sel
187	SizeSel_7P_2_USA_RRFS_BLK3repl_1992	-1.5	_	-2	-5	3	-1.5	NA	_	Sym_Beta	-5	0.05	sel
188	SizeSel_7P_3_USA_RRFS_BLK3repl_1992	6.48538	_	-3	-4	12	6.4854	NA	_	No_prior	0	0	sel
189	SizeSel_7P_4_USA_RRFS_BLK3repl_1992	0.9731	_	-3	-2	6	0.9731	NA	_	No_prior	0	0	sel
190	SizeSel_7P_5_USA_RRFS_BLK3repl_1992	-999	_	-2	-15	5	-999	NA	_	No_prior	0	0	sel

Table 6. Benchmarks (SE) and relative stock status for SS runs 12 and 13.

	Run 12, late spawning	Run 13, early spawning
SSB_Unfished	193552 (7001)	244362 (8874)
TotBio_Unfished	248251 (9032)	250887 (9119)
Recr_Unfished	640.72 (24)	646.78 (24)
SSB_Btgt40%B0	77420.7 (2800)	97745 (3549)
SPR_Btgt40%B0	0.52 (0.01)	0.57 (0.02)
Fstd_Btgt40%B0	0.04 (0.002)	0.05 (0.003)
TotYield_Btgt40%B0	4527.8 (219)	4363.49 (230)
SSB_SPRtgtSPR40%	46862.9 (3811)	40458.5 (7041)
Fstd_SPRtgtSPR40%	0.06 (0.001)	0.08 (0.001)
TotYield_SPRtgtSPR40%	4332.22 (357)	3228.21 (565)
SSB_MSY	67100.1 (3651)	95106.4 (4570)
SPR at MSY	0.48 (0.02)	0.56 (0.022)
F(avg 10-20) at MSY	0.05 (0.004)	0.048(0.004)
TotYieldat FMSY	4579.49 (235.4)	4365.57 (232.5)
F0.1(avg F 10-20)	0.082	0.079
SSB_F0.1	25551	40321
Yield_F0.1	3196	3077
Fcurr (avg F 10-20) 2013-2015	0.048	0.047
Fcurrent/F0.1	0.58	0.60
Fcurrent/Fmsy	0.95	0.976
current SSB (2015)	27870	39204
current SSB/SSB.F0.1, (assuming Stock/recruit relationship)	1.09	0.972
current SSB/SSB.MSY (assuming Stock/recruit relationship)	0.42	0.412

Table 7. Projected yields at various F levels and recruitment assumptions.

	Run 12. later spawning				
Assumed recruitment	SRR	3yr	6yr	10yr	SRR
F_{metric}	$F_{0.1}$	$F_{0.1}$	$F_{0.1}$	$F_{0.1}$	F_{MSY}
Prelim. Catch 2016 (t)	1912	1912	1912	1912	1912
TAC_2017 (t)	2000	2000	2000	2000	2000
ForeCatch 2018 (t)	2883	2836	2839	2850	1453
ForeCatch 2019 (t)	2793	2676	2684	2711	1461
ForeCatch 2020 (t)	2743	2527	2541	2592	1486
ForeCatch 2021 (t)	2707	2384	2406	2481	1515
rec 2015 (1000s)	286	121	132	170	286
rec 2016 (1000s)	289	122	133	172	289
rec 2017 (1000s)	289	122	133	172	289
rec 2018 (1000s)	288	122	133	172	288
rec 2019 (1000s)	281	119	129	167	289
rec 2020 (1000s)	270	114	125	161	285

	Run 13. early spawning				
Assumed recruitment	SRR	3yr	6yr	10yr	SRR
F_{metric}	$F_{0.1}$	$F_{0.1}$	$F_{0.1}$	$F_{0.1}$	F_{MSY}
Prelim. Catch 2016 (t)	1912	1912	1912	1912	1912
TAC_2017 (t)	2000	2000	2000	2000	2000
ForeCatch_2018 (t)	2813	2762	2782	2781	1445
ForeCatch_2019 (t)	2719	2607	2630	2648	1448
ForeCatch_2020 (t)	2650	2456	2484	2527	1460
ForeCatch_2021 (t)	2584	2312	2346	2412	1470
rec 2015 (1000s)	262	120	132	172	262
rec 2016 (1000s)	260	119	131	170	260
rec 2017 (1000s)	257	118	130	169	257
rec 2018 (1000s)	252	115	127	165	252
rec 2019 (1000s)	245	111	122	159	252
rec 2020 (1000s)	240	106	118	154	253

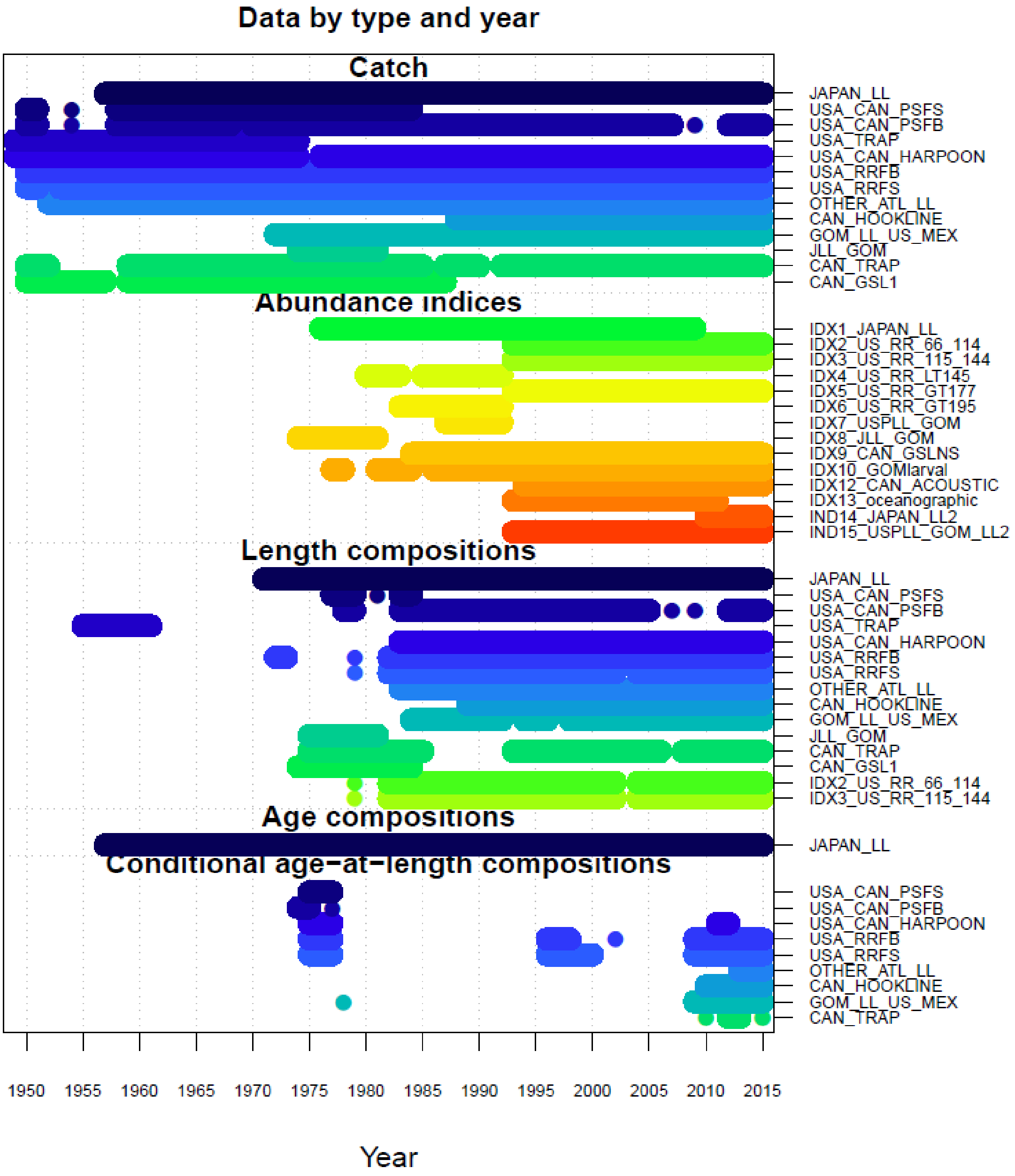


Figure 1. Time series of data inputs to the WBFT SS model.

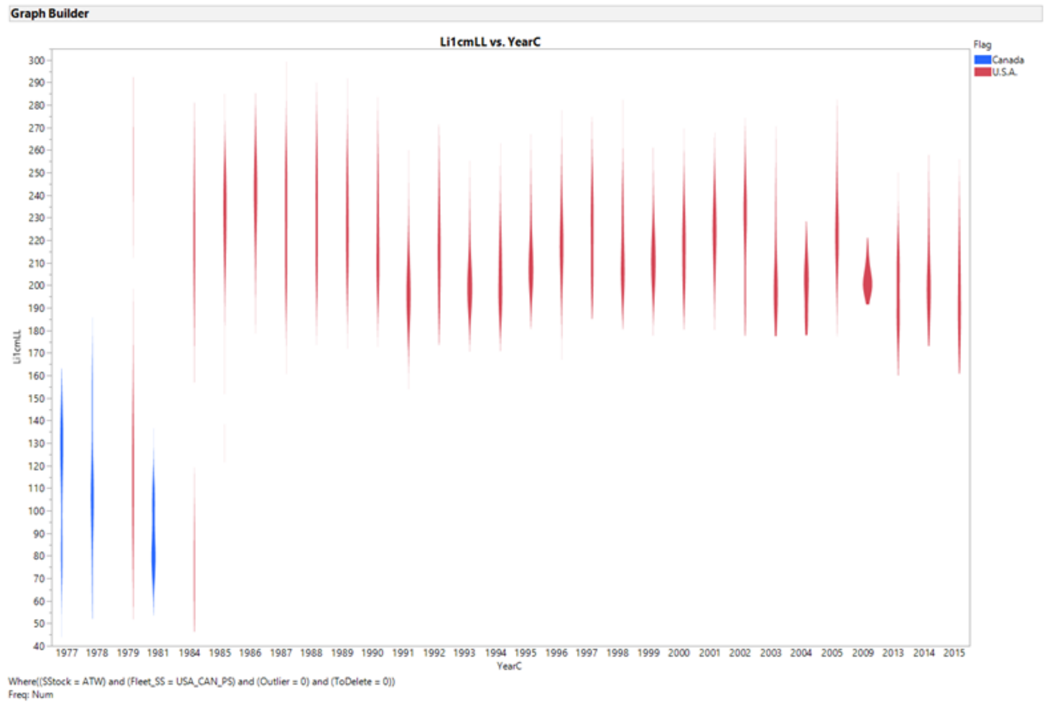


Figure 2. Fleet CAN_USA_PS sz frq ATW.

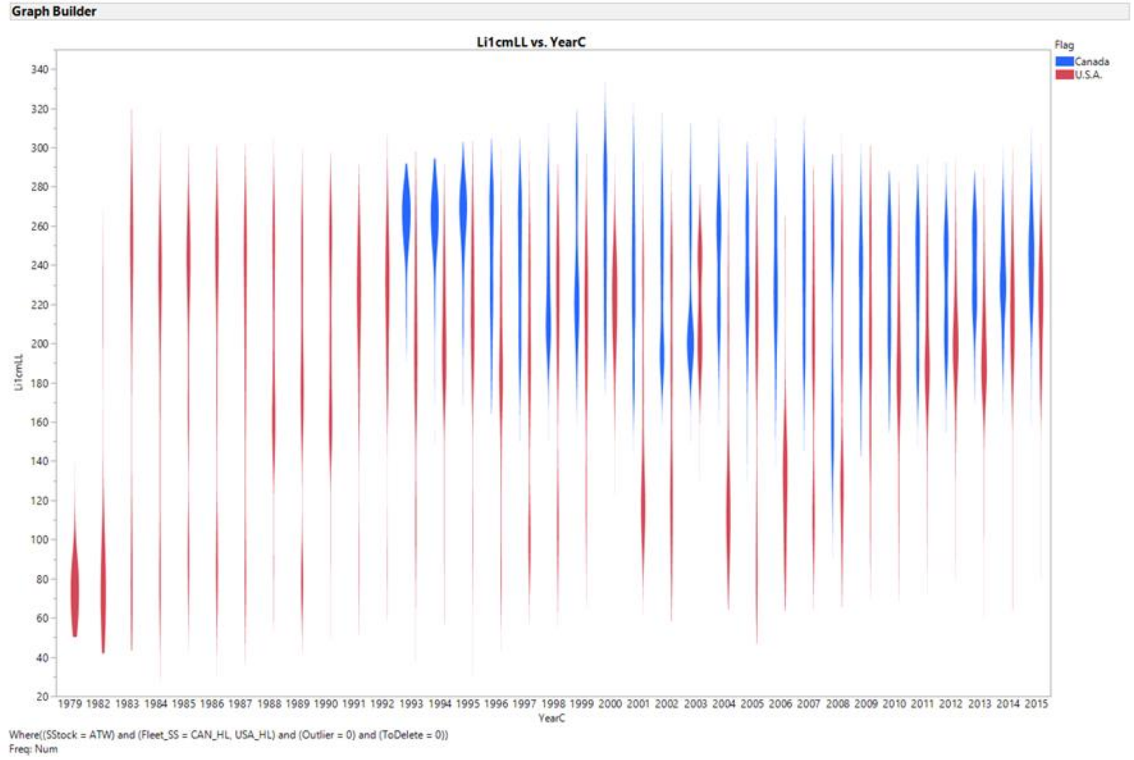
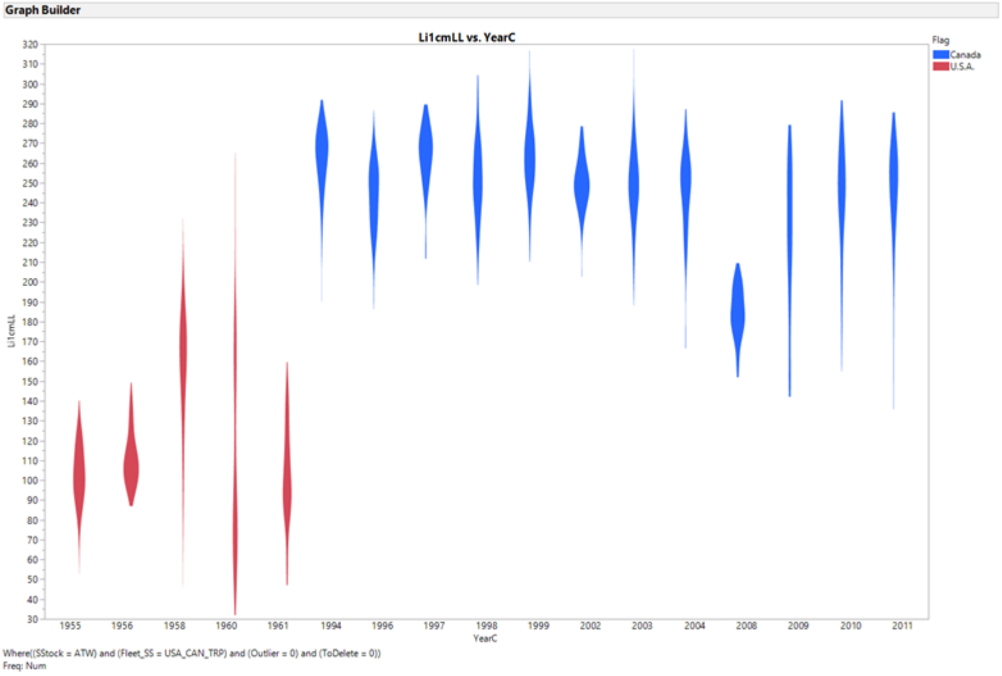


Figure 3. Fleet USA HL and CAN HL.



Where((SStock = ATW) and (Fleet_SS = USA_CAN_TRP) and (Outlier = 0) and (ToDelete = 0))
Freq: Num

Figure 4. Fleet CAN_USA_Trap, noting the clear separation between the two fleets.

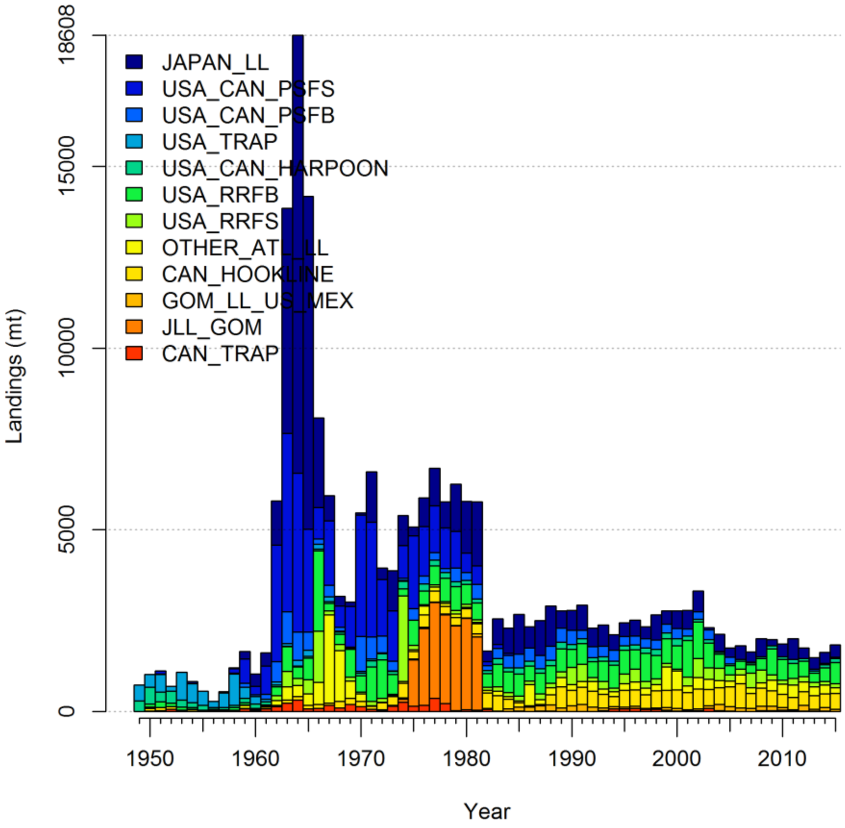


Figure 5. Task I catch by SS fleet.

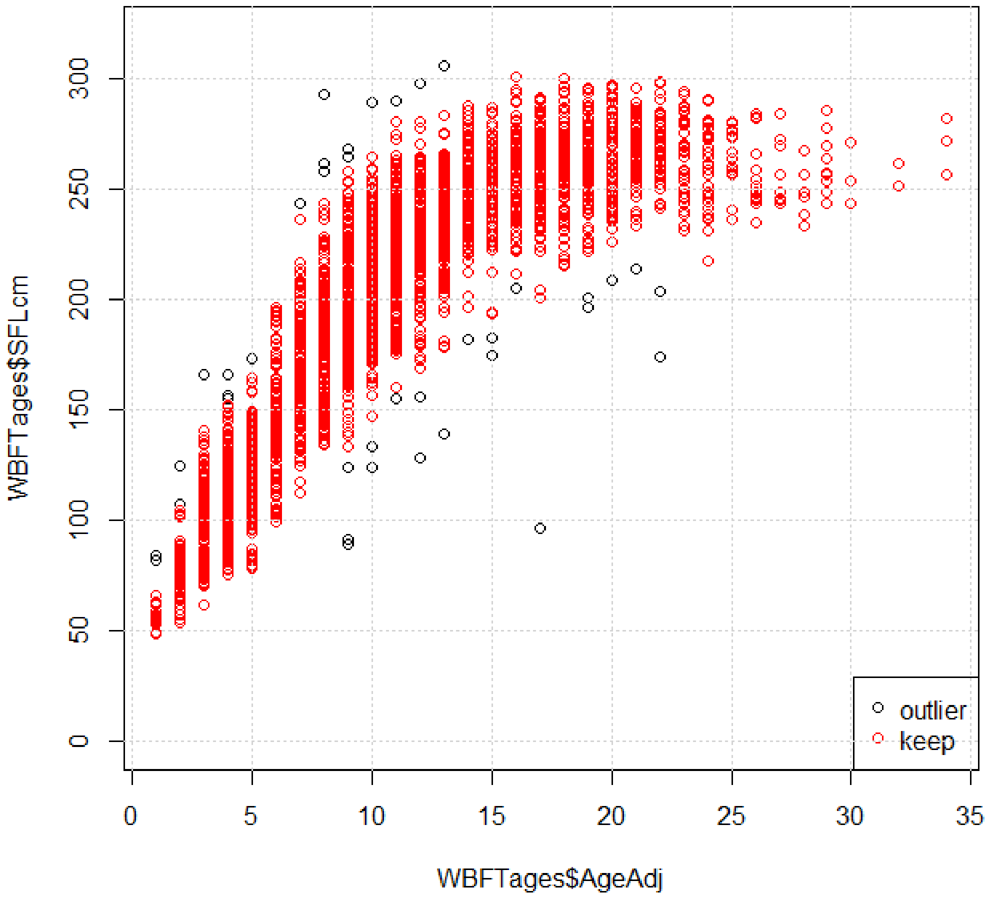


Figure 6. Available WBFT age-length data (n=4298).

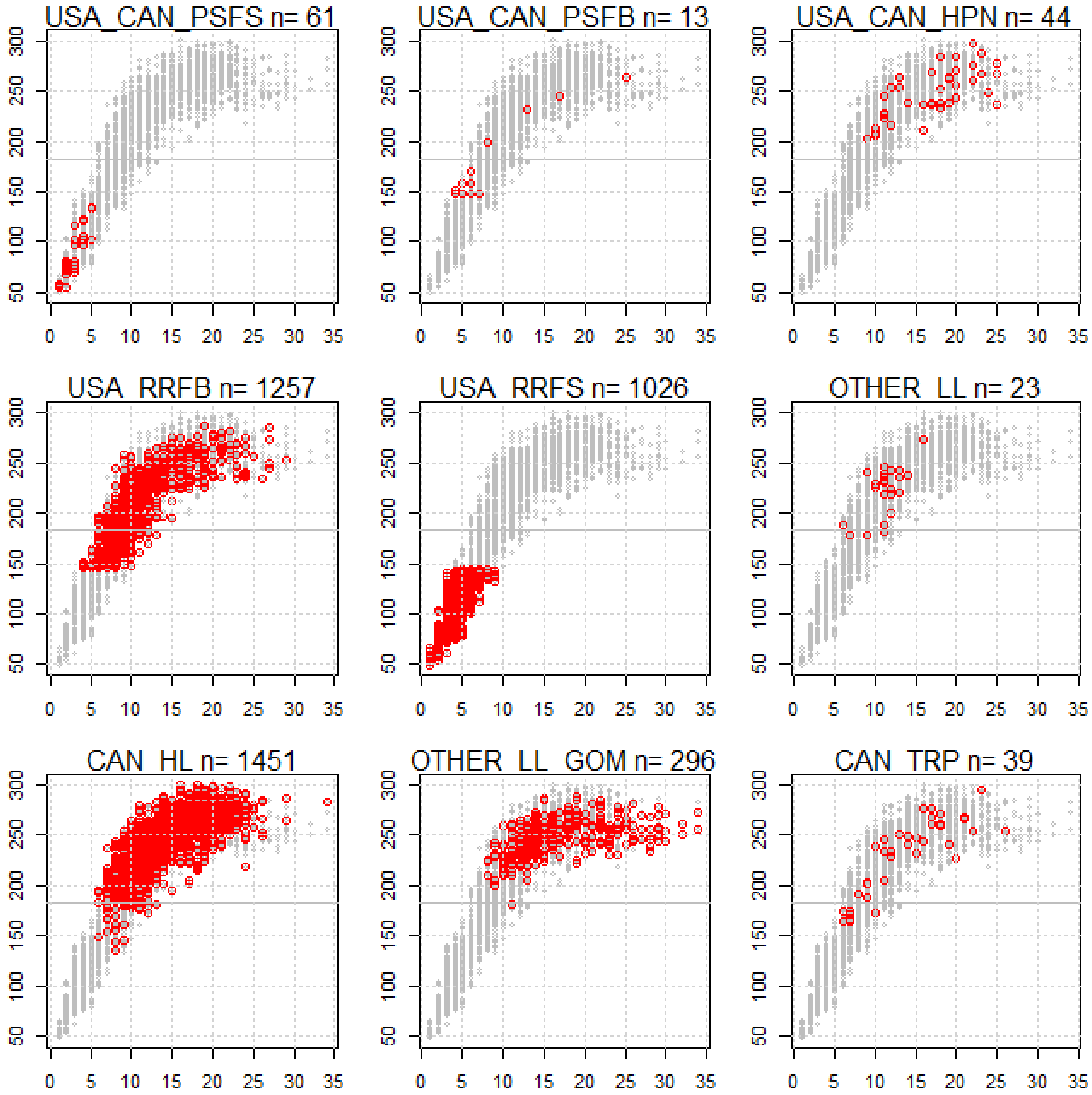


Figure 7. Available WBFT age-length data assigned to each fleet (red dots). Total age-length data are represented by the gray dots).

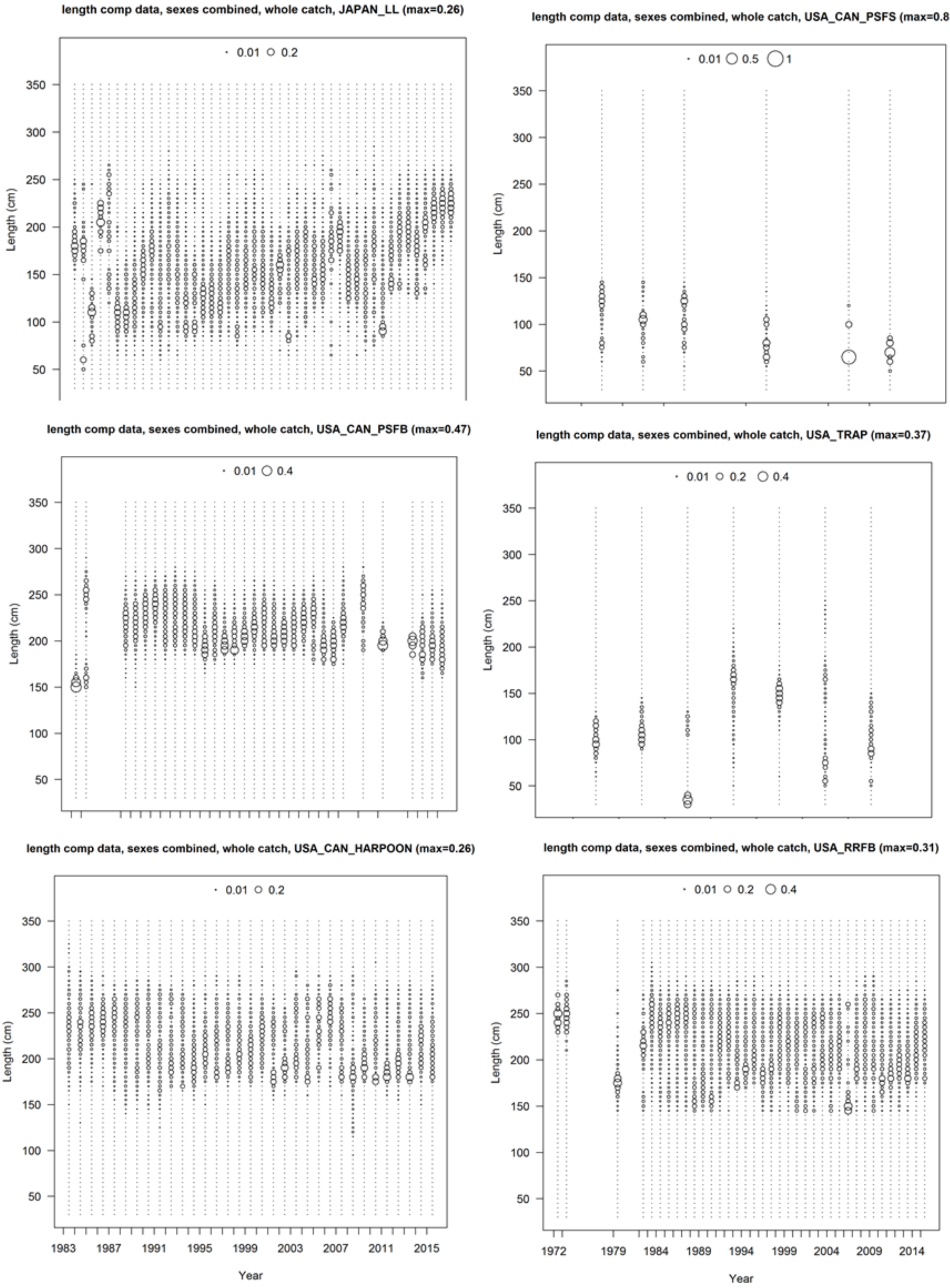


Figure 8. Size composition input for fleets 1-6.

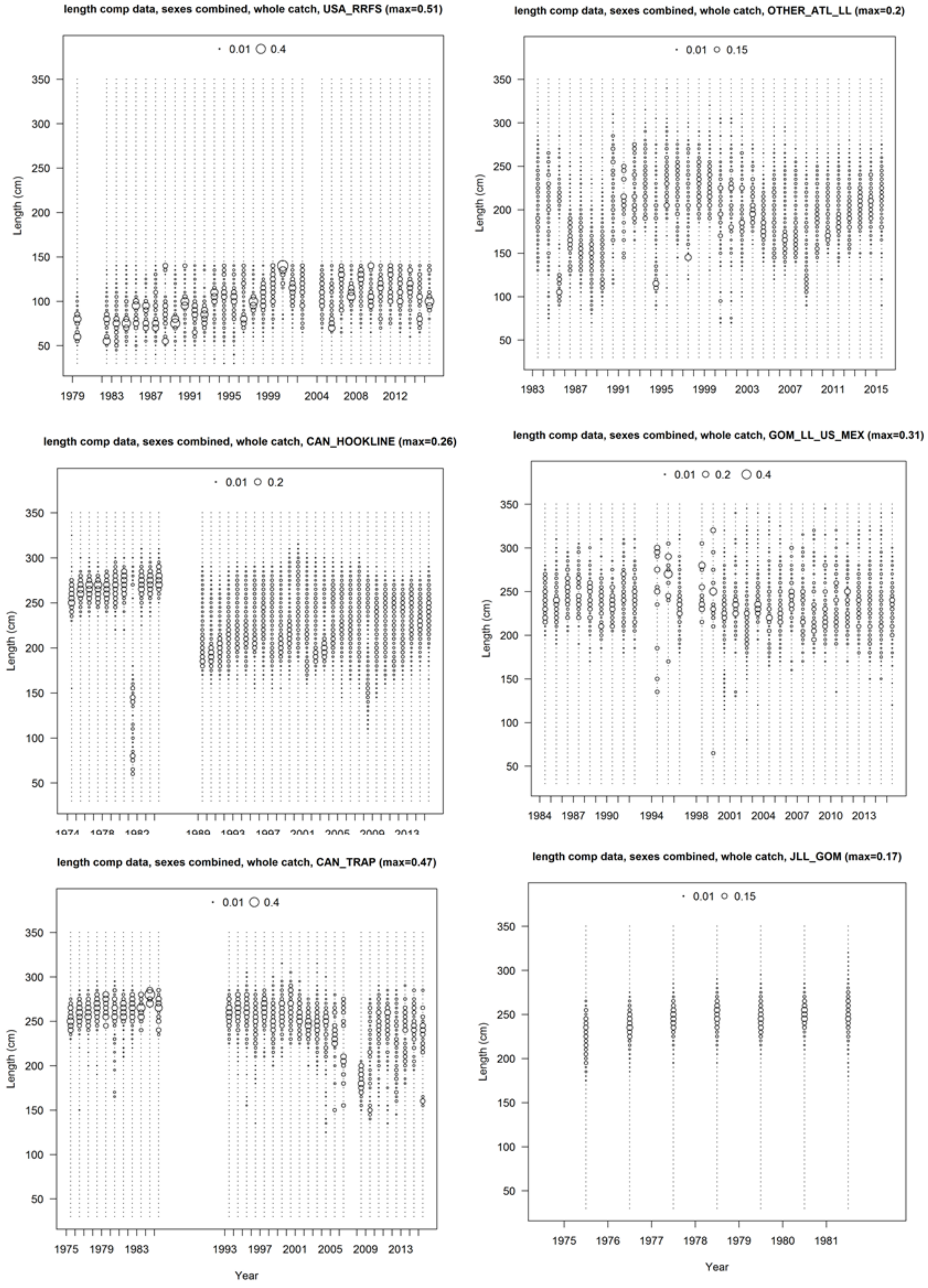
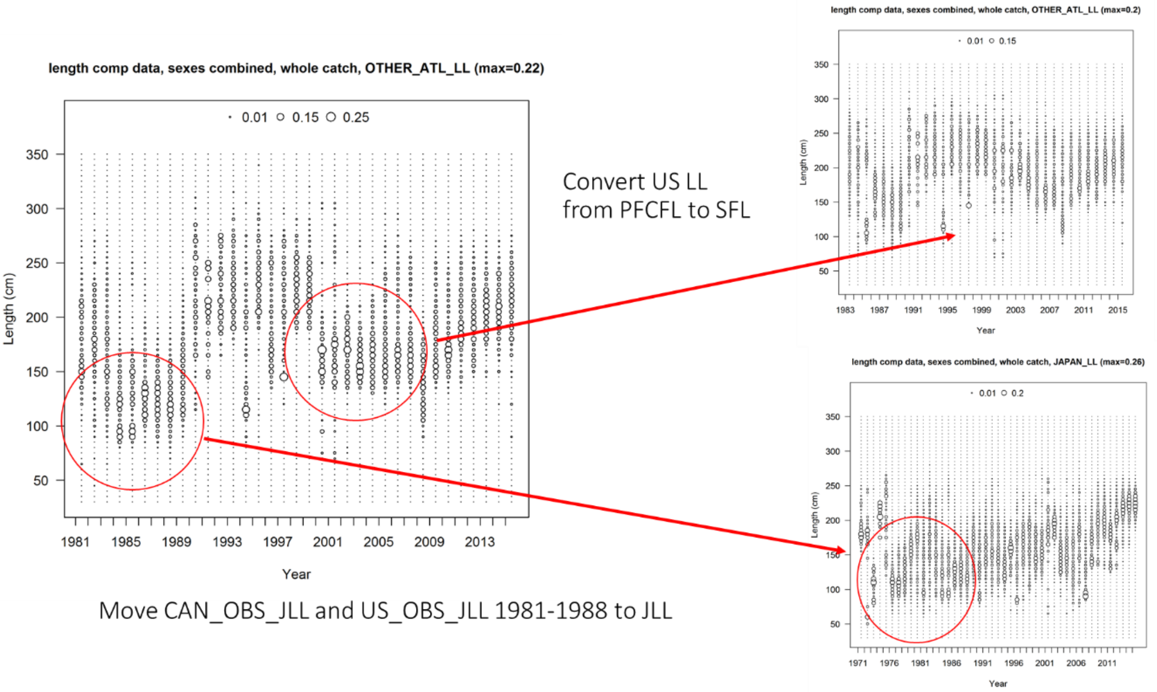


Figure 9. Size composition input for fleets 7-12.



Convert US LL
from PFCFL to SFL

Move CAN_OBS_JLL and US_OBS_JLL 1981-1988 to JLL

Figure 10. Adjustments to size frequency information for OTHER_ATL_LL.

