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Blue Grenadier (*Macruronus novaezelandiae*) stock assessment based on data up to 2021 – development of a preliminary base case

For discussion at SERAG1, 5-6 October 2022, Melbourne, Victoria

Version 1.0

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Contents

Acknowledgments

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Executive Summary

This document presents the preliminary base case for an updated quantitative Tier 1 assessment of Blue Grenadier (*Macruronus novaezelandiae*) for presentation at the SERAG 1 meeting in October 2022. The last full assessment was conducted during 2021 (Tuck and Bessell-Browne, 2021b; 2021b). The preliminary base case has been updated with the inclusion of data up to the end of 2021, which entails an additional 1 year of catch, discard, catch rate (CPUE), length and age data and ageing error updates since the 2021 assessment. In addition, new acoustic survey points for 2020 and 2021 were included in the preliminary base case model, with the survey from 2019 included as a sensitivity. This document describes the process used to develop a preliminary base case for Blue Grenadier through the sequential updating of recent data in the stock assessment, using the stock assessment package Stock Synthesis (SS-V3.30.19.01, Methot and Wetzel (2013)).

This document describes the standard Bridge 1, which updates the assessment to the most recent version of Stock Synthesis, ensures correct settings are used and updates the historical catch series, and Bridge 2, which sequentially incorporates updated data through to 2021. The base case specifications agreed by the SERAG in 2021 were maintained into the preliminary base case presented here. The main difference between the assessment model of 2021 and 2022 is the inclusion of 2020 and 2021 acoustic survey estimates of biomass.

Results of the preliminary base case show reasonably good fits to the length-composition data, conditional age at length, egg survey, discards and acoustic survey. As has been noted in previous Blue Grenadier assessments, the fit to the standardized non-spawning catch-rate index is generally poor; the model is unable to fit to the high early catch rates and fits are above the observed catch rates during the early 2000s. More recent catch rates fit reasonably well, with a reduction in recent estimated catch rates coinciding with a decrease in the observed catch rate value in 2021.

The estimated time series of recruitment under the base-case parameter set shows the typical episodic nature of Blue Grenadier recruitment, with strong year-classes in 1979, the mid-1980s, 1994, and 2003, with very little recruitment between these years. However, recent recruitments are more stable, as was first observed in the 2018 assessment. The trajectories of spawning biomass show increases and decreases in spawning biomass as strong cohorts move into and out of the spawning population.

The estimated virgin female spawning biomass (B_0) is 35,680 tonnes (compared to 37,445 tonnes in the 2021 assessment) and the projected 2023 spawning stock biomass will be 124% of virgin female spawning biomass (projected assuming 2021 catches in 2022), compared to 155% at the start of 2022 from the 2021 assessment. The reduction in estimated relative spawning biomass is likely due to the reduced 2021 catch rate, the inclusion of the acoustic survey points and updated composition data leading to slightly reduced estimates of recent recruitment.

1 Introduction

1.1 2022 Blue Grenadier assessment base case

The 2022 preliminary base case assessment of Blue Grenadier uses an age- and size-structured model implemented in the generalized stock assessment software package, Stock Synthesis (SS) (Version 3.30.19.01, Methot et al. (2022)). The methods utilised in SS are based on the integrated analysis paradigm. SS can allow for multiple seasons, areas and fleets, but most applications are based on a single season and area. Recruitment is governed by a stochastic Beverton-Holt stock-recruitment relationship, parameterized in terms of the steepness (h) of the stock-recruitment function, the expected average recruitment in an unfished population (R_0), and the degree of variability about the stock-recruitment relationship (σ_r). SS allows the user to choose among a large number of age- and length-specific selectivity patterns. The values for the parameters of SS are estimated by fitting to data on catches, catch-rates, discard mass, discard and retained catch length-frequencies, and conditional age-at-length data. The population dynamics model and the statistical approach used in fitting the model to the various data types are given in the SS technical documentation (Methot et al., 2022).

Model data have been updated by the inclusion of data up to the end of the 2021 calendar year (length-composition and conditional age-at-length data; age reading-error matrices, standardized catch rate series; landings and discard catch weight) and information from acoustic surveys of spawning biomass (series from 2003-2010; 2020-2021), with an assumption of 2-times turnover on the spawning ground (Russell and Smith, 2006; Punt et al. 2015). The egg survey estimates of female (only) spawning biomass for 1994 and 1995 are included in the base case assessment model. The model fits directly to length-composition data (by sex where possible) and conditional age-at-length data by fleet. Retained length-composition data from port and onboard samples are separated.

The first bridging exercise (Bridge 1) highlights changes that have occurred since 2021 simply through changes to software and assessment practices. The subsequent bridging exercise (Bridge 2) then sequentially updates the assessment model with new data through to 2021.

The base–case model includes the following key features:

(a) Blue Grenadier consists of a single stock within the area of the fishery.
(b) The model accounts for males and females separately (growth, natural mortality, age at first breeding).
(c) The population was at its unfished biomass with the corresponding equilibrium (unfished) age-structure at the start of 1960.
(d) The rate of natural mortality, M, is assumed to be constant with age, and also time-invariant. The value for male and female M is estimated within the assessment.
(e) Recruitment to the stock is assumed to follow a Beverton-Holt type stock-recruitment relationship, parameterised by the average recruitment at unexploited spawning biomass, R_0, and

the steepness parameter, *h*. Steepness for the base-case analysis is set to 0.75. Deviations from the average recruitment at a given spawning biomass (recruitment residuals) are estimated for 1974 to 2018. Deviations are not estimated before 1974 or after 2018 because there are insufficient data to permit reliable estimation of recruitment residuals outside of this time period.

(f) The population plus-group is modelled at age 20 years. The maximum age for age observations is 20 years.

(g) Growth is assumed to follow a von Bertalanffy type length-at-age relationship, with the parameters of the growth function being estimated separately for females and males inside the assessment model. Growth is also assumed to vary through time and to be cohort (year class) specific. Evidence for time-varying and cohort specific growth in Blue Grenadier has been accumulating over several decades (see Punt and Smith 2001; Whitten et al., 2013). The 2022 preliminary base-case model treats conditional age-at-length information as data (i.e. to incorporate error), and predicts the expected length-at-age for each year. This is achieved by estimating the parameters of a von Bertalanffy growth function where the expected annual growth increment is based on the von Bertalanffy growth function but with a growth rate parameter that is determined by an expected value and a cohort-specific deviation. Cohort-specific deviations from average growth are estimated in the preliminary base case model for year classes 1978 to 2018.

(h) Two fleets are included in the model – the spawning fishery that operates during winter (June – August inclusive) off western Tasmania (zone 40), and the non-spawning sub-fishery that operates during other times of the year and in other areas throughout the year. GAB catches are not included and are small in comparison to those used in the assessment .

(i) Each selectivity pattern was assumed to be length-specific and time-invariant, a logistic pattern was assumed for the spawning fleet and a dome-shaped pattern assumed for the non-spawning fleet. The parameters of the selectivity functions for each fleet were estimated within the assessment.

(j) The CVs of the CPUE indices were initially set at a value equal to the standard error from a loess fit (0.248; Sporcic, 2022), before being re-tuned to the model-estimated standard errors within SS. The acoustic biomass estimates were tuned through the estimation of an extra variance component that is added to the model input standard errors. This is done within SS.

(k) Discard tonnage was estimated through the assignment of a retention function for the non-spawning fleet. This was defined as a logistic function of length, and the inflection and slope of this function were estimated where discard information was available. In addition, the discard length data from 1993, 1995 and 1996 were removed for the 2018 base case as recommended by SERAG (September, 2018) due to the existence of unusually large fish in the length distribution which is likely to be misreporting.

(l) Retained and discarded onboard length sample sizes were capped at 200 and a minimum of 100 fish measured was required for length-composition data to be included in the assessment. For port samples, numbers of trips were used as the sampling unit, with a cap of 100. The number of fish measured is not used as the sample size because the appropriate sample size for length-composition data is probably more closely related to the number of shots (onboard) or trips (port) sampled, rather than the number of fish measured.

The values assumed for fixed parameters of the preliminary base case model are shown in Table 1.

Table 1. Parameter values assumed for some of the non-estimated parameters of the preliminary base-case model.

Parameter	Description	Value
M_f	Natural mortality for females	Estimated
M_m	Natural mortality for males	Estimated
h	"steepness" of the Beverton-Holt stock-recruit curve	0.75
x	age observation plus group	20 years
μ	fraction of mature population that spawn each year	0.84
a_f	Female allometric length-weight equations	0.01502 g^{-1}.cm
b_f	Female allometric length-weight equations	2.728
a_m	Male allometric length-weight equations	0.0168 g^{-1}.cm
b_m	Male allometric length-weight equations	2.680
l_m	Female length at 50% maturity	63.7cm
l_s	Parameter defining the slope of the maturity ogive	-0.261

2 The fishery

Blue Grenadier are found from New South Wales around southern Australia to Western Australia, including the coast of Tasmania. Blue Grenadier is a moderately long-lived species with a maximum age of about 25 years. Age at maturity is approximately 4 years for males and 5 years for females (length-at-50% maturity for females is 57 cm and 64 cm respectively) based upon 32,000 Blue Grenadier sampled between February 1999 and October 2001 (Russell and Smith, 2006). There is also evidence that availability to the gear on the spawning ground differs by sex, with a higher proportion of small males being caught than females. This is most likely due to the arrival of males on the spawning ground at a smaller size (and younger age) than females. This was also noted by Russell and Smith (2006) who state that “young males entered the fishery one year earlier than females” and is consistent with information for Hoki from New Zealand (Annala et al., 2003). Large fish arrive earlier in the spawning season than small fish. Spawning occurs predominantly off western Tasmania in winter (the peak spawning period based upon mean gonadosomatic indices calculated by month was estimated to be between June and August according to Russell and Smith (2006). There is some evidence that a high proportion of fish remain spawning in September. Variations in spawning period noted by Gunn et al. (1989) may occur due to inter-annual differences in the development of coastal current patterns around Tasmania. Adults disperse following the spawning season and while fish are found throughout the south east region during the non-spawning season, their range is not well defined. Spawning fish have been caught off the east coast of Australia, and larvae from a likely eastern spawning area have been described by Bruce et al. (2001). Blue Grenadier are caught by demersal trawling. There are two defined fleets: the spawning (Zone 40, months June, July and August) and non-spawning fisheries (all other months and zones).

3 Bridging methodology

The previous full quantitative assessment for Blue Grenadier was performed in 2021 (Tuck and Bessell-Browne, 2021a; 2021b) using Stock Synthesis (version SS-V3.30.17.00, Methot et al. (2021)). The 2022 assessment uses the current version of Stock Synthesis (version SS-V3.30.19.01).

As a first step in the process of bridging to a new model, the data used in the 2021 assessment was used in the new software (SS-V3.30.19.01). The catch series was then updated to include any amended estimates for the historical period from 1998 to 2020 since the 2021 assessment. Following this step, the model was re-tuned (the data sources re-weighted within the likelihood) using the most recent tuning protocols (Pacific Fishery Management Council, 2018), thus allowing the examination of changes to both assessment practices and the tuning procedure on the previous model structure. These changes to software and tuning practices may lead to changes to key model outputs, such as the estimates of depletion and the trajectory of spawning biomass. This initial bridging phase (Bridge

1) highlights changes that have occurred since 2021 simply through changes to software and assessment practices.

The subsequent bridging exercise (Bridge 2) then sequentially updates the model with new data through to 2021. These additional data included new catch, discard estimates, CPUE, length composition data, conditional age-at-length data, an updated ageing error matrix and new acoustic survey points from 2020 and 2021. The last year of recruitment estimation and cohort dependent growth was extended to 2018 (from 2017 in Tuck and Bessell-Browne (2021a; 2021b)). The final step is to re-tune the model.

4 Bridge 1

The 2021 Blue Grenadier assessment (labelled 'GRE_2018_30_12_00') was converted to the most recent version of the software, Stock Synthesis version SS-V3.30.19.01 (labelled 'GRE_2018_30_19_01'). This resulted in no changes to the stock status estimates throughout the timeseries (Figure 1). There were no changes to the SS settings since 2021. Likewise updating catches to 2020 also resulted in no discernible changes (labelled 'Updated_catch' and includes the previous changes (Figure 1)). The assessment was then tuned using the latest tuning protocol (labelled 'Tuned'). This process demonstrates the outcomes that could theoretically have been achieved with the last assessment if we had the latest software, tuning protocols and corrected data available in 2021. This initial bridging step, Bridge 1, does not incorporate any data after 2020 or any structural changes to the assessment. Re-tuning did not lead to any discernible change to the assessment results from 2021.

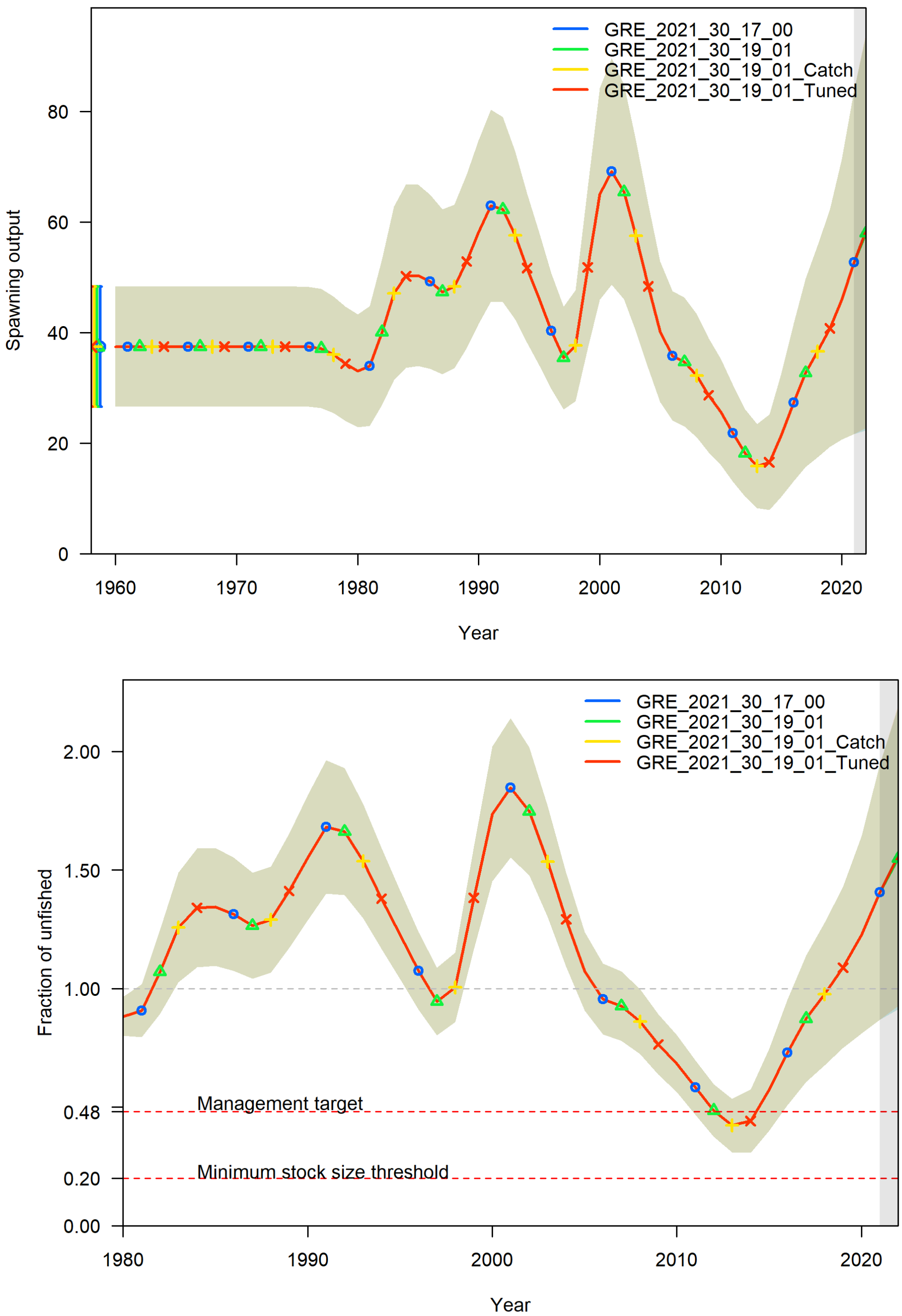


Figure 1 Comparison of the absolute spawning biomass (top) and relative spawning biomass (bottom) time series for the 2021 assessment (SS3-30.17), a model converted to SS-V3.30.19.01, with updated settings and catches (_Catch) and then re-tuned (_Tuned).

5 Bridge 2

5.1 Inclusion of new data

The data inputs to the assessment comes from multiple sources, including: length and conditional age-at-length data, updated standardized CPUE series (Sporcic, 2022), acoustic survey points, the annual total mass landed, discard mass, and age-reading error.

Starting from the converted 2021 base case model (labelled GRE_2021_30_19_01_Tuned) from Bridge 1 additional and updated data to 2021 were added sequentially to develop a preliminary base case for the 2022 assessment, these steps included:

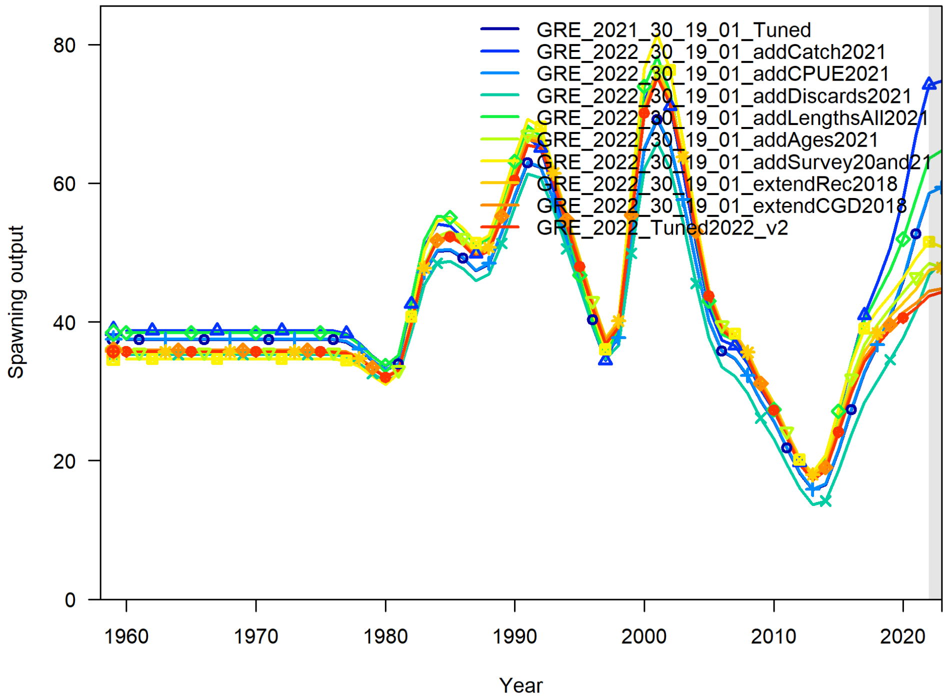
1. Change final assessment year to 2021, add catch to 2021 (addCatch2021).
2. Add updated CPUE series through to 2021 (from Sporcic (2022)) (addCPUE2021).
3. Add updated discard estimates to 2021 (add_Discards2021).
4. Update length frequency data, including both port and onboard length frequencies (addLengthsAll2021).
5. Add updated conditional-age-at-length data (addAges2021). Age reading error matrix was also updated (no discernible difference so not shown here).
6. Add new acoustic biomass survey estimates for 2020 and 2021 (addSurvey20and21)
7. Change the final year for which recruitments are estimated from 2017 to 2018 (extendRec2018).
8. Change the final year for which cohort dependent growth is estimated from 2017 to 2018 (extendCGD2018).
9. Retune using latest tuning protocols, including Francis weighting on length-compositions and conditional age-at-length data (Tuned2022_v2).

5.2 Results - base case

Inclusion of the new data resulted in a series of changes to the outputs of the model. The addition of updated catch data increased the biomass, while the new catch rate data returned the biomass to a similar series to the 2021 assessment (Figure 2). The addition of updated discard estimates reduced the 2022 estimate of spawning biomass (Figure 2). There were small changes in the biomass trajectory from the 2021 assessment resulting from the addition of length (increase in biomass) and age data (decrease in biomass). Including the 2020 and 2021 acoustic surveys led to a small increase in biomass from the previous bridging step (adding ages). Extending recruitment deviations and cohort dependent growth led to small incremental decreases in relative biomass compared to previous bridging steps. Tuning did not result in a substantial change compared to the untuned previous bridging step. However, the tuned trajectory showed a marked decrease in the relative biomass in the final assessment year compared to the 2021 assessment (Figure 2).

The sequential addition of data resulted in various changes to the recruitment estimates (Figure 3), and generally a reduction in estimates from 2010 (Figure 3). The addition of a further recruitment year (to 2018; extendRec2018) has led to a decrease in the magnitude of the recent recruitment (2017) from the 2021 assessment (Figure 3). This is not uncommon as further data from length and age compositions that help inform recruitment estimation are added to assessments.

The impacts of inclusion of new data on fits to the non-spawning fishery CPUE series and the inclusion of the 2020 and 2021 acoustic biomass estimates are illustrated in Figure 4 and Figure 5 respectively. As has been noted before, the fits to CPUE are generally poor until the mid-2000s. The addition of a new data point for 2021 which is lower than 2020, and an updated data series, including the acoustic surveys, has led to a decrease in the estimated CPUE in recent years. The fit to the acoustic estimates of 2020 and 2021 tends to prefer the higher biomass estimate from 2020, as presumably other data inputs are more consistent with the higher value (Figure 5).



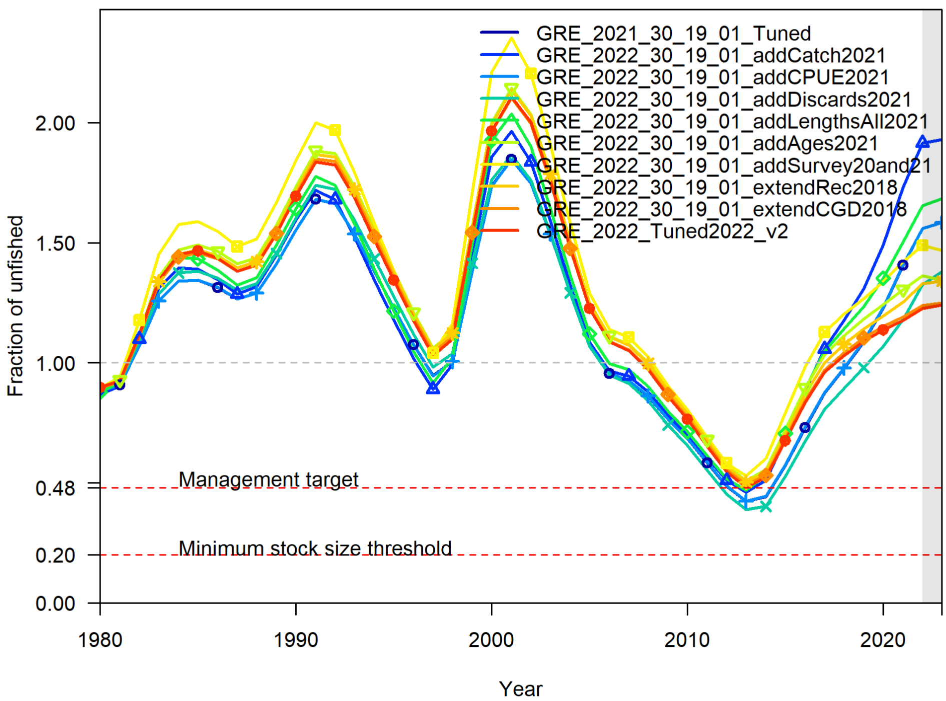


Figure 2. Comparison of the absolute (top) and relative (bottom) spawning biomass for the updated 2021 assessment converted to SS-V3.30.19 (GRE_2021_Tuned – dark blue) with various bridging models leading to the 2022 preliminary base case (Tuned2022_v2 - red).

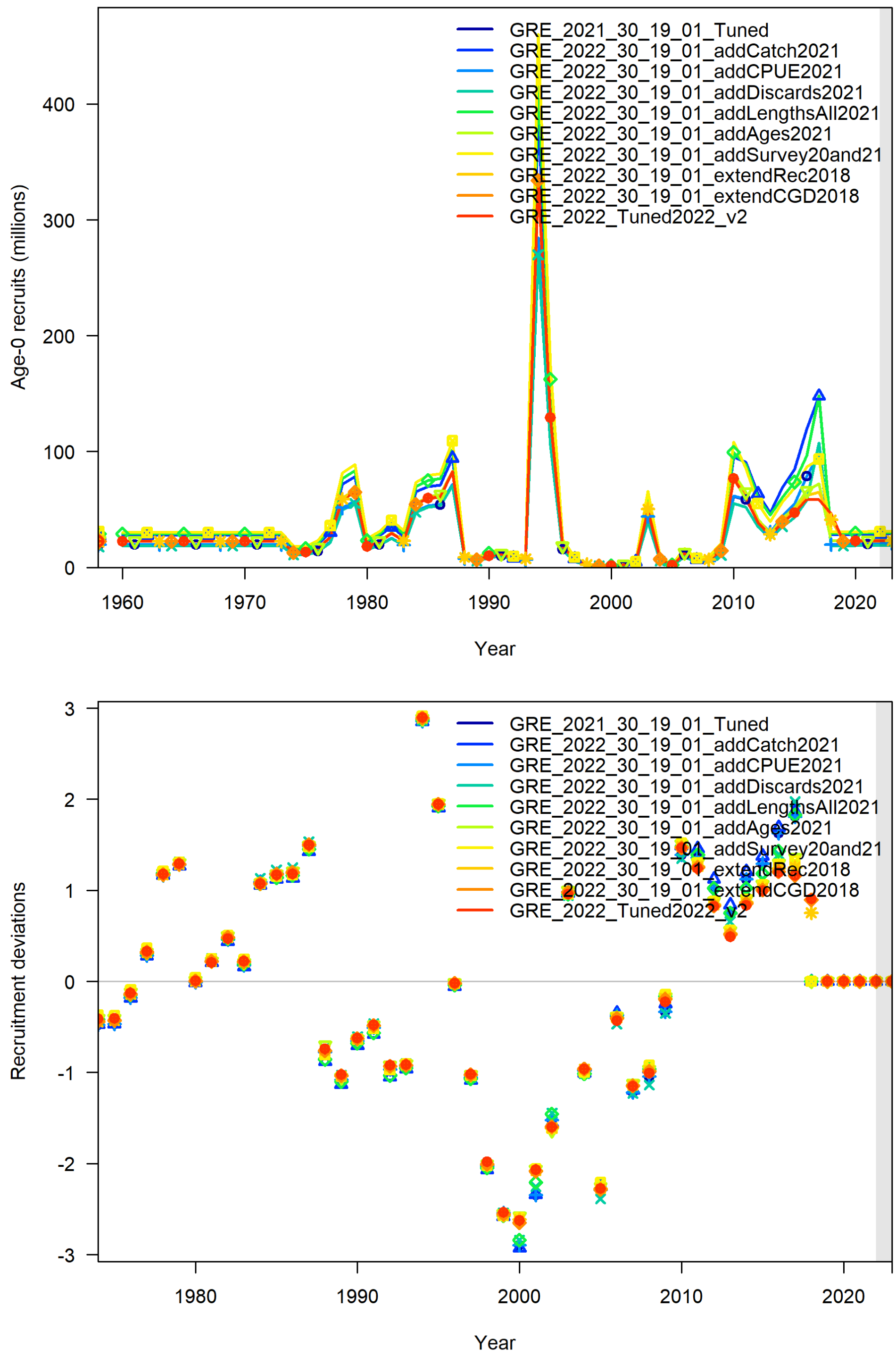


Figure 3. Comparison of the estimated recruitment (top) and deviations (bottom) for the updated 2021 assessment model converted to SS-V3.30.19.01 (_Tuned – dark blue) with various bridging steps leading to the 2022 preliminary base case (Tuned2022_v2 - red).

