4.1 Assessment of Northern and Southern rock sole (*Lepidopsetta polyxstra* and *bilineata*) stocks in the Gulf of Alaska

by
Meaghan D. Bryan

Executive Summary

Summary of Changes in Assessment Inputs

The Gulf of Alaska (GOA) northern and southern rock sole assessment has been moved to a 4-year assessment cycle per the stock assessment prioritization schedule. During years when a full assessment is not completed a partial assessment will be done. This year marks a full assessment year. The last full assessment was completed in 2015.

New data inputs:

1. 2015 and 2016 catch data were updated and 2017 catch was extrapolated to include expected catch in October-December, 2017
2. 2017 GOA trawl survey biomass estimates were added to the model.
3. 2017 fishery lengths were added to the model.
4. 2017 GOA trawl survey length composition data were added to the model.
5. 2015 GOA trawl survey conditional-age-at-length (CAAL) data were added to the model.

Changes to the assessment model:
In September 2017, a modified assessment model was presented as an alternative to the 2015 assessment model. The modified model used the GOA groundfish survey length composition and CAAL data rather than the survey age composition and CAAL data. The modified assessment model was the author's preferred assessment model.

The biomass, OFL and ABC values for northern and southern rock sole are added into the shallow-water flatfish complex values to estimate OFL and ABC for the complex.

Summary of Results

Several models are presented in this report:

1. Model 17.1 – a re-run of the 2015 assessment model with updated data,
2. Model 17.2 - a modified version of model 17.1 using the GOA groundfish survey length composition and CAAL data rather than the survey age composition and CAAL data,
3. Model 17.2a – model 17.2 while implementing iterative re-weighting using the Francis method, and
4. Model 17.2b – model 17.2 while implementing iterative re-weighting using the McAllister-Ianelli method, and model 17.2 while implementing Dirichlet error distribution for data weighting that is internal to SS3.

Based on the model fit and retrospective performance and more appropriate treatment of the data, model 17.2 is the recommended model for this year's assessment rather than model 17.1. Models 17.2a and

17.2b were not recommended given the high weights assigned to the length composition data and conditional age-at-length data and the unrealistic estimated fishery selectivity curves. Lastly, the results from model 17.2c indicated that the underlying weights (i.e., input sample sizes for the length composition and CAAL data) of model 17.2 were adequate and produced the same assessment outcomes as model 17.2.

The northern rock sole models estimate an increasing trend in total and spawning biomass and relatively low fishing mortality rates in recent years. The 2017 northern rock sole SSB estimates were above $B_{35\%}$ and the 2017 fishing mortality estimates were below $F_{35\%}$. The southern rock sole models estimate the start of an increasing trend in total biomass, a continued decline in SSB, and fishing mortality rates that have remained relatively low. The 2017 southern rock sole SSB estimates were above $B_{35\%}$ and the fishing mortality estimates were below $F_{35\%}$.

The key management results of the assessment, based on the author's preferred model (model 17.2), are compared to the results of the accepted 2016 update assessment in the tables below. The results are presented separately for each species.

Northern Rock Sole

Quantity	As estimated or *specified last* year for: 2017	2018	As estimated or *recommended this* year for: 2018	2019
M (natural mortality rate; female, male)	0.2, 0.25*	0.2, 0.25*	0.2, 0.253*	0.2, 0.253*
Tier	3a	3a	3a	3a
Projected total (age 0+) biomass (t)	76,837	80,120	90,794	93,374
Projected Female spawning biomass (t)	36,683	38,431	44,536	45,519
$B_{100\%}$	51,800	51,800	51,553	51,553
$B_{40\%}$	20,700	20,700	20,621	20,621
$B_{35\%}$	18,100	18,100	18,044	18,044
F_{OFL}	0.299	0.299	0.462	0.462
$maxF_{ABC}$	0.248	0.248	0.382	0.382
F_{ABC}	0.248	0.248	0.382	0.382
OFL (t)	14,548	15,146	19,960	20,477
maxABC (t)	12,283	12,788	16,802	17,243
ABC (t)	12,283	12,788	16,802	17,243
Status	As determined *last* year for: 2015	2016	As determined *this* year for: 2016	2017
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*Male natural mortality was estimated

Southern Rock Sole

Quantity	As estimated or *specified last* year for: 2017	2018	As estimated or *recommended this* year for: 2018	2019
M (natural mortality rate; female, male)	0.2, 0.248*	0.2, 0.248*	0.2, 0.262*	0.2, 0.262*
Tier	3a	3a		
Projected total (age 0+) biomass (t)	133,922	131,828	138,620	139,907
Projected Female spawning biomass (t)	71,786	67,851	71,913	69,178
$B_{100\%}$	93,500	93,500	93,583	93,583
$B_{40\%}$	37,400	37,400	37,433	37,433
$B_{35\%}$	32,700	32,700	32,754	32,754
F_{OFL}	0.222	0.222	0.326	0.326
$maxF_{ABC}$	0.186	0.186	0.271	0.271
F_{ABC}	0.186	0.186	0.271	0.271
OFL (t)	22,215	21,927	25,333	25,689
maxABC (t)	18,865	18,618	21,424	21,717
ABC (t)	18,865	18,618	21,424	21,717
Status	As determined *last* year for: 2015	2016	As determined *this* year for: 2016	2017
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*Male natural mortality was estimated

Responses to SSC and Plan Team Comments on Assessments in General

NA

Responses to SSC and Plan Team Comments Specific to this Assessment

Northern rock sole

"The team recommends that some alternative weighting methods be considered in addition to the current method of weighting by standard error to help alleviate the residual problems"

This was done for northern and southern rock sole and discussed in this document.

Southern rock sole

The plan team recommends running the 2015 assessment model and the modified model presented in September. The plan team recommends looking at data weighting options and incorporating fishery age data as a model input in the future.

Both assessment models were run and discussed in this document. Data weighting options were also evaluated.

Introduction

Rock sole are demersal flatfish that can be found in shelf waters to 600 m depth (Allen and Smith, 1988). Two species of rock sole are known to occur in the north Pacific Ocean, northern rock sole (*Lepidopsetta polyxystra*) and southern rock sole (*L. bilineata*) (Orr and Matarese, 2000). Adult northern rock sole are found from Puget Sound through the Bering Sea and Aleutian Islands to the Kuril Islands, while southern rock sole range from the southeast Bering Sea to Baja California (Stark and Somerton, 2002). These species have an overlapping distribution in the Gulf of Alaska (Wilderbuer and Nichol, 2009). Rock sole are most abundant in the Kodiak and Shumagin areas. Northern rock sole spawns in midwinter and spring, and southern rock sole spawns in summer (Stark and Somerton, 2002). Northern rock sole spawning occurred in areas where bottom temperatures averaged 3°C in January, and southern rock sole spawned in areas where bottom temperatures averaged 6°C in June (Stark and Somerton, 2002). Rock soles grow to approximately 60 cm and can live in excess of 20 years (http://www.afsc.noaa.gov/race/behavioral/rocksole_fbe.htm).

Both rock sole species are managed as part of the shallow-water flatfish complex, which also includes yellowfin sole (*Pleuronectes asper*), starry flounder (*Platichthys stellatus*), butter sole (*Pleuronectes isolepis*), English sole (*Pleuronectes vetulus*), Alaska plaice (*Pleuronectes quadrituberculatus*), and sand sole (*Psettichthys melanostictus*), because these species are caught in the shallow-water flatfish fishery (Turnock et al., 2009).

Fishery

Northern and southern rock sole in the Gulf of Alaska are part of the shallow water flatfish complex. The fishery does not report rock sole by species, so the catch statistics represent total rock sole (Table 4.1). The fishery observer program began collecting differentiated northern and southern rock sole data in 1997. The observer data since 1997 lists species as northern (N), southern (S), or “undifferentiated” (U) rock sole because adult northern and southern rock sole are difficult to differentiate visually (Orr and Matarese, 2000). There is considerable uncertainty about the fraction of annual rock sole catch that is northern or southern rock sole.

Rock sole are not targeted specifically because they co-occur with several other species. They are primarily caught with bottom trawl gear in NMFS area 630 followed by areas 620 and 610 (Figure 4.1). Rock sole discards by area and gear type are reported in Table 4.2. Rock sole discards are primarily associated with non-pelagic trawl gear and in NMFS area 610, 620, and 630 (Table 4.2).

Data

The following data were used in the model.

Data source	Years
Fishery catch (assumed 50% NRS, 50% SRS)	1977-2017
NMFS GOA groundfish survey biomass and SE	1996, 1999, 2001, 2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017
Fishery length composition	1997-2017
NMFS GOA groundfish survey length composition	1996, 1999, 2001, 2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017
NMFS GOA groundfish survey CAAL (2017 age data were not available)	1996, 1999, 2001, 2003, 2005, 2007, 2009, 2011, 2013, 2015*

Fishery

Northern and southern catches are currently reported as rock sole by year and management area (Figure 4.1). These data are included in the assessment model as a total catch time-series. Rock sole catch has ranged from 1,765mt to 8,112mt since 1993 and has average 4,403mt (Table 4.1). Catch has been fairly stable since 2010 and averaged 3191mt.

Catch data for 2017 were extracted from the AKFIN database on September 27, 2017. As of September 27, 2017 a total of 1,604 t of rock sole had been captured. On average 62% of the total annual rock sole catch is captured by September 27th. An estimate of catch extrapolated to the end of 2017 was used as input in the assessment model based on the capture to date and the average fraction mentioned previously. A value of 2,575 t was use as the 2017 catch input.

For assessment purposes it was assumed that 50% of the total rock sole catch was northern rock sole and 50% was southern rock sole. Catch was assumed to be known without error in the assessment models.

Size composition data are available from the NMFS observer program from 1985 to present. Observations were recorded as rock sole until 1996. Northern and southern rock sole were differentiated after 1996. Fishery length composition data from 1997 through 2017 are included in the assessment model (Figure 4.2). Mean length of northern and southern rock sole has varied over time (Figure 4.3). Northern rock sole mean length declined between 1999 and 2004, increased until 2011, declined until 2014, and has increased since. Southern rock sole mean length exhibited a declining trend between 1997 and 2001, was relatively stable between 2002 and 2010, increased in 2011, and has declined until 2014, and has exhibited a declining trend since.

The number of sampled hauls was used as the input sample size. The number of sampled hauls and the number of length samples by species and sex are summarized in Table 4.3a.

Survey

Survey data are available from the NMFS Gulf of Alaska groundfish survey conducted by the AFSC's Resource Assessment and Conservation Engineering (RACE) division. Surveys were conducted triennially from 1984 until 1999 and biennially from 2001 until present. These data include biomass estimates by area, length composition data, age composition data, and conditional age-at-length data. Northern and southern rock sole were not differentiated until 1996. After 1996, observed rock sole were classified as northern, southern, or unidentified rock sole.

Estimates of total biomass and the associated standard errors were included in the northern and southern rock sole assessment model. The survey total biomass estimates are summarized in Table 4.4 and shown in Figure 4.4. Total biomass declined between 1996 and 1999 for both northern and southern rock sole. Biomass increased to a peak in 2007 and 2009 for northern rock sole and southern rock sole, respectively. Southern rock sole biomass declined in 2011 but has since remained relatively stable. The southern rock sole biomass estimate declined by 14% from 2016 to 2017. Northern rock sole biomass has generally declined since 2007. The northern rock sole biomass estimate increased by 5% from 2016 to 2017.

Survey length composition data and conditional age-at-length data were also included in the assessment models. The number of hauls with northern or southern rock sole was used as the input sample size for the length composition data. The number of sampled lengths and number of sampled hauls are summarized in Table 4.3b. The input sample size for the conditional age-at-length data was the ratio of the number of hauls and number of lengths sampled scaled by the number of age samples.

The survey length composition data for northern and southern rock sole are shown in Figure 4.5. Northern rock sole mean length has been relatively flat, but exhibited a decline between 2007 and 2009, an increase in 2011, a decline between 2013 and 2015, and an increase in 2017 (Figure 4.6). Southern rock mean length exhibited a decline between 1999 and 2007, an increase between 2009 and 2013, and another decline between 2013 and 2015(Figure 4.6).

The survey conditional age at length data are shown in Figures 4.7 and 4.8.

Analytic approach

General Model Structure

All models were configured using Stock Synthesis (SS3). SS3 equations can be found in Methot and Wetzel (2013) and further technical documentation is outlined in Methot (2009). The models covered ages 0 to 30, were sex-specific, and started in 1977. Age-0 individuals represent recruits to the population and the oldest age class represents as plus group. As mentioned in the data section, fishery catch (retained catch and discards) are reported as undifferentiated rock sole. Annual total catch was split evenly between northern and southern rock sole and included in the model as the catch time-series. Catch was assumed to be known without error.

Growth was assumed to follow the von Bertalanffy growth relationship and assumed constant over time. All growth parameters were estimated including two error terms describing the standard deviation of young and old individuals. The standard deviation of the intermediate ages was interpolated frim these two parameters and assumed to be a function of length and age. Female natural mortality was fixed and set equal to 0.2. Male natural mortality was estimated. Age-based maturity was a fixed input vector and is shown in Figure 4.9. The length-weight relationship was assumed to be the same for females and males and are shown in Figure 4.10. Fecundity was assumed to be equivalent to spawning biomass.

The stock recruitment relationship was assumed to be an average level of recruitment unrelated to stock size. Two of the stock-recruit parameters were fixed. Steepness was fixed equal to 1 in all model configurations, recruitment variability σ_R was fixed equal to 0.6. Unfished recruitment (R_0) and the R1_offset parameter, which adjusts the starting recruitment relative to R_0, were estimated within the model. Annual recruitment deviations were estimated for the full time period.

Sex-specific, size-based selectivity functions were estimated for the fishery and survey and were assumed to be constant over time. A double normal selectivity pattern was used for the fishery and the survey. The double normal pattern is described by 6 parameters;

1. Peak- beginning size of the plateau,
2. Width of the plateau,
3. Width of the ascending limb,
4. Width of the descending limb,
5. Selectivity at the smallest length, and
6. Selectivity of the largest length.

The selectivity parameters for the fishery were estimated and allowed for a dome-shape relationship. It was assumed that the survey selectivity was asymptotic. The parameters associated with the descending side of the double normal curve and the selectivity of the final size bin were fixed to accommodate this assumption. Male selectivity was estimated as an offset of female selectivity. When using a double normal pattern, five additional parameters are required to differentiate from the opposite sex. These parameters offset the female peak, ascending and descending limbs, and the selectivity at the final length bin. An additional parameter represents the apical selectivity for males.

Catchability was fixed equal to 1 in all model configurations. This assumes that the survey biomass estimates reflect absolute abundance for fully selected individuals.

Description of Alternative Models

Several models are presented independently for northern and southern rock sole. A general summary of the models can be found in Table 4.5.

Model 17.1 was a re-run of the 2015 full assessment model with data updated through 2017. The main difference between model 17.1 and 17.2 pertains to which data were fit to the model. Model 17.1 was fit to the survey total biomass estimates, the 2017 survey length composition, the survey age composition data (1997-2015) and the survey conditional age-at-length (1997-2015). Hence, the age data were fit to twice and effectively gave higher weight to these data. Model 17.2 was fit to the survey total biomass estimates, the available survey length composition data (1997-2017) and the conditional age at length data (1997-2015).

Data weighting

Models 17.1 and 17.2 used the same methods for data weighting. Length and age composition data were weighted according to input sample sizes. Input sample size was set equal to the number of hauls for which lengths or ages were measured. The conditional age-at-length data were weighted by the ratio of the number of hauls and length samples scaled by the number of age samples.

Models 17.2a-c included iterative re-weighting methods. Model 17.2a used the Francis method (Francis 2011), model 17.2b used the McAllister-Ianelli (McAllister and Ianelli 1997), and 17.2c used the Dirichlet method (Thorson *et al.* 2017). The Dirichlet method estimates the effective sample size as $N_{Eff} = \frac{1}{1+\theta} + \frac{N\theta}{1+\theta}$, where N is the input sample size and θ is an estimated parameter (Thorson *et al.* 2017). When the Dirichlet multinomial error distribution is selected in SS3, a fleet specific θ parameter can be estimated. As θ approaches infinity the N_{Eff} is equivalent to the input sample size.

Parameters estimated outside the assessment model

The initial values for the growth parameters used in the model are from Stark and Somerton (2002). The parameters for the weight-length relationship ($W = aL^b$, weight in kg and length in cm) for northern and southern rock sole are from Turnock et al. (2011) (Figure 4.10).

Species	Parameter	Female	Male
Northern rock sole	L_∞	429 mm	382 mm
	K	0.236	0.261
	t_0	0.387	0.160
	a	9.984×10^{-6}	9.984×10^{-6}
	b	3.0468	3.0468
Southern rock sole	L_∞	520 mm	387 mm
	K	0.120	0.182
	t_0	-0.715	-0.962
	a	9.984×10^{-6}	9.984×10^{-6}
	b	3.0468	3.0468

Parameters Estimated Inside the Assessment Model

The parameters estimated within the assessment model were the log of unfished recruitment (R_0), log-scale recruitment deviations, annual fishing mortality, female and male growth parameters (i.e., length at minimum age, asymptotic length, von Bertalanffy growth coefficient, and CVs at young and old age), and the selectivity parameters for the fishery and the survey.

Table 4.5 further summarizes the fixed and estimated model parameters for the northern and southern rock sole assessment models. A total of 91 parameters were estimated in the assessment models and included annual recruitment deviations and fishing mortality rates.

Results

Model evaluation

The resulting likelihoods, model fits to the data, and likelihood profiles for several key parameters are presented to evaluate the northern and southern rock sole assessment models. The results from models 17.1, 17.2, 17.2a, and 17.2b are presented. Model 17.2c used the Dirichlet error distribution in SS3. The θ parameter was estimated for the fishery and survey length composition data and the survey conditional age-at-length data. The resulting estimated θs were quite large:

Component	Northern rock sole	Southern rock sole
$Ln(\theta_{fishery\ lengths})$	15.04	15.20
$Ln(\theta_{survey\ lengths})$	14.58	14.44
$Ln(\theta_{survey\ CAAL})$	16.45	16.69

Hence, the results from model 17.2c are not presented because it suggests that the input sample sizes used in model17.2 provide sufficient weight to the data. Also, the results were identical to those from model 17.2.

Models 17.2a and 17.2b used the Francis and McAllister and Ianelli re-weighting methods, respectively. The Francis method downweighted the fishery length composition data and upweighted the survey lengths and CAAL data. The degree of which was species dependent. The upweighting of the northern rock sole survey length composition was relatively small as compared to the survey CAAL data, whereas, the upweighting of the southern rock sole survey CAAL data was relatively small as compared to the survey length composition data.

The McAllister and Ianelli method resulted in upweighting the fishery and survey length composition data and the survey CAAL data. The survey length composition data were assigned the highest weights followed by the survey CAAL data and fishery length composition data for both northern and southern rock sole.

Species	Component	Francis weight	McAllister and Ianelli weight
Northern rock sole	Fishery lengths	0.25	2.15
	Survey lengths	1.09	5.87
	Survey CAAL	4.07	4.44
Southern rock sole	Fishery lengths	0.41	3.95
	Survey lengths	2.82	11.74
	Survey CAAL	1.12	4.08

Northern rock sole

The northern rock sole assessment model fit to the survey biomass estimates and the length composition data are shown in Figures 4.11 – 4.17. The total likelihood and the likelihood components associated with these data types are reported in Table 4.6. These values cannot be directly compared given the differences in the data included in the models and the data weighting schemes.

The fits to survey biomass are similar for models 17.1, 17.2, and 17.2a (Figure 4.11). The model fit of 17.2c (McAllister and Ianelli data weighting) was a departure from the others. The root mean square error (RMSE) statistics indicate that Model 17.2a fit the survey biomass data better than models 17.1 and 17.2. That said, the residual pattern of models 17.1, 17.2, and 17.2a are similar in that they underestimate total biomass in 2005, 2007, 2009, 2011, and 2013 and overestimate survey biomass in 2015 and 2017 (Figure 4.11). The models predict a relatively large number of recruits in 2011 (Figure 4.21). These fish would be 6-years old now and should be vulnerable to the survey fishing gear and the model expects to see them.

Figure 4.12 shows the model fits to the fishery and survey size composition data aggregated over year. The model fit to the female and male size composition data from the fishery are similar among the models and exhibit an adequate fit to the aggregate length composition data. The overall survey size composition data used in 17.1, 17.2, 17.2a, and 17.2c differed. The data in 17.1 was from 2015, whereas the full complement of data (1996-2017) was used in the other models. The models are similar in that they do not fit the male size composition data particularly well. The model fits underestimate the frequency of 27cm – 31cm northern rock sole. This size range corresponds to the overall peak of the observed size distribution.

Figures 4.13 and 4.14 show the model fits to the annual fishery length composition data and Figure 4.15 shows the Pearson residuals from the resulting model fits. A residual pattern is consistent in all model fits where the models are underestimating a cohort, especially females, in years 2001 through 2011. Model 17.2a (model with Francis re-weighting) has noticeably smaller residuals than the other models. The annual fits to the survey length data are similar among the models with regard to pattern and scale of the residuals. (Figures 4.16 and 4.17). The peak of the male size distribution (~27cm-31cm) is consistently underestimated by all models and the model fits to the female size composition data indicate that the model underestimates an apparent cohort in 1996, 1999, and 2001.

The models were also fit to the survey conditional age-at-length data (Figure 18). The fit to the larger, older individuals have larger residuals than the smaller, younger fish. Notably the models underestimate the age of larger fish, especially in 2003, 2013, and 2015. The predicted standard deviation in the age-at-length estimates is higher than observed for the larger fish since there are very few observations.

The fishery size composition data were fit using a double normal pattern to allow for dome-shape selectivity, whereas, the bottom trawl survey selectivity was modeled assuming selectivity was asymptotic (Figure 4.19). Fitting the model to survey size composition data in model 17.2 caused the estimated selectivity curves to shift to the right of the selectivity curve estimated from model 17.1 so that length at full selection was larger and selectivity was higher for the largest northern rock sole. The shift was more substantial for the fishery data. The models that implemented Francis and McAllister and Ianelli reweighting methods, 17.2a and 17.2b, exhibited a further rightward shift in fishery selectivity. Full selection of females by the fishery was at the tails of the length distribution which seems unlikely. The coefficient of variation (CV) associated with the selectivity parameters that control the width of plateau and descending width of the selectivity curve were unrealistically large indicating that these parameters were poorly determined by models 17.2a and 17.2b (Table 4.7). The rightward shift in the survey selectivity curve was more modest and models 17.2 and 17.2a estimated similar selectivities.

The growth parameters were estimated by all northern rock sole models. Estimated asymptotic length was largest for model 17.1 followed by 17.2, 17.2a, and 17.b (Table 4.7, Figures 4.20 and 4.21). This was true for females and males. The von Bertalanffy growth coefficient for the female growth curve was similar among the models, whereas, models 17.2a and 17.b estimated larger growth coefficients (0.32, 0.30, respectively) than models 17.1 and 17.2, which were estimated to be 0.27 (Table 4.7). The estimate of female asymptotic length was largest for model 17.1 followed by 17.2, 17.2a, and 17.2b (45.08 cm, 42.67 cm, 41.96 cm, and 40.9 cm, respectively). This was also true for male asymptotic length, 38.83 cm, 37.18 cm, 36.03 cm, and 35.15 cm, respectively (Table 4.7). Model 17.2a estimated a more precise growth curve for females and males than the other models, which estimated greater uncertainty in the young and old ages (Table 4.7 and Figure 4.21). Because the growth relationship began to asymptote at age 10, coupled with the large uncertainty associated with older ages, a wide range of length classes were associated with a given age class.

Male natural mortality was estimated by all models. The estimates were similar; 0.25 for models 17.1 and 17.2 and 0.26 for models 17.2a and 17.2b (Table 4.7).

Tables 4.8 - 4.10 summarize the model estimates of and uncertainty in SSB, age-0 recruits, and fishing mortality. Figure 4.22 shows the results for the models considered and includes estimates of annual age-0 recruits, unfished recruitment on the log-scale, annual spawning biomass, and spawning biomass (SSB) in 2017, the terminal year of the assessment. The initial conditions of the model, estimated as $Ln(R_0)$ were similar among the models and ranged from 11.64 to 11.89 (Table 4.7, Figure 4.22). The density plot on Ln (R0) shows that the greatest divergence was between model 17.1 and 17.2b and that models 17.2 and 17.2a show considerable overlap with each other and the other two models (Figure 4.22). The offset from the initial conditions were similar between models 17.1 and 17.2 (-0.08 and -0.07, respectively) and were smaller than those from models 17.2a and 17.2b (-0.11 and -0.14, respectively). This resulted similar estimates of age-0 recruits and SSB in 1977 among models 17.1, 17.2a, and 17.2b.The recruitment time-series shows strong similarities among the models early in the time series and then some divergence in the 2000s. Namely the peaks estimated by model 17.2c were larger than the other models and a peak was predicted in 2014 that was not predicted by the other models.

The SSB time-series were similar among the models, where model 17.2 had slightly higher SSB between 1977 and 1994 and between 2003 and 2017 than 17.1. This was also true for total biomass (Figure 4.23). The survey biomass estimates cover the time period between 1996 and 2017 (Figure 4.11). Predicted survey biomass from model 17.2 are less than that from model 17.1 between 1996 and 2005 and greater from model 17.2 than model 17.1 between 2009 and 2015 (Figure 4.11); a similar trend is seen in the SSB and total biomass time series. At the end of the SSB time-series, the median estimate of SSB in the terminal year (2017) was identical for models 17.1 and 17.2a (Figure 4.22). Estimates of SSB 2017 was lowest for models 17.1 and 17.2a followed by model 17.2, and 17.2b. Model 17.1 and 17.2a distributions exhibited considerable overlap with model 17.2. SSB and total biomass are estimated to increase in recent years (Figures 4.22 and 4.23). This corresponds to a period of relatively low and stable fishing mortality (Figure 4.23).

The author recommends that model 17.2 be used to provide management advice. Model 17.1 was fit to the age composition twice, which is not a suggested practice when conducting stock assessments. Therefore, this model is not being recommended. Model 17.2a had improved fits to the survey total biomass time-series and to the fishery length composition data. This was partially the result of an estimated selectivity curve that was unrealistic. Length at full selection was associated with sizes in the tails of the length distribution where there is very little data and the selectivity parameters were highly uncertain (i.e., CVs in the tens of thousands). Therefore, this model is not recommended for use. Model 17.2b used the McAllister and Ianelli re-weighting approach, which led to upweights length composition and CAAL data by factors of 2, 4, and 5 for fishery length comp, survey length comp, and survey CAAL, respectively. This did not lead to an improvement in the index fit or fits to these data components. This model is not recommended for use.

Likelihood profiles

Likelihood profiling was conducted for several estimated model parameters for model 17.2 (Figure 4.24). Likelihood profiles can help evaluate how well parameters are estimated and highlight possible data conflicts in the assessment model. The profiles indicate that there are some apparent conflicts between the data components. The von Bertalanffy growth parameters were mainly informed by the CAAL data, which conflicted with the length data for asymptotic length and the length at the minimum age. The length and survey biomass data suggested asymptotic length should be lower than the CAAL and the length at minimum age should be higher. There was general agreement about male natural mortality and R_0.

Retrospective analysis

A retrospective analysis was conducted for model 17.2 to examine the consistency among parameter estimates as data were removed from the assessment model. The analysis extends back 10 years (2007-2016). A single peel of the data removed annual fishery catch and length composition data and every other year survey biomass estimates, survey length composition data, and survey CAAL data were removed. The results are shown in Figure 4.25 for SSB, age-0 recruits, fishing mortality, and the estimate of R_0. SSB increased and fishing mortality declined with each successively peel of the data. R_0 generally increased with each peel of the data. The estimates of age-0 recruits did not have a clear pattern, but the 2011 peak increased with the first three peels of the data and then declined with further removal of data.

The revised Mohn's ρ was calculated to indicate the direction and size of the retrospective bias. The revised Mohn's ρ statistic for SSB was equal to 0.14 indicating a positive bias. This indicates that previous assessments would have been more optimistic about stock size and would have resulted in more optimistic management advice. When models have a directional retrospective bias, this indicates that some aspect of the model that is assumed time-invariant may change over time (e.g., selectivity, natural mortality, catchability, etc.). Simulation results from Hurtado-Ferro *et al.* (2015) suggest that models with retrospective patterns with ρ values greater than 0.2 should explicitly address the cause of the retrospective pattern in the model. Model 17.2 has a ρ value less than 0.2, suggesting that at this time the cause of the retrospective does not have to be explicitly modeled, but should be evaluated in the future.

Southern rock sole

The southern rock sole assessment model was fit to the survey biomass estimates and the fishery and survey length composition data, and the survey conditional age-at-length data are shown in Figures 4.26 – 4.33. The total likelihood and the likelihood components associated with these data types are reported in Table 4.11. These values cannot be directly compared given the differences in the data included in the models and the data weighting schemes.

The fits to survey biomass were similar for all models and exhibit similar residual patterns (Figure 4.26). The models overestimate biomass in 1996 and 1999, underestimate biomass in 2005, 2007, and 2009, overestimate biomass in 2011, and fit the remainder of the biomass trend relatively well (Figure 4.26). The lines of best fit generally lie within the error bars of the biomass estimates indicating relatively good fit.

Figure 4.27 shows the model fits to the fishery and survey size composition data aggregated over year. The model fit to the female and male size composition data from the fishery are similar among the models and exhibit an adequate fit to the aggregate length composition data. The survey size composition data used in 17.1, 17.2, 17.2a, and 17.2c differed. Model17.1 used the 2015 survey size composition data, whereas the full complement of data (1996-2017) was used in the other models. The models were similar in that they did not fit the female size composition data particularly well. The model fits underestimated the frequency of 35cm – 45 cm southern rock sole. This size range corresponds to the overall peak of the observed survey size distribution.

Figures 4.28 and 4.29 show the model fits to the annual fishery length composition data and Figure 4.30 shows the Pearson residuals from the resulting model fits. The annual fits to the fishery length composition data were similar with regard to patterns and scale, except the model 17.2c residuals were larger than the other models. A residual pattern was consistent in all model fits where the models underestimated a cohort of females in years 2004 through 2008. The annual fits to the survey length data were similar among the models with regard to pattern and scale of the residuals (Figures 4.31 and 4.32). The 35cm – 45cm size range of the female survey length distribution was consistently underestimated by all models.

The fishery size composition data were fit using a double normal pattern to allow for dome-shape selectivity, whereas, the bottom trawl survey selectivity was modeled assuming asymptotic selectivity (Figure 4.34). The estimated fishery selectivity curves from models 17.2, 17.2a, and 17.2b shifted to the right of the model 17.1 estimated curve. This resulted in length at full selection that was larger and selectivity was higher for the largest female and male southern rock sole. The shift was more substantial for the fishery data. The models that implemented Francis and McAllister and Ianelli reweighting methods, 17.2a and 17.2b, exhibited a further rightward shift in fishery selectivity. Full selection of females by the fishery was at the tails of the length distribution which seems unlikely. The male fishery selectivity was estimated to be asymptotic for all models except model 17.2a where the curve was domed at ~57cm. The coefficient of variation (CV) associated with the selectivity parameters that control the width of plateau, descending width of the selectivity curve, and the selectivity of the final length bin were large indicating that these parameters were poorly determined by all of the models (Table 4.12). The estimated female survey selectivity curve for models 17.2, 17.2a, and 17.2b were similar and the rightward shift in comparison to the model 17.1's selectivity curve was more modest than what was seen for fishery selectivity. The estimated male survey selectivity curves were similar for models 17.2, 17.2a, and 17.2b and shifted to the left of the model 17.1 selectivity curve. Length at full selection was smaller than for model 17.1.

The models were also fit to the survey conditional age-at-length data (Figure 4.33). The fit to the larger, older individuals have larger residuals than the smaller, younger fish. Notably the models overestimated the age of larger fish in 2001 and 2007 and underestimated the age of larger fish in 2013 and 2015. The estimated standard deviation in the age-at-length estimates was higher than observed for the larger fish since there were very few observations of these length classes.

The growth parameters were estimated by all southern rock sole models. The growth curves were similar among the models (Figures 4.35 and 4.36). The von Bertalanffy growth coefficients were similar among the models for both females and males (Table 4.12). The range was 0.19 – 0.22 for females and 0.21 – 0.24 for males. Female asymptotic length was larger from model 17.1 than 17.2 (49.31 cm and 48.06 cm, respectively). The asymptotic length from models 17.2a and 17.2b were smaller, 46.8 cm and 47.11cm, respectively. Male asymptotic length was estimated to be between 38.52 cm and 40.4 cm (40.4 cm and 40.34 cm for models 17.1 and 17.2 and 38.52 cm and 39.17 cm for models 17.2a and 17.2b). The uncertainty in the growth curves was similar among the models. Given the fact that the growth relationship began to asymptote at age 10 and large uncertainty associated with older ages, a wide range of length classes were associated with a certain age class.

Male natural mortality was estimated by all models. The estimates were similar; 0.25 and 0.26 for models 17.1 and 17.2 and 0.28 for models 17.2a and 17.2b (Table 4.12).

Tables 4.13 – 4.15 summarize the model estimates of and uncertainty in SSB, age-0 recruits, and fishing mortality. Figures 4.37 and 4.38 show the results for the models considered and includes estimates of annual age-0 recruits, unfished recruitment on the log-scale, annual spawning biomass, spawning biomass (SSB) in 2017, the terminal year of the assessment, total biomass, and fishing mortality. The initial conditions, measured as R_0, were similar among the models, where the estimates were 12.25, 12.42, 12.51, and 12.53 for models 17.1, 17.2, 17.2a, and 17.2b, respectively (Table 4.12). The density plot of Ln (R_0) shows the greatest divergence between model 17.1 and 17.2b. It also shows that the model 17.2 distribution considerably overlapped with the other models' distributions (Figure 4.37). The offset from the initial conditions were similar for models 17.1, 17.2, and 17.2a, where the offset was estimated to be -0.10 and -0.09. A larger offset was estimated for model 17.2b, -0.22. The estimated time-series of age-0 recruits and SSB were similar among the models. The median estimate of SSB in the terminal year (2017) was also similar between models 17.1 and 17.2a. Estimates of SSB 2017 was lowest for model 17.1 followed by 17.2, 17.2a, and 17.2b. Although SSB has a declining trend in recent years, total biomass was estimated to increase after 2015 (Figure 4.38).

The author recommends that model 17.2 be used to provide management advice. Model 17.1 was fit to the age composition twice, which is not a suggested practice when conducting stock assessments. Therefore, this model is not being recommended. Models 17.2a and 17.2b did not lead to an improvement in the fit to the survey biomass data. Additionally, the Francis method suggested a larger weighting factor of 2.82 for the survey length composition data and the McAllister and Ianelli method led to weighting factors of 3.95, 11.74, and 4.08 for fishery length comp, survey length comp, and survey CAAL, respectively. These weighting factors are quite large; therefore, these models are not recommended for use.

Likelihood profiles

Likelihood profiling was conducted for several estimated model parameters for model 17.2. The results are shown in Figure 4.39. The von Bertalanffy growth parameters were mainly informed by the CAAL data and conflicted with the length composition data for several parameters. The length composition data suggested that the male von Bertalanffy growth coefficient and asymptotic length should be lower and the length at the minimum length should have been larger than what was suggested by the CAAL data. The length data suggested that the female asymptotic length should have been smaller and the length at the minimum age and male natural mortality should have been larger than what was suggested by the CAAL. There was general agreement about male natural mortality and R_0.

Retrospective analysis

A retrospective analysis was conducted for model 17.2. The analysis extends back 10 years (2007-2016). The results are shown in Figure 4.40. The retrospective pattern in spawning biomass for southern rock sole was not as obvious as northern rock sole. The spawning biomass estimates were similar for the first five peels and then were split above and below the estimates from the full model. The retrospective analysis showed little pattern in fishing mortality, but the 2010 estimate was smaller with each peel of the data. The estimates of R_0 varied. The R0 estimate for the first data peel was similar to the full model, the second peel and the last four peels were above the full model estimate, and peels three through six were below the full model estimate. A clear pattern in the age-0 recruit estimates was not apparent, but the estimated peaks in 2010 and 2013 were reduced with successive peels of the data.

The revised Mohn's ρ was calculated to indicate the direction and size of the retrospective bias. The revised Mohn's ρ statistic for SSB and was equal to 0.06 indicating a small, positive bias. Simulation results from Hurtado-Ferro *et al.* (2015) suggest that models with retrospective patterns with ρ values greater than 0.2 should explicitly address the cause of the retrospective pattern in the model. Model 17.2

has a ρ value less than 0.2, suggesting that at this time the cause of the retrospective does not have to be explicitly modeled, but should be evaluated in the future.

Time Series Results

Northern rock sole

Table 4.16 summarizes the spawning biomass and recruitment (age-0 recruits) time-series for northern rock sole with uncertainty. This table includes estimated time-series from the previous full assessment and the recommended model, 17.2. Spawning biomass has varied over time with a pronounced decline between 1995 and 2001, followed by an increase to peak spawning biomass in 2007, and a declining trend since. Recruitment has been quite variable overtime with predicted peaks in 1987, 1999, and 2011. The models generally follow the same trend, but recruitment is predicted to be generally higher by model 17.2 than the 2015 assessment model. Model 17.2 predicted that the 2011 peak in recruitment was 20% higher than the 2015 assessment.

SSB has been well above $SSB_{35\%}$ and fishing mortality has been well below $F_{35\%}$ (Figure 4.41).

The estimated total numbers-at-age for northern rock sole by model 17.2 are summarized in Table 4.18. It shows that the model estimated strong year classes for 1987, the mid- to late-1990s, 2004, and 2011.

Southern rock sole

Table 4.17 summarizes the spawning biomass and recruitment (age-0 recruits) time-series for southern rock sole with uncertainty (reported as CV). This table includes estimated time-series from the previous full assessment model and the recommended model, model 17.2. Spawning biomass was similar between the two models from 1977 until 1987, model 17.2 spawning biomass was less than the 2015 assessment from 1988 until 1998, and after 1988 the model estimates of spawning biomass converge to similar levels over the remainder of the time-series. Recruitment is also similar between the 2015 assessment model and model 17.2. The biggest departure between the estimates is at the end of the time series when the age-0 recruit estimates from model 17.2 are larger than the 2015 assessment. Model 17.2 predicts a large increase in recruitment between 2012 and 2013 followed by a decline through 2015 and then an increase, whereas the 2015 assessment model predicts increasing recruitment between 2012 and 2017.

SSB has been well above $SSB_{35\%}$ and fishing mortality has been well below $F_{35\%}$ (Figure 4.42).

The estimated total numbers-at-age for northern rock sole by model 17.2 are summarized in Table 4.19. Model 17.2 estimated strong year classes in the late 1970s and early 1980s, 1987, 1998, 2003, 2010, and 2013. The length and age data start in 1997.