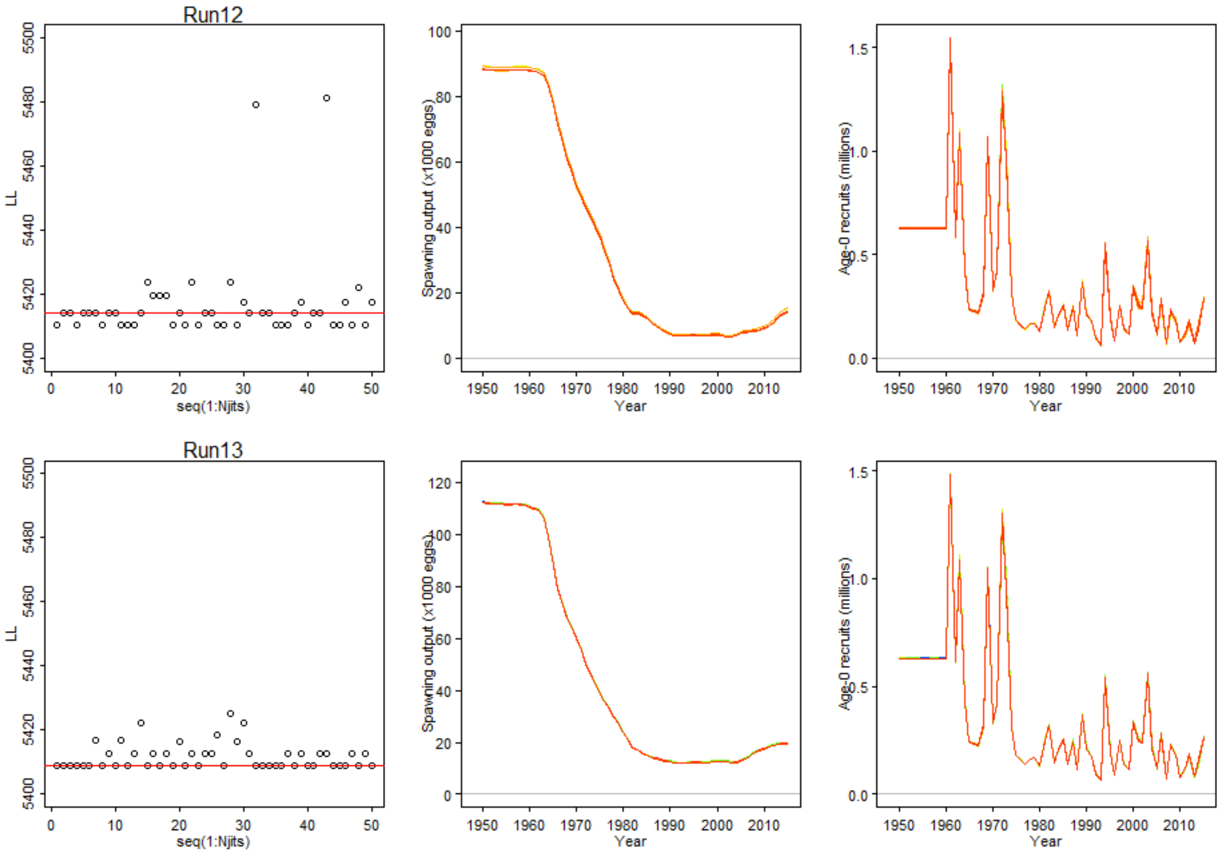


Figure 11. Jitter results for runs 12 and 13.

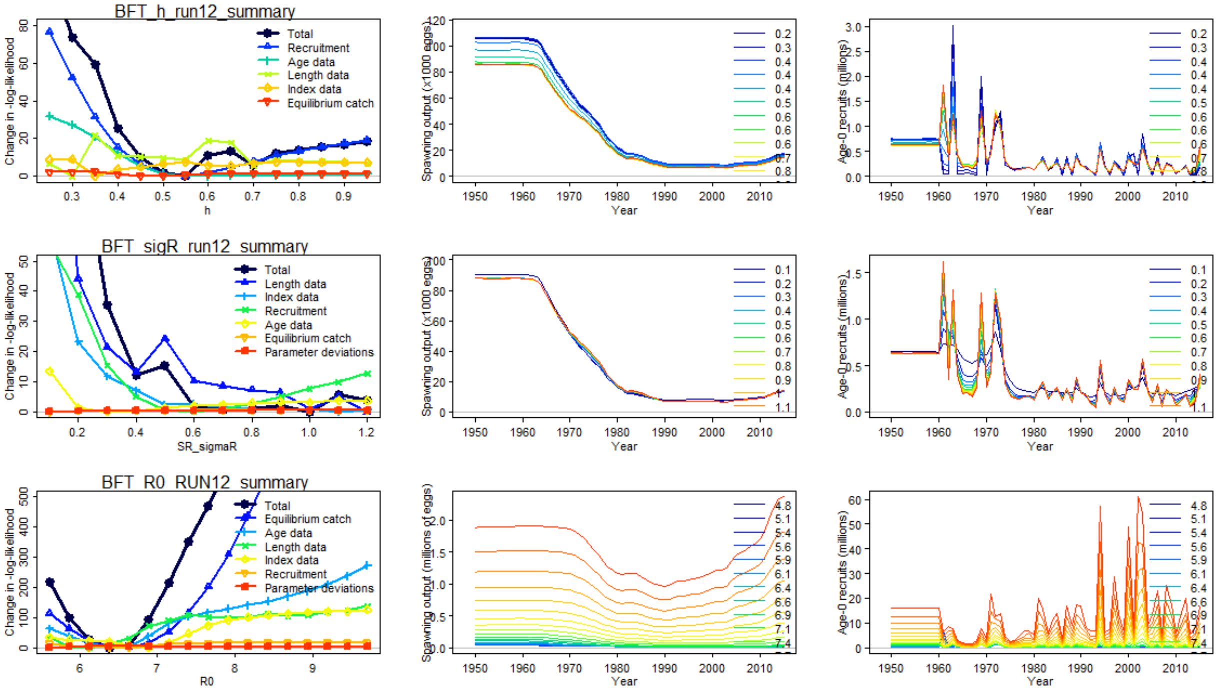


Figure 12. Run 12. Profiles of steepness (h), sigmaR and R0 and resulting SSB and recruitment trends.

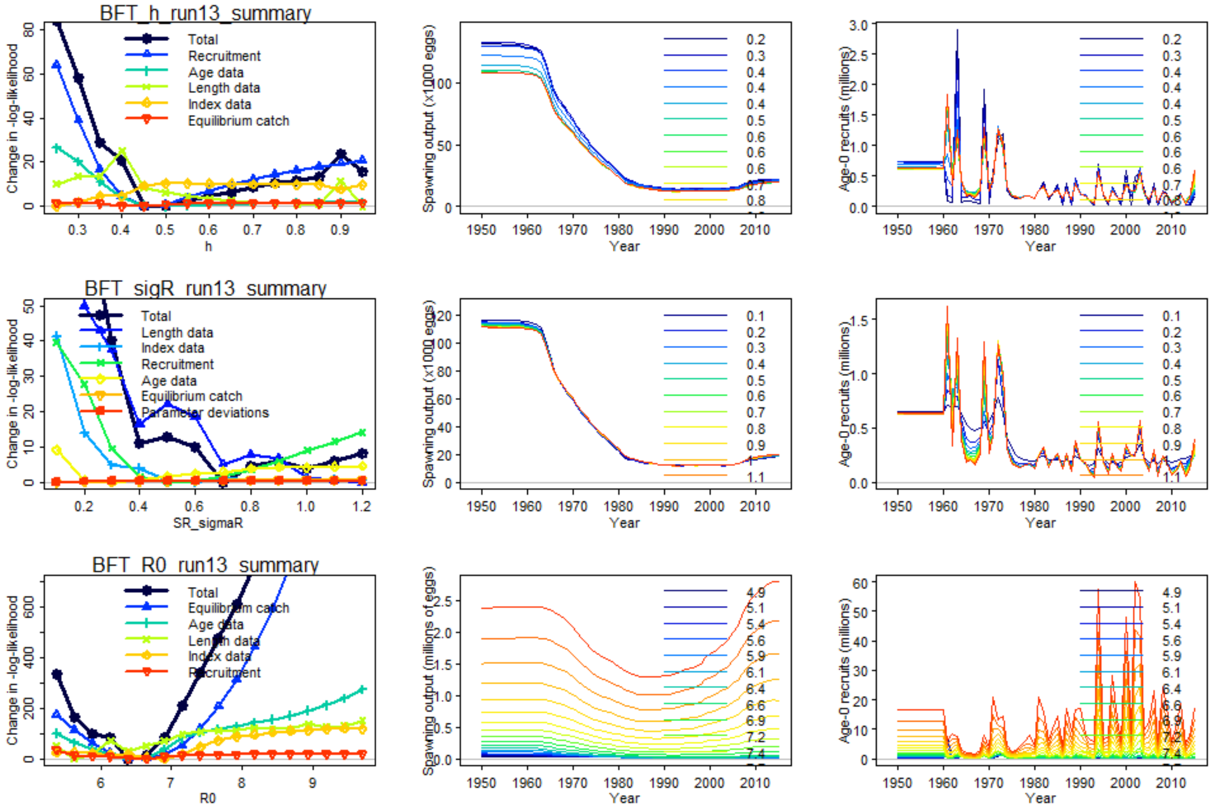


Figure 13. Run 13. Profiles of steepness (h), sigmaR and R0 and resulting SSB and recruitment trends.

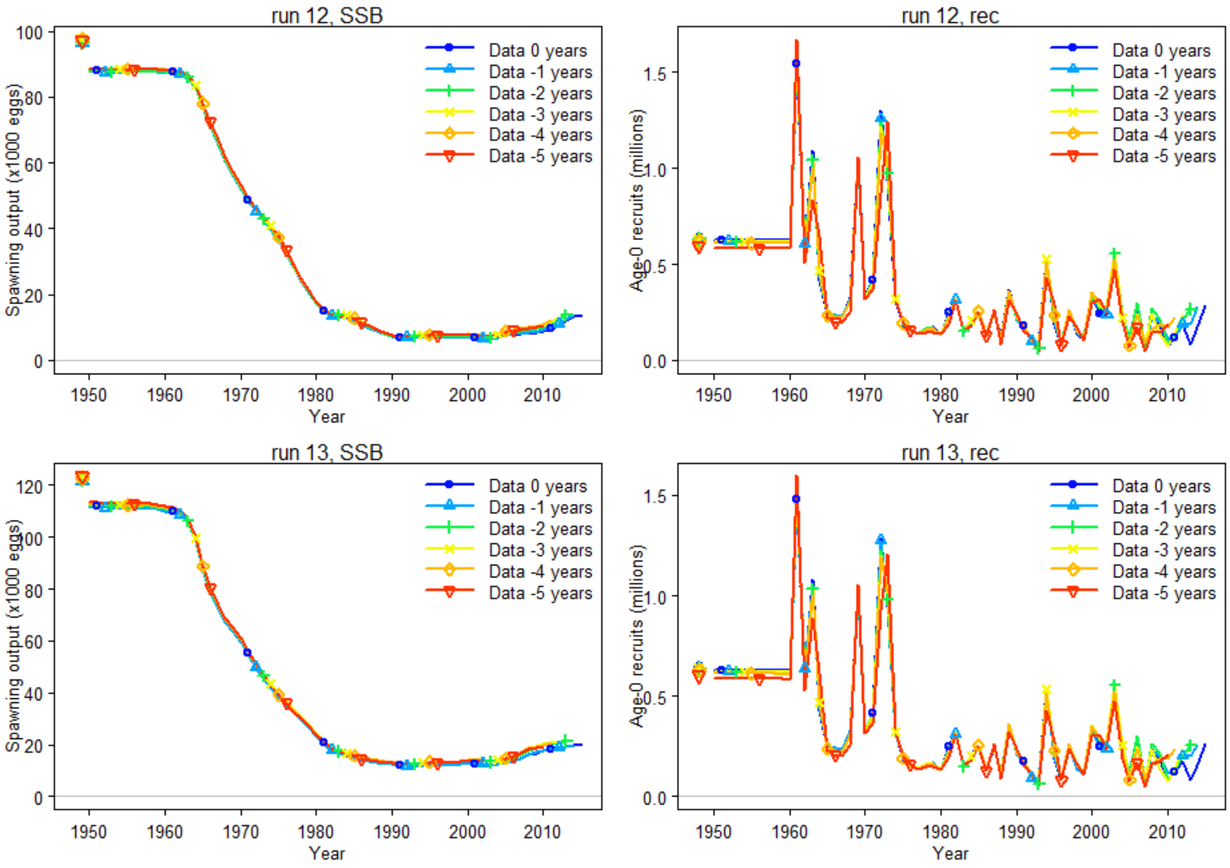


Figure 14. Retrospective plots of SSB and recruitment for runs 12 and 13.

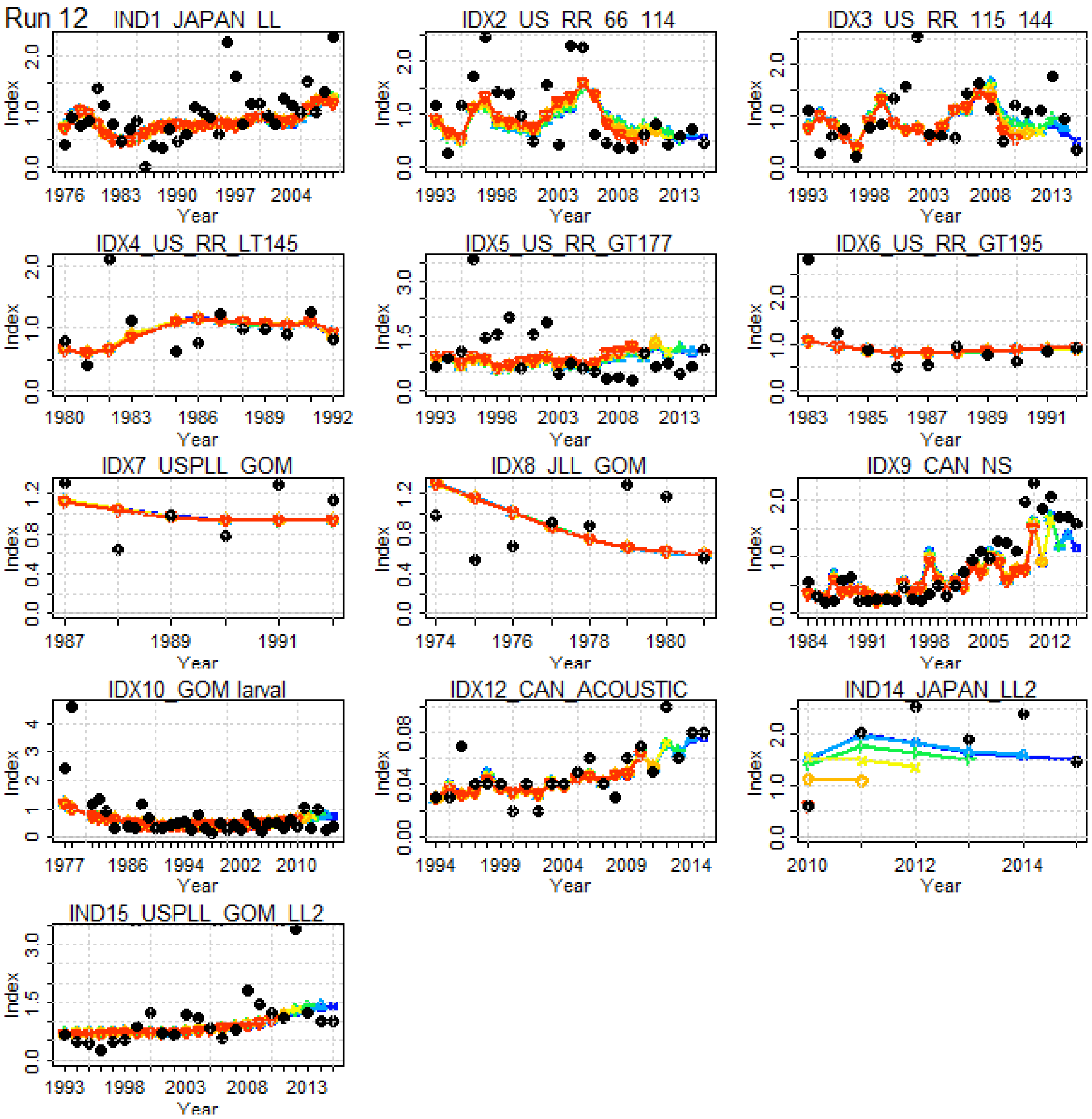


Figure 15. Retrospective plots of fits to CPUE for run 12.

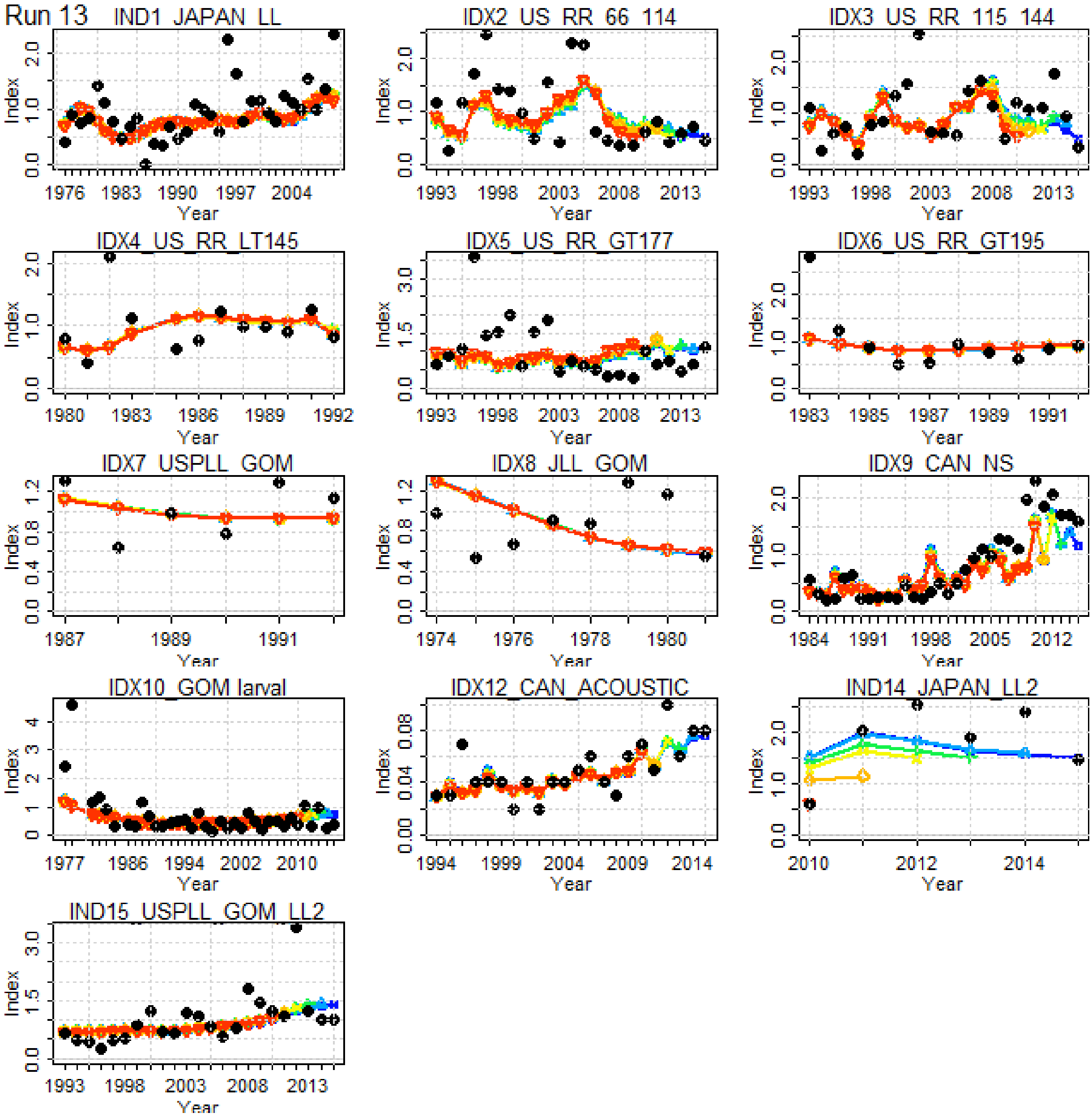


Figure 16. Retrospective plots of fits to CPUE for run 13.

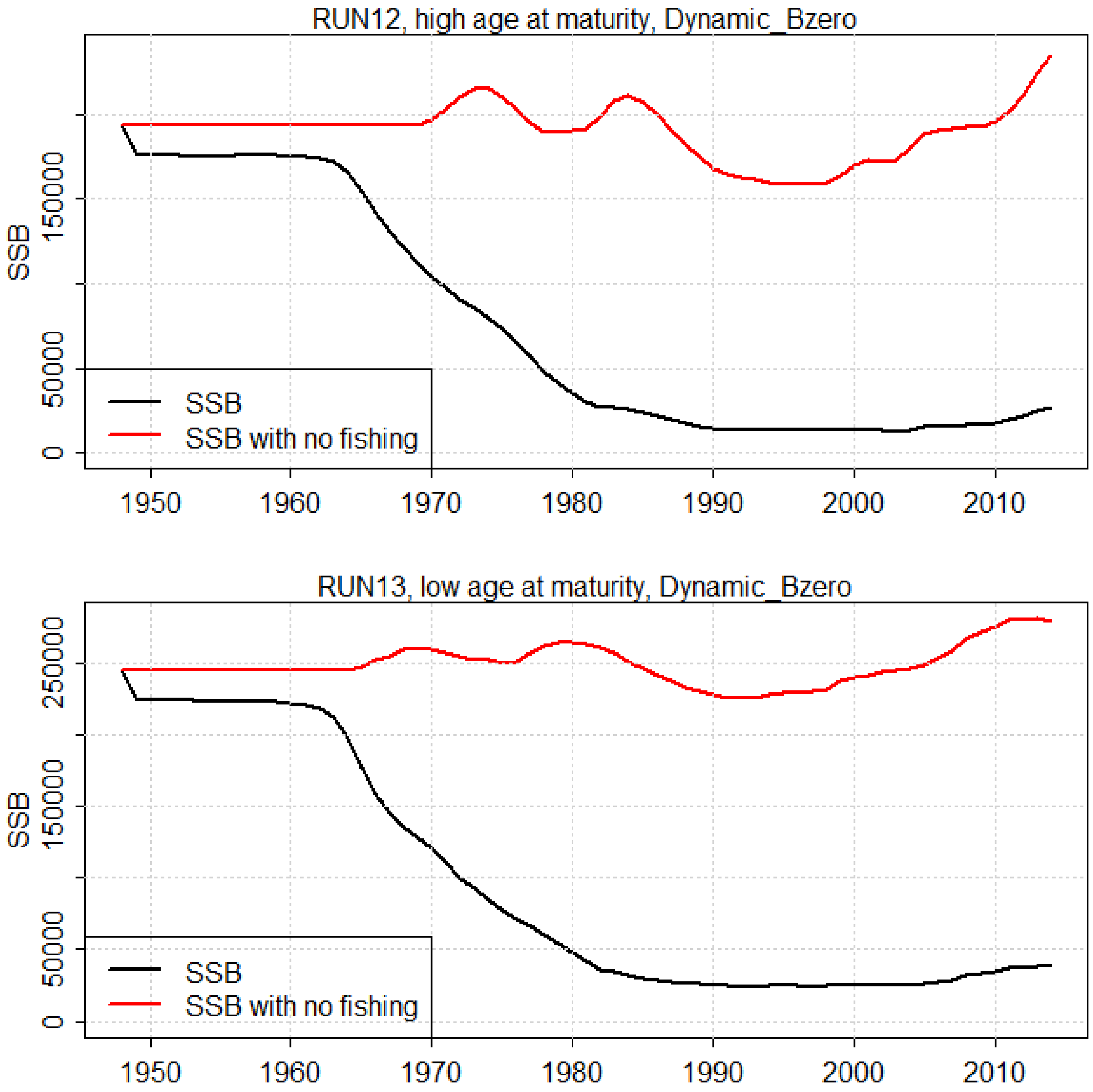


Figure 17. Dynamic SSB0 plot indicating SSB with and without fishing indicating how much ‘extra’ recruitment the model has to produce to maintain the population.

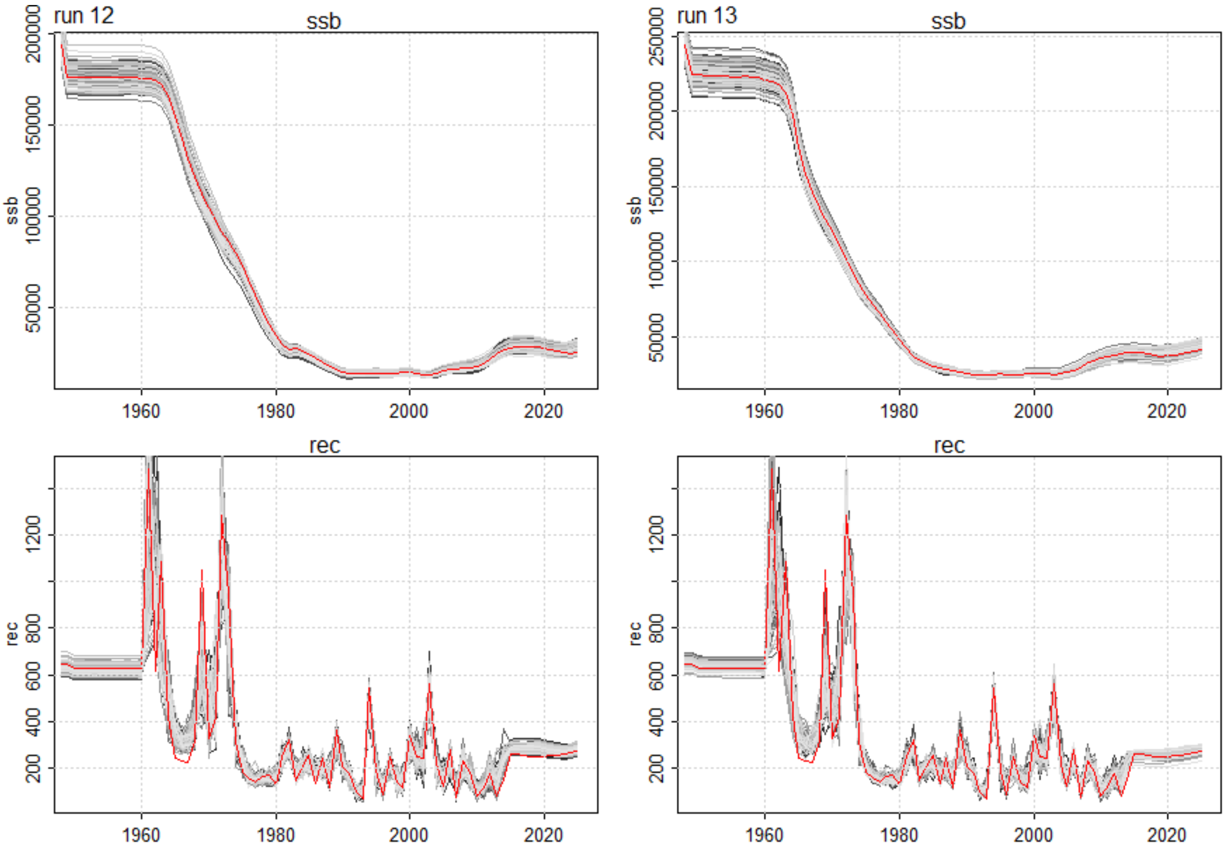


Figure 18. Results of 500 bootstraps of model 12 and model 13 SSB and recruitment. Note that bootstraps were projected until 2025 fishing at F0.1.

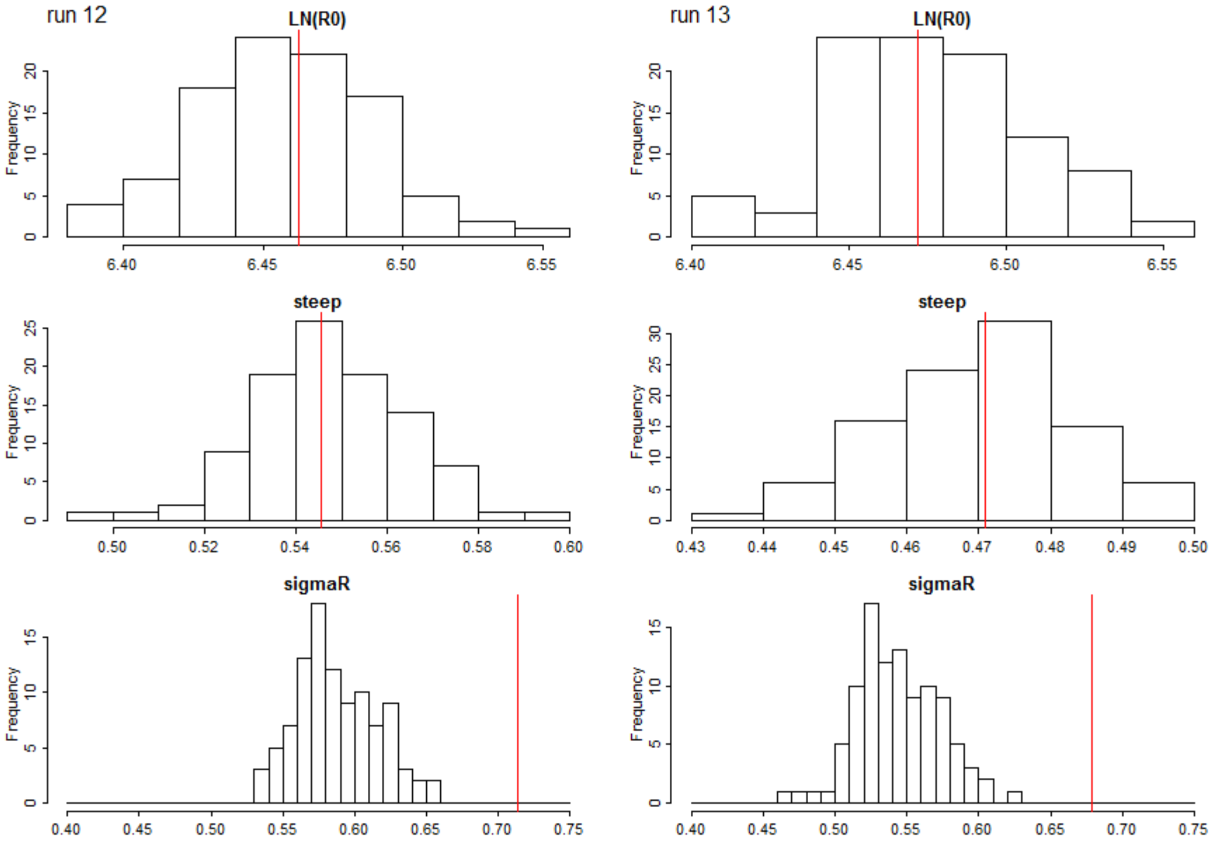


Figure 19. Results of 100 bootstraps of model 12 and model 13, ln(R0), steepness and sigmaR estimates.

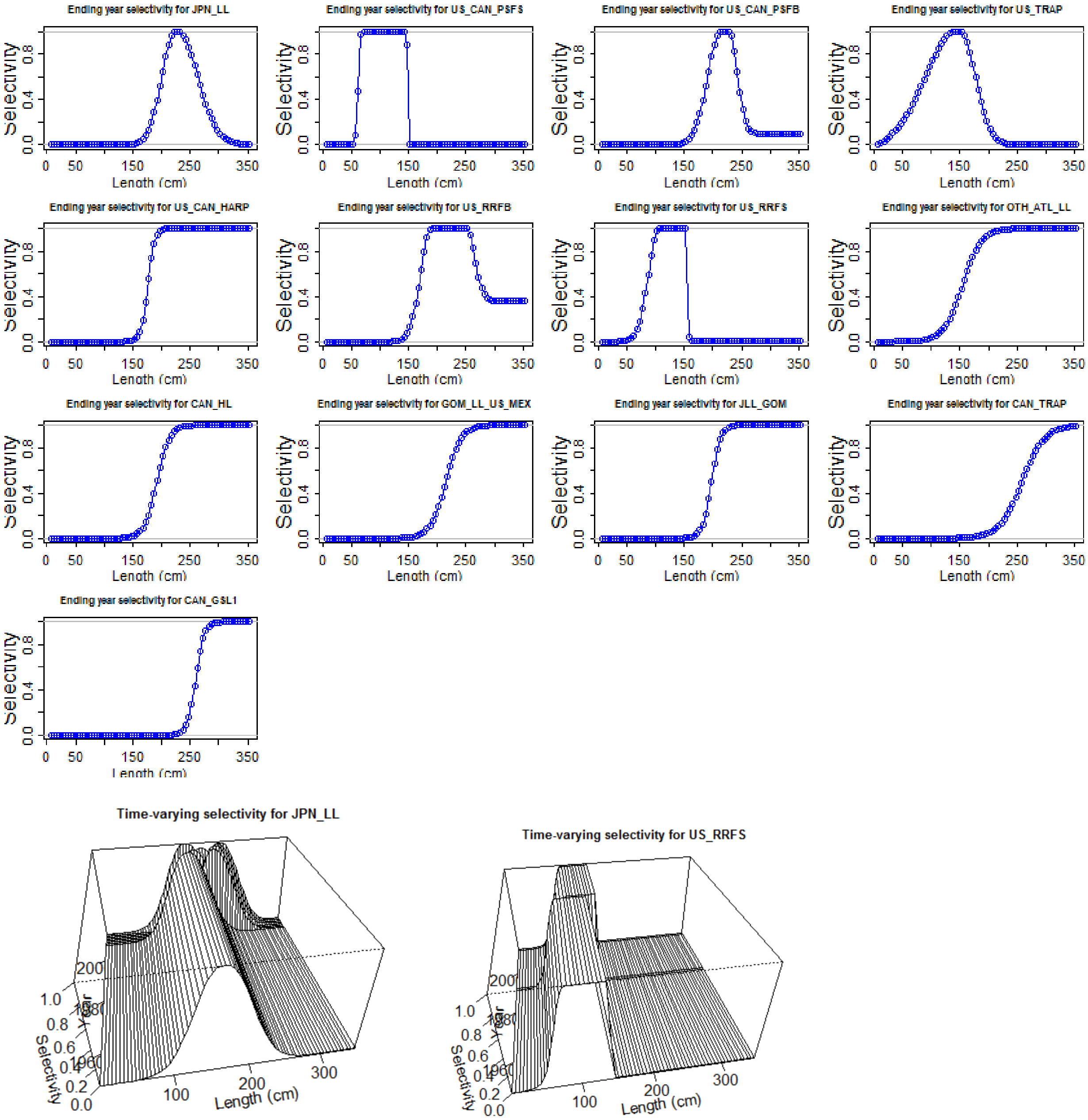


Figure 20. Estimated selectivity for SS run 10 (assuming older spawning, and the results for SS run 12, younger spawning, were essentially the same) for the western stock. For JPN_LL and US_RRFS time varying selectivity is shown on bottom.