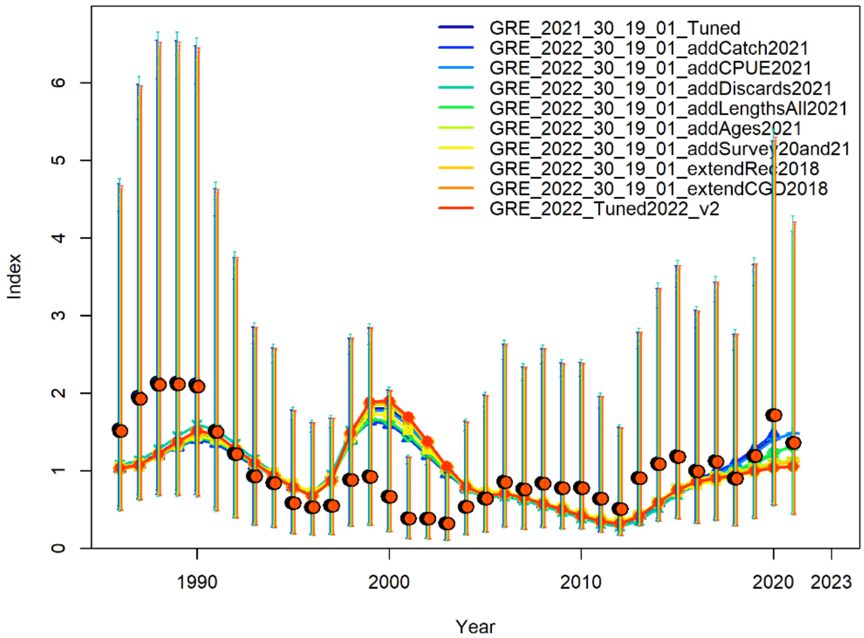


Figure 4. Comparison of the fit to the non-spawning fishery CPUE index for the updated 2021 assessment model converted to SS-V3.30.19.01 (_Tuned – dark blue) with various bridging models leading to the 2022 preliminary base case (_Tuned2022_v2 - red).

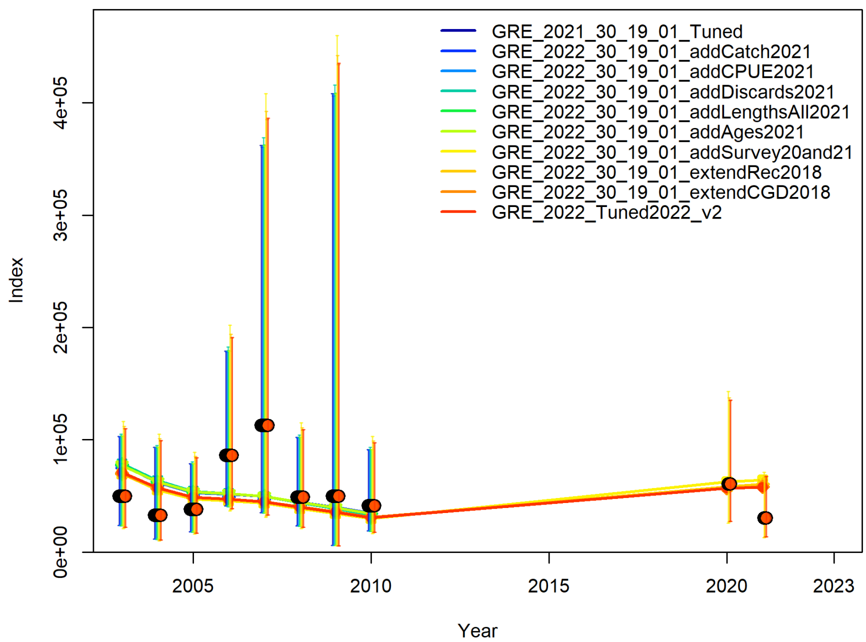


Figure 5. Comparison of the fit to acoustic survey points for the updated 2021 assessment model converted to SS-V3.30.19.01 (_Tuned – dark blue) with various bridging models leading to the 2022 preliminary base case (_Tuned2022_v2 - red).

5.3 Fits to data – base case

Estimated quantities and fits to the data of the preliminary base case are presented in Figures 6–13. Fits are comparable to those in the previous assessment (see Tuck and Bessell-Browne, 2021b). Fits to the acoustic survey data are reasonable, although there is little variation in the estimated values and the fit is relatively flat while passing through the confidence intervals. The fit to discard mass is reasonable, although there is some under-fitting from 2015-2017. Fits to the length composition data are good across the retained and discard lengths, and for port and onboard lengths. Note the saw-tooth pattern in the port length data which may be due to in-port rounding of measurements, however, it is unlikely to impact the assessment. Natural mortality for females was estimated to be M_f = 0.239 and males was M_m = 0.246, which is a small increase compared to the 2021 assessment.

5.4 Assessment outcomes – base case

The estimated virgin female spawning biomass (B_0) is 35,680 tonnes (compared to 37,445 tonnes in the 2021 assessment) and the projected 2023 spawning stock biomass will be 124% of virgin female spawning biomass (projected assuming 2021 catches in 2022), compared to 155% for 2022 in the 2021 assessment. The reduction in relative spawning biomass is likely due to the reduced 2021 catch rate and the inclusion of the 2020 and 2021 acoustic biomass survey points, while updated age and length data have led to reduced estimates of the magnitude of recent recruitments.

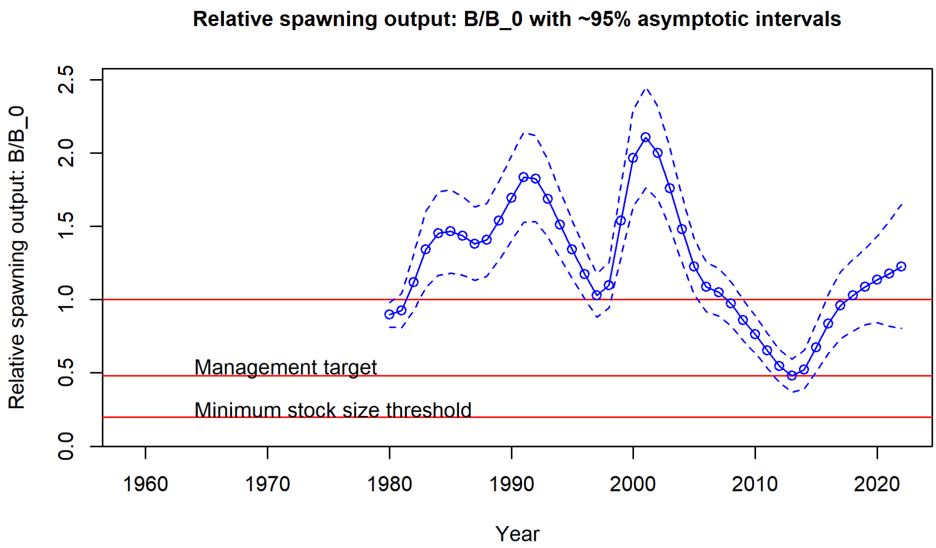


Figure 6. The estimated time-series of relative spawning biomass for the 2022 preliminary base case assessment.

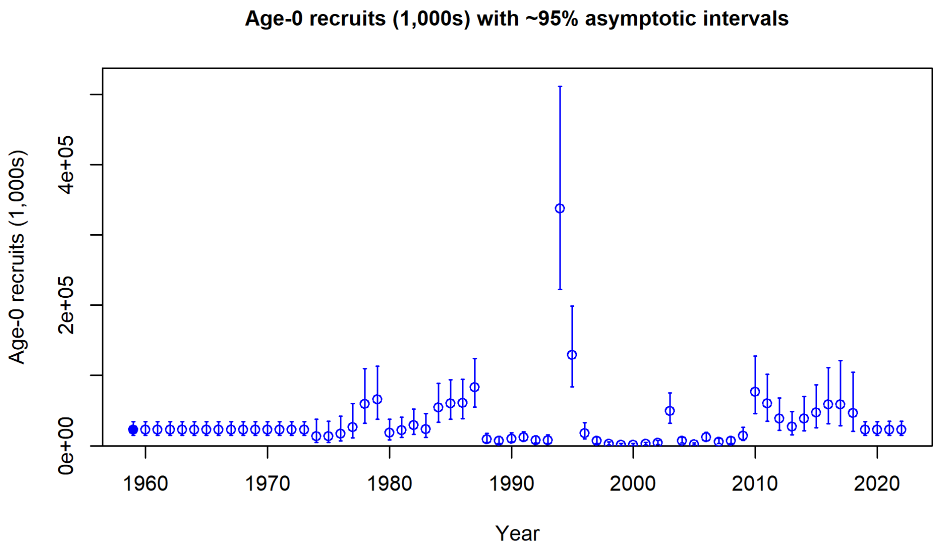


Figure 7. The estimated time-series of recruitment for the 2022 preliminary base case assessment.

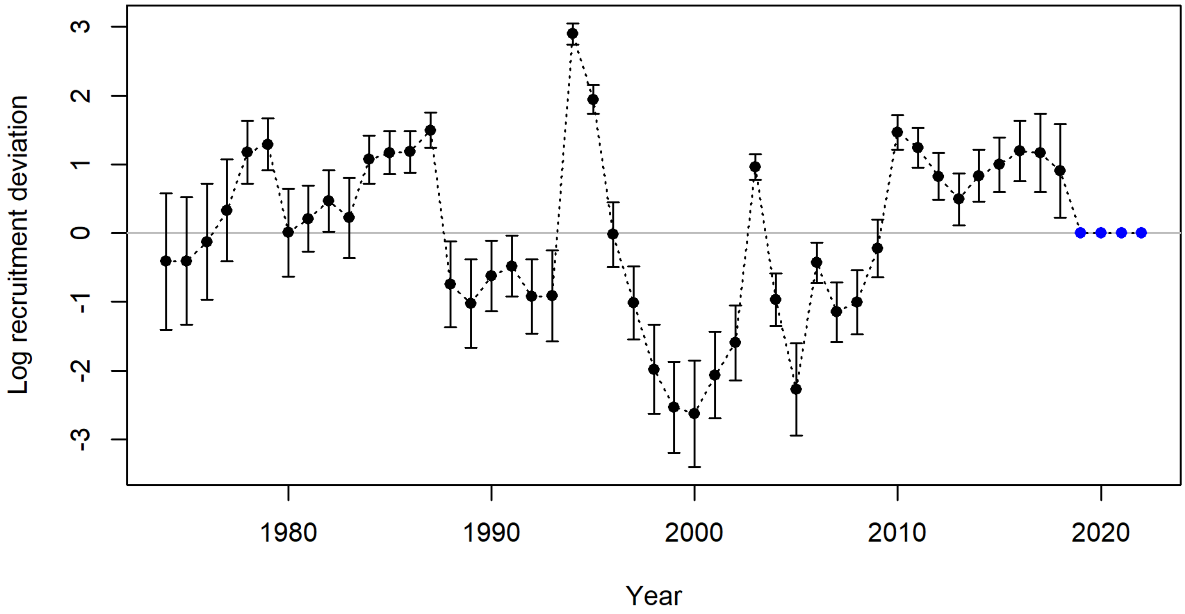


Figure 8. The estimated time-series of recruitment deviations for the 2022 preliminary base case assessment.

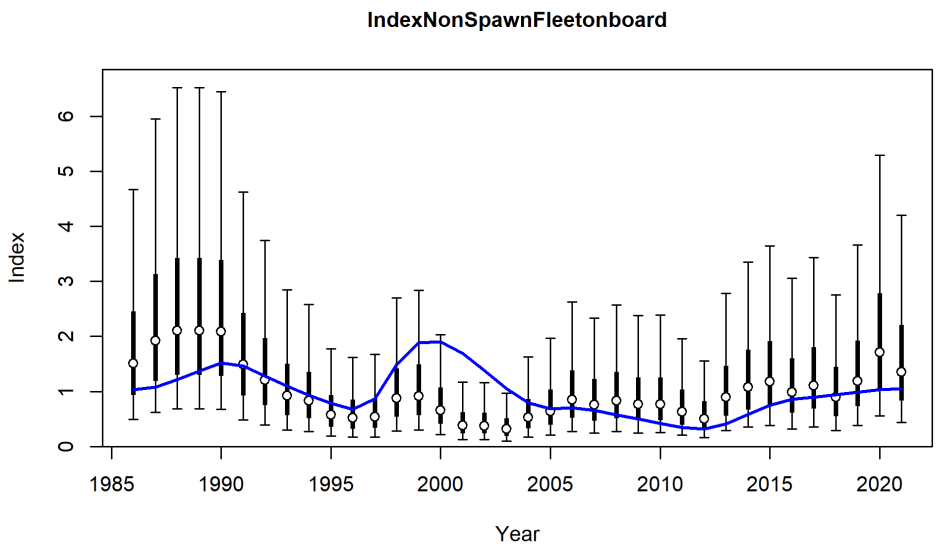


Figure 9. Fits to the non-spawning fishery CPUE for the 2022 preliminary base case assessment.

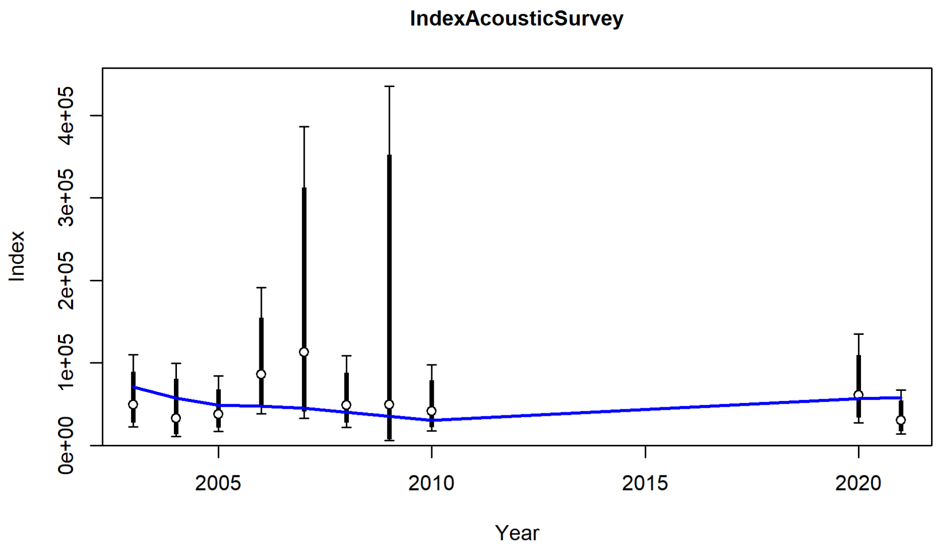


Figure 10. Fits to the acoustic survey data for the 2022 preliminary base case assessment.

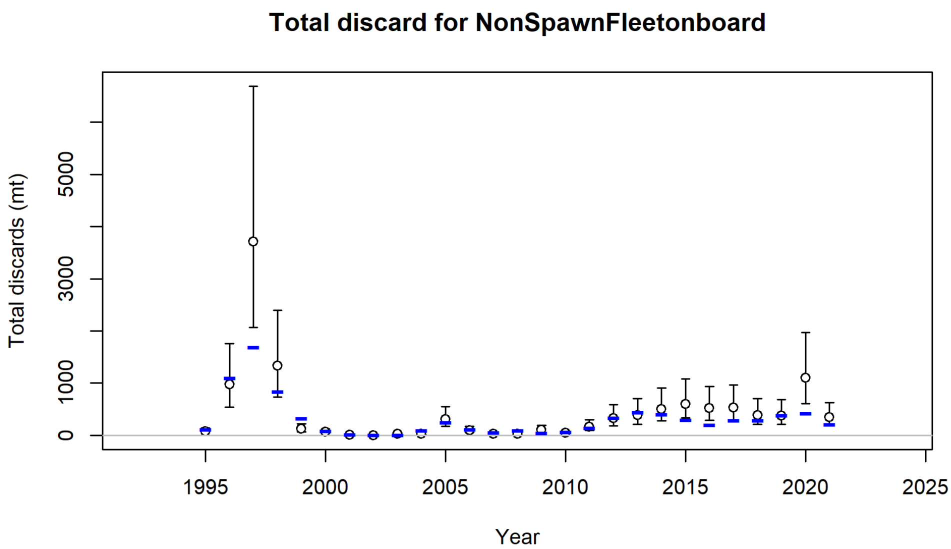


Figure 11. Fits to the non-spawning fishery discards for the 2022 preliminary base case assessment.

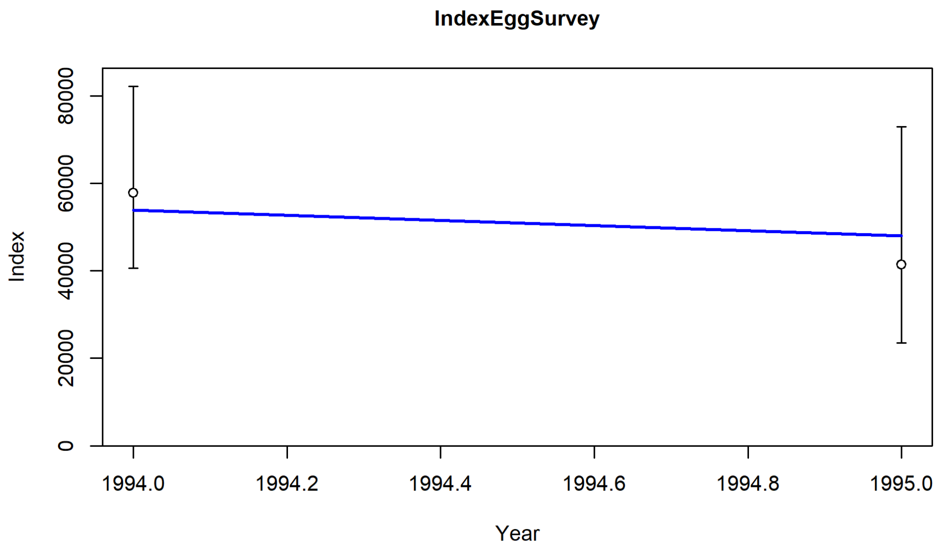


Figure 12. Fits to the egg survey data for the 2022 preliminary base case assessment.

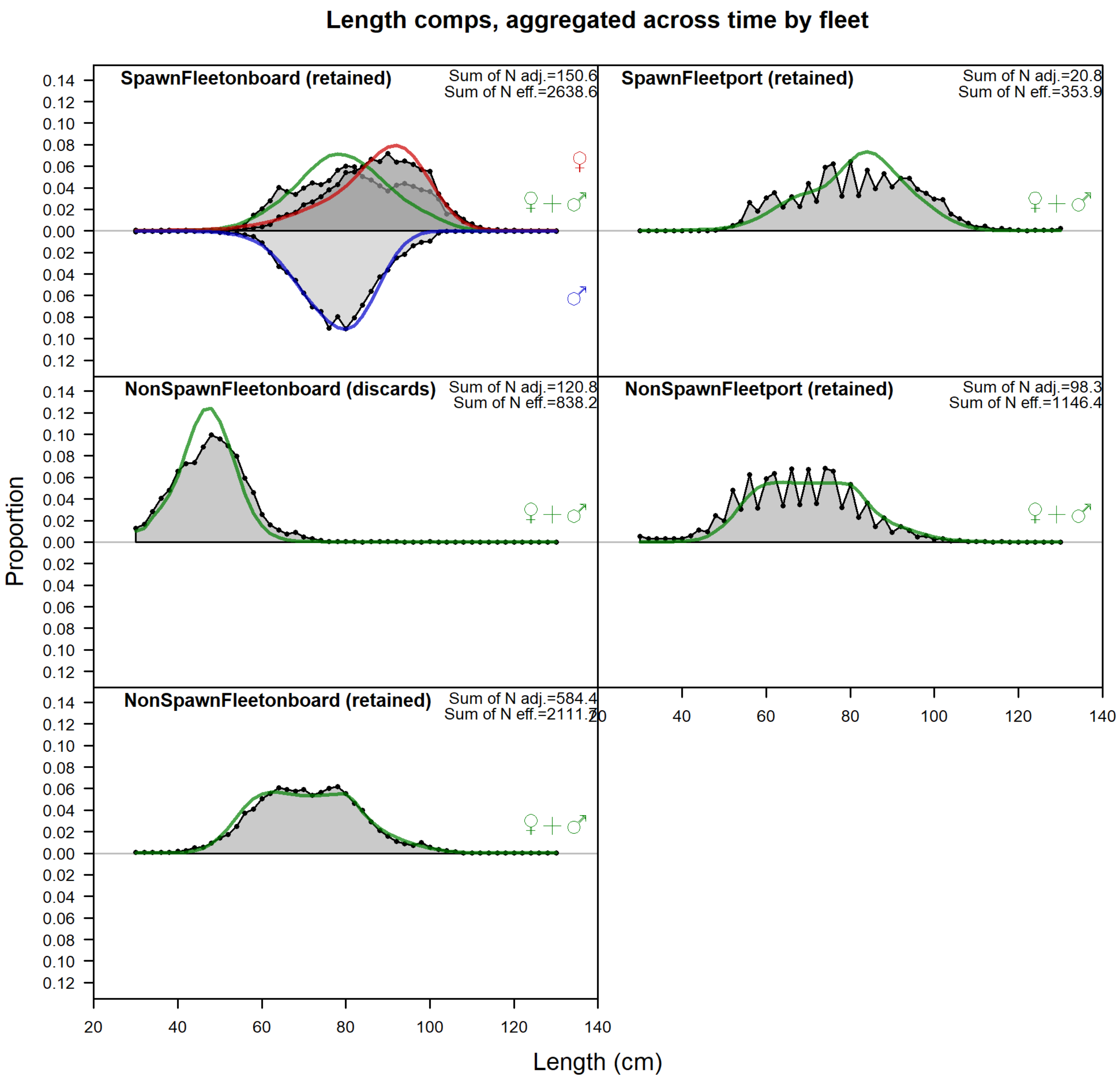


Figure 13. Fits to the aggregated length data for the 2022 preliminary base case assessment.

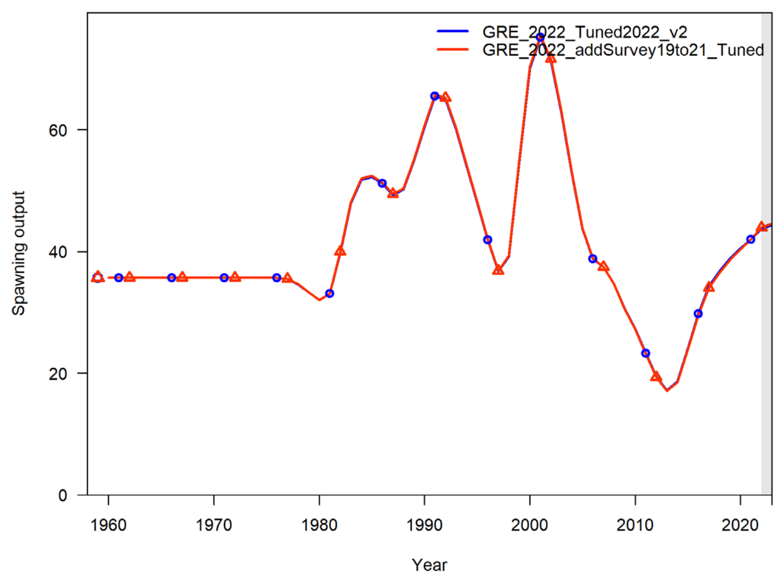
5.6 Inclusion of the 2019 Acoustic Survey Point

The 2019 acoustic survey point was not included in the agreed preliminary base case (SESSFRAG, August 2022) due to concerns regarding representativeness (Ryan and Kunnath, 2022). However, it is included here for consideration as a sensitivity. Table 2 shows the estimates of spawning biomass with their corresponding CV's used in the assessment. The CVs of any acoustic biomass survey estimates less than 0.3 were increased to 0.3 to account for process error. Low sampling CVs were considered too low for an acoustic survey and a minimum of 0.3 should be used to reflect the total uncertainty (D. Smith, pers comm.; Tuck et al., 2004; Slope RAG 2011). It is assumed that the spawning ground experiences a turnover rate of two (i.e. for the model applied here, the spawning biomass estimates are doubled, Russell and Smith, (2006); Punt et al., (2015)). The acoustic survey selectivity is mirrored to the estimated maturity ogive, as it is assumed the acoustic survey observes mature fish on the spawning ground.

A comparison of the base case model (that uses only 2020 and 2021 acoustic estimates; Tuned2022_v2) with a tuned model that includes the 2019 acoustic estimate (addSurvey19to21_Tuned) shows very little change in spawning biomass trajectory and slightly lower estimated values for the acoustic estimates for all years.

Table 2. The estimated biomass (tonnes) of Blue Grenadier on the spawning grounds in years 2003 to 2010 (Ryan and Kloser, 2012), and 2019 to 2021 (Ryan and Kunnath, 2022).

	2003	2004	2005	2006	2007	2008	2009	2010	2019	2020	2021
Biomass (t)	24,690	16,295	18,852	42,882	56,330	24,450	24,787	20,622	5,162	30,328	15,101
CV for assessment model	0.30	0.46	0.30	0.30	0.52	0.30	1	0.33	0.3	0.3	0.3
Sampling CV	0.16	0.46	0.14	0.14	0.52	0.22	1	0.33	0.22	0.11	0.2



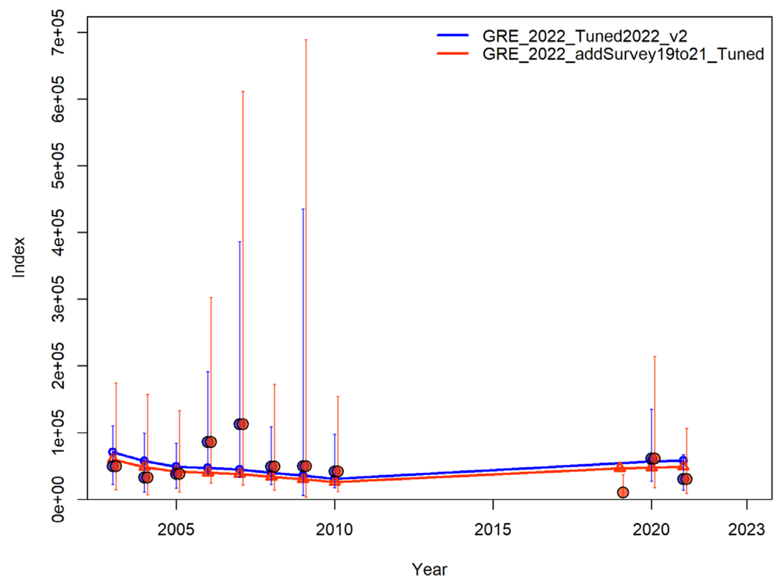


Figure 14 A comparison of relative spawning biomass (top) and the acoustic biomass survey (bottom) for the base case model (Tuned2022_v2) and a model including all surveys from 2019 to 2021 (addSurvey19to21_Tuned).