Harvest Recommendations

The GOA northern and southern rock sole stocks were moved from Tier 4 to Tier 3 of the NPFMC harvest guidelines in 2011. In Tier 3, reference mortality rates are based on the spawning biomass per recruit (SPR), while biomass reference levels are estimated by multiplying the SPR by average recruitment. Estimates of the FSPR harvest rates were obtained using the life history characteristics. Spawning biomass reference levels were based on average age-0 recruitment for 1977-2017. Female spawning biomass was calculated using the mean weight-at-age of mature females at the time of spawning. A summary of the projection results are presented here and in the executive summary table at the beginning of the report. The projection inputs are from model 17.2. These inputs include, natural mortality, mature female weight-at-age, female and male weight-at-age, female and male age-based fishery selectivity, female and male numbers at age in the terminal year (2017), age-0 recruits from 1977 to 2017, and spawning biomass from 1977 to 2017.

	Northern rock sole	Southern rock sole
SB_{2017}	41,831	76,053
$SB_{40\%}$	20,621	37,433
$SB_{35\%}$	18,044	32,754
F_{ABC}	0.382	0.271
ABC	16,802	21,424
F_{OFL}	0.462	0.326
OFL	19,960	25,333

Biomass projections

A standard set of projections is required for stocks managed under Tier 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2017 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2018 using the schedules of natural mortality and fishery selectivity described in the assessment and the best available estimate of total annual catch for 2017 and 2018. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2018, are as follows ("max FABC" refers to the maximum permissible value of FABC under Amendment 56):

Scenario 1: In all future years, F is set equal to max FABC. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In all future years, F is set equal to a constant fraction of max FABC, where this fraction is equal to the ratio of the FABC value for 2015 recommended in the assessment to the max FABC for 2016. (Rationale: When FABC is set at a value below max FABC, it is often set at the value recommended in the stock assessment.)

Scenario 3: In all future years, F is set equal to the average of the five most recent years. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of FTAC than FABC.)

Scenario 4: In all future years, the upper bound on FABC is set at F60%. (Rationale: This scenario provides a likely lower bound on FABC that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follows (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

> Scenario 6: In all future years, F is set equal to FOFL. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above its MSY level in 2017 and above its MSY level in 2030 under this scenario, then the stock is not overfished.)
>
> Scenario 7: In 2018 and 2019, F is set equal to max FABC, and in all subsequent years, F is set equal to FOFL. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2030 under this scenario, then the stock is not approaching an overfished condition.)

The projection results indicate the northern (Table 4.20) and southern (Table 4.21) rock sole are not currently overfished and are not approaching an overfished condition. Under scenario 6, northern rock sole spawning biomass in 2017 is 40,363 t and the year 2030 spawning biomass is 19,343 t, both are above the $B_{35\%}$ level of 18,044 t. For scenario 7, the year 2030 spawning biomass is 19,345 t, also above $B_{35\%}$. Southern rock sole spawning biomass under scenario 6 in 2030 is 35,351 t and 2017 biomass is 73,436 t, both of which are above the $B_{35\%}$ level of 32,754 t. For scenario 7, the 2030 spawning biomass is 35,354 t and is also above $B_{35\%}$.

The author's recommendation for F_{ABC} and ABC for northern and southern rock sole for 2018 are 0.382 and 16,802 t and 0.271and 21,424 t, respectively. F_{OFL}, max F_{ABC}, and F_{ABC} are larger than those from the 2016 projections. Age-based fishery selectivity was derived from length based selectivity in SS3 and used as the input for the projections (Figure 4.43 and 4.44). Female and male northern rock sole 2017 fishery selectivity was to the right of the selectivity curve estimated by the 2015 assessment model. Maximum selectivity was also lowered from 0.84 for older ages to 0.68 and 0.93 to 0.80 for females and males, respectively. Female and male southern rock sole 2017 fishery selectivity also shifted to the right of the selectivity curve estimated by the 2015 assessment model. The difference was minimal for males, but maximum selectivity was lowered from 0.93 to 0.8 for females. Additionally, the male natural mortality estimates from model 17.2 were higher than the 2016 projection input. Male natural mortality was increased from 0.25 to 0.253 and from 0.248 to 0.262 for northern and southern rock sole, respectively. The directional change in selectivity and natural mortality led to the increase in F_{OFL}, max F_{ABC}, and F_{ABC}.

Ecosystem Considerations

See the shallow water flatfish chapter for information on ecosystem considerations for the Gulf of Alaska shallow-water flatfish fishery and stocks.

Ecosystem Effects on the Stock

See the shallow water flatfish chapter for information on ecosystem considerations for the Gulf of Alaska shallow-water flatfish fishery and stocks.

Fishery Effects on the Ecosystem

See the shallow water flatfish chapter for information on ecosystem considerations for the Gulf of Alaska shallow-water flatfish fishery and stocks.

Data Gaps and Research Priorities

Several data gaps and research priorities stand out for this assessment. The first is the apportionment of total rock sole catch, which has been a consistent concern over time. Potential future avenues to address this problem include determining the proportion of northern and southern catch from the observer and survey databases and compare the changes over time. Additionally, future models should include a measure of uncertainty associated with the catch. Currently the model assumes that catch is known perfectly when in fact we know this is not true. Another priority should be to evaluate how to best model mixed species fisheries that do not have a specific target, as it pertains to rock sole. The author suggests using a simulation framework to evaluate the current single species models, the previously used mixed species model, and other mixed species modeling approaches. One possible future modeling approach could evaluate how the growth morph option in SS3 could be used to model mixed species population dynamics while not making assumptions about the apportionment of total rock sole catch. The author and Carey McGilliard are planning to apply for research funds to carry out this work.

Literature Cited

Allen, M.J., Smith, G.B. 1988. Atlas and Zoogeography of Common Fishes in the Bering Sea and Northeastern Pacific. NOAA Technical Report NMFS 66, 151 pp.

Francis, R.I.C.C. 2011. Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68: 1124-1138.

McAllister, M.K., Ianelli, J.N. 1997. Bayesian stock assessment using catch-at-age data nad sampling-importance resampling algorithm. Canadian Journal of Fisheries and Aquatic Sciences 54: 284-300.

Methot, R. D., Wetzell, C. R. 2013. Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management. Fisheries Research 142: 86-99.

Orr, J.W., Matarese, A.C. 2000. Revision of the genus Lepidopsetta Gill, 1862 (Teleostei: Pleuronectidae) based on larval and adult morphology, with a description of a new species from the North Pacific Ocean and Bering Sea. Fisheries Bulletin 98(3), 539-582.

Stark, J.W., Somerton, D.A. 2002. Maturation, spawning and growth of rock soles off Kodiak Island in the Gulf of Alaska. Journal of Fish Biology 61: 417 – 431.

Thorson, J., Johnson, K.F., Methot, R.D., Taylor, I.G. 2017. Model-based estimates of effective sample size in stock assessment models using the Dirichlet-multinomial distribution. Fisheries Research 192: 84-93.

Turnock, B.J., A'mar, Z.T., Wilderbuer, T.K. 2009. Assessment of the shallow-water flatfish stock assemblage in the Gulf of Alaska for 2010. In: Stock Assessment and Fishery Evaluation Report for Groundfish Resources in the Gulf of Alaska. North Pacific Fishery Management Council, Anchorage, AK, USA.

Turnock, B.J., A'mar, Z.T., Wilderbuer, T.K. 2011. Assessment of the shallow-water flatfish stock assemblage in the Gulf of Alaska for 2012. In: Stock Assessment and Fishery Evaluation Report for Groundfish Resources in the Gulf of Alaska. North Pacific Fishery Management Council, Anchorage, AK, USA.

Wilderbuer, T.K, Nichol, D.G. 2009. Assessment of northern rock sole in the eastern Bering Sea and Aleutian Islands for 2010. In: Stock Assessment and Fishery Evaluation Report for Groundfish Resources in the Eastern Bering Sea and Aleutian Islands. North Pacific Fishery Management Council, Anchorage, AK, USA.

Tables

Table 4.1. Total rock sole catch from Alaska Fisheries Information Network (AKFIN) as of 2017-08.
*Value represents an estimate of 2017 catch.

Year	Catch (t)
1993	8112.12
1994	3008.11
1995	3923.91
1996	6595.32
1997	5466.78
1998	2532.34
1999	1765.35
2000	5386.69
2001	4771.73
2002	5564.29
2003	3554.642
2004	2216.745
2005	4130.501
2006	5763.282
2007	6727.395
2008	7269.088
2009	6538.692
2010	3285.281
2011	3094.423
2012	2828.570
2013	4058.255
2014	3440.340
2015	2622.197
2016	3008.461
2017	2575.325*

Table 4.2. Discarded catches (t) of rock sole, percent of total catch, and total catch (t) by gear (NPT = bottom trawl and non-pelagic trawl and Other = pot, jig, and hook and line. Gears were combined for confidentiality) by NMFS area for 1993-2017. Source: NMFS Alaska Regional Office via AKFIN, October 25, 2017.

		610			620			630			Combined		
Year	Gear	Discard	% Discard	Catch	Discard	% Discard	Catch	Discard	% Discard	Catch	Discard	% Discard	Catch
1993	NPT	121	97.90	123	92	24.45	376	2105	27.65	7612	2318	28.58	8112
	Other	0	100.00	0							0	100.00	0
1994	NPT	31	70.98	43	159	16.11	987	374	19.43	1924	566	19.16	2956
	Other	1	100.00	1	0	0	0			51	1	2.03	52
1995	NPT	41	87.78	47	66	11.32	583	623	19.09	3264	731	18.75	3896
	Other	0	100.00	0				0		0	2	7.21	28
1996	NPT	4	5.13	71	126	6.03	2089	427	9.74	4386	556	8.50	6546
	Other	1	100.00	1				4	8.51	47	6	11.68	49
1997	NPT	15	56.94	26	140	16.02	872	392	8.64	4530	547	10.01	5463
	Other		0.00	0	0	74.47	0	1	31.56	3	1	37.11	4
1998	NPT	21	55.05	39	2	0.36	476	13	0.66	1930	36	1.44	2497
	Other	1	67.44	1		0.00	0		0.00	34	1	2.47	35
1999	NPT	21	33.94	63	0	0.85	57	11	0.70	1630	33	1.90	1753
	Other	1	87.39	1		0.00	0	0	1.62	11	1	9.69	13
2000	NPT	192	56.33	341	4	1.00	408	27	0.60	4499	223	4.21	5289
	Other	0	71.43	1	0	9.03	4		0.00	90	1	0.87	98
2001	NPT	6	7.96	75	2	0.60	333	12	0.28	4328	20	0.43	4737
	Other												
2002	NPT	26	26.30	99	1	0.05	1754	76	2.10	3633	103	1.88	5488
	Other	2	71.16	3									
2003	NPT	13	11.46	117	8	0.85	898	66	2.63	2492	87	2.47	3506
	Other	7	55.17	12	8	77.04	10	4	15.95	26	19	38.44	49
2004	NPT	24	30.02	81	25	6.08	413	96	5.61	1711	145	6.59	2206
	Other	1	80.56	2	1	47.20	3	1	8.96	6	3	31.77	11
2005	NPT	1	1.05	80	21	3.37	620	150	4.39	3423	172	4.18	4123
	Other	1	89.75	1	0	75.31	0	0	2.23	6	1	18.87	7

Table 4.2. continued

		610			620			630			Combined		
Year	Gear	Discard	% Discard	Catch	Discard	% Discard	Catch	Discard	% Discard	Catch	Discard	% Discard	Catch
2006	NPT	5	9.45	48	13	1.57	853	118	2.44	4811	135	2.37	5712
	Other	3	87.09	3	1	5.30	18	0	0.76	29	4	7.75	51
2007	NPT	10	16.88	57	29	2.91	988	161	2.86	5614	199	2.99	6659
	Other	2	77.26	2	0	1.48	25	1	1.56	41	3	4.12	68
2008	NPT	6	11.77	54	40	3.29	1217	185	3.09	5976	231	3.19	7247
	Other	3	86.39	4	1	9.35	8				4	19.41	22
2009	NPT	16	23.09	68	2	0.21	1146	20	0.38	5317	38	0.59	6531
	Other	1	19.09	7							1	17.98	8
2010	NPT	12	28.69	43	1	0.56	233	8	0.26	2975	21	0.65	3250
	Other	3	54.53	5	1	34.03	3	1	1.92	26	4	12.82	35
2011	NPT	19	44.76	43	3	0.76	371	6	0.23	2596	28	0.93	3010
	Other	3	4.08	69	1	48.56	2				4	4.41	84
2012	NPT	7	12.10	55	1	0.36	311	5	0.20	2417	13	0.45	2783
	Other	0	0.89	42					0.00	2	0	1.05	45
2013	NPT	9	36.64	25	3	0.38	658	2	0.06	3303	14	0.35	3987
	Other	2	47.15	4	2	8.08	22	1	2.76	46	5	6.70	72
2014	NPT	3	23.84	14	5	0.91	525	36	1.30	2797	45	1.33	3336
	Other	4	19.19	22	2	15.89	13				6	5.92	104
2015	NPT	6	30.28	19	0	0.05	292	3	0.14	2216	9	0.35	2527
	Other	6	15.86	41	1	9.61	13				8	8.18	95
2016	NPT	2	21.50	7	0	0.13	346	3	0.12	2561	5	0.18	2914
	Other	11	96.11	12	1	38.87	2		0.00	80	12	13.01	95
2017	NPT	1	19.27	7	1	0.16	723	2	0.23	931	5	0.29	1661
	Other	16	86.67	18	3	22.15	15				19	57.01	34

Table 4.3. a) Number of lengths by year, species, and sex and hauls sampled by the NMFS fisheries observer program. b) Number of Number of lengths by year, species, and sex and hauls sampled by the NMFS GOS trawl survey.

a)

	NRS			SRS			U/NRS/SRS	
Year	Female	Male	Hauls	Female	Male	Hauls	Female	Male
1989	-	-	-	-	-	-	184	211
1990	-	-	-	-	-	-	2319	2585
1991	-	-	-	-	-	-	4915	3323
1992	-	-	-	-	-	-	11995	10988
1993	-	-	-	-	-	-	12093	9306
1994	-	-	-	-	-	-	3171	2872
1995	-	-	-	-	-	-	6326	4909
1996	-	-	-	-	-	-	15756	11890
1997	542	334	14	1020	587	9	14864	11826
1998	1807	1148	95	3168	2081	109	8171	5276
1999	394	242	41	197	197	17	955	713
2000	1818	1482	204	1404	1121	150	3756	3146
2001	1913	1545	273	1828	1332	200	3983	3049
2002	3256	1929	368	1643	1162	242	5205	3461
2003	1293	1192	189	1041	779	116	2616	2173
2004	520	314	81	1242	719	112	1944	1205
2005	977	803	157	1120	681	128	2457	1896
2006	1979	1177	244	1113	634	124	3233	1930
2007	1978	1713	296	1731	1197	191	4598	3697
2008	1717	1087	224	1999	1455	167	4353	3005
2009	2273	1679	301	2218	1459	187	4569	3223
2010	1064	1093	174	1087	742	119	2216	1914
2011	314	327	65	479	275	35	818	622
2012	1036	657	140	1733	1202	175	2769	1859
2013	851	1154	114	669	498	84	1520	1652
2014	746	779	92	338	249	45	1084	1028
2015	520	547	15	104	90	27	624	637
2016	1172	1504	147	379	203	60	1551	1707
2017	174	272	29	178	118	34	352	390

b)

Year	Northern rock sole			Southern rock sole		
	Female	Male	Hauls	Female	Male	Hauls
1996	160	113	22	210	118	39
1999	268	184	31	273	212	36
2001	396	274	101	538	301	107
2003	299	207	65	353	223	67
2005	221	166	55	262	158	61
2007	302	224	77	269	172	75
2009	290	224	54	293	220	56
2011	240	172	73	241	143	71
2013	225	173	61	268	183	62
2015	259	199	51	248	151	46
2017	360	232	74	428	296	81

Table 4.4. NMFS GOA bottom trawl survey total biomass estimates (in metric tons) and standard deviation.

Year	Species	Total biomass	SD
1984	Unidentified	137623.3	12208.20
1987	Unidentified	123393	20328.94
1990	Unidentified	156032.4	19472.26
1993	Unidentified	173043.6	14569.99
1996	northern rock sole	78845	9929.87
1999	northern rock sole	61543.4	15133.87
2001	northern rock sole	64808.8	9887.32
2003	northern rock sole	79648.2	9513.65
2005	northern rock sole	91452.8	10123.21
2007	northern rock sole	102640.7	12063.82
2009	northern rock sole	95845.8	16067.68
2011	northern rock sole	72875	12426.75
2013	northern rock sole	74587	13586.89
2015	northern rock sole	52068.9	7612.96
2017	northern rock sole	55047.1	8262.62
1996	southern rock sole	127390	12580.04
1999	southern rock sole	106234.5	10580.32
2001	southern rock sole	122491.6	14643.07
2003	southern rock sole	126819.3	12479.76
2005	southern rock sole	147580.1	15092.81
2007	southern rock sole	162357.7	11810.29
2009	southern rock sole	191764.5	22591.33
2011	southern rock sole	120572.9	10318.33
2013	southern rock sole	131427.5	13993.24
2015	southern rock sole	125234.2	9530.97
2017	southern rock sole	107985	9568.10

Table 4.5. Summary of data and model assumptions for the northern and southern rock sole model alternatives.

Model	**17.1**	**17.2**
SS version	SS3v3.30.06	SS3v3.30.06
Model dimensions		
Start and end year	1977, 2017	1977, 2017
Data		
Fishery catch	1977-2017	1977-2017
Survey biomass estimates	1996-2011 (triennial), 2003-2017 (biennial)	1996-2011 (triennial), 2003-2017 (biennial)
Fishery length comp	1997-2017	1997-2017
Survey length comp	2015	1996-2011 (triennial), 2003-2017 (biennial)
Survey age composition	1996-2011 (triennial), 2003-2015 (biennial)	-
Survey conditional age at length	1996-2011 (triennial), 2003-2015 (biennial)	1996-2011 (triennial), 2003-2015 (biennial)
Growth	Von Bertalannfy	Von Bertalannfy
L_at_Amin (Fem & Mal)	Estimated	Estimated
L_at_Amax (Fem & Mal)	Estimated	Estimated
K (Fem & Mal)	Estimated	Estimated
CV_young (Fem & Mal)	Estimated	Estimated
CV_old (Fem & Mal)	Estimated	Estimated
Natural mortality	0.2 (Female), Estimated (Male)	0.2 (Female), Estimated (Male)
Maturity	Fixed input vector	Fixed input vector
Stock recruitment		
Ln(R0)	Estimated	Estimated
Steepness	Fixed = 1	Fixed = 1
σ_R	Fixed = 0.6	Fixed = 0.6
R1_offset*	Estimated	Estimated
Recruitment devs	Estimated (1977-2017)	Estimated (1977-2017)
Catchability	Fixed =1	Fixed =1
Selectivity – length	Double normal	Double normal
Fishery		
P1: Peak (Fem)	Estimated	Estimated
P2: top (Fem)	Estimated	Estimated
P3:Ascend width (Fem)	Estimated	Estimated
P4: Descend width (Fem)	Estimated	Estimated
P5:Selex first bin (Fem)	Fixed = -4	Fixed = -4
P6: Selex last bin (Fem)	Estimated	Estimated
P1: Peak (Male)	Estimated	Estimated
P2: Ascend width (Male)	Estimated	Estimated
P3: Descend width (Male)	Fixed = 0	Fixed = 0
P4: Selex last bin (Male)	Fixed = 0	Fixed = 0
P5: Scale (Male)	Fixed = 1	Fixed = 1

*In SS3v3.30 R1_offset parameter no longer exists. It is estimated as a SR regime parameter

Table 4.5. Continued

Model	17.1	17.2
Selectivity – length	Double normal	Double normal
Survey		
P1: Peak (Fem)	Estimated	Estimated
P2: top (Fem)	Fixed = 0	Fixed = 0
P3:Ascend width (Fem)	Estimated	Estimated
P4: Descend width (Fem)	Fixed = 0	Fixed = 0
P5:Selex first bin (Fem)	Fixed = -10	Fixed = -10
P6: Selex last bin (Fem)	Fixed = 10	Fixed =10
P1: Peak (Male)	Estimated	Estimated
P2: Ascend width (Male)	Estimated	Estimated
P3: Descend width (Male)	Fixed = 0	Fixed = 0
P4: Selex last bin (Male)	Fixed = 0	Fixed = 0
P5: Scale (Male)	Fixed = 1	Fixed = 1

Table 4.6. Total likelihood and likelihood components for the northern rock sole models.

	Model			
Likelihood	17.1	17.2	17.2a	17.2b
Total	1005.08	1006.15	1871.00	2765.03
Survey	-13.44	-11.94	-14.93	-4.69
Length composition	244.33	298.59	131.98	813.99
Age composition	781.02	727.65	1760.83	1960.44

Table 4.7. Parameter estimates/values and CVs for key parameters from the northern rock sole models.

	17.1		17.2		17.2a		17.2b	
Label	Value	CV	Value	CV	Value	CV	Value	CV
Growth								
Female								
Natural mortality	0.20	-	0.20	-	0.20	-	0.20	-
L_at_Amin	10.59	0.06	10.80	0.05	9.77	0.05	10.86	0.04
L_at_Amax	45.08	0.02	42.67	0.02	41.96	0.01	40.91	0.01
VonBert_K	0.21	0.06	0.23	0.06	0.25	0.04	0.24	0.03
CV_young	2.27	0.13	2.18	0.13	3.01	0.08	2.46	0.08
CV_old	7.78	0.05	7.50	0.04	6.12	0.03	6.94	0.02
Male								
Natural mortality	0.25	0.03	0.25	0.03	0.26	0.03	0.26	0.02
L_at_Amin	9.80	0.07	10.55	0.06	9.39	0.06	10.70	0.04
L_at_Amax	38.83	0.02	37.18	0.02	36.03	0.01	35.15	0.01
VonBert_K	0.27	0.07	0.27	0.07	0.32	0.05	0.30	0.04
CV_young	2.51	0.12	2.23	0.12	2.91	0.08	2.26	0.07
CV_old	5.27	0.05	5.52	0.05	4.25	0.04	5.02	0.03
Stock-recruitment								
LN R0	11.64	0.01	11.78	0.01	11.76	0.01	11.89	0.01
Steepness	1.00	-	1.00	-	1.00	-	1.00	-
SR_regime	-0.08	1.54	-0.07	1.75	-0.11	1.16	-0.14	0.92
Selectivity								
Fishery								
Peak - beginning size for plateau (Female)	46.58	0.04	52.25	0.02	65.00	0.00	65.00	0.00
Top - width of plateau (Female)	0.36	0.18	-0.03	4.34	0.00	80046	0.03	8161
Ascending width (Female)	5.41	0.02	5.69	0.01	6.20	0.01	6.10	0.01
Descending width (Female)	-5.02	3.71	-8.49	2.74	0.00	174543	0.00	120455
Selectivity of first length bin (Female)	-10.00	-	-10.00	-	-10.00	-	-10.00	-
Selectivity of final length bin (Female)	-0.24	4.34	1.30	2.47	5.04	14.91	7.37	6.27
Added to peak (Male)	-9.34	0.16	-11.78	0.08	-14.72	0.15	-15.53	0.06
Added to ascending width (Male)	-0.80	0.19	-0.87	0.13	-0.74	0.26	-0.81	0.09
Added to descending width (Male)	0.00	-	0.00	-	0.00	-	0.00	-
Added to final size bin (Male)	0.00	-	0.00	-	0.00	-	0.00	-
Apical selectivity (Male)	1.00	-	1.00	-	1.00	-	1.00	-

Table 4.7. continued

	17.1		17.2		17.2a		17.2b	
Label	Value	CV	Value	CV	Value	CV	Value	CV
Selectivity								
Survey								
Peak - beginning size for plateau (Female)	33.96	0.08	36.46	0.05	36.28	0.05	38.71	0.02
Top - width of plateau (Female)	0.00	-	0.00	-	0.00	-	0.00	-
Ascending width (Female)	4.84	0.07	5.07	0.04	5.11	0.05	5.20	0.02
Descending width (Female)	0.00	-	0.00	-	0.00	-	0.00	-
Selectivity of first length bin (Female)	-10.00	-	-10.00	-	-10.00	-	-10.00	-
Selectivity of final length bin (Female)	10.00	-	10.00	-	10.00	-	10.00	-
Added to peak (Male)	-5.68	-0.49	-6.38	-0.31	-6.45	-0.32	-7.55	-0.11
Added to ascending width (Male)	-0.72	-0.66	-0.74	-0.39	-0.74	-0.40	-0.81	-0.14
Added to descending width (Male)	0.00	-	0.00	-	0.00	-	0.00	-
Added to final size bin (Male)	0.00	-	0.00	-	0.00	-	0.00	-
Apical selectivity (Male)	1.00	-	1.00	-	1.00	-	1.00	-

Table 4.8. Spawning biomass (SSB) and associated CV estimates from the northern rock sole assessment models.

	17.1		17.2		17.2a		17.2b	
Year	SSB	CV	SSB	CV	SSB	CV	SSB	CV
1977	42070	0.22	45484	0.22	40384	0.21	41970	0.20
1978	41468	0.22	44900	0.22	39664	0.21	41090	0.20
1979	40832	0.22	44267	0.22	38898	0.21	40152	0.20
1980	40073	0.22	43499	0.22	37999	0.21	39075	0.20
1981	39318	0.22	42727	0.22	37084	0.21	37971	0.19
1982	38427	0.21	41845	0.21	36027	0.20	36729	0.19
1983	38527	0.20	41932	0.21	35924	0.19	36393	0.18
1984	38524	0.20	41985	0.20	35799	0.19	36052	0.17
1985	39395	0.18	42912	0.19	36586	0.17	36563	0.16
1986	40744	0.17	44280	0.17	37824	0.16	37448	0.15
1987	41744	0.16	45258	0.16	38622	0.15	37887	0.14
1988	41702	0.15	45183	0.15	38412	0.14	37378	0.13
1989	41637	0.14	45009	0.14	38276	0.13	36964	0.12
1990	41009	0.13	44231	0.14	37706	0.12	36163	0.11
1991	41186	0.12	43938	0.13	38106	0.11	36242	0.10
1992	42814	0.11	44601	0.12	40121	0.10	37779	0.09
1993	45137	0.10	45865	0.10	42696	0.09	39838	0.08
1994	48148	0.08	47526	0.09	45912	0.09	42446	0.07
1995	49768	0.08	48314	0.09	47612	0.08	43853	0.07
1996	49083	0.07	47388	0.08	47116	0.08	43414	0.06
1997	47062	0.07	45522	0.08	45372	0.07	42009	0.06
1998	45243	0.07	43958	0.07	43604	0.07	40708	0.06
1999	43704	0.07	42715	0.07	42096	0.07	39647	0.06
2000	42264	0.06	41683	0.07	40858	0.07	38811	0.06
2001	41084	0.06	40959	0.07	40222	0.07	38507	0.05
2002	41466	0.06	41742	0.06	41281	0.06	39754	0.05
2003	42121	0.06	43038	0.06	42286	0.06	41199	0.05
2004	43960	0.06	45532	0.06	44228	0.06	43798	0.05
2005	47321	0.05	49351	0.06	48188	0.06	48005	0.05
2006	50964	0.05	52827	0.05	53182	0.06	52342	0.05
2007	51625	0.05	52878	0.05	54903	0.06	53449	0.05
2008	49249	0.05	50103	0.06	53081	0.06	51454	0.05
2009	45933	0.06	46819	0.06	49730	0.06	48707	0.05
2010	43695	0.06	45188	0.06	47072	0.06	47728	0.05
2011	43214	0.06	45555	0.06	46088	0.06	49099	0.06
2012	42660	0.06	45612	0.06	45286	0.06	50331	0.06
2013	41013	0.06	44204	0.07	43509	0.07	49717	0.06
2014	38349	0.07	41590	0.07	40689	0.07	47541	0.06
2015	36015	0.07	39428	0.07	37969	0.07	45536	0.07
2016	35386	0.07	39284	0.08	36566	0.07	45677	0.07
2017	37151	0.08	41831	0.08	37227	0.08	49535	0.07

Table 4.9. Estimates of age-0 recruits and associated CVs from the northern rock sole assessment models.

	17.1		17.2		17.2a		17.2b	
Year	Recruits	CV	Recruits	CV	Recruits	CV	Recruits	CV
1977	89696	0.5526	106962	0.5619	93259	0.5295	96252	0.5102
1978	101211	0.5646	119916	0.5742	106459	0.5389	108787	0.5148
1979	108930	0.5551	127793	0.5664	115225	0.5247	115430	0.498
1980	95328	0.5458	113071	0.5559	97712	0.5176	96833	0.4915
1981	88176	0.5185	104665	0.5289	89629	0.4937	88283	0.4695
1982	83380	0.5017	98061	0.5128	88494	0.4758	87012	0.4515
1983	75874	0.5004	89764	0.5081	81194	0.4798	79763	0.4554
1984	98032	0.5063	109819	0.5012	103752	0.4862	101151	0.4554
1985	150121	0.4528	139528	0.4836	170296	0.4086	162753	0.3811
1986	127796	0.5082	136307	0.4984	135303	0.4842	132463	0.4449
1987	228140	0.277	208062	0.3297	245323	0.2563	232039	0.2439
1988	96227	0.3926	100840	0.4172	107094	0.3712	105764	0.3485
1989	77745	0.3262	86682	0.3595	89756	0.3054	89363	0.2907
1990	81753	0.2574	93963	0.2964	98647	0.2351	101964	0.2221
1991	89683	0.2072	100920	0.2467	92991	0.205	99854	0.1914
1992	72411	0.2059	82595	0.2414	80321	0.1897	85782	0.1767
1993	58372	0.2198	72409	0.248	68621	0.1902	73677	0.1755
1994	92613	0.1724	107671	0.212	108702	0.1462	115012	0.1325
1995	128794	0.138	139538	0.1779	157200	0.1148	158666	0.1039
1996	111889	0.1442	137186	0.1773	126406	0.1208	137619	0.1076
1997	129555	0.1331	153088	0.1684	137935	0.1136	159603	0.0987
1998	143668	0.1309	171682	0.162	165531	0.1084	187077	0.0941
1999	207862	0.1109	221981	0.1371	270684	0.0925	254277	0.0843
2000	112354	0.1433	107992	0.1838	147045	0.1168	142992	0.1059
2001	57006	0.1811	62825	0.218	84933	0.1422	81856	0.1306
2002	54670	0.1859	62512	0.2287	66134	0.1547	74921	0.1408
2003	87477	0.16	112056	0.1948	94122	0.1378	132332	0.1195
2004	104867	0.151	139592	0.1796	111660	0.1313	175731	0.1113
2005	103462	0.1479	126834	0.1782	121949	0.1278	174246	0.1103
2006	56667	0.1823	71533	0.2125	72795	0.1483	99440	0.1306
2007	51544	0.1905	59389	0.2254	64778	0.1563	83290	0.1391
2008	44153	0.2194	58535	0.2489	50649	0.1768	75610	0.1564
2009	76456	0.2101	98832	0.2416	76770	0.1751	120259	0.1522
2010	119936	0.2086	157376	0.2373	107103	0.1808	199577	0.1509
2011	190680	0.1972	226533	0.2234	188157	0.1864	334359	0.1453
2012	129378	0.2405	138936	0.2745	195008	0.2151	269555	0.1677
2013	77147	0.364	84364	0.3827	141161	0.325	105679	0.291
2014	102956	0.4489	127100	0.4501	106902	0.4687	272452	0.2531
2015	100807	0.5735	113609	0.5672	116027	0.5779	112446	0.5275
2016	107690	0.5865	122753	0.5834	120069	0.5825	117926	0.5428
2017	113630	0.6034	131118	0.6039	128329	0.603	145716	0.6026

Table 4.10. Fishing mortality estimates from the northern rock sole assessment models.

	17.1		17.2		17.2a		17.2b	
Year	F	CV	F	CV	F	CV	F	CV
1977	0.042	0.216	0.05	0.219	0.114	0.226	0.126	0.202
1978	0.04	0.216	0.048	0.220	0.11	0.226	0.122	0.201
1979	0.043	0.215	0.05	0.219	0.116	0.225	0.129	0.200
1980	0.041	0.213	0.048	0.218	0.112	0.223	0.125	0.197
1981	0.046	0.210	0.055	0.215	0.127	0.220	0.143	0.194
1982	0.014	0.203	0.017	0.209	0.039	0.214	0.044	0.187
1983	0.031	0.194	0.037	0.200	0.088	0.206	0.1	0.178
1984	0.018	0.183	0.021	0.191	0.049	0.197	0.057	0.168
1985	0.008	0.173	0.009	0.181	0.022	0.187	0.025	0.157
1986	0.007	0.162	0.008	0.171	0.019	0.178	0.022	0.146
1987	0.026	0.153	0.031	0.163	0.074	0.171	0.087	0.137
1988	0.013	0.145	0.016	0.155	0.037	0.164	0.043	0.129
1989	0.031	0.136	0.037	0.147	0.086	0.157	0.103	0.121
1990	0.039	0.127	0.048	0.139	0.11	0.152	0.132	0.112
1991	0.041	0.118	0.052	0.130	0.117	0.146	0.143	0.104
1992	0.055	0.111	0.071	0.123	0.157	0.142	0.193	0.097
1993	0.064	0.105	0.085	0.117	0.183	0.139	0.227	0.092
1994	0.024	0.100	0.031	0.112	0.066	0.136	0.082	0.088
1995	0.031	0.096	0.041	0.106	0.085	0.132	0.106	0.084
1996	0.053	0.092	0.071	0.103	0.144	0.130	0.179	0.082
1997	0.046	0.090	0.061	0.100	0.124	0.128	0.152	0.080
1998	0.022	0.087	0.029	0.097	0.059	0.126	0.072	0.078
1999	0.016	0.085	0.02	0.094	0.041	0.124	0.05	0.076
2000	0.048	0.083	0.062	0.092	0.127	0.123	0.153	0.075
2001	0.043	0.082	0.055	0.090	0.113	0.122	0.135	0.074
2002	0.049	0.080	0.062	0.088	0.129	0.121	0.153	0.072
2003	0.03	0.078	0.038	0.086	0.079	0.119	0.093	0.071
2004	0.018	0.075	0.022	0.083	0.046	0.117	0.054	0.069
2005	0.031	0.073	0.04	0.081	0.081	0.114	0.095	0.067
2006	0.044	0.070	0.055	0.079	0.11	0.112	0.129	0.065
2007	0.052	0.068	0.066	0.077	0.129	0.109	0.151	0.064
2008	0.059	0.067	0.074	0.077	0.143	0.108	0.166	0.064
2009	0.056	0.068	0.069	0.077	0.134	0.106	0.151	0.064
2010	0.029	0.068	0.035	0.077	0.069	0.105	0.076	0.064
2011	0.028	0.068	0.034	0.078	0.067	0.104	0.071	0.064
2012	0.027	0.068	0.032	0.078	0.064	0.103	0.065	0.064
2013	0.04	0.070	0.047	0.079	0.096	0.103	0.096	0.065
2014	0.035	0.071	0.041	0.081	0.085	0.104	0.082	0.066
2015	0.027	0.075	0.031	0.084	0.067	0.105	0.061	0.068
2016	0.029	0.080	0.034	0.088	0.076	0.108	0.067	0.070
2017	0.029	0.088	0.034	0.093	0.062	0.113	0.053	0.074

Table 4.11. Total likelihood and likelihood components for the southern rock sole models.

	Model			
Likelihood	17.1	17.2	17.2a	17.2b
Total	985.74	953.22	942.63	2951.20
Survey	-17.76	-18.71	-16.78	-16.70
Length composition	148.11	189.00	158.49	985.41
Age composition	856.54	787.12	805.04	1980.15

Table 4.12. Parameter estimates and CVs for key parameters from the southern rock sole model.

	17.1		17.2		17.2a		17.2b	
Label	Value	CV	Value	CV	Value	CV	Value	CV
Growth								
Female								
Natural mortality	0.20	-	0.20	-	0.20	-	0.20	-
L_at_Amin	12.22	0.05	12.29	0.05	11.59	0.06	12.82	0.03
L_at_Amax	49.31	0.01	48.06	0.01	46.81	0.01	47.11	0.01
VonBert_K	0.19	0.05	0.20	0.05	0.22	0.04	0.21	0.03
CV_young	3.20	0.09	3.18	0.09	3.51	0.09	3.17	0.05
CV_old	4.93	0.05	4.83	0.04	4.34	0.04	4.65	0.02
Male								
Natural mortality	0.25	0.03	0.26	0.03	0.28	0.03	0.28	0.01
L_at_Amin	13.20	0.04	13.69	0.04	13.16	0.04	14.48	0.02
L_at_Amax	40.40	0.02	40.34	0.02	38.52	0.01	39.17	0.01
VonBert_K	0.23	0.07	0.21	0.07	0.24	0.06	0.21	0.04
CV_young	2.42	0.10	2.39	0.10	2.70	0.10	2.23	0.07
CV_old	4.44	0.06	4.49	0.06	3.60	0.07	4.61	0.03
Stock-recruitment								
LN R0	12.35	0.01	12.42	0.01	12.51	0.00	12.53	0.00
Steepness	1.00	-	1.00	-	1.00	-	1.00	-
SR_regime	-0.10	-1.19	-0.09	-1.39	-0.09	-1.32	-0.22	-0.55
Selectivity								
Fishery								
Peak - beginning size for plateau (Female)	48.24	0.04	54.46	0.05	65.00	0.00	63.05	0.02
Top - width of plateau (Female)	2.39	9.82	1.88	21.71	0.22	665.17	1.06	86.38
Ascending width (Female)	5.46	0.03	5.80	0.03	6.22	0.01	6.14	0.01
Descending width (Female)	-0.49	-397.25	0.44	449.34	0.00	-68182	0.07	3148
Selectivity of first length bin (Female)	-10.00	-	-10.00	-	-10.00	-	-10.00	-
Selectivity of final length bin (Female)	2.80	36.41	3.25	32.18	0.95	194.04	3.53	27.95
Added to peak (Male)	-10.39	-0.18	-15.06	-0.15	-19.84	-0.08	-20.79	-0.05
Added to ascending width (Male)	-0.89	-0.20	-1.16	-0.14	-1.14	-0.15	-1.33	-0.05
Added to descending width (Male)	0.00	-	0.00	-	0.00	-	0.00	-
Added to final size bin (Male)	0.00	-	0.00	-	0.00	-	0.00	-
Apical selectivity (Male)	1.00	-	1.00	-	1.00	-	1.00	-

Table 4.12. continued

Label	17.1 Value	17.1 CV	17.2 Value	17.2 CV	17.2a Value	17.2a CV	17.2b Value	17.2b CV
Selectivity								
Survey								
Peak - beginning size for plateau (Female)	41.42	0.06	43.63	0.04	45.29	0.03	46.05	0.01
Top - width of plateau (Female)	0.00	-	0.00	-	0.00	-	0.00	-
Ascending width (Female)	5.26	0.05	5.42	0.03	5.55	0.02	5.54	0.01
Descending width (Female)	0.00	-	0.00	-	0.00	-	0.00	-
Selectivity of first length bin (Female)	-10.00	-	-10.00	-	-10.00	-	-10.00	-
Selectivity of final length bin (Female)	10.00	-	10.00	-	10.00	-	10.00	-
Added to peak (Male)	0.76	5.40	-6.17	-0.35	-7.57	-0.21	-8.71	-0.09
Added to ascending width (Male)	0.18	2.27	-0.52	-0.47	-0.61	-0.27	-0.71	-0.11
Added to descending width (Male)	0.00	-	0.00	-	0.00	-	0.00	-
Added to final size bin (Male)	0.00	-	0.00	-	0.00	-	0.00	-
Apical selectivity (Male)	1.00	-	1.00	-	1.00	-	1.00	-

Table 4.13. Spawning biomass (SSB in tons) estimates and associated CVs from the southern rock sole assessment models.