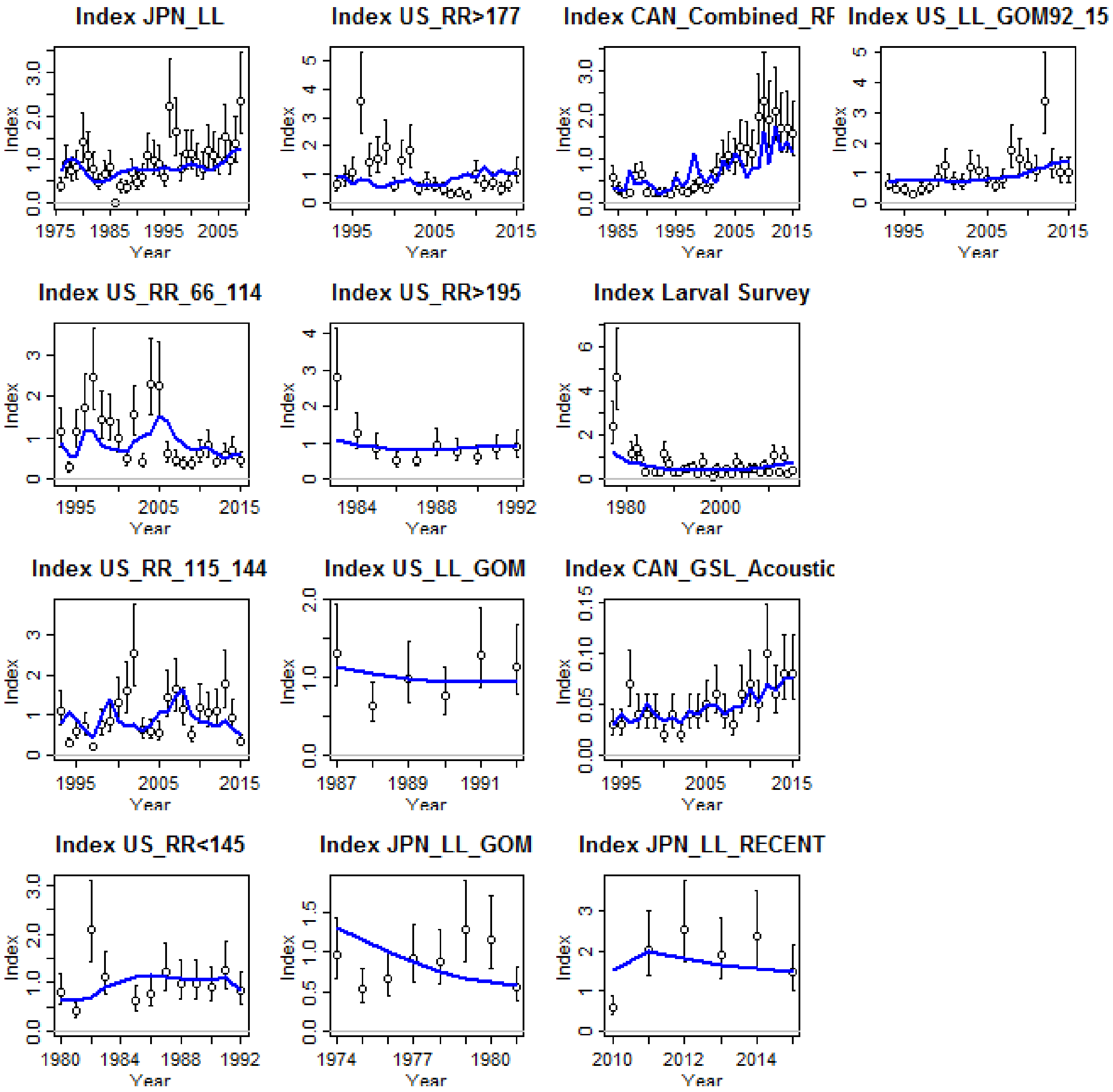


Figure 21. Fits to CPUE indices for Run12 (run 13 not shown for brevity, mostly the same).

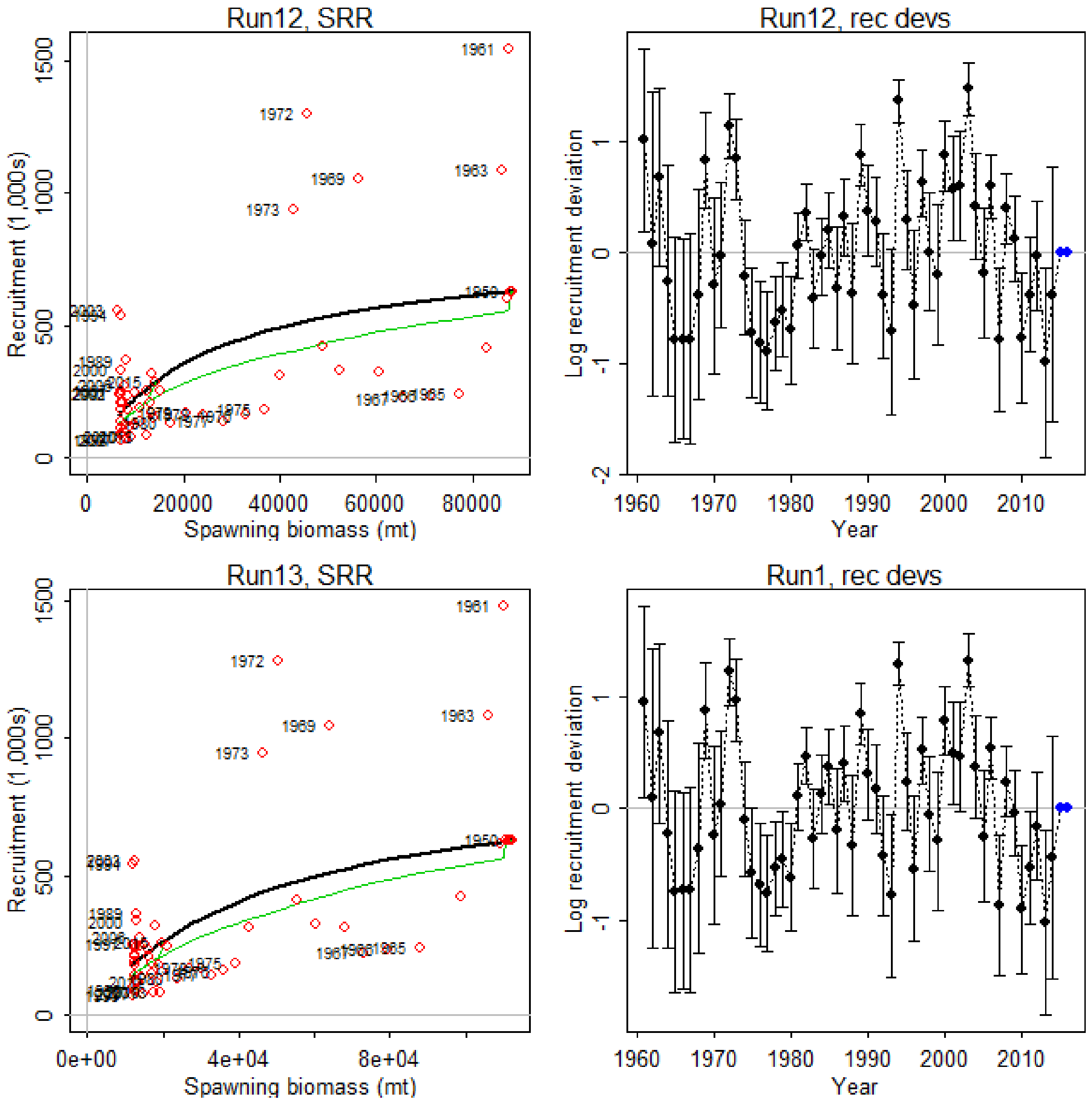


Figure 22. Estimated Beverton-Holt Spawner-recruit relationship and recruitment (age 0) deviations for SS runs 12 (older spawning - top) and 13 (younger spawning - bottom) for the western stock. Green line is the adjusted recruitment level during the period where recruitment deviations are estimated. The level of the adjustment, or reduction in recruitment level is determined by a bias correction factor that makes the mean recruitment level during the recruitment deviation estimation period equal to R0. Steepness was estimated to be 0.54 and 0.45, respectively, for SS3 runs 12 and 13. Blue points are ‘future’ recruitment deviations that are partially estimated for 2015 and not estimated for 2016.

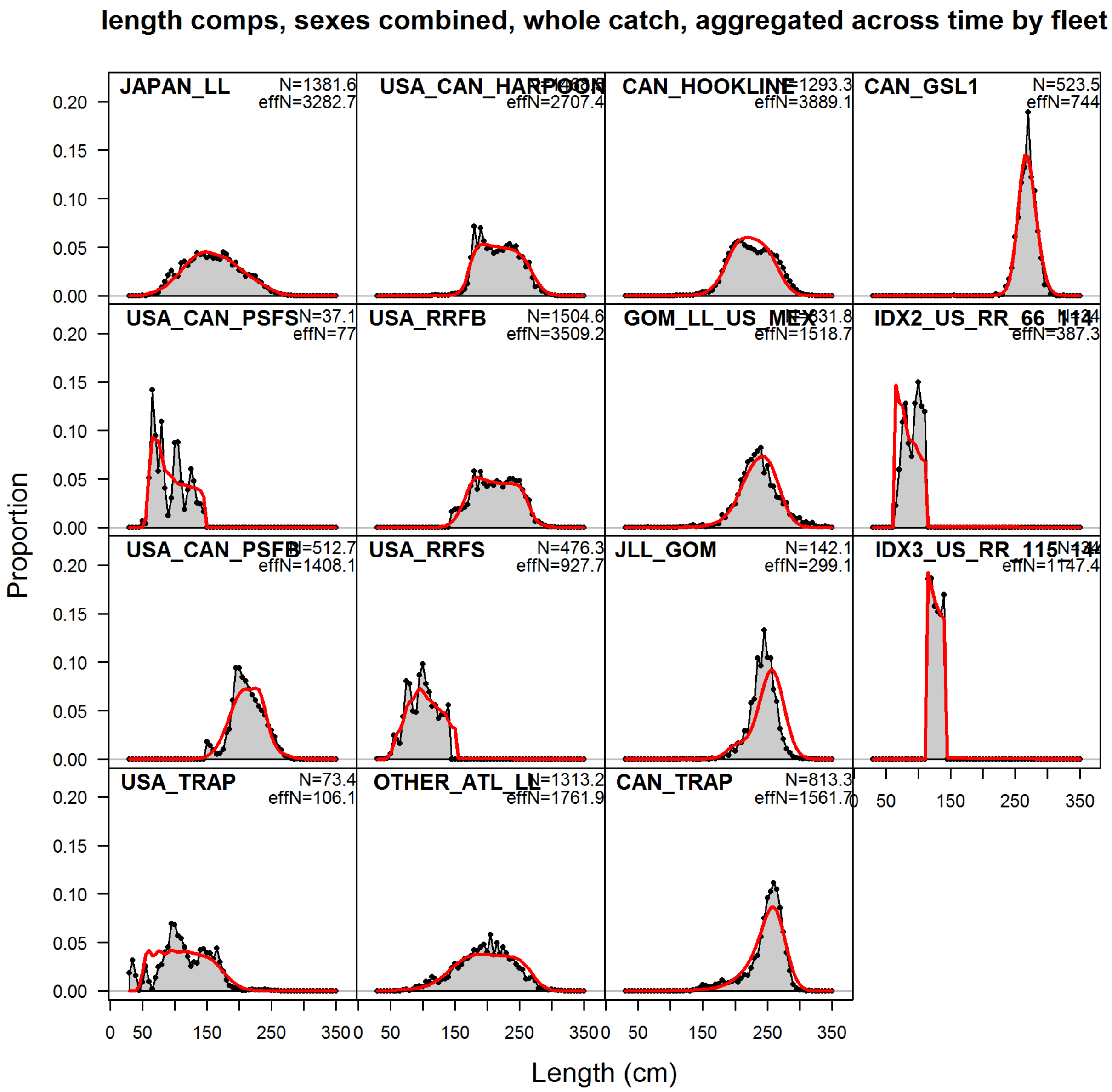


Figure 23. Fits to length composition data over all years for Run 12 (run 13 not shown for brevity, mostly the same).

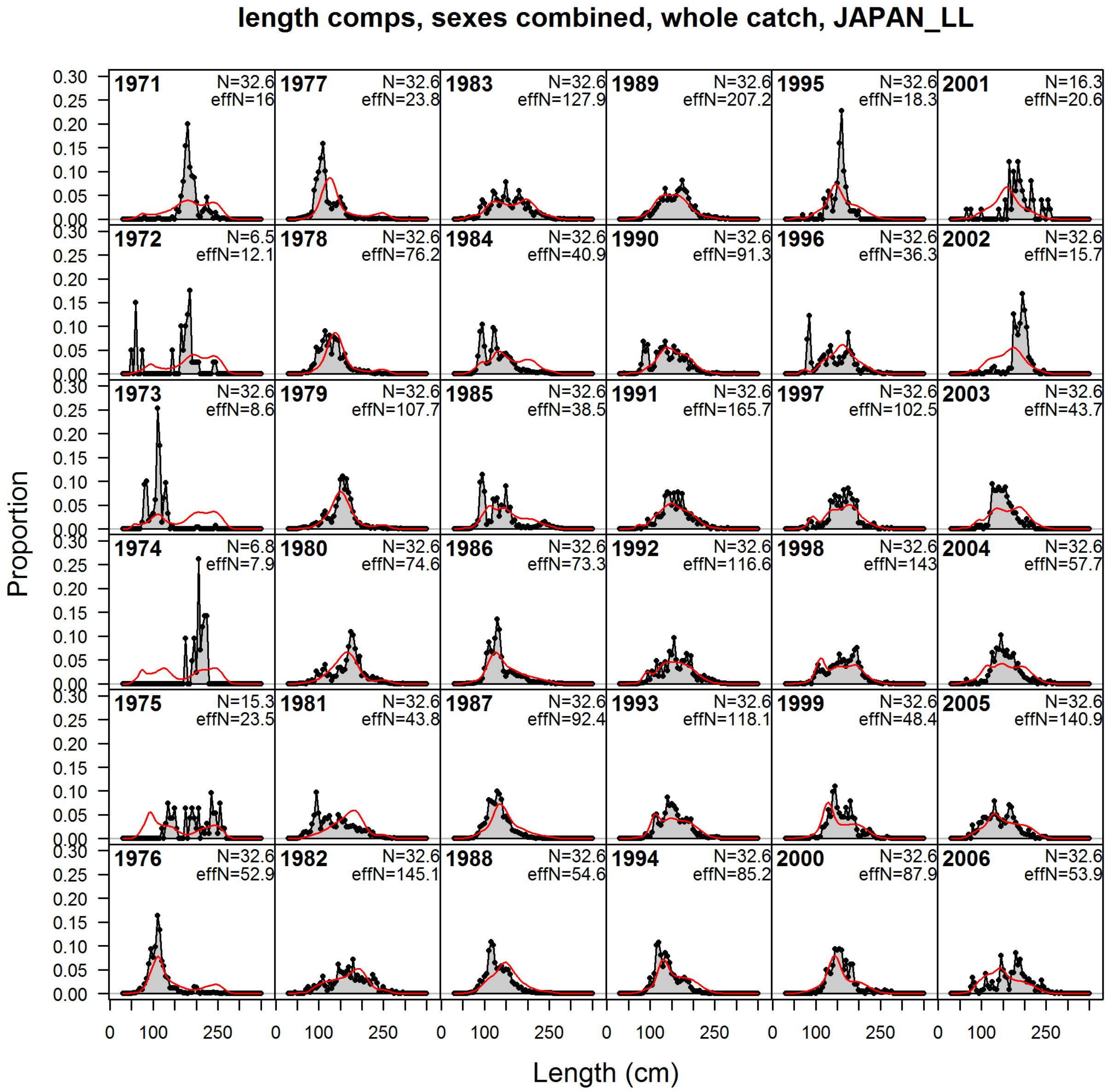


Figure 24. Fits to length composition data for JAPAN_LL for Run 12 (run 13 not shown for brevity, mostly the same).

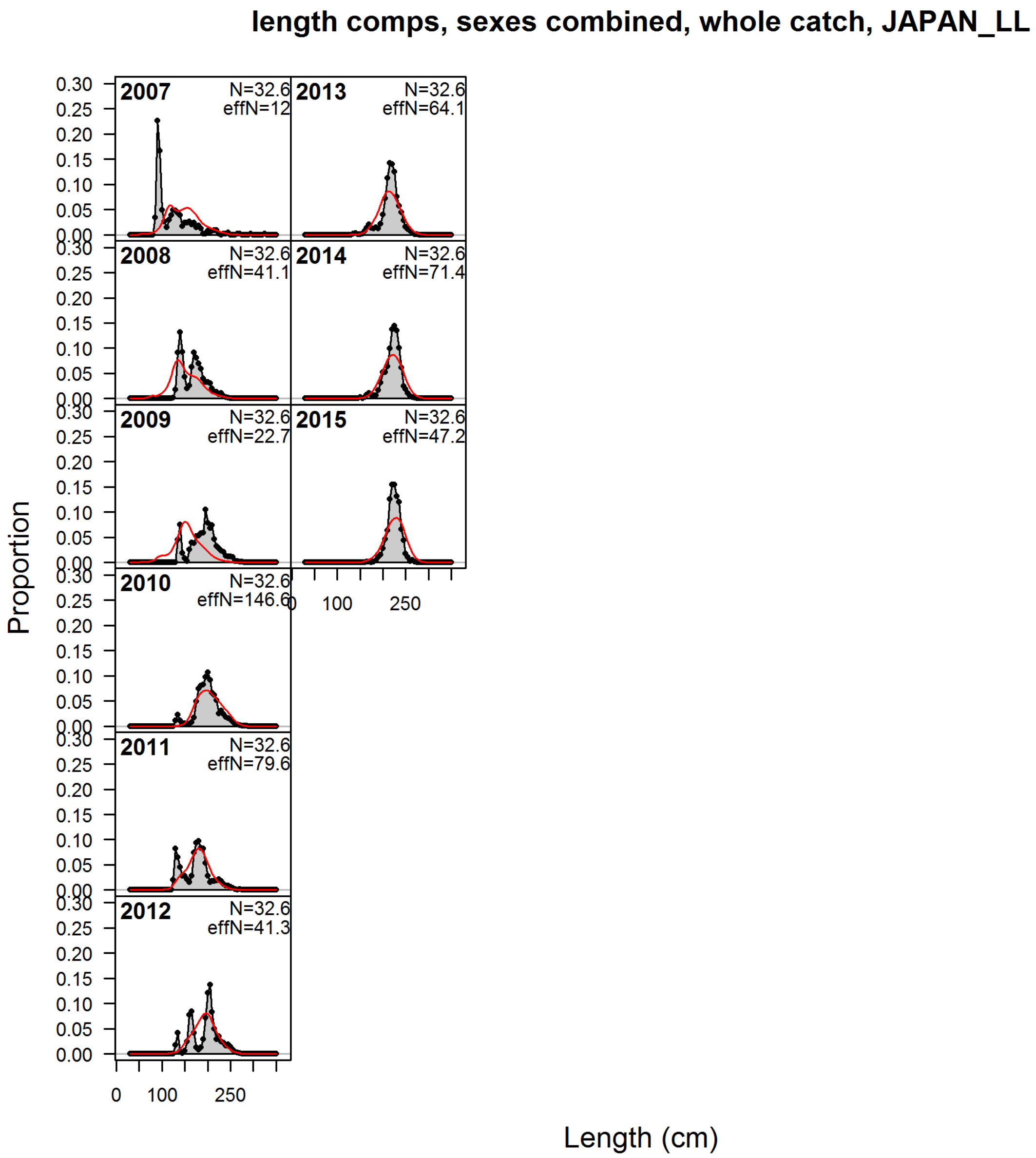


Figure 24. Cont.

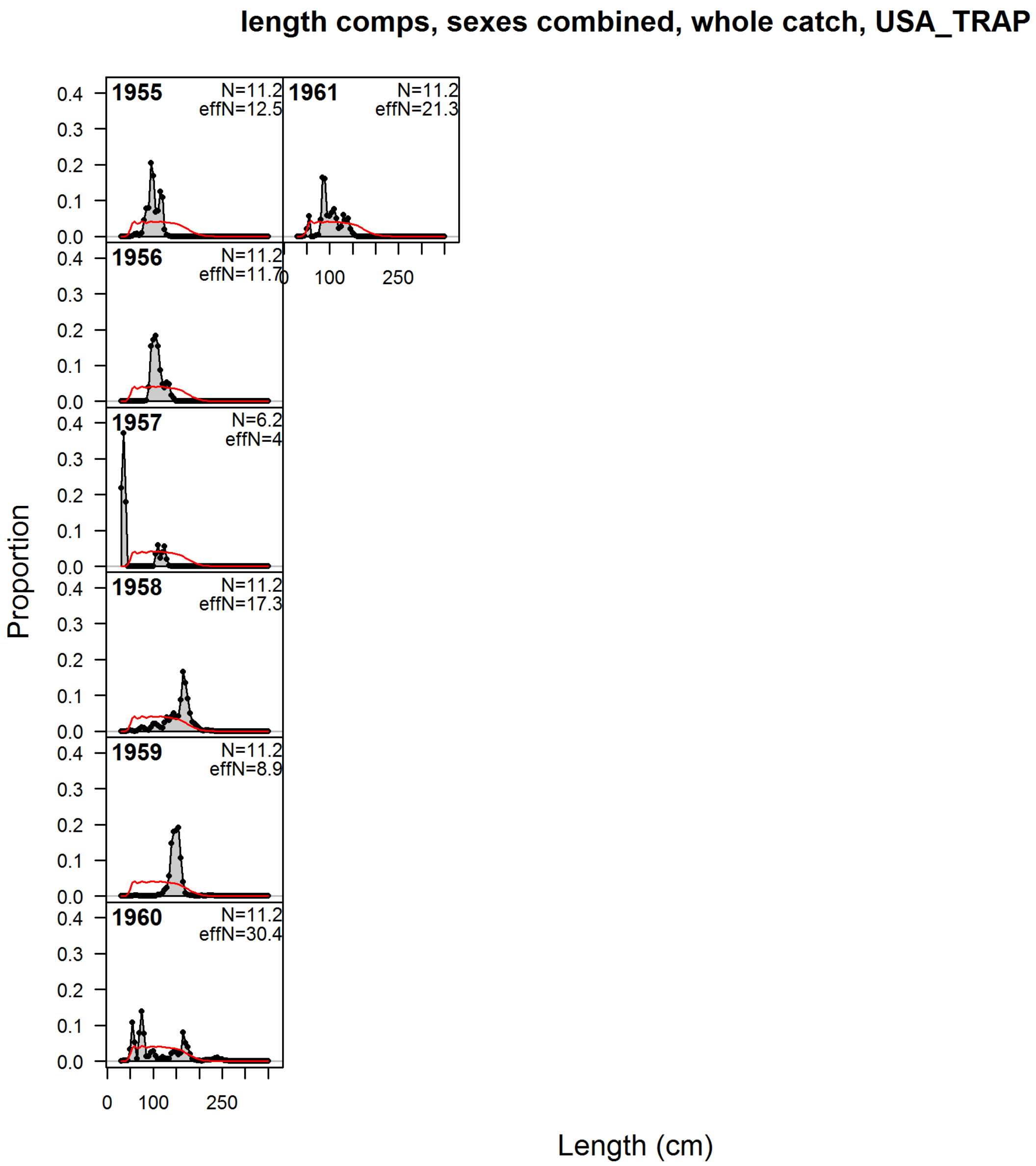


Figure 25. Fits to length composition data for USA_CAN_PSFS for Run 12 (run 13 not shown for brevity, mostly the same).

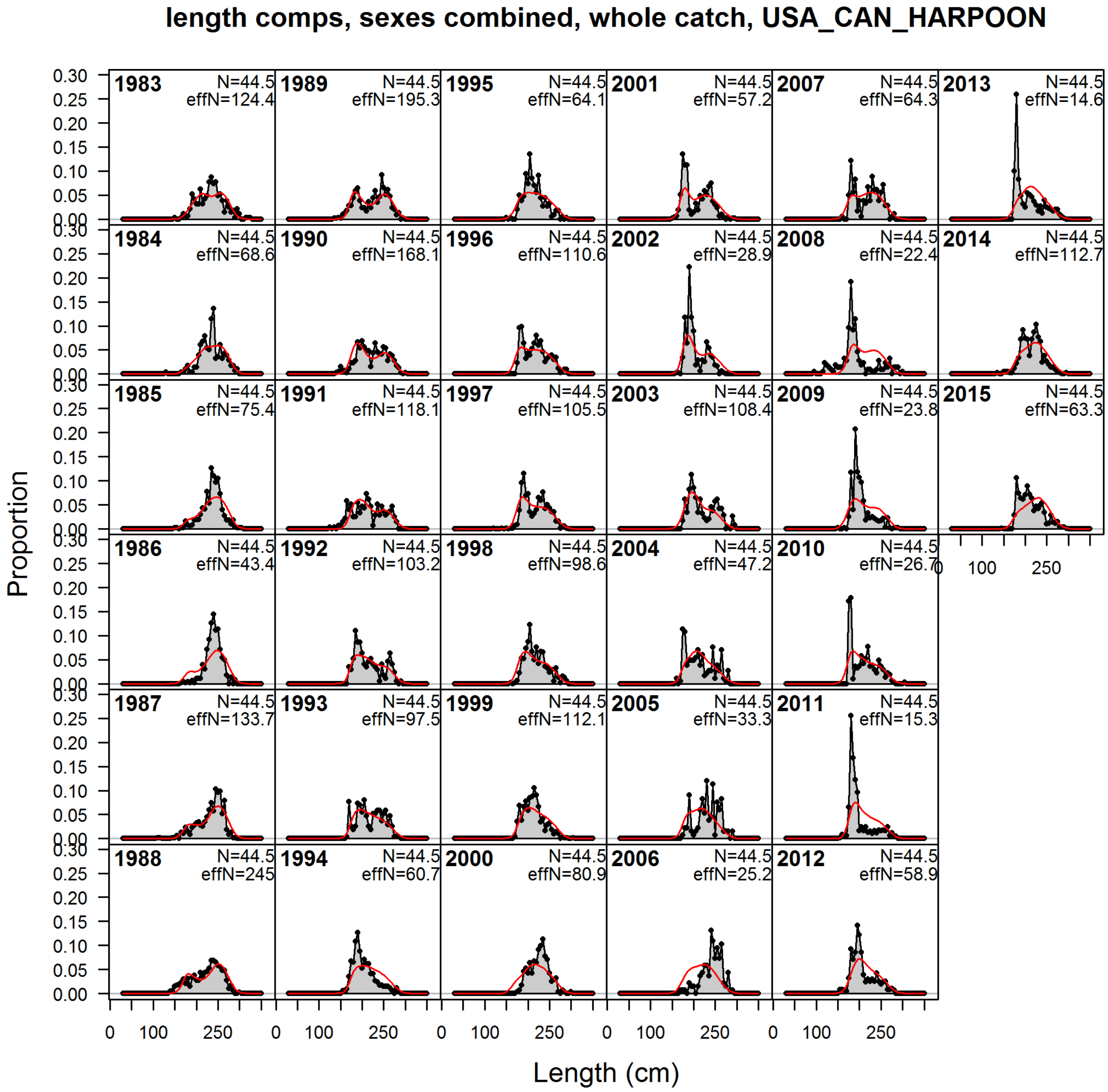


Figure 26. Fits to length composition data for USA_CAN_PSFB for Run 12 (run 13 not shown for brevity, mostly the same).

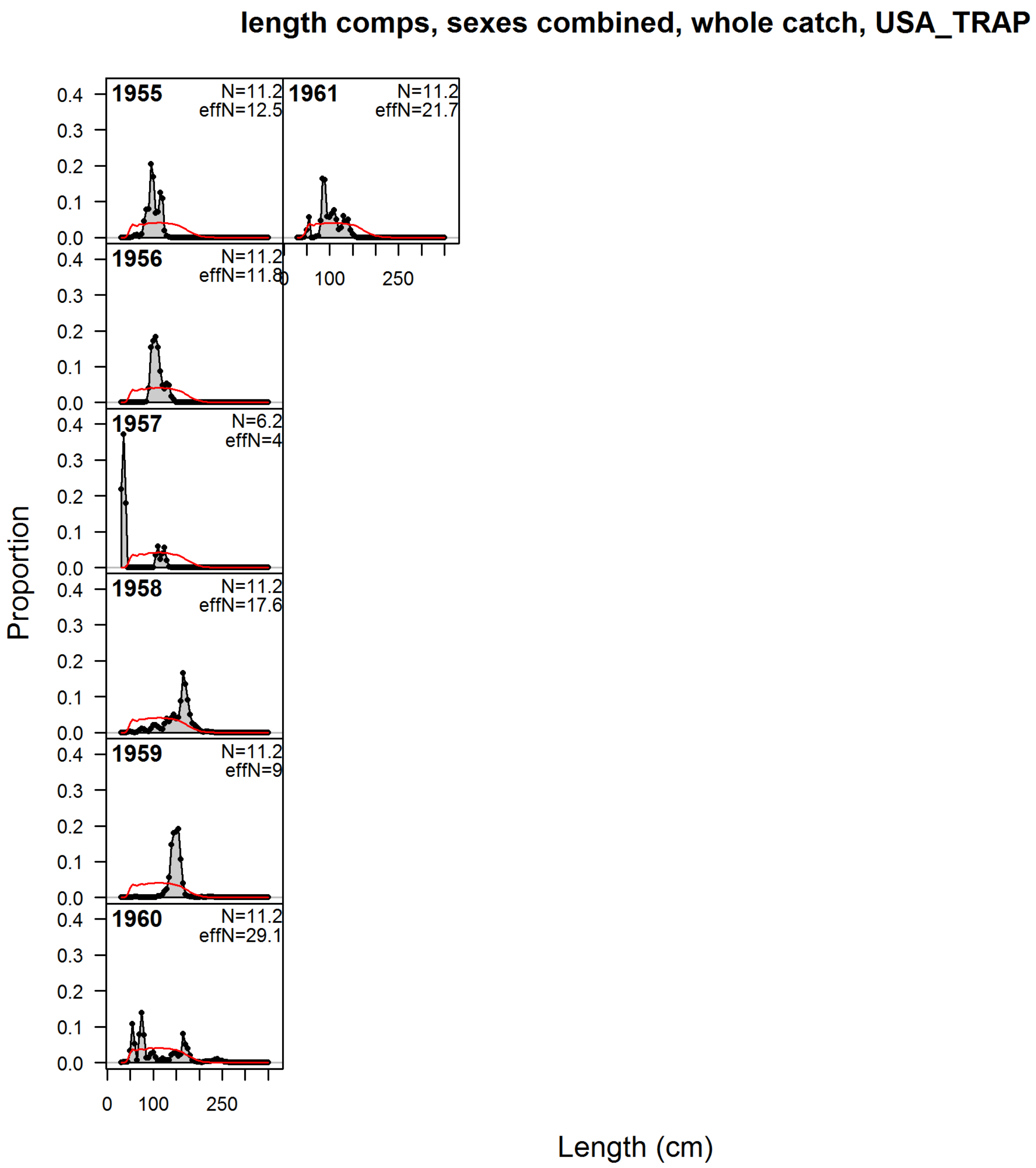


Figure 27. Fits to length composition data for USA_TRAP for Run 12 (run 13 not shown for brevity, mostly the same).

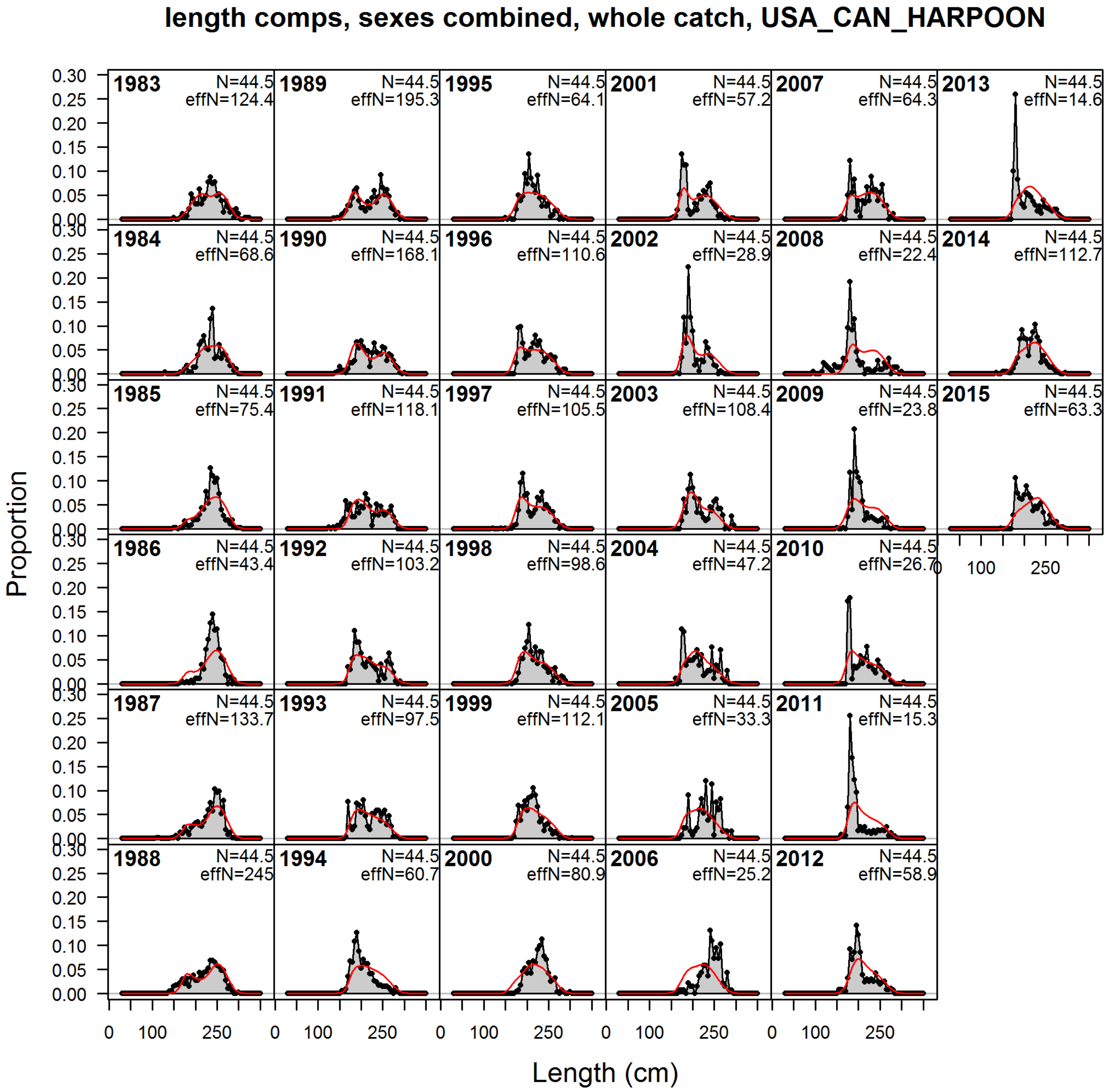


Figure 28. Fits to length composition data for USA_CAN_HARPOON for Run 12 (run 13 not shown for brevity, mostly the same).