6 Appendix – base case results

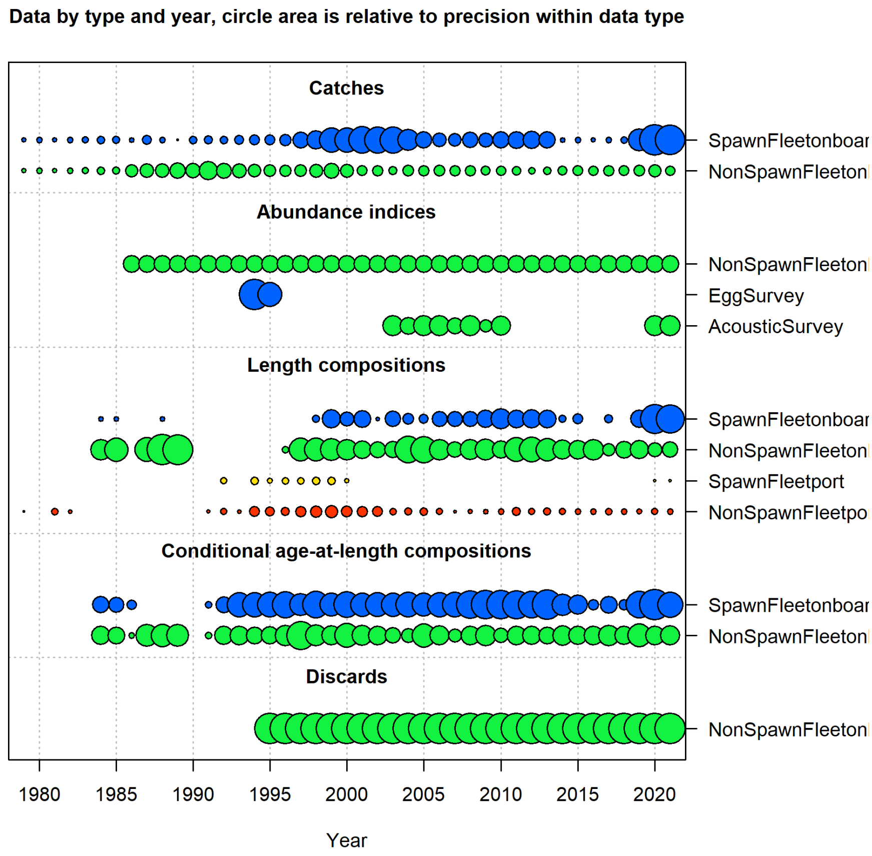


Figure 15. Summary of Blue Grenadier data sources.

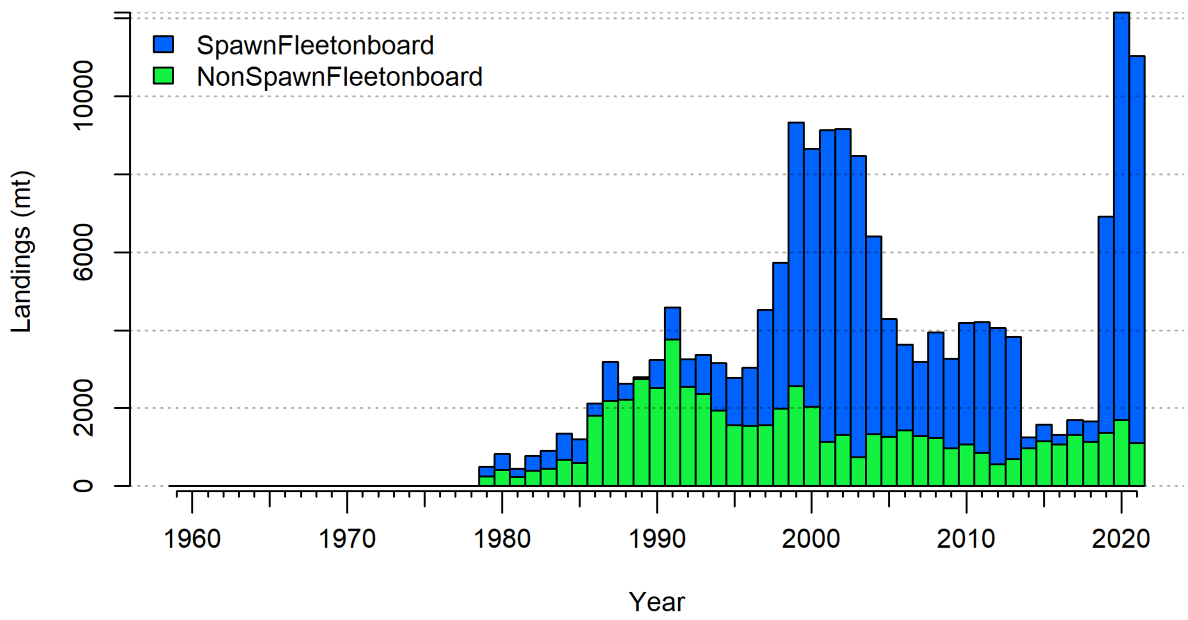


Figure 16. Summary of catch by fleet.

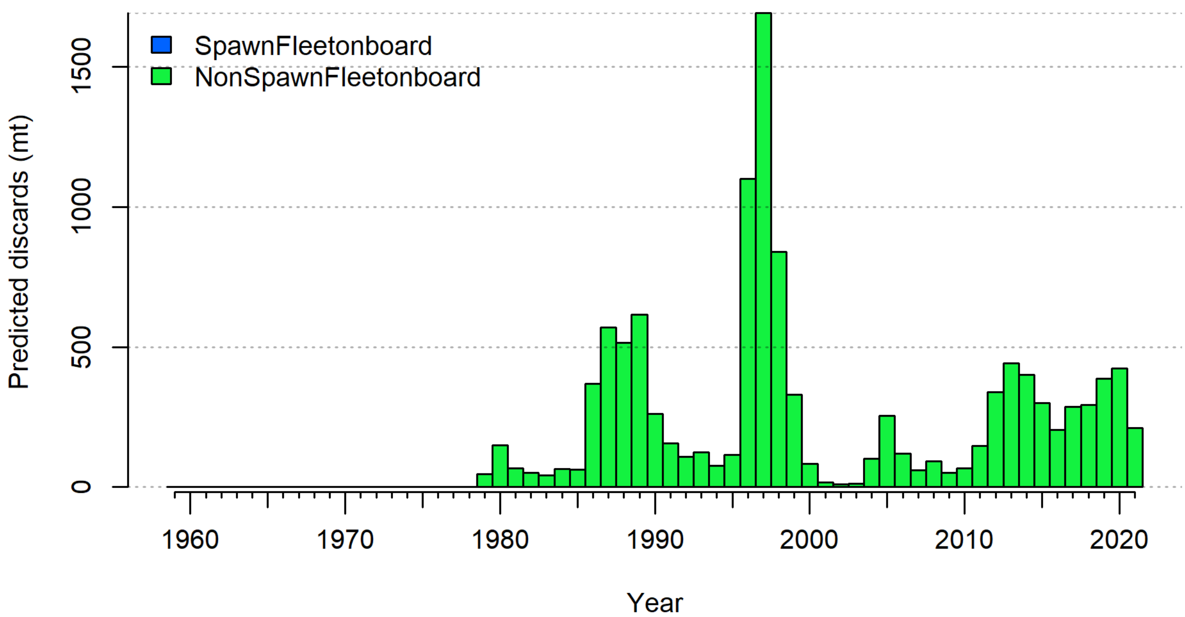


Figure 17. Summary of total discards by fleet.

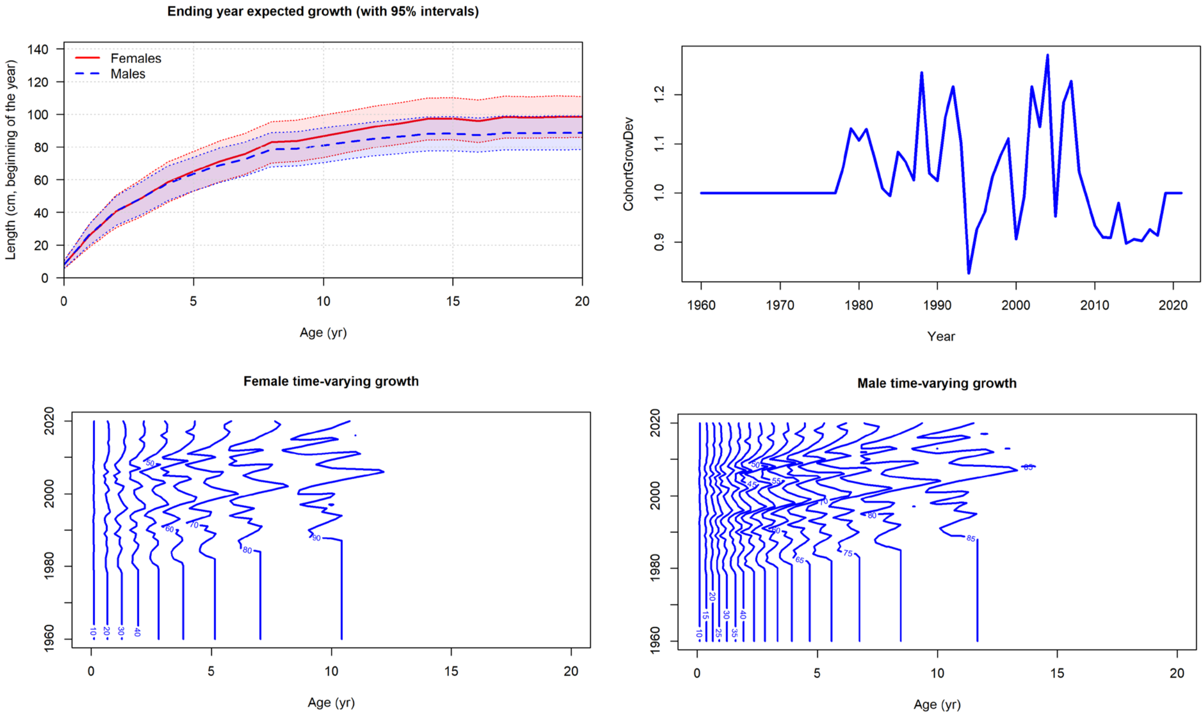


Figure 18 Estimated growth for Blue Grenadier, with cohort dependent growth for Blue Grenadier.

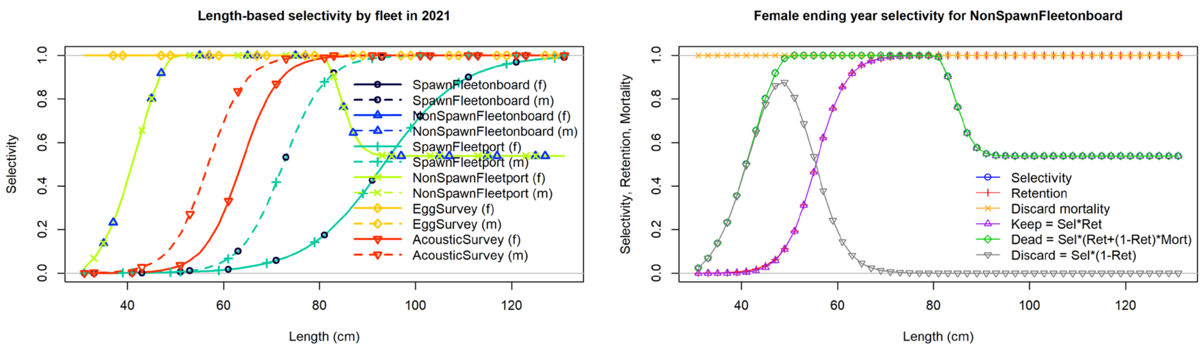


Figure 19. Estimated selectivity and retention by fleet for the base case.

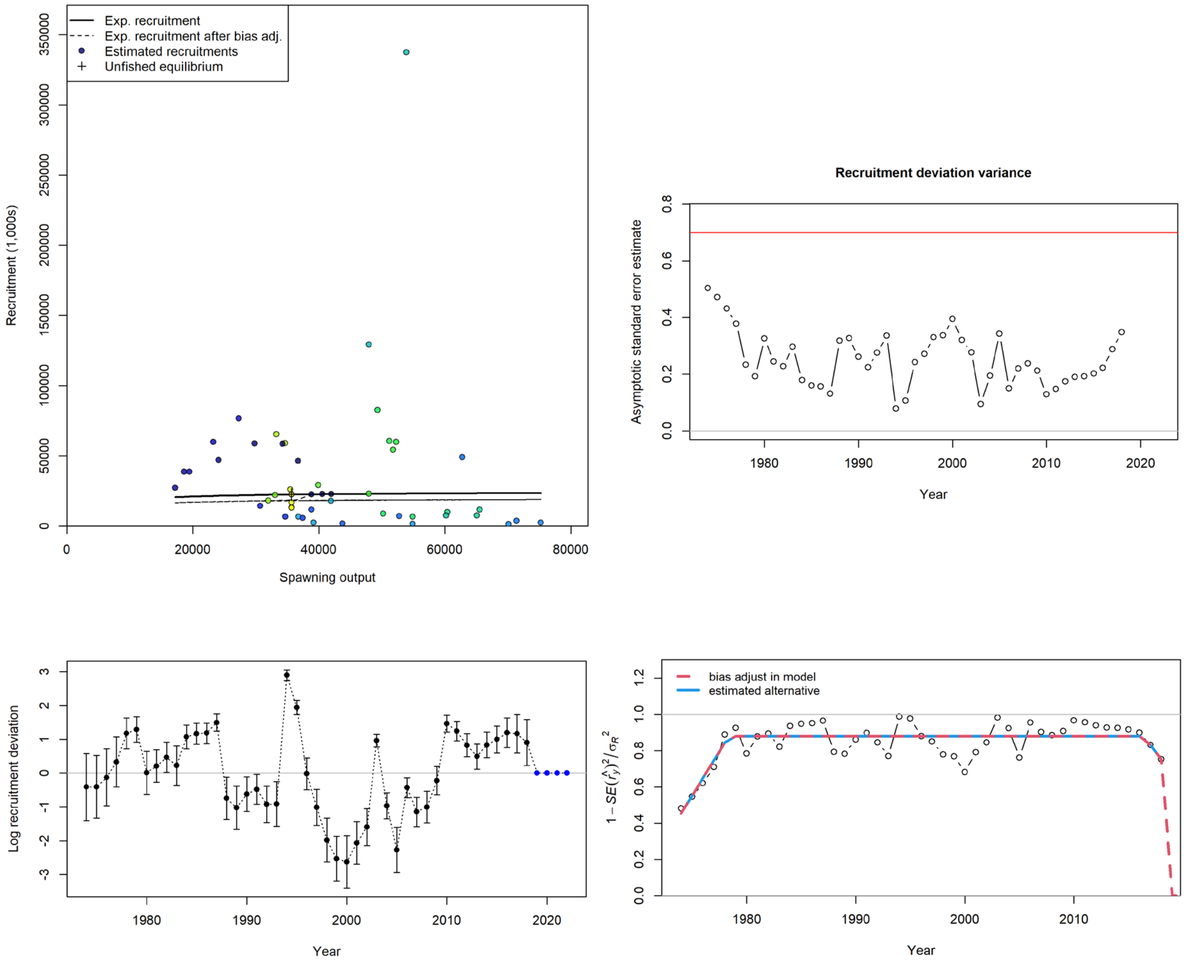


Figure 20. Time series showing the stock recruitment curve, recruitment deviations and recruitment deviation variance check for Blue Grenadier.

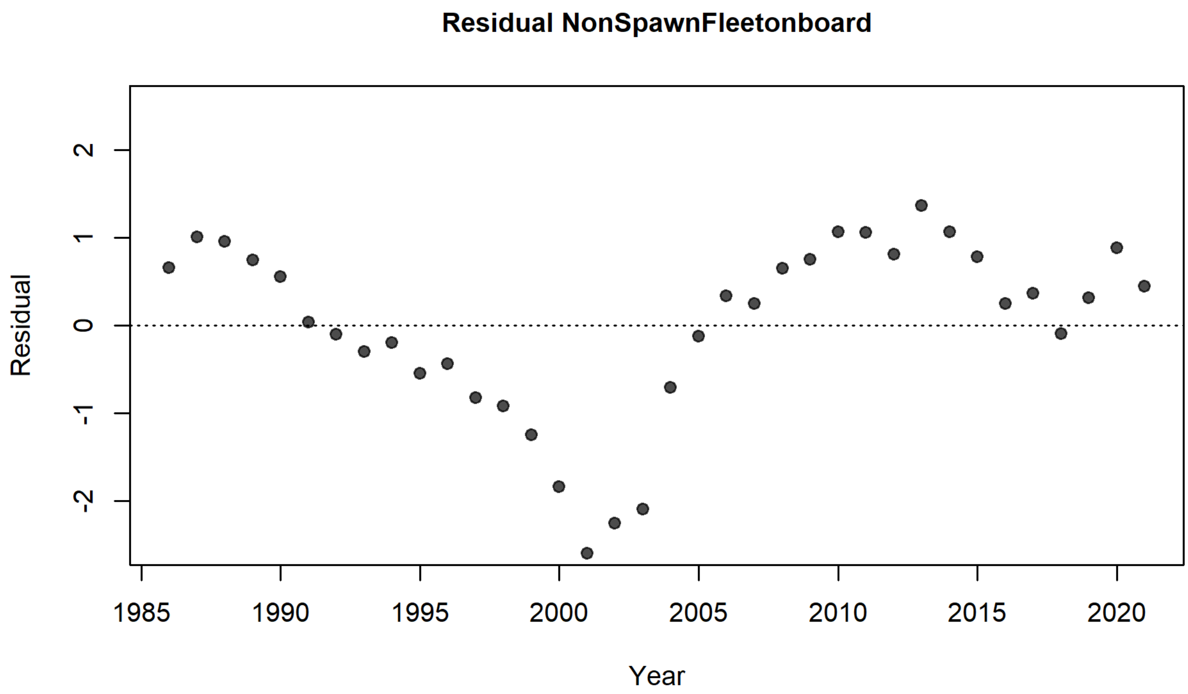


Figure 21. Residuals for fits to CPUE for the non-spawning fleet.

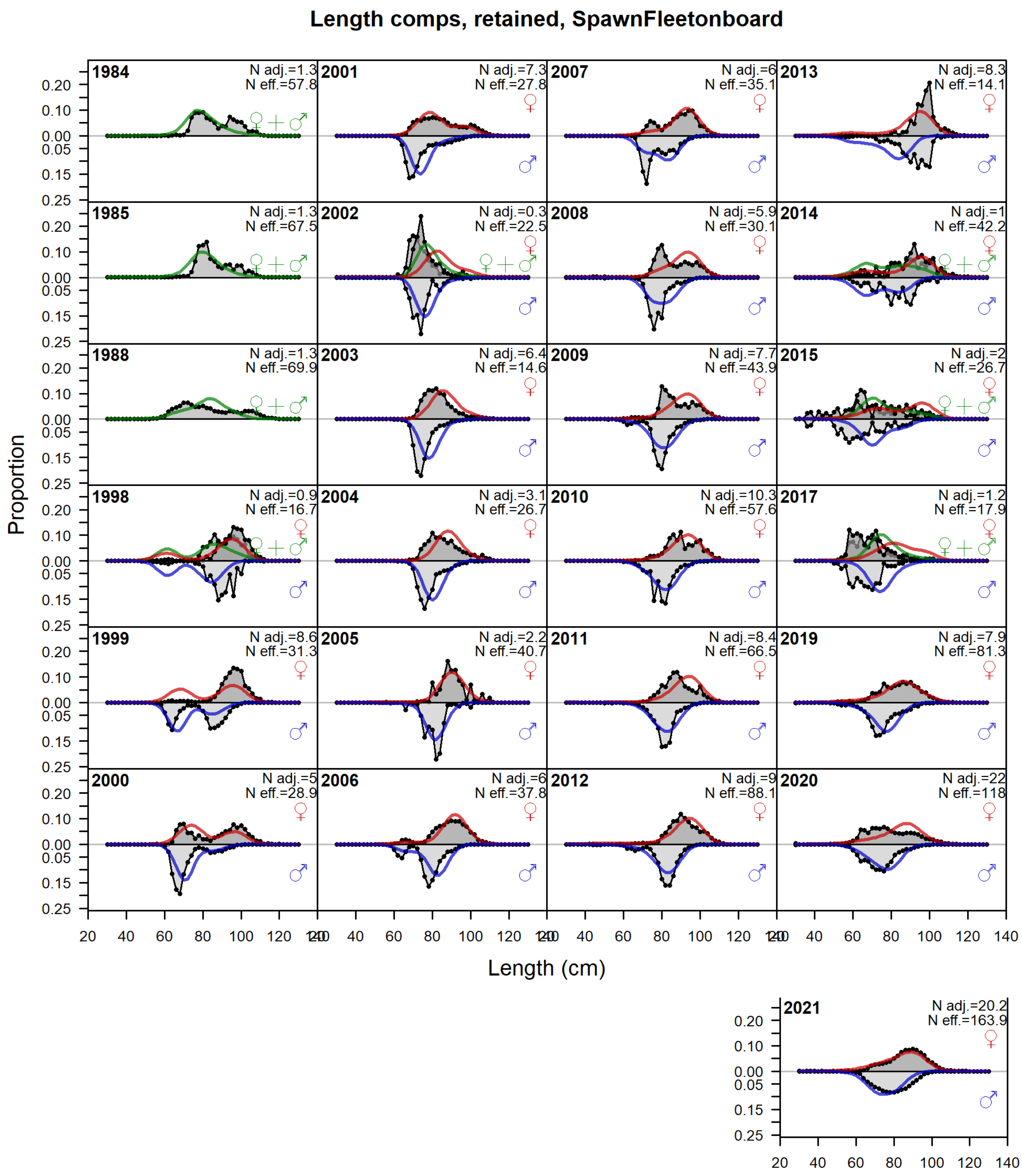


Figure 22. Length composition fits: onboard spawning fleet retained.

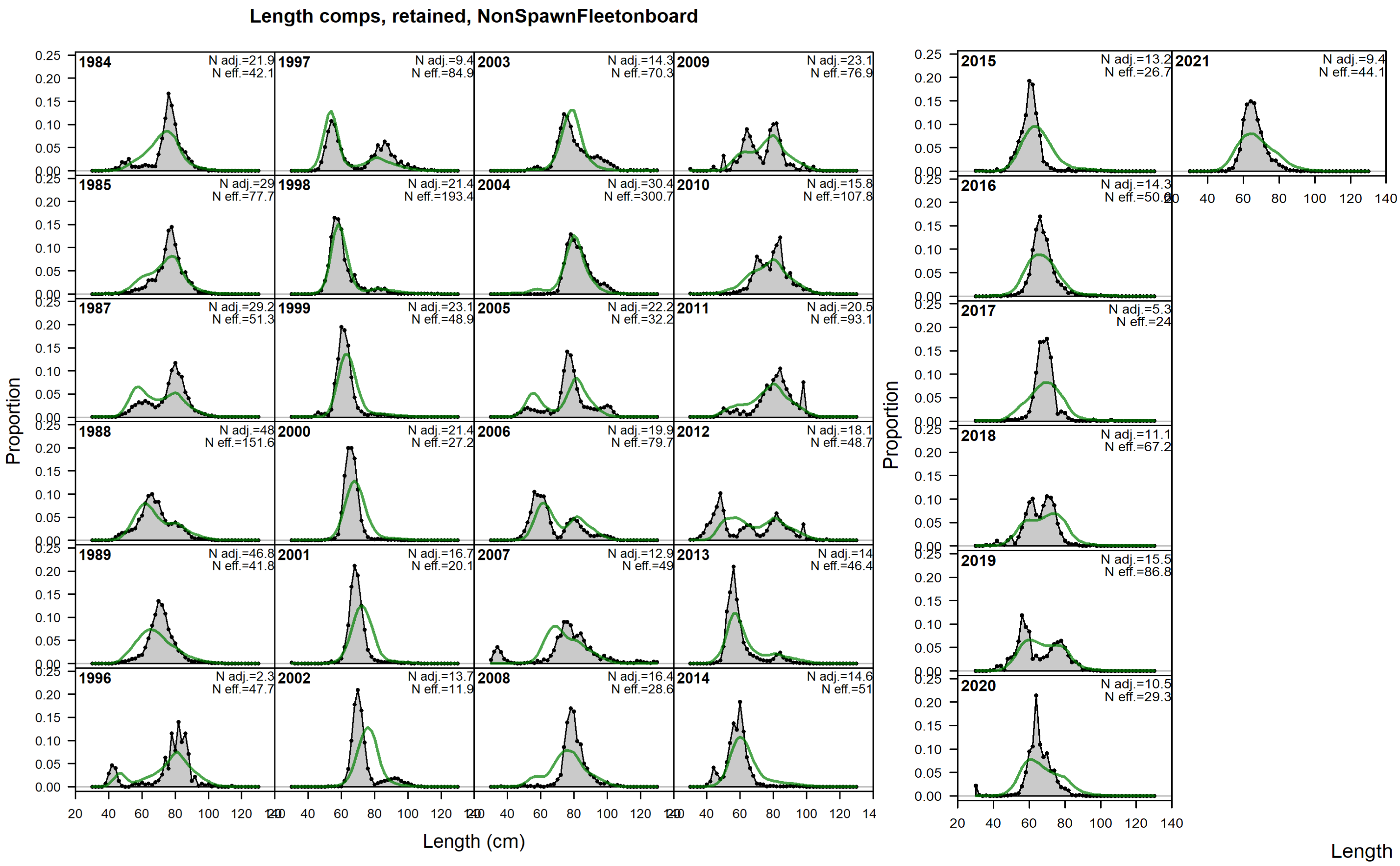


Figure 23. Length composition fits: onboard non-spawning fleet retained.

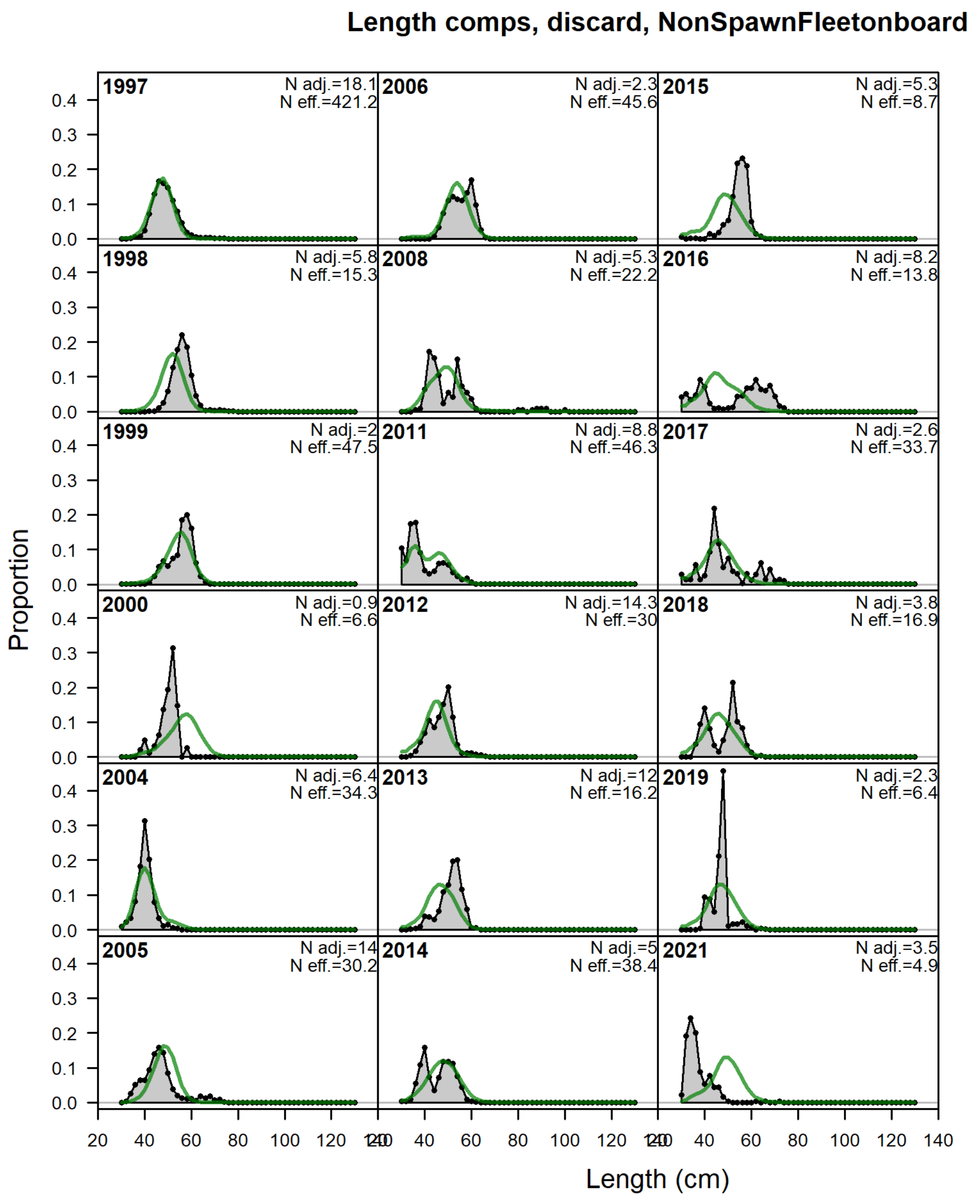


Figure 24. Length composition fits: onboard non-spawning fleet discard.