	17.1		17.2		17.2a		17.2b	
Year	SSB	CV	SSB	CV	SSB	CV	SSB	CV
1977	74,903	0.196	80,187	0.198	85,349	0.197	69,675	0.183
1978	73,747	0.196	79,183	0.197	84,244	0.196	67,774	0.181
1979	72,482	0.194	77,997	0.196	82,936	0.195	65,770	0.179
1980	71,110	0.192	76,598	0.195	81,396	0.193	63,674	0.177
1981	70,009	0.189	75,351	0.192	80,012	0.190	61,843	0.173
1982	69,431	0.185	74,497	0.188	79,060	0.187	60,476	0.169
1983	71,004	0.177	75,638	0.181	80,197	0.179	61,134	0.160
1984	74,226	0.167	78,045	0.173	82,740	0.171	63,308	0.150
1985	80,447	0.154	82,781	0.162	87,791	0.160	68,677	0.136
1986	88,953	0.141	89,110	0.150	94,566	0.149	77,003	0.121
1987	97,960	0.128	95,648	0.139	101,588	0.138	86,554	0.108
1988	105,471	0.116	100,839	0.128	107,200	0.127	94,798	0.096
1989	111,322	0.106	104,865	0.118	111,492	0.117	101,106	0.087
1990	113,828	0.098	106,318	0.110	113,021	0.109	104,084	0.080
1991	113,579	0.092	105,771	0.102	112,486	0.102	104,889	0.074
1992	112,102	0.085	104,319	0.095	111,179	0.094	105,399	0.068
1993	109,507	0.080	101,946	0.088	109,134	0.087	105,524	0.062
1994	105,794	0.075	98,747	0.082	106,414	0.081	104,913	0.058
1995	102,897	0.070	96,617	0.075	104,827	0.074	105,187	0.053
1996	98,995	0.067	93,695	0.069	102,348	0.068	104,295	0.049
1997	93,290	0.065	89,208	0.066	97,987	0.064	100,822	0.047
1998	87,332	0.064	84,628	0.063	93,206	0.061	96,126	0.045
1999	82,678	0.062	81,255	0.060	89,509	0.058	92,243	0.043
2000	79,181	0.060	78,874	0.058	86,781	0.055	89,305	0.042
2001	75,938	0.060	76,594	0.057	84,066	0.054	86,417	0.040
2002	74,112	0.059	75,608	0.057	82,338	0.053	84,454	0.039
2003	73,268	0.059	75,558	0.056	81,054	0.053	83,190	0.039
2004	74,514	0.059	77,632	0.056	81,610	0.052	84,287	0.038
2005	78,330	0.058	82,221	0.054	84,971	0.051	88,404	0.037
2006	83,345	0.058	87,656	0.053	89,894	0.050	93,802	0.036
2007	87,386	0.058	91,658	0.053	93,945	0.049	97,865	0.036
2008	88,912	0.059	92,952	0.053	95,416	0.050	99,129	0.036
2009	88,618	0.059	92,549	0.053	95,228	0.050	98,751	0.037
2010	88,518	0.060	92,502	0.054	95,621	0.050	99,192	0.038
2011	89,559	0.060	93,645	0.054	97,534	0.050	101,521	0.039
2012	90,048	0.061	94,210	0.054	99,154	0.051	103,615	0.040
2013	88,833	0.062	93,032	0.054	99,057	0.051	103,577	0.041
2014	84,995	0.063	89,178	0.056	95,962	0.053	100,037	0.042
2015	79,953	0.065	84,110	0.057	91,105	0.054	94,576	0.044
2016	75,154	0.066	79,374	0.058	86,045	0.056	89,137	0.045
2017	71,715	0.069	76,053	0.060	82,114	0.058	85,437	0.048

Table 4.14. Age-0 recruit estimates (in 1000s) and associated CVs from the southern rock sole assessment models.

	17.1		17.2		17.2a		17.2b	
Year	Recruits	CV	Recruits	CV	Recruits	CV	Recruits	CV
1977	389,714	0.704	353,516	0.644	381,490	0.638	356,735	0.609
1978	400,833	0.721	349,040	0.647	379,442	0.643	436,685	0.636
1979	336,098	0.709	324,754	0.636	354,991	0.635	377,649	0.659
1980	376,016	0.649	329,571	0.608	361,639	0.606	374,447	0.590
1981	314,606	0.579	295,131	0.555	320,732	0.554	308,341	0.523
1982	197,438	0.537	211,277	0.535	229,871	0.534	204,931	0.506
1983	210,607	0.512	217,254	0.516	238,959	0.518	226,272	0.503
1984	289,524	0.455	274,107	0.484	309,671	0.489	378,185	0.414
1985	234,043	0.436	228,800	0.475	264,775	0.481	301,509	0.420
1986	145,482	0.465	173,086	0.482	199,639	0.493	173,109	0.476
1987	277,045	0.260	269,195	0.331	325,343	0.327	423,087	0.211
1988	126,739	0.367	151,365	0.400	175,979	0.404	170,770	0.345
1989	126,743	0.282	148,586	0.324	168,348	0.323	170,988	0.239
1990	109,781	0.276	138,637	0.306	153,198	0.303	133,060	0.239
1991	167,174	0.199	182,132	0.238	202,983	0.232	209,706	0.159
1992	127,949	0.221	148,282	0.251	168,366	0.244	185,215	0.164
1993	211,619	0.160	233,209	0.191	255,473	0.184	251,179	0.120
1994	179,080	0.172	197,183	0.207	197,968	0.202	187,860	0.130
1995	179,255	0.169	199,522	0.204	184,006	0.198	199,084	0.118
1996	231,861	0.152	272,032	0.180	234,668	0.179	277,715	0.099
1997	317,076	0.133	353,310	0.162	358,895	0.154	403,362	0.082
1998	418,699	0.113	431,113	0.140	473,448	0.132	463,328	0.076
1999	206,602	0.162	211,436	0.202	232,716	0.193	241,530	0.109
2000	148,443	0.184	158,301	0.225	167,853	0.219	166,569	0.130
2001	231,321	0.147	259,935	0.177	278,398	0.170	280,334	0.099
2002	226,905	0.154	251,328	0.191	271,483	0.184	281,115	0.107
2003	305,955	0.132	320,438	0.163	367,558	0.155	433,258	0.085
2004	185,517	0.164	215,800	0.191	253,431	0.185	257,307	0.111
2005	171,066	0.161	183,365	0.188	240,000	0.174	240,209	0.104
2006	63,222	0.238	76,569	0.258	94,219	0.251	76,345	0.172
2007	81,886	0.222	96,840	0.242	109,889	0.232	103,684	0.149
2008	119,875	0.213	141,588	0.230	147,284	0.220	147,456	0.142
2009	170,471	0.215	190,688	0.234	186,836	0.226	220,417	0.138
2010	237,537	0.215	254,480	0.229	264,602	0.213	339,662	0.126
2011	106,540	0.314	122,900	0.324	140,331	0.306	127,494	0.229
2012	153,663	0.341	163,649	0.351	182,832	0.326	136,833	0.268
2013	323,657	0.366	349,492	0.376	487,002	0.285	490,525	0.181
2014	237,546	0.545	280,872	0.555	289,927	0.518	530,613	0.256
2015	195,685	0.566	219,759	0.577	215,964	0.547	151,407	0.472
2016	208,711	0.574	231,224	0.582	229,117	0.555	175,181	0.492
2017	229,909	0.603	247,039	0.603	270,708	0.603	275,798	0.601

Table 4.15. Fishing mortality estimates from the southern rock sole assessment models.

	17.1		17.2		17.2a		17.2b	
Year	F	CV	F	CV	F	CV	F	CV
1977	0.022	0.201	0.026	0.210	0.041	0.197	0.047	0.189
1978	0.021	0.200	0.025	0.209	0.040	0.196	0.046	0.188
1979	0.022	0.197	0.026	0.207	0.042	0.194	0.048	0.186
1980	0.021	0.194	0.025	0.205	0.040	0.192	0.047	0.182
1981	0.023	0.189	0.027	0.200	0.044	0.187	0.052	0.177
1982	0.007	0.180	0.008	0.194	0.013	0.180	0.016	0.168
1983	0.014	0.170	0.017	0.186	0.028	0.172	0.033	0.157
1984	0.007	0.161	0.009	0.178	0.015	0.163	0.017	0.147
1985	0.003	0.152	0.004	0.170	0.006	0.154	0.007	0.137
1986	0.002	0.143	0.003	0.162	0.005	0.145	0.006	0.129
1987	0.009	0.135	0.012	0.155	0.020	0.138	0.021	0.122
1988	0.004	0.127	0.006	0.149	0.010	0.130	0.010	0.117
1989	0.010	0.121	0.014	0.143	0.023	0.123	0.023	0.112
1990	0.013	0.115	0.018	0.137	0.030	0.117	0.029	0.108
1991	0.015	0.110	0.020	0.132	0.033	0.110	0.031	0.104
1992	0.021	0.106	0.029	0.128	0.047	0.104	0.044	0.101
1993	0.027	0.103	0.036	0.124	0.057	0.099	0.053	0.098
1994	0.010	0.100	0.014	0.120	0.022	0.094	0.020	0.096
1995	0.014	0.097	0.019	0.117	0.029	0.090	0.026	0.094
1996	0.025	0.095	0.033	0.114	0.051	0.086	0.046	0.092
1997	0.022	0.094	0.029	0.112	0.044	0.083	0.039	0.091
1998	0.011	0.093	0.014	0.110	0.021	0.081	0.019	0.089
1999	0.008	0.092	0.010	0.109	0.015	0.079	0.013	0.088
2000	0.024	0.092	0.030	0.108	0.048	0.078	0.042	0.087
2001	0.022	0.092	0.027	0.107	0.043	0.077	0.038	0.086
2002	0.025	0.093	0.031	0.106	0.050	0.077	0.044	0.085
2003	0.016	0.094	0.019	0.106	0.032	0.076	0.028	0.084
2004	0.009	0.095	0.011	0.105	0.019	0.076	0.017	0.083
2005	0.016	0.094	0.020	0.105	0.034	0.074	0.030	0.082
2006	0.022	0.093	0.028	0.103	0.047	0.073	0.041	0.081
2007	0.026	0.092	0.032	0.102	0.054	0.071	0.047	0.080
2008	0.028	0.091	0.034	0.101	0.058	0.070	0.050	0.079
2009	0.025	0.091	0.031	0.100	0.051	0.070	0.045	0.078
2010	0.013	0.090	0.015	0.099	0.026	0.069	0.022	0.078
2011	0.012	0.089	0.015	0.098	0.024	0.068	0.021	0.077
2012	0.011	0.088	0.014	0.097	0.022	0.067	0.019	0.077
2013	0.017	0.087	0.021	0.096	0.033	0.066	0.029	0.076
2014	0.015	0.087	0.018	0.096	0.029	0.066	0.025	0.076
2015	0.012	0.088	0.015	0.096	0.023	0.066	0.020	0.076
2016	0.014	0.092	0.017	0.098	0.027	0.068	0.024	0.077
2017	0.016	0.097	0.018	0.100	0.024	0.071	0.021	0.078

Table 4.16. GOA northern rock sole SSB (t) and age-0 recruit estimates from the 2015 assessment and the preferred model 17.2.

	2015 Assessment				2017 Preferred model			
Year	SSB	CV	Recruits	CV	SSB	CV	Recruits	CV
1977	42,786	0.218	89,705	0.548	45,484	0.218	106,962	0.562
1978	42,151	0.218	100753	0.558	44,900	0.218	119,916	0.574
1979	41,482	0.218	107934	0.548	44,267	0.218	127,793	0.566
1980	40,685	0.217	94,561	0.539	43,499	0.217	113,071	0.556
1981	39,890	0.215	87,327	0.512	42,727	0.215	104,665	0.529
1982	38,951	0.213	82,407	0.496	41,845	0.213	98,061	0.513
1983	39,030	0.205	75,108	0.495	41,932	0.205	89,764	0.508
1984	38,997	0.196	96,645	0.498	41,985	0.197	109,819	0.501
1985	39,839	0.184	146112	0.448	42,912	0.186	139,528	0.484
1986	41,161	0.170	126503	0.498	44,280	0.173	136,307	0.498
1987	42,147	0.158	222418	0.277	45,258	0.162	208,062	0.330
1988	42,077	0.149	95,663	0.388	45,183	0.153	100,840	0.417
1989	41,999	0.139	77,367	0.325	45,009	0.144	86,682	0.360
1990	41,329	0.131	81,702	0.257	44,231	0.136	93,963	0.296
1991	41,395	0.121	90,527	0.206	43,938	0.126	100,920	0.247
1992	42,851	0.109	73,835	0.205	44,601	0.116	82,595	0.241
1993	44,989	0.097	60,304	0.218	45,865	0.105	72,409	0.248
1994	47,806	0.087	94,232	0.172	47,526	0.094	107,671	0.212
1995	49,445	0.079	132216	0.137	48,314	0.087	139,538	0.178
1996	48,860	0.075	116508	0.143	47,388	0.081	137,186	0.177
1997	46,945	0.072	134732	0.133	45,522	0.078	153,088	0.168
1998	45,266	0.070	151632	0.130	43,958	0.075	171,682	0.162
1999	43,910	0.067	220746	0.110	42,715	0.072	221,981	0.137
2000	42,657	0.065	119571	0.143	41,683	0.069	107,992	0.184
2001	41,614	0.063	61,266	0.181	40,959	0.067	62,825	0.218
2002	42,174	0.061	60,008	0.187	41,742	0.065	62,512	0.229
2003	43,058	0.059	94,559	0.164	43,038	0.063	112,056	0.195
2004	45,195	0.056	115387	0.155	45,532	0.060	139,592	0.180
2005	48,977	0.053	113649	0.155	49,351	0.056	126,834	0.178
2006	53,132	0.052	62,498	0.190	52,827	0.054	71,533	0.213
2007	54,211	0.053	55,178	0.205	52,878	0.055	59,389	0.225
2008	52,099	0.055	46,687	0.239	50,103	0.056	58,535	0.249
2009	48,965	0.058	67,154	0.255	46,819	0.058	98,832	0.242
2010	46,924	0.060	83,793	0.297	45,188	0.061	157,376	0.237
2011	46,720	0.063	187763	0.354	45,555	0.062	226,533	0.223
2012	46,419	0.066	131347	0.534	45,612	0.064	138,936	0.275
2013	44,881	0.069	101836	0.596	44,204	0.067	84,364	0.383
2014	42,143	0.074	103266	0.597	41,590	0.070	127,100	0.450
2015	39,468	0.078	109799	0.603	39,428	0.073	113,609	0.567
2016	37,981	0.083	114853	0.603	39,284	0.077	122,753	0.583
2017					41,831	0.083	131,118	0.604

Table 4.17. GOA southern rock sole SSB (t) and age-0 recruit estimates from the 2015 assessment and the preferred model 17.2.

	2015 Assessment				2017 Preferred			
Year	SSB	CV	Recruits	CV	SSB	CV	Recruits	CV
1977	76,687	0.197	380,305	0.700	80,187	0.198	353,516	0.644
1978	75,474	0.197	394,784	0.715	79,183	0.197	349,040	0.647
1979	74,146	0.195	331,533	0.706	77,997	0.196	324,754	0.636
1980	72,706	0.193	369,959	0.648	76,598	0.195	329,571	0.608
1981	71,537	0.190	311,801	0.578	75,351	0.192	295,131	0.555
1982	70,896	0.186	195,164	0.537	74,497	0.188	211,277	0.535
1983	72,418	0.178	207,962	0.513	75,638	0.181	217,254	0.516
1984	75,586	0.168	288,539	0.456	78,045	0.173	274,107	0.484
1985	81,730	0.155	234,340	0.437	82,781	0.162	228,800	0.475
1986	90,144	0.142	145,209	0.467	89,110	0.150	173,086	0.482
1987	99,075	0.129	280,160	0.261	95,648	0.139	269,195	0.331
1988	106,538	0.118	128,252	0.369	100,839	0.128	151,365	0.400
1989	112,368	0.108	128,415	0.283	104,865	0.118	148,586	0.324
1990	114,867	0.100	110,931	0.278	106,318	0.110	138,637	0.306
1991	114,617	0.093	169,108	0.199	105,771	0.102	182,132	0.238
1992	113,164	0.087	128,676	0.222	104,319	0.095	148,282	0.251
1993	110,632	0.082	212,065	0.161	101,946	0.088	233,209	0.191
1994	107,012	0.078	177,670	0.173	98,747	0.082	197,183	0.207
1995	104,230	0.073	180,934	0.169	96,617	0.075	199,522	0.204
1996	100,456	0.070	241,559	0.150	93,695	0.069	272,032	0.180
1997	94,851	0.068	316,856	0.133	89,208	0.066	353,310	0.162
1998	88,952	0.067	410,749	0.115	84,628	0.063	431,113	0.140
1999	84,335	0.065	206,070	0.163	81,255	0.060	211,436	0.202
2000	80,859	0.064	147,705	0.185	78,874	0.058	158,301	0.225
2001	77,630	0.064	232,602	0.150	76,594	0.057	259,935	0.177
2002	75,814	0.064	236,560	0.156	75,608	0.057	251,328	0.191
2003	75,026	0.064	331,563	0.135	75,558	0.056	320,438	0.163
2004	76,402	0.064	204,014	0.167	77,632	0.056	215,800	0.191
2005	80,368	0.063	177,730	0.170	82,221	0.054	183,365	0.188
2006	85,454	0.063	61,890	0.250	87,656	0.053	76,569	0.258
2007	89,478	0.063	72,520	0.249	91,658	0.053	96,840	0.242
2008	90,973	0.064	118,466	0.243	92,952	0.053	141,588	0.230
2009	90,737	0.065	147,424	0.280	92,549	0.053	190,688	0.234
2010	90,923	0.066	218,871	0.327	92,502	0.054	254,480	0.229
2011	92,538	0.067	193,941	0.443	93,645	0.054	122,900	0.324
2012	93,736	0.068	132,196	0.531	94,210	0.054	163,649	0.351
2013	93,051	0.070	180,518	0.569	93,032	0.054	349,492	0.376
2014	89,325	0.072	197,647	0.582	89,178	0.056	280,872	0.555
2015	83,979	0.074	221,642	0.603	84,110	0.057	219,759	0.577
2016	78,724	0.076	231,844	0.603	79,374	0.058	231,224	0.582
2017					76,053	0.060	247,039	0.603

Table 4.18. Model 17.2 estimated northern rock sole numbers-at-age (total).

	Age																														
Year	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+
1977	106962	78560	62078	50467	41368	33949	27795	22405	17956	14314	11361	8986	7089	5582	4389	3447	2705	2122	1665	1306	1024	807	633	496	389	306	240	189	148	117	434
1978	119916	85299	62691	49568	40280	32938	26920	21940	17615	14073	11194	8871	7010	5527	4351	3421	2687	2110	1656	1299	1019	800	631	495	388	305	239	188	148	116	432
1979	127793	95629	68069	50057	39565	32078	26127	21260	17261	13817	11016	8750	6928	5472	4313	3395	2670	2098	1647	1293	1015	797	626	494	387	304	239	188	148	116	431
1980	113071	101911	76312	54351	39953	31501	25434	20621	16711	13526	10803	8599	6824	5400	4264	3361	2646	2081	1636	1285	1009	793	623	489	386	303	238	187	147	116	430
1981	104665	90171	81325	60933	43383	31816	24987	20085	16222	13108	10587	8443	6715	5325	4213	3327	2623	2065	1625	1278	1004	789	620	487	383	302	237	187	147	115	429
1982	98061	83467	71956	64935	48629	34529	25207	19696	15763	12687	10226	8245	6568	5220	4138	3274	2585	2039	1606	1264	994	782	615	483	380	299	236	185	146	115	426
1983	89764	78200	66609	57461	51872	38833	27548	20090	15685	12546	10096	8137	6562	5229	4157	3298	2610	2062	1627	1282	1010	795	625	492	387	304	239	189	149	117	435
1984	109819	71584	62405	53188	45878	41348	30864	21825	15872	12365	9876	7940	6396	5157	4109	3268	2593	2053	1622	1281	1010	796	627	493	388	305	240	189	150	118	437
1985	139528	87577	57126	49833	42483	36623	32964	24569	17351	12608	9818	7840	6303	5079	4096	3265	2598	2062	1633	1292	1020	805	634	500	394	310	244	192	151	120	445
1986	136307	111269	69889	45620	39816	33948	29260	26330	19622	13858	10072	7845	6268	5042	4065	3280	2616	2082	1654	1311	1037	820	647	510	402	317	250	197	155	122	456
1987	208062	108701	88796	55812	36450	31820	27128	23378	21037	15679	11076	8053	6276	5017	4037	3257	2630	2099	1672	1328	1054	834	659	521	411	324	256	201	159	125	467
1988	100840	165923	86745	70906	44568	29071	25319	21530	18512	16629	12379	8739	6352	4950	3957	3186	2571	2076	1658	1321	1050	834	660	522	413	326	257	203	160	126	471
1989	86682	80417	132411	69271	56643	35594	23199	20186	17151	14740	13238	9855	6958	5059	3944	3154	2541	2051	1658	1325	1056	840	667	529	418	331	261	206	163	128	480
1990	93963	69126	64173	105731	55308	45154	28293	18381	15949	13523	11604	10411	7746	5468	3976	3100	2480	1998	1614	1305	1043	832	662	526	417	330	261	207	163	129	483
1991	100920	74933	55163	51241	84395	44047	35820	22348	14464	12513	10586	9071	8131	6046	4267	3102	2419	1936	1561	1261	1020	816	651	519	412	327	259	205	162	128	481
1992	82595	80481	59796	44046	40897	67188	34916	28259	17557	11326	9775	8256	7066	6330	4706	3321	2414	1883	1508	1216	983	796	637	508	405	322	256	203	160	127	478
1993	72409	65867	64222	47743	35137	32503	53070	27393	22038	13627	8760	7541	6358	5436	4866	3616	2551	1855	1448	1159	935	756	612	490	392	312	248	197	156	124	468
1994	107671	57744	52560	51274	38072	27892	25608	41469	21249	16996	10464	6705	5760	4849	4141	3705	2752	1942	1412	1102	883	713	577	467	374	299	238	190	151	120	453
1995	139538	85865	46081	41970	40944	30364	22193	20324	32840	16800	13423	8259	5290	4544	3825	3268	2924	2173	1534	1116	871	698	564	457	370	297	237	189	151	120	456
1996	137186	111277	68521	36795	33506	32627	24117	17564	16035	25848	13201	10536	6478	4148	3562	2999	2562	2294	1705	1204	876	685	549	444	359	291	234	187	149	119	455
1997	153088	109402	88797	54708	29353	26631	25773	18923	13699	12448	19999	10189	8119	4986	3191	2739	2306	1970	1764	1311	926	675	527	423	342	277	225	180	144	115	444
1998	171682	122083	87302	70900	43654	23350	21076	20281	14816	10684	9681	15523	7899	6289	3861	2470	2120	1785	1525	1366	1016	718	523	409	328	266	215	175	140	112	436
1999	221980	136911	97424	69713	56619	34823	18588	16739	16076	11727	8449	7652	12266	6242	4970	3052	1953	1677	1413	1208	1082	805	569	415	325	261	211	171	139	112	437
2000	107992	177023	109258	77798	55684	45199	27764	14799	13311	12774	9314	6709	6077	9744	4960	3951	2427	1554	1335	1125	962	862	642	454	331	259	208	169	137	111	440
2001	62825	86121	141262	87236	62076	44289	35759	21836	11579	10372	9925	7222	5195	4701	7535	3835	3055	1877	1202	1033	871	745	668	498	352	257	201	162	131	106	429
2002	62512	50101	68724	112793	69620	49406	35088	28186	17135	9054	8090	7728	5617	4038	3653	5854	2980	2374	1459	935	804	678	580	520	388	275	200	157	126	102	419
2003	112056	49852	39980	54872	89998	55374	39087	27597	22054	13353	7035	6273	5984	4345	3122	2824	4526	2304	1837	1129	724	622	525	450	403	301	213	156	122	98	406
2004	139592	89361	39782	31924	43810	71735	44006	30961	21798	17383	10508	5531	4929	4701	3414	2453	2220	3559	1812	1445	889	570	490	414	355	318	237	168	123	96	399
2005	126834	111321	71312	31768	25499	34968	57173	35016	24603	17305	13792	8336	4387	3910	3730	2710	1948	1764	2829	1442	1150	708	454	391	330	283	254	190	134	98	397
2006	71533	101147	88834	56943	25362	20321	27779	45261	27636	19373	13605	10831	6542	3442	3068	2927	2127	1530	1385	2223	1134	905	557	358	308	260	223	200	150	106	392
2007	59389	57046	80714	70931	45443	20185	16098	21893	35509	21605	15106	10590	8422	5083	2674	2383	2273	1652	1189	1077	1729	882	704	434	279	240	203	174	156	117	389
2008	58535	47361	45522	64445	56591	36133	15958	12647	17105	27623	16753	11688	8181	6500	3921	2062	1837	1753	1275	917	831	1336	682	545	336	216	186	157	135	121	393
2009	98832	46680	37793	36345	51406	44965	28525	12509	9852	13258	21332	12904	8986	6283	4988	3008	1581	1409	1345	978	704	639	1026	524	419	258	166	143	121	104	397
2010	157376	78815	37250	30175	28995	40864	35532	22394	9764	7655	10268	16481	9953	6924	4838	3840	2316	1217	1085	1036	754	543	493	792	405	324	200	128	111	94	388
2011	226532	125503	62895	29745	24093	23117	32492	28168	17708	7706	6034	8086	12973	7833	5450	3809	3024	1824	959	856	817	595	429	389	626	320	256	158	102	88	383
2012	138936	180653	100153	50223	23751	19211	18385	25768	22285	13984	6078	4756	6371	10219	6171	4294	3002	2384	1439	757	676	646	470	339	308	495	253	203	125	81	374
2013	84364	110797	144164	79974	40104	18941	15285	14589	20401	17614	11041	4796	3751	5025	8061	4869	3389	2370	1883	1137	599	534	511	372	269	244	393	201	161	99	361
2014	127100	67278	88416	115112	63836	31940	15027	12074	11482	16009	13794	8635	3748	2930	3924	6295	3802	2647	1852	1472	889	468	418	400	292	211	191	308	158	126	363
2015	113609	101359	53688	70600	91898	50868	25368	11892	9525	9035	12577	10824	6772	2938	2297	3077	4937	2983	2078	1454	1157	699	368	329	315	230	166	151	243	125	386
2016	122753	90600	80886	42871	56377	73293	40477	20134	9417	7531	7135	9925	8540	5342	2318	1813	2429	3899	2357	1643	1150	915	553	292	261	250	182	132	120	193	407
2017	131118	97892	72299	64588	34231	44951	58286	32095	15925	7434	5937	5621	7815	6724	4206	1826	1428	1914	3074	1859	1296	908	723	437	231	206	198	144	104	95	476

Table 4.19. Model 17.2 estimated southern rock sole numbers-at-age (total).

	Age																														
Year	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+
1977	353516	222483	140371	95808	71043	55857	45745	38383	32017	25936	20576	16293	12973	10370	8298	6635	5298	4226	3368	2682	2135	1723	1367	1086	862	686	545	434	345	275	1086
1978	349040	280688	176816	111662	76272	56560	44428	36323	30418	25328	20490	16241	12854	10233	8180	6546	5236	4183	3338	2661	2121	1689	1364	1083	860	684	544	433	344	274	1083
1979	324754	277135	223075	140654	88893	60726	44993	35284	28794	24073	20020	16183	12821	10146	8077	6458	5170	4137	3306	2640	2106	1679	1338	1081	859	683	543	432	344	274	1082
1980	329572	257852	220250	177451	111972	70771	48300	35724	27960	22776	19016	15800	12765	10111	8001	6371	5096	4081	3267	2612	2087	1666	1329	1059	856	681	541	431	343	273	1079
1981	295130	261676	204925	175205	141268	89150	56298	38360	28320	22128	18004	15019	12474	10076	7982	6318	5032	4026	3226	2584	2067	1652	1320	1053	840	680	540	430	342	273	1077
1982	211276	234331	207965	163013	139476	112461	70896	44685	30382	22387	17467	14197	11837	9828	7938	6289	4979	3968	3176	2546	2040	1633	1306	1044	833	665	538	428	341	272	1072
1983	217254	167752	186236	165439	129796	111129	89636	56513	35621	24222	17852	13934	11331	9452	7853	6347	5032	3987	3179	2546	2042	1638	1312	1050	839	670	535	434	345	275	1086
1984	274106	172498	133320	148150	131715	103374	88478	71303	44907	28281	19219	14161	11052	8989	7501	6234	5041	3999	3170	2529	2027	1627	1305	1046	837	670	536	428	347	276	1090
1985	228800	217638	137093	106058	117960	104940	82382	70508	56814	35781	22536	15319	11292	8818	7176	5991	4983	4032	3200	2538	2026	1625	1305	1048	840	673	539	431	344	279	1103
1986	173086	181665	172970	109061	84450	94004	83684	65730	56284	45377	28594	18021	12259	9043	7067	5755	4809	4002	3241	2574	2043	1632	1310	1053	846	678	544	435	348	279	1120
1987	269196	137428	144380	137601	86842	67302	74969	66778	52480	44965	36274	22874	14427	9821	7250	5670	4621	3865	3219	2608	2073	1647	1316	1057	850	683	548	440	352	282	1135
1988	151365	213738	109221	114855	109558	69179	53615	59700	53151	41754	35768	28855	18199	11483	7821	5776	4520	3686	3085	2571	2085	1658	1318	1054	847	681	548	440	353	283	1140
1989	148586	120182	169870	86888	91453	87300	55153	42757	47622	42410	33329	28564	23056	14551	9187	6261	4628	3624	2958	2477	2066	1676	1334	1061	849	682	549	442	355	285	1152
1990	138637	117976	95515	135132	69178	72847	69532	43904	34013	37862	33706	26486	22701	18329	11572	7309	4985	3687	2889	2359	1977	1649	1339	1066	849	679	547	440	354	285	1155
1991	182132	110076	93761	75981	107585	55094	57992	55299	34876	26992	30024	26717	20991	17993	14531	9177	5800	3957	2928	2296	1876	1573	1313	1067	850	677	542	436	352	283	1153
1992	148282	144611	87483	74586	60491	85672	43848	46099	43897	27651	21381	23769	21146	16613	14243	11505	7270	4596	3138	2323	1823	1490	1250	1044	849	677	539	432	348	281	1148
1993	233208	117734	114928	69590	59375	48151	68114	34788	36487	34670	21802	16839	18706	16634	13067	11203	9052	5721	3619	2472	1831	1437	1176	987	825	671	535	427	342	276	1133
1994	197183	185166	93567	91420	55393	47248	38251	53956	27470	28729	27235	17098	13191	14643	13017	10224	8766	7084	4479	2834	1937	1436	1127	923	775	648	527	421	336	269	1111
1995	199522	156561	147160	74433	72787	44124	37633	30452	42929	21845	22840	21651	13595	10490	11650	10360	8141	6984	5648	3573	2262	1547	1147	902	738	620	519	423	337	269	1110
1996	272032	158418	124426	117065	59259	57967	35125	29927	24188	34064	17322	18103	17159	10775	8316	9238	8219	6462	5547	4488	2841	1800	1231	914	718	589	495	414	338	270	1104
1997	353310	215991	125901	98976	93187	47163	46067	27844	23658	19073	26807	13612	14214	13465	8453	6524	7249	6451	5073	4356	3526	2233	1416	969	719	566	464	390	327	266	1086
1998	431114	280525	171656	100150	78791	74180	37500	36554	22043	18690	15044	21121	10718	11188	10598	6654	5137	5709	5082	3999	3435	2782	1763	1118	766	569	448	367	309	259	1074
1999	211436	342300	222948	136553	79738	62762	59085	29855	29084	17531	14860	11960	16795	8525	8903	8437	5300	4094	4552	4055	3192	2744	2224	1410	895	613	456	359	295	248	1072
2000	158301	167878	272044	177357	108726	63528	50015	47081	23785	23170	13967	11842	9535	13396	6804	7109	6742	4238	3275	3644	3248	2559	2201	1784	1132	719	493	366	289	237	1065
2001	259936	125689	133419	216402	141185	86542	50501	39670	37249	18775	18257	10992	9313	7495	10529	5348	5589	5302	3334	2578	2870	2559	2017	1736	1408	894	568	389	290	228	1032
2002	251328	206386	99890	106131	172272	112395	68823	40086	31421	29446	14821	14397	8663	7337	5905	8297	4215	4407	4183	2631	2036	2267	2023	1595	1373	1115	708	450	309	230	1002
2003	320438	199552	164023	79459	84485	137118	89339	54579	31706	24795	23194	11659	11316	6806	5764	4639	6519	3313	3465	3290	2071	1603	1786	1594	1258	1083	880	559	355	244	976
2004	215800	254425	158593	130478	63261	67281	109145	71038	43345	25153	19655	18378	9237	8966	5394	4569	3679	5173	2631	2753	2615	1647	1275	1422	1270	1002	864	702	446	284	976
2005	183365	171344	202205	126162	103887	50396	53605	86938	56565	34506	20023	15648	14636	7359	7146	4301	3646	2938	4133	2103	2202	2094	1319	1022	1140	1019	805	694	564	359	1015
2006	76569	145590	136174	160852	100441	82728	40110	42612	69014	44848	27335	15854	12387	11586	5826	5660	3408	2890	2330	3280	1670	1750	1664	1049	813	908	812	641	553	450	1098
2007	96840	60795	115706	108323	128049	79958	65784	31832	33743	54540	35388	21546	12489	9755	9124	4589	4459	2686	2279	1838	2589	1319	1382	1316	830	644	719	643	508	439	1229
2008	141588	76890	48316	92040	86229	101915	63549	52159	25171	26617	42939	27823	16926	9806	7658	7162	3603	3502	2110	1791	1446	2037	1038	1089	1037	654	508	567	508	401	1320
2009	190688	112420	61107	38433	73265	68623	80978	50361	41212	19835	20930	33713	21823	13268	7685	6001	5614	2825	2746	1656	1406	1135	1600	816	856	816	515	400	447	400	1359
2010	254480	151404	89344	48609	30595	58315	54548	64223	39839	32527	15627	16469	26506	17150	10425	6038	4717	4413	2221	2161	1303	1107	895	1262	644	676	644	407	316	354	1394
2011	122900	202055	120328	71073	38701	24369	46439	43411	51069	31658	25837	12411	13081	21058	13630	8289	4803	3754	3515	1770	1723	1040	884	715	1008	515	541	516	326	253	1402
2012	163649	97582	160583	95721	56587	30826	19408	36963	34527	40595	25157	20529	9863	10397	16744	10843	6597	3825	2992	2802	1412	1376	831	707	571	807	412	433	413	261	1330
2013	349492	129936	77553	127744	76212	45075	24553	15451	29408	27456	32272	19998	16323	7844	8273	13330	8636	5258	3051	2387	2237	1128	1100	664	565	458	646	330	347	332	1279
2014	280872	277494	103266	61693	101701	60689	35873	19517	12264	23314	21747	25548	15828	12920	6210	6552	10560	6845	4170	2421	1895	1777	897	874	529	450	364	515	263	277	1287
2015	219758	223009	220537	82147	49116	80995	48313	28530	15505	9733	18489	17240	20252	12548	10245	4927	5200	8386	5439	3315	1925	1508	1415	715	697	422	359	291	412	211	1253
2016	231224	174487	177237	175437	65404	39123	64507	38457	22694	12325	7735	14691	13700	16098	9979	8151	3922	4142	6683	4337	2645	1537	1205	1131	571	558	338	288	233	330	1176
2017	247040	183590	138673	140991	139676	52090	31149	51317	30562	18019	9781	6136	11654	10869	12775	7923	6475	3117	3294	5318	3453	2107	1225	961	903	456	446	270	230	187	1207

Table 4.20. Northern rock sole projection alternatives for model 17.2.