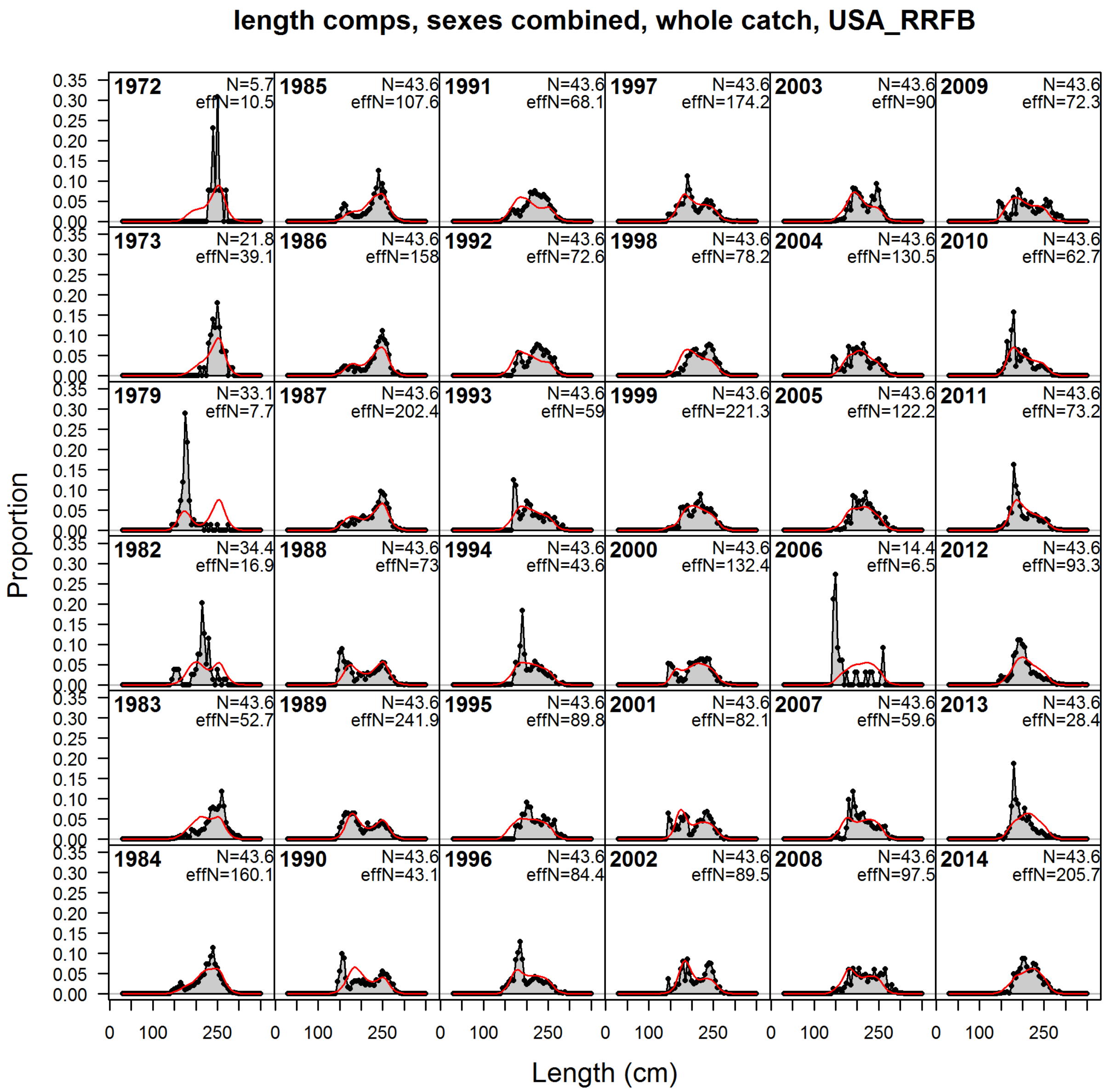


Figure 29. Fits to length composition data for USA_RRFB for Run 12 (run 13 not shown for brevity, mostly the same).

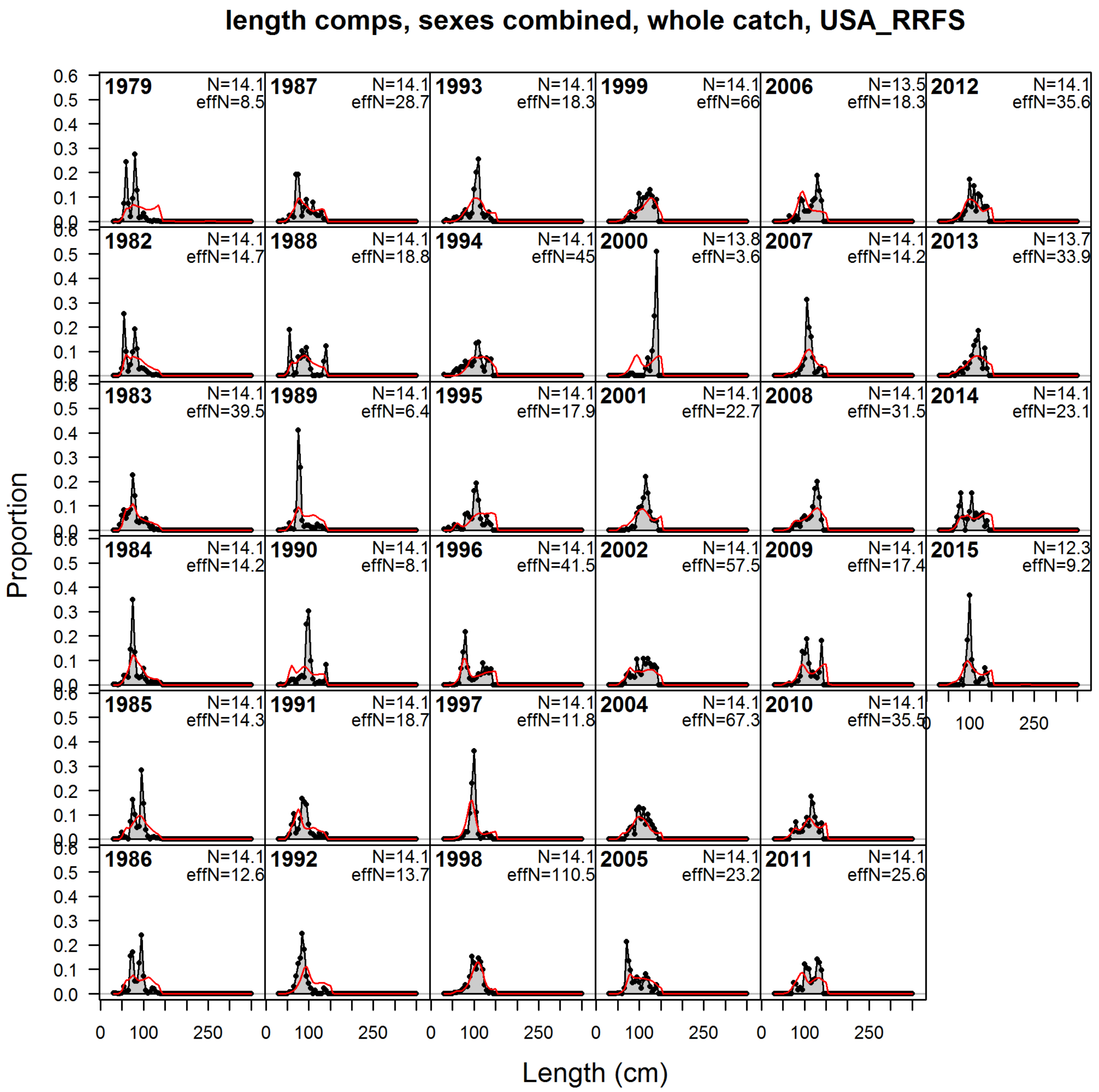
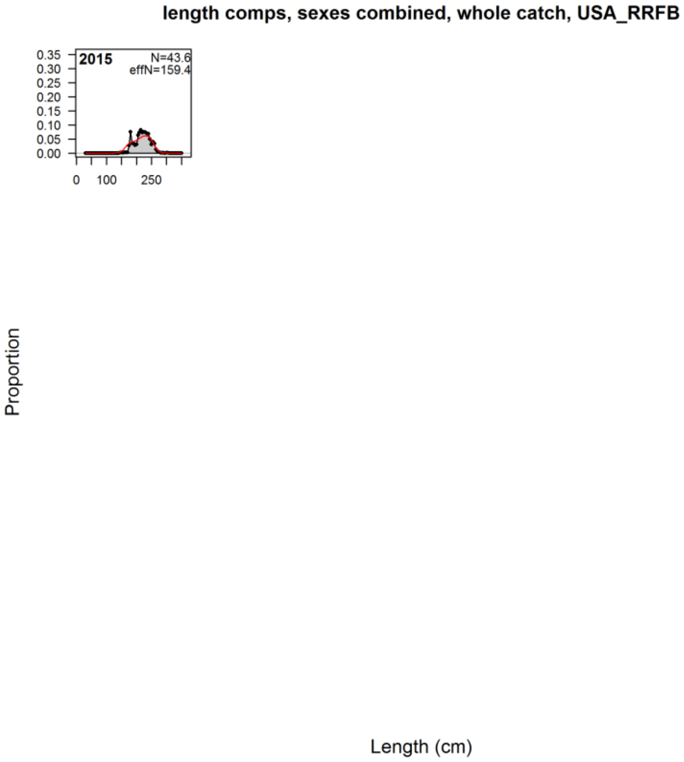


Figure 30. Fits to length composition data for USA_RRFS for Run 12 (run 13 not shown for brevity, mostly the same).

Figure 30, cont.



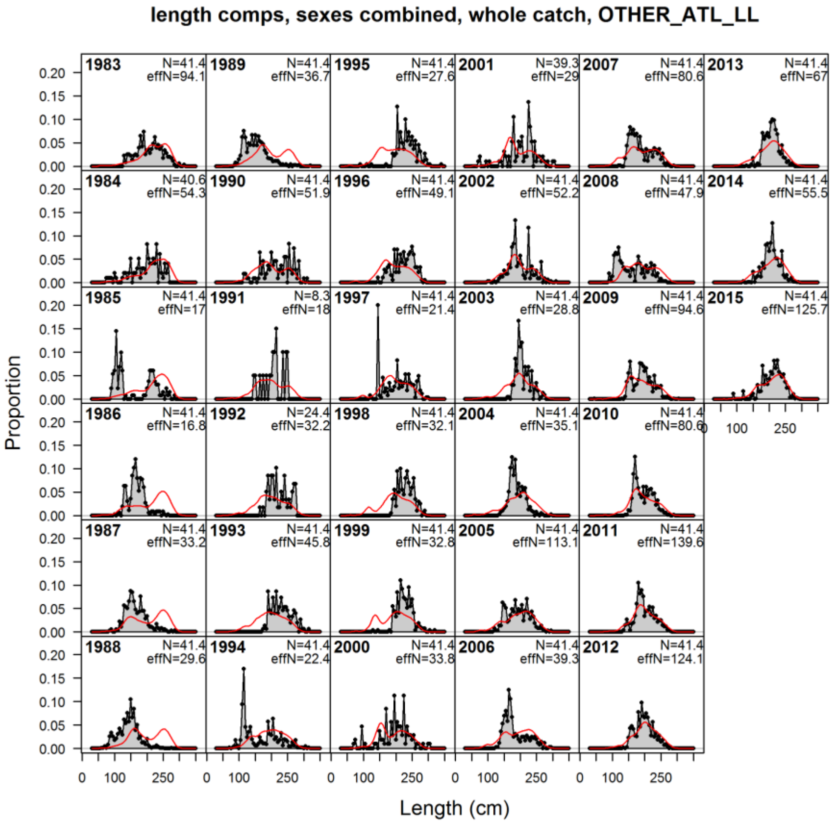


Figure 31. Fits to length composition data for OTHER_ATL_LL for Run 12 (run 13 not shown for brevity, mostly the same).

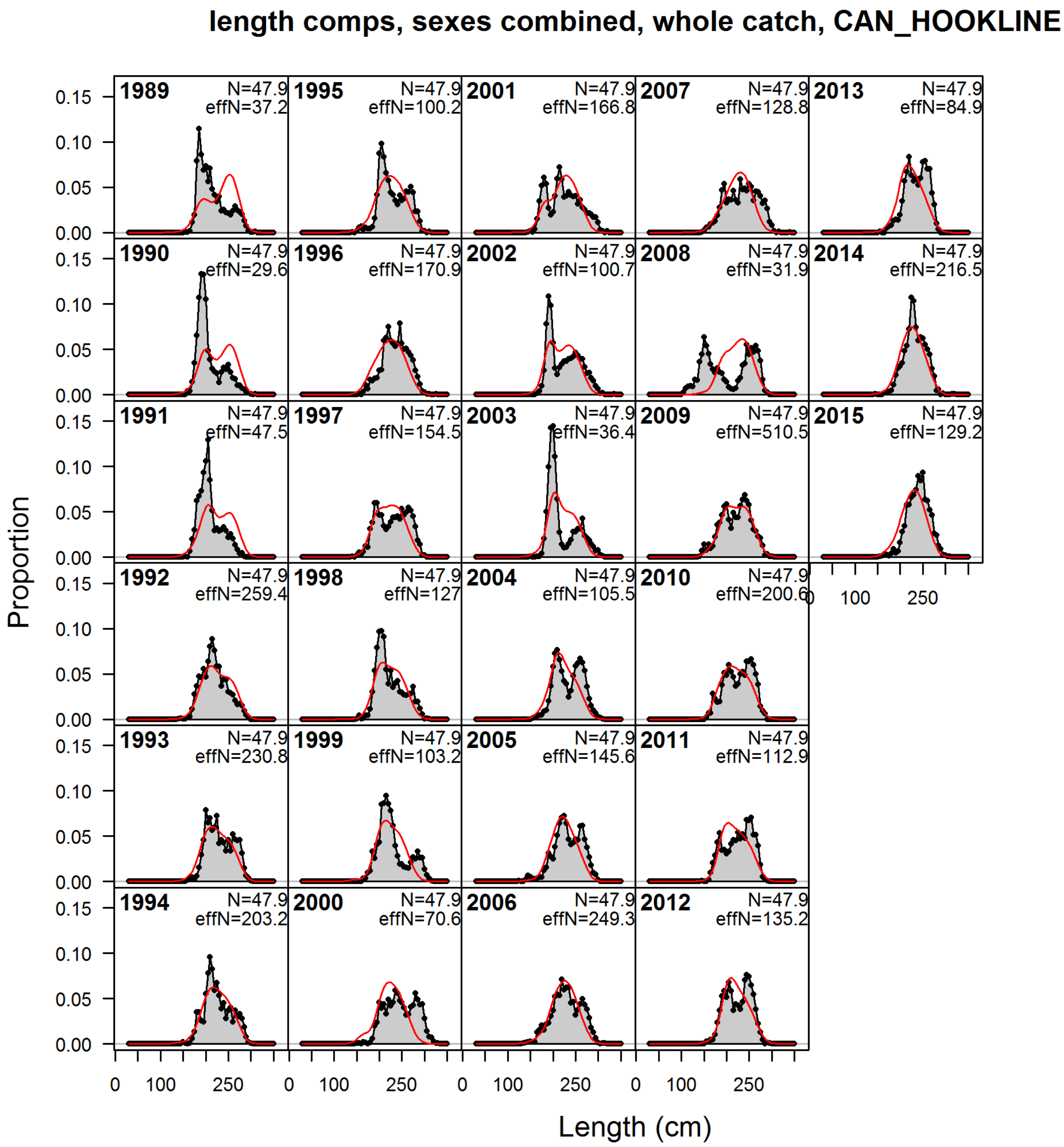


Figure 32. Fits to length composition data for CAN_HOOKLINE for Run 12 (run 13 not shown for brevity, mostly the same).

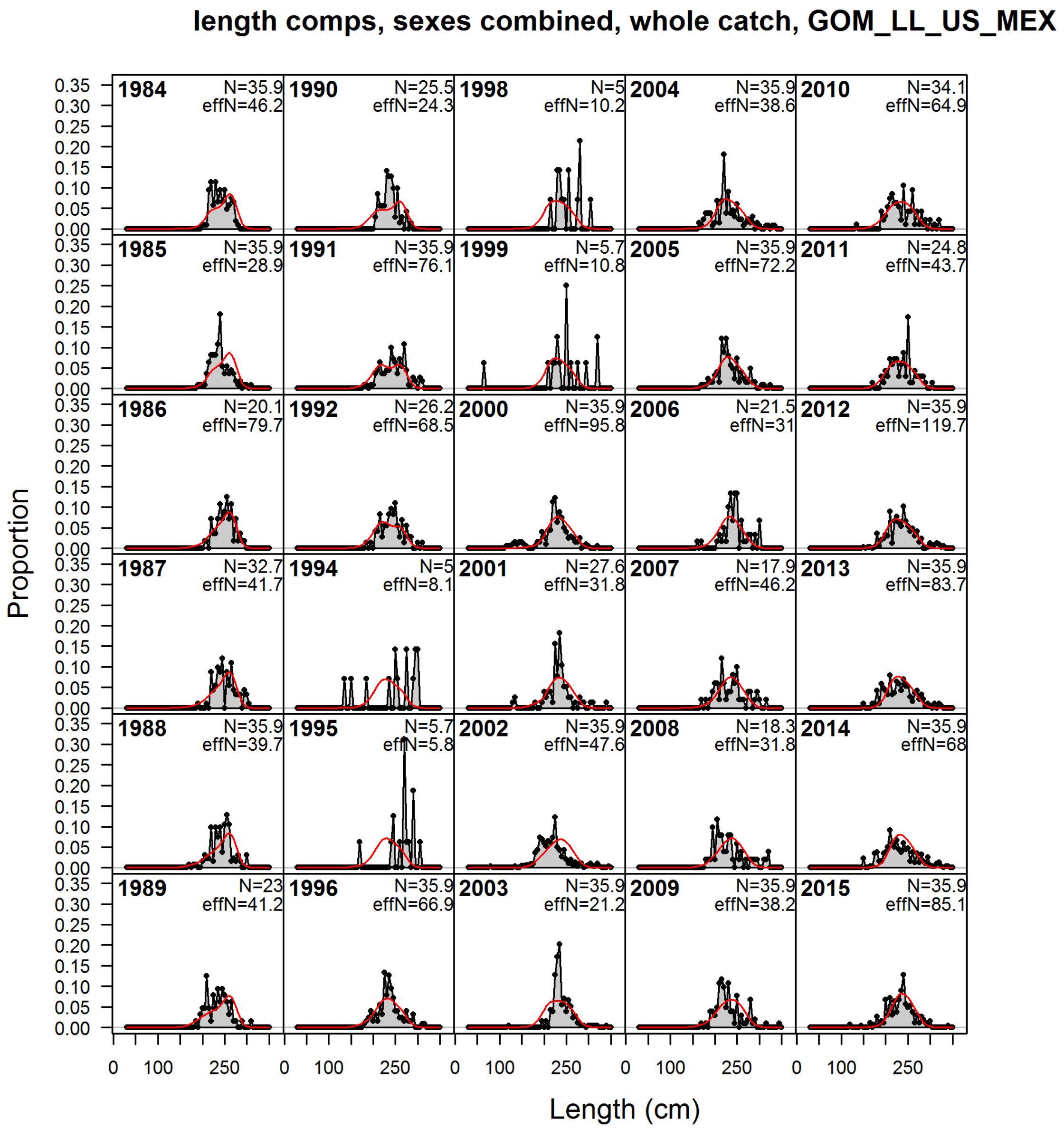


Figure 33. Fits to length composition data for GOM_LL_US_MEX for Run 12 (run 13 not shown for brevity, mostly the same).

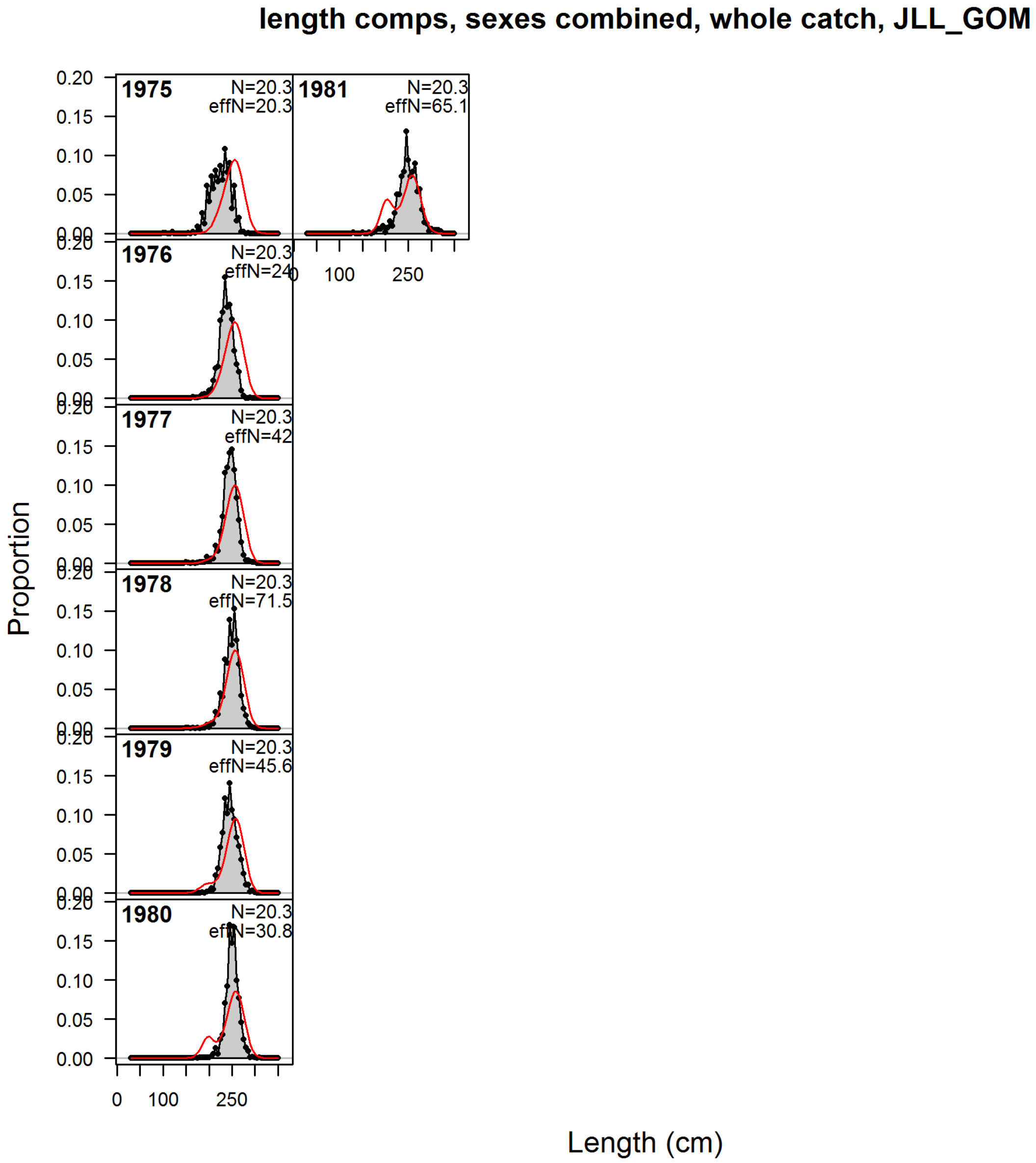


Figure 34. Fits to length composition data for JLL_GOM for Run 12 (run 13 not shown for brevity, mostly the same).

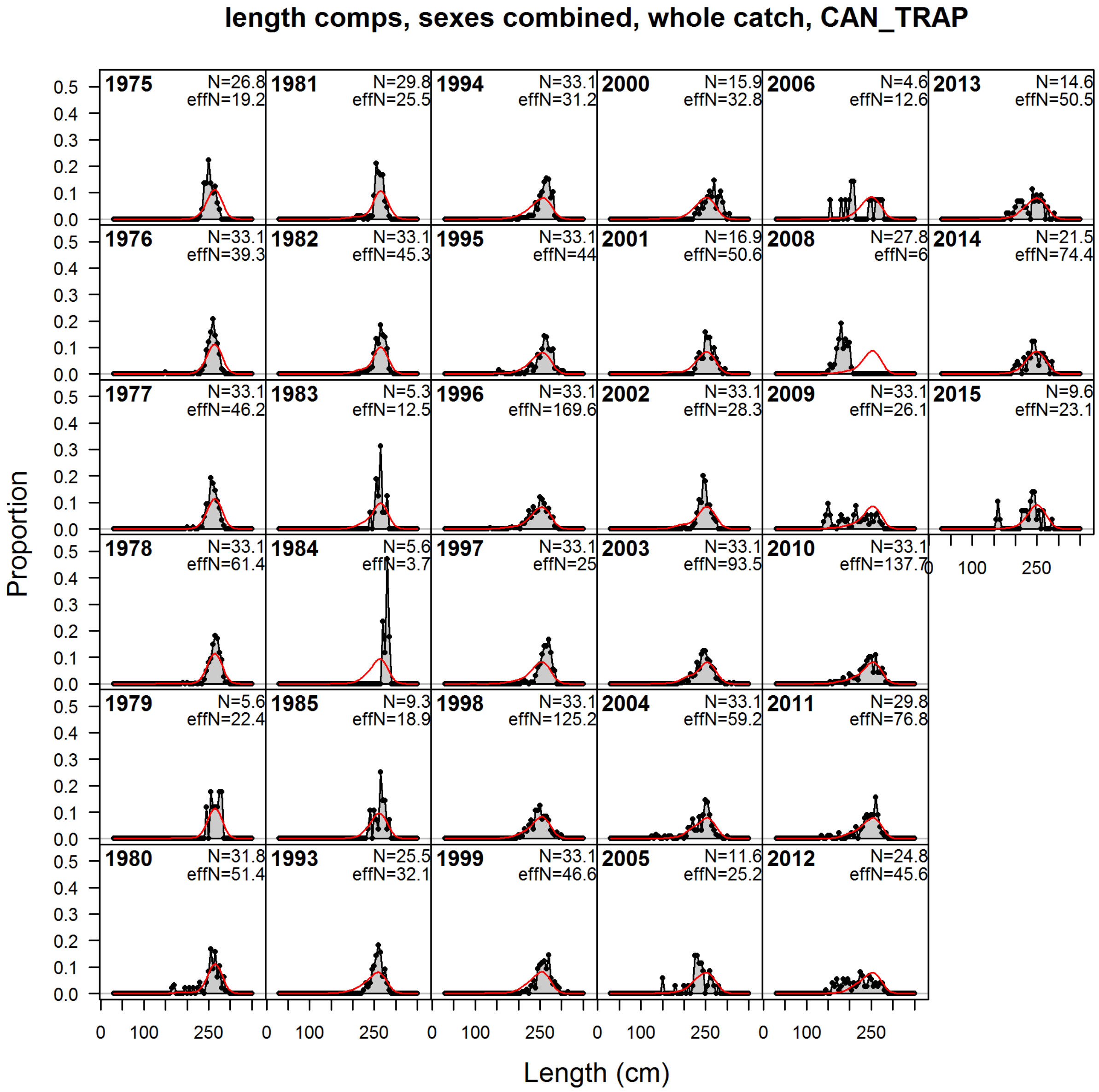


Figure 35. Fits to length composition data for CAN_TRAP for Run 12 (run 13 not shown for brevity, mostly the same).

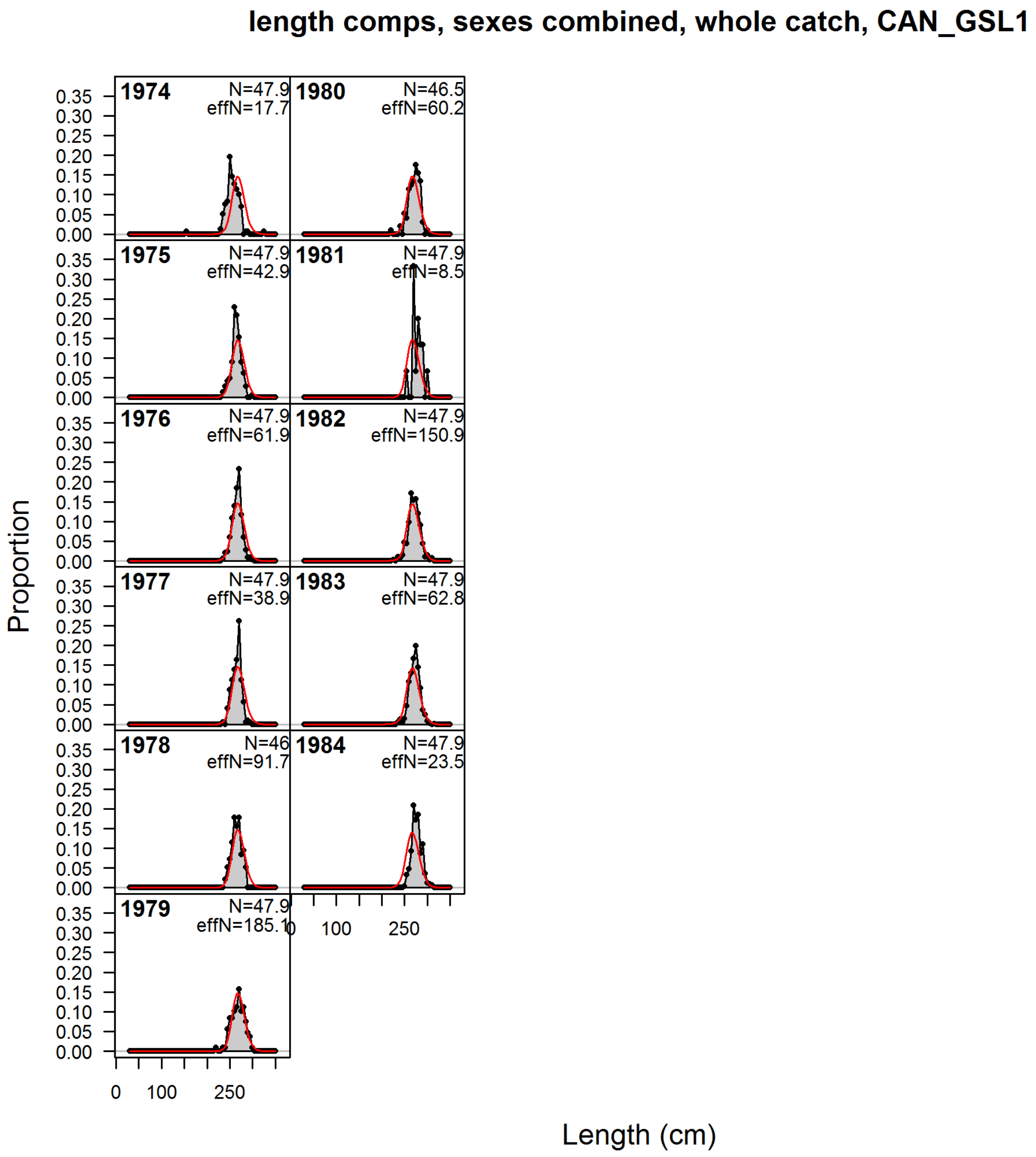


Figure 36. Fits to length composition data for CAN_GSL1 for Run 12 (run 13 not shown for brevity, mostly the same).

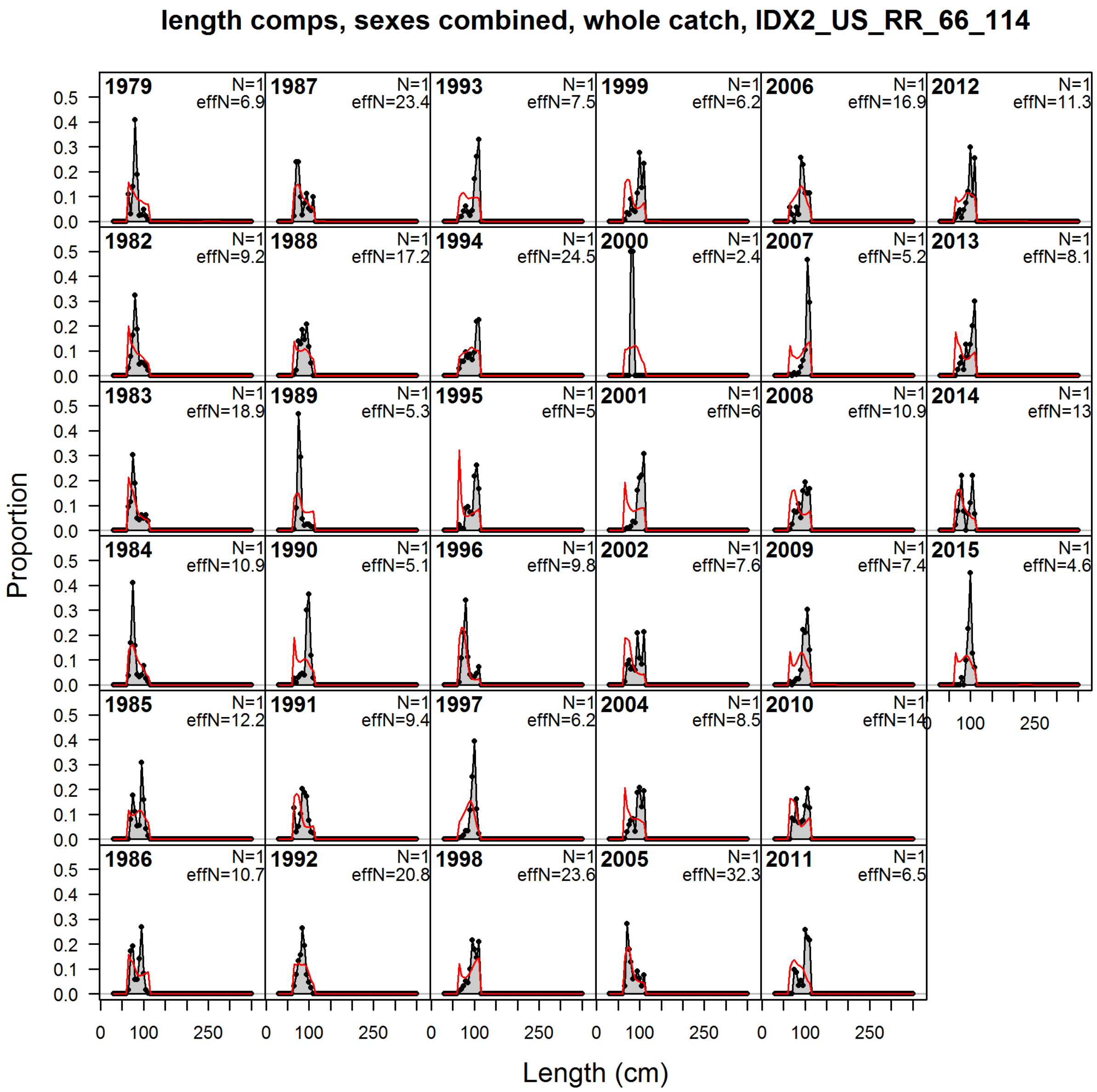


Figure 37. Fits to length composition data for Index_USRR_66_114 for Run 12 (run 13 not shown for brevity, mostly the same).