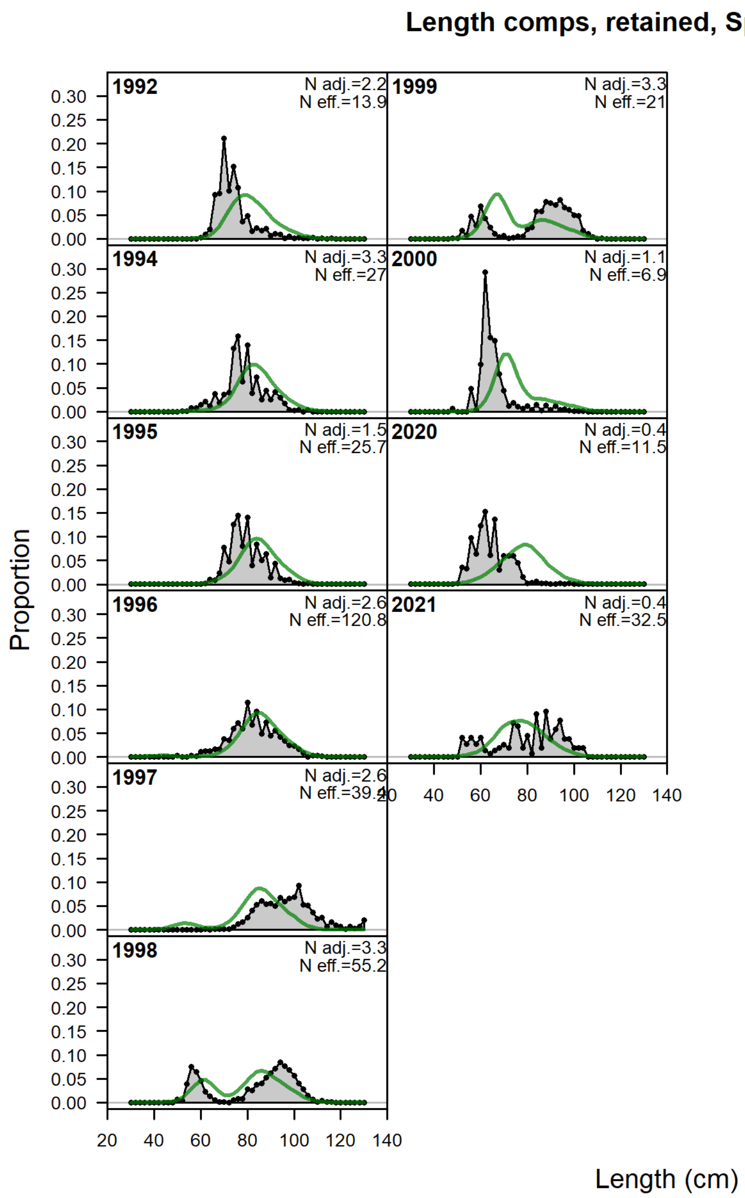


Figure 25. Length composition fits: port spawning fleet retained.

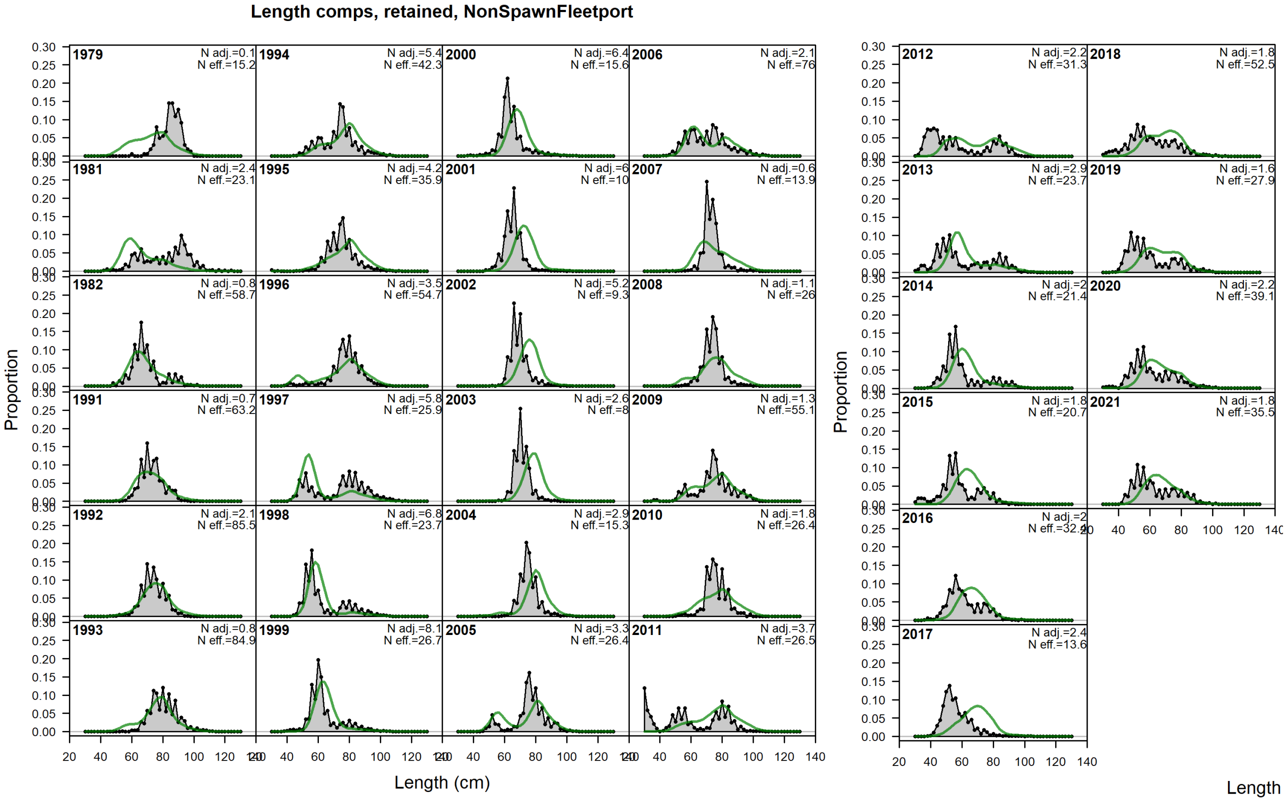


Figure 26. Length composition fits: port non-spawning fleet retained.

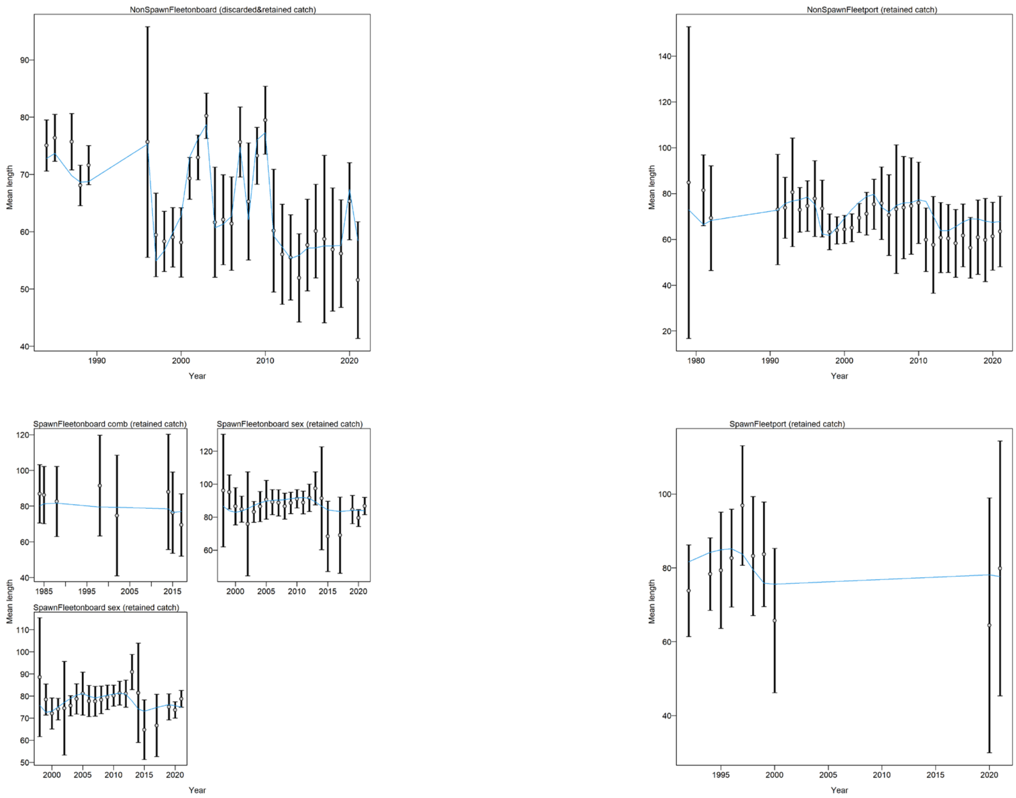


Figure 27. Length composition fit diagnostics from tuning. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) for length data.

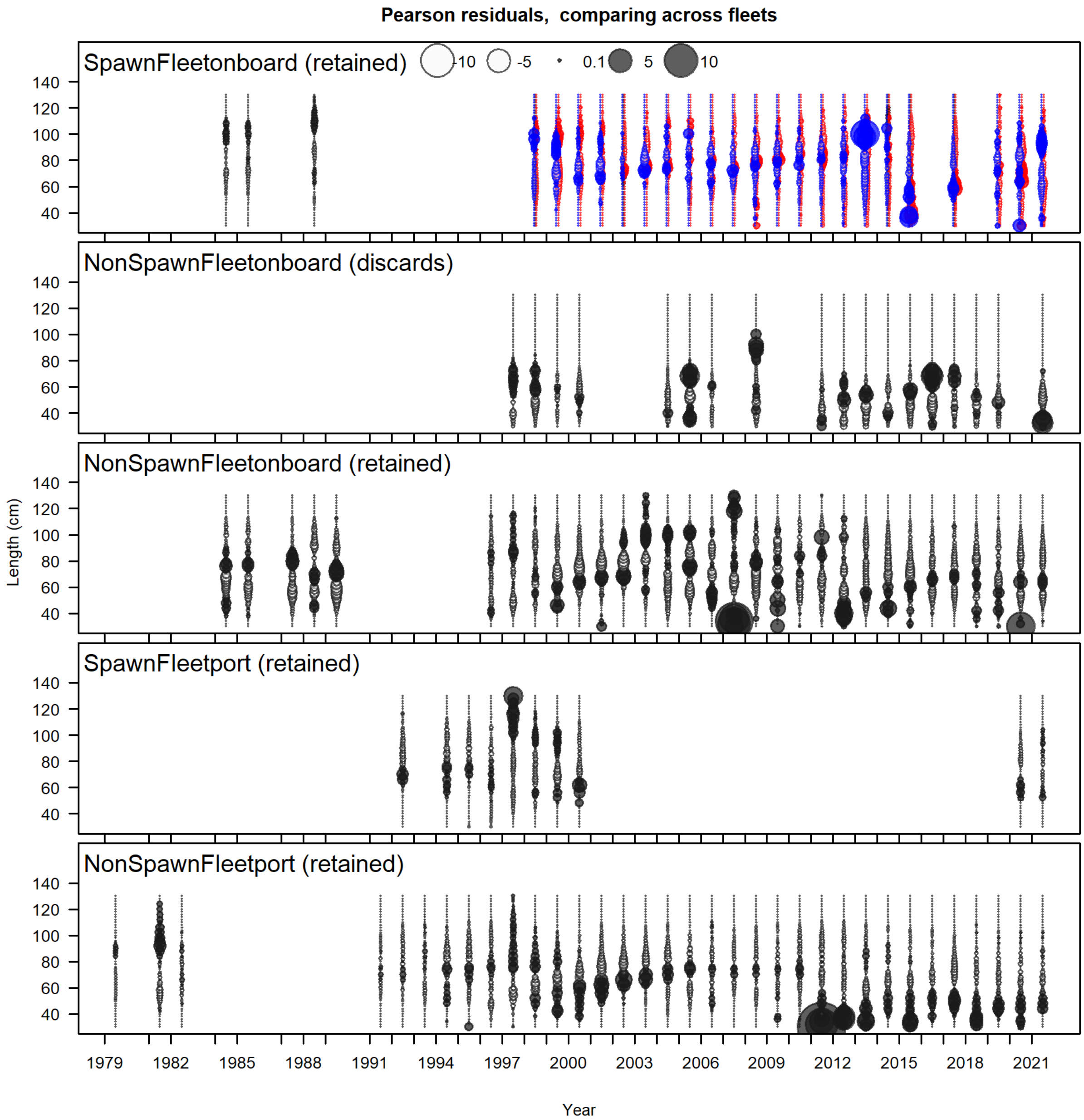
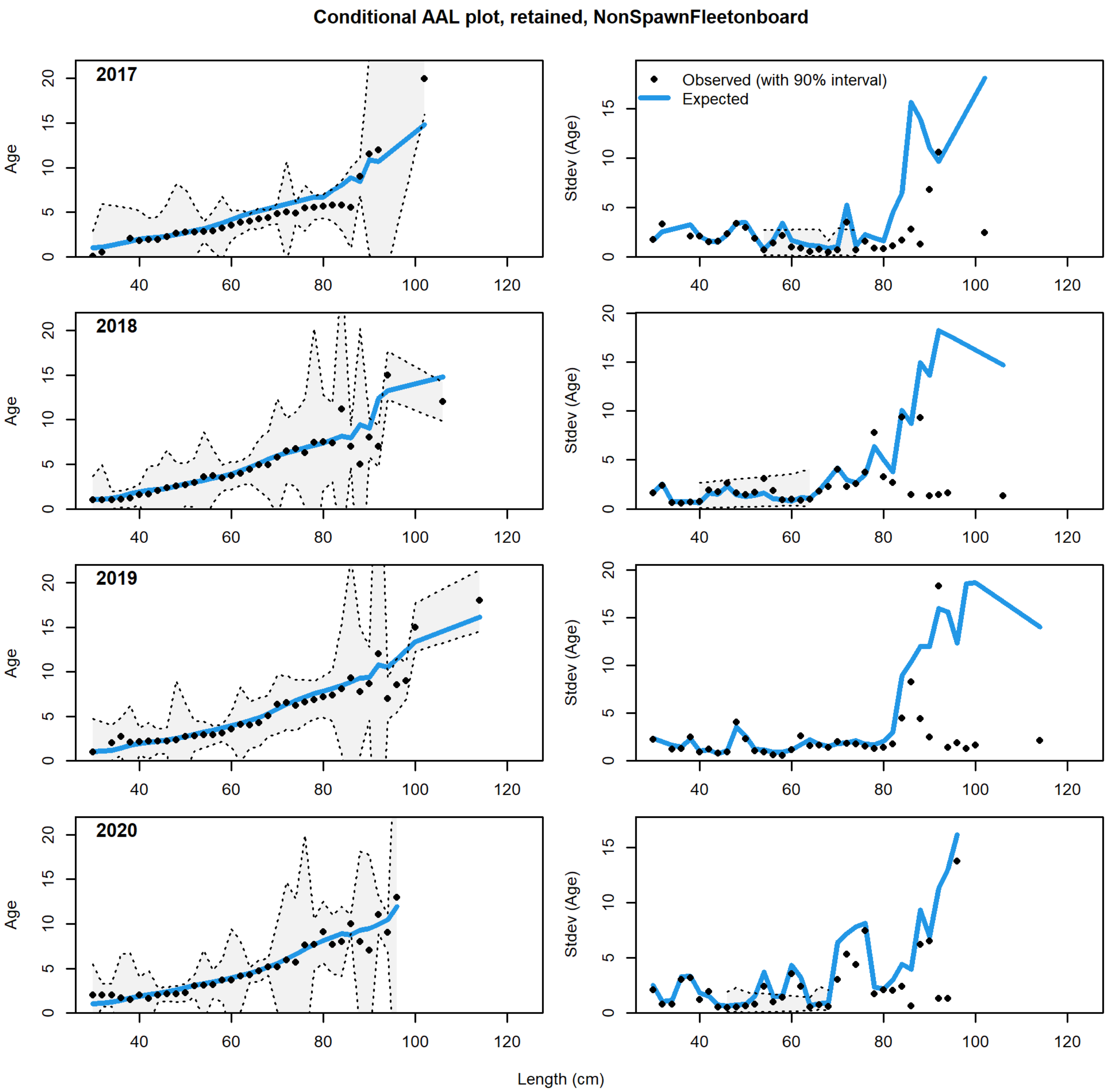
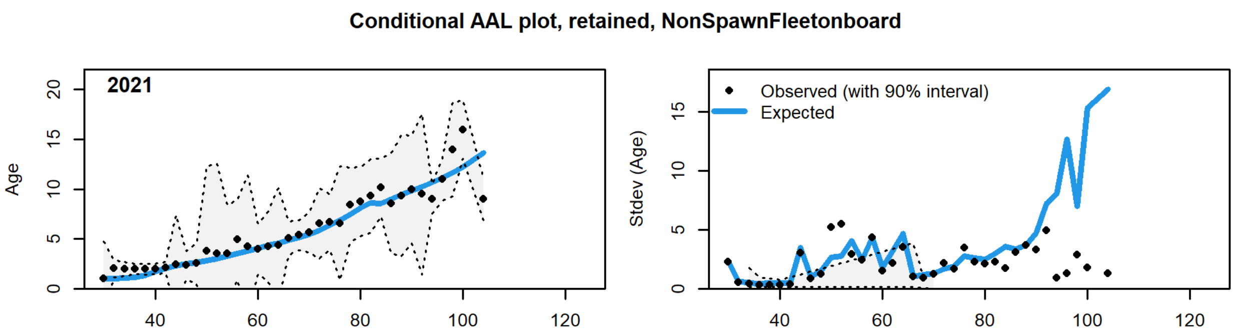
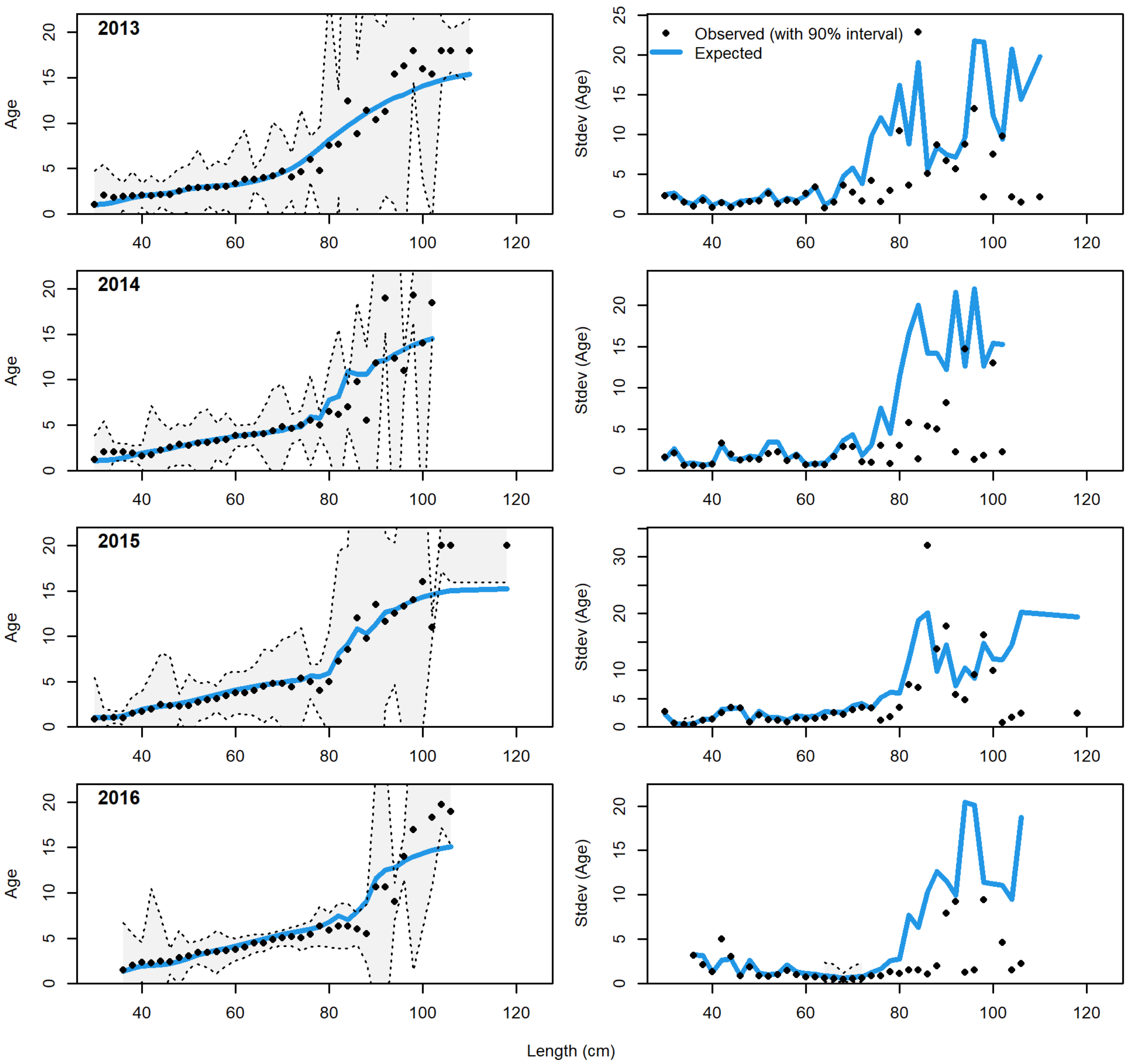


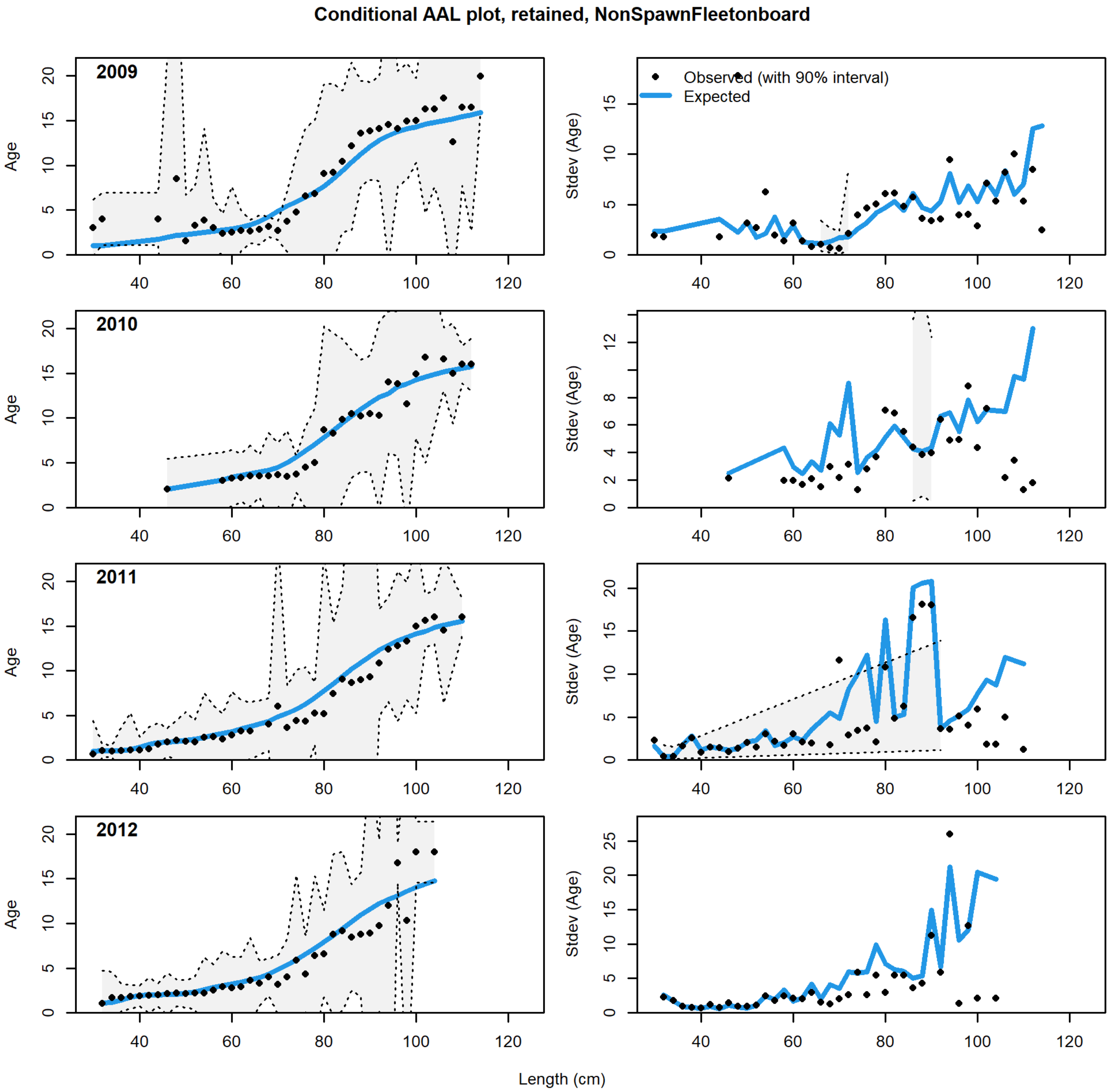
Figure 28. Residuals from the annual length compositions for base case


Conditional AAL plot, retained, NonSpawnFleetonboard
2017
2018
2019
2020
Age
Stdev (Age)
Observed (with 90% interval)
Expected
Length (cm)

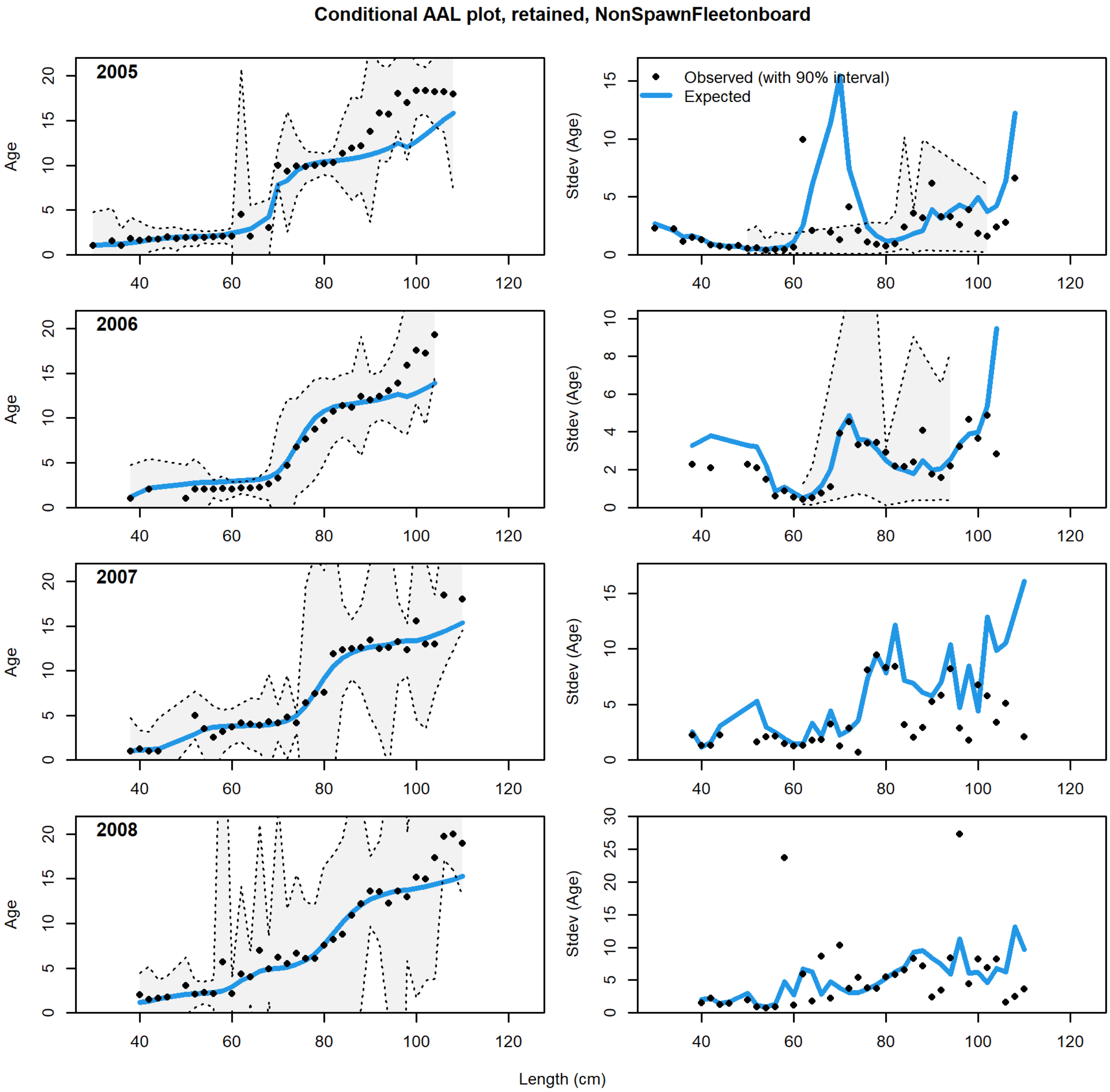

Conditional AAL plot, retained, NonSpawnFleetonboard
2021
Age
Stdev (Age)
Observed (with 90% interval)
Expected