	Scenarios 1 and 2, max ABC is permissible					
	Total biomass	SSB	F	Catch	OFL	ABC
2017	86209	40363	0.028	1287.7	19192.9	16153.8
2018	90794	44536	0.027	1287.7	19959.6	16802.0
2019	93374	45519	0.382	17242.6	20477.4	17242.6
2020	81426	38953	0.382	14882.6	17677.7	14882.6
2021	72591	33788	0.382	13066.7	15526.0	13066.7
2022	66214	29886	0.382	11745.3	13961.7	11745.3
2023	61850	27191	0.382	10811.1	12856.5	10811.1
2024	58992	25430	0.382	10153.3	12078.4	10153.3
2025	56927	24126	0.382	9688.9	11528.9	9688.9
2026	55464	23155	0.381	9350.9	11125.3	9350.9
2027	54444	22452	0.378	9060.6	10774.2	9060.6
2028	53795	21999	0.375	8844.5	10514.9	8844.5
2029	53421	21688	0.372	8708.2	10351.6	8708.2
2030	53252	21503	0.371	8628.2	10256.0	8628.2
	Scenario 3, Harvest average F over past 5 years					
	Total biomass	SSB	F	Catch	OFL	ABC
2017	86209	40363	0.028	1287.7	19192.9	1728.4
2018	90794	44536	0.027	1287.7	19959.6	1799.0
2019	93374	46844	0.038	1848.3	20477.4	1848.3
2020	93546	47000	0.038	1869.9	20691.9	1869.9
2021	93550	47031	0.038	1881.5	20806.7	1881.5
2022	93421	47005	0.038	1888.8	20880.0	1888.8
2023	93351	47098	0.038	1893.1	20922.5	1893.1
2024	93403	47313	0.038	1894.2	20930.8	1894.2
2025	93265	47373	0.038	1892.5	20908.1	1892.5
2026	93027	47304	0.038	1888.7	20862.7	1888.7
2027	92745	47168	0.038	1883.4	20803.0	1883.4
2028	92474	47035	0.038	1877.6	20737.6	1877.6
2029	92231	46871	0.038	1871.8	20673.2	1871.8
2030	92050	46724	0.038	1866.7	20617.7	1866.7

Table 4.20. Northern rock sole projection alternatives for model 17.2. *(continued)*

	Scenario 4, the upper bound on FABC is set at F60%.					
	Total biomass	SSB	F	Catch	OFL	ABC
2017	86209	40363	0.028	1287.7	19192.9	7951.6
2018	90794	44536	0.027	1287.7	19959.6	8274.2
2019	93374	46294	0.179	8497.0	20477.4	8497.0
2020	88294	43491	0.179	8045.0	19384.3	8045.0
2021	84027	40988	0.179	7635.8	18401.9	7635.8
2022	80524	38867	0.179	7295.1	17589.2	7295.1
2023	77856	37283	0.179	7020.5	16936.1	7020.5
2024	75933	36177	0.179	6799.0	16409.2	6799.0
2025	74321	35218	0.179	6619.6	15982.3	6619.6
2026	73008	34383	0.179	6474.6	15637.4	6474.6
2027	71957	33683	0.179	6358.0	15360.2	6358.0
2028	71146	33140	0.179	6265.6	15140.6	6265.6
2029	70534	32687	0.179	6193.4	14969.4	6193.4
2030	70107	32340	0.179	6139.5	14842.1	6139.5
	Scenario 5, No fishing					
	Total biomass	SSB	F	Catch	OFL	ABC
2017	86209	40363	0.028	1287.7	19192.9	0
2018	90794	44536	0.027	1287.7	19959.6	0
2019	93374	46991	0	0	20477.4	0
2020	95011	47984	0	0	21056.9	0
2021	96328	48801	0	0	21509.5	0
2022	97346	49487	0	0	21884.6	0
2023	98256	50208	0	0	22190.1	0
2024	99137	50969	0	0	22423.5	0
2025	99690	51497	0	0	22590.7	0
2026	100019	51820	0	0	22703.3	0
2027	100200	52010	0	0	22773.5	0
2028	100302	52147	0	0	22813.7	0
2029	100358	52203	0	0	22834.5	0
2030	100415	52234	0	0	22847.0	0

Table 4.20. Northern rock sole projection alternatives for model 17.2. *(continued)*

	Scenario 6, Determination of whether NRS is currently overfished					
	Total biomass	SSB	F	Catch	OFL	ABC
2017	86209	40363	0.028	1287.7	19192.9	19192.9
2018	90794	42959	0.462	19959.6	19959.6	19959.6
2019	78683	37213	0.462	16851.9	16851.9	16851.9
2020	68686	31413	0.462	14472.9	14472.9	14472.9
2021	61756	27134	0.462	12761.8	12761.8	12761.8
2022	57048	24105	0.462	11604.1	11604.1	11604.1
2023	54041	22187	0.462	10840.9	10840.9	10840.9
2024	52214	21056	0.462	10327.5	10327.5	10327.5
2025	50910	20263	0.445	9668.0	9668.0	9668.0
2026	50233	19796	0.434	9285.7	9285.7	9285.7
2027	49924	19539	0.428	9094.4	9094.4	9094.4
2028	49819	19429	0.425	9010.1	9010.1	9010.1
2029	49816	19364	0.424	8976.0	8976.0	8976.0
2030	49884	19343	0.424	8973.5	8973.5	8973.5
	Scenario 7, Determination of whether NRS are approaching overfished condition					
	Total biomass	SSB	F	Catch	OFL	ABC
2017	86209	40363	0.028	1287.7	19192.9	19192.9
2018	90794	43246	0.382	16802.0	19959.6	19959.6
2019	81153	38819	0.382	14695.7	17459.8	17459.8
2020	72562	33599	0.462	15437.8	15437.8	15437.8
2021	64440	28732	0.462	13444.5	13444.5	13444.5
2022	58860	25240	0.462	12073.6	12073.6	12073.6
2023	55232	22967	0.462	11155.2	11155.2	11155.2
2024	52981	21577	0.462	10537.3	10537.3	10537.3
2025	51392	20595	0.450	9891.2	9891.2	9891.2
2026	50462	19974	0.437	9400.6	9400.6	9400.6
2027	50019	19626	0.429	9148.0	9148.0	9148.0
2028	49846	19467	0.426	9031.1	9031.1	9031.1
2029	49815	19376	0.424	8981.5	8981.5	8981.5
2030	49875	19345	0.424	8972.6	8972.6	8972.6

Table 4.21. Southern rock sole projection alternatives for model 17.2.

	Scenarios 1 and 2, max ABC is permissible					
	Total biomass	SSB	F	Catch	OFL	ABC
2017	137686	73436	0.015	1287.66	25419.50	21504.00
2018	138620	71913	0.015	1287.66	25332.70	21424.00
2019	139907	69178	0.271	21717.38	25688.77	21717.38
2020	125402	59140	0.271	19371.86	22928.59	19371.86
2021	115975	52887	0.271	17770.13	21042.55	17770.13
2022	110321	49475	0.271	16626.99	19695.26	16626.99
2023	106314	47071	0.271	15790.64	18709.05	15790.64
2024	102992	44912	0.271	15174.00	17981.78	15174.00
2025	100413	43172	0.271	14717.78	17443.64	14717.78
2026	98544	41896	0.271	14379.05	17044.08	14379.05
2027	97201	40952	0.271	14112.92	16724.97	14112.92
2028	96212	40237	0.268	13826.64	16375.33	13826.64
2029	95577	39747	0.266	13597.11	16100.93	13597.11
2030	95252	39429	0.264	13458.16	15934.81	13458.16
	Scenario 3, Harvest average F over past 5 years					
	Total biomass	SSB	F	Catch	OFL	ABC
2017	137686	68466	0.0150	1287.66	23725.40	1528.45
2018	138620	67048	0.0151	1287.66	23641.30	1520.61
2019	139907	66303	0.0178	1538.85	23969.81	1538.85
2020	141340	66186	0.0178	1573.76	24548.39	1573.76
2021	144087	67534	0.0178	1616.76	25234.63	1616.76
2022	148081	70282	0.0178	1659.86	25908.13	1659.86
2023	151814	73027	0.0178	1699.19	26515.45	1699.19
2024	154541	75046	0.0178	1733.20	27036.40	1733.20
2025	156594	76602	0.0178	1761.45	27466.54	1761.45
2026	158245	77893	0.0178	1784.15	27810.24	1784.15
2027	159558	78930	0.0178	1801.86	28077.12	1801.86
2028	160504	79684	0.0178	1815.35	28279.52	1815.35
2029	161222	80255	0.0178	1825.39	28429.57	1825.39
2030	161830	80708	0.0178	1832.87	28541.24	1832.87

Table 4.21. SRS Projection alternatives *(continued)*

	Scenario 4, the upper bound on FABC is set at F60%.					
	Total biomass	SSB	F	Catch	OFL	ABC
2017	137686	73436	0.015	1287.66	25419.50	10783.40
2018	138620	71913	0.015	1287.66	25332.70	10734.80
2019	139907	70271	0.130	10871.71	25688.77	10871.71
2020	133938	65459	0.130	10454.10	24739.83	10454.10
2021	130496	62917	0.130	10191.99	24142.96	10191.99
2022	129177	62314	0.130	10009.61	23723.51	10009.61
2023	128336	62080	0.130	9870.59	23401.03	9870.59
2024	127229	61506	0.130	9758.17	23138.78	9758.17
2025	126135	60868	0.130	9663.58	22917.22	9663.58
2026	125229	60336	0.130	9581.88	22725.46	9581.88
2027	124485	59874	0.130	9510.49	22557.70	9510.49
2028	123818	59425	0.130	9448.16	22411.18	9448.16
2029	123269	59031	0.130	9394.15	22284.31	9394.15
2030	122873	58702	0.130	9349.06	22178.67	9349.06
	Scenario 5, No fishing					
	Total biomass	SSB	F	Catch	OFL	ABC
2017	137686	73436	0.015	1287.66	25419.50	0
2018	138620	71913	0.015	1287.66	25332.70	0
2019	139907	71297	0	0	25688.77	0
2020	142565	71956	0	0	26572.17	0
2021	146427	74128	0	0	27549.38	0
2022	151456	77772	0	0	28493.92	0
2023	156146	81384	0	0	29348.81	0
2024	159734	84169	0	0	30091.77	0
2025	162550	86396	0	0	30717.71	0
2026	164867	88279	0	0	31231.52	0
2027	166756	89831	0	0	31644.30	0
2028	168192	91017	0	0	31970.52	0
2029	169326	91957	0	0	32224.69	0
2030	170287	92725	0	0	32423.43	0

Table 4.21. SRS Projection alternatives *(continued)*

	Scenario 6, Determination of whether SRS is currently overfished					
	Total biomass	SSB	F	Catch	OFL	ABC
2017	137686	73436	0.015	1287.66	25419.50	25419.50
2018	138620	69446	0.326	25332.70	25332.70	25332.70
2019	120768	56685	0.326	21616.82	21616.82	21616.82
2020	108587	47944	0.326	19324.50	19324.50	19324.50
2021	101271	42945	0.326	17874.35	17874.35	17874.35
2022	97349	40588	0.326	16902.75	16902.75	16902.75
2023	94732	39061	0.326	16225.66	16225.66	16225.66
2024	92528	37642	0.326	15744.64	15744.64	15744.64
2025	90828	36539	0.317	15034.72	15034.72	15034.72
2026	89898	35919	0.310	14563.02	14563.02	14563.02
2027	89469	35598	0.305	14275.70	14275.70	14275.70
2028	89296	35431	0.302	14109.47	14109.47	14109.47
2029	89288	35366	0.301	14036.25	14036.25	14036.25
2030	89388	35351	0.300	14012.12	14012.12	14012.12
	Scenario 7, Determination of whether SRS are approaching overfished condition					
	Total biomass	SSB	F	Catch	OFL	ABC
2017	137686	73436	0.015	1287.66	25419.50	25419.50
2018	138620	69874	0.271	21424.00	25332.70	25332.70
2019	123856	58984	0.271	18822.81	22273.08	22273.08
2020	113481	51028	0.326	20366.30	20366.30	20366.30
2021	104817	45258	0.326	18638.03	18638.03	18638.03
2022	99900	42319	0.326	17453.98	17453.98	17453.98
2023	96540	40333	0.326	16616.28	16616.28	16616.28
2024	93783	38554	0.326	16016.40	16016.40	16016.40
2025	91681	37161	0.322	15418.83	15418.83	15418.83
2026	90322	36263	0.313	14760.47	14760.47	14760.47
2027	89653	35775	0.306	14364.44	14364.44	14364.44
2028	89358	35512	0.303	14143.78	14143.78	14143.78
2029	89292	35395	0.301	14044.68	14044.68	14044.68
2030	89371	35354	0.300	14009.47	14009.47	14009.47

Figures

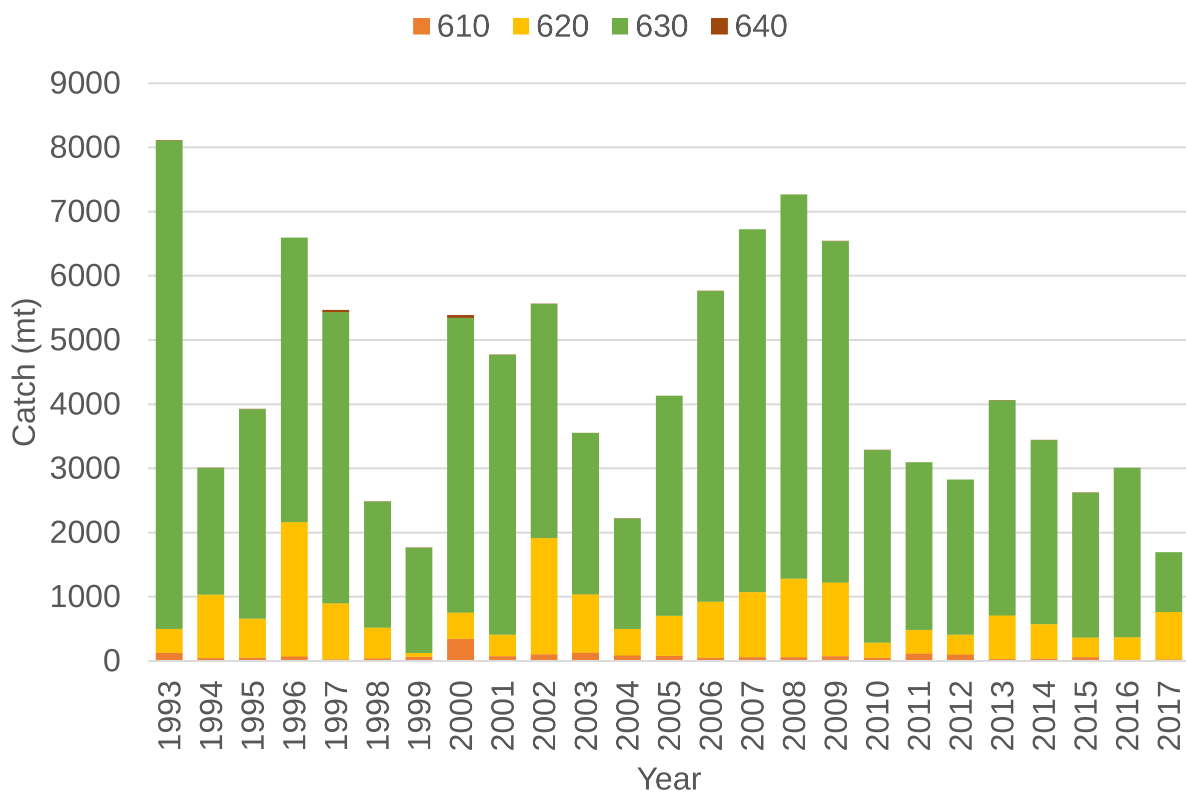
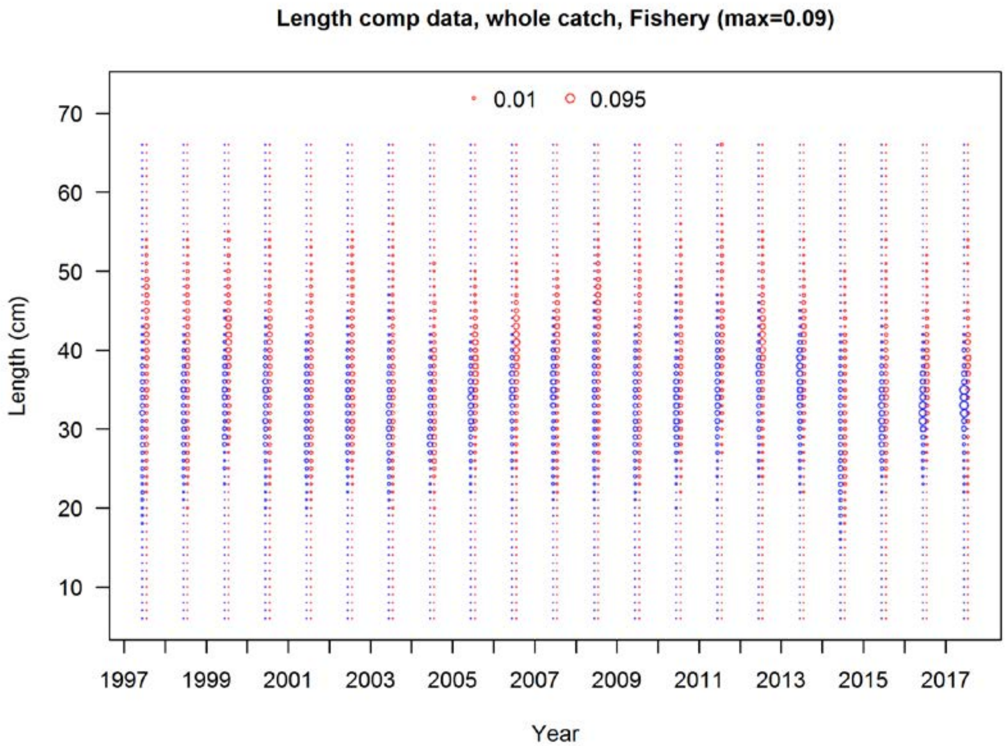


Figure 4.1. Total rock sole catch (retained + discards) by area (as of 2017-10-25).



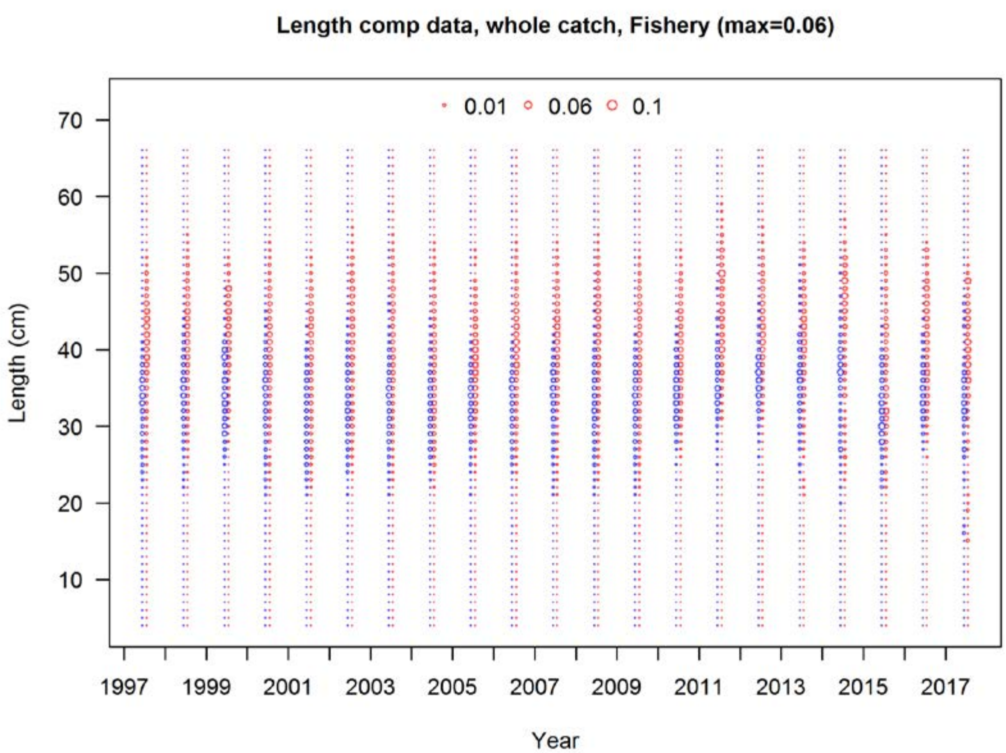
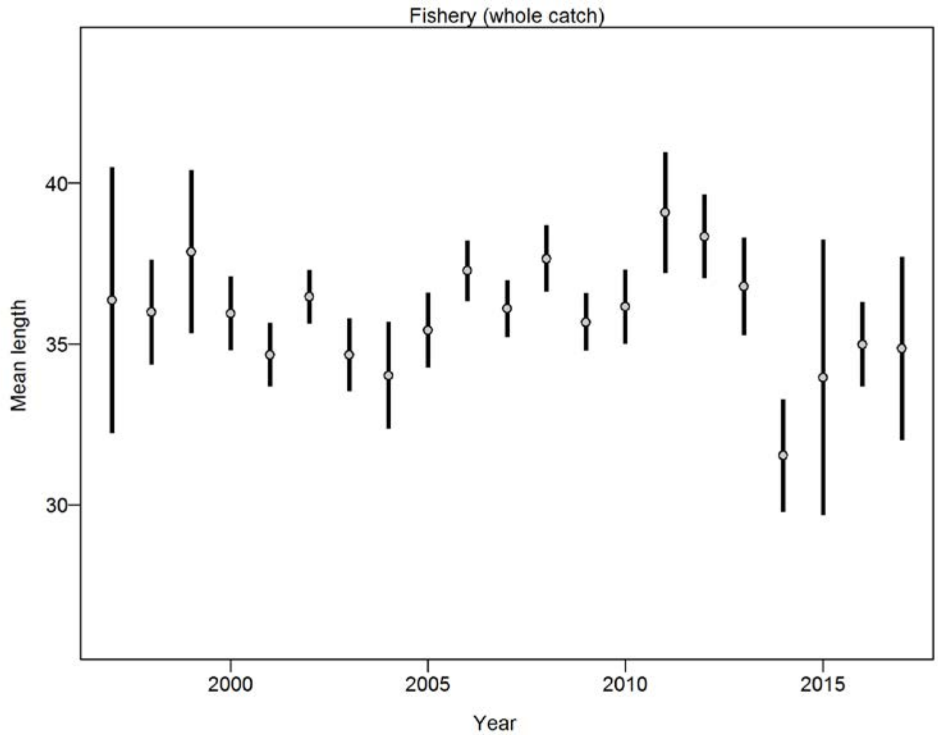


Figure 4.2. Fishery annual length composition data in centimeters. The red bubbles represent females and the blue bubbles represent males. Northern rock sole (top), southern rock sole (bottom).



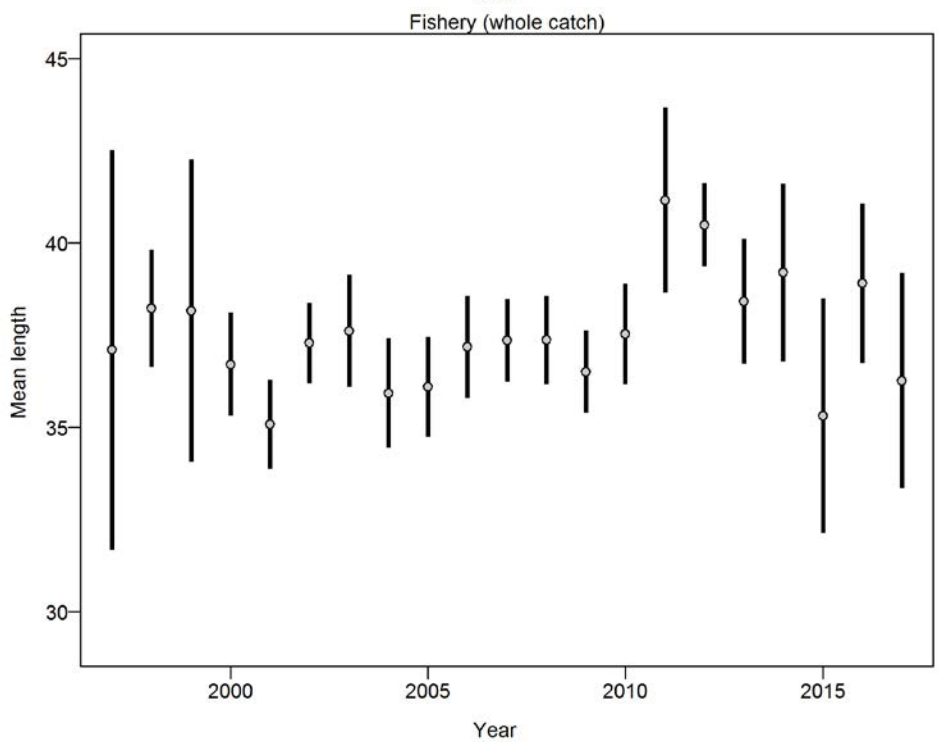


Figure 4.3 Mean length and the 95% confidence intervals based on the input sample size. Northern rock sole (top), southern rock sole (bottom).

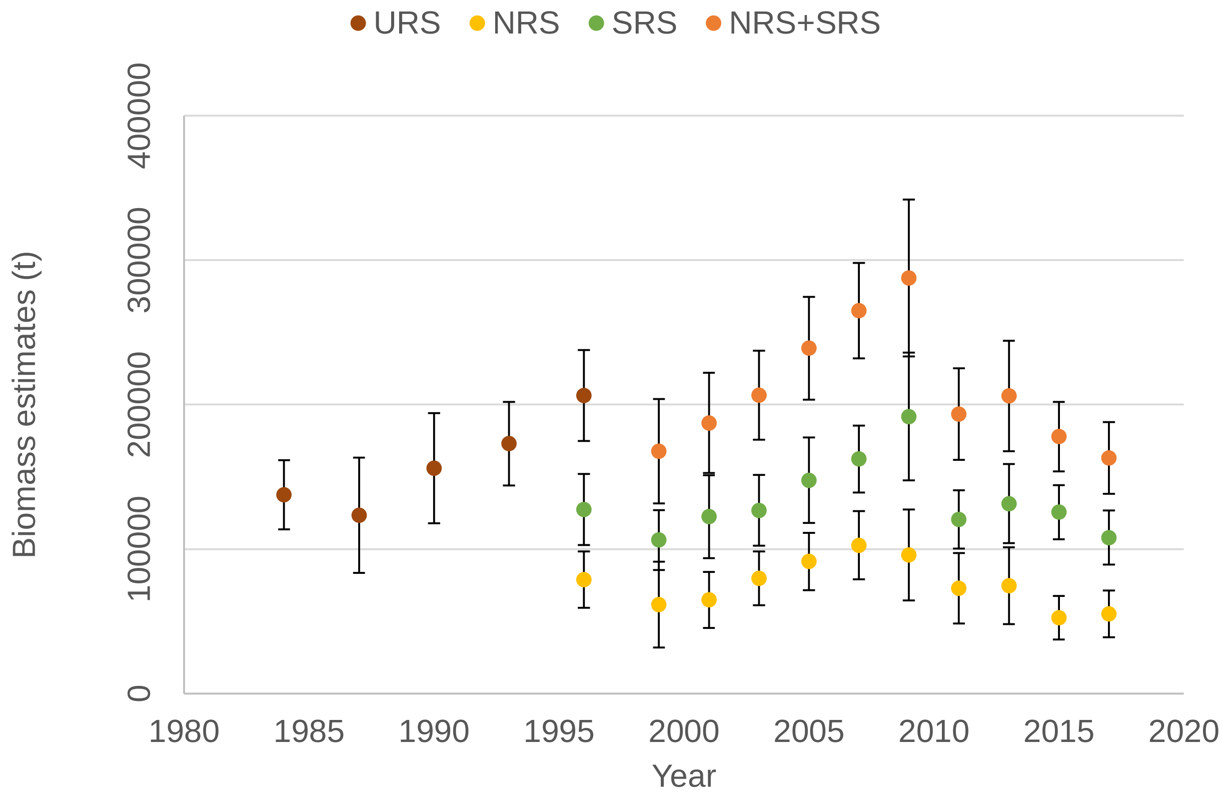
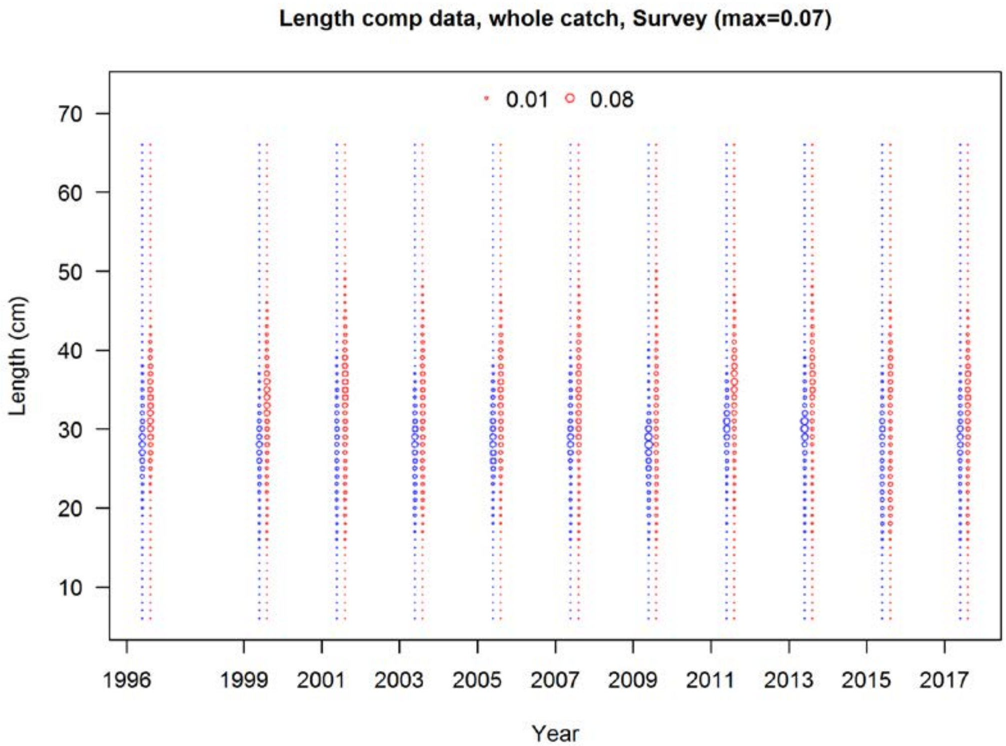


Figure 4.4. Total biomass estimates from the NMFS GOA bottom trawl survey for unidentified, northern, southern rock sole.



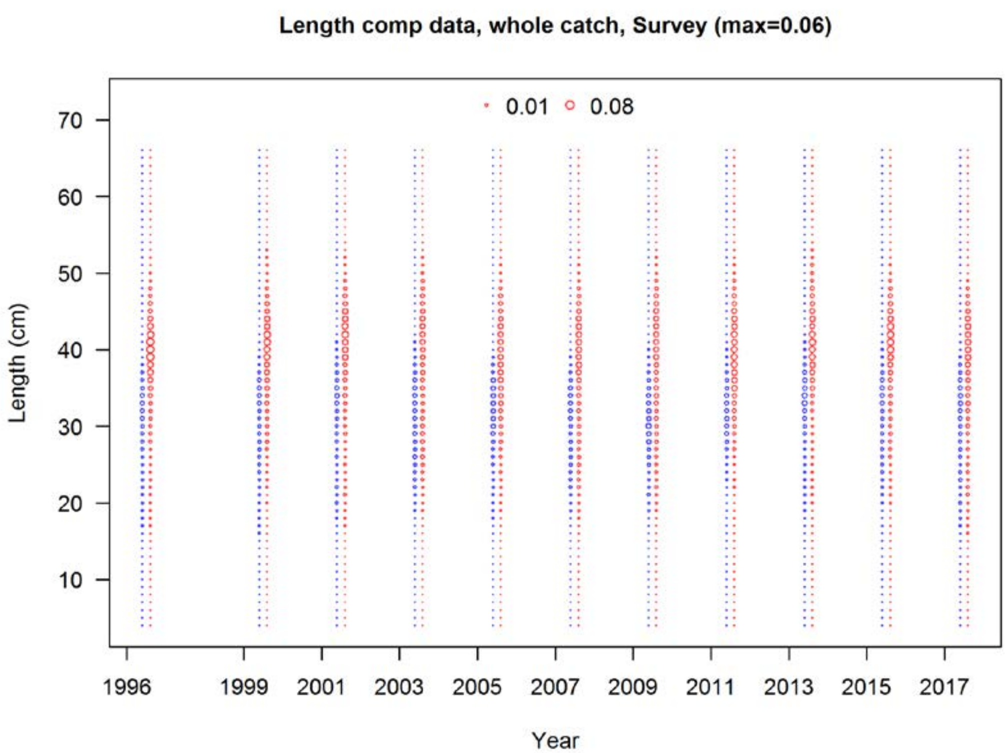
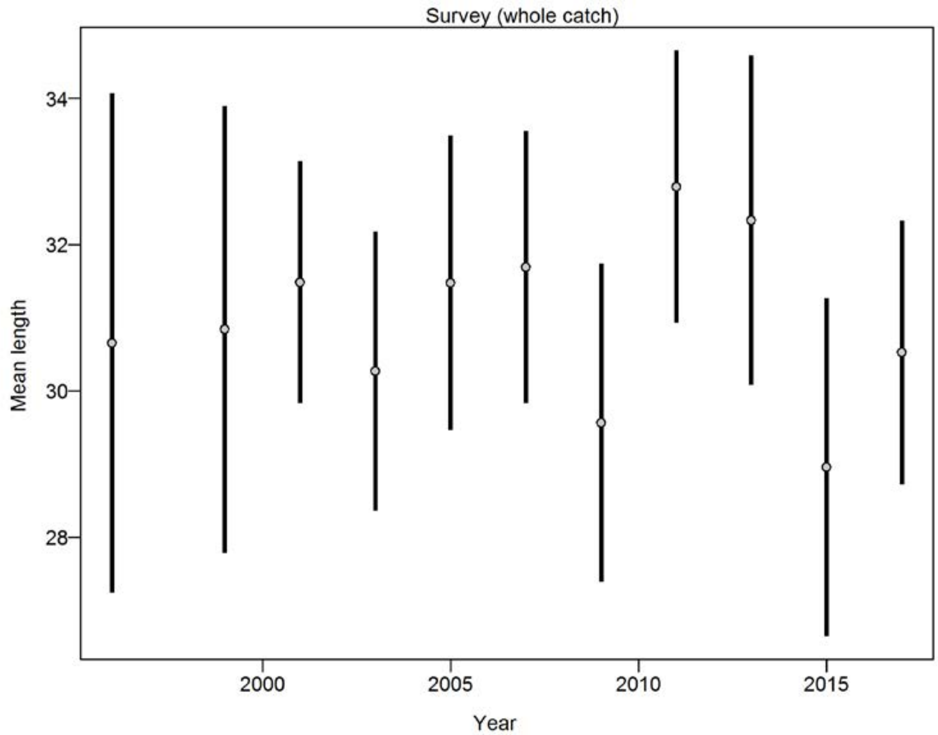


Figure 4.5. AFSC GOA bottom trawl survey annual length composition data in centimeters. The red bubbles represent females and the blue bubbles represent males. Northern rock sole (top), southern rock sole (bottom).



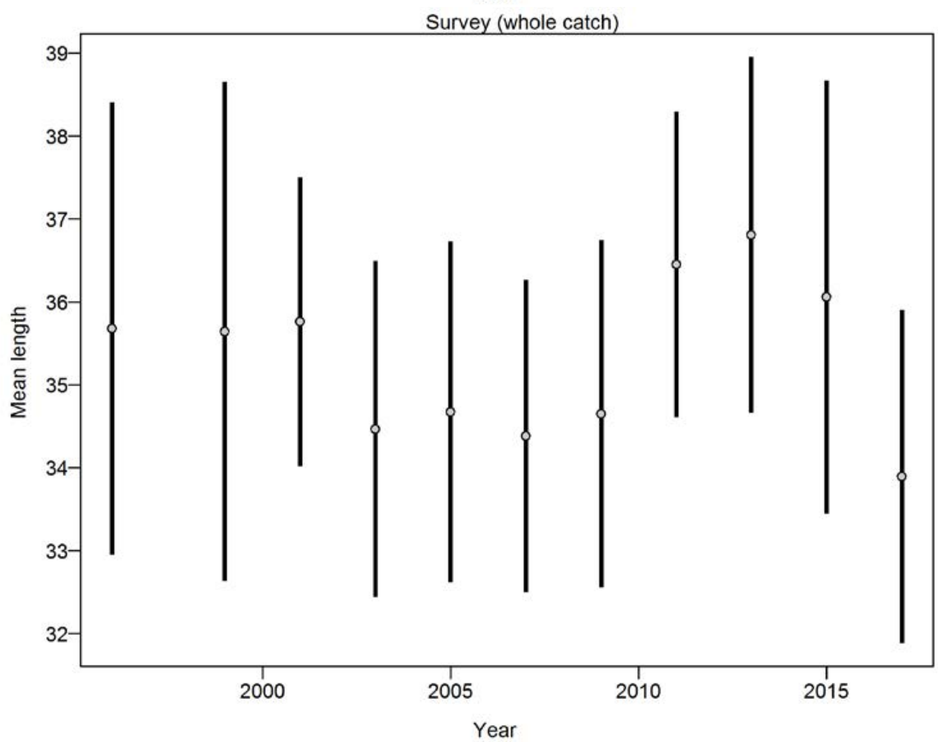


Figure 4.6 Northern rock sole mean length (cm) and the 95% confidence intervals based on the input sample size. Northern rock sole (top), southern rock sole (bottom).

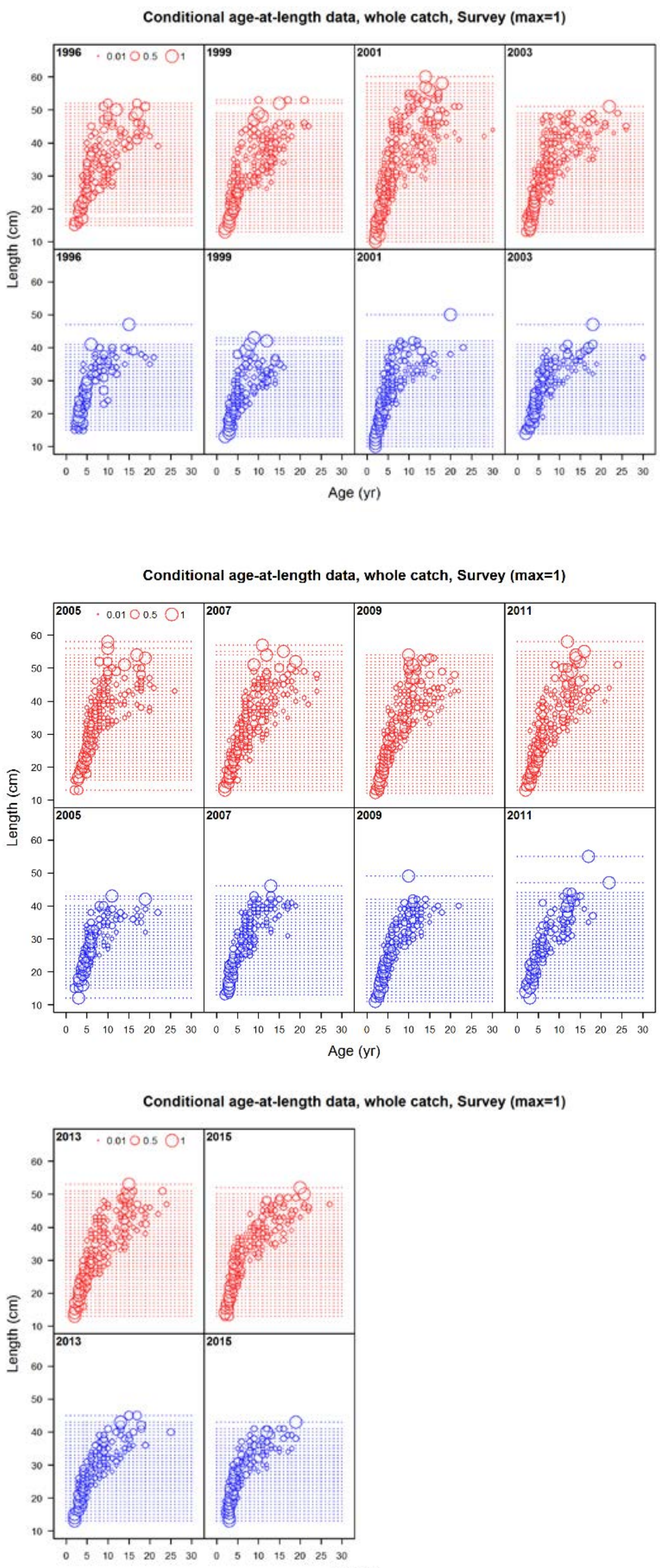


Figure 4.7. Survey conditional age-at-length data for northern rock sole.