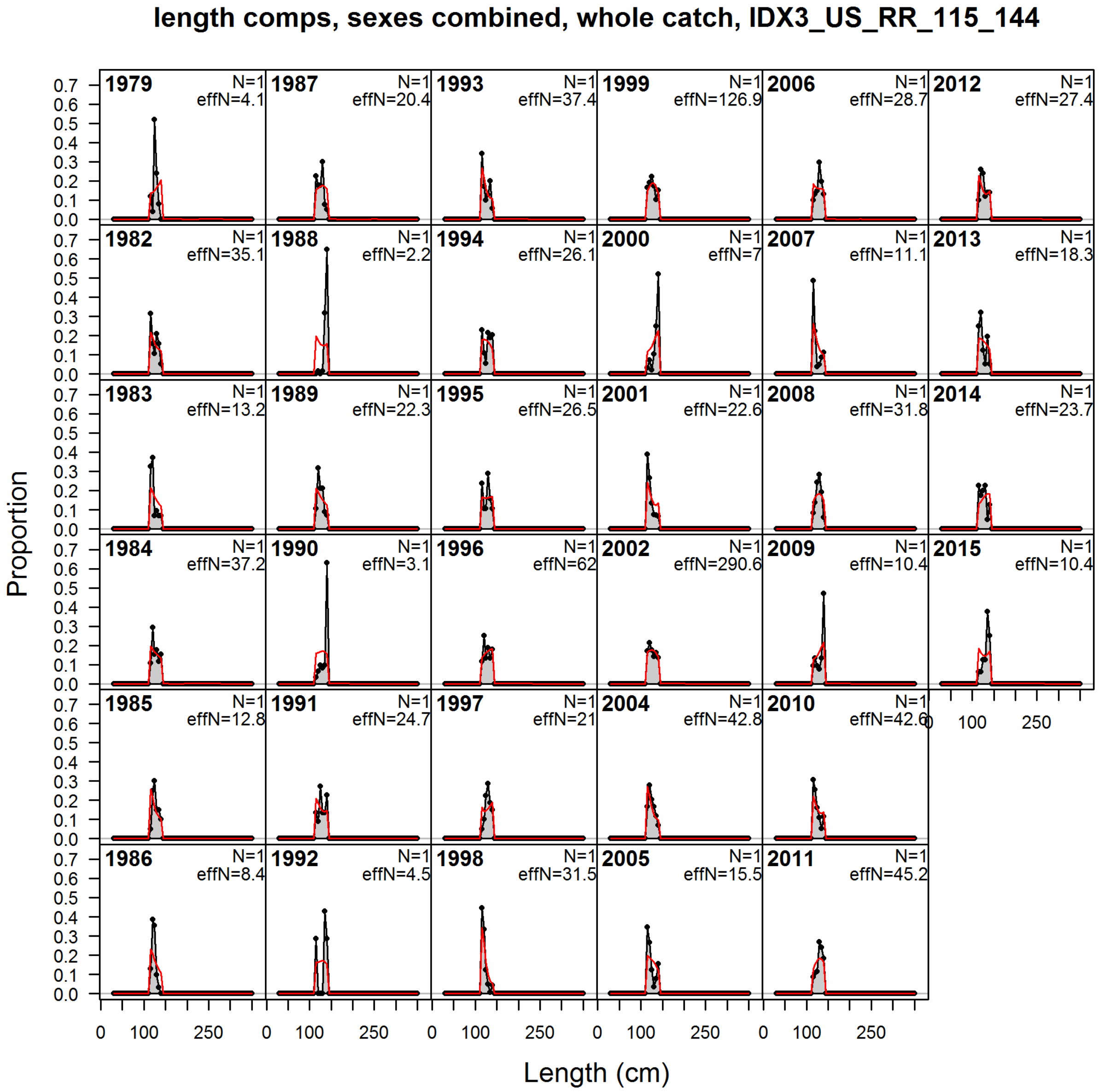
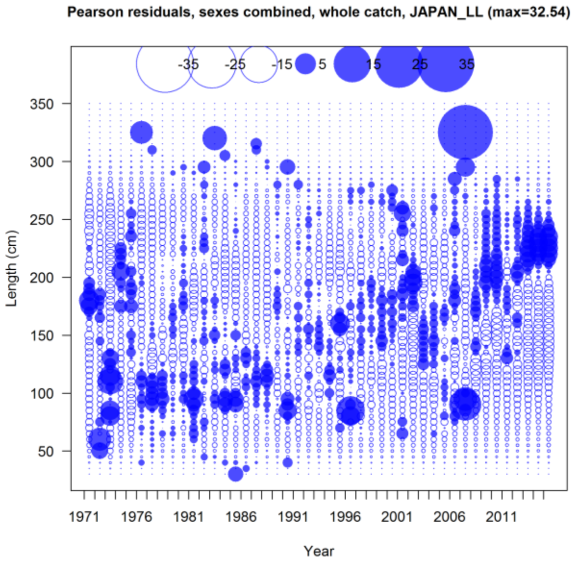


Figure 38. Fits to length composition data for Index_USRR_115_144 for Run 12 (run 13 not shown for brevity, mostly the same).



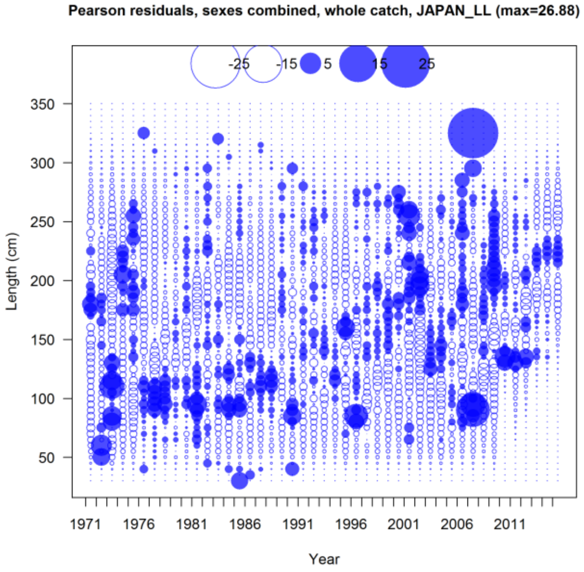


Figure 39. Pearson residuals to length composition fits for run 1 (left) and run 10 (right) with the time varying selectivity for the Japan longline fleet. Blue dots are higher than expected, white circles are lower.

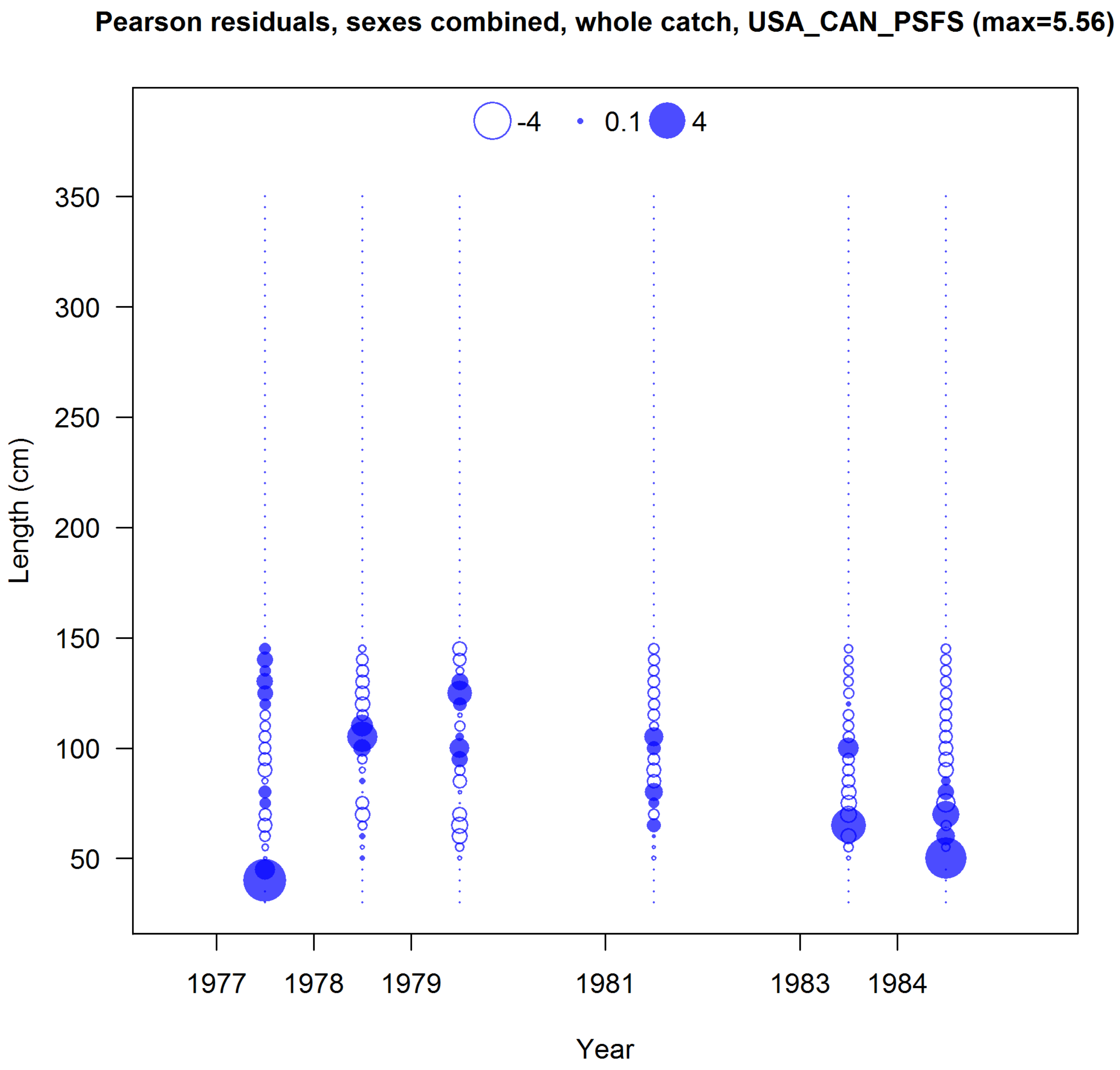


Figure 40. Pearson residuals to length composition fits for run 12. Blue dots are higher than expected, white circles are lower.

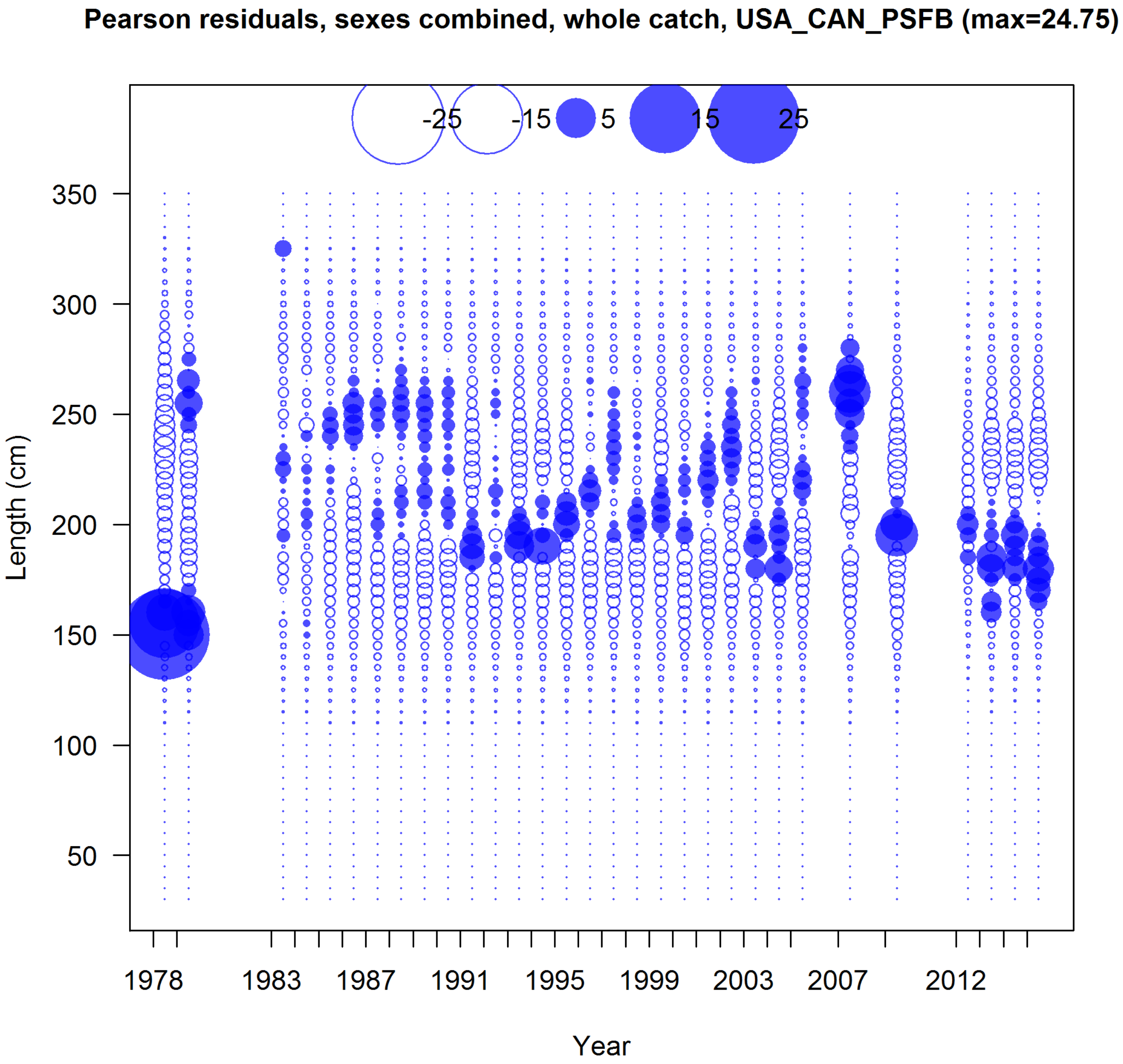


Figure 41. Pearson residuals to length composition fits for run 12. Blue dots are higher than expected, white circles are lower.

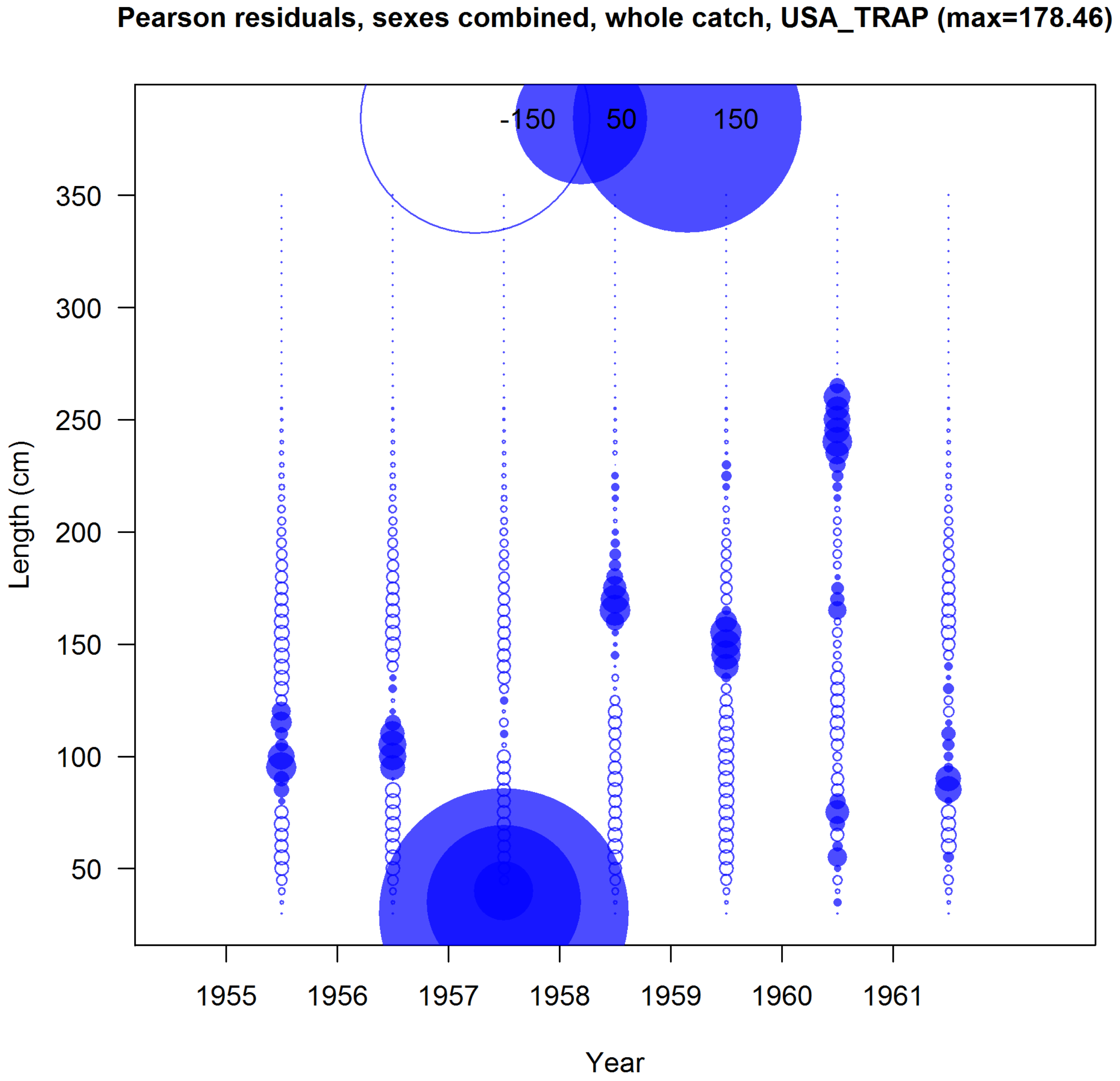


Figure 42. Pearson residuals to length composition fits for run 12. Blue dots are higher than expected, white circles are lower.

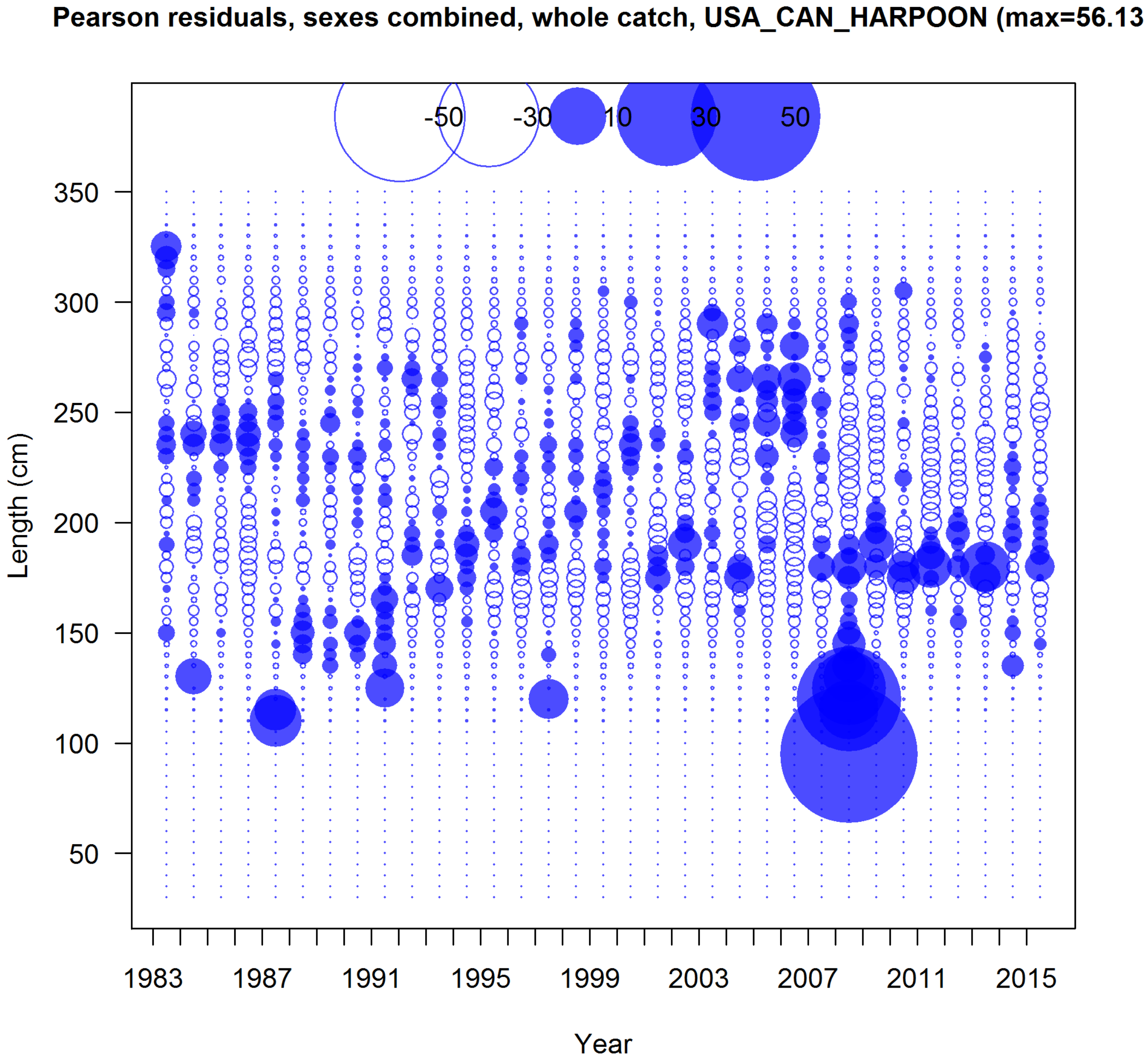


Figure 43. Pearson residuals to length composition fits for run 12. Blue dots are higher than expected, white circles are lower.

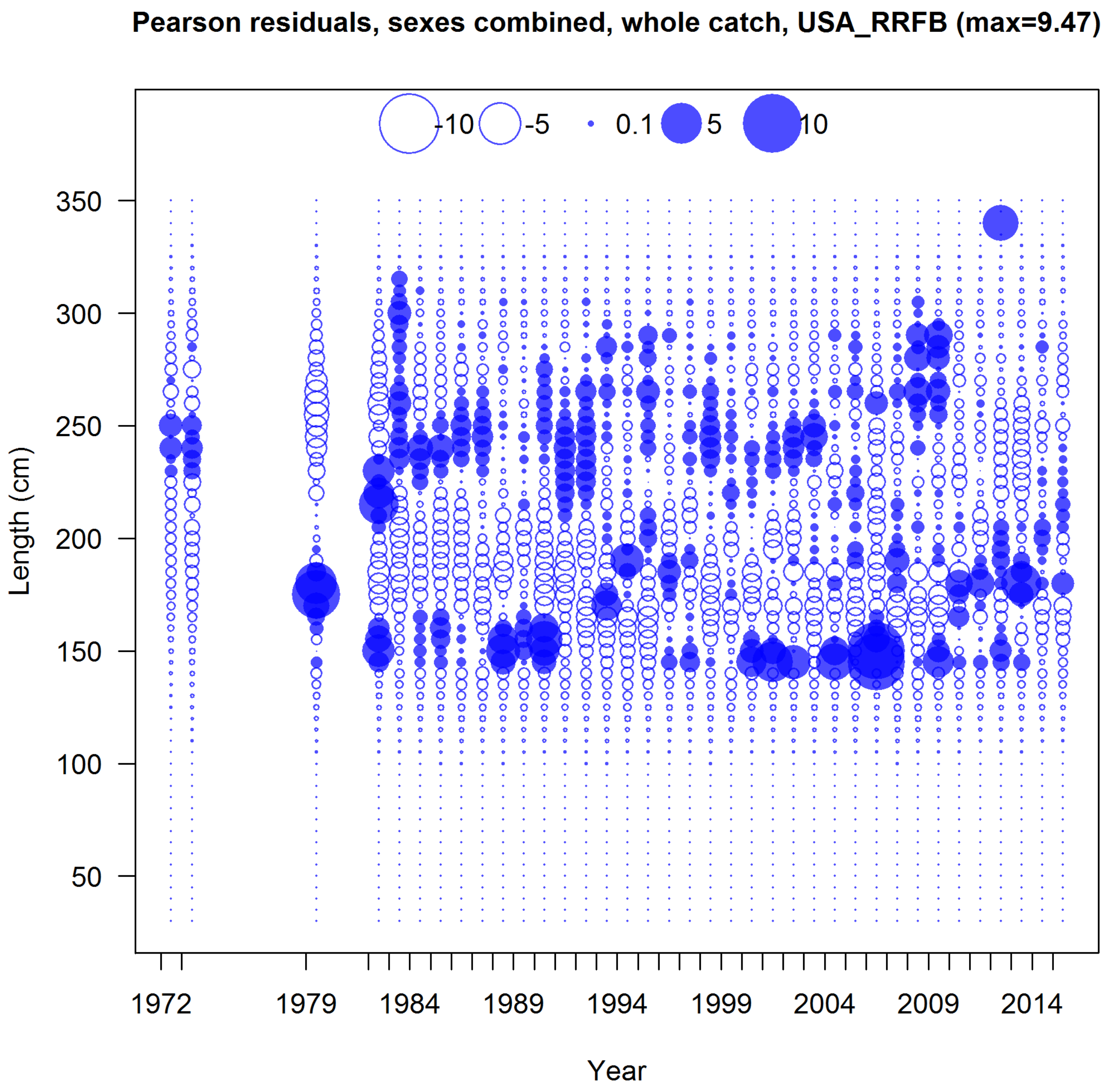


Figure 44. Pearson residuals to length composition fits for run 12. Blue dots are higher than expected, white circles are lower.

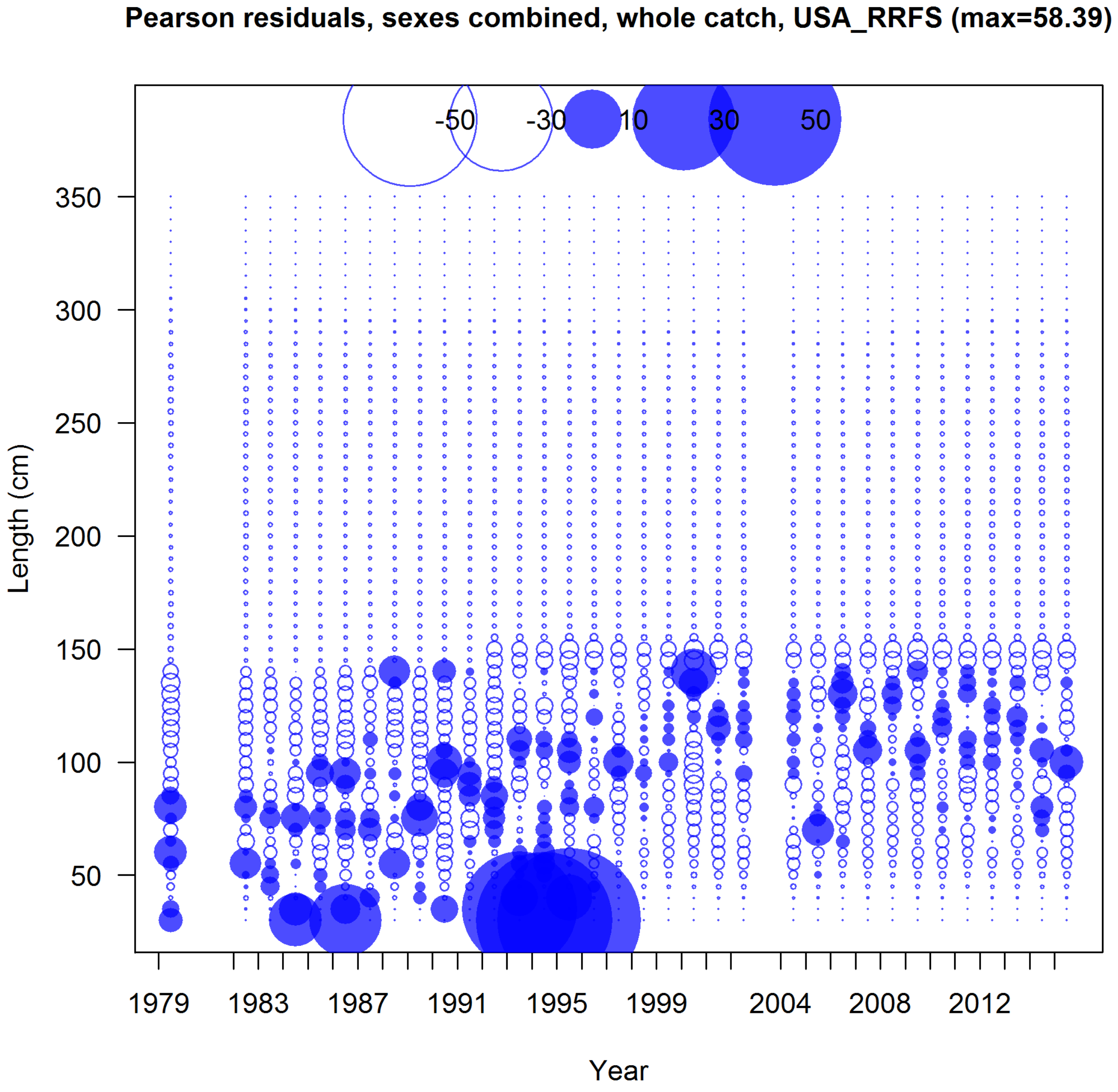


Figure 45. Pearson residuals to length composition fits for run 12. Blue dots are higher than expected, white circles are lower.

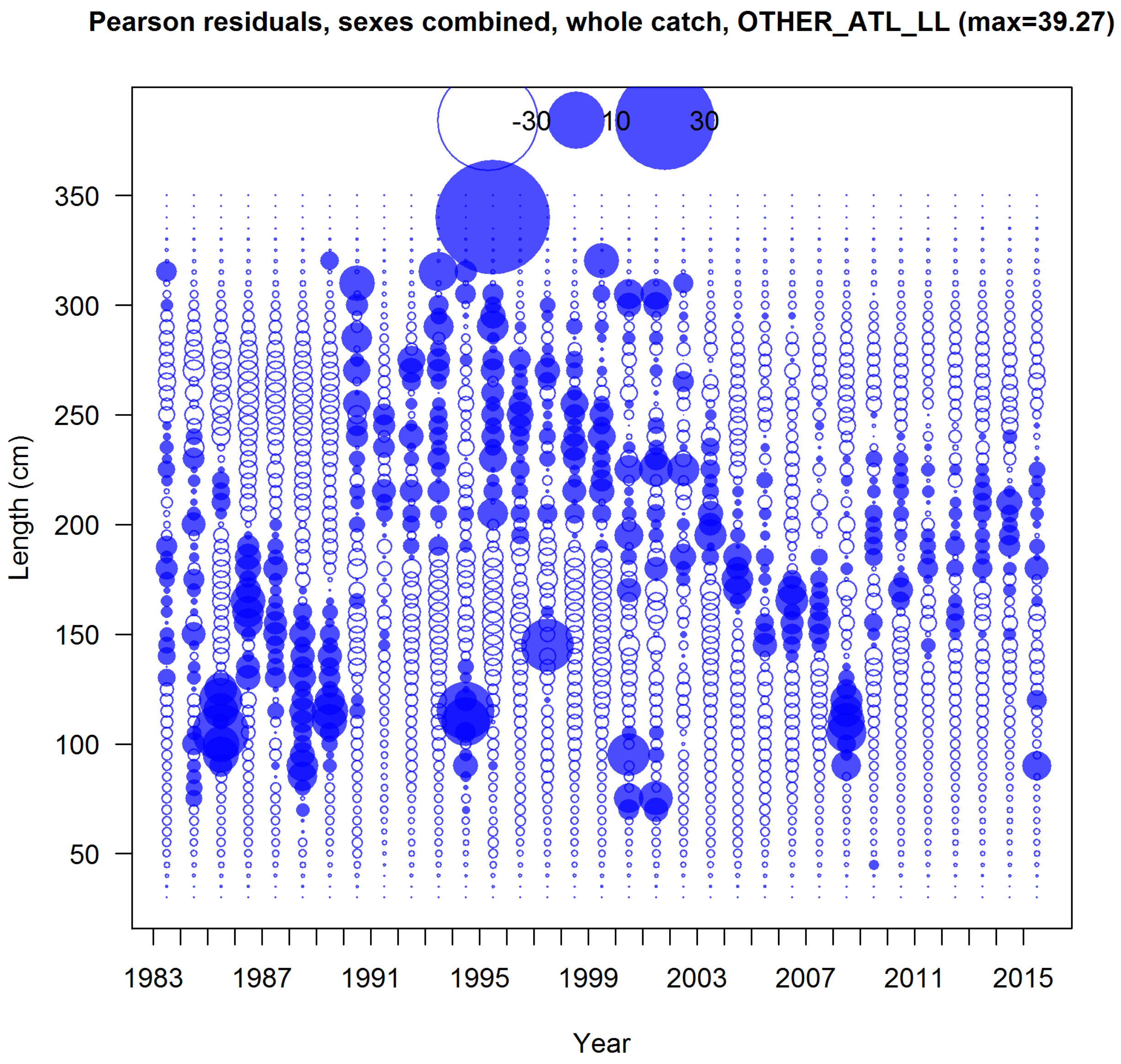


Figure 46. Pearson residuals to length composition fits for run 12. Blue dots are higher than expected, white circles are lower.

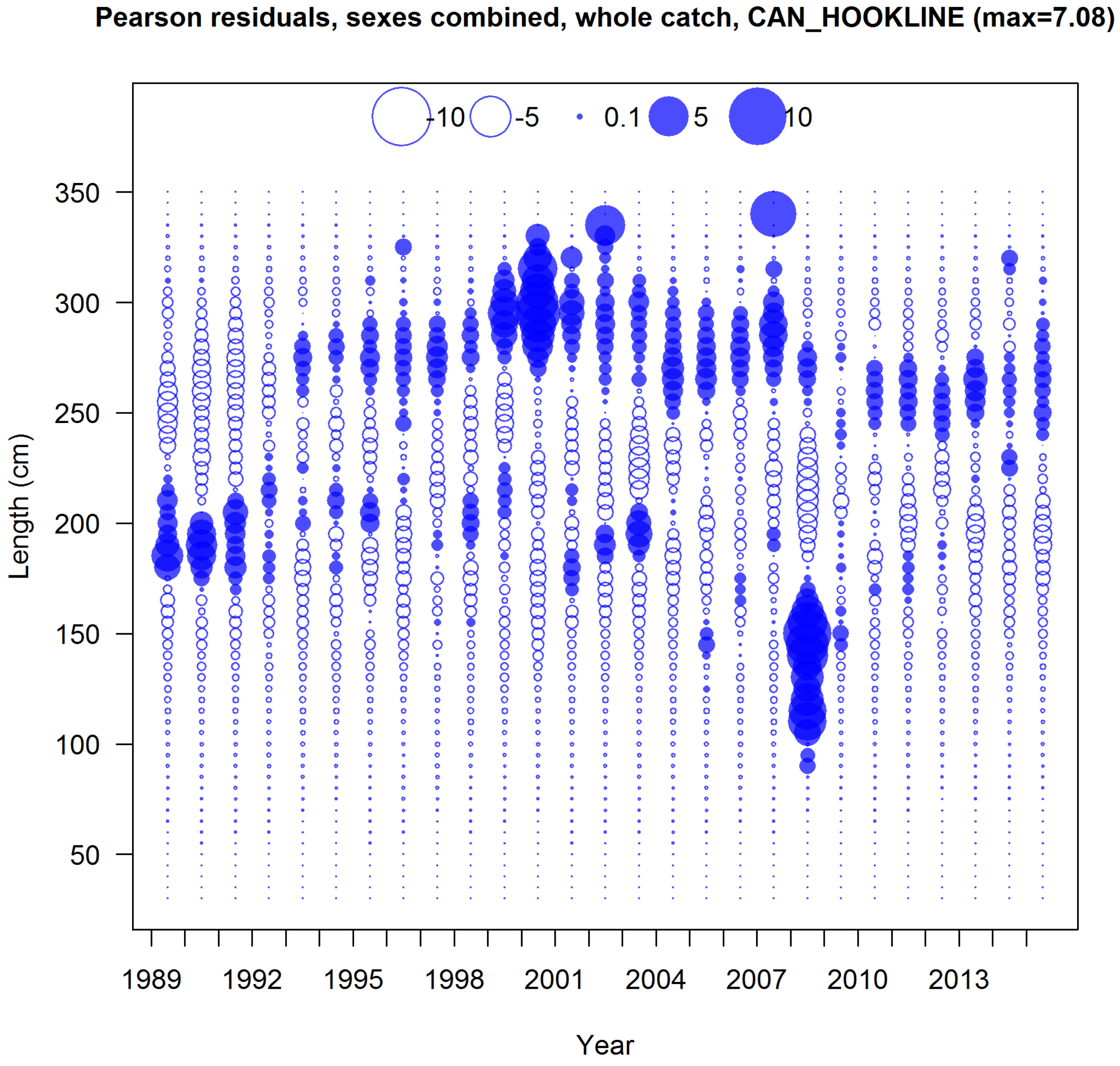


Figure 47. Pearson residuals to length composition fits for run 12. Blue dots are higher than expected, white circles are lower.