Conditional AAL plot, retained, NonSpawnFleetonboard



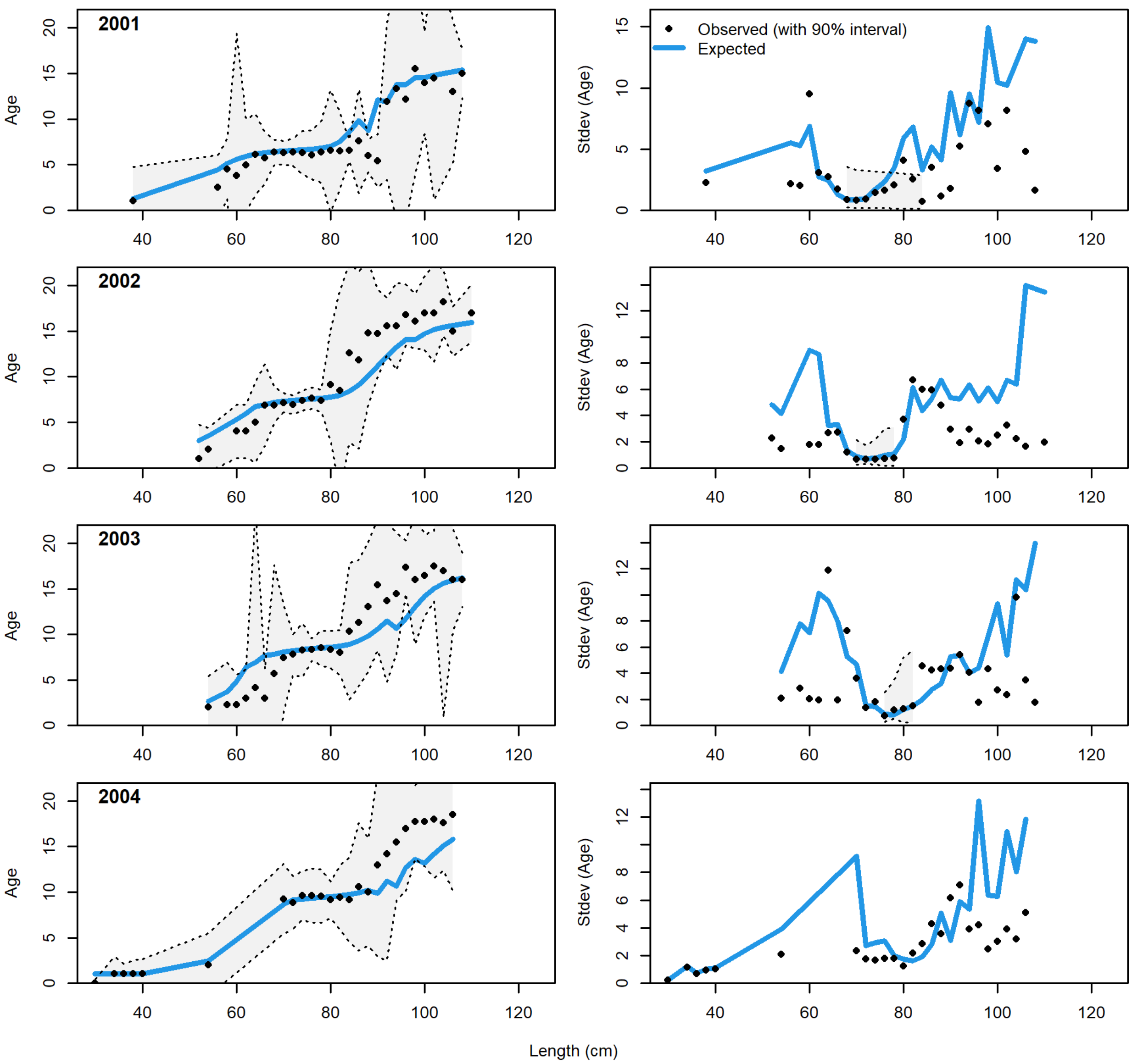


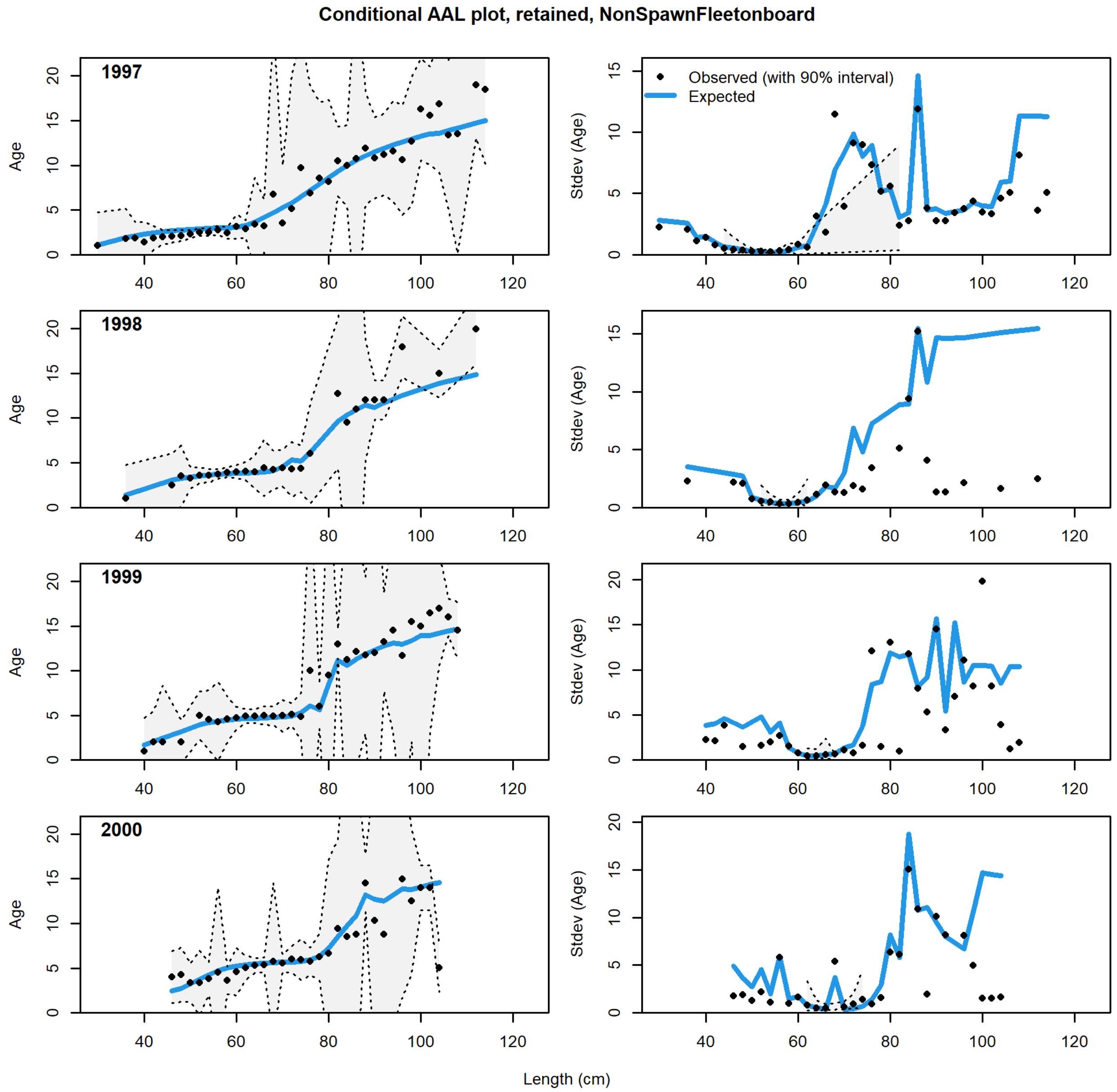
Conditional AAL plot, retained, NonSpawnFleetonboard
2009
2010
2011
2012
Age
Stdev (Age)
Observed (with 90% interval)
Expected
Length (cm)



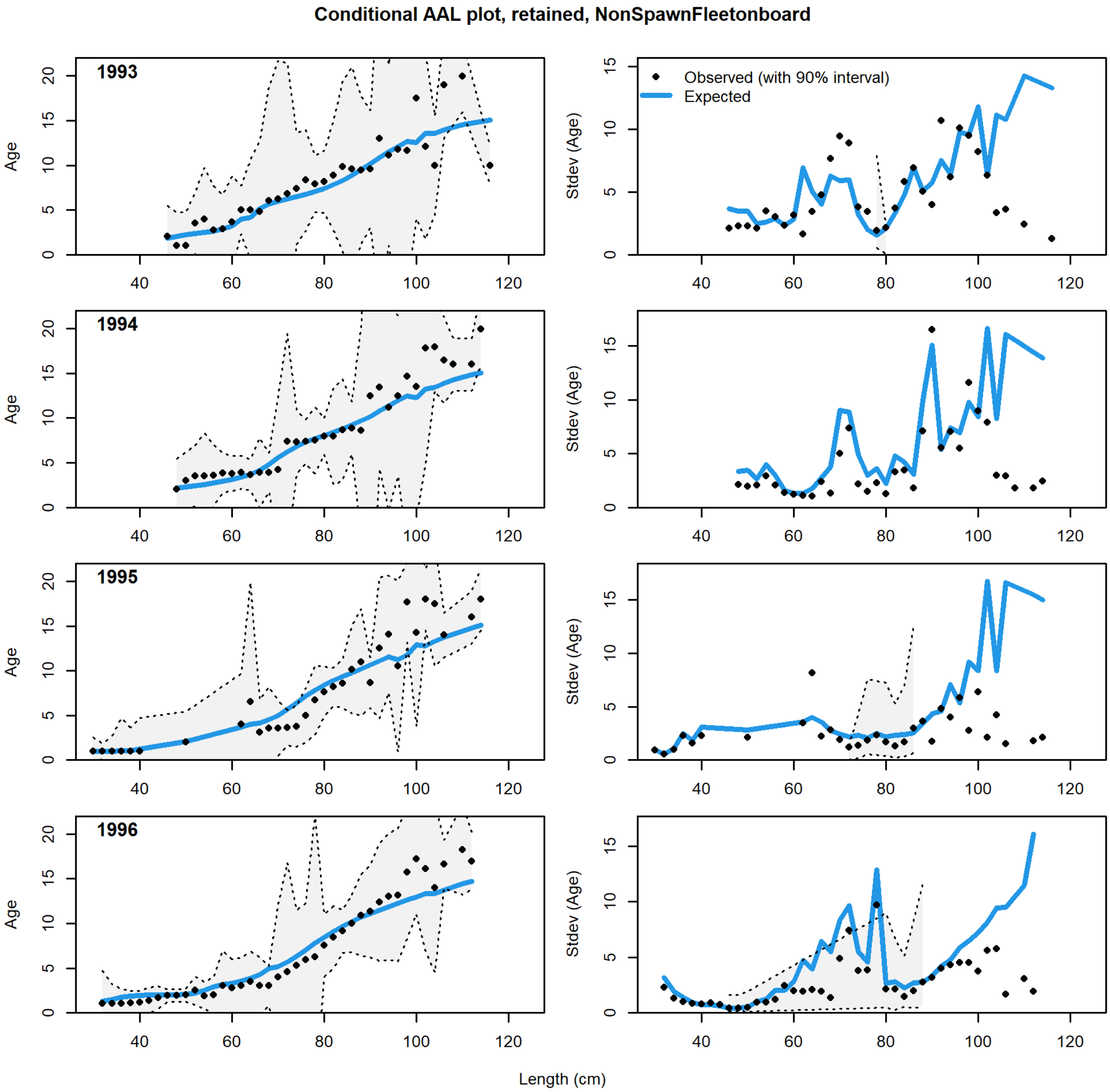
Conditional AAL plot, retained, NonSpawnFleetonboard
2005
2006
2007
2008
Age
Stdev (Age)
Observed (with 90% interval)
Expected
Length (cm)

Conditional AAL plot, retained, NonSpawnFleetonboard



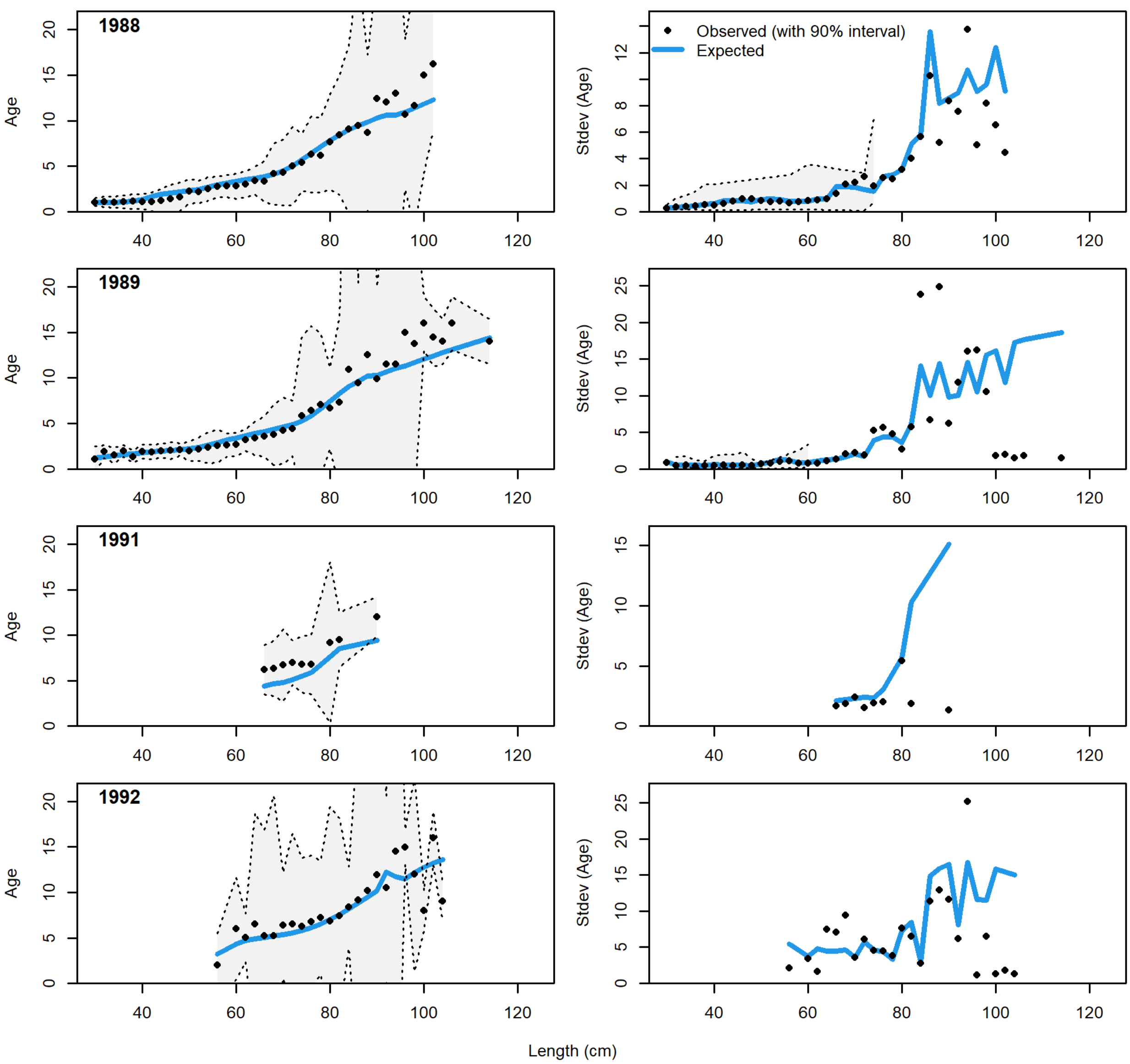


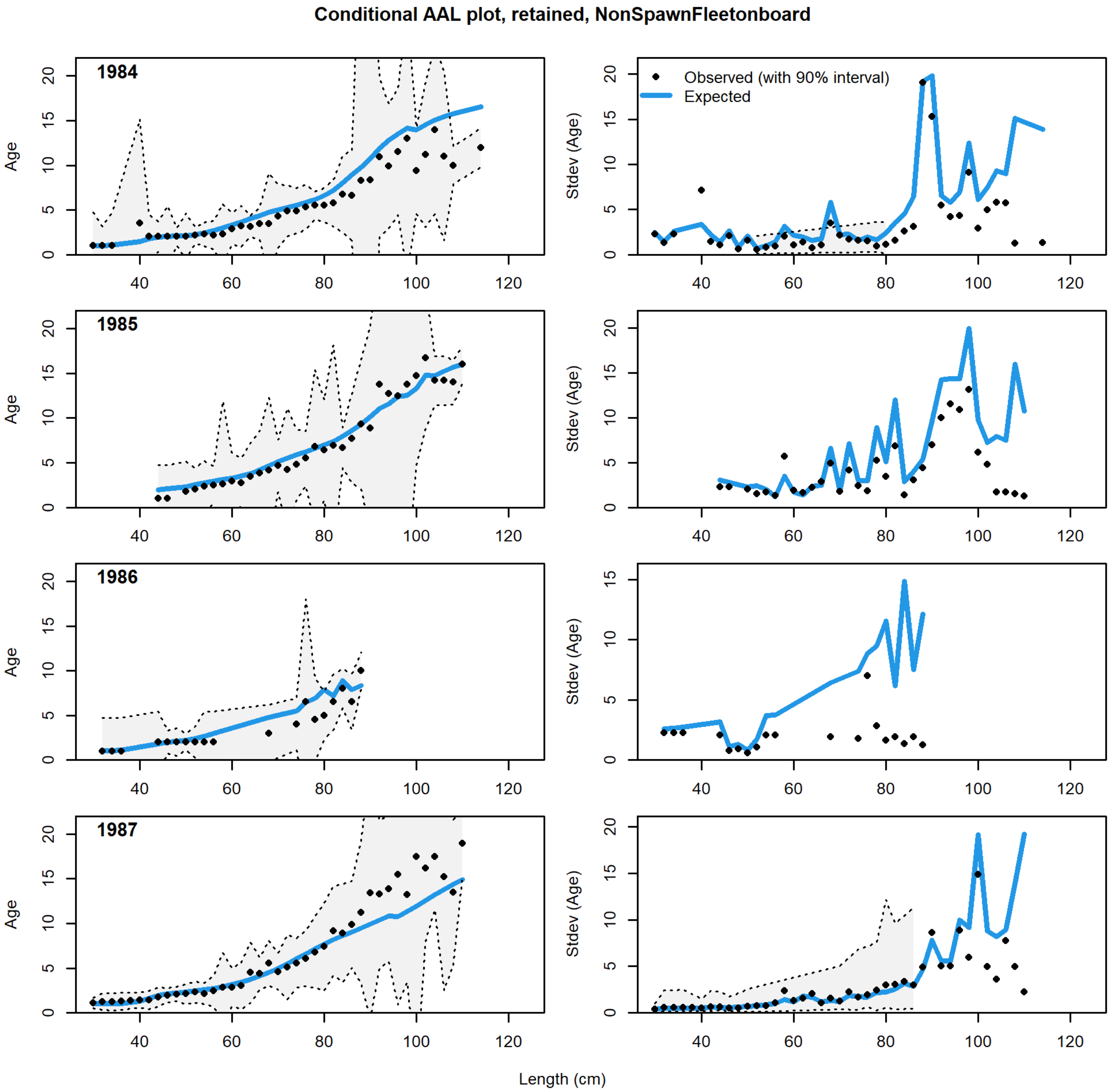
Conditional AAL plot, retained, NonSpawnFleetonboard
1997
1998
1999
2000
Age
Stdev (Age)
Observed (with 90% interval)
Expected
Length (cm)



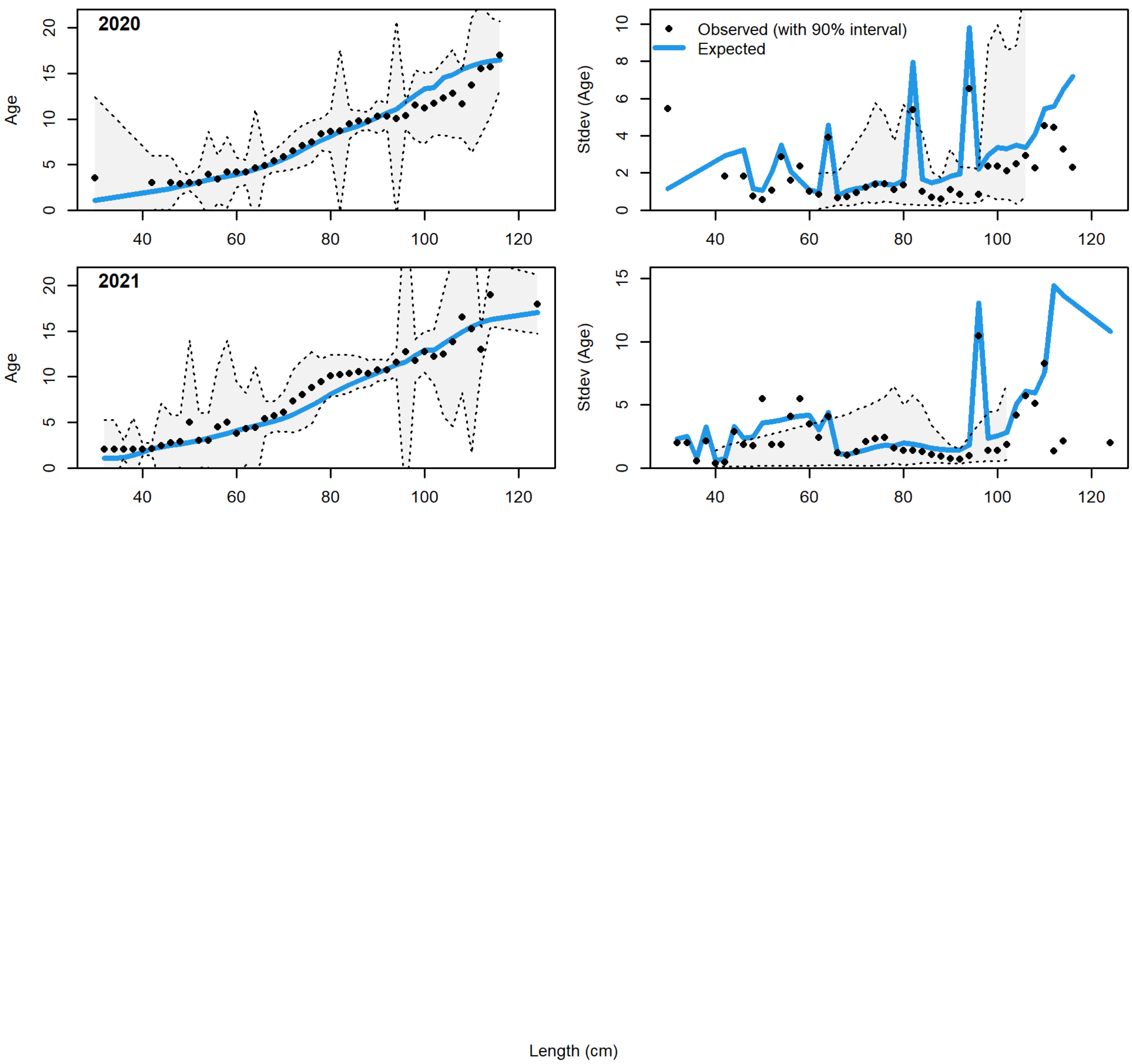
Conditional AAL plot, retained, NonSpawnFleetonboard
1993
1994
1995
1996
Age
Stdev (Age)
Observed (with 90% interval)
Expected
Length (cm)

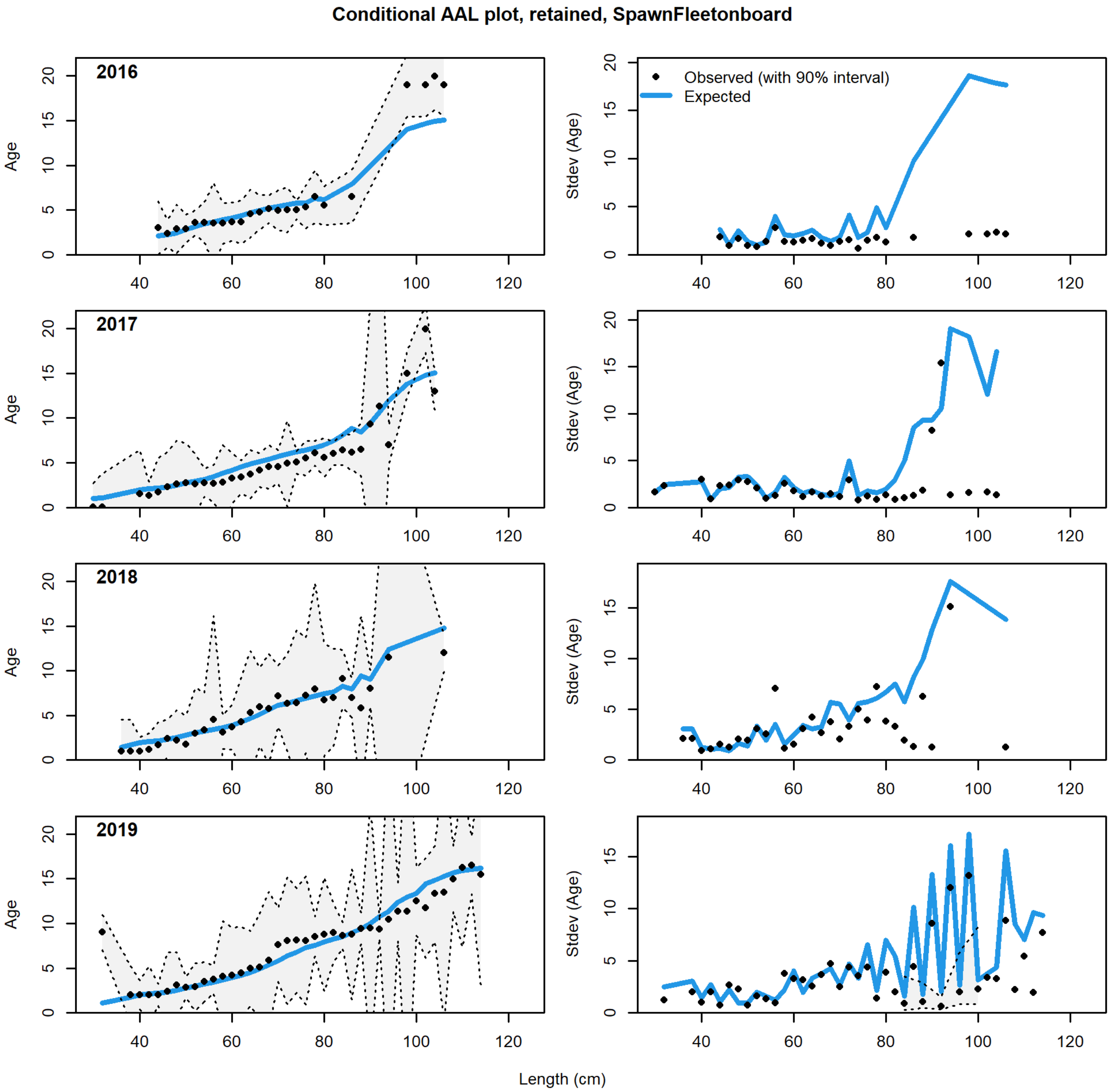
Conditional AAL plot, retained, NonSpawnFleetonboard