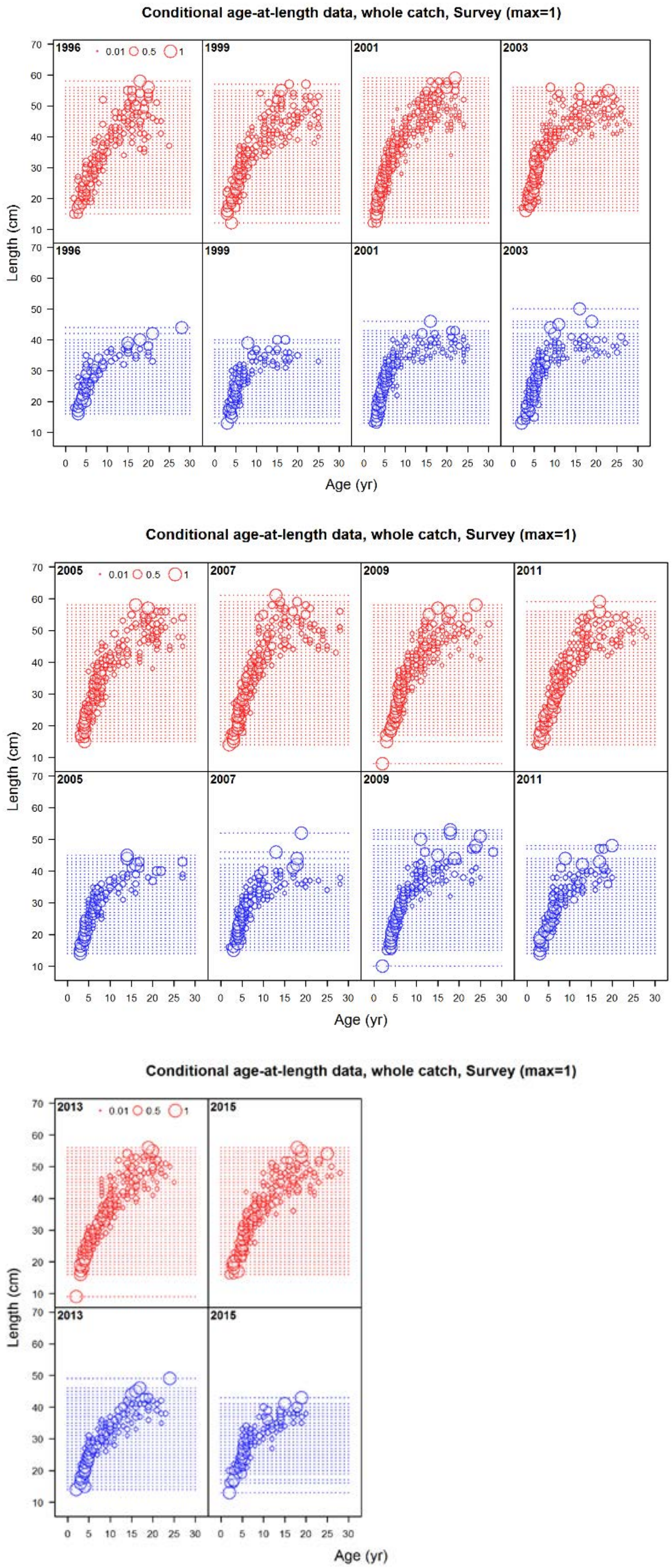


Figure 4.8. Survey conditional age-at-length data for southern rock sole.

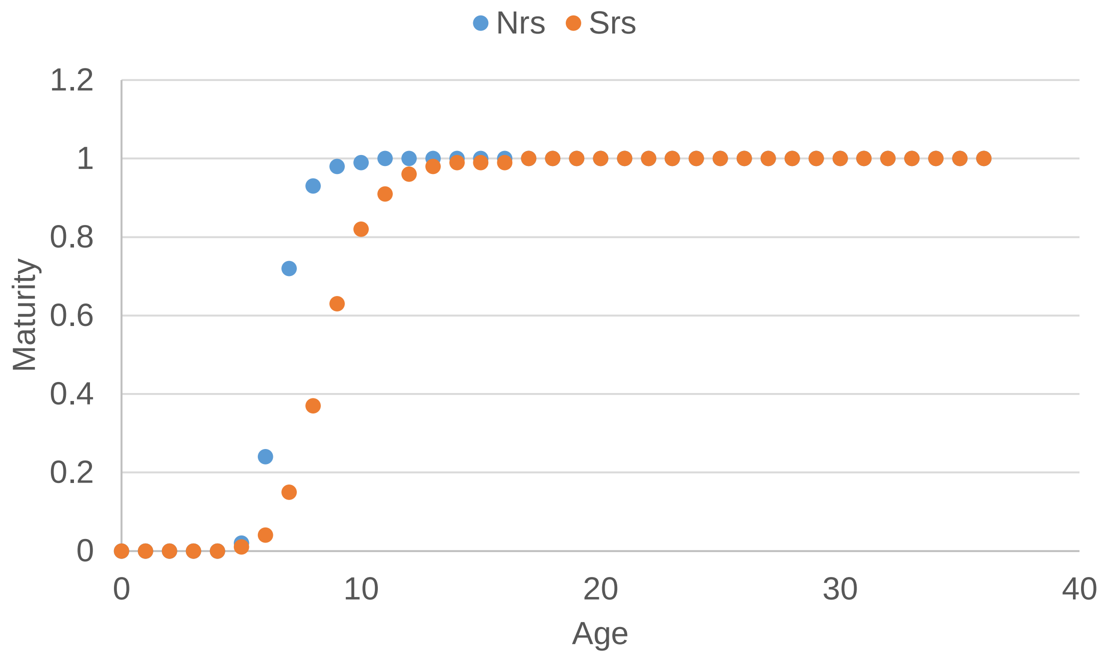
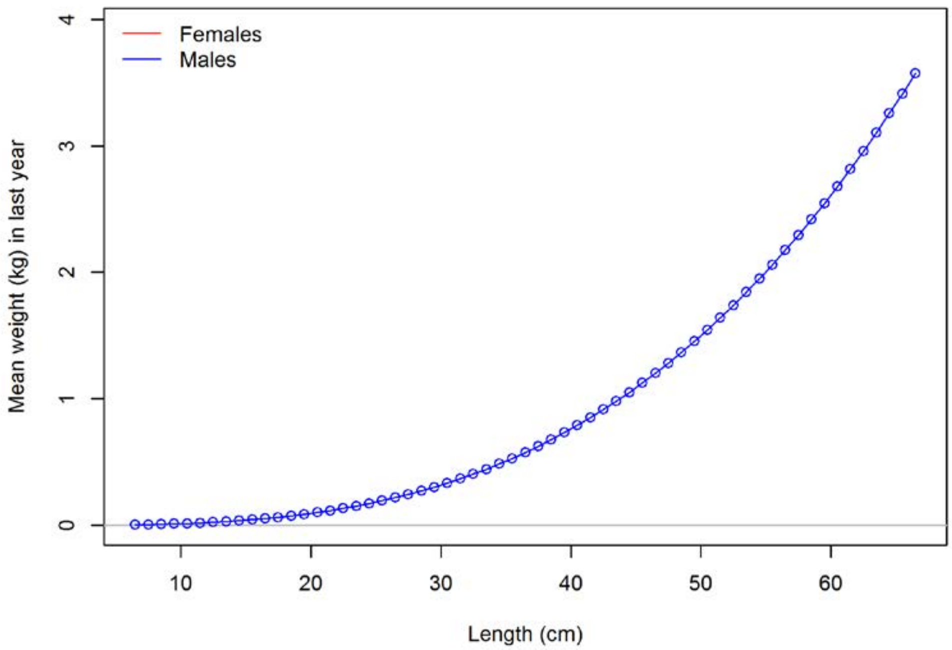


Figure 4.9. Northern and southern rock sole maturity curves.

a)



b)

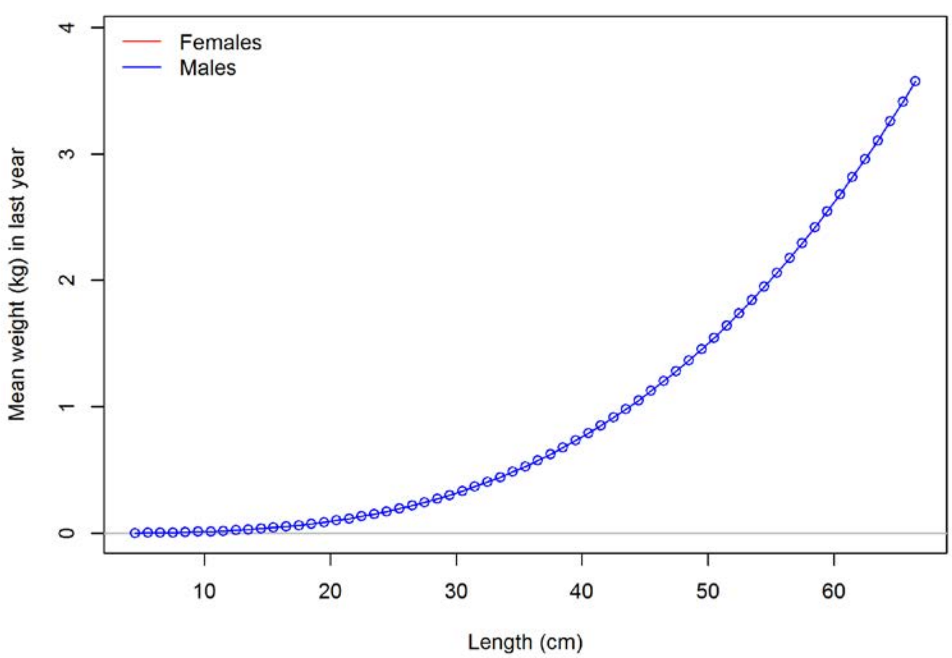
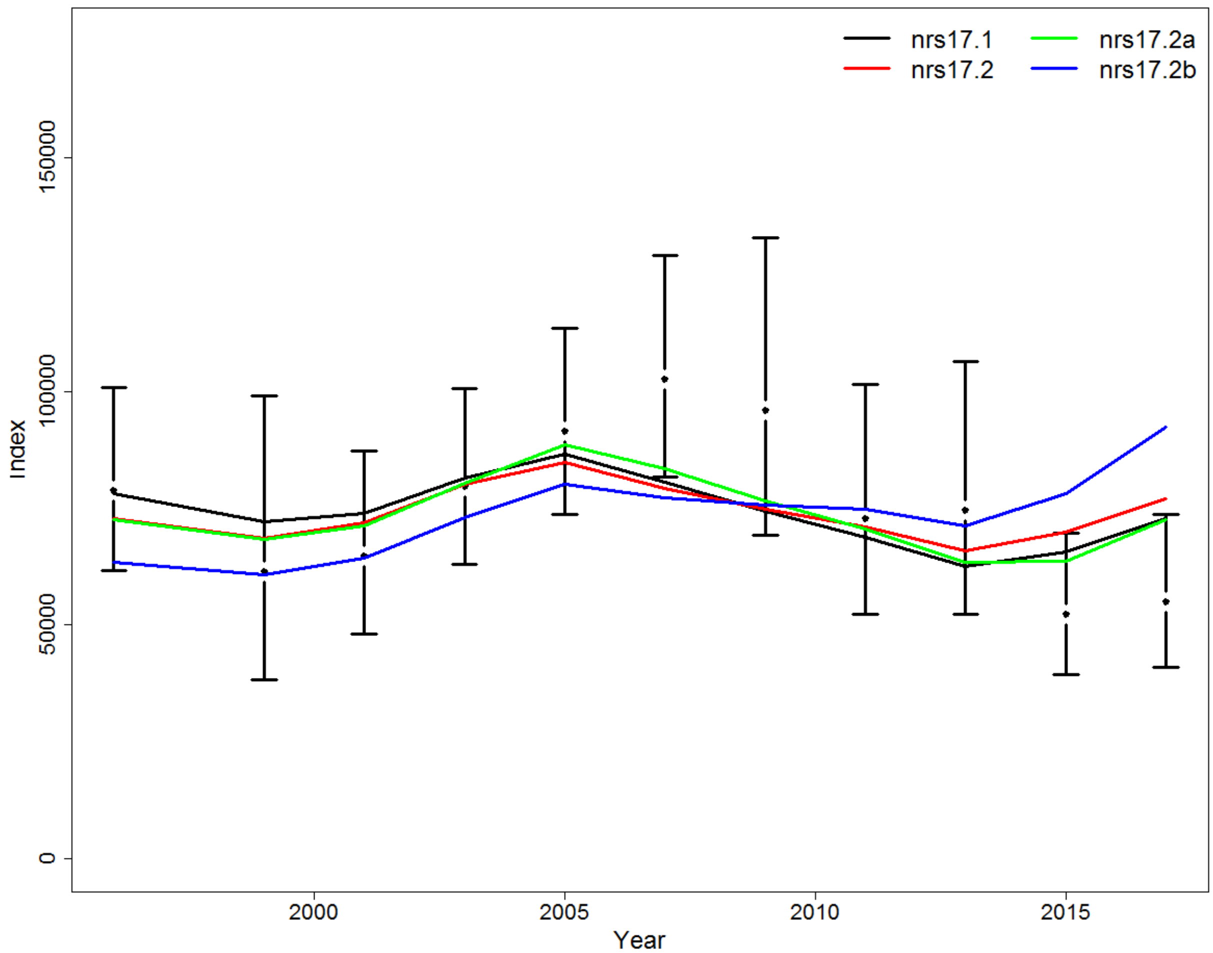


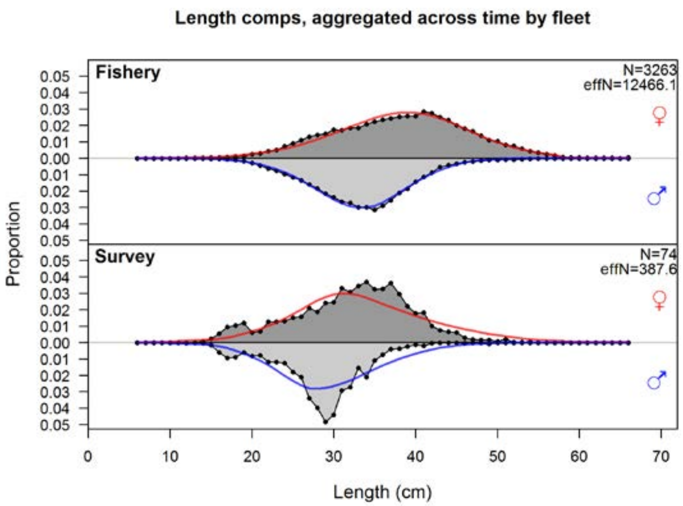
Figure 4.10. a) Northern and b) southern rock sole length-weight relationships.



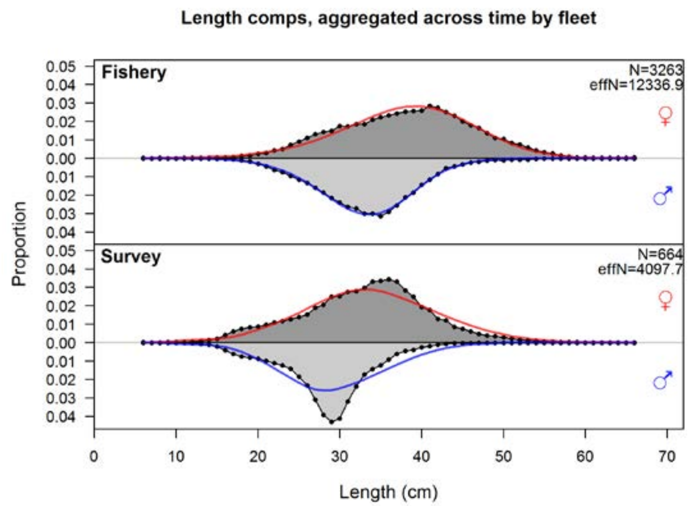
Model	RMSE
17.1	0.174
17.2	0.184
17.2a	0.155
17.2b	0.241

Figure 4.11. NMFS GOA bottom trawl survey northern rock sole index and model fit comparison.

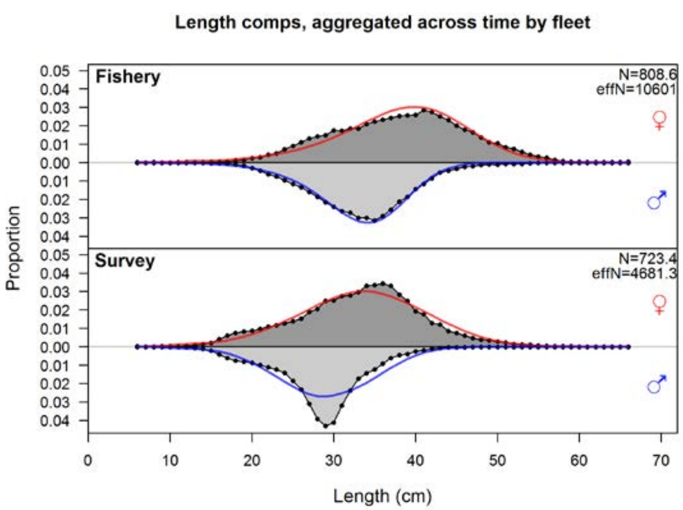
Model 17.1



Model 17.2



Model 17.2a



Model 17.2b

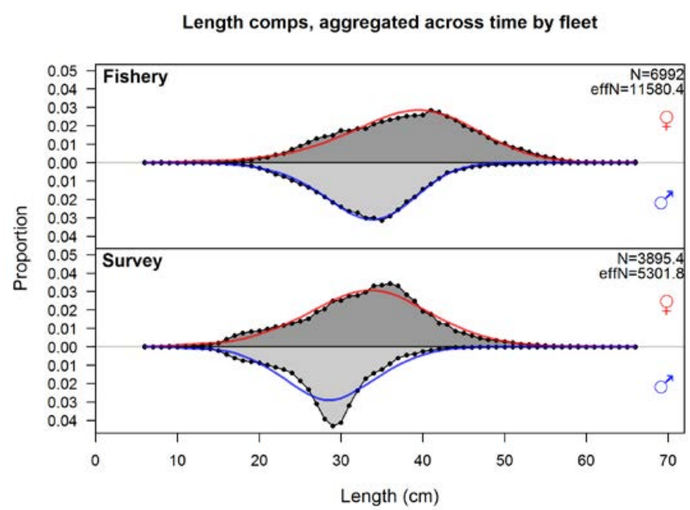
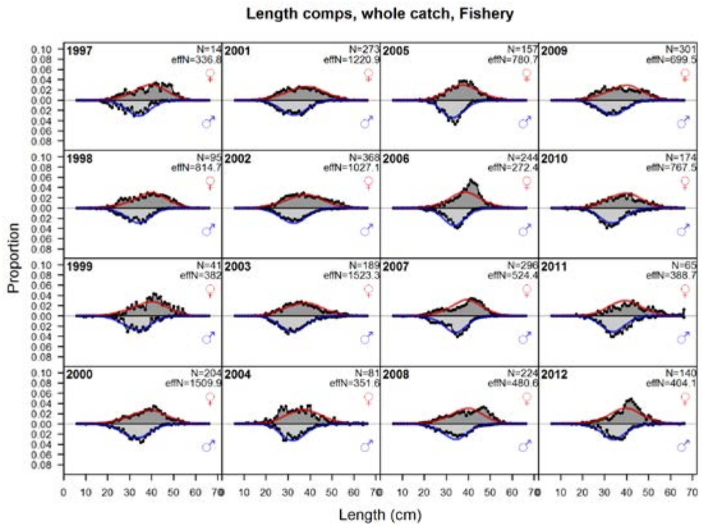
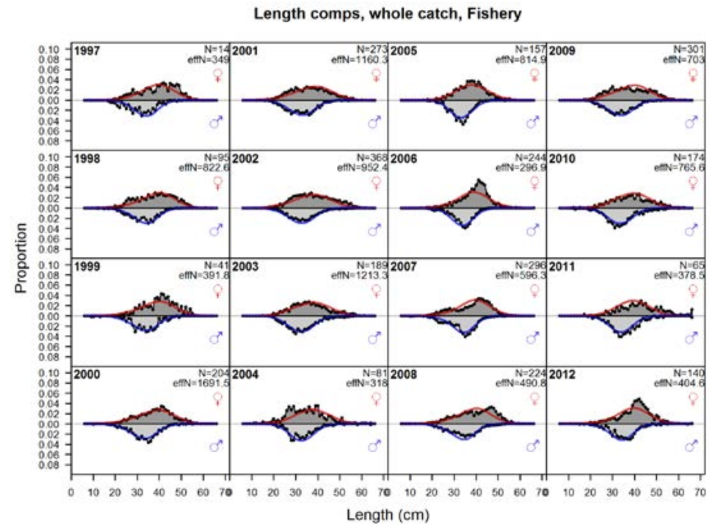


Figure 4.12. Fits (red line - female, blue line – male) to the northern rock sole fishery and survey size composition data aggregated over years.

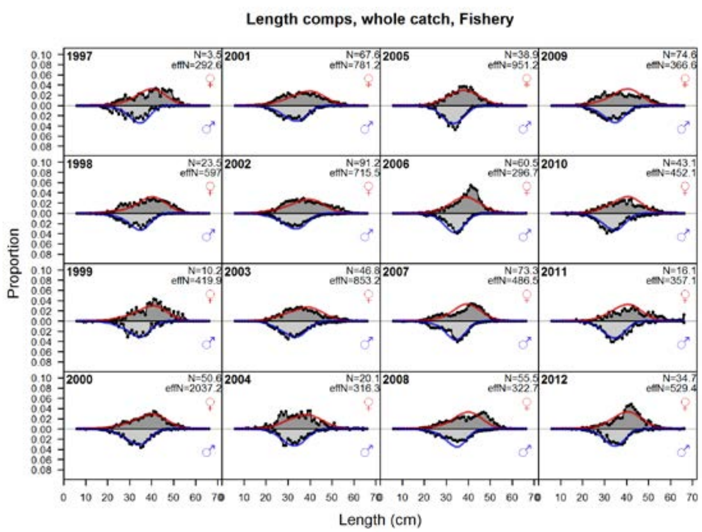
Model 17.1



Model 17.2



Model 17.2a



Model 17.2b

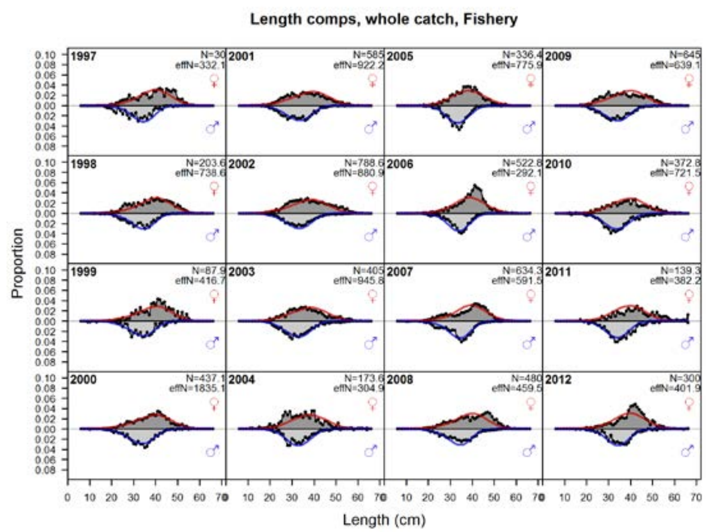
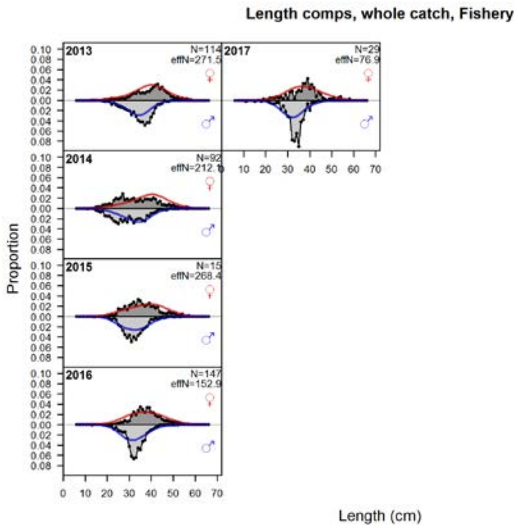
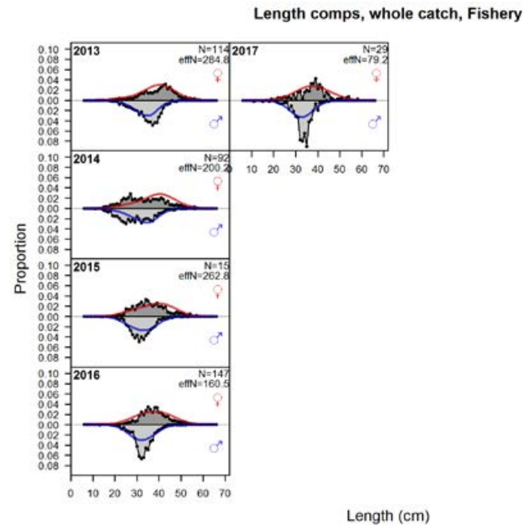


Figure 4.13. Fits (red line - female, blue line – male) to the northern rock sole fishery size composition data (1997-2012).

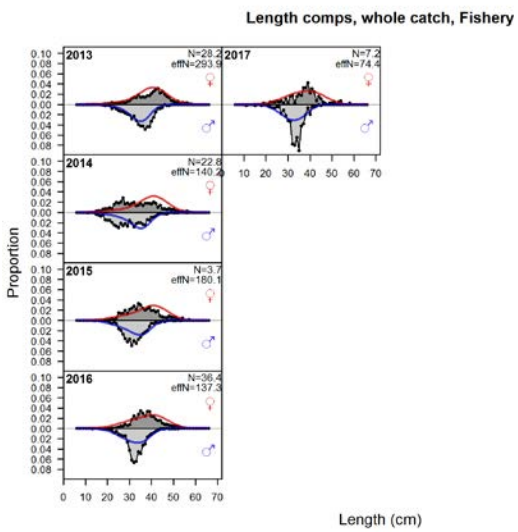
Model 17.1



Model 17.2



Model 17.2a



Model 17.2b

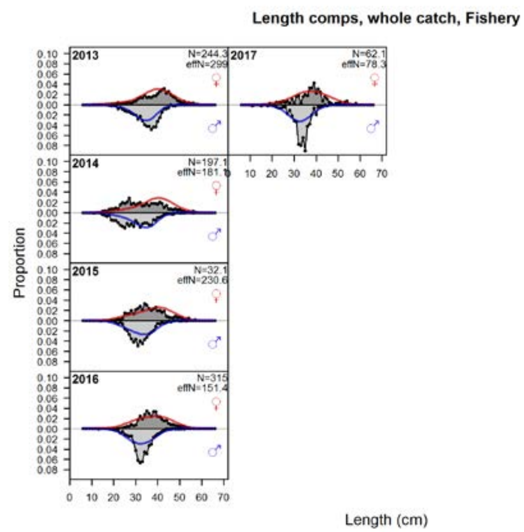
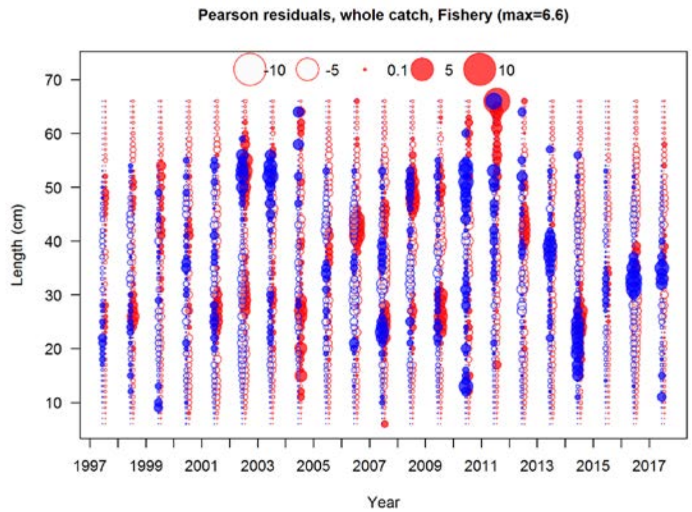
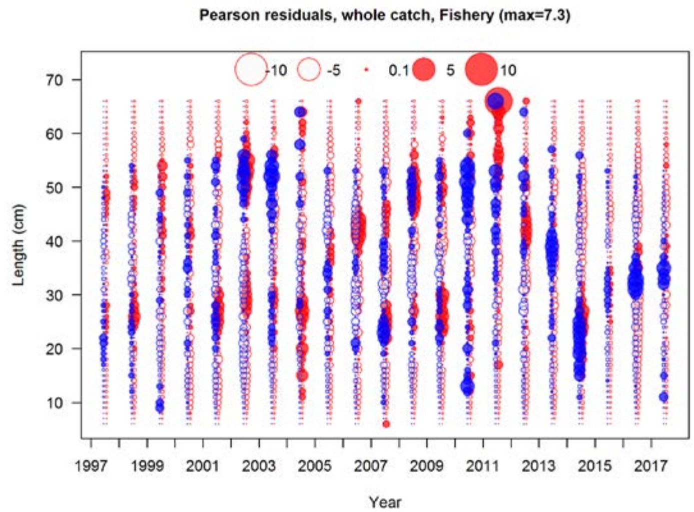


Figure 4.14. Fits (red line - female, blue line – male) to the northern rock sole fishery size composition data (2013-2017).

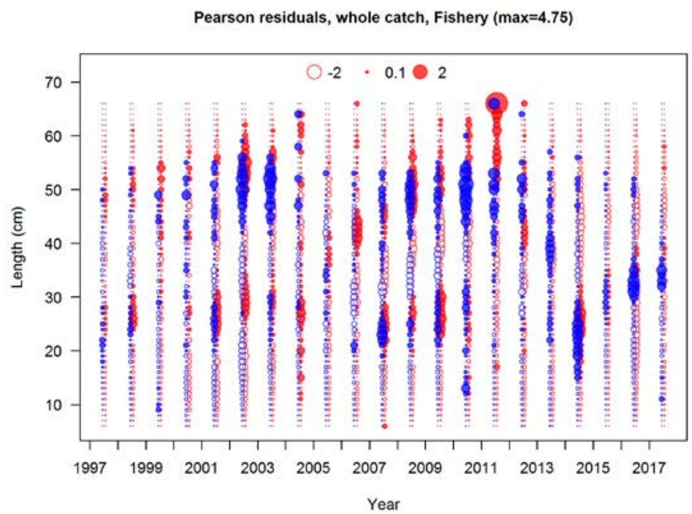
Model 17.1



Model 17.2



Model 17.2a



Model 17.2b

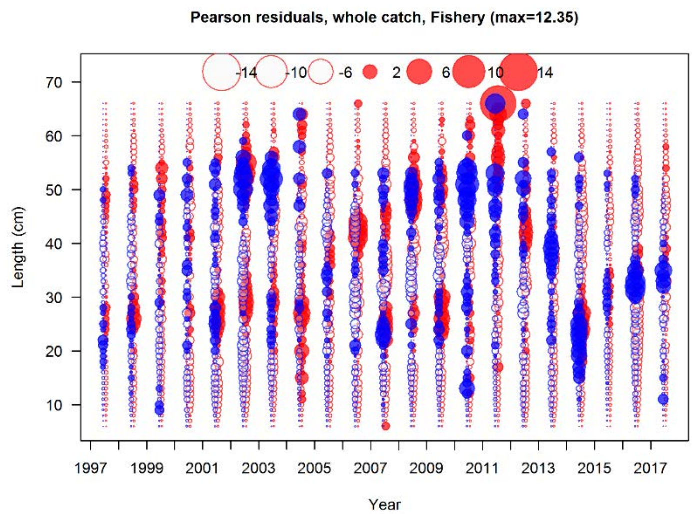
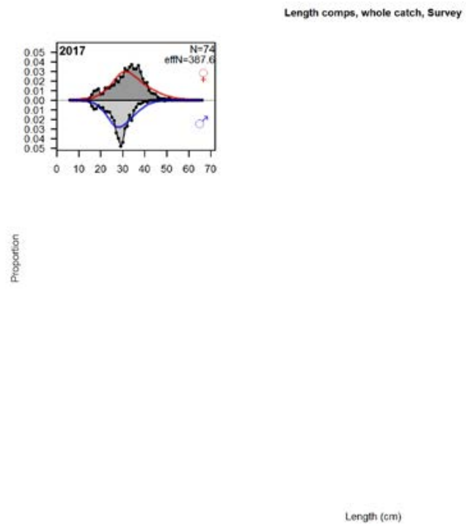
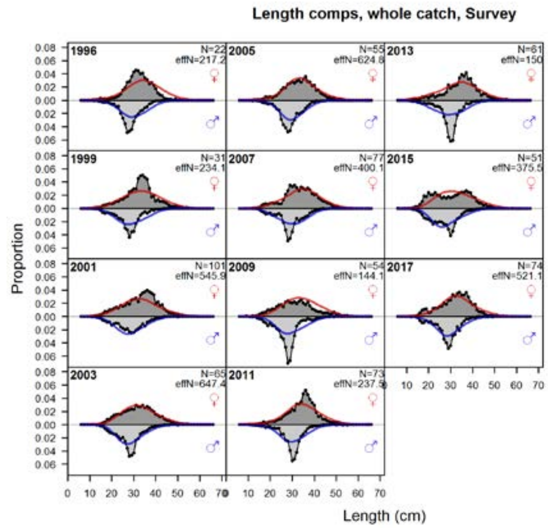


Figure 4.15. Pearson residuals (red - female, blue – male) for fishery size composition data. Closed bubbles are positive residuals (observed > estimated). Scales differ by model.

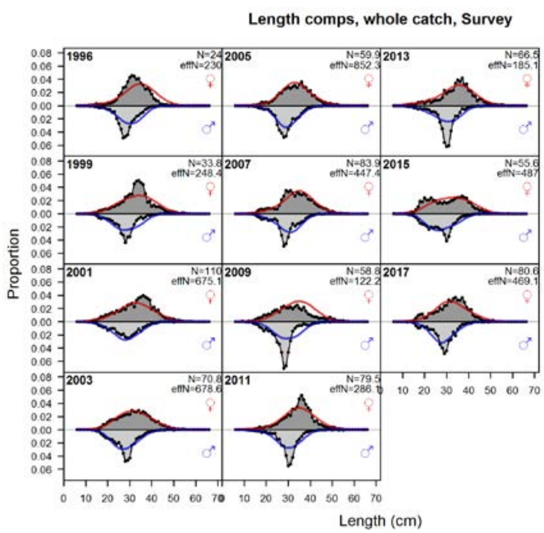
Model 17.1



Model 17.2



Model 17.2a



Model 17.2b

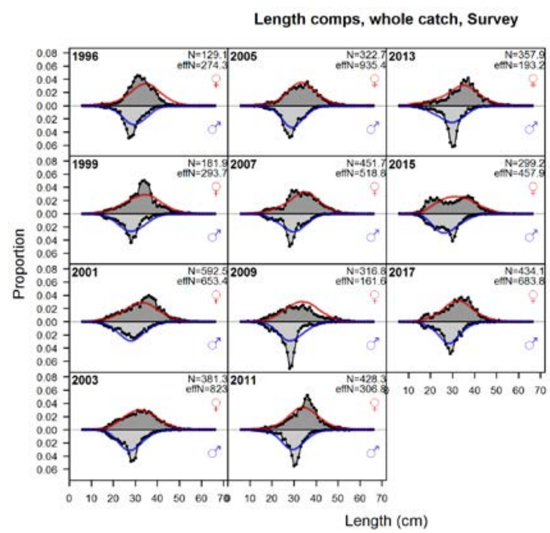
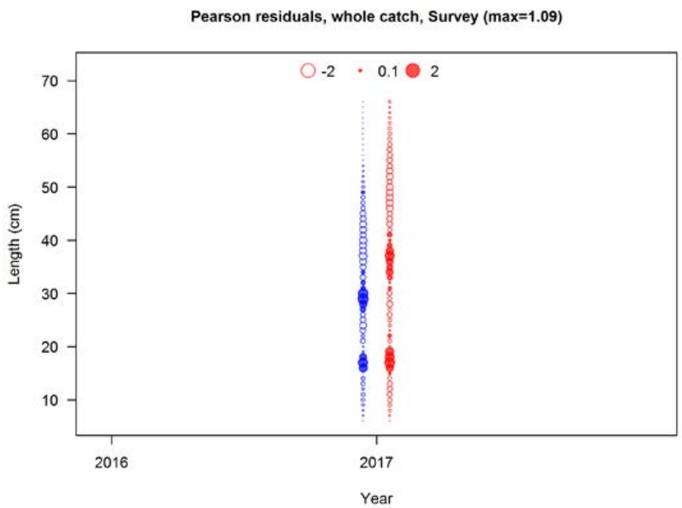
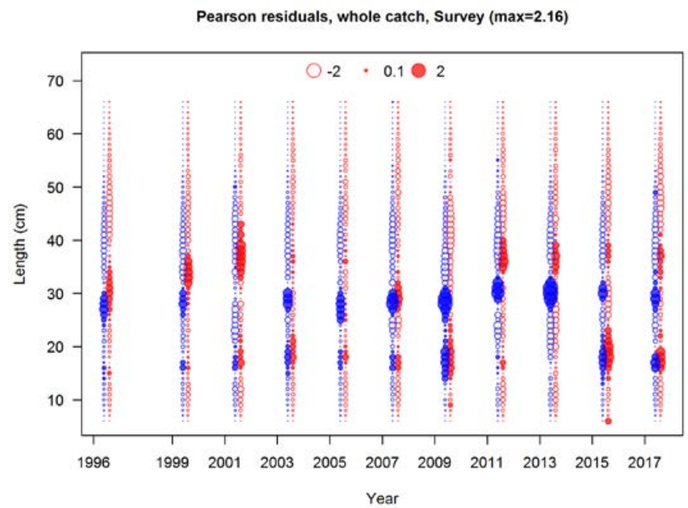


Figure 4.16. Fits (red line - female, blue line – male) to the northern rock sole survey size composition data (1996-2017).