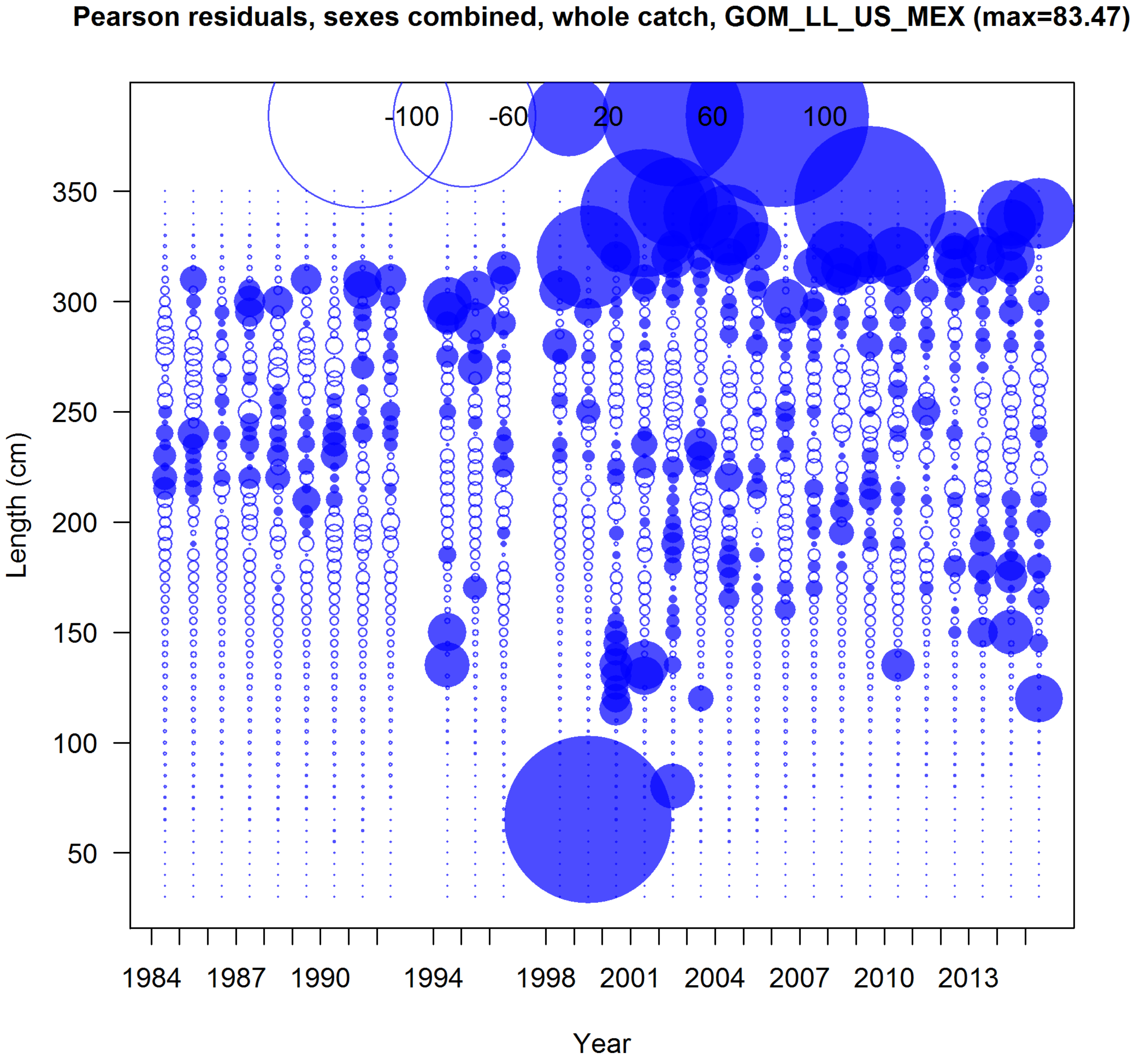


Figure 48. Pearson residuals to length composition fits for run 12. Blue dots are higher than expected, white circles are lower.

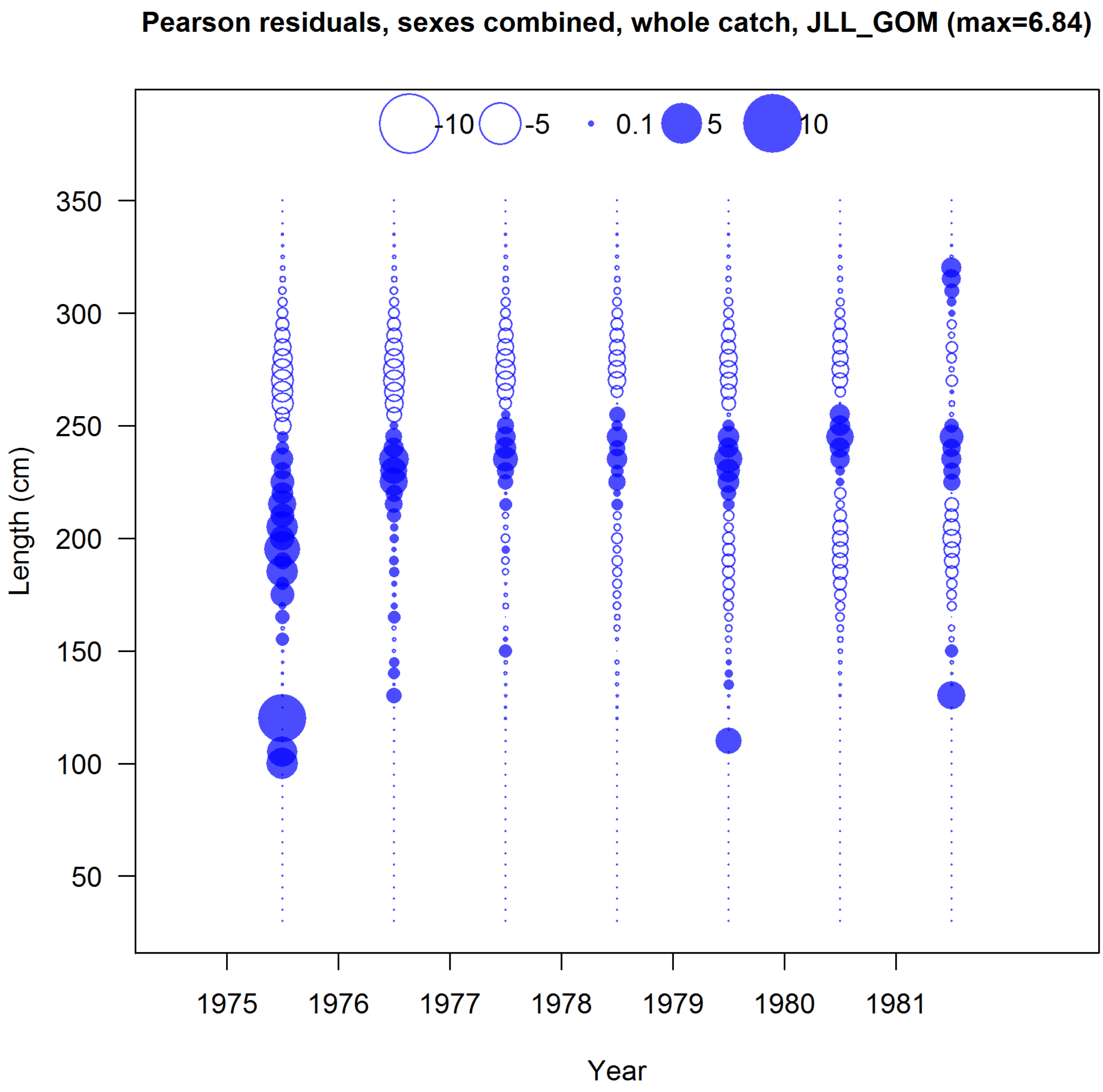


Figure 49. Pearson residuals to length composition fits for run 12. Blue dots are higher than expected, white circles are lower.

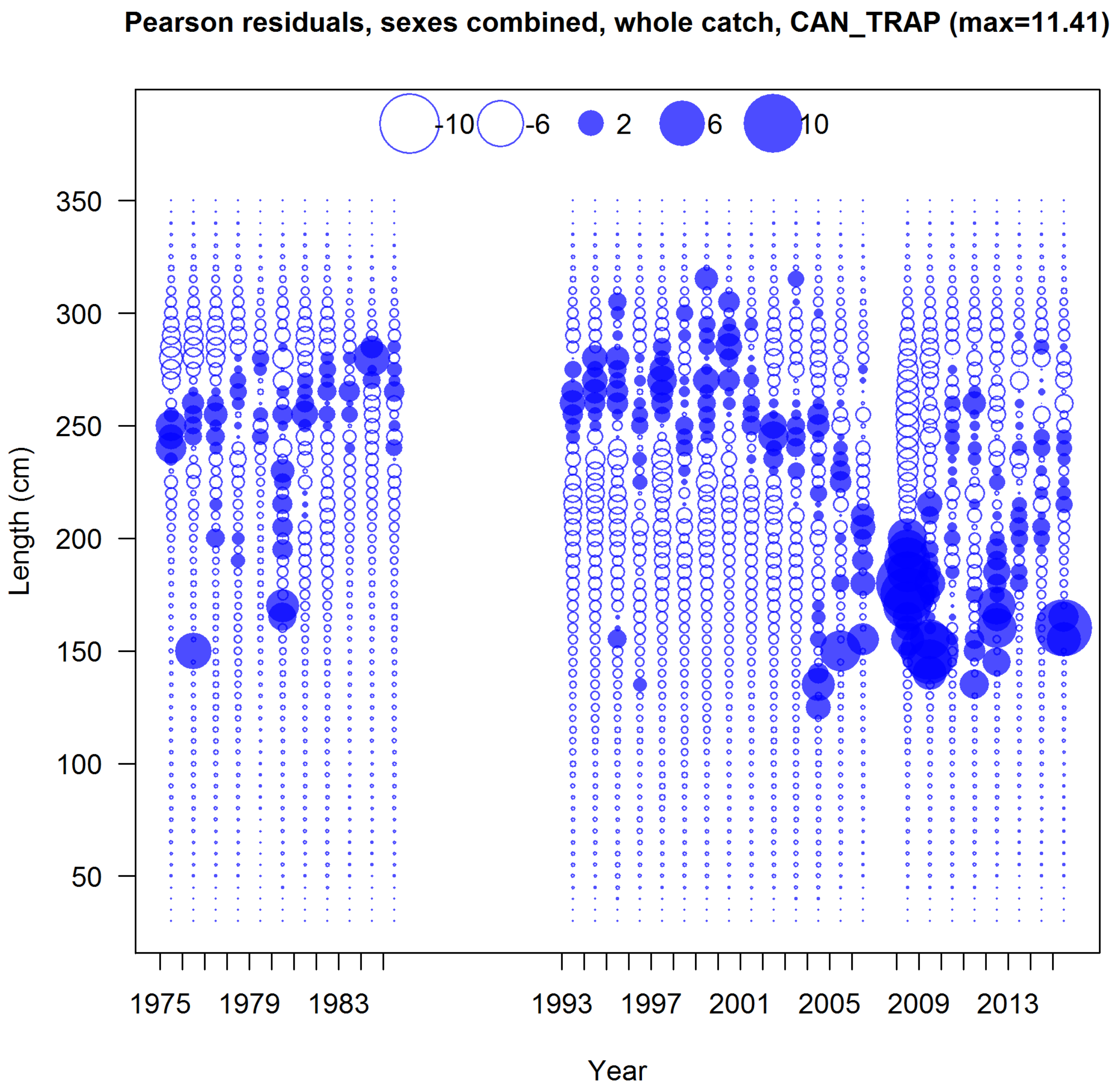


Figure 50. Pearson residuals to length composition fits for run 12. Blue dots are higher than expected, white circles are lower.

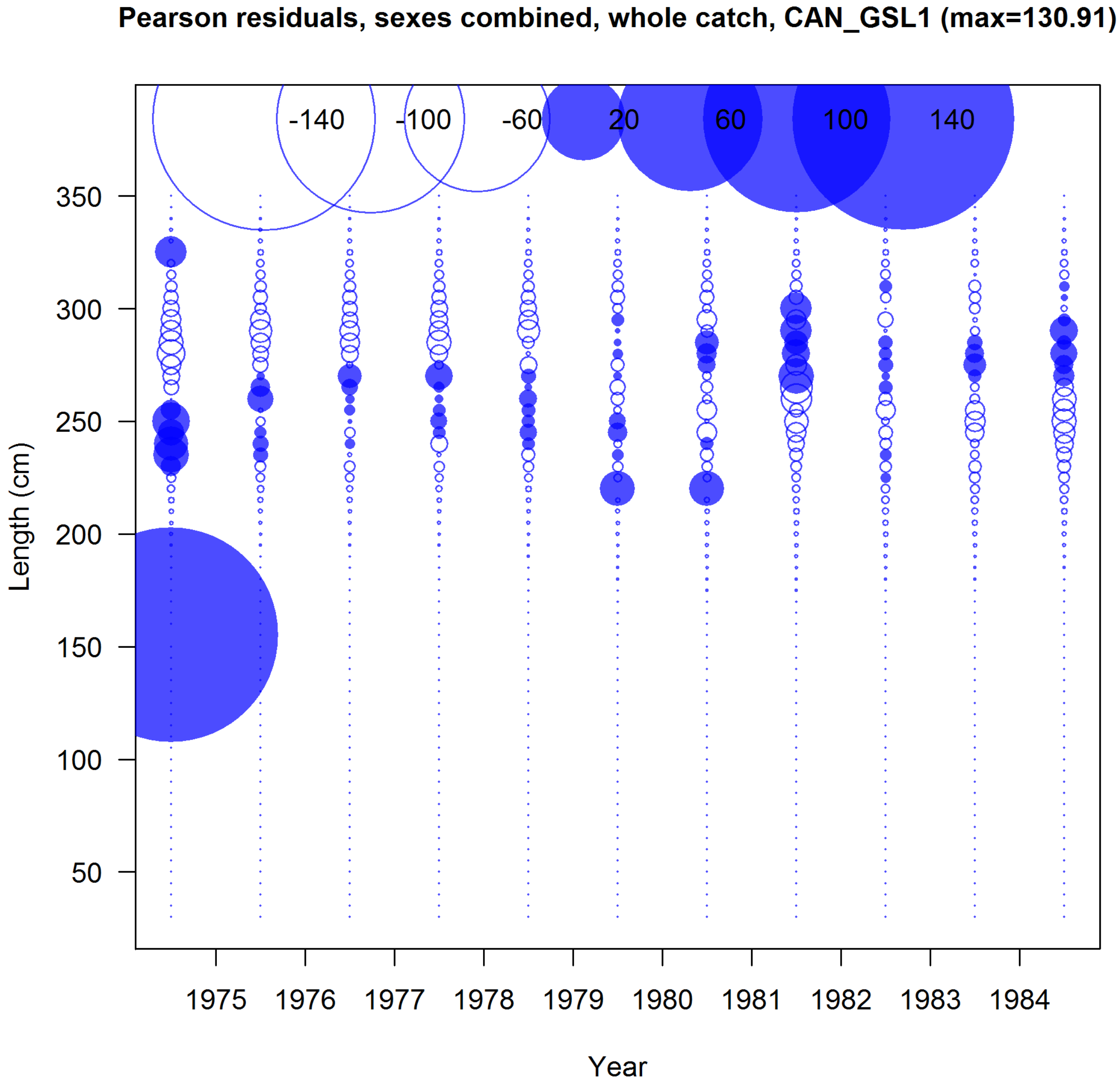


Figure 51. Pearson residuals to length composition fits for run 12. Blue dots are higher than expected, white circles are lower.

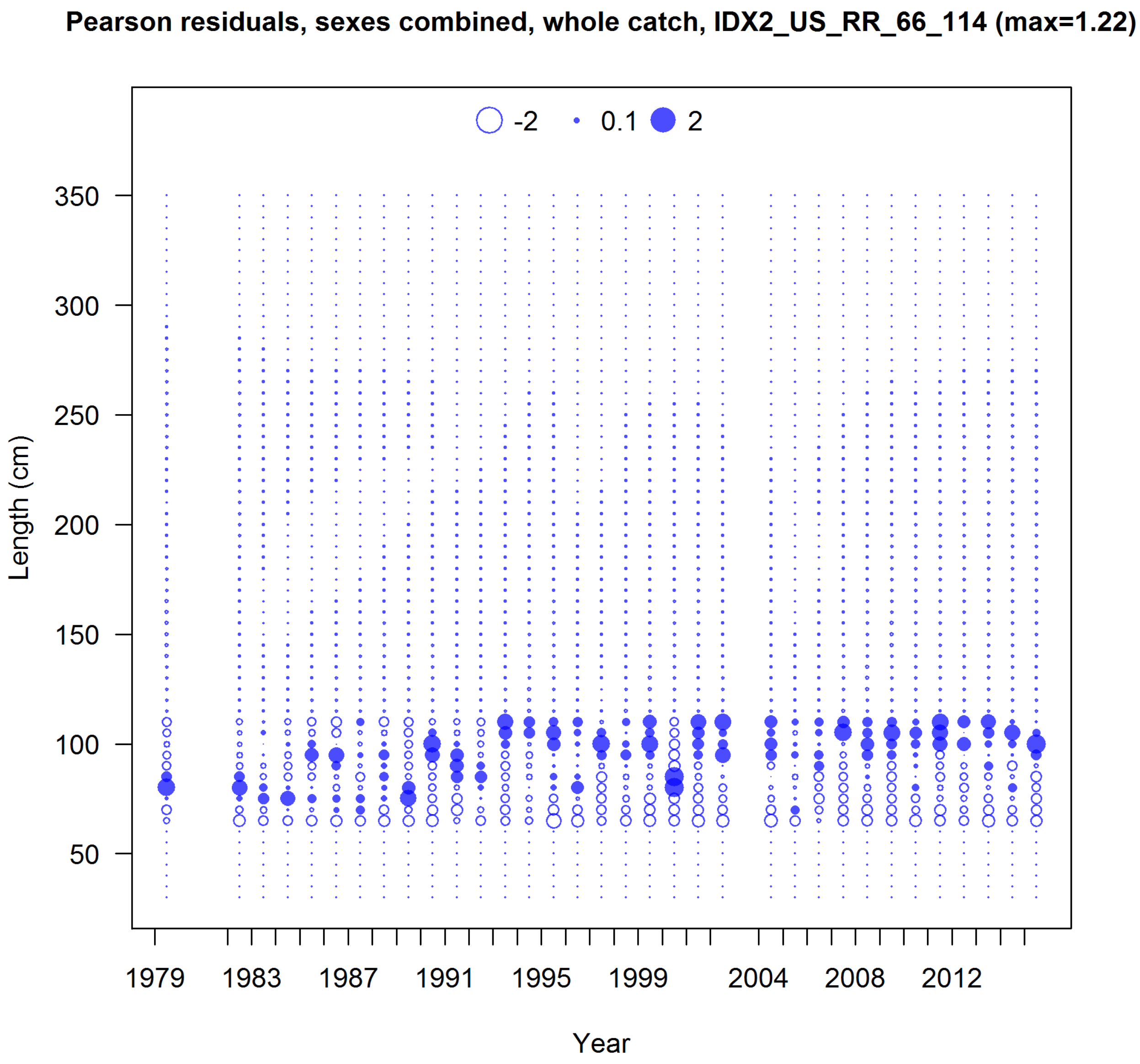


Figure 52. Pearson residuals to length composition fits for run 12. Blue dots are higher than expected, white circles are lower.

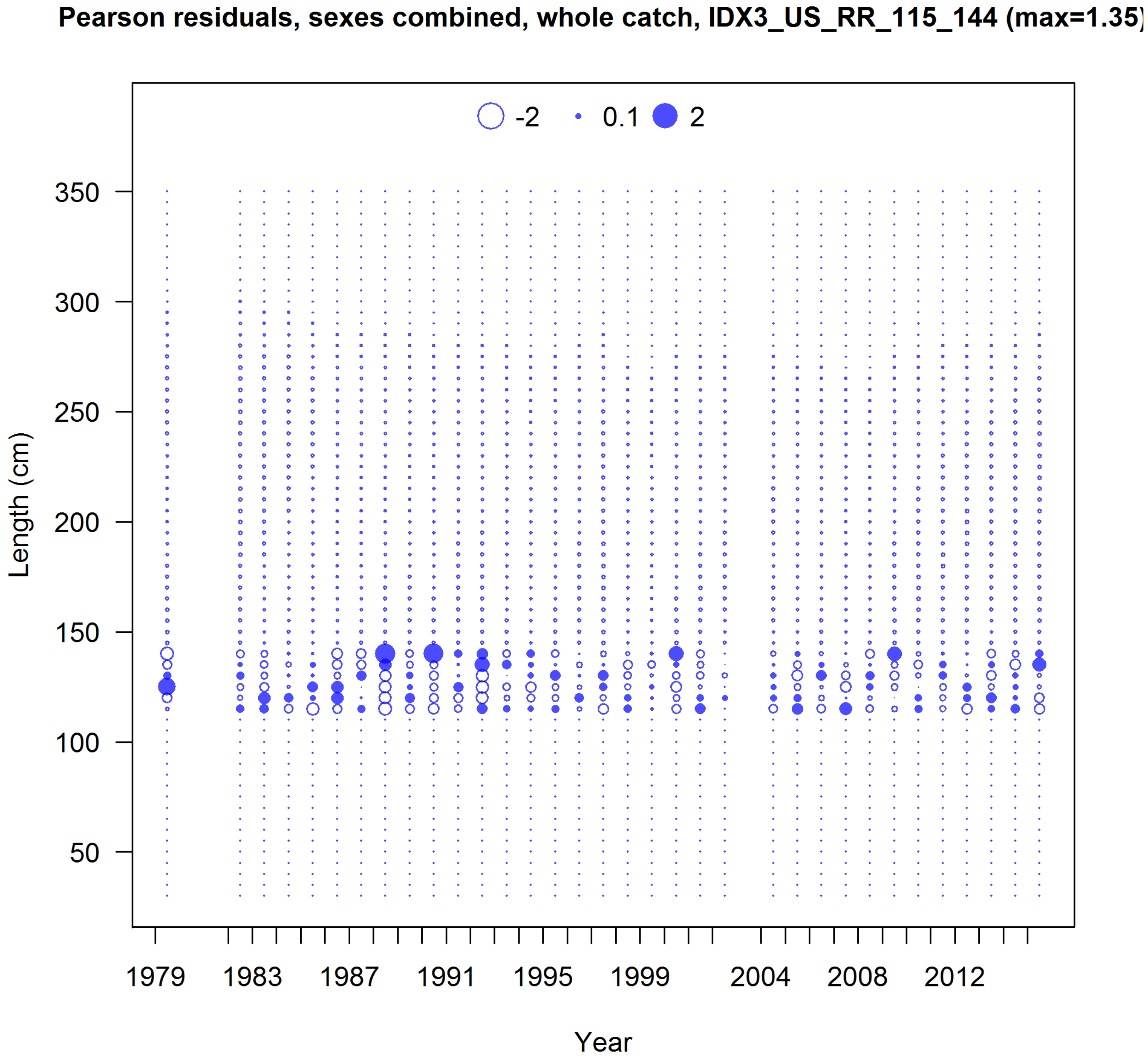


Figure 53. Pearson residuals to length composition fits for run 12. Blue dots are higher than expected, white circles are lower.

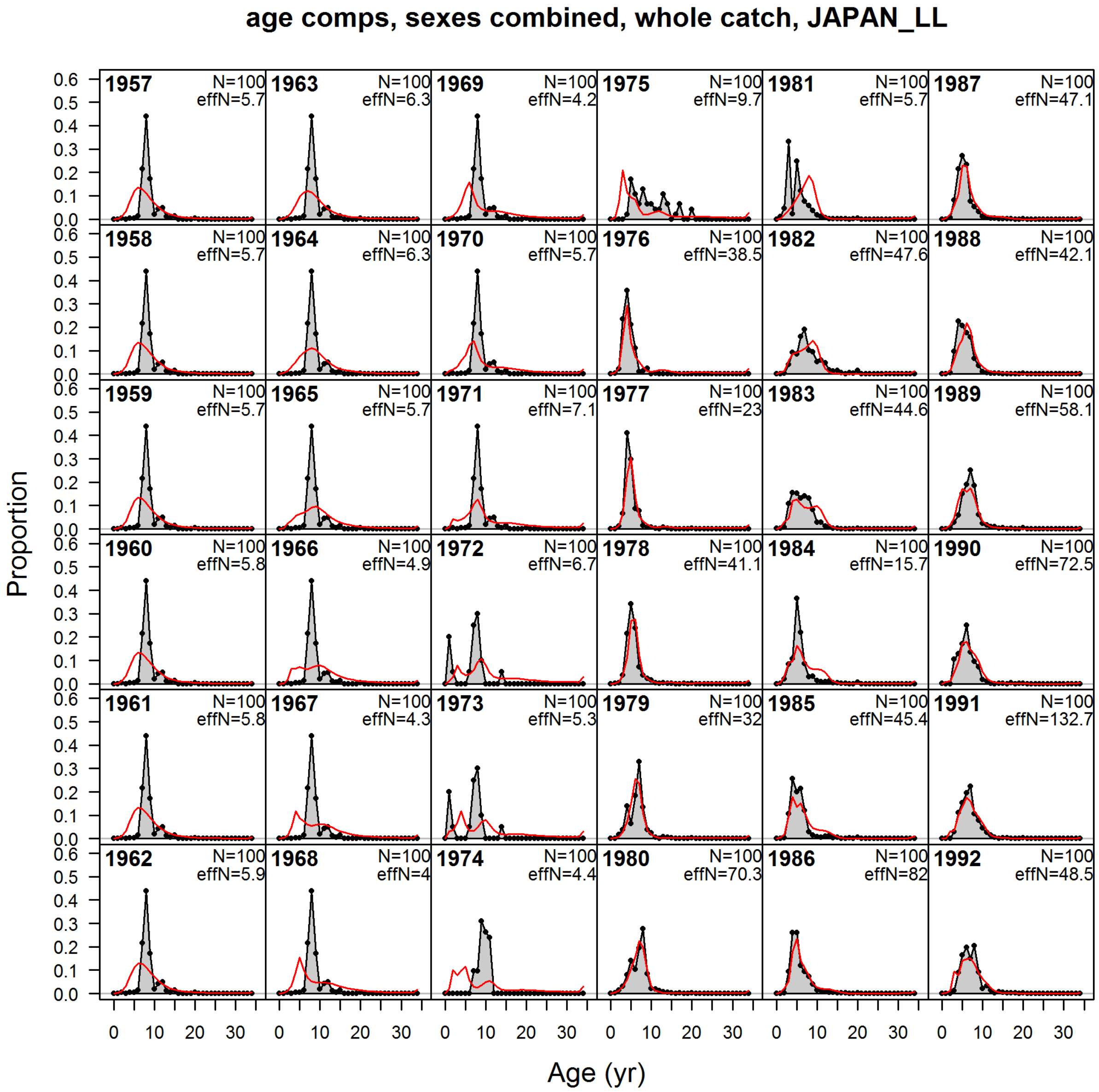


Figure 54. Observed versus expected catch at age for the Japan_LL in the Atlantic. Note that the model does not actually use this data to fit.

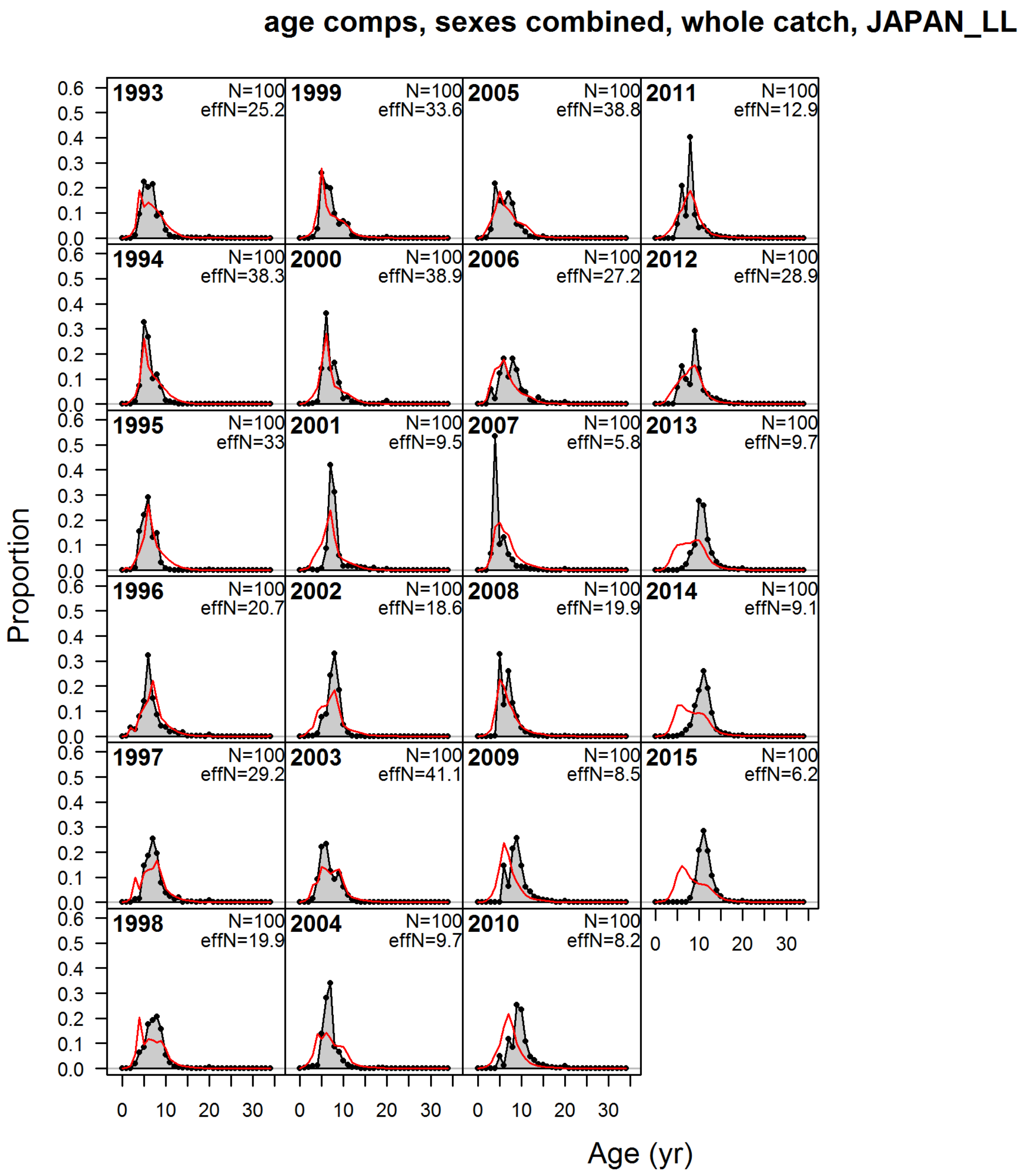


Figure 54. Cont.

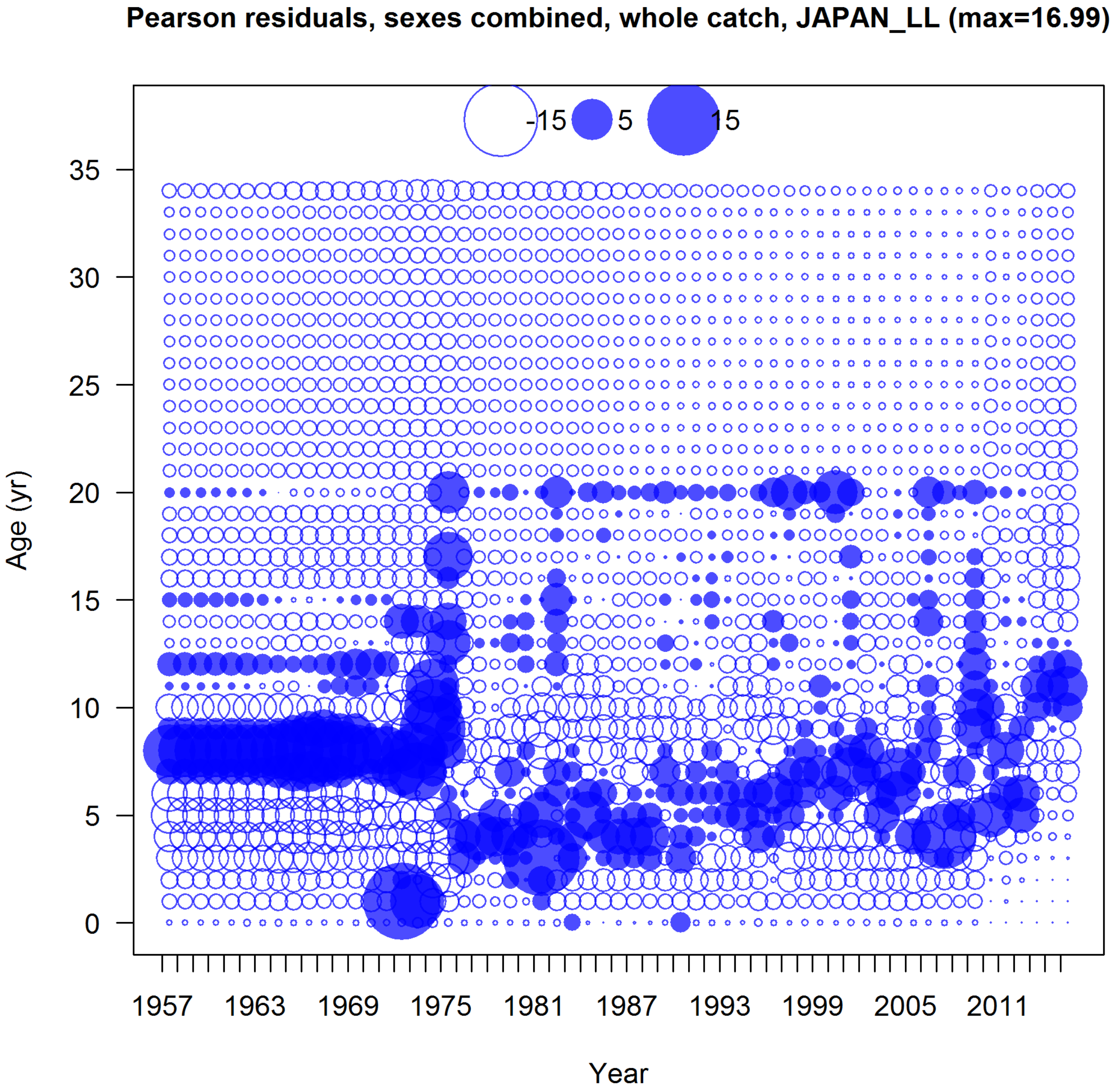


Figure 55. Pearson residuals for observed versus expected catch at age for the Japan_LL in the Atlantic. Note that the model does not actually use this data to fit.