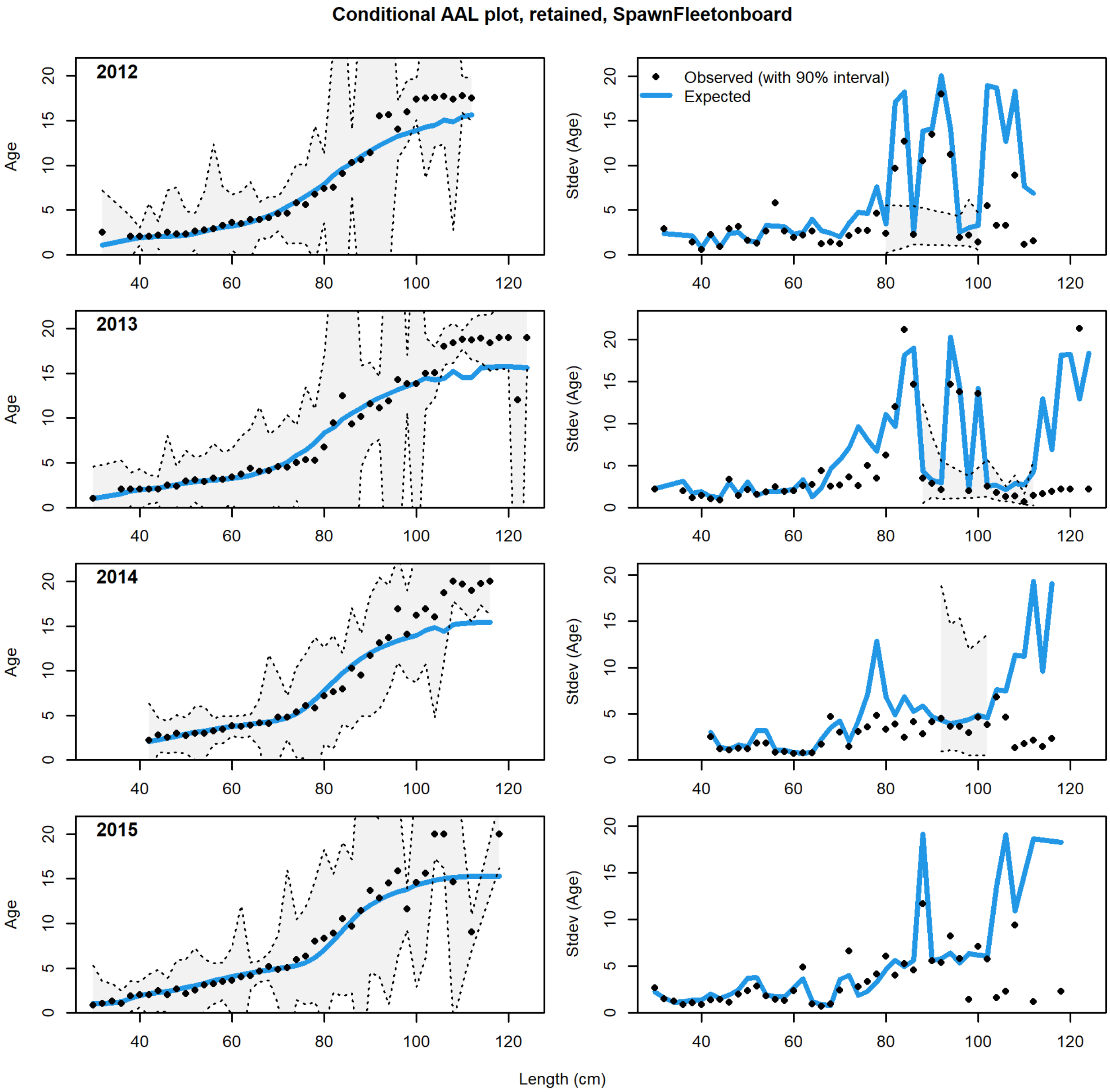

Conditional AAL plot, retained, NonSpawnFleetonboard
1984
1985
1986
1987
Age
Stdev (Age)
Observed (with 90% interval)
Expected
Length (cm)

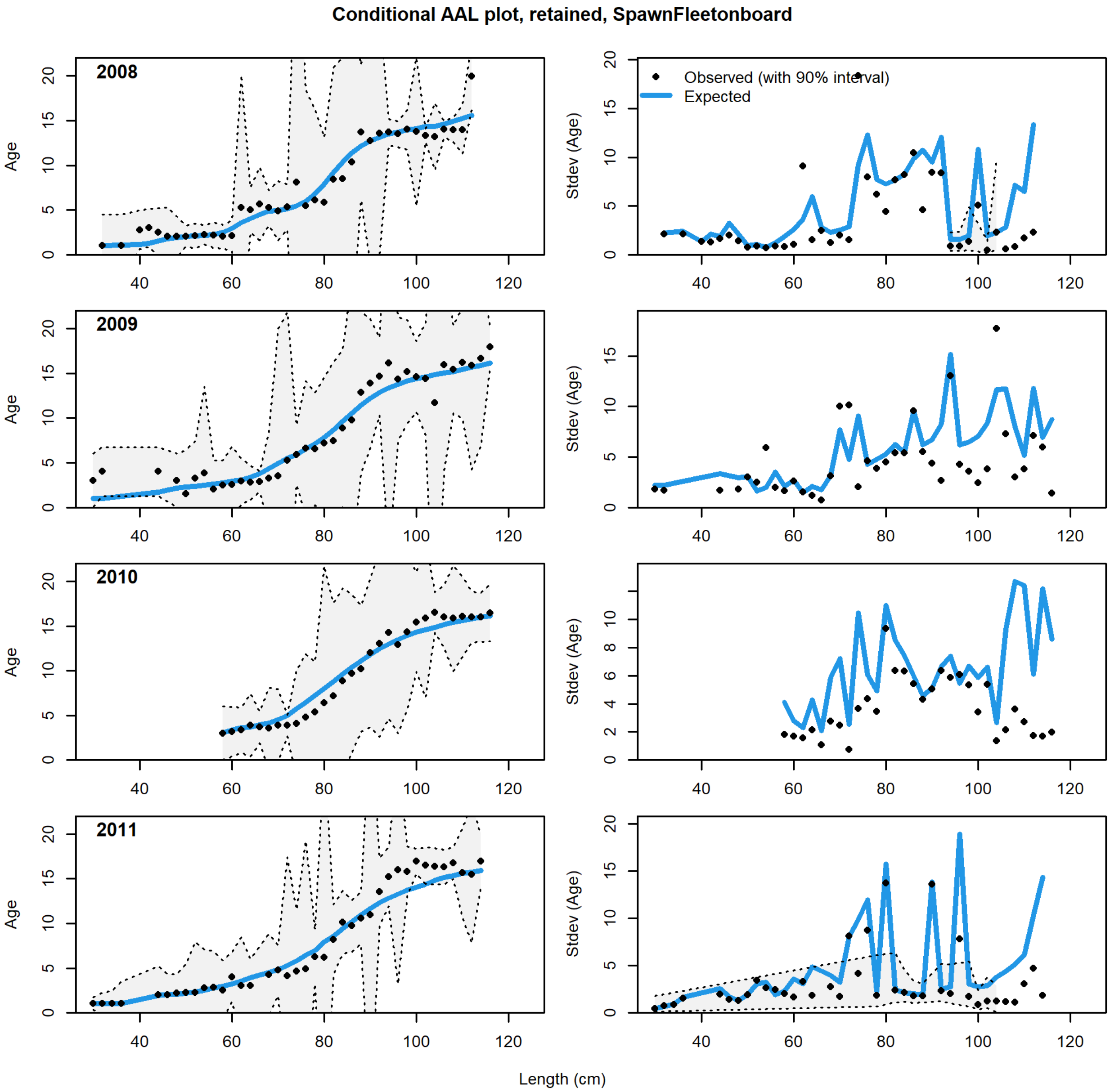
Conditional AAL plot, retained, SpawnFleetonboard

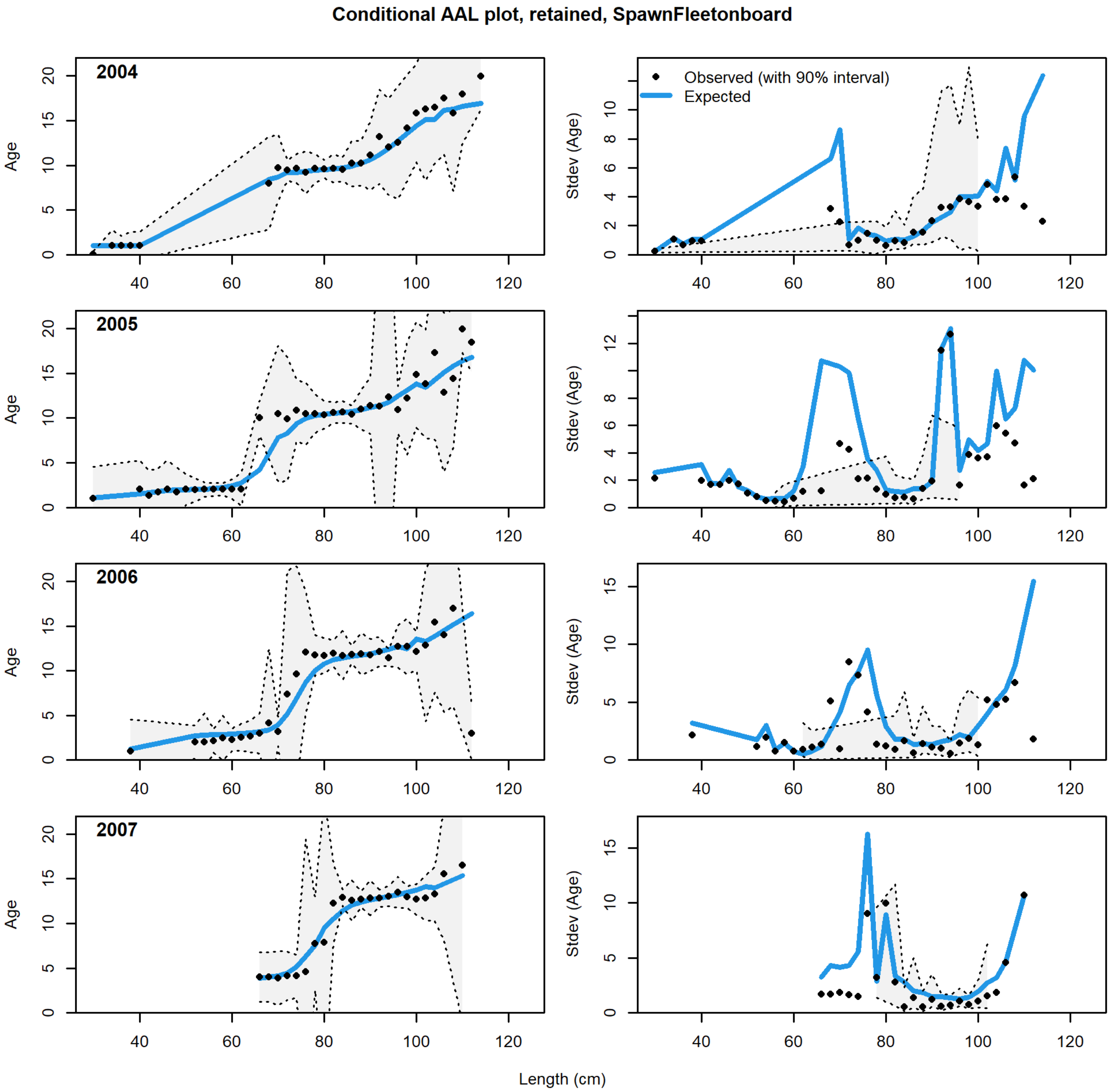


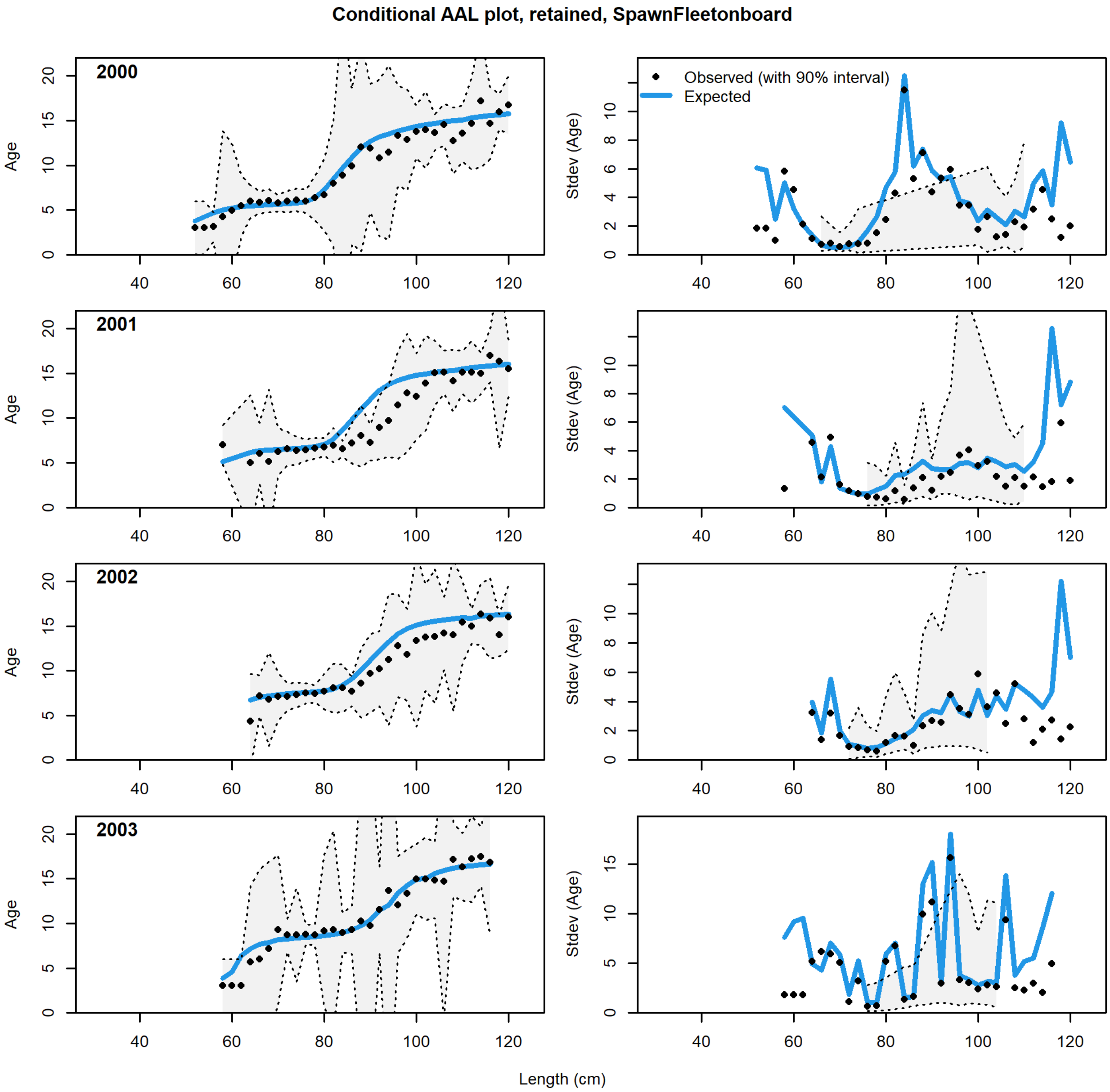


Conditional AAL plot, retained, SpawnFleetonboard
2016
2017
2018
2019
Age
Stdev (Age)
Observed (with 90% interval)
Expected
Length (cm)


Conditional AAL plot, retained, SpawnFleetonboard
2012
2013
2014
2015
Age
Stdev (Age)
Observed (with 90% interval)
Expected
Length (cm)

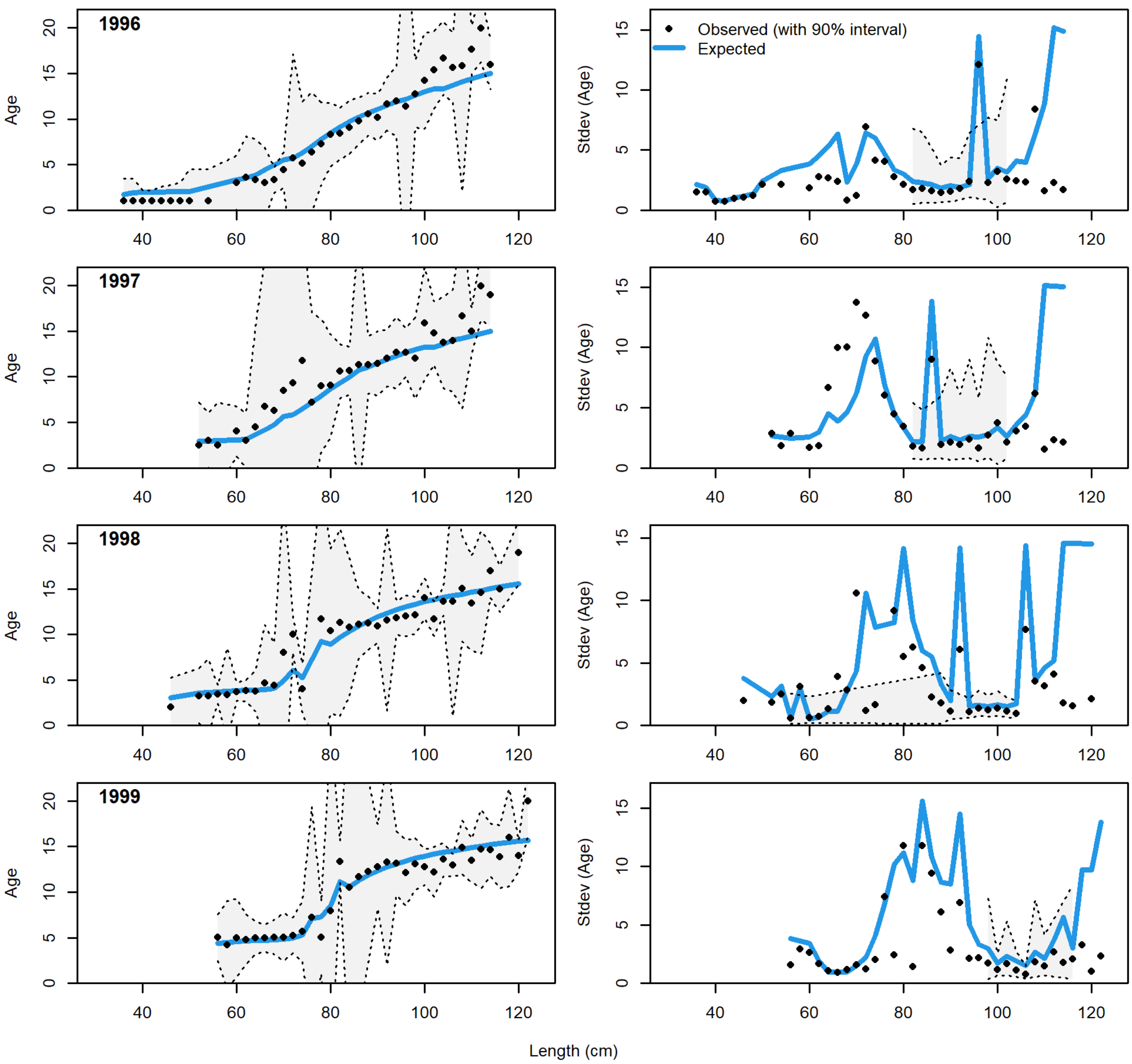

Conditional AAL plot, retained, SpawnFleetonboard
2008
2009
2010
2011
Age
Stdev (Age)
Observed (with 90% interval)
Expected
Length (cm)

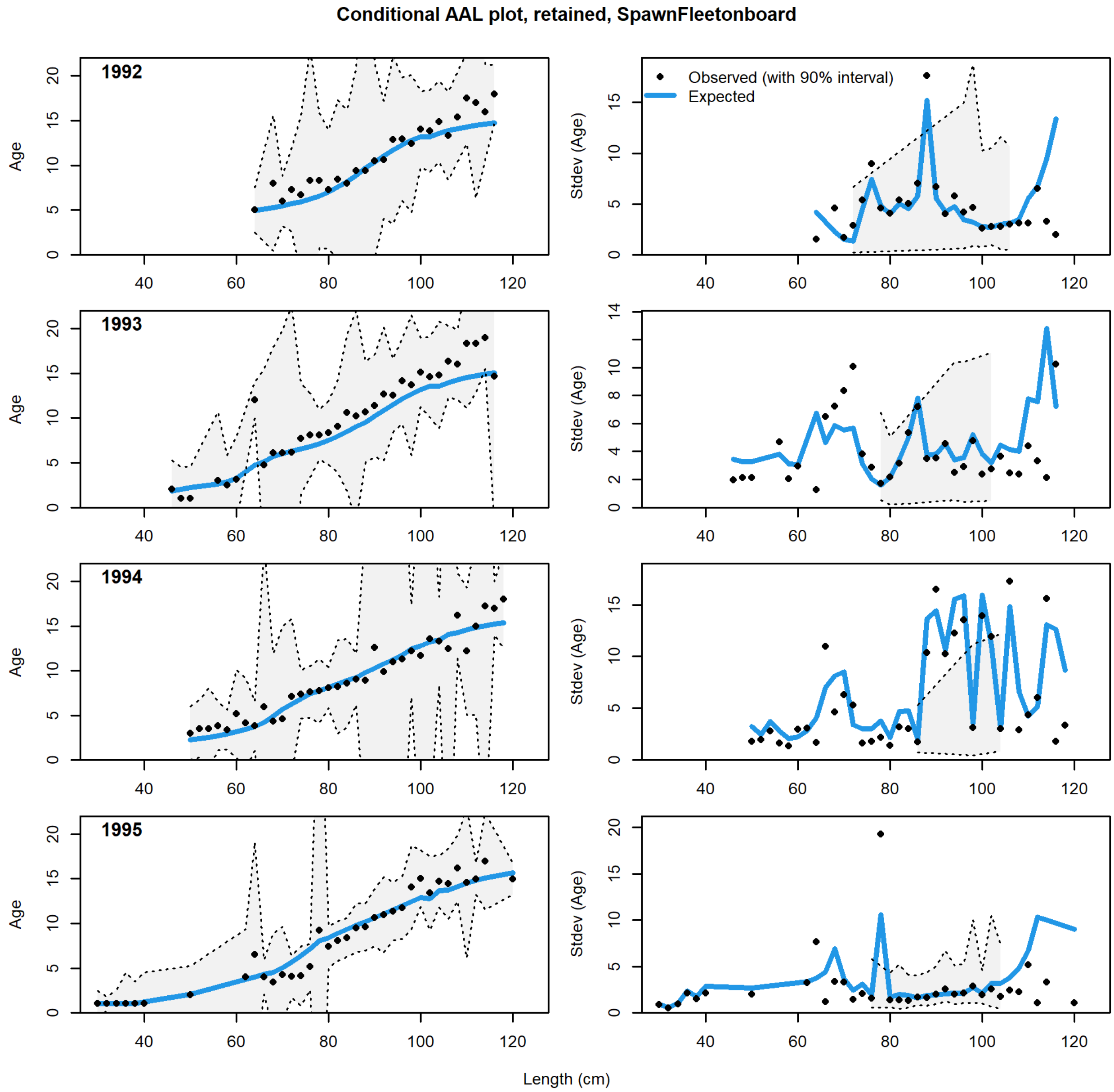

Conditional AAL plot, retained, SpawnFleetonboard
2004
2005
2006
2007
Age
Stdev (Age)
Observed (with 90% interval)
Expected
Length (cm)

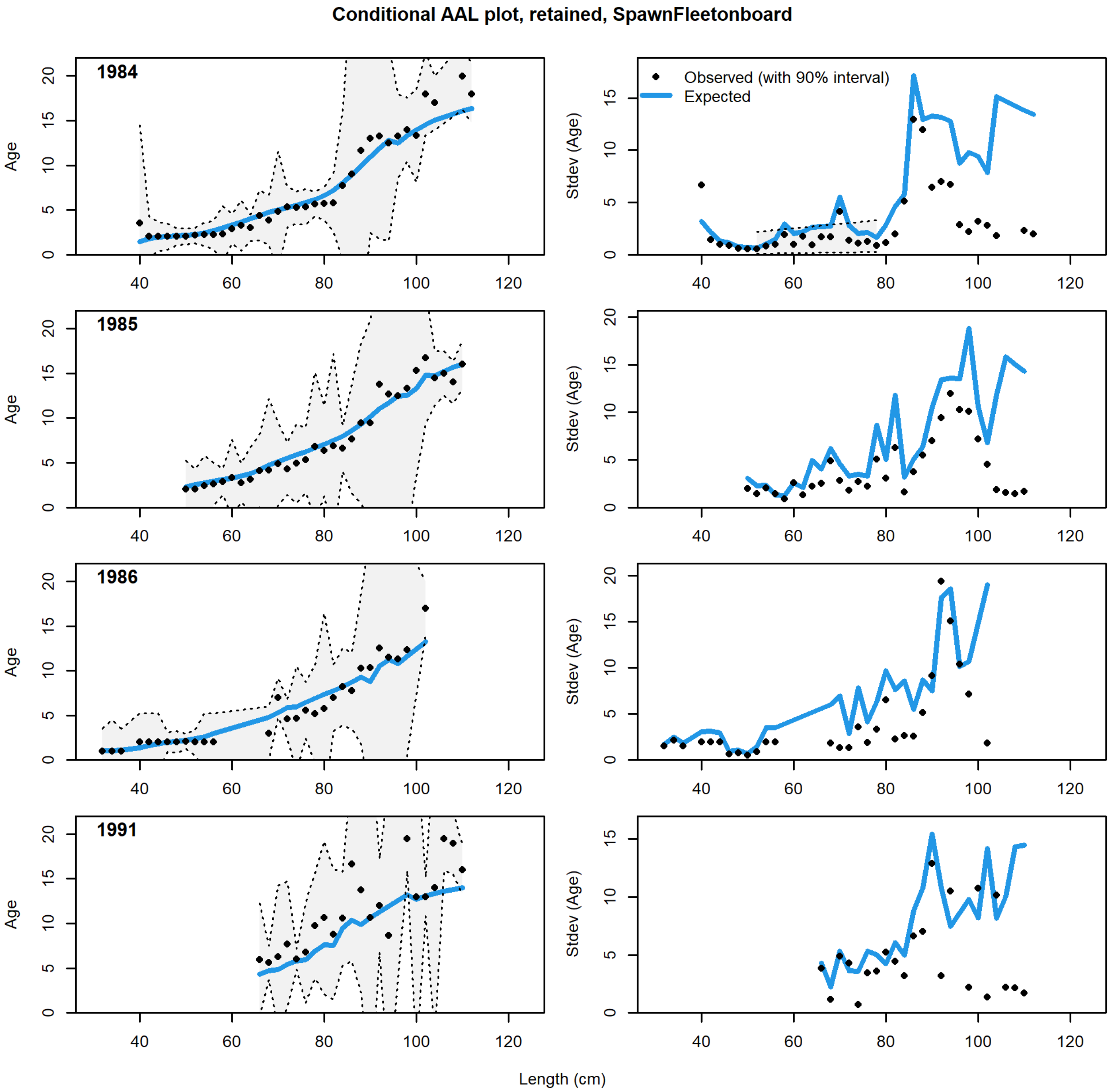


Conditional AAL plot, retained, SpawnFleetonboard
2000
2001
2002
2003
Age
Stdev (Age)
Observed (with 90% interval)
Expected
Length (cm)