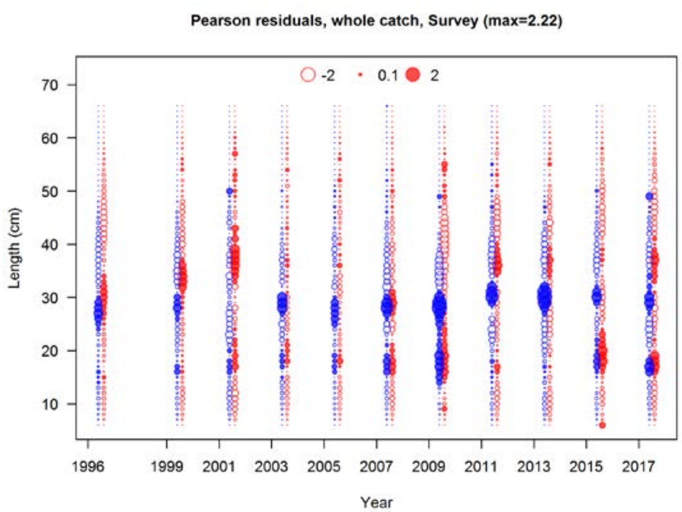
Model 17.1



Model 17.2



Model 17.2a



Model 17.2b

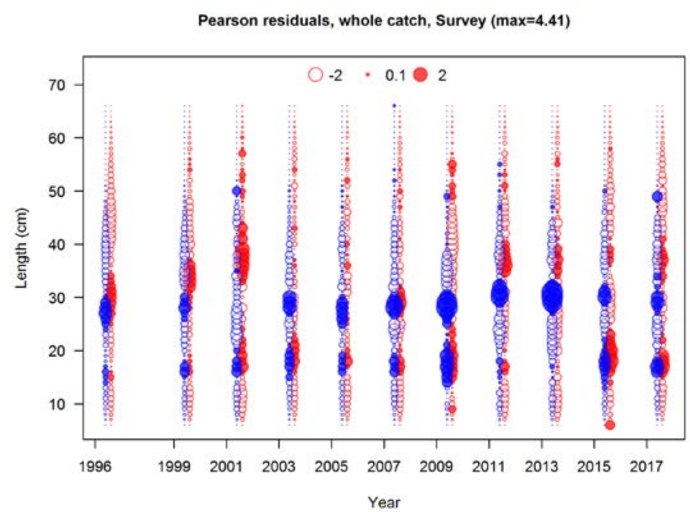
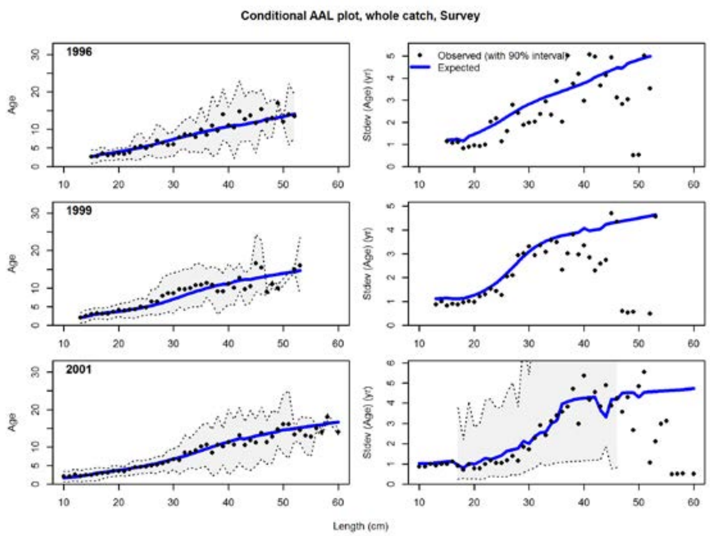
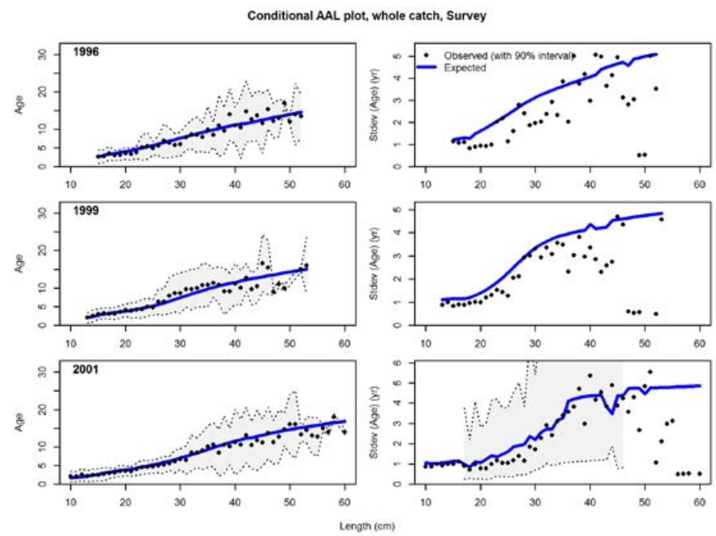


Figure 4.17. Pearson residuals (red - female, blue – male) for survey size composition data. Closed bubbles are positive residuals (observed > estimated).

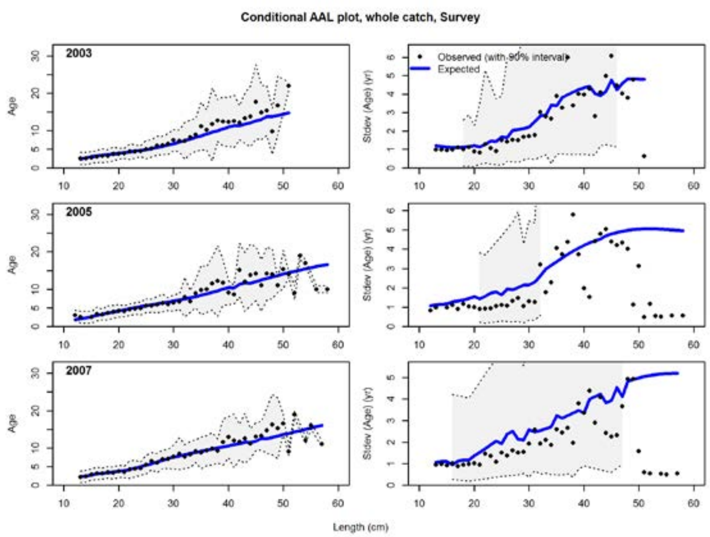
a)



b)



c)



d)

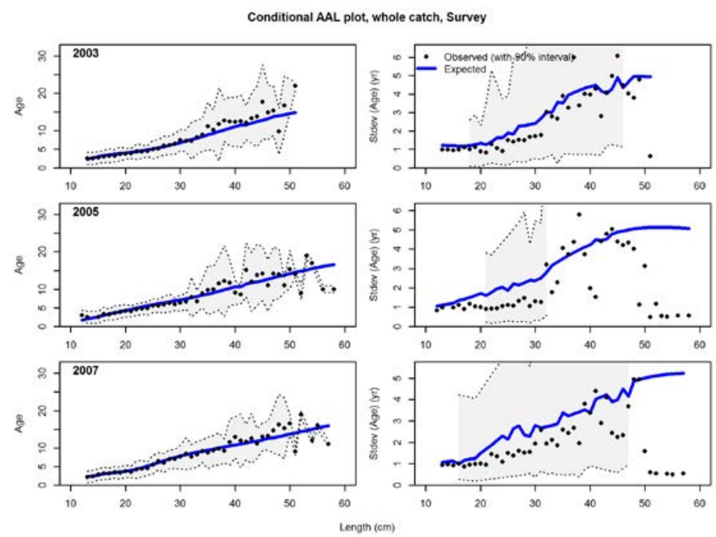
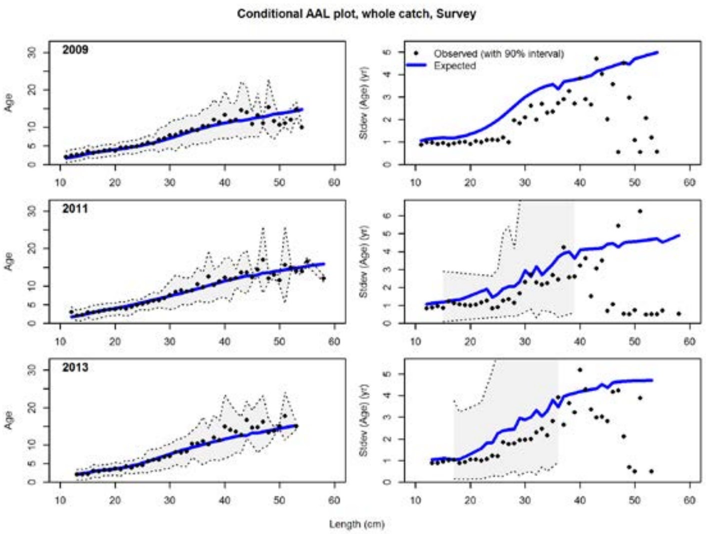
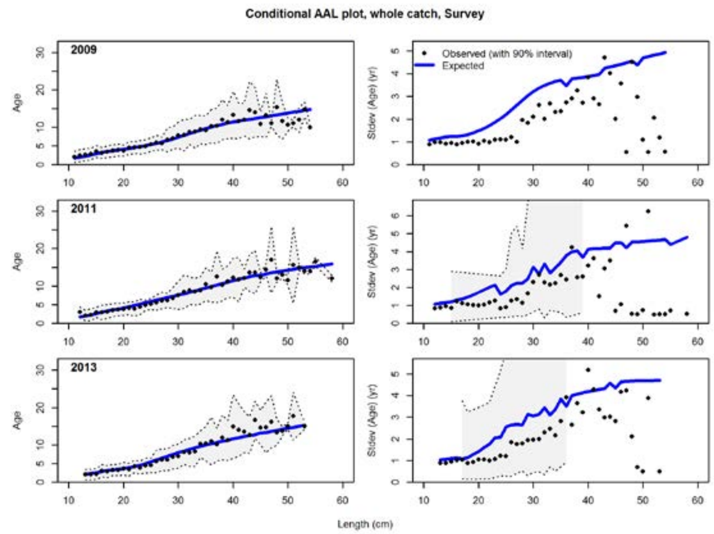


Figure 4.18. Model fit to the survey conditional age-at-length data and the associated error. a) Model 17.1, 1996 - 2001, b) model 17.2, 1996 - 2001, c) model 17.1 2003 - 2007, and d) model 17.2, 2003 - 2007.

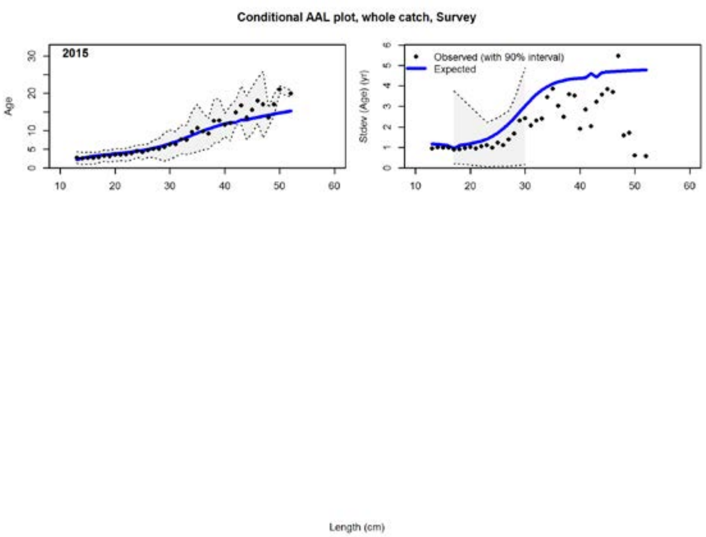
e)



f)



g)



h)

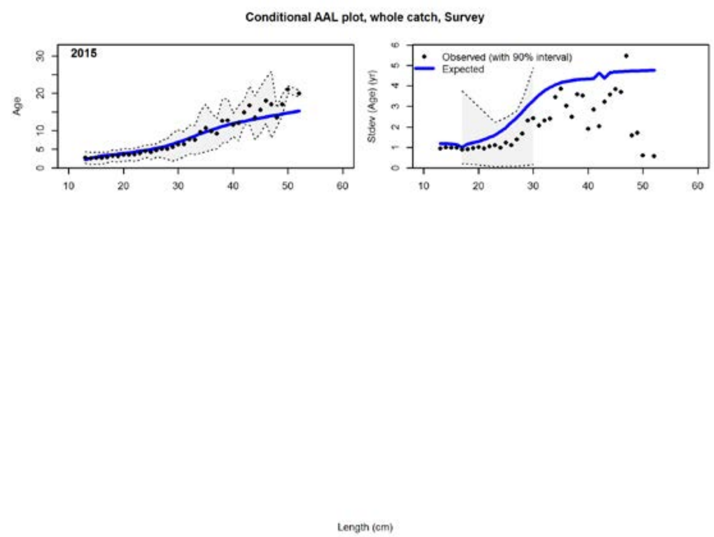


Figure 4.18 continued. Model fit to the survey conditional age-at-length data and the associated error. e) Model 17.1, 2009 - 2013, f) model 17.2, 2009 - 2013, g) model 17.1 2015, and h) model 17.2, 2015.

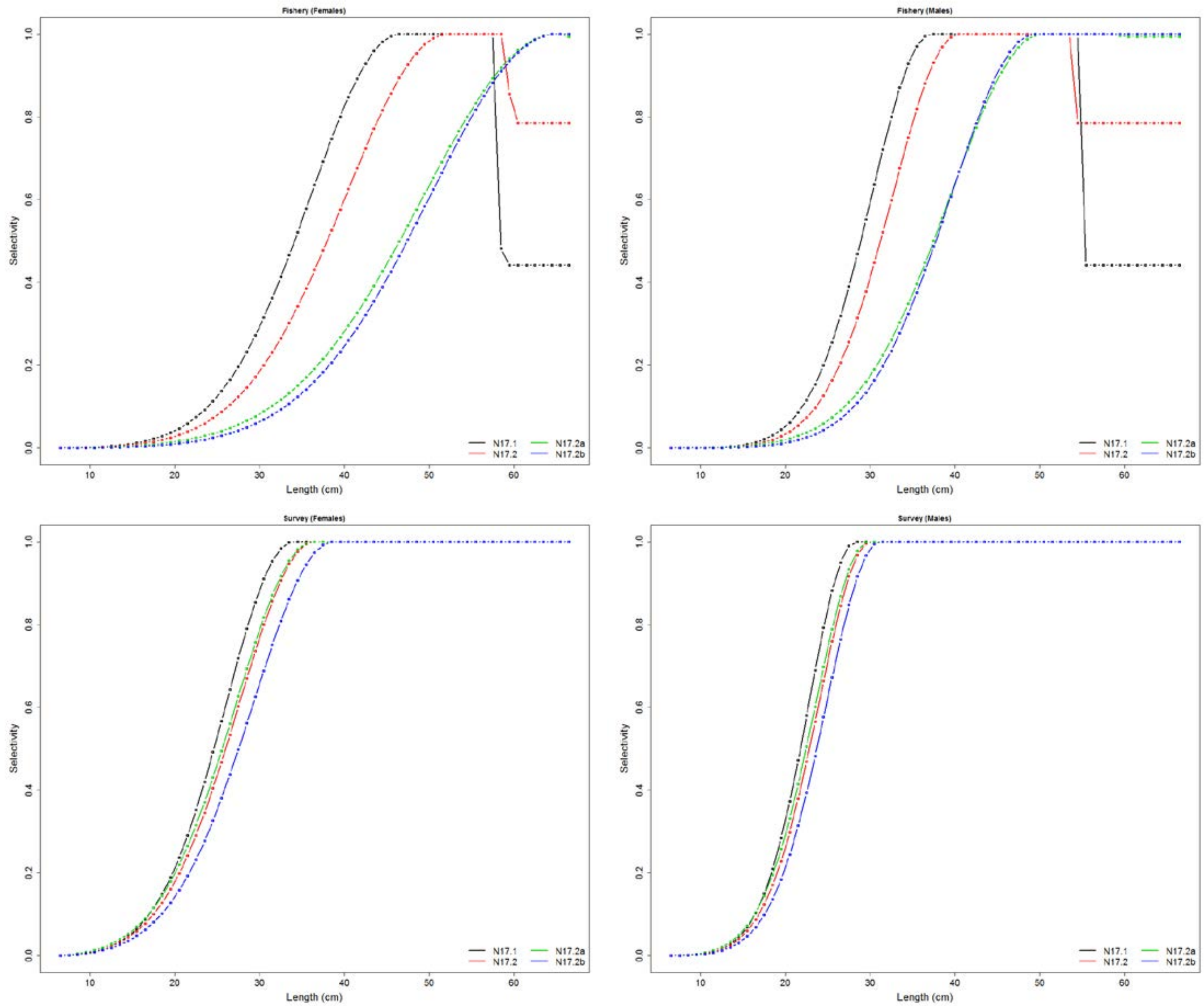


Figure 4.19. Female (left) and male (right) northern rock sole survey (top) and fishery (bottom) selectivity curves.

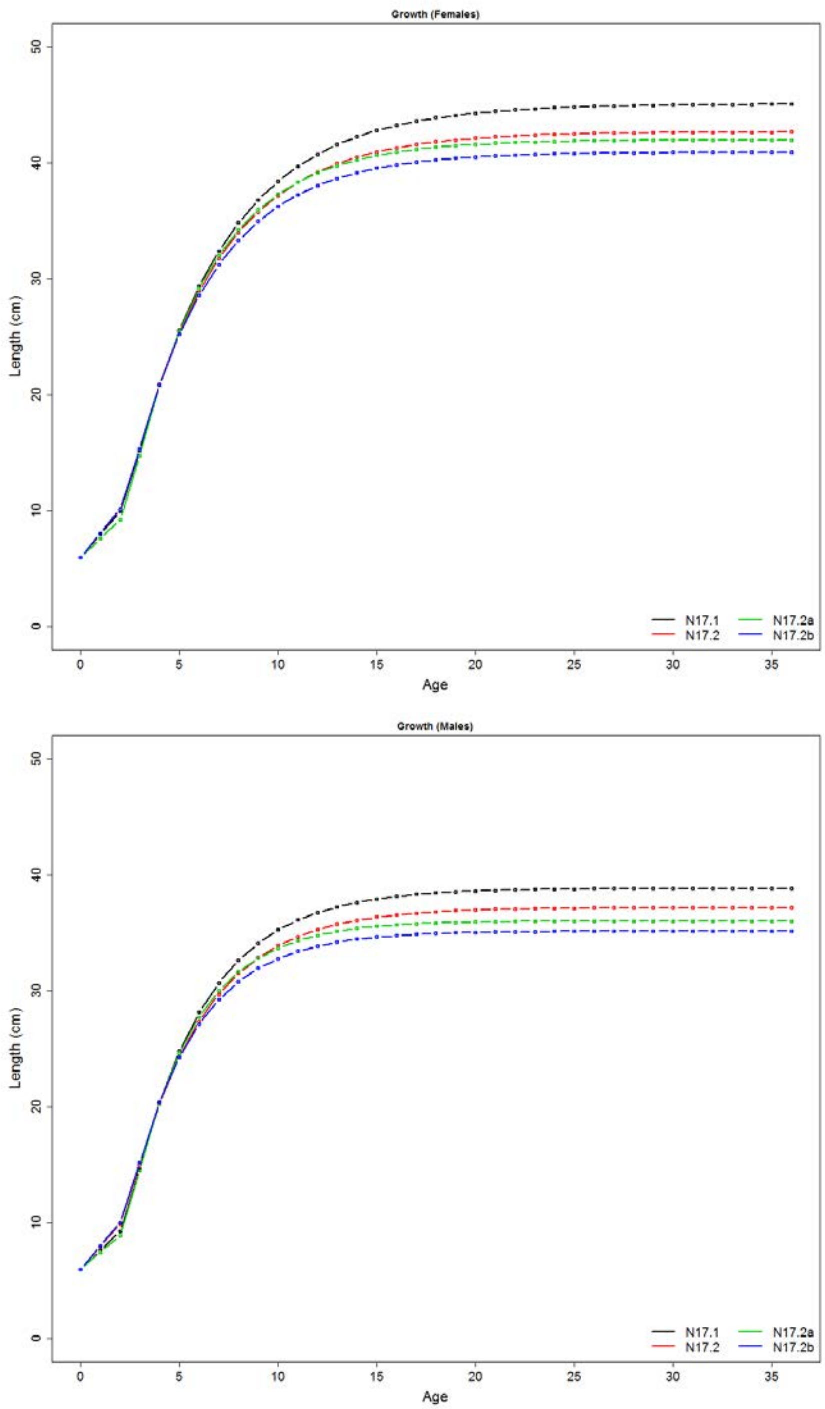
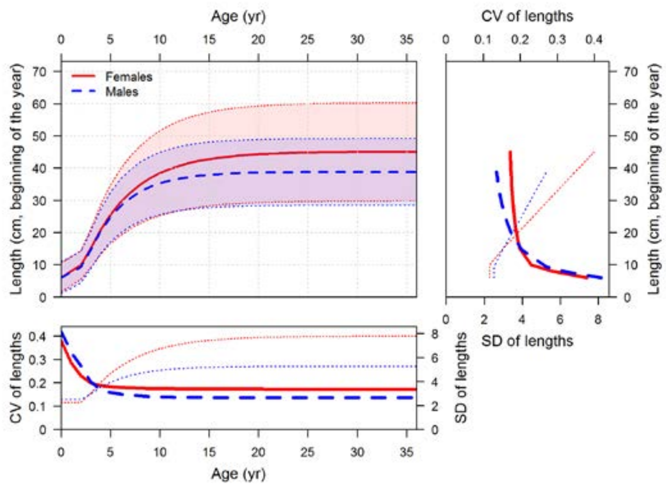
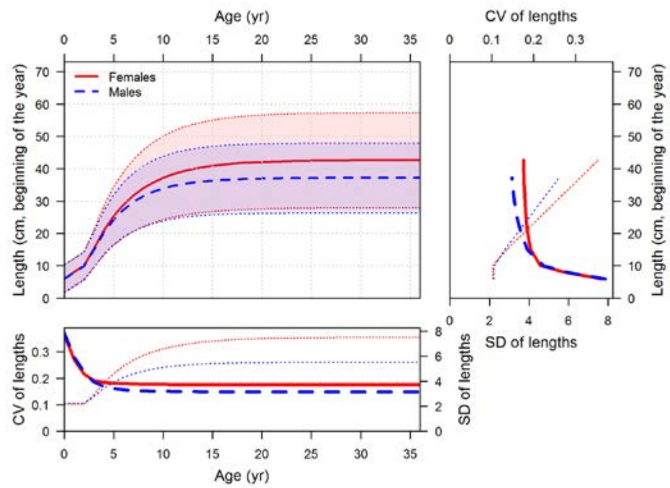


Figure 4.20. Northern rock sole growth, female (top) and male (bottom).

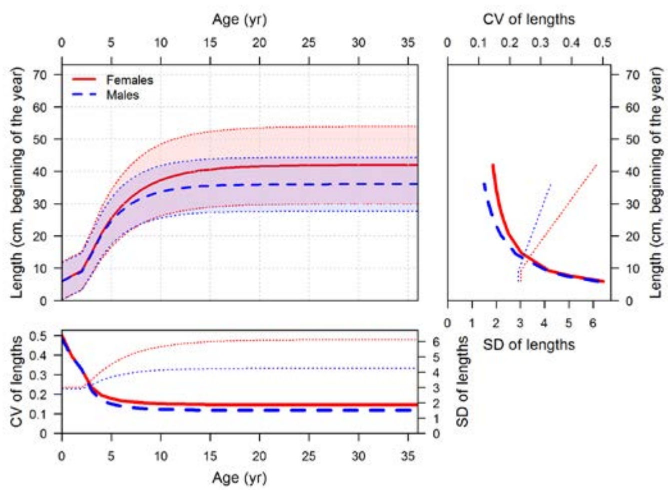
Model 17.1



Model 17.2



Model 17.2a



Model 17.2b

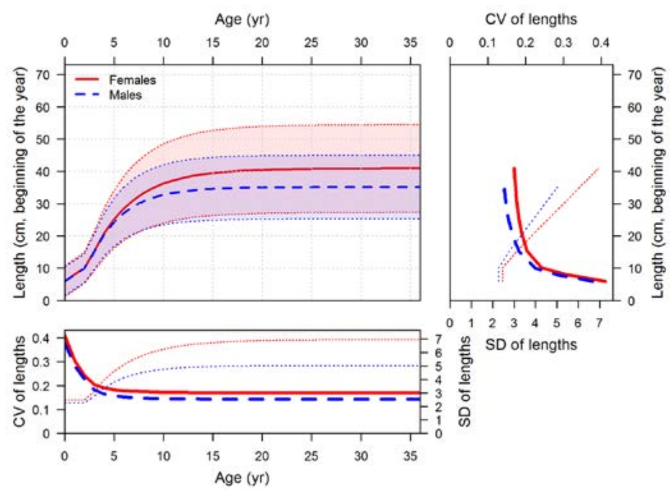


Figure 4.21. Northern rock sole growth with uncertainty. The red area represents females and the blue area represents males.

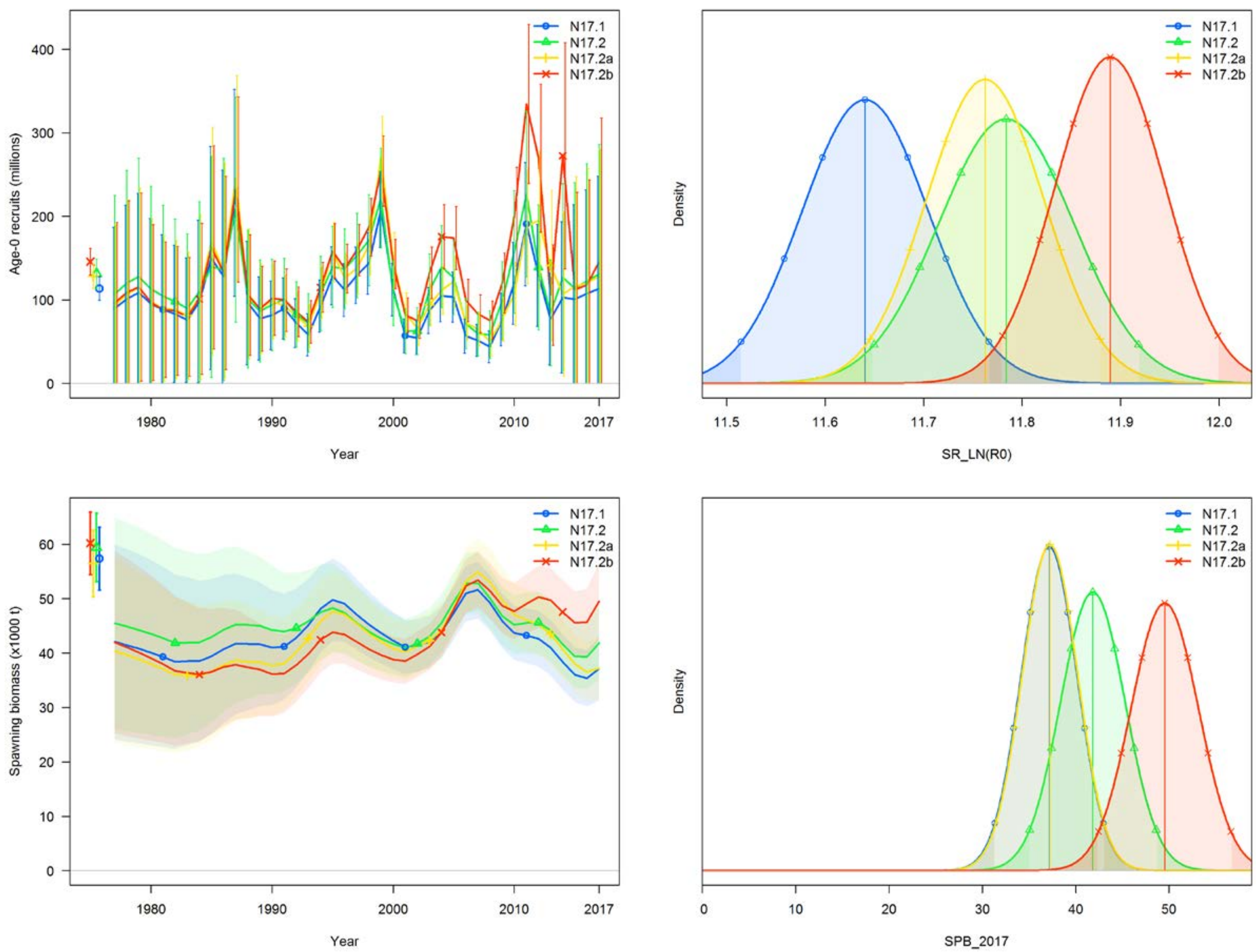
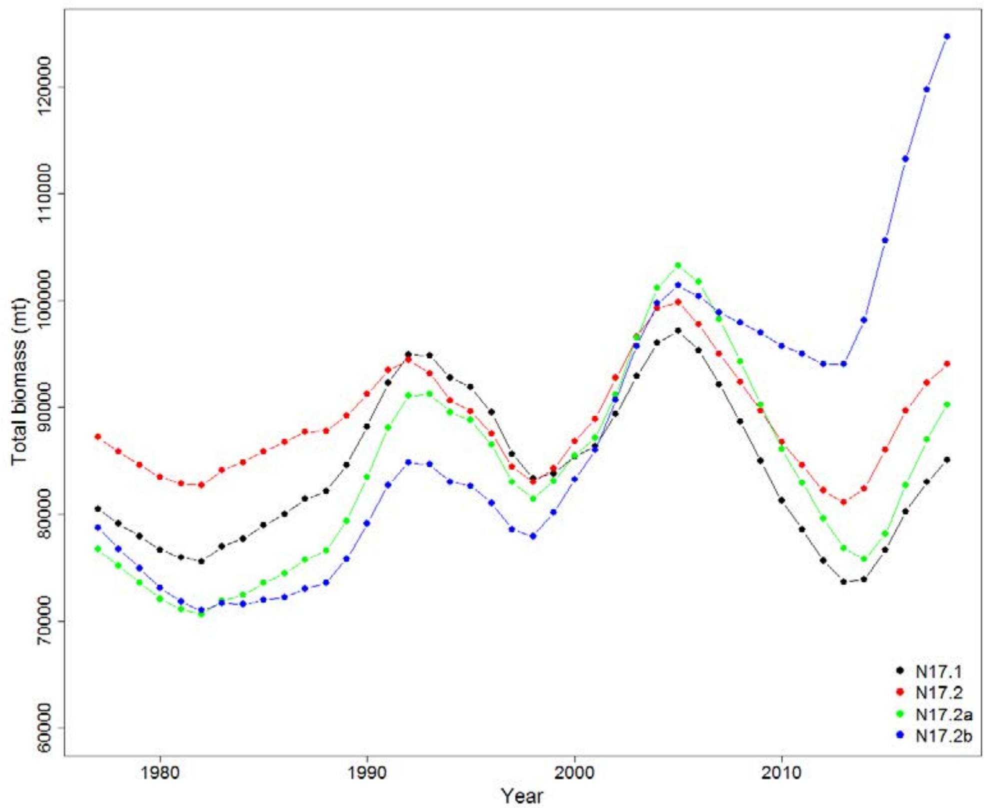


Figure 4.22. Northern rock sole age-0 recruits, $Ln(R_0)$ density, spawning stock biomass with uncertainty, and spawning biomass density in 2017.



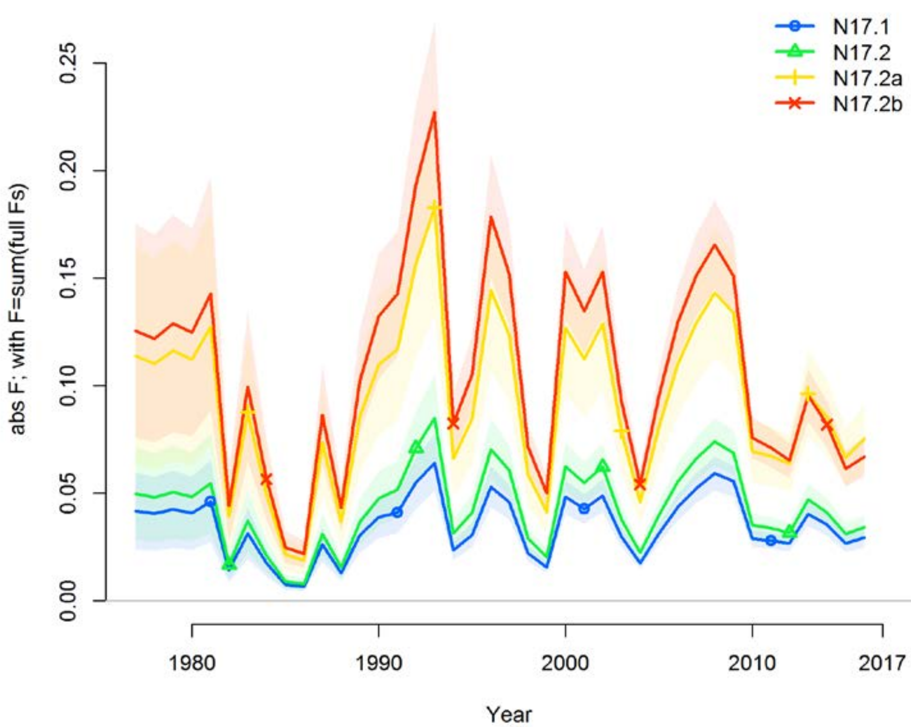


Figure 4.23. Northern rock sole total biomass (age0+) and fishing mortality estimates.

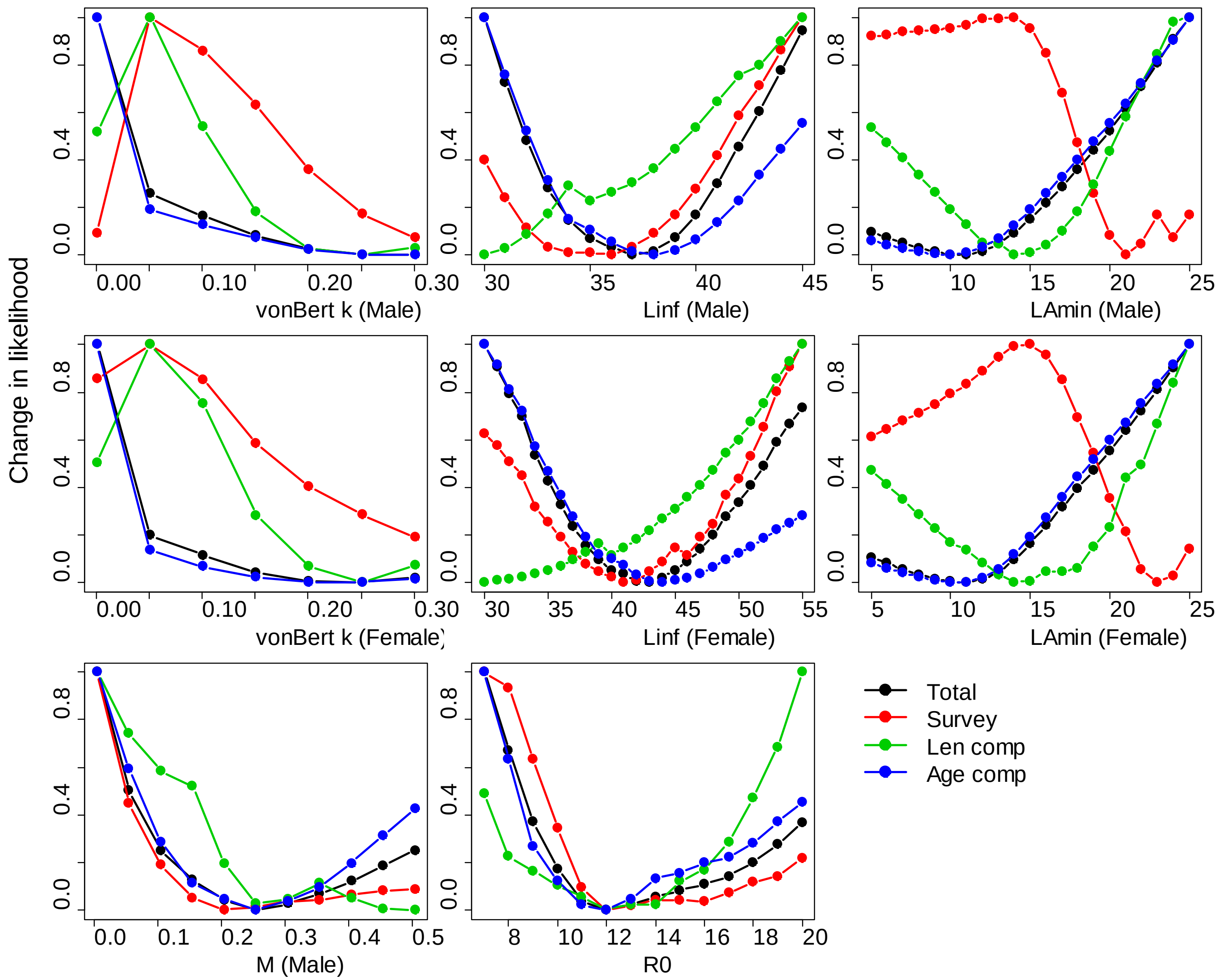


Figure 4.24. Likelihood profiles for the preferred northern rock sole assessment model, model 17.2. The change in the likelihood was scaled to 1 so that the pattern could be seen for all likelihood components. Likelihood profiles are shown for estimated model parameters, excluding the selectivity parameters.