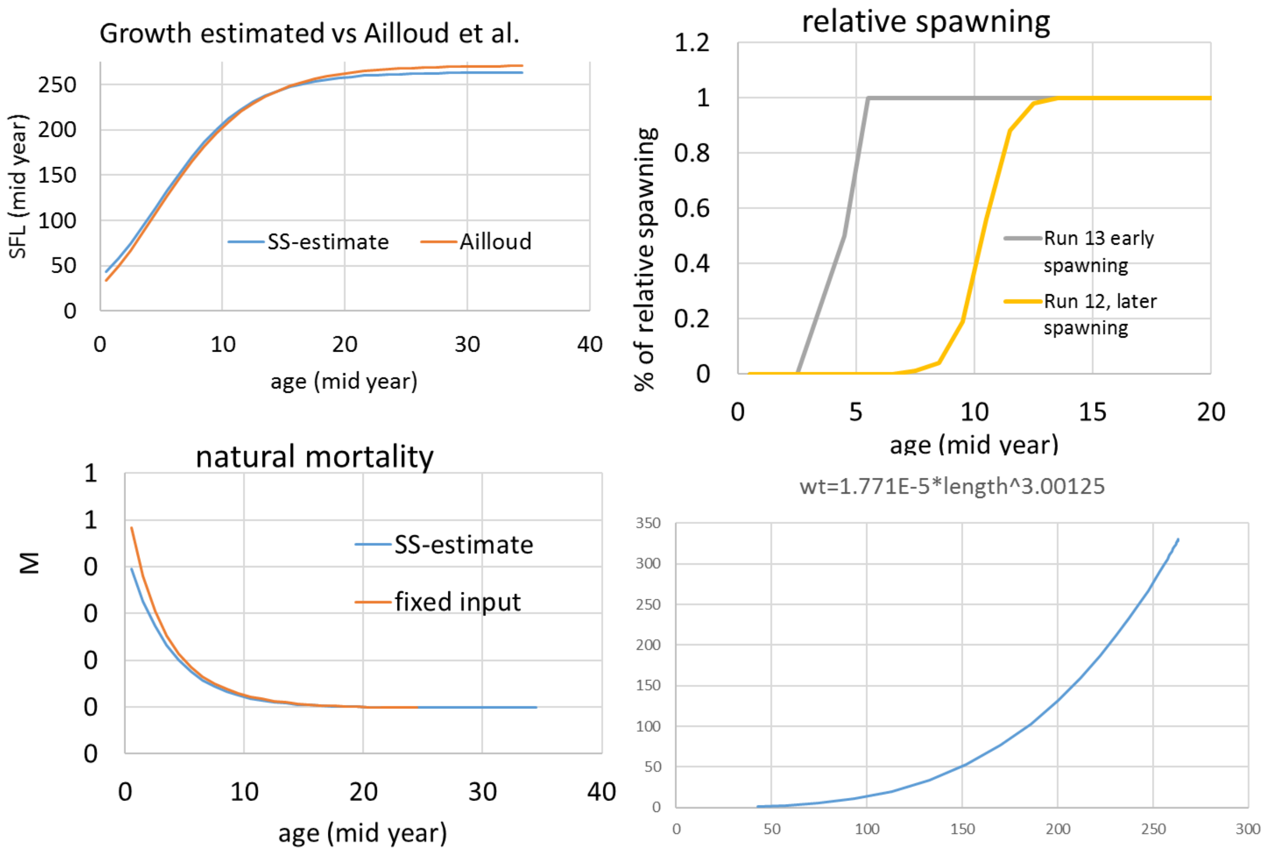


Figure 56. Estimated growth using a Richards function compared with Ailloud *et al.* (2017) and other biological inputs of maturity, mortality scaled with to growth and the length weight relationship (Rodriguez *et al*. 2015)

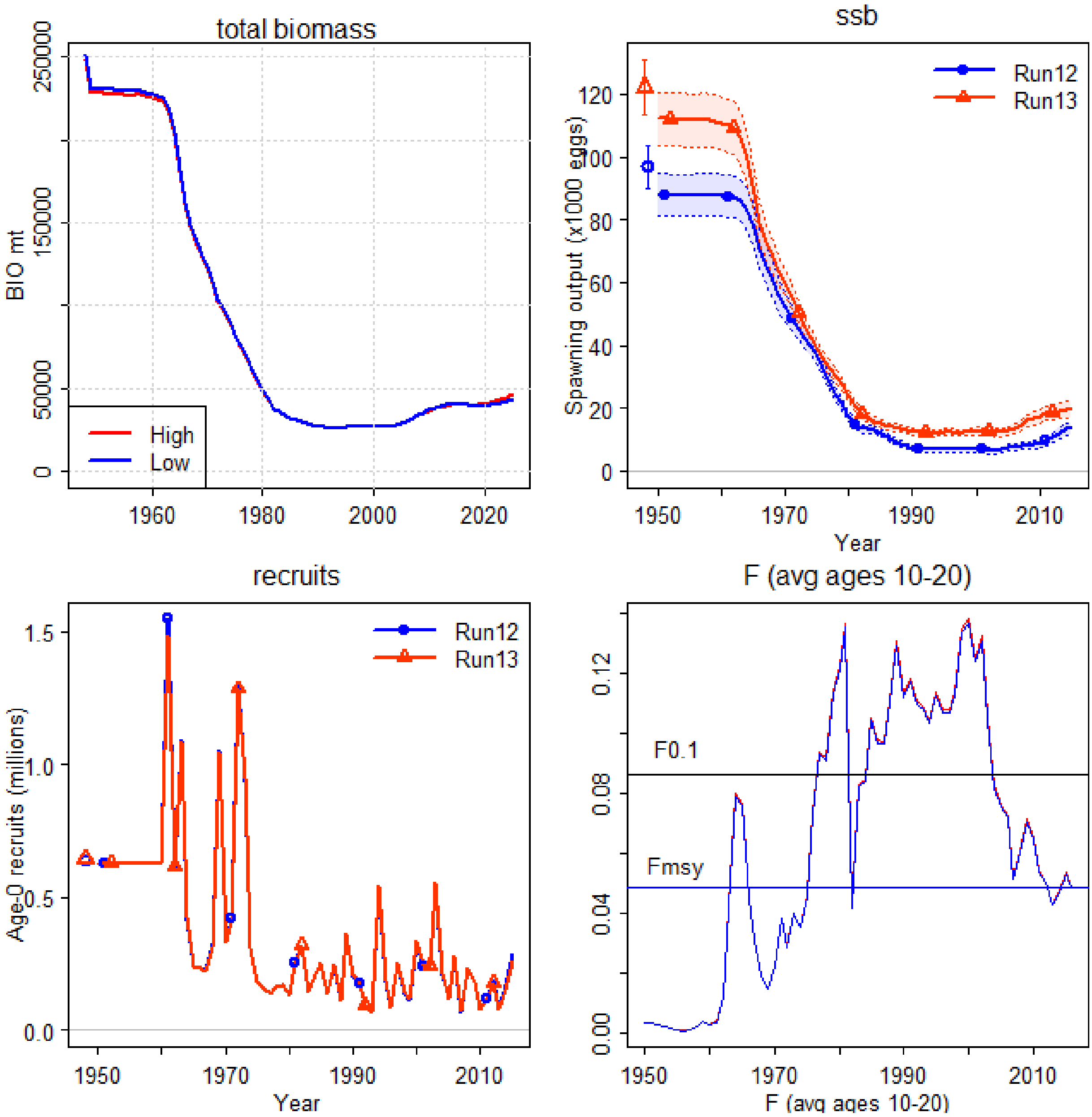


Figure 57. Time series of total biomass, SSB, recruits (age 0), and F (average F on ages 10-20) for SS3 runs 12 (older spawning) and 13 (younger spawning) for the western stock.

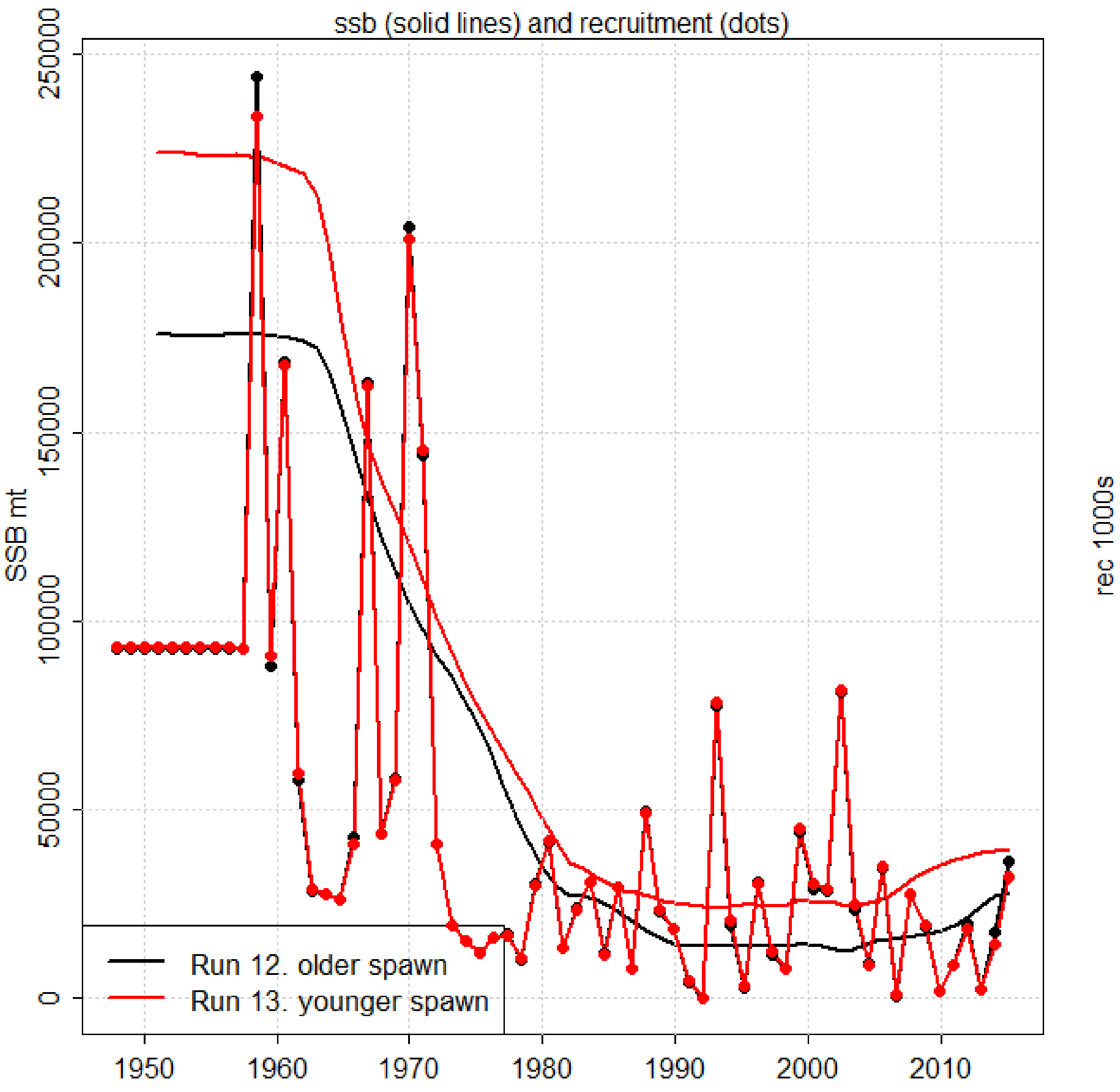


Figure 58. Time series of SSB, and recruits.

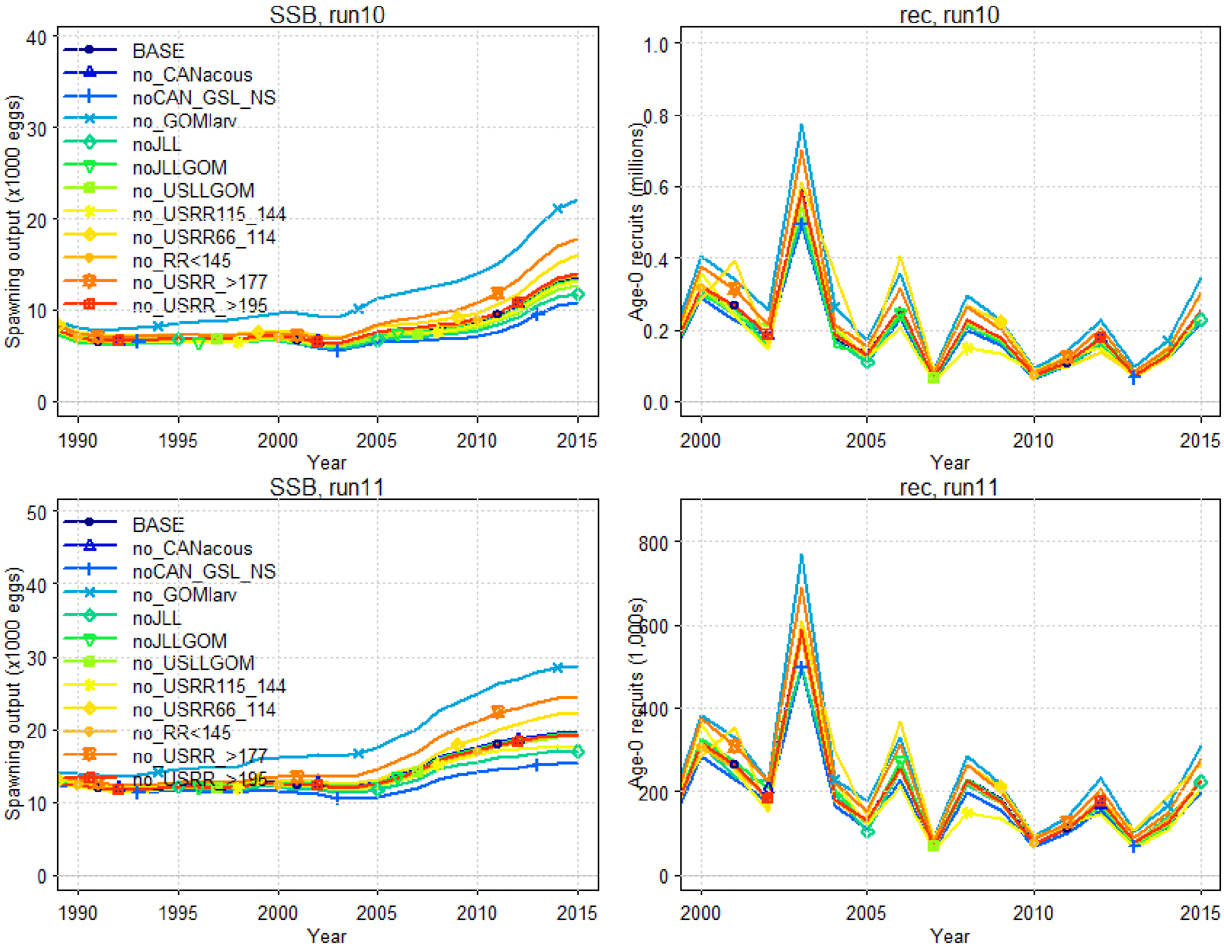


Figure 59. Results of ‘jackknife’ procedure of removing one index at a time for runs 10 and 11. Note that these were only conducted for runs 10 and 11.

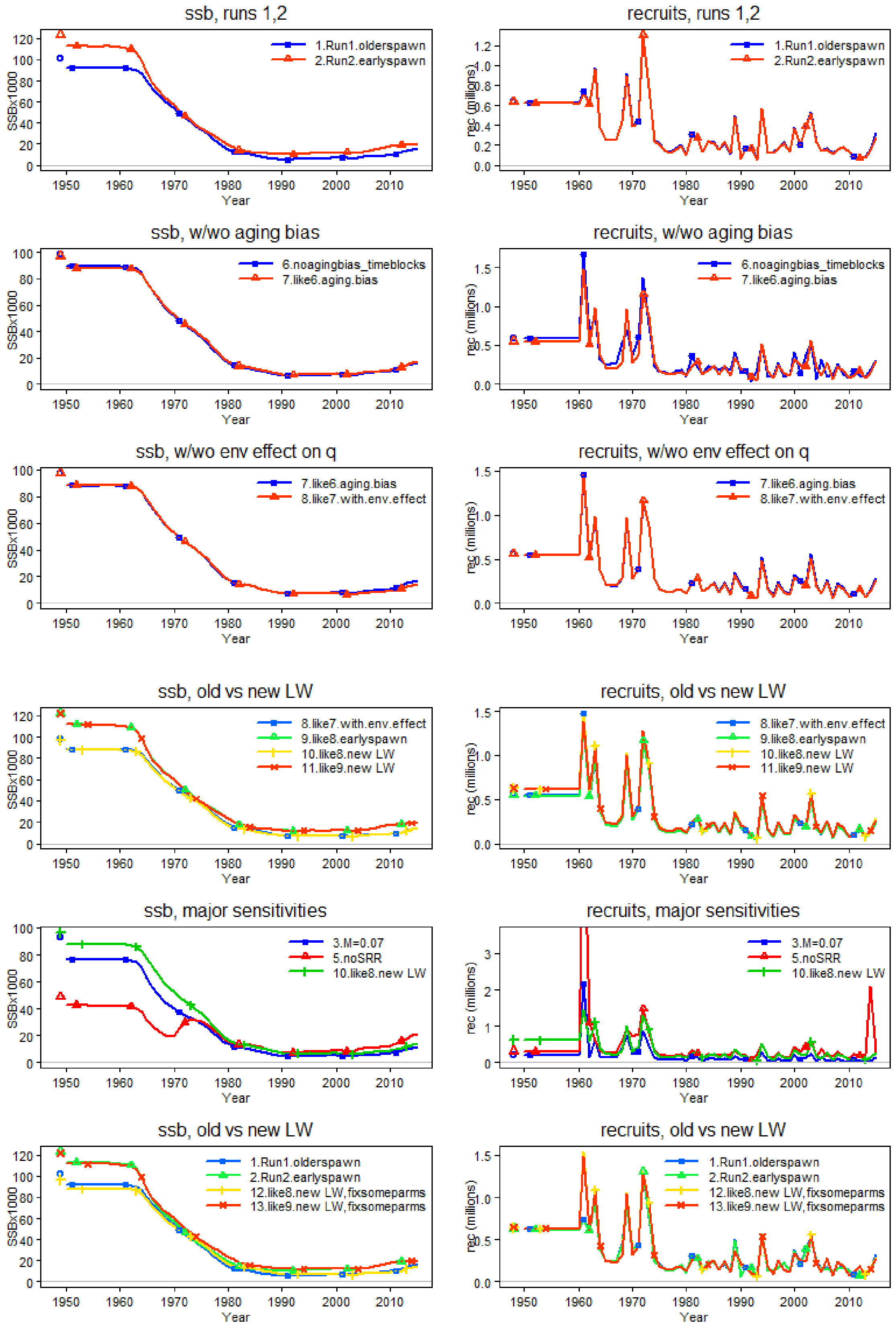


Figure 60. Comparison of different model runs and major sensitivities.

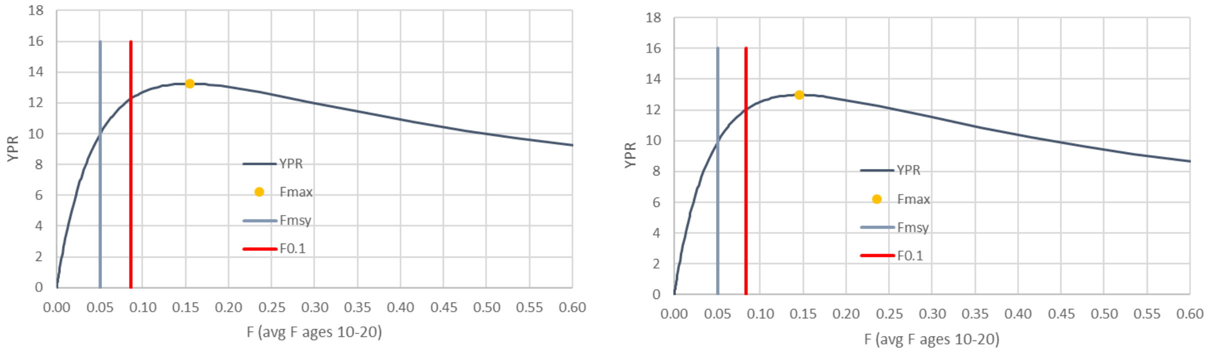


Figure 61. Western stock yield per recruit for SS3 runs 12 (older spawning - left) and 13 (younger spawning - right).

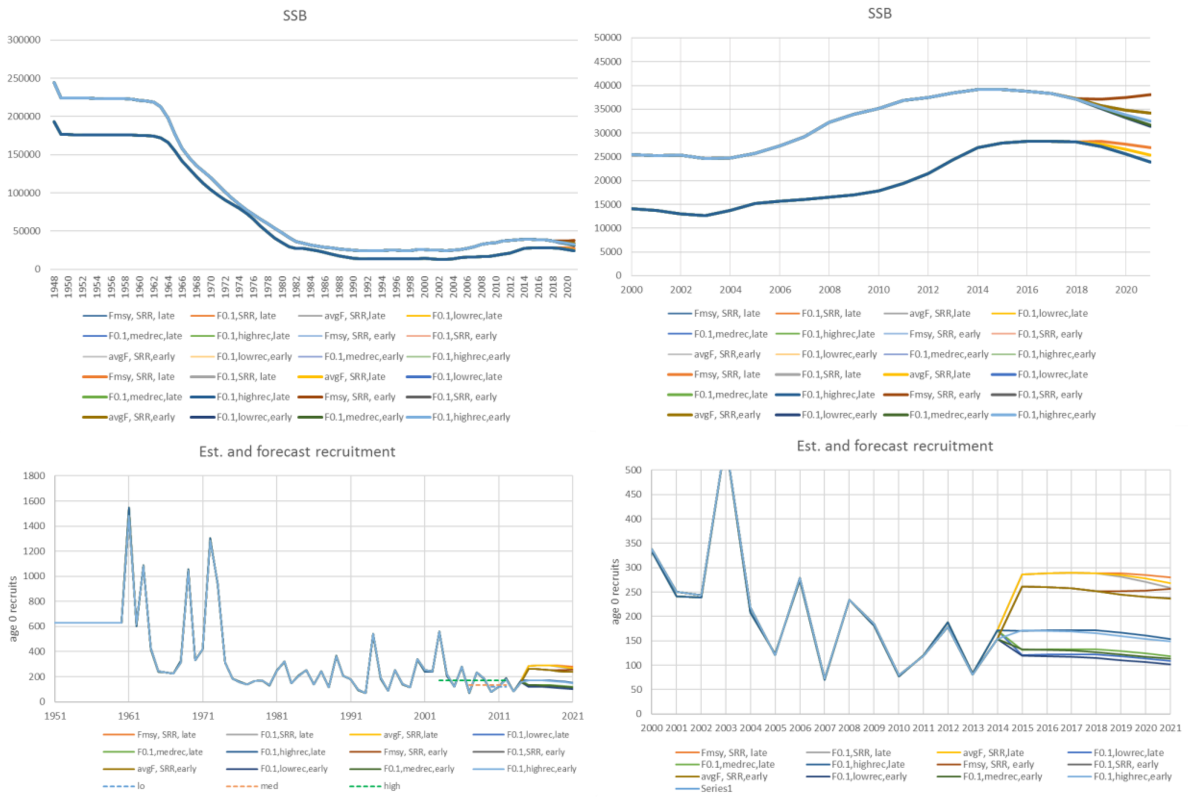


Figure 62. Historical estimated and future projected spawning biomass and recruitment (age 0) for older(Hi) and younger (Lo) spawning from SS3 for the western stock. Right panel shows the same plots for a short time period (2000-2025). Recruitments are generated from recruitment deviations from the Beverton and Holt stock-recruitment relationship from high (2003-2012), medium (2007-2012) or low (2009-2012) years or revert to the long-term average recruitment (SRR).

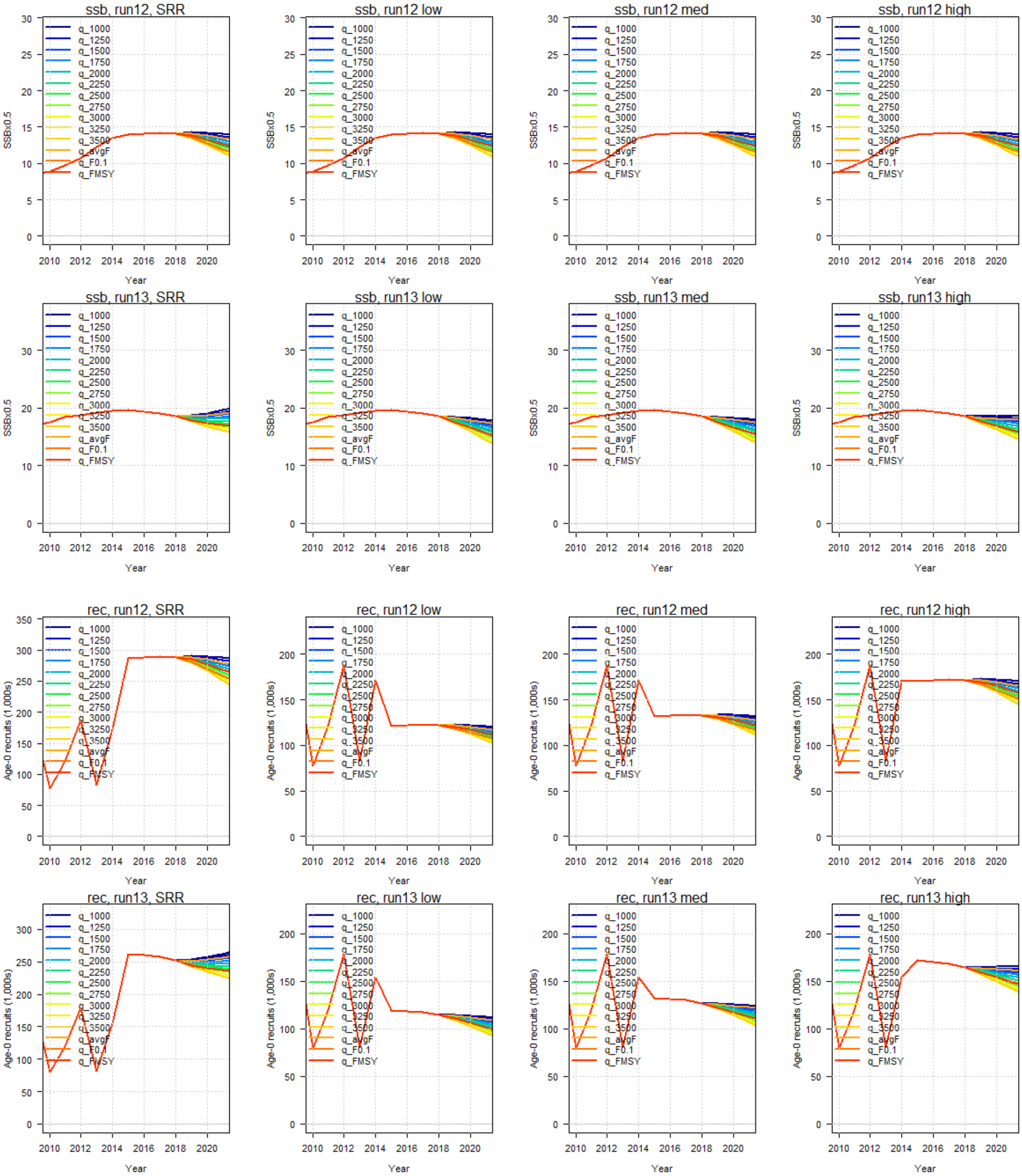


Figure 63. Projected SSB (top two rows) and recruits (age 0, bottom two rows) across the fixed catch limits and $F_{0.1}$, F_{MSY} and average of the current F scenarios from SS3 for the western stock, assuming older spawning (run 12) and younger spawning (run 13). Recruitment is drawn from either the Beverton and Holt stock recruitment relationship assuming the long-term average recruitment for these runs (SRR), or the high (2003-2012), medium (2007-2012) or low (2009-2012) geometric mean recruitment.

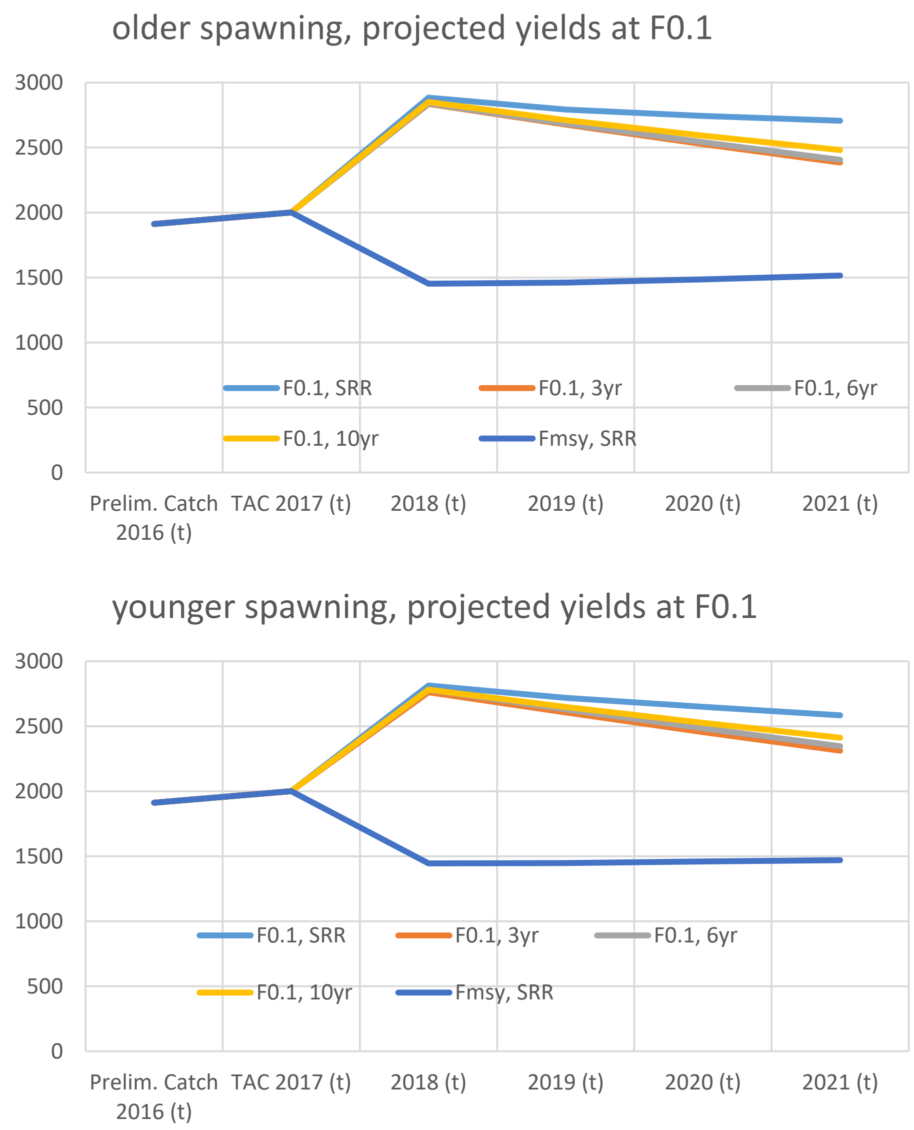


Figure 64. Projected yields from SS3 for the western stock assuming older (top) and younger spawning (bottom), at $F_{0.1}$ for the 3, 6 and 10 year recruitments and F_{MSY} assuming that recruitment deviations from the Beverton and Holt stock-recruitment relationship are drawn from the high (2003-2012), medium (2007-2012) or low (2009-2012) years or revert to the long-term average recruitment (SRR).