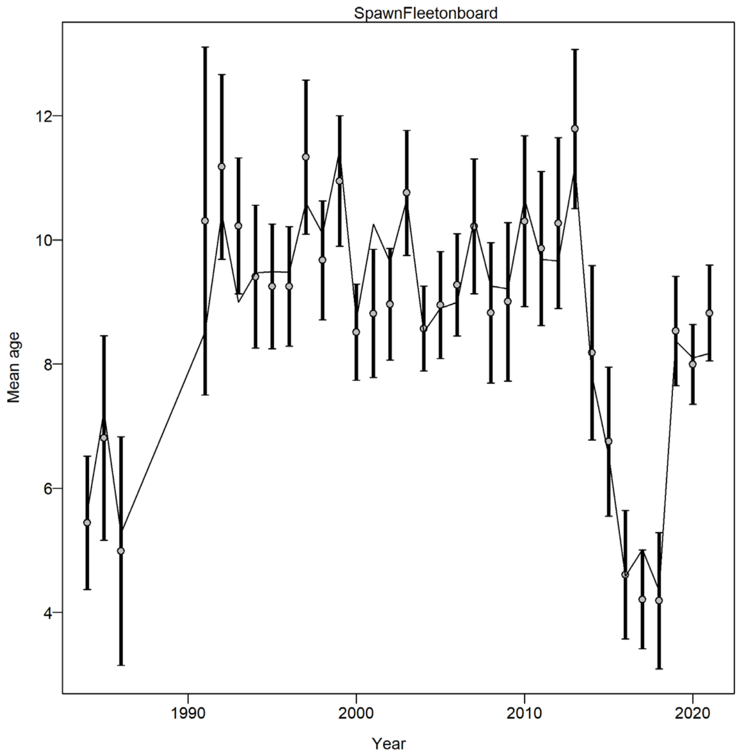
Conditional AAL plot, retained, SpawnFleetonboard




Conditional AAL plot, retained, SpawnFleetonboard
1992
1993
1994
1995
Age
Stdev (Age)
Observed (with 90% interval)
Expected
Length (cm)



1 Figure 29. Fits to conditional age at length data.



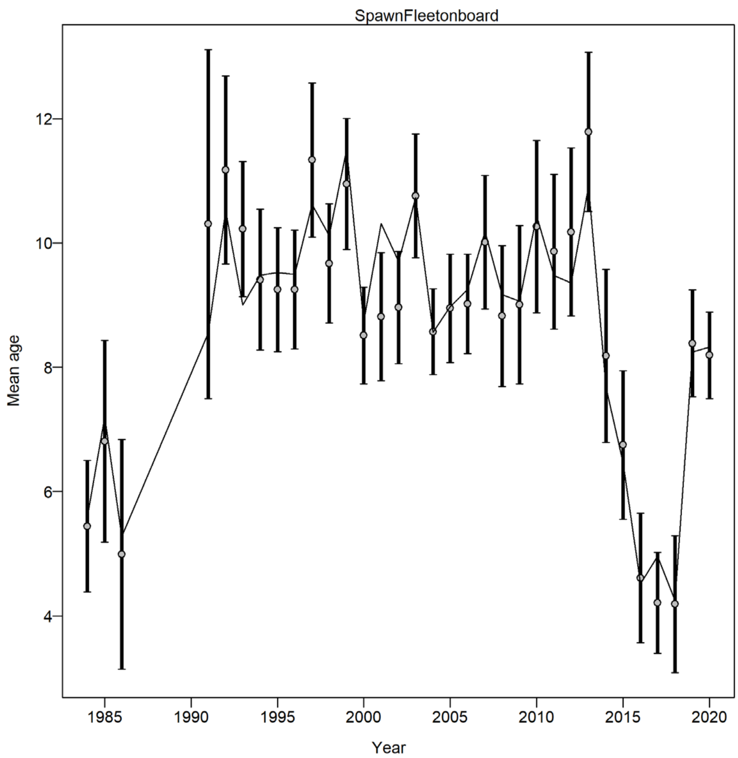
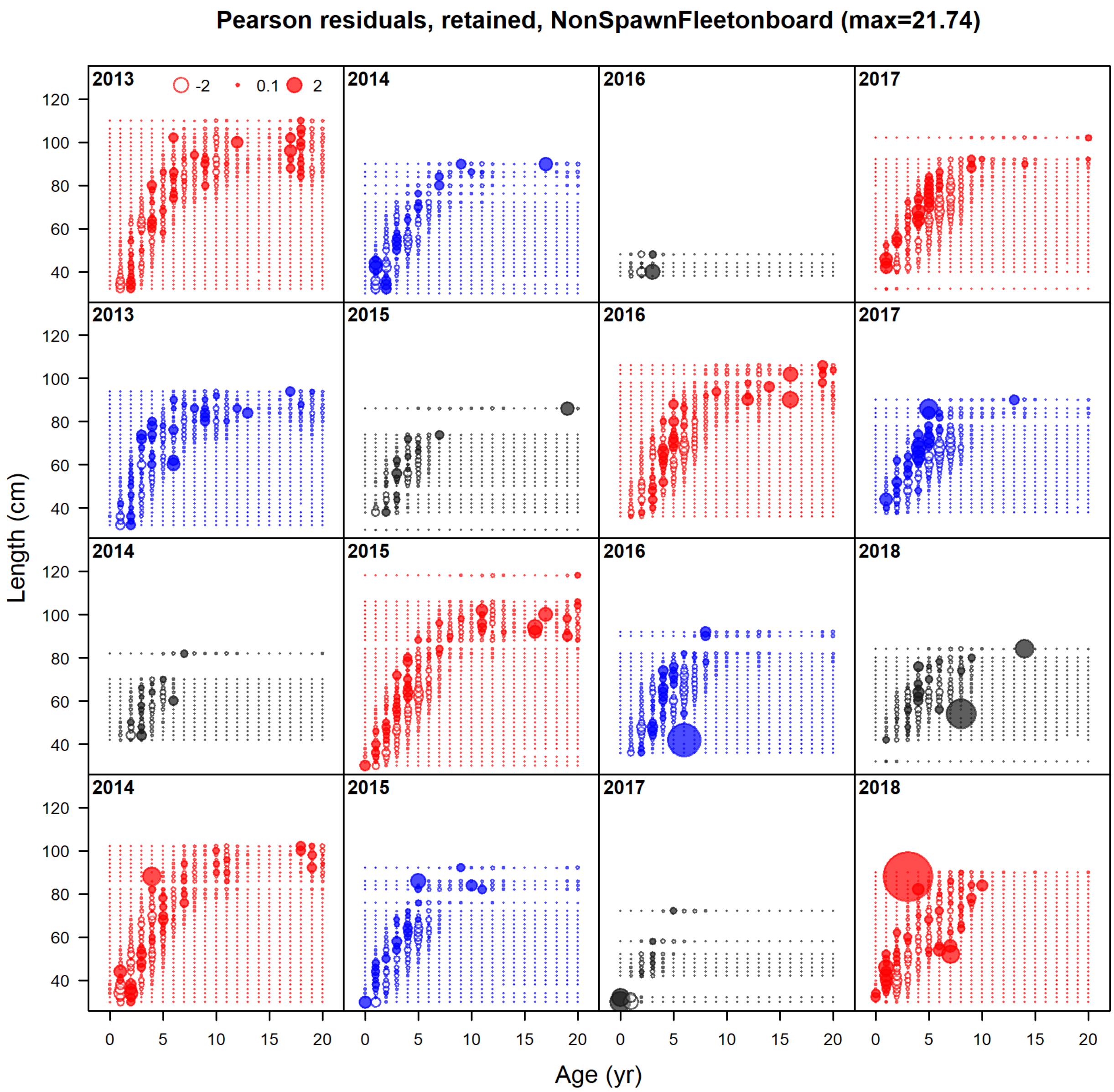
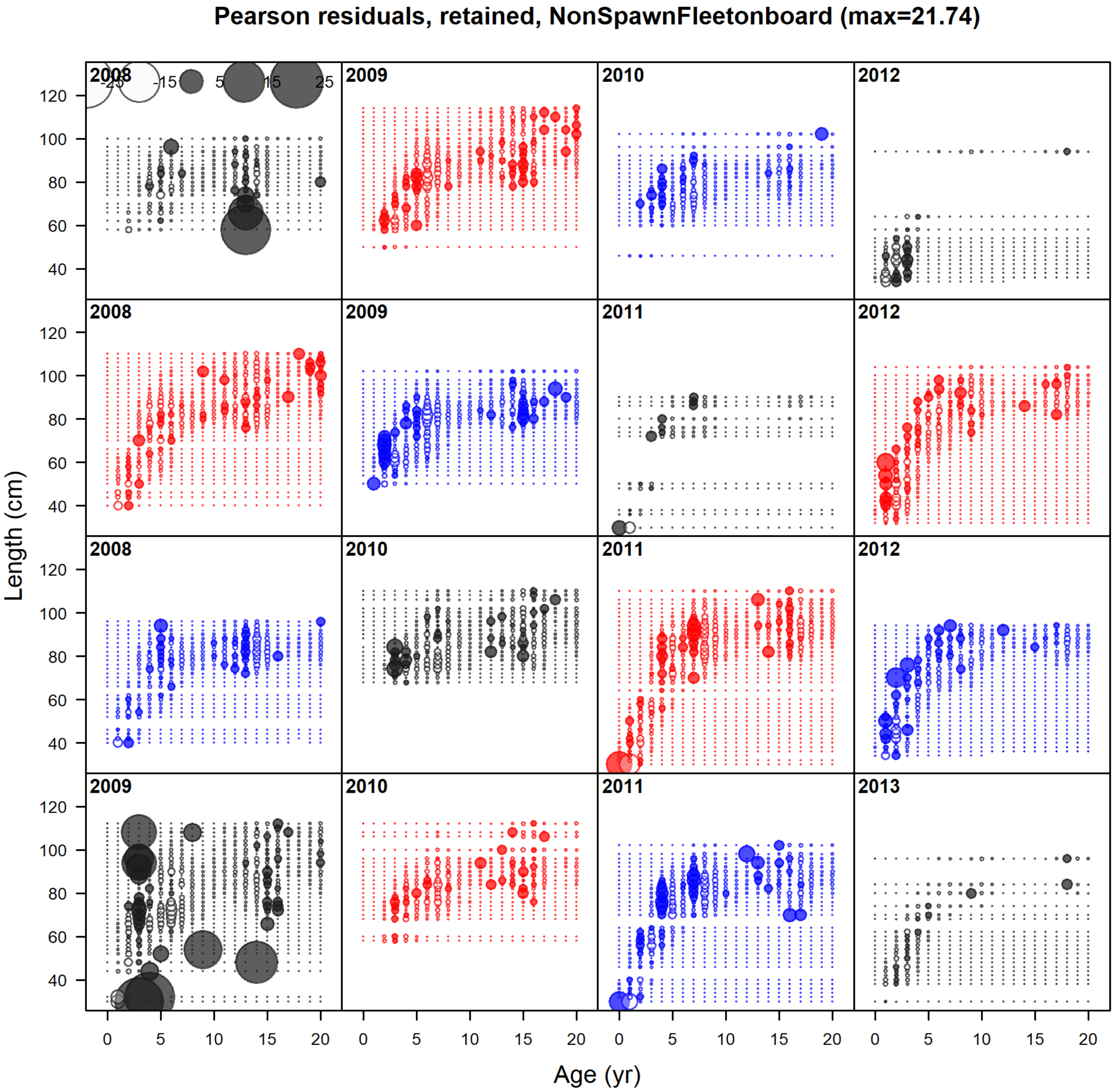
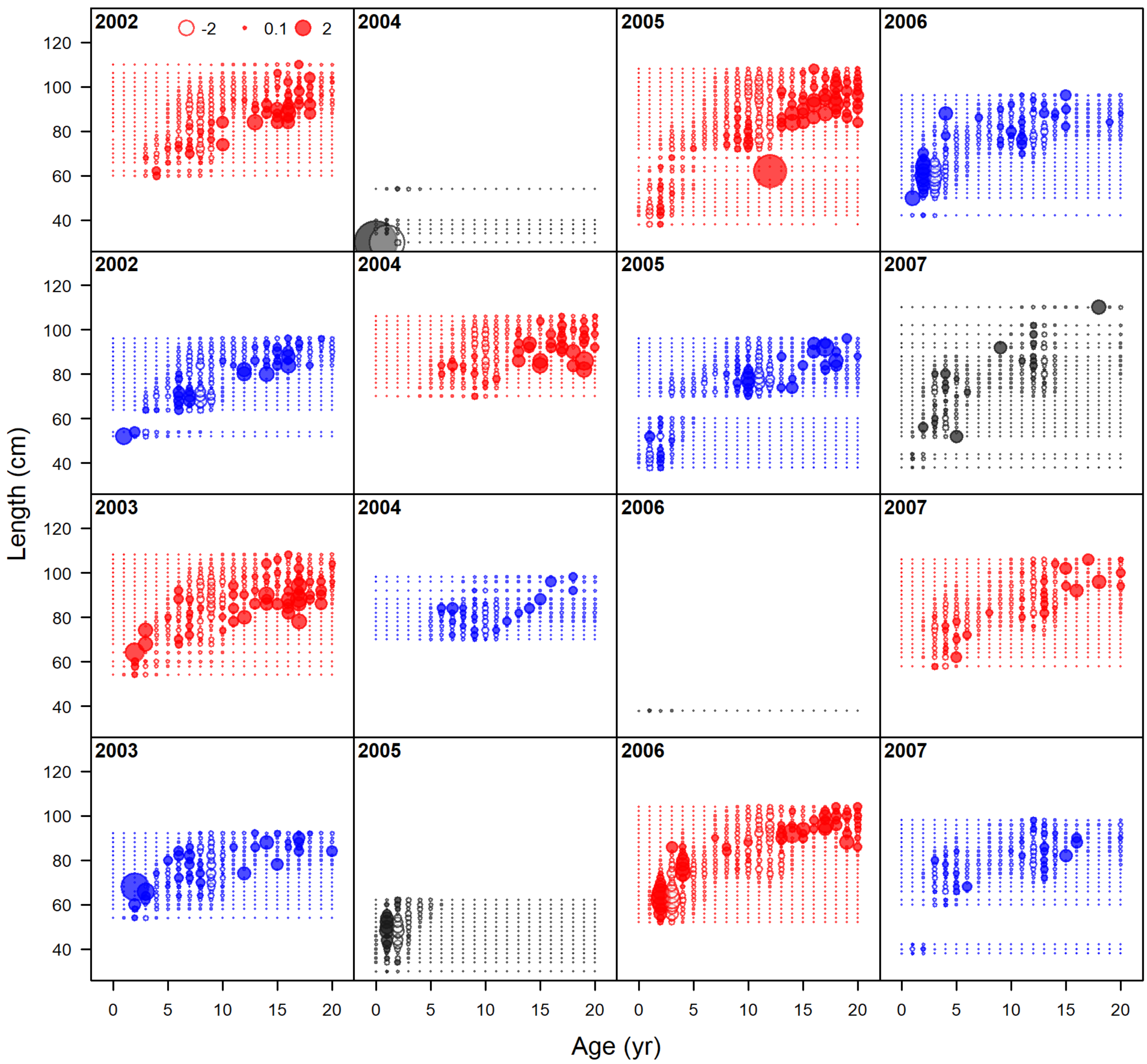


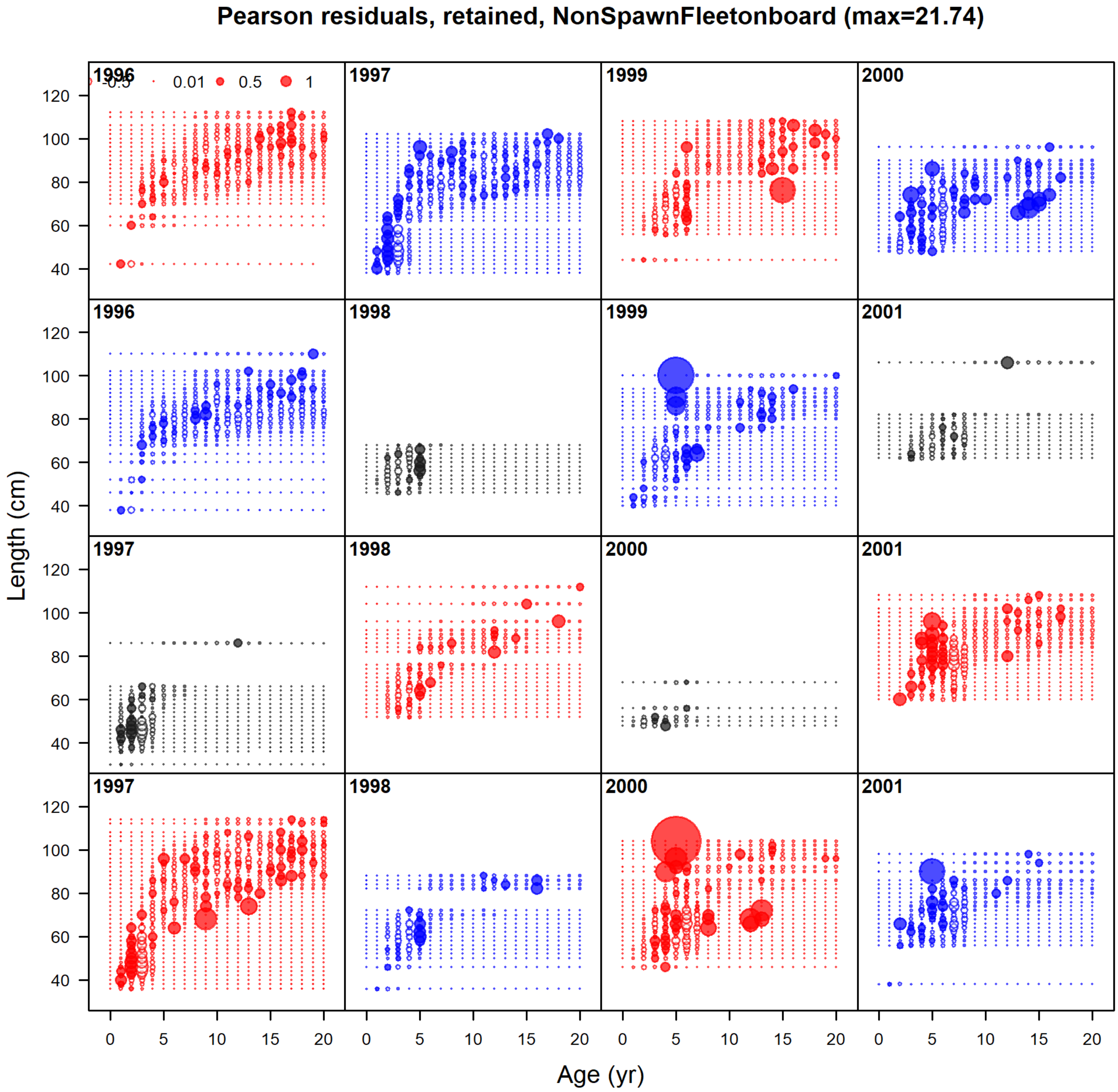
Figure 30. Data weighting of conditional age at length data for the onboard non spawning and spawning fleets.

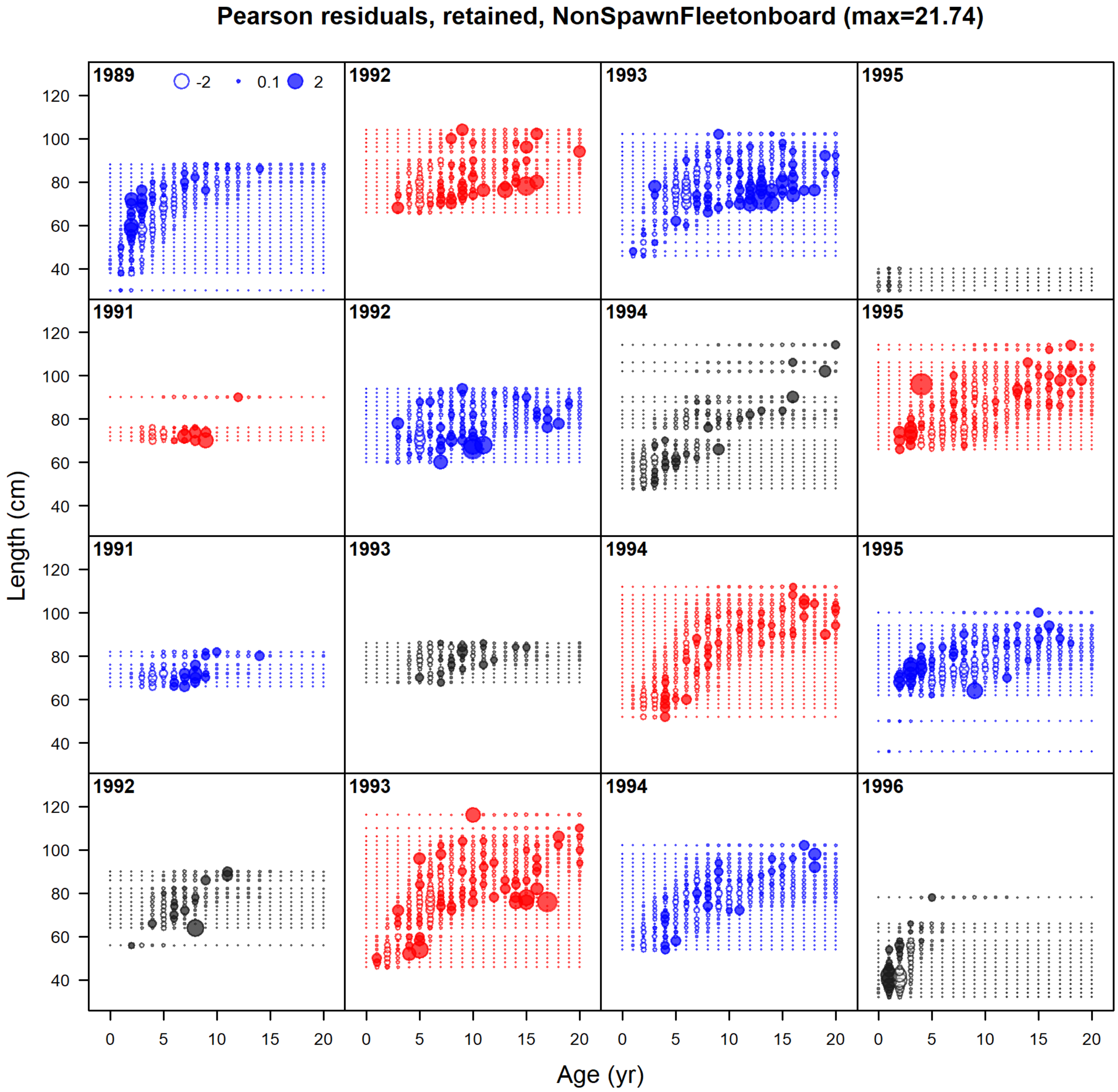

Pearson residuals, retained, NonSpawnFleetonboard (max=21.74)
-2
0.1
2
2013
2014
2016
2017
2013
2015
2016
2017
2014
2015
2016
2018
2014
2015
2017
2018
Length (cm)
Age (yr)

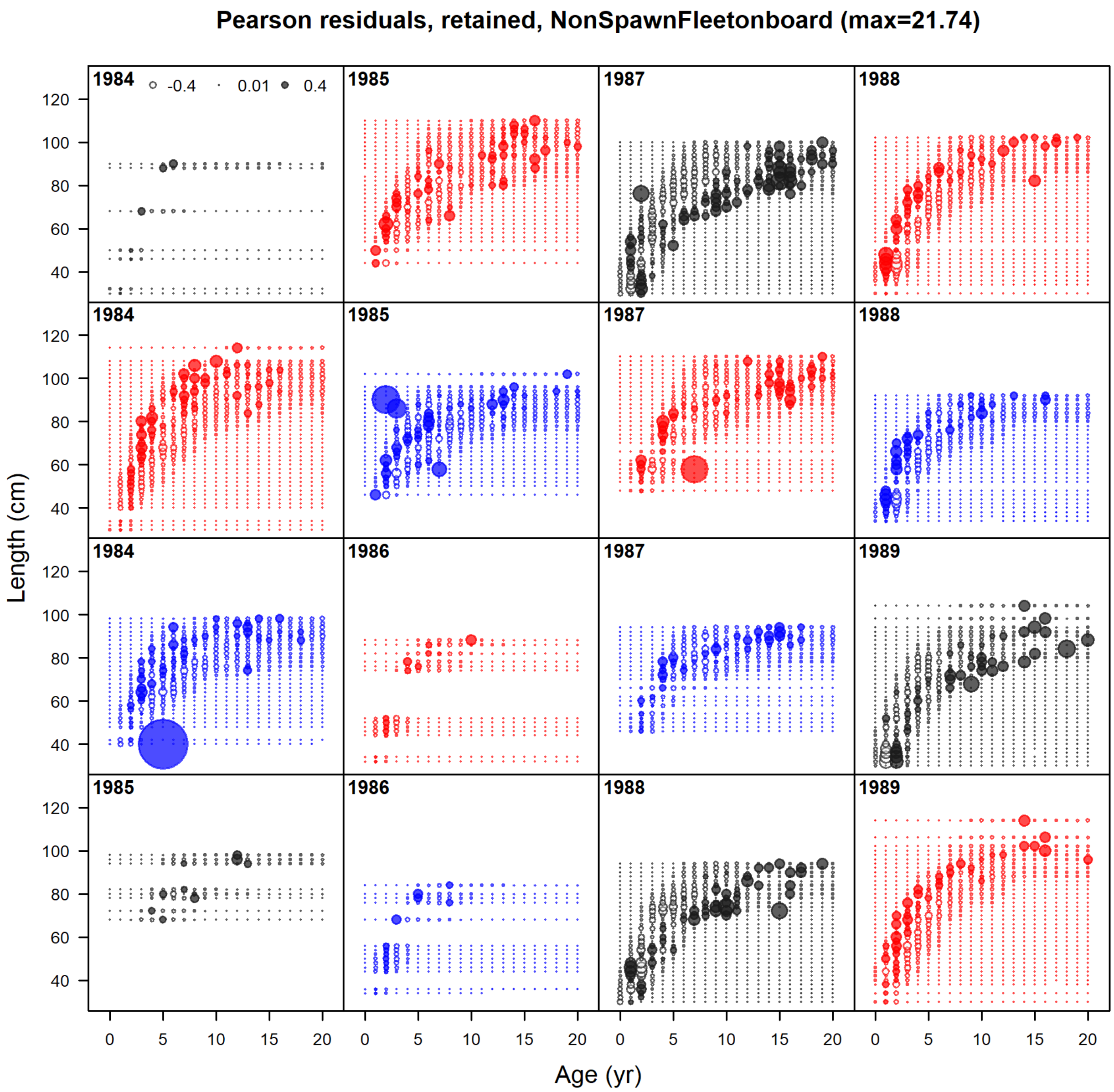

Pearson residuals, retained, NonSpawnFleetonboard (max=21.74)
2008
-25
-15
-5
5
15
25
2009
2010
2012
2008
2009
2011
2012
2008
2010
2011
2012
2009
2010
2011
2013
Length (cm)
Age (yr)
120
100
80
60
40
0
5
10
15
20

Pearson residuals, retained, NonSpawnFleetonboard (max=21.74)