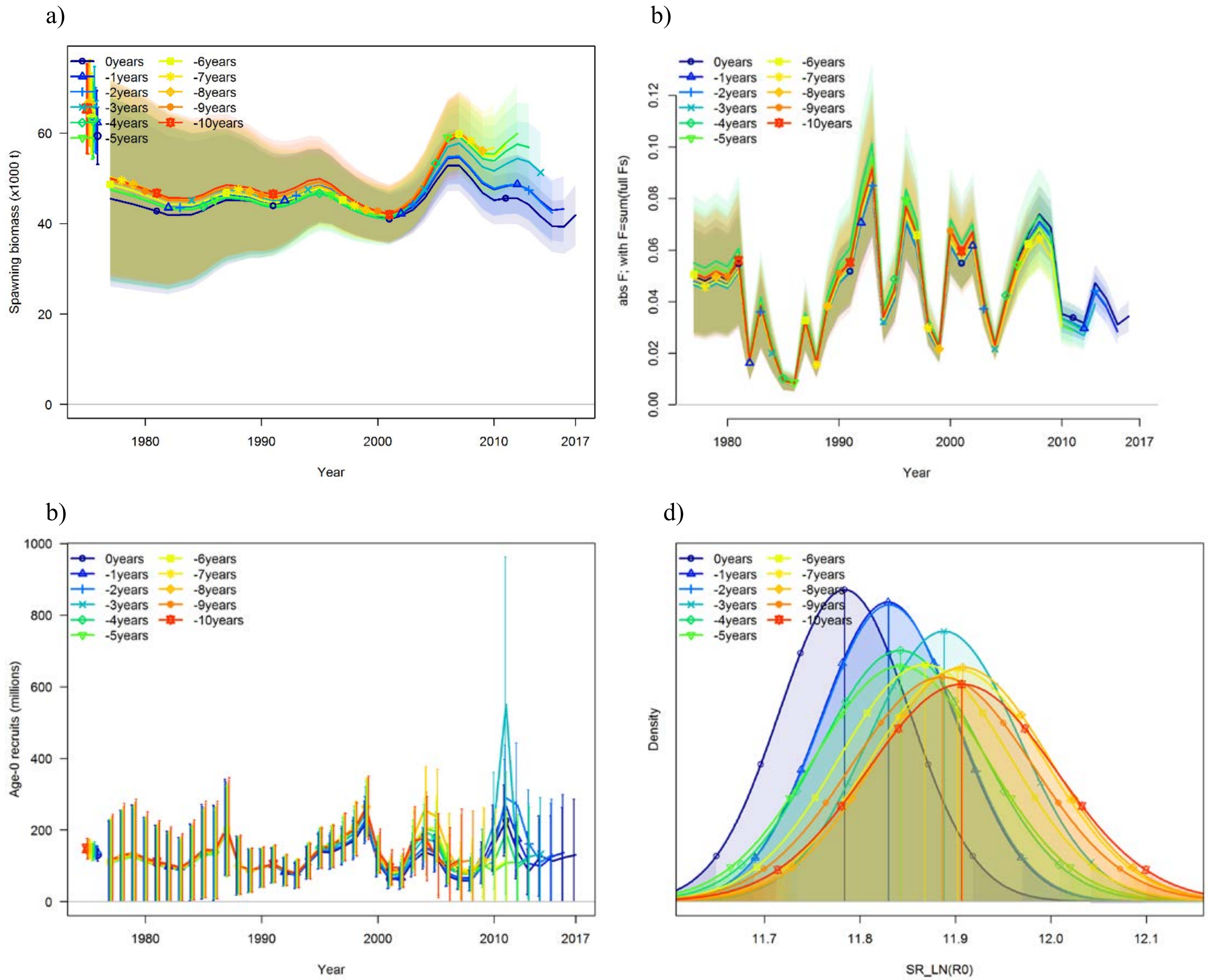
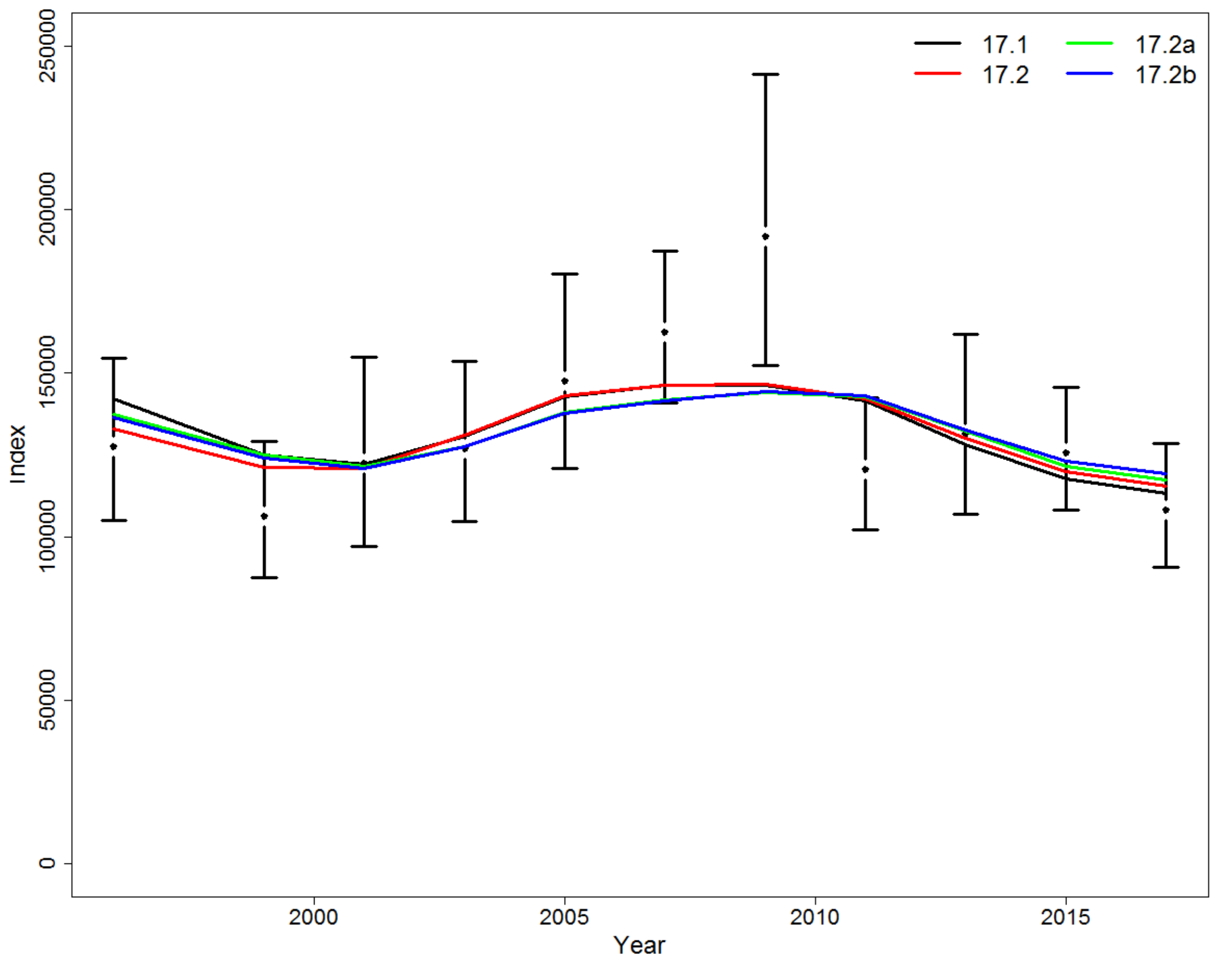


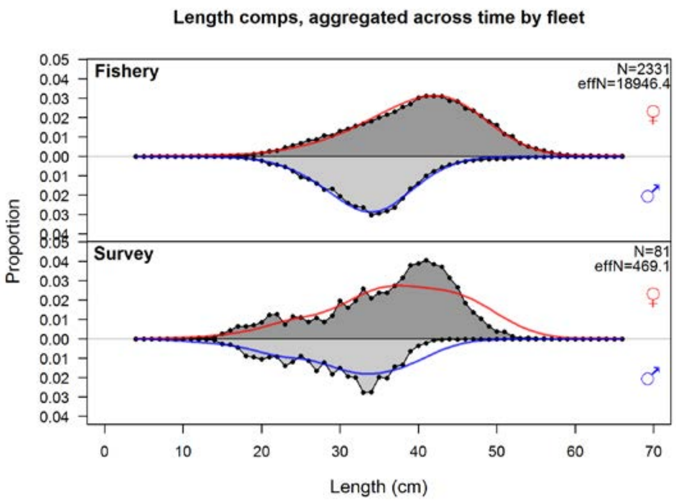
Figure 4.25. Northern rock sole retrospective analysis results. a) spawning biomass, b) fishing mortality, c) age-0 recruits, and d) density of LN(R_0).



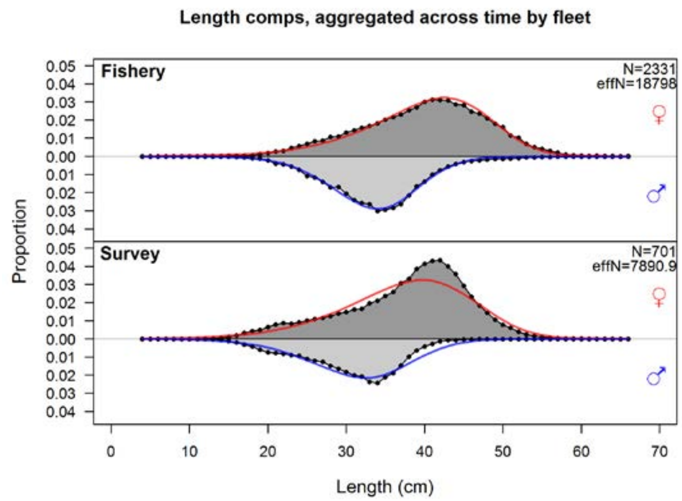
Model	RMSE
17.1	0.12
17.2	0.112
17.2a	0.126
17.2b	0.126

Figure 4.26. NMFS GOA bottom trawl survey southern rock sole index and model fit comparison.

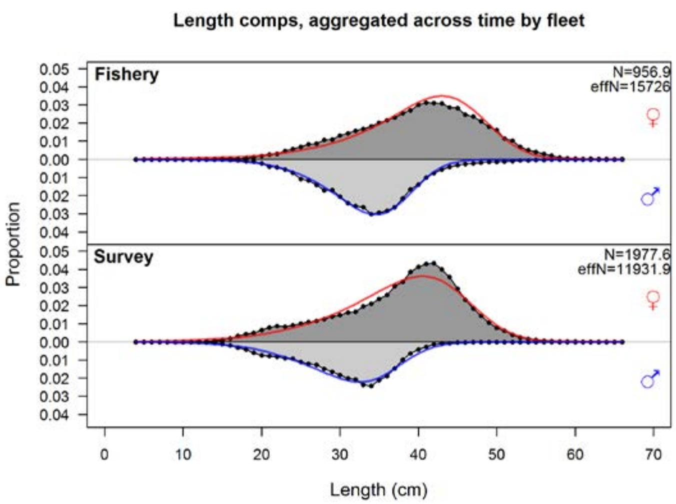
Model 17.1



Model 17.2



Model 17.2a



Model 17.2b

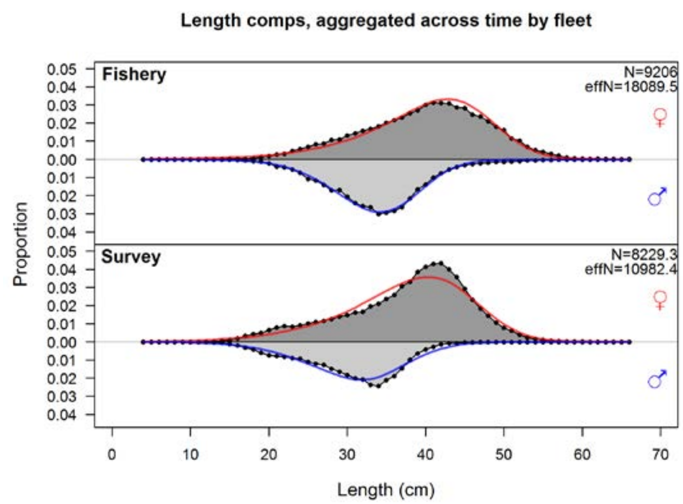
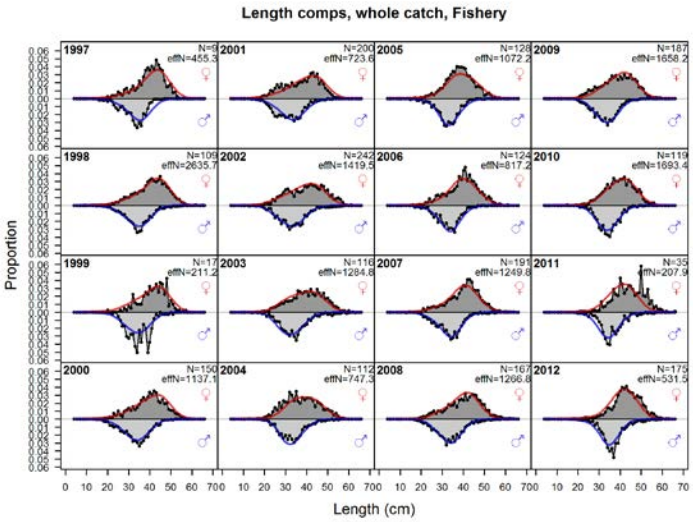
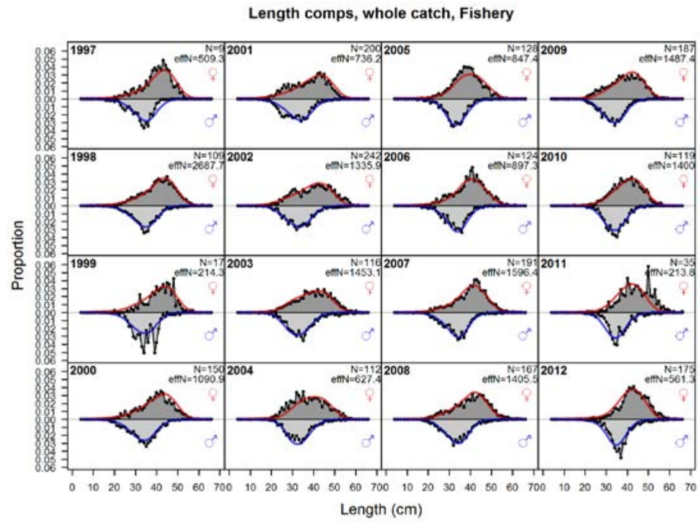


Figure 4.27. Fits (red line - female, blue line – male) to the southern rock sole fishery and survey size composition data aggregated over years.

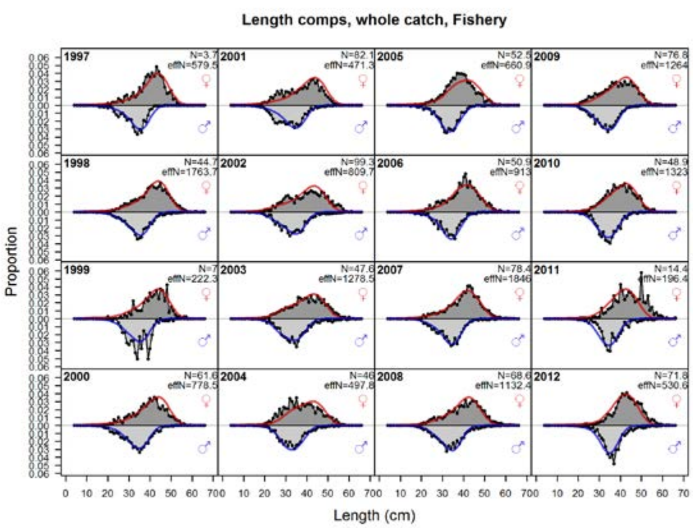
Model 17.1



Model 17.2



Model 17.2a



Model 17.2b

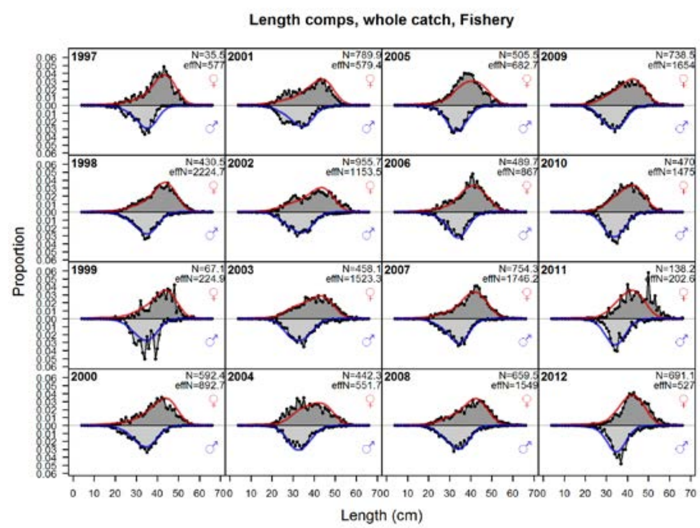
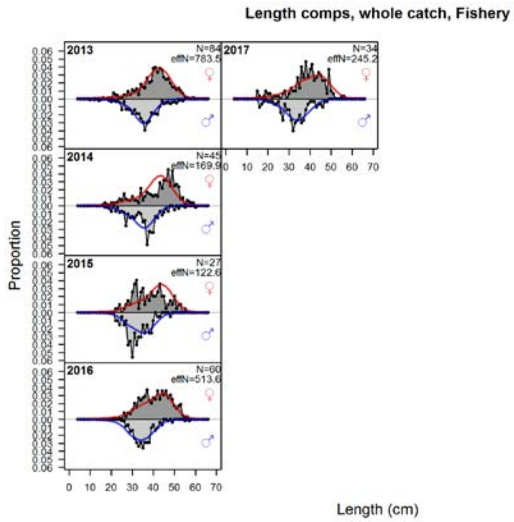
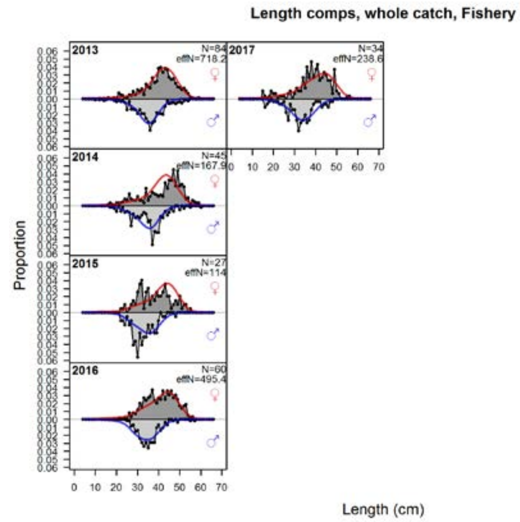


Figure 4.28. Fits (red line - female, blue line – male) to the southern rock sole fishery size composition data (1997-2012).

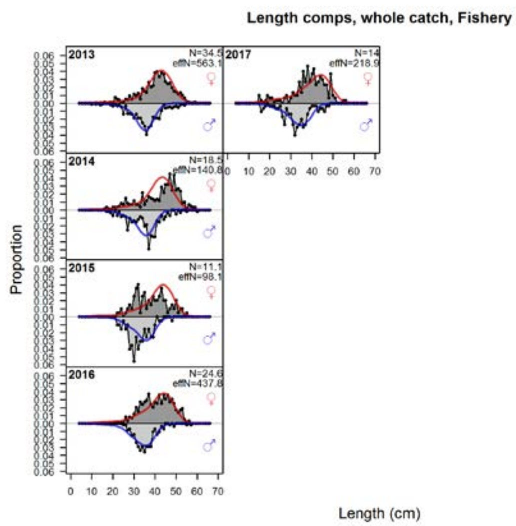
Model 17.1



Model 17.2



Model 17.2a



Model 17.2b

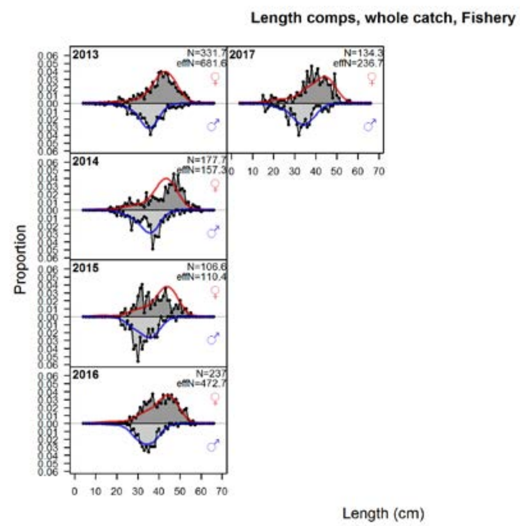
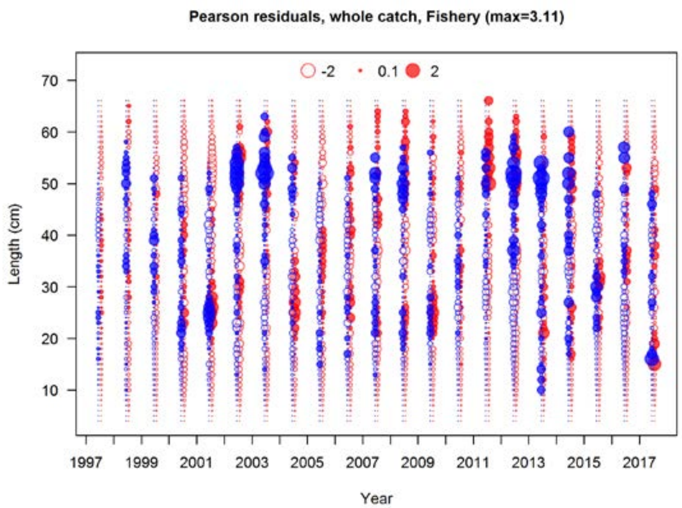
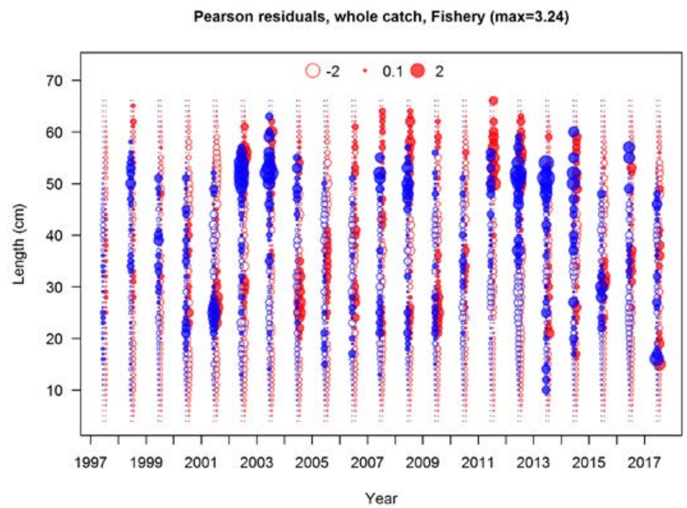


Figure 4.29. Fits (red line - female, blue line – male) to the southern rock sole fishery size composition data (2013-2017).

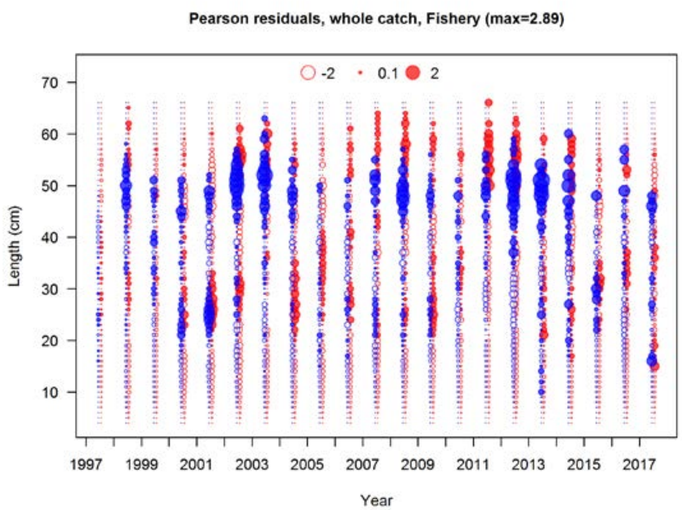
Model 17.1



Model 17.2



Model 17.2a



Model 17.2b

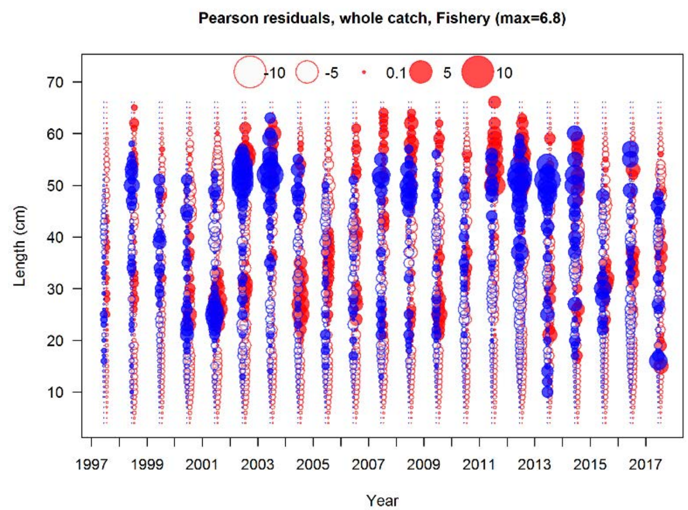
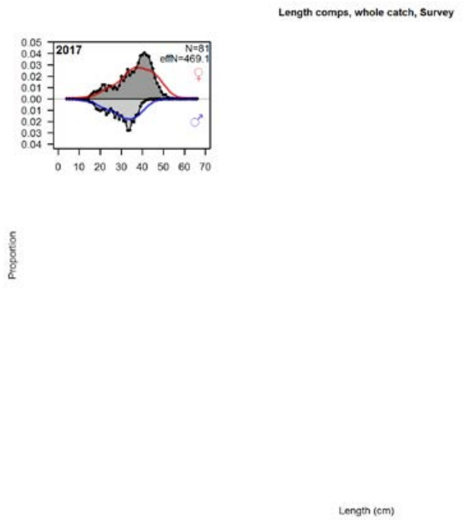
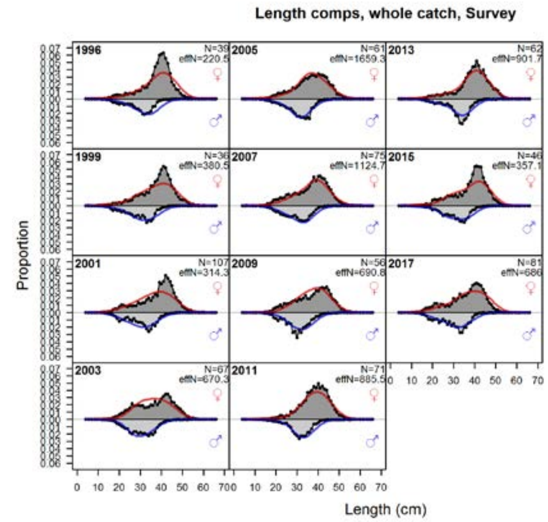


Figure 4.30. Pearson residuals (red - female, blue – male) for fishery size composition data. Closed bubbles are positive residuals (observed > estimated). Scales differ by model.

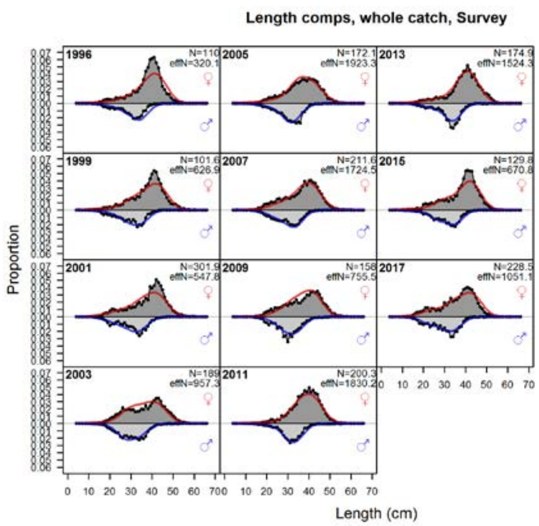
Model 17.1



Model 17.2



Model 17.2a



Model 17.2b

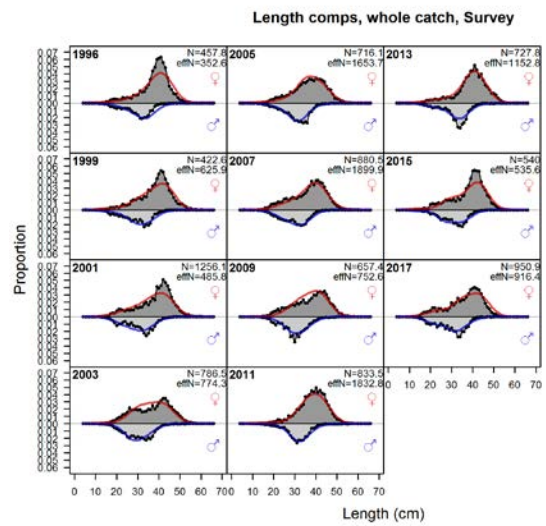
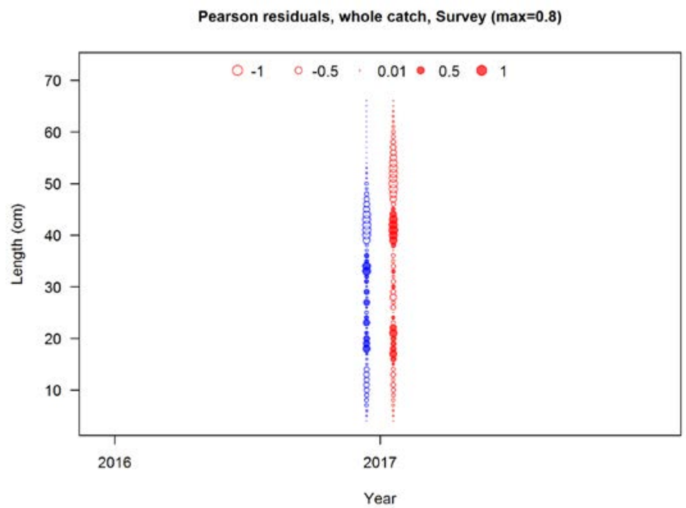
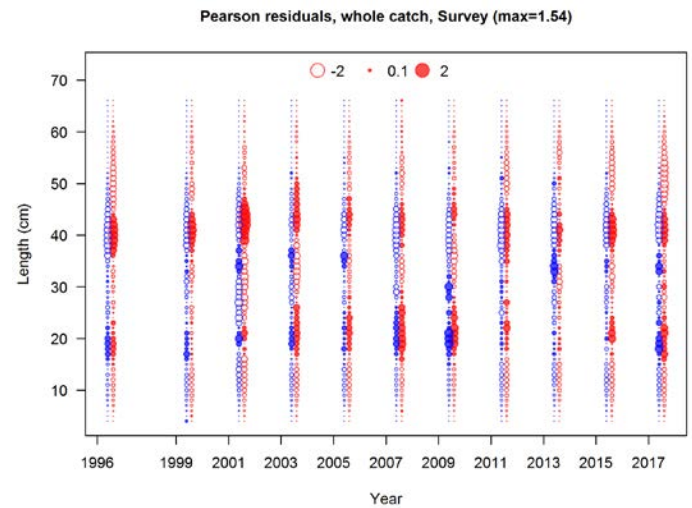


Figure 4.31. Fits (red line - female, blue line – male) to the southern rock sole survey size composition data (1996-2015).

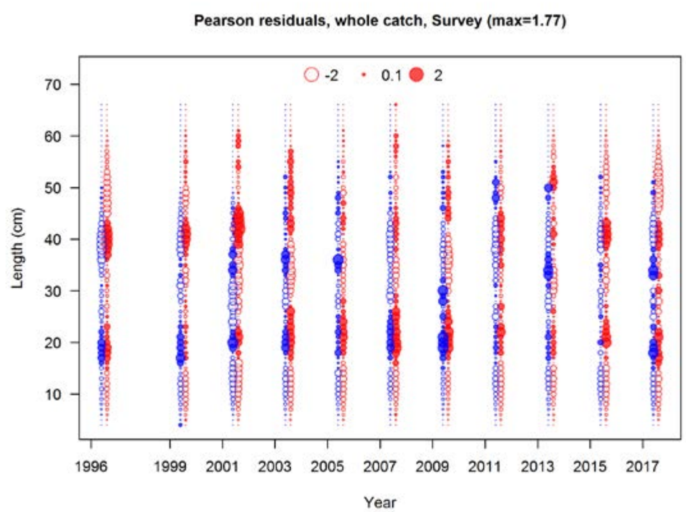
Model 17.1



Model 17.2



Model 17.2a



Model 17.2b

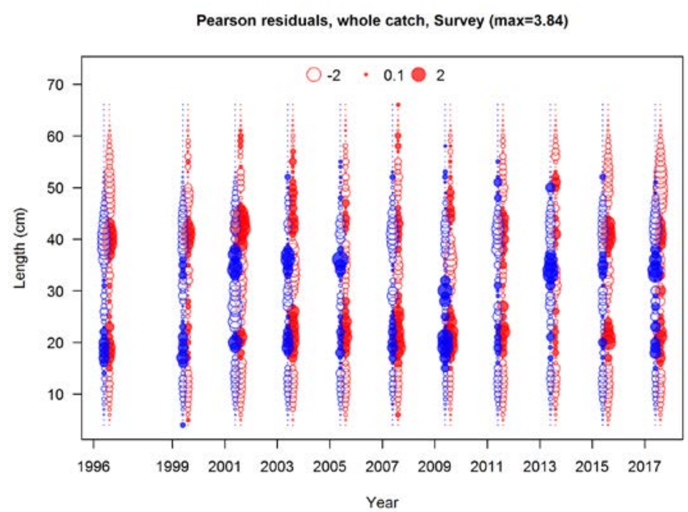
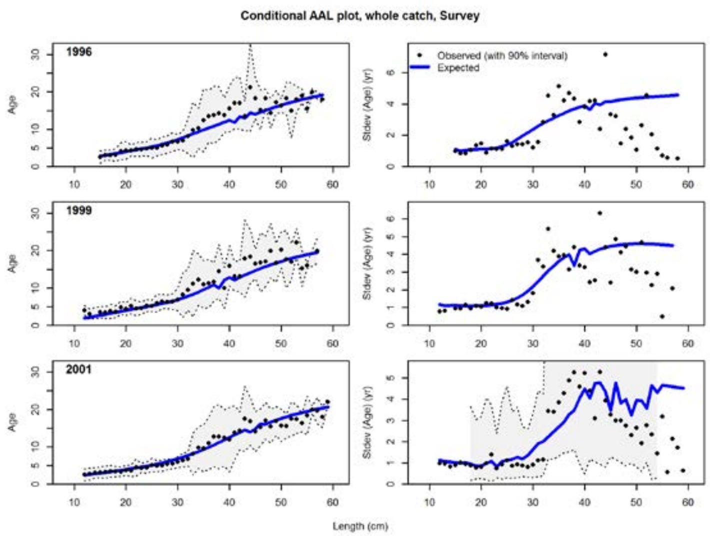
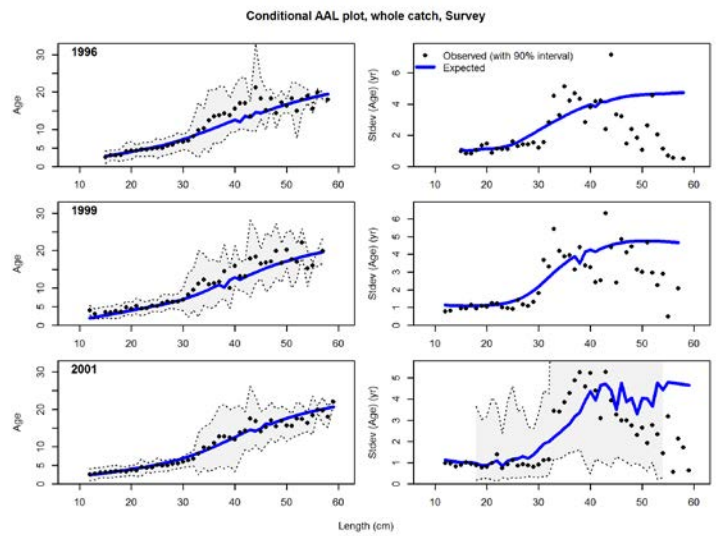


Figure 4.32. Pearson residuals (red - female, blue – male) for southern rock sole survey size composition data. Closed bubbles are positive residuals (observed > estimated). Scales differ by model. Model 15.1 was fit to the 2017 length composition data, hence the absence of residuals.

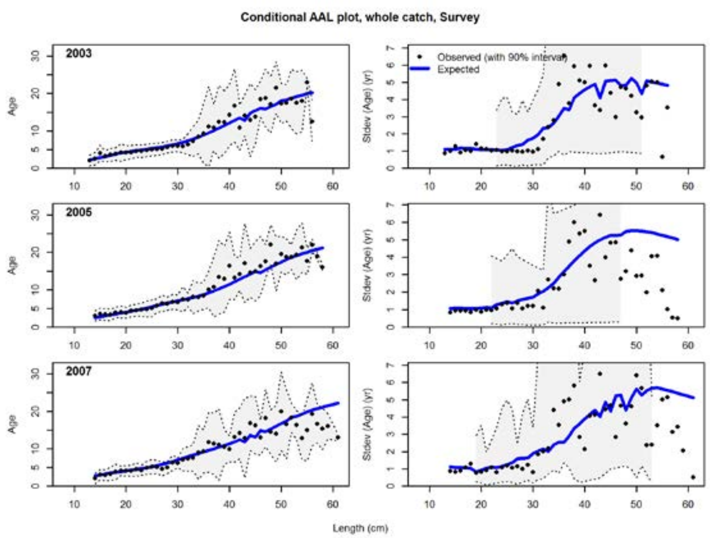
a)



b)



c)



d)

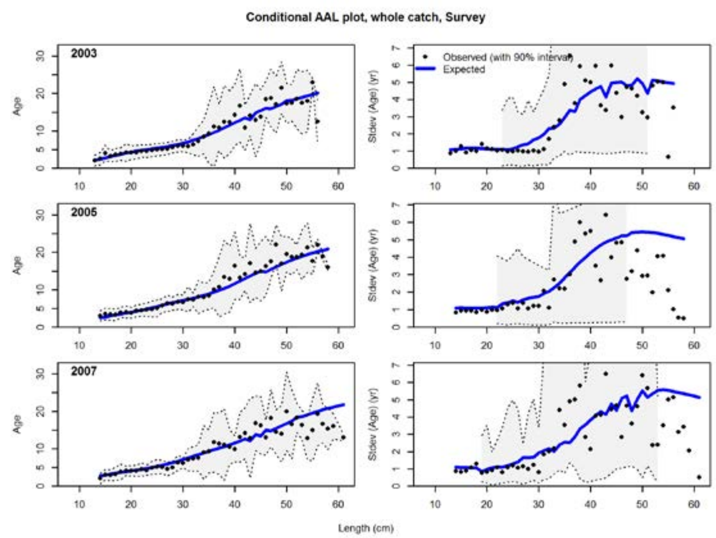
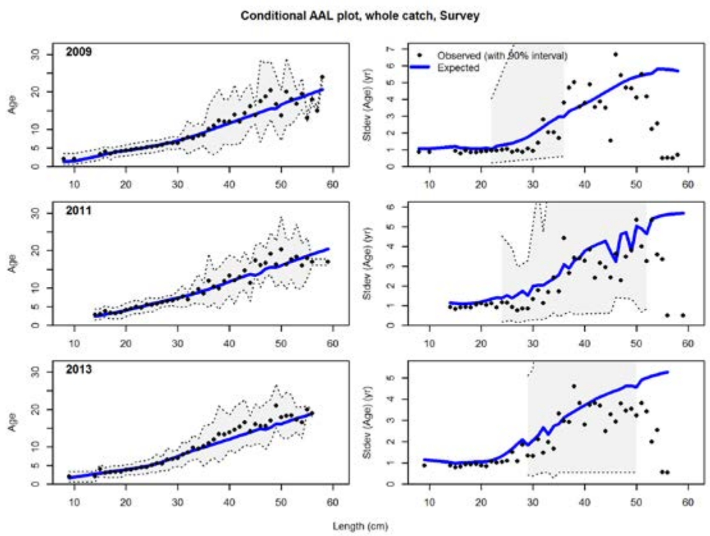
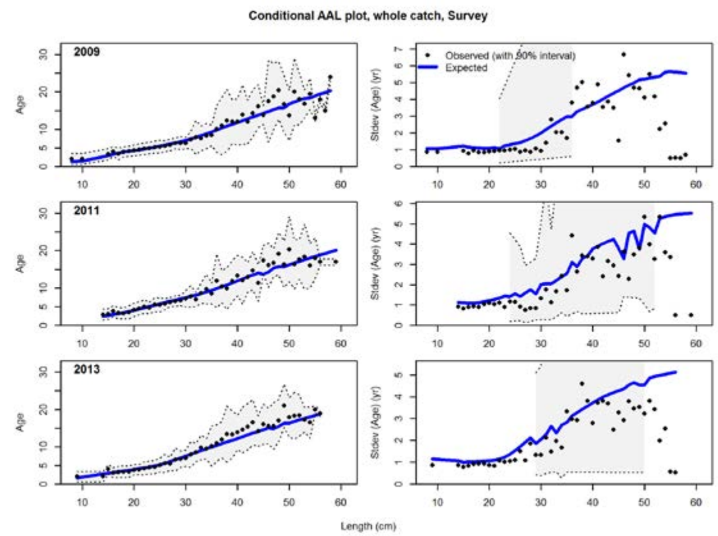


Figure 4.33. Southern rock sole assessment model fit to the conditional age at length data. Model fit to the survey conditional age-at-length data and the associated error. a) Model 17.1, 1996 - 2001, b) model 17.2, 1996 - 2001, c) model 17.1 2003 - 2007, and d) model 17.2, 2003 - 2007.