Appendix 1. SS control file

For early spawning uncomment out line 33 and comment line 34, late spawning. The file is available as electronic online documents at:

```
#ICCAT WBFT 2017 control file
#JFW. SEFSC, MIAMI, FL
#SS-V3.24P
1         #_N_Growth_Patterns
1         #_N_Morphs_Within_GrowthPattern
#_Cond    1         #_Morph_between/within_stdev_ratio      (no       read      if        N_morphs=1)
#_Cond    1         #vector_Morphdist_(-1_in_first_val_gives_normal_approx)
#_Cond    0         #         N         recruitment         designs   goes      here      if        N_GP*nseas*area>1
#_Cond    0         #         placeholder         for       recruitment         interaction         request
#_Cond    1         1         1         #         example   recruitment         design    element   for       GP=1,
          seas=1,   area=1
#_Cond    0         #         N_movement_definitions        goes      here      if        N_areas   >         1
#_Cond    1         #         first     age       that      moves     (real     age       at        begin     of
          season,   not       integer)  also      cond      on        do_migration>0
#_Cond    1         1         1         2         4         10        #         example   move      definition          for
          seas=1,   morph=1,            source=1            dest=2,   age1=4,   age2=10
#
3 #_Nblock_Patterns
1  1 1
1950 2009     #JLL   this splits the JLL selex at 2010
 1950 1987     #NOT USED Can HL  this splits the CAN HL selex at 1988 when the SWNS fishery starts   not
needed
1992 2015     #US RRFS and USRR RR66_114  splits fleet and index pre and post 1992, based upon visual
inspection of data0.5          #_fracfemale
0.5       #_fracfemale
2         #_natM_type:_0=1Parm;
          1=N_breakpoints;_2=Lorenzen;_3=agespecific;_4=agespec_withseasinterpolate
20  #ref  age       for       M
#_no      additional          input     for       selected  M         option;   read      1P        per       morph
2         #         GrowthModel:        1=vonBert           with      L1&L2;    2=Richards          with      L1&L2;
          3=not     implemented;        4=not     implemented
0.5       #_Growth_Age_for_L1 (size of an age-0 fish- the size for the M0)
34        #_Growth_Age_for_L2           (999      to        use       as        Linf)
#_Cond    5         #Min      age-      for       age_specific        k
#_Cond    7         #Maxage             for       age_specific        k
0         #_SD_add_to_LAA               (set      to        0.1       for       SS2       V1.x      compatibility)
          RECOMMEND  0
0         #_CV_Growth_Pattern:          0         CV=f(LAA);          1         CV=F(A);            2         SD=F(LAA);
          3         SD=F(A);            4         logSD=F(A)
3         #_maturity_option:            1=lengthlogistic;   2=age     logistic; 3=read    age-maturity        matrix    by
          growth_pattern;     4=read    age-fecundity;      5=read    fec       and       wt        from      wtatage.ss
# ages 0  1         2         3         4         5         6         7         8         9         10        11        12
          13        14        15        16        17        18        19        20        21        22        23        24
          25        26 27 28 29 30 31 32 33 34
# 0       0         0         0.25      0.5       1         1         1         1         1         1         1         1
          1         1         1         1         1         1         1         1         1         1         1         1
          1         1         1         1         1 1 1 1 1 1 #early
 0        0         0         0         0         0         0         0.01      0.04      0.19      0.56      0.88      0.98
          1         1         1         1         1         1         1         1         1         1         1         1
          1         1         1         1         1 1 1 1 1 1 #late
3         #_First_Mature_Age  (overidden by vector)
3         #_fecundity         option:(1)eggs=Wt*(a+b*Wt);(2)eggs=a*L^b;(3)eggs=a*Wt^b;
          (4)eggs=a+b*L;      (5)eggs=a+b*W
0         #_hermaphroditism             option:   0=none;   1=age-specific      fxn
1         #_parameter_offset_approach             (1=none,2=          M,        G,        CV_G      as        offset    from
          female-GP1,         3=like    SS2       V1.x)
```

```
2       #_env/block/dev_adjust_method   (1=standard;    2=logistic      transform       keeps   in
        base    parm    bounds; 3=standard      w/      no      bound   check)
#_growth_parms
#_LO    HI      INIT    PRIOR   PR_type SD      PHASE   env-var use_dev dev_minyr       dev_maxyr
        dev_stddev      Block   Block_Fxn
 0.05 0.3 0.1 0.1 -1 0.8 -3 0 0 0 0 0 0 0 # NatM_p_1_Fem_GP_1
 0 50 42.9753 30 -1 10 -2 0 0 0 0 0 0 0 # L_at_Amin_Fem_GP_1
 200 400 266.906 284 -1 10 4 0 0 0 0 0 0 0 # L_at_Amax_Fem_GP_1
 0.05 0.4 0.257706 0.089 -1 0.8 4 0 0 0 0 0 0 0 # VonBert_K_Fem_GP_1
 -3 3 -0.655679 0.58 -1 0.8 4 0 0 0 0 0.5 0 0 # Richards_Fem_GP_1
 0.05 0.25 0.107265 0.1 -1 0.8 3 0 0 0 0 0 0 0 # CV_young_Fem_GP_1
 0.02 0.25 0.0481051 0.1 -1 0.8 3 0 0 0 0 0 0 0 # CV_old_Fem_GP_1
 1e-008 0.01 1.77054E-05 1.77054E-05 -1 0.8 -3 0 0 0 0 0 0 0 # Wtlen_1_Fem   Rodriguez
 2 4 3.001252 3.001252 -1 0.8 -3 0 0 0 0 0 0 0 # Wtlen_2_Fem
 4 15 8.8 8.8 -1 0.8 -3 0 0 0 0 0 0 0 # Mat50%_Fem
 -100 -1 -50 -50 -1 0.8 -3 0 0 0 0 0 0 0 # Mat_slope_Fem
 1 1 1 1 -1 0.8 -3 0 0 0 0 0 0 0 # Eggs_scalar_Fem
 1 1 1 1 -1 0.8 -3 0 0 0 0 0 0 0 # Eggs_exp_wt_Fem
 0 0 0 0 -1 0 -4 0 0 0 0 0 0 0 # RecrDist_GP_1
 0 0 0 0 -1 0 -4 0 0 0 0 0 0 0 # RecrDist_Area_1
 0 0 0 0 -1 0 -4 0 0 0 0 0 0 0 # RecrDist_Seas_1
 0 0 0 0 -1 0 -4 0 0 0 0 0 0 0 # CohortGrowDev
        0       0       0       0       0       0       0       0       0       0
        #_Wtlen_1_Fem, Wtlen_2_Fem,     Mat50%_Fem,     Mat_slope_Fem,  Eggs/kg_inter_Fem,
        Eggs/kg_inter_Fem,      L1,     K
#_Spawner-Recruitment
3       #_SR_function:  2=Ricker;       3=std_B-H;      4=SCAA;         5=Hockey;       6=B-
H_flattop;      7=survival_3Parm
#_LO    HI      INIT    PRIOR   PR_type SD      PHASE
 3 18 6.49034 8 -1 10 2 # SR_LN(R0)
 0.2 0.99 0.552035 0.5 -1 0.05 2 # SR_BH_steep
 0 2 0.740543 0.6 -1 0.3 6 # SR_sigmaR
 -5 5 0 0 -1 1 -3 # SR_envlink # SR_envlink  This could be used to create a future “regime shift” by setting
historical values
 #of the relevant environmental variable equal to zero and future values equal to 1,
 #in which case the magnitude of the regime shift would be dictated by the value of the
 #environmental linkage parameter.
 -5 5 0 0 -1 1 -4 # SR_R1_offset
 0 0 0 0 -1 0 -99 # SR_autocorr
0 #_SR_env_link
0 #_SR_env_target_0=none;1=devs;_2=R0;_3=steepness
1 #do_recdev:  0=none; 1=devvector; 2=simple deviations
1961 # first year of main recr_devs; early devs can preceed this era
2014 # last year of main recr_devs; forecast devs start in following year
6 #_recdev phase
1 # (0/1) to read 13 advanced options
 0 #_recdev_early_start (0=none; neg value makes relative to recdev_start)
 -4 #_recdev_early_phase
 -1 #_forecast_recruitment phase (incl. late recr) (0 value resets to maxphase+1)
 1 #_lambda for Fcast_recr_like occurring before endyr+1
 1950.9 #_last_early_yr_nobias_adj_in_MPD
 1973 #_first_yr_fullbias_adj_in_MPD
 2011.7 #_last_yr_fullbias_adj_in_MPD
 2016 #_first_recent_yr_nobias_adj_in_MPD
 0.8935 #_max_bias_adj_in_MPD (-1 to override ramp and set biasadj=1.0 for all estimated recdevs)
 0 #_period of cycles in recruitment (N parms read below)
 -5 #min rec_dev
 5 #max rec_dev
54 #_read_recdevs
#_end of advanced SR options
```

```
#_placeholder for full parameter lines for recruitment cycles
# read specified recr devs
#_Yr Input_value
# all recruitment deviations NOTE THAT THESE ARE INPUT AS STARTING GUESSES to aid convergence
1961    0.367027        #       Main_RecrDev_1961
1962    0.0645511       #       Main_RecrDev_1962
1963    0.48233 #       Main_RecrDev_1963
1964    -0.438039       #       Main_RecrDev_1964
1965    -0.784369       #       Main_RecrDev_1965
1966    -0.744618       #       Main_RecrDev_1966
1967    -0.687635       #       Main_RecrDev_1967
1968    -0.0271688      #       Main_RecrDev_1968
1969    0.62289 #       Main_RecrDev_1969
1970    -0.166794       #       Main_RecrDev_1970
1971    0.00997055      #       Main_RecrDev_1971
1972    1.11948 #       Main_RecrDev_1972
1973    0.620815        #       Main_RecrDev_1973
1974    -0.400979       #       Main_RecrDev_1974
1975    -0.435079       #       Main_RecrDev_1975
1976    -0.905073       #       Main_RecrDev_1976
1977    -0.920341       #       Main_RecrDev_1977
1978    -0.602674       #       Main_RecrDev_1978
1979    -0.268141       #       Main_RecrDev_1979
1980    -0.919227       #       Main_RecrDev_1980
1981    0.394313        #       Main_RecrDev_1981
1982    0.35708 #       Main_RecrDev_1982
1983    -0.3714 #       Main_RecrDev_1983
1984    0.249326        #       Main_RecrDev_1984
1985    0.189884        #       Main_RecrDev_1985
1986    0.113172        #       Main_RecrDev_1986
1987    0.31583 #       Main_RecrDev_1987
1988    -0.147574       #       Main_RecrDev_1988
1989    1.38716 #       Main_RecrDev_1989
1990    -0.742459       #       Main_RecrDev_1990
1991    0.436776        #       Main_RecrDev_1991
1992    0.290081        #       Main_RecrDev_1992
1993    -0.719029       #       Main_RecrDev_1993
1994    1.56383 #       Main_RecrDev_1994
1995    -0.1184 #       Main_RecrDev_1995
1996    0.00826561      #       Main_RecrDev_1996
1997    0.26489 #       Main_RecrDev_1997
1998    0.504973        #       Main_RecrDev_1998
1999    -0.0770637      #       Main_RecrDev_1999
2000    1.01504 #       Main_RecrDev_2000
2001    0.396427        #       Main_RecrDev_2001
2002    1.08302 #       Main_RecrDev_2002
2003    1.39628 #       Main_RecrDev_2003
2004    0.415991        #       Main_RecrDev_2004
2005    0.0594356       #       Main_RecrDev_2005
2006    0.00417469      #       Main_RecrDev_2006
2007    -0.314161       #       Main_RecrDev_2007
2008    -0.00664716     #       Main_RecrDev_2008
2009    0.070972        #       Main_RecrDev_2009
2010    -0.309061       #       Main_RecrDev_2010
2011    -0.72319#       Main_RecrDev_2011
2012    -1.3122 #       Main_RecrDev_2012
2013    -1.11118#       Main_RecrDev_2013
2014    -0.55149#       Main_RecrDev_2014
#_end   of      advanced        SR      options
#Fishing Mortality      info
```

```
0.3     #       F       ballpark for    tuning  early   phases
-2001   #       F       ballpark year   (neg    value   to      disable)
3       #       F_Method:       1=Pope; 2=instan.       F;      3=hybrid        (hybrid is
        recommended)
#hybrid method that does a Pope's approximation to provide initial values for iterative adjustment of
#the continuous F values to closely approximate the observed catch
2.9     #       max     F       or      harvest rate,   depends on      F_Method
#       no      additional      F       input   needed  for     Fmethod1
#       if      Fmethod=2;      read    overall start   F       value;  overall phase;  N
        detailed inputs to      read
#       if      Fmethod=3;      read    N       iterations      for     tuning  for     Fmethod3
12      #       N       iterations      for     tuning  F       in      hybrid  method  (recommend
        3       to      7)
#_initial_F_parms
#_LO    HI      INIT    PRIOR   PR_type SD      PHASE
0       1       0       0.01    -1      99      -2      #1_JAPAN_LL
0       1       0       0.01    -1      99      -2      #2_USA_CAN_PSFS
0       1       0       0.01    -1      99      -2      #3_USA_CAN_PSFB
 1e-005 1 0.0125865 0.01 -1 99 5 # InitF_4USA_TRAP
 1e-005 1 0.0014672 0.002 -1 0.3 -5 # InitF_5USA_CAN_HARPOON
0       1       0       0.01    -1      99      -2      #6_USA_RRFB
0       1       0       0.01    -1      99      -2      #7_USA_RRFS
0       1       0       0.01    -1      99      -2      #8_OTHER_ATL_LL
0       1       0       0.01    -1      99      -2      #9_CAN_HOOKLINE
0       1       0       0.01    -1      99      -2      #10_GOM_LL_US_MEX
0       1       0       0.01    -1      99      -2      #11_JLL_GOM
0       1       0       0.01    -1      99      -2      #12_CAN_TRAP
0       1       0       0.01    -1      99      -2      #13_CAN_GSL1
#       Q_type  options: <0=mirror,     0=median_float, 1=mean_float,   2=parameter,
        3=parm_w_random_dev,    4=parm_w_randwalk,      5=mean_unbiased_float_assign_to_parm
#_Den-dep        env-var extra_se Q_type
 0 0 0 0 #       1       #1_JAPAN_LL
        0       0       0       0       #       2       #2_USA_CAN_PSFS
        0       0       0       0       #       3       #3_USA_CAN_PSFB
        0       0       0       0       #       4       #4_USA_TRAP
        0       0       0       0       #       5       #5_USA_CAN_HARPOON
        0       0       0       0       #       6       #6_USA_RRFB
        0       0       0       0       #       7       #7_USA_RRFS
        0       0       0       0       #       8       #8_OTHER_ATL_LL
        0       0       0       0       #       9       #9_CAN_HOOKLINE
        0       0       0       0       #       10      #10_GOM_LL_US_MEX
        0       0       0       0       #       11      #11_JLL_GOM
        0       0       0       0       #       12      #12_CAN_TRAP
        0       0       0       0       #       13      #12_CAN_GSL1
        0       0       0       0       #       14      #1_IND1_JAPAN_LL1
        0       0       0       0       #       15      #2_IDX2_US_RR_66_114
        0       0       0       0       #       16      #3_IDX3_US_RR_115_144
        0       0       0       0       #       17      #4_IDX4_US_RR_LT145
        0       4       0       2       #       18      #5_IDX5_US_RR_GT177
        0       0       0       0       #       19      #6_IDX6_US_RR_GT195
        0       0       0       0       #       20      #7_IDX7_USPLL_GOM1
        0       0       0       0       #       21      #8_IDX8_JLL_GOM
        0       4       0       2       #       22      #9_IDX9_CAN_GSLNS
        0       0       0       0       #       23      #10_IDX10_GOM larval
        0       0       0       0       #       24      #11_IDX11_tagging
        0       4       0       2       #       25      #12_IDX12_CAN_ACOUSTIC
        0       0       0       0       #       26      #13_IDX13_oceanographic
        0       0       0       0       #       27      #14_IND14_JAPAN_LL2
        0       0       0       0       #       28      #15_IDX15_USPLL_GOM2
```

```
#_Cond 0 #_If q has random component, then 0=read one parm for each fleet with random q; 1=read a parm for each year of index
#_Q_parms(if_any)
-5  5  0  1  -1  99  4    # ENV relation parm  5_IDX5_US_RR_GT177
-5  5  0  1  -1  99  4    # ENV relation parm  9_IDX9_CAN_GSLNS
-5  5  0  1  -1  99  4    # ENV relation parm  12_IDX12_CAN_ACOUSTIC

#Extra variance

#-5  5  0  1  -1  99  -4  #  Extra variance  5_IDX5_US_RR_GT177
#-5  5  0  1  -1  99  -4  #  Extra variance  9_IDX9_CAN_GSLNS
#-5  5  0  1  -1  99  -4  #  Extra variance  12_IDX12_CAN_ACOUSTIC
#Create a short parameter line to estimate the base q value for that fishery/survey

-15  0.000001  -4.73526  1  -1  99  1  #  base q 5_IDX5_US_RR_GT177
-15  0.000001  -4.73526  1  -1  99  1  # base q  9_IDX9_CAN_GSLNS
-15  0.000001  -4.73526  1  -1  99  1  #  base q 12_IDX12_CAN_ACOUSTIC
#_size_selex_types 1 is logistic; 24 is double normal; 15 is mirror the fleet noted in column 4
#_Pattern  Discard  Male  Special
        24   0   0   0    #   1     #1_JAPAN_LL
        24   0   0   0    #   2     #2_USA_CAN_PSFS
        24   0   0   0    #   3     #3_USA_CAN_PSFB
        24   0   0   0    #   4     #4_USA_TRAP
        1    0   0   0    #   5     #5_USA_CAN_HARPOON
        24   0   0   0    #   6     #6_USA_RRFB
        24   0   0   0    #   7     #7_USA_RRFS
        1    0   0   0    #   8     #8_OTHER_ATL_LL
        1    0   0   0    #   9     #9_CAN_HOOKLINE
        1    0   0   0    #   10    #10_GOM_LL_US_MEX
        1    0   0   0    #   11    #11_JLL_GOM
        1    0   0   0    #   12    #12_CAN_TRAP
        1    0   0   0    #   13    #13_CAN_GSL1
        15   0   0   1    #   14    #1_IND1_JAPAN_LL1
        24   0   0   0    #   15    #2_IDX2_US_RR_66_114
        24   0   0   0    #   16    #3_IDX3_US_RR_115_144
        15   0   0   7    #   17    #4_IDX4_US_RR_LT145
        15   0   0   6    #   18    #5_IDX5_US_RR_GT177
        15   0   0   6    #   19    #6_IDX6_US_RR_GT195
        15   0   0   10   #   20    #7_IDX7_USPLL_GOM
        15   0   0   11       #21   #8_IDX8_JLL_GOM
        15   0   0   9        #22   #9_IDX9_CAN_GSLNS
        15   0   0   10       #23   #10_IDX10_GOM larval
        30   0   0   0        #24   #11_IDX11_tagging
        15   0   0   13       #25   #12_IDX12_CAN_ACOUSTIC
        31   0   0   0        #26   #13_IDX13_oceanographic
        15   0   0   1        #27   #14_IND14_JAPAN_LL2
        15   0   0   10    #  28    #15_IDX15_USPLL_GOM2
#_age_selex_types
#_Pattern  ___  Male  Special
        10   0   0   0    #   1     #1_JAPAN_LL
        10   0   0   0    #   2     #2_USA_CAN_PSFS
        10   0   0   0    #   3     #3_USA_CAN_PSFB
        10   0   0   0    #   4     #4_USA_TRAP
        10   0   0   0    #   5     #5_USA_CAN_HARPOON
        10   0   0   0    #   6     #6_USA_RRFB
        10   0   0   0    #   7     #7_USA_RRFS
        10   0   0   0    #   8     #8_OTHER_ATL_LL
        10  0    0   0    #   9     #9_CAN_HOOKLINE
        10   0   0   0    #   10    #10_GOM_LL_US_MEX #
```

```
        10      0       0       0       #       11      #11_JLL_GOM   #
        10      0       0       0       #       12      #12_CAN_TRAP#
        10      0       0       0       #       13      #12_CAN_GSL1 #
        10      0       0       0       #       14      #1_IND1_JAPAN_LL1     #mirror fleet 1      DN
        10      0       0       0       #       15      #2_IDX2_US_RR_66_114
        10      0       0       0       #       16      #3_IDX3_US_RR_115_144           #Each age as
random walk from
        10      0       0       0       #       17      #4_IDX4_US_RR_LT145 mirror fleet 7
        10      0       0       0       #       18      #5_IDX5_US_RR_GT177 mirror fleet 6
        10      0       0       0       #       19      #6_IDX6_US_RR_GT195 mirror fleet 6
        LOGISTIC
        10      0       0       0       #       20      #7_IDX7_USPLL_GOM   mirror fleet 10
        10      0       0       0       #       21      #8_IDX8_JLL_GOM        mirror fleet 11
        10      0       0       0 #     22      #9_IDX9_CAN_NS          mirror fleet 9
        10      0       0       0       #       23      #10_IDX10_GOM larval
        0       0       0       0       #       24      #11_IDX11_tagging          link to F pick min and
max age
        10      0       0       0       #       25      #12_IDX12_CAN_ACOUSTIC      mirror fleet 9
        10      0       0       0       #       26      #13_IDX13_oceanographic
        10      0       0       0       #       27      #14_IND14_JAPAN_LL2
        10      0       0       0        #      28      #15_IDX15_USPLL_GOM2
#_LO    HI      INIT    PRIOR   PR_type SD      PHASE   env-var  use_dev dev_minyr          dev_maxyr
        dev_stddev      Block   Block_Fxn
#FLT    1       JAPAN   LL      DOUBLE          NORMAL
#_LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block
Block_Fxn  peak fix due to correlation with parm 3
 40 250 155 120 -1 1000  2 0 3 2011 2015 0.2 1 2 # SizeSel_1P_1_JAPAN_LLLL          peak
 -10 3 -1.78877 -1.16787 -1 1000 2 0 0 0 0 0 1 2 # SizeSel_1P_2_JAPAN_LL     width of top
 -5 9 7.43702 4.81298 -1 1000 3 0 0 0 0 0 1 2 # SizeSel_1P_3_JAPAN_LL        asc          width
 -5 9 7.74345 6.75951 -1 1000 -2 0 0 0 0 0 1 2 # SizeSel_1P_4_JAPAN_LL       dsc          width
 -999 15 -999 -1 -1 5 -3 0 0 0 0 0 1 2 # SizeSel_1P_5_JAPAN_LL              init selex smooth increase from 0 -
999
 -20 10 -13.5864 2 -1 100 4 0 0 0 0 0 1 2 # SizeSel_1P_6_JAPAN_LL           final selex

 40 100 68.4973 68.4973 -1 0.1 -2 0 0 0 0 0 0 0 # SizeSel_2P_1_USA_CAN_PSFS   peak  fix
 -5 3 -1 -5 -1 0.05 -3 0 0 0 0 0.5 0 0      # SizeSel_2P_2_USA_CAN_PSFS  width of top fixed at minus -1 to get
it to drop sharply at 150
 -4 12 3.91039 0.5 1 0.1 4 0 0 0 0 0.5 0 0 # SizeSel_2P_3_USA_CAN_PSFS asc width   prior
 -5 6 -5 1.4 -1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_2P_4_USA_CAN_PSFS dsc       width
 -15 5 -999 -14.5 -1 0.05 -2 0 0 0 0 0.5 0 0 # SizeSel_2P_5_USA_CAN_PSFSFS
 -15 10 -999 -4.6 -1 0.05 -2 0 0 0 0 0.5 0 0 # SizeSel_2P_6_USA_CAN_PSFSFS
           # SizeSel_2P_3_USA_CAN_PSFS
 40 250 213.666 120 -1 .1 -1 0 0 0 0 0 0 0 # SizeSel_3P_1_USA_CAN_PSFB    fix
 -5 3 -2.16018 -5 -1 0.05 2 0 0 0 0 0.5 0 0 # SizeSel_3P_2_USA_CAN_PSFBB
 -4 12 6.89979 0.5  1 0.1 3 0 0 0 0 0.5 0 0 # SizeSel_3P_3_USA_CAN_PSFBB
 -2 6 6 1.4 -1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_3P_4_USA_CAN_PSFBFB
 -15 5 -999 -14.5 -1 0.05 -2 0 0 0 0 0.5 0 0 # SizeSel_3P_5_USA_CAN_PSFB
 -15 5 -3.13668 4.6 -1 0.05 4 0 0 0 0 0.5 0 0 # SizeSel_3P_6_USA_CAN_PSFBFB
 40 200 143.78 120 -1 1000 1 0 0 0 0 0 0 0 # SizeSel_4P_1_USA_TRAPSFB

 -5 3 -4.35683 -4 1 0.1 3 0 0 0 0 0.5 0 0 # SizeSel_4P_2_USA_TRAP   prior to help it to not hit bound
 -4 12 8.49596 2.2 -1 0.05 3 0 0 0 0 0.5 0 0 # SizeSel_4P_3_USA_TRAP
 -2 10 7.24992 1.2  1 0.1 3 0 0 0 0 0.5 0 0 # SizeSel_4P_4_USA_TRAP
 -15 5 -999 -14.5 -1 0.05 -2 0 0 0 0 0.5 0 0 # SizeSel_4P_5_USA_TRAP   smooth increase from 0
 -15 10 -999 -4.6 -1 0.05 -2 0 0 0 0 0.5 0 0 # SizeSel_4P_6_USA_TRAP   smooth decline to 0

 30 250 176.926 150 -1 0.2 2 0 0 0 0 0 0 0 # SizeSel_5P_1_USA_CAN_HARPOON
 10 100 17.7819 40 -1 0.2 2 0 0 0 0 0 0 0 # SizeSel_5P_2_USA_CAN_HARPOON

 40 200 191.229 120 -1 1000 1 0 0 0 0 0 0 0 # SizeSel_6P_1_USA_RRFB
```

```
 -5 3 -0.554289 -5 -1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_6P_2_USA_RRFB
 -4 12 6.56855 0.5 -1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_6P_3_USA_RRFB
 -2 6 6 1.4 1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_6P_4_USA_RRFB
 -15 5 -999 -14.5 -1 0.05 -2 0 0 0 0 0.5 0 0 # SizeSel_6P_5_USA_RRFB  smooth increase
 -15 5 -1.24189 4.6 -1 0.05 2 0 0 0 0 0.5 0 0 # SizeSel_6P_6_USA_RRFB

 40 200 93.9709 120 -1 1000 1 0 0 0 0 0 3 2 # SizeSel_7P_1_USA_RRFS
 -5 3 -1.5 -5 1 5  -2 0 0 0 0 0 3 2 # SizeSel_7P_2_USA_RRFS  tighter prior   fixed at minus -1.5 to get it to drop
sharply at 150
 -4 12 6.48538 2.2 -1 0.05 -3 0 0 0 0 0  3 2 # SizeSel_7P_3_USA_RRFS
 -2 6 0.973103 1.2 -1 0.05 -3 0 0 0 0 0  3 2  # SizeSel_7P_4_USA_RRFS
 -15 5 -999 -14.5 -1 0.05 -2 0 0 0 0 0  3 2  # SizeSel_7P_5_USA_RRFS  smooth increase
 -15 10 -5 -14.6 -1 0.05 -2 0 0 0 0 0  3 2  # SizeSel_7P_6_USA_RRFS   fix at 0

  30 250 176.926 150 -1 0.2 2 0 0 0 0 0 0 0  # SizeSel_8P_1_OTHER_ATL_
 10 100 17.7819 40 -1 0.2 2 0 0 0 0 0 0 0  # SizeSel_8P_2_OTHER_ATL_
# 40 250 199.999 120 -1 1000 1 0 0 0 0 0 0 0 # SizeSel_8P_1_OTHER_ATL_
# -10 3 -0.910661 -1.16787 -1 1000 2 0 0 0 0 0 0 0 # SizeSel_8P_2_OTHER_ATL_LL
# -5 9 7.91519 4.81298 -1 1000 3 0 0 0 0 0 0 0 # SizeSel_8P_3_OTHER_ATL_LL
# -5 9 1.24 1.24 -1 1000 -4 0 0 0 0 0 0 0 # SizeSel_8P_4_OTHER_ATL_LL  smooth decline
# -999 15 -999 -1 -1 5 -3 0 0 0 0 0 0 0 # SizeSel_8P_5_OTHER_ATL_LL  down to 0
# -20 10 0.279958 2 -1 100 4 0 0 0 0 0 0 0 # SizeSel_8P_6_OTHER_ATL_LL

 30 300 212.925 150 -1 0.2 2 0 0 0 0 0 0 0 # SizeSel_9P_1_CAN_HOOKLINELL
 10 100 58.1822 40 -1 0.2 2 0 0 0 0 0 0 0 # SizeSel_9P_2_CAN_HOOKLINELL

 30 300 208.858 150 -1 0.2 2 0 0 0 0 0 0 0 # SizeSel_10P_1_GOM_LL_US_MEX_LL
 10 100 34.1114 40 -1 0.2 2 0 0 0 0 0 0 0 # SizeSel_10P_2_GOM_LL_US_MEX  fix cor with parm 2 is -0.99

 30 250 193.167 150 -1 0.2 2 0 0 0 0 0 0 0 # SizeSel_11P_1_JLL_GOM             selex
 10 100 20.1817 40 -1 0.2 2 0 0 0 0 0 0 0 # SizeSel_11P_2_JLL_GOM

 30 300 248.137 245 -1 0.2 2 0 0 0 0 0 0 0 # SizeSel_12P_1_CAN_TRAP
 10 100 55.2643 40 -1 0.2 2 0 0 0 0 0 0 0 # SizeSel_12P_2_CAN_TRAP

 30 320 212.925 150 -1 0.2 2 0 0 0 0 0 0 0 # SizeSel_13P_1_CAN_GSL1
 10 100 58.1822 40 -1 0.2 2 0 0 0 0 0 0 0 # SizeSel_13P_2_CAN_GSL1

 40 200 65 120 -1 1000 -3 0 0 0 0 0 0 0 # SizeSel_14P_1_IDX2_US_RR_66_114   PEAK     fix to start at 66
 -5 3 -1.7 -5 -1 0.05  -3 0 0 0 0 0.5 0 0 # SizeSel_14P_2_IDX2_US_RR_66_114    width fix to get it to stop at
114
 -4 12 -4 2.2 -1 0.05  -3 0 0 0 0 0.5 0 0 # SizeSel_14P_3_IDX2_US_RR_66_114 asc width  fix to make sharp
break
 -2.5 6 -2 1.2 -1 0.05  -3 0 0 0 0 0.5 0 0 # SizeSel_14P_4_IDX2_US_RR_66_114 desc width fix to make sharp
break
 -15 5 -999 -14.5 -1 0.05 -2 0 0 0 0 0.5 0 0 # SizeSel_14P_5_IDX2_US_RR_66_114 init
 -15 10 -5 -14.6 -1 0.05 -2 0 0 0 0 0.5 0 0 # SizeSel_14P_6_IDX2_US_RR_66_114 final

  40 200 115 120 -1 1000 -3 0 0 0 0 0 0 0 # SizeSel_15P_1_IDX2_US_RR_115_144   PEAK   fix to make
 -5 3 -2.1 -5 -1 0.05  -3 0 0 0 0 0.5 0 0 # SizeSel_15P_2_IDX2_US_RR_115_144      width fix to get it to start at
115
 -4 12 -4 2.2 -1 0.05 -3 0 0 0 0 0.5 0 0 # SizeSel_15P_3_IDX2_US_RR_115_144  asc width  fix to get it to start
at 144
 -2.5 6 -2 1.2 -1 0.05  -3 0 0 0 0 0.5 0 0 # SizeSel_15P_4_IDX2_US_RR_115_144  desc width
 -15 5 -999 -14.5 -1 0.05 -2 0 0 0 0 0.5 0 0 # SizeSel_15P_5_IDX2_US_RR_115_144
 -15 10 -5 -14.6 -1 0.05 -2 0 0 0 0 0.5 0 0 # SizeSel_15P_6_IDX2_US_RR_115_144

#  30 320 212.925 150 -1 0.2 2 0 0 0 0 0 0 0 # SizeSel_13P_1_CAN_ACOUSTIC
# 10 100 58.1822 40 -1 0.2 2 0 0 0 0 0 0 0 # SizeSel_13P_2_CAN_ACOUSTIC
```

```
#_Cond  -2      2       0       0       -1      99      -2      #_placeholder   when    no
        enviro  fxns
1 #_Cond        0       #_custom_sel-blk_setup  (0/1)
# LO   HI    INIT   PRIOR   PR_TYPE  SD   PHASE
 40 250  162   120    -1 1   -5   # SizeSel_1P_1_JAPAN_LLLL   peak
 -10  3  -1.78  -1.16  -1 1   5   # SizeSel_1P_2_JAPAN_LL     top
 -5 9     7.43   4.81  -1 1   5   # SizeSel_1P_3_JAPAN_LL     asc     width
 -5 9     7.74   6.75  -1 1  -2   # SizeSel_1P_4_JAPAN_LL     dsc     width, fix due to cor
 -999 15 -999     -1   -1 5  -3   # SizeSel_1P_5_JAPAN_LL     init    selex
 -20  10 -13.58    2   -1 1   5   # SizeSel_1P_6_JAPAN_LL     final selex

 40 200 93.9709 120 -1 1000 1   # SizeSel_7P_1_USA_RRFS
 -5 3 -1.5 -5 1 0.05 -2   # SizeSel_7P_2_USA_RRFS
 -4 12 6.48538 2.2 -1 0.05 -3   # SizeSel_7P_3_USA_RRFS
 -2 6 0.973103 1.2 -1 0.05 -3   # SizeSel_7P_4_USA_RRFS
 -15 5 -999 -14.5 -1 0.05 -2    # SizeSel_7P_5_USA_RRFS  smooth increase
 -15 10 -5 -14.6 -1 0.05 -2   # SizeSel_7P_6_USA_RRFS   fix at 0

#30 300 250 250 0 2 3  # SizeSel_9P_1_CAN_HOOKLINEL    prior
#10 200 58.1822 40 -1 0.2 3   # SizeSel_9P_2_CAN_HOOKLINEL_LL

#_Cond  -2      2       0       0       -1      99      -2      #_placeholder   when    no
        block   usage
#_Cond  No      selex   parm    trends
6 #_Cond        -4      #       placeholder     for     selparm_Dev_Phase
2 #_env/block/dev_adjust_method  (1=standard;   2=logistic      trans   to      keep    in      base
        parm    bounds; 3=standard      w/      no      bound   check)
#
#       Tag     loss    and     Tag     reporting       parameters      go      next
0       #       TG_custom:      0=no    read;   1=read  if      tags    exist
#_Cond  -6      6       1       1       2       0.01    -4      0       0       0       0       0
        0       0       #_placeholder   if      no      parameters
#
1       #_Variance_adjustments_to_input_values
#_fleet/survey:
#       1       2       3       4       5       6       7       8       9       10      11      12
        13      14      15      16      17      18      19      20      21      22      23      24
        25  26 27
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       #_add_to_survey_CV
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       #_add_to_discard_stddev
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       #_add_to_bodywt_CV
0.326   0.066   0.171   0.112   0.445   0.436   0.141   0.414   0.479   0.359   0.203   0.331
        0.479   0.00001 0.00001 0.00001 1       1       1       1       1       1       1       1
        0.0000001       1       1       1       #_mult_by_lencomp_N
1       0.275   0.81    1       0.488   0.249   0.164   0.87    0.337   0.463   1       0.783
        0.337   1       1       1       1       1       1       1       1       1       1       1
        1       1       1       1       #_mult_by_agecomp_N
1       1       1       1       1       1       1       1       1       1       1       1       1
        1       1       1       1       1       1       1       1       1       1       1       1
        1       1       1       #_mult_by_size-at-age_N
#    for the weights for the lengths for CAN acoustic (that come from GSL lengths) I downweiht to 0.000001
7       #_maxlambdaphase
1       #_sd_offset
#
```

```
18 #    number  of       changes to       make     to       default  Lambdas           (default  value    is
        1.0)
#       Like_comp        codes:   1=surv;  2=disc;  3=mnwt;           4=length;         5=age;    6=SizeFreq;
        7=sizeage;       8=catch;
#       9=init_equ_catch;         10=recrdev;       11=parm_prior;    12=parm_dev;      13=CrashPen;
        14=Morphcomp;  15=Tag-comp;   16=Tag-negbin
#like_comp       fleet/survey     phase    value    sizefreq_method
5 1 1 0 1  #turn off JLL age comps
1       24       1        0        1                #turn off the tagging index
1       26       1        0        1                #turn off the env index
4       15       1        0        1                #turn off the length comps for IDX14_US_RR_66_114
4       16       1        0        1                #turn off the env index    IDX15_US_RR_115_144

1 14 1 1 1 #turn off index 14 IND1_JAPAN_LL
1 15 1 1 1 #turn off index 15 IDX2_US_RR_66_114
1 16 1 1 1 #turn off index 16 IDX3_US_RR_115_144
1 17 1 1 1 #turn off index 17 IDX4_US_RR_LT145
1 18 1 1 1 #turn off index 18 IDX5_US_RR_GT177
1 19 1 1 1 #turn off index 19 IDX6_US_RR_GT195
1 20 1 1 1 #turn off index 20 IDX7_USPLL_GOM
1 21 1 1 1 #turn off index 21 IDX8_JLL_GOM
1 22 1 1 1 #turn off index 22 IDX9_CAN_NS
1 23 1 1 1 #turn off index 23 IDX10_GOM larval
1 25 1 1 1 #turn off index 25 IDX12_CAN_ACOUSTIC
1 27 1 1 1 #turn off index 27 IND14_JAPAN_LL2
1 28 1 1 1 #turn off index 28 IND15_USPLL_GOM_LL2


0       #        (0/1)    read     specs    for      more     stddev   reporting
#       0        1        -1       5        1        5        1        -1       5        #        placeholder
        for      selex    type,
#       placeholder       for      vector   of       selex    bins     to       be       reported
#       placeholder       for      vector   of       growth   ages     to       be       reported
#       placeholder       for      vector   of       NatAges  ages     to       be       reported
999
```