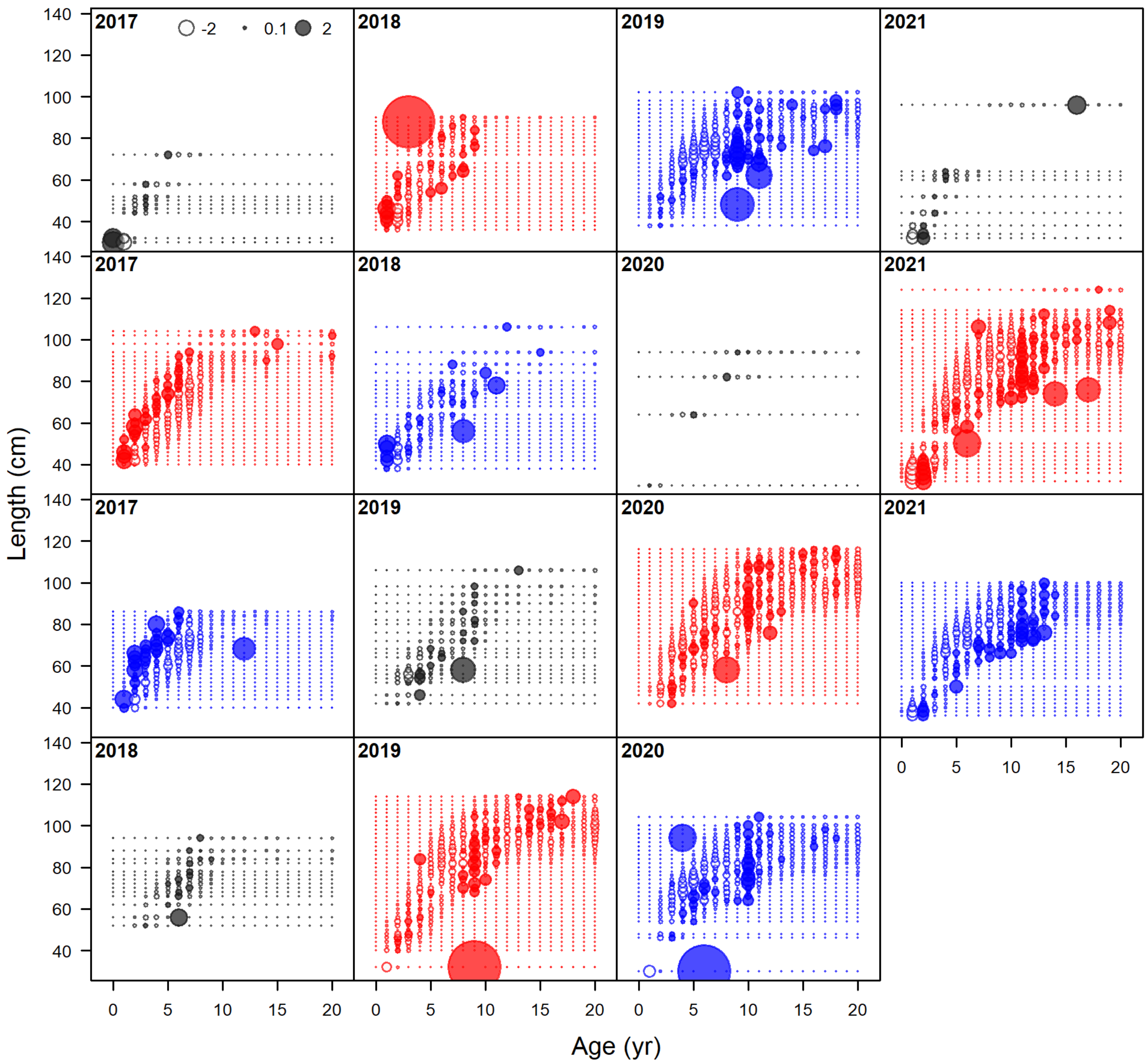


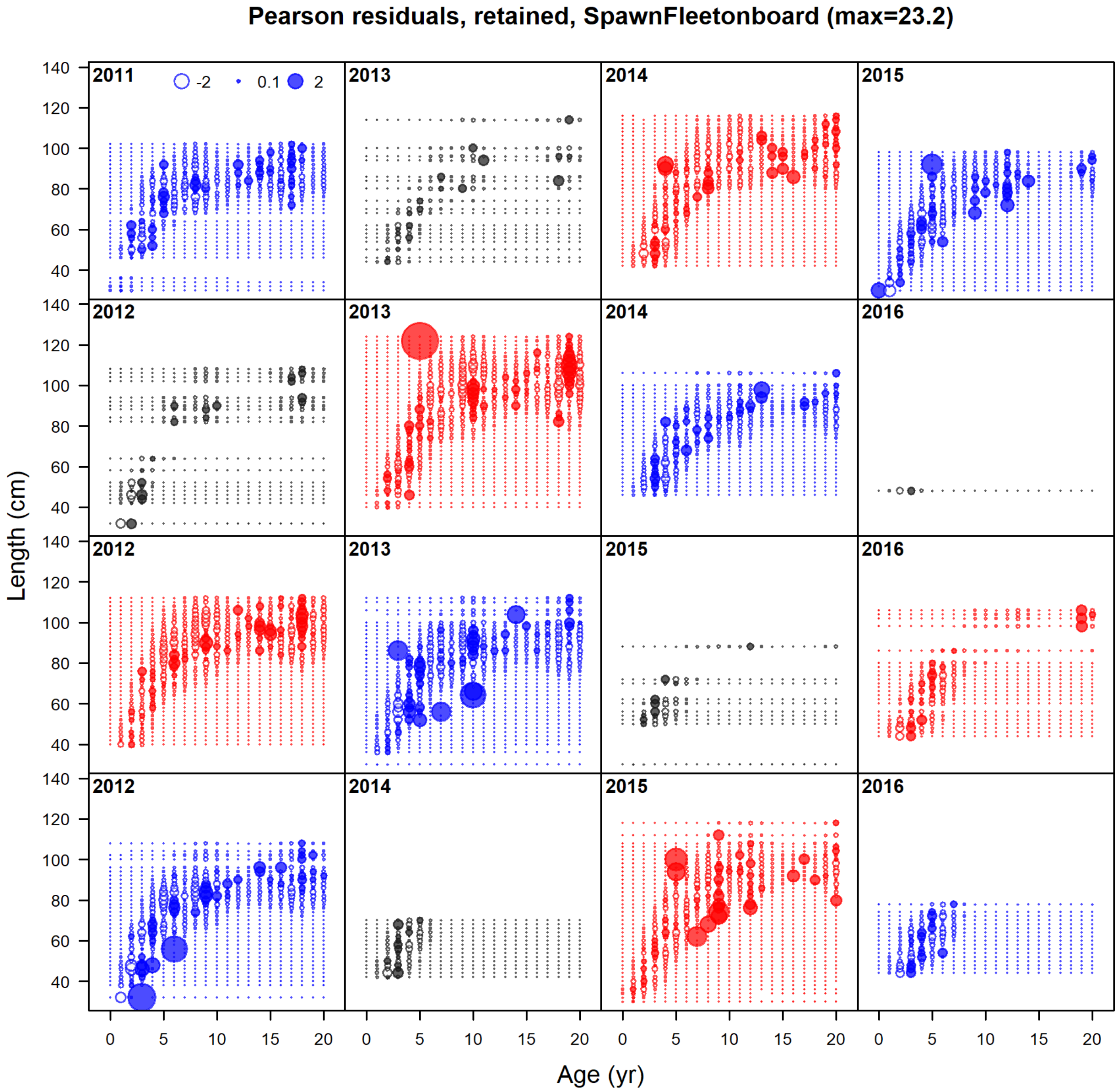

Pearson residuals, retained, NonSpawnFleetonboard (max=21.74)
-0.5
0.01
0.5
1
1996
1997
1999
2000
1996
1998
1999
2001
1997
1998
2000
2001
1997
1998
2000
2001
Length (cm)
Age (yr)
120
100
80
60
40
0
5
10
15
20


Pearson residuals, retained, NonSpawnFleetonboard (max=21.74)
1989
-2
0.1
2
1992
1993
1995
1991
1992
1994
1995
1991
1993
1994
1995
1992
1993
1994
1996
Length (cm)
Age (yr)

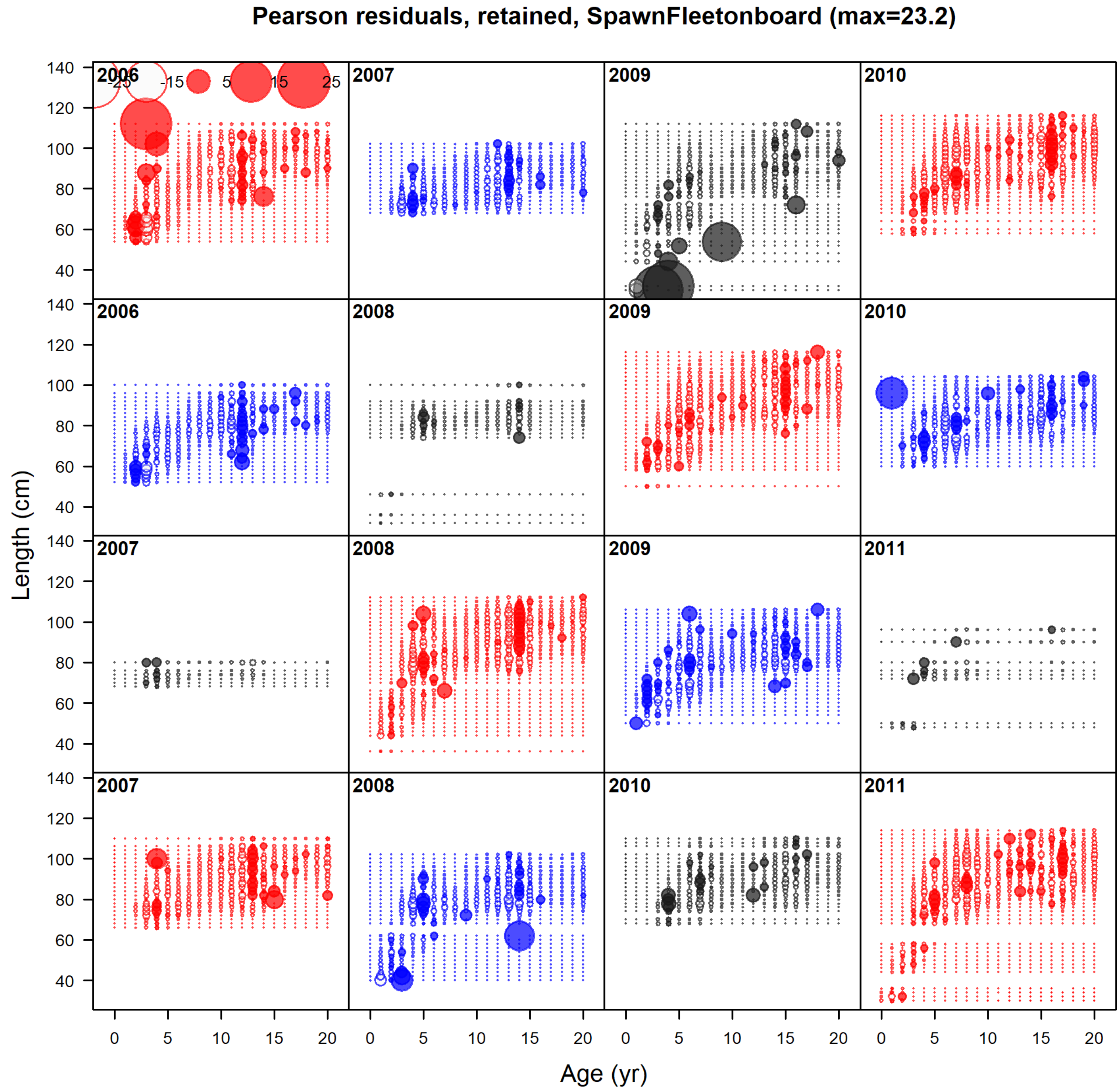

Pearson residuals, retained, NonSpawnFleetonboard (max=21.74)
1984
-0.4
0.01
0.4
1985
1987
1988
1984
1985
1987
1988
1984
1986
1987
1989
1985
1986
1988
1989
Length (cm)
Age (yr)
120
100
80
60
40
0
5
10
15
20

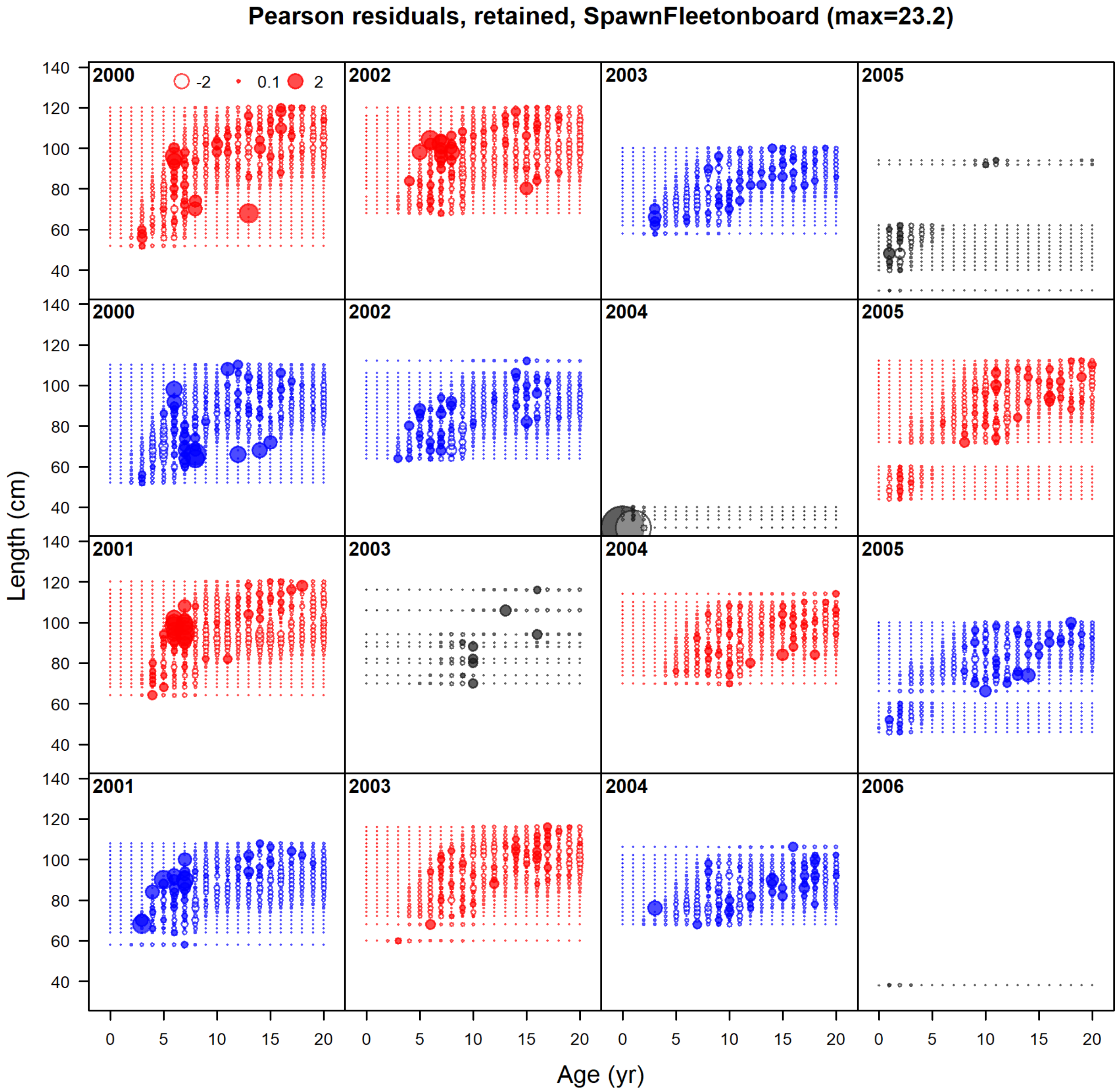
Pearson residuals, retained, SpawnFleetonboard (max=23.2)



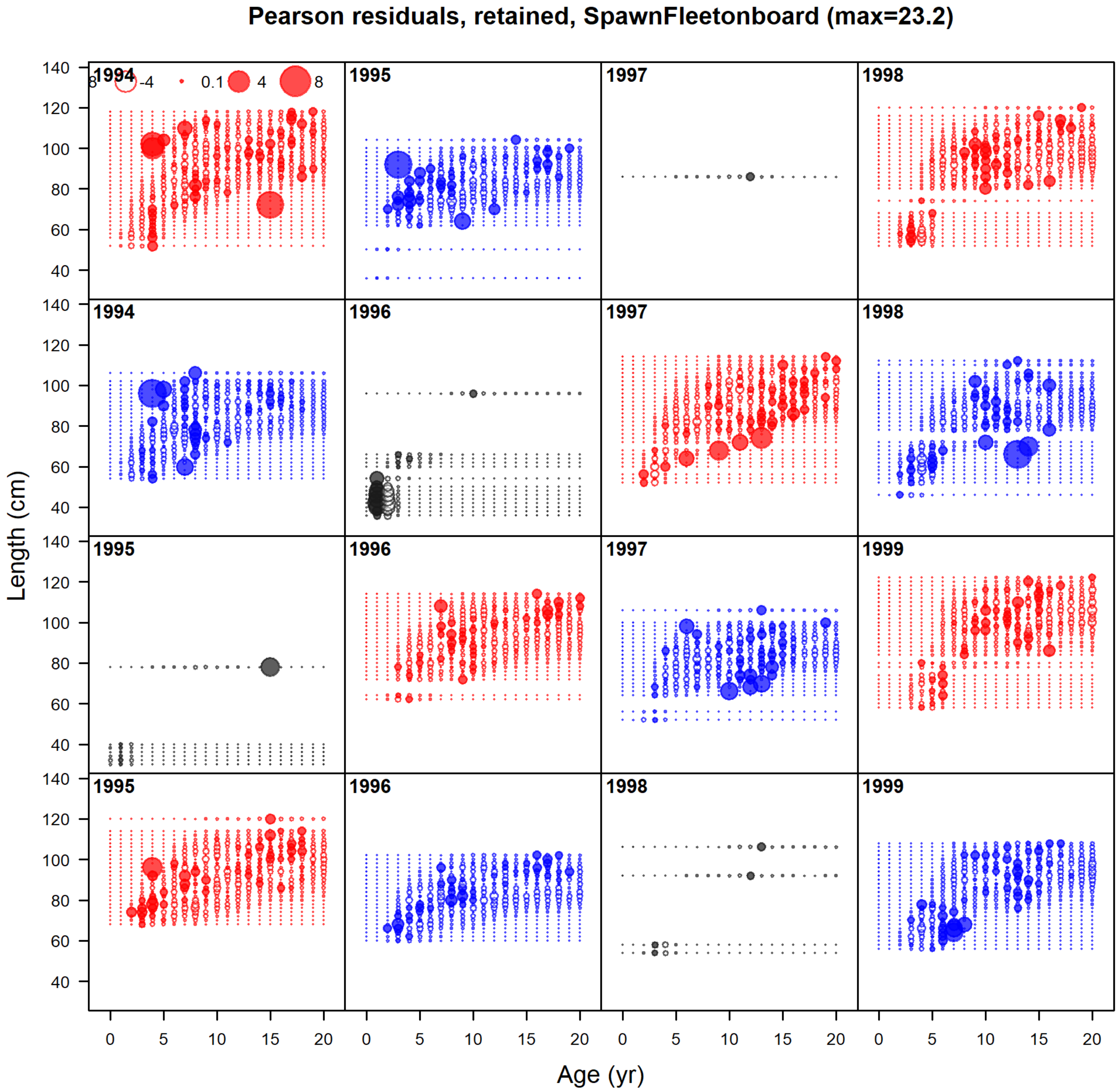


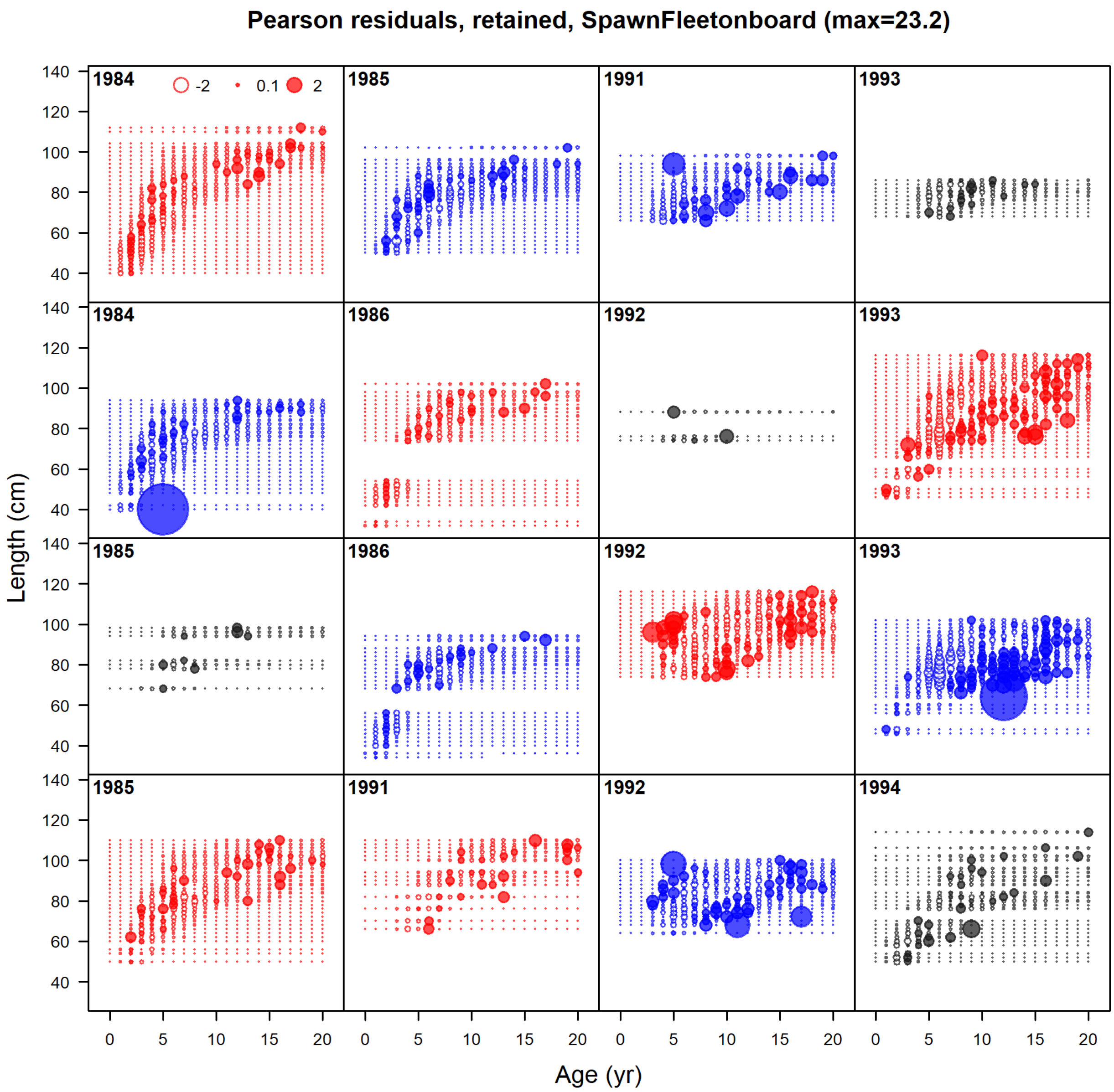
Pearson residuals, retained, SpawnFleetonboard (max=23.2)
2011
-2
0.1
2
2013
2014
2015
2012
2013
2014
2016
2012
2013
2015
2016
2012
2014
2015
2016
Length (cm)
Age (yr)


Pearson residuals, retained, SpawnFleetonboard (max=23.2)
-25
-15
5
15
25
2006
2007
2009
2010
2006
2008
2009
2010
2007
2008
2009
2011
2007
2008
2010
2011
Length (cm)
Age (yr)
140
120
100
80
60
40
0
5
10
15
20



Pearson residuals, retained, SpawnFleetonboard (max=23.2)
2000
-2
0.1
2
2002
2003
2005
2000
2002
2004
2005
2001
2003
2004
2005
2001
2003
2004
2006
Length (cm)
Age (yr)
140
120
100
80
60
40
0
5
10
15
20


Pearson residuals, retained, SpawnFleetonboard (max=23.2)
-8
-4
0.1
4
8
1994
1995
1997
1998
1994
1996
1997
1998
1995
1996
1997
1999
1995
1996
1998
1999
Length (cm)
Age (yr)


Pearson residuals, retained, SpawnFleetonboard (max=23.2)
Length (cm)
Age (yr)
-2
0.1
2
1984
1985
1991
1993
1984
1986
1992
1993
1985
1986
1992
1993
1985
1991
1992
1994

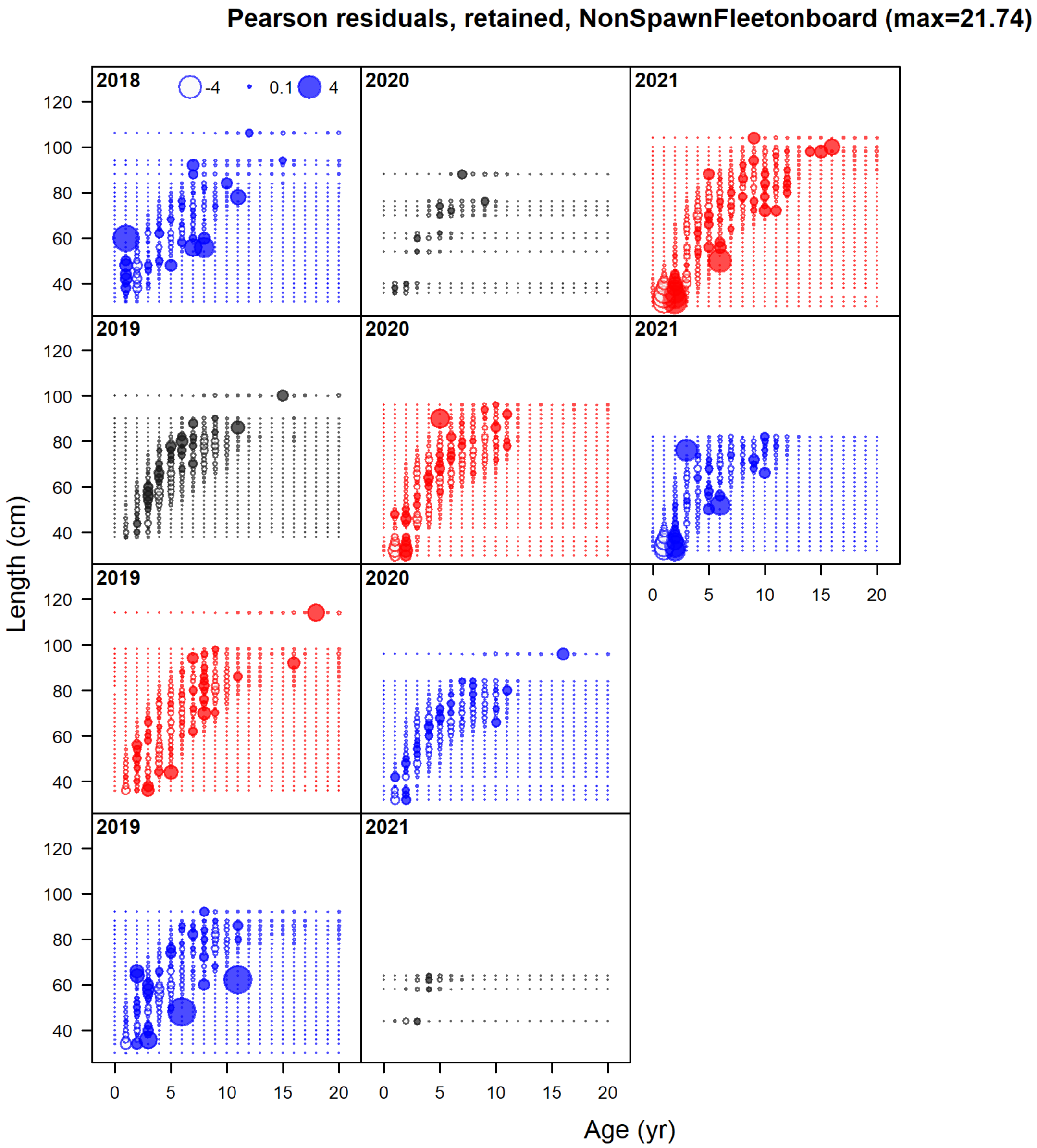


Figure 31. Pearson residuals of conditional age at length data.

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