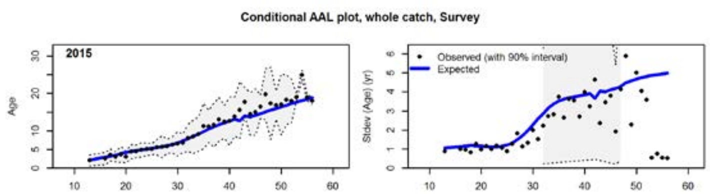
e)



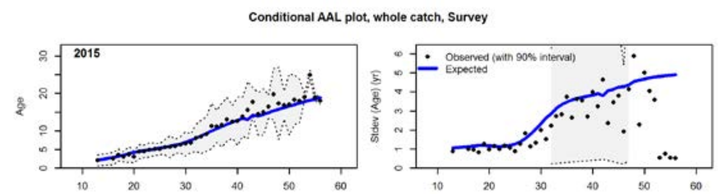
f)



g)



h)



Length (cm)

Length (cm)

Figure 4.33. continued. Southern rock sole assessment model fit to the conditional age at length data.. e) Model 17.1, 2009 - 2013, f) model 17.2, 2009 - 2013, g) model 17.1 2015, and h) model 17.2, 2015.

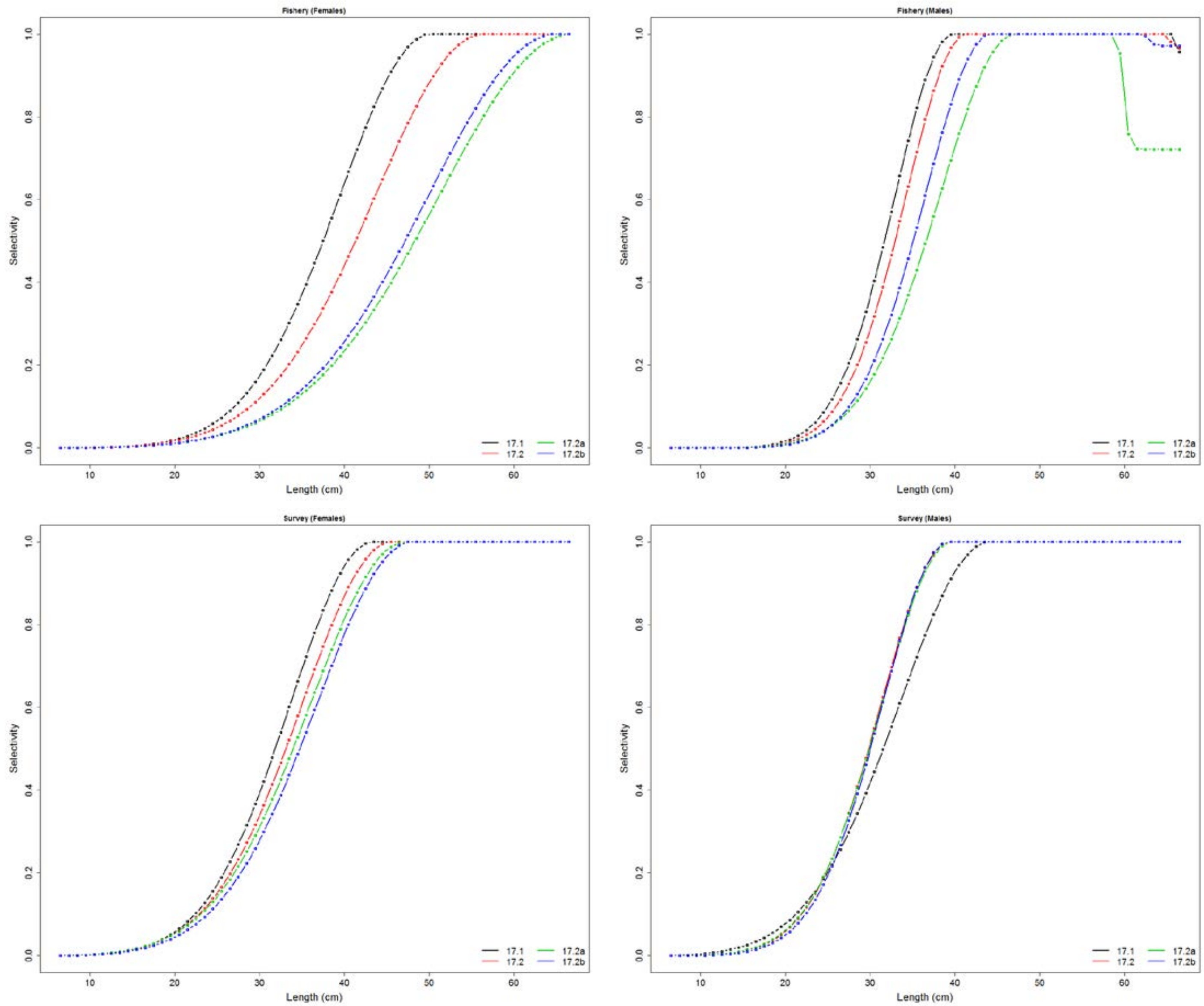


Figure 4.34. Southern rock sole, female (left) and male (right), fishery (top) and survey (bottom) selectivity.

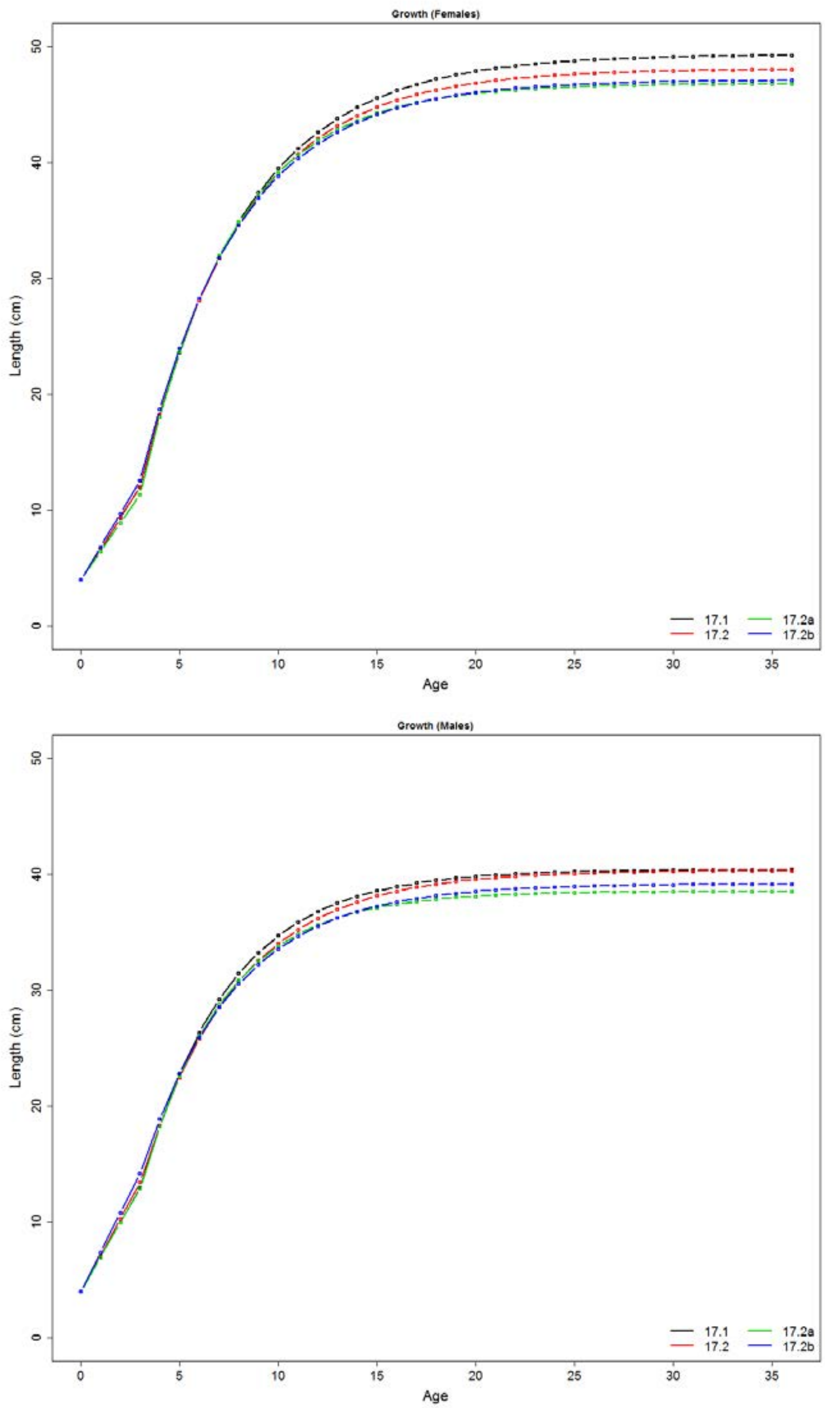
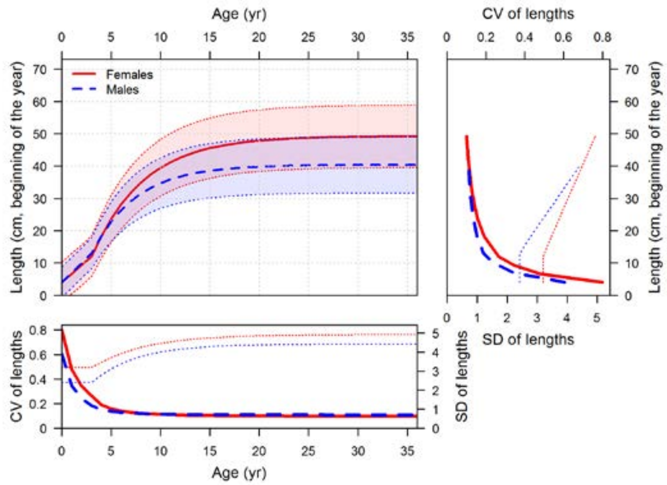
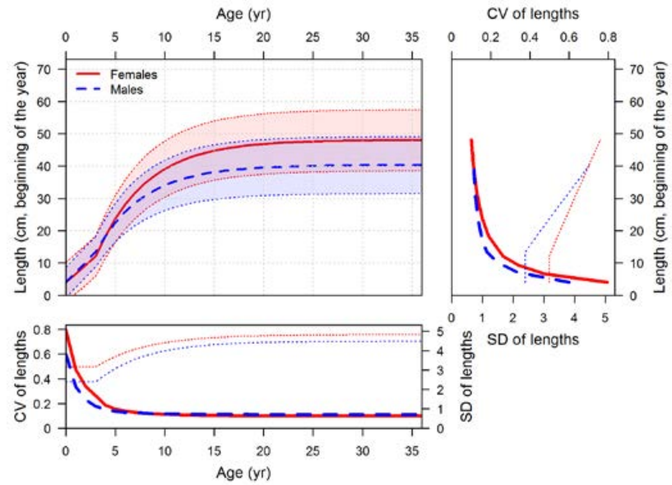


Figure 4.35. Southern rock sole growth, female (top) and male (bottom).

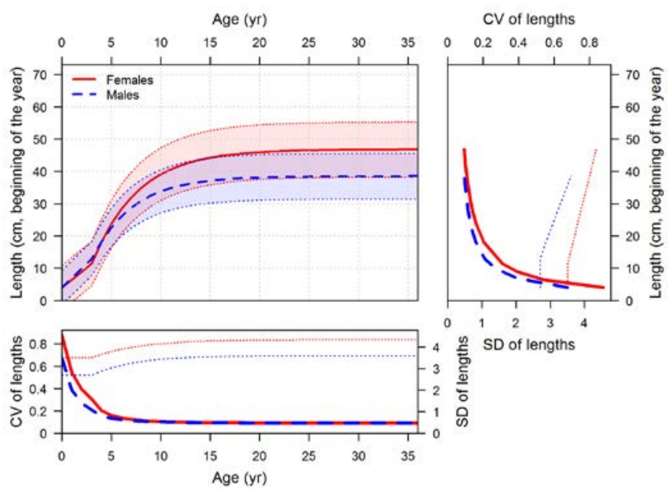
Model 17.1



Model 17.2



Model 17.2a



Model 17.2b

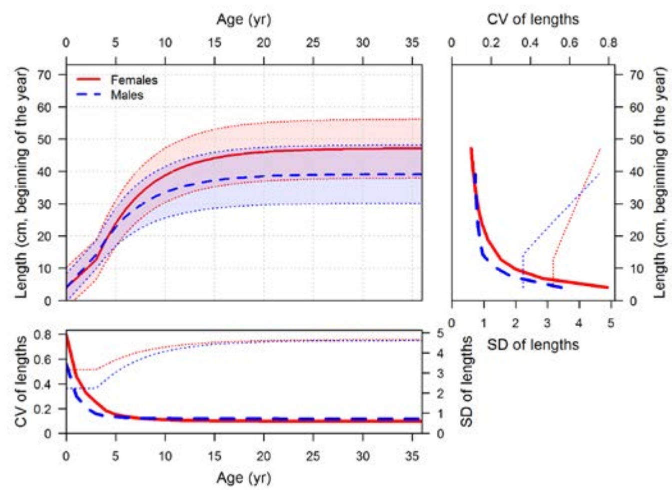


Figure 4.36. Southern rock sole growth with uncertainty. Red represents females and blue represents males.

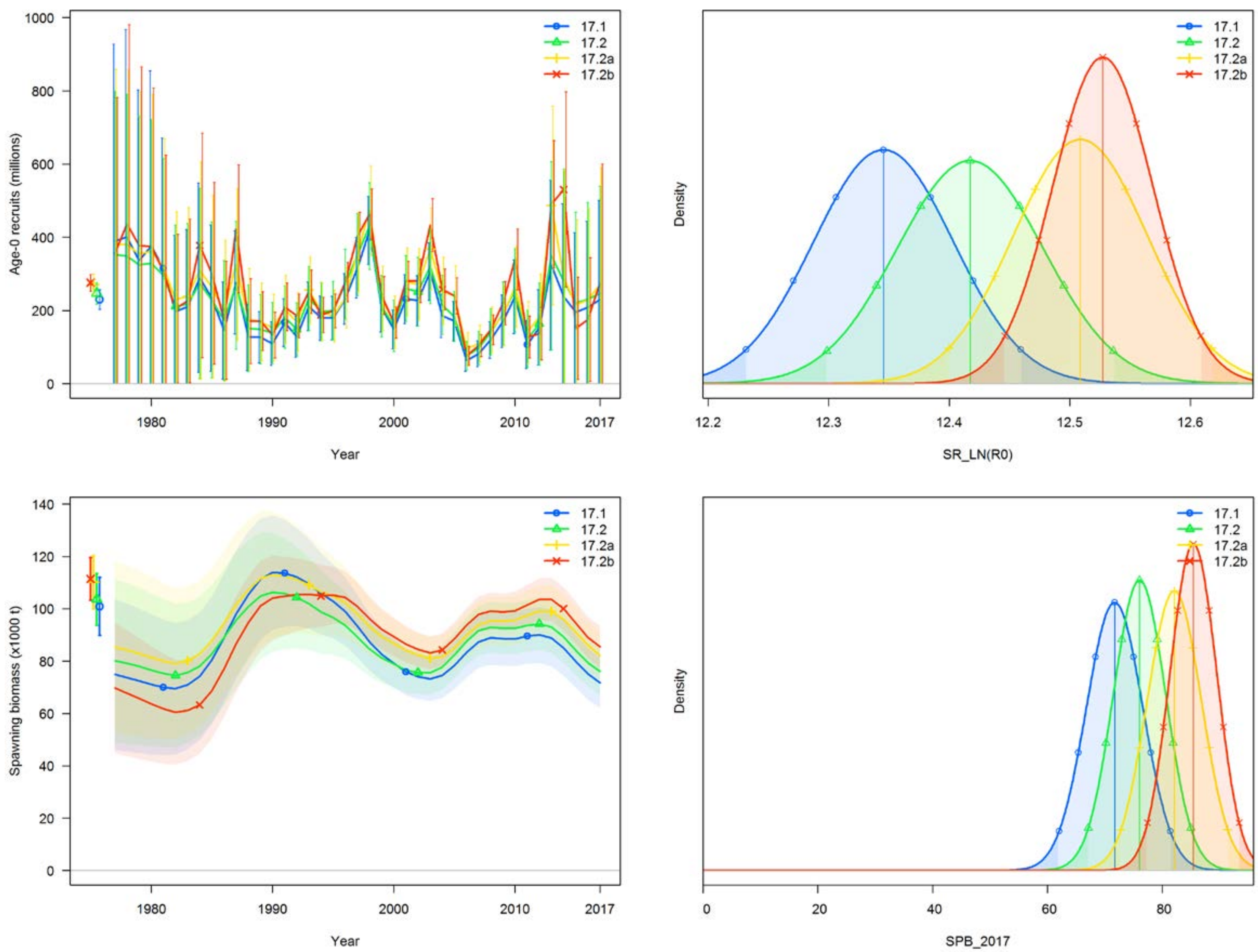


Figure 4.37. Southern rock sole age-0 recruits, Ln(R_0) density, spawning stock biomass with uncertainty, and spawning biomass density in 2017.

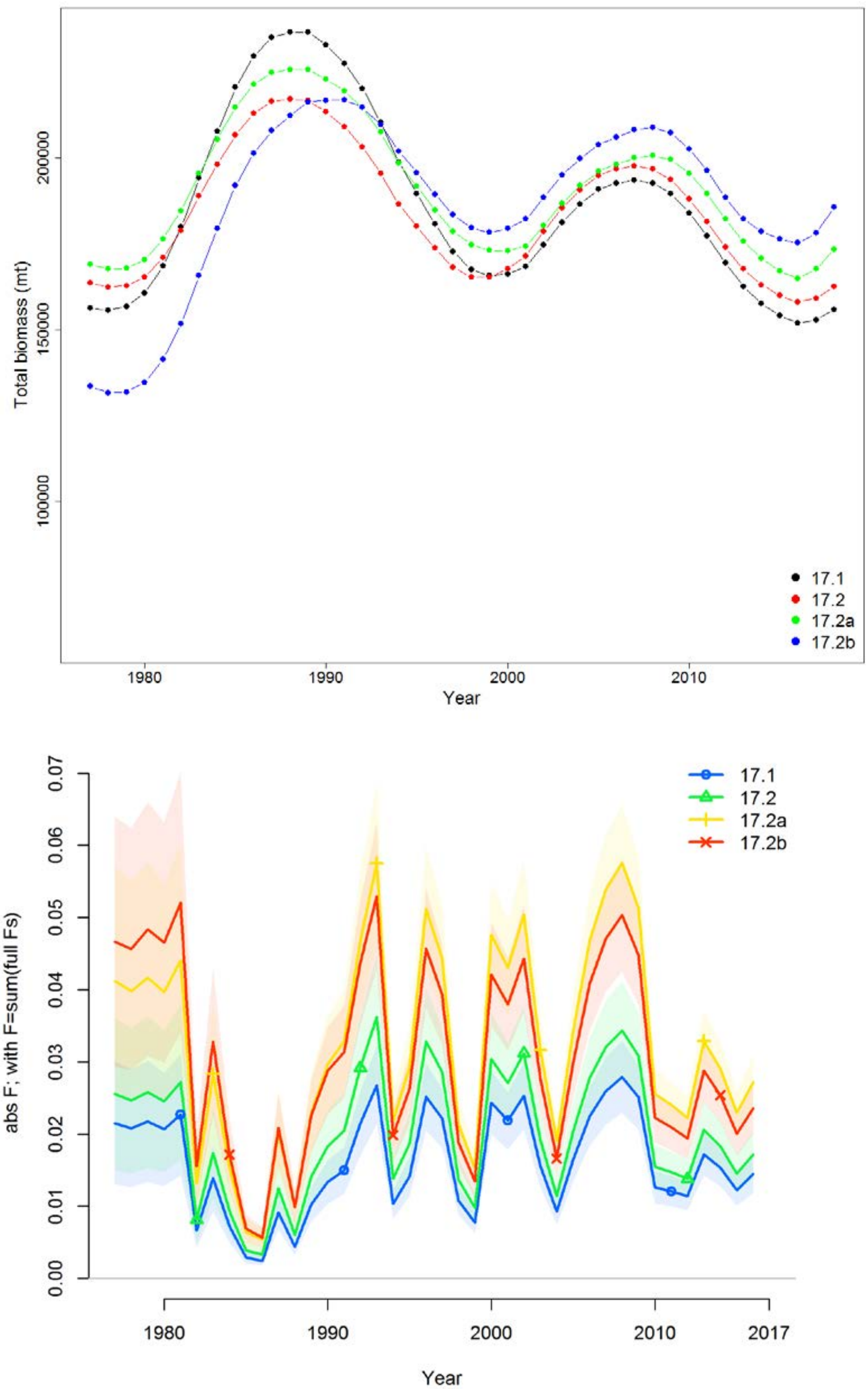


Figure 4.38. Southern rock sole total biomass and fishing mortality time-series.

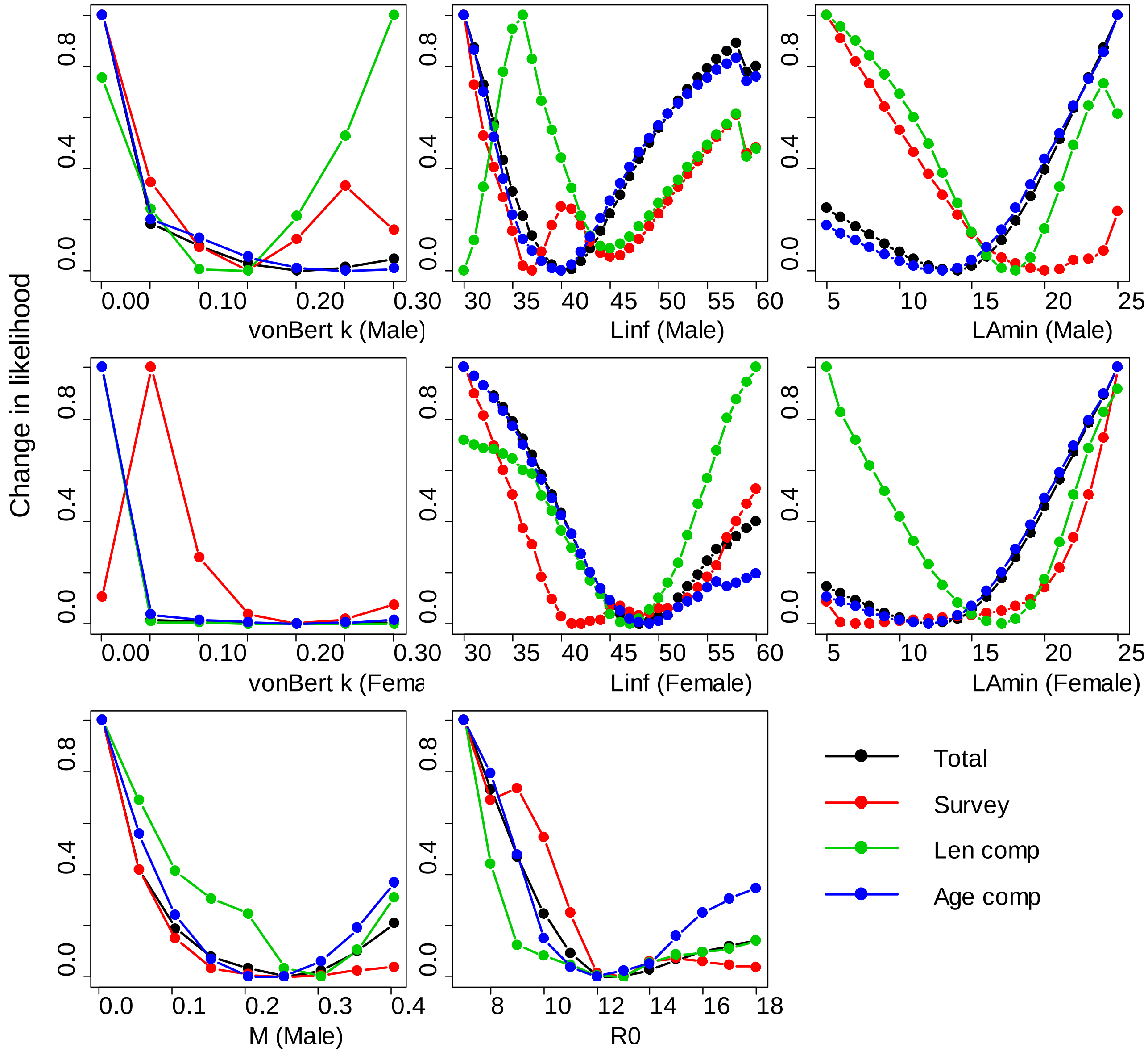


Figure 4.39. Likelihood profiles for southern rock sole assessment model 17.2.

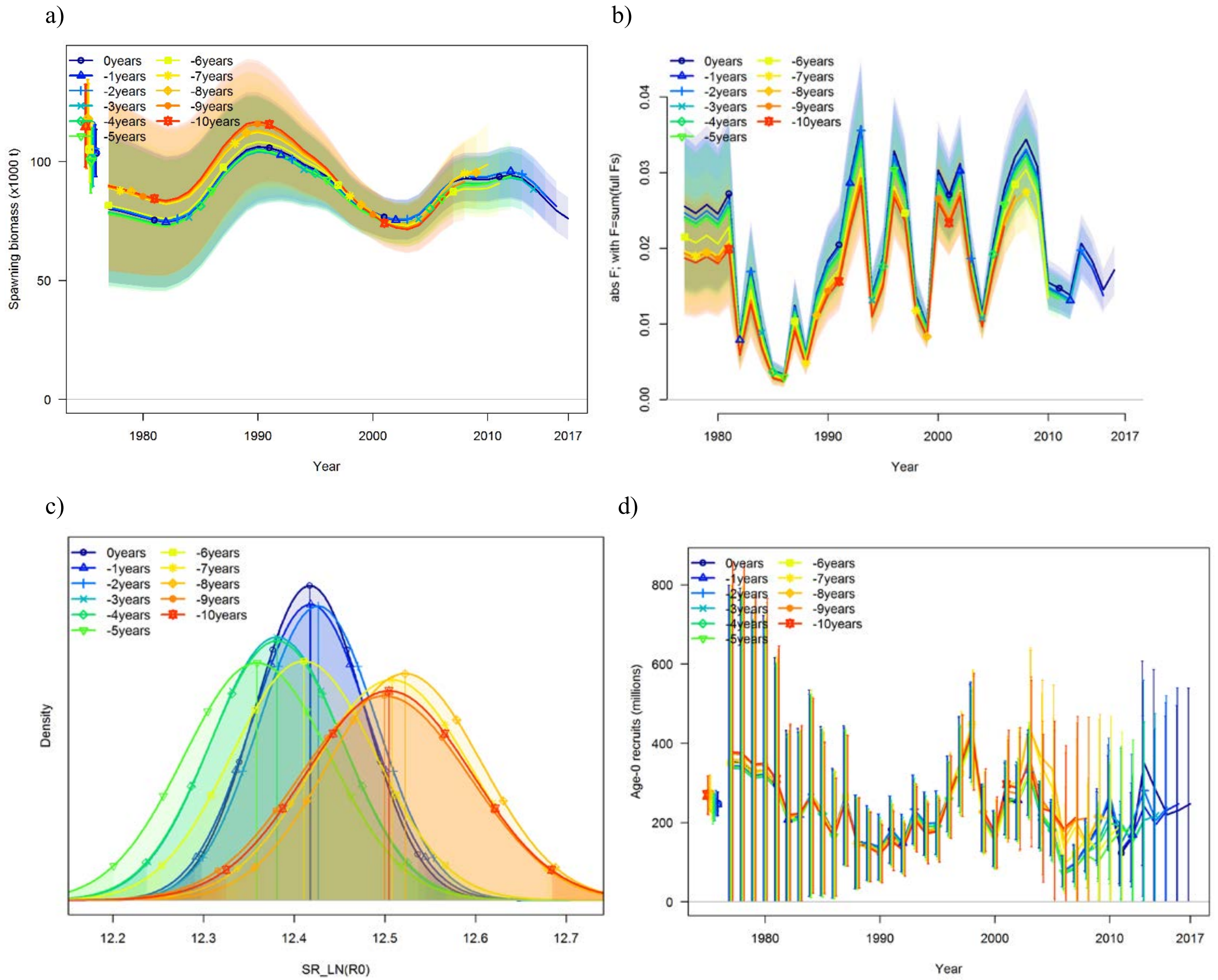


Figure 4.40. Southern rock sole retrospective analysis for model 17.2. a) spawning biomass, b) fishing mortality, c) density of $LN(R_0)$, and d) age-0 recruits.

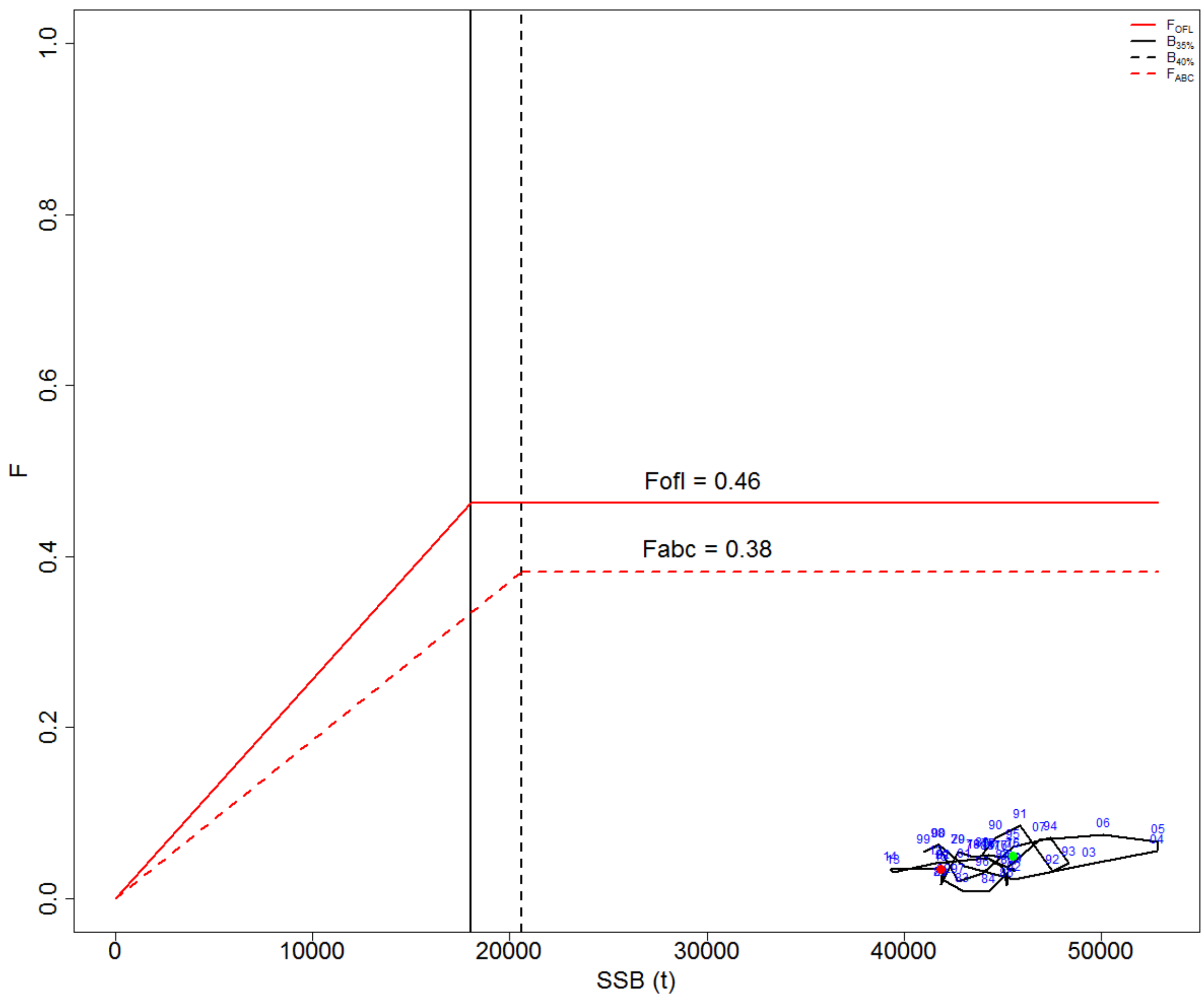


Figure 4.41. Northern rock sole phase plot. The green dot represents 1977 and the red dot represents 2017.

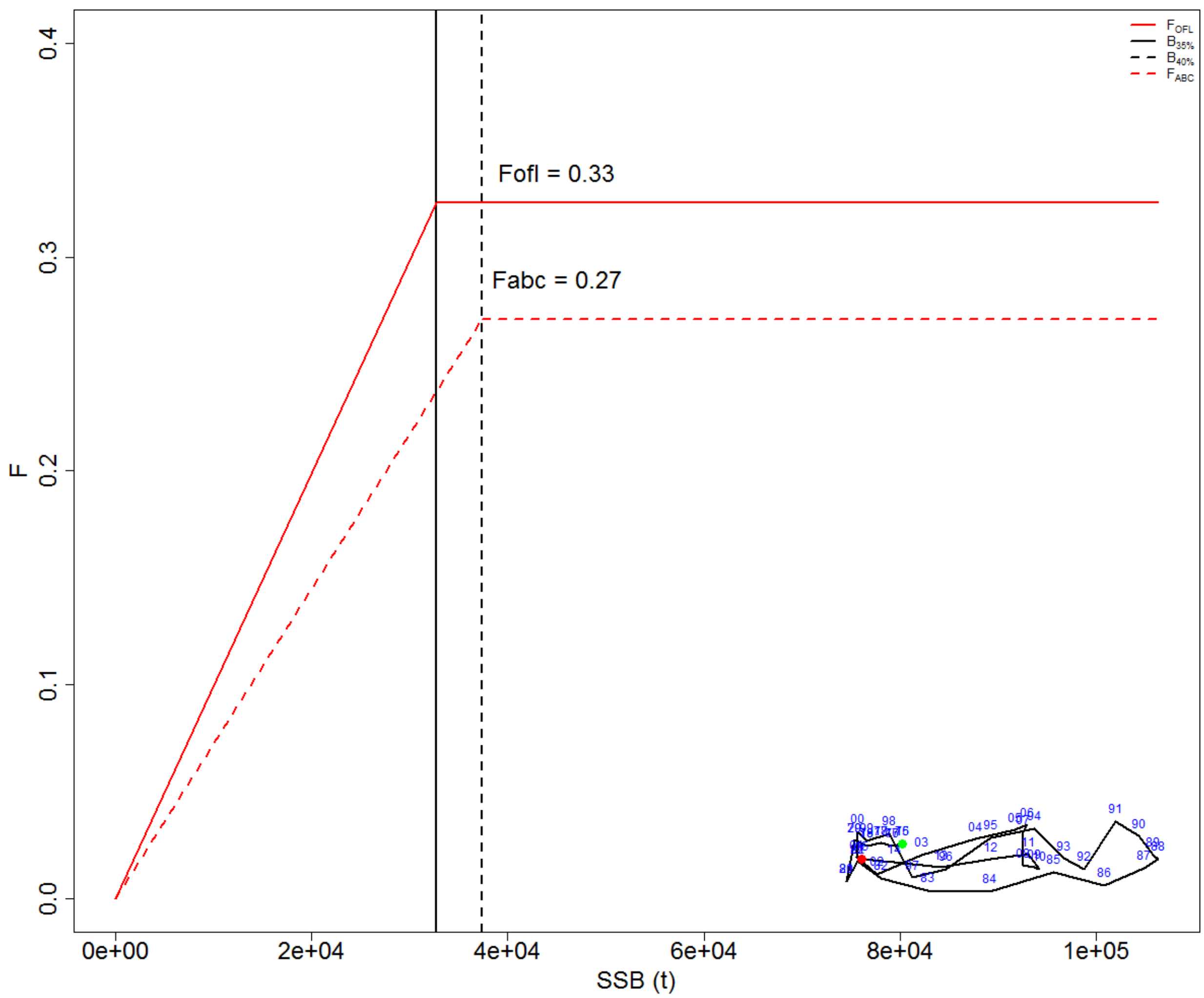


Figure 4.42. Southern rock sole phase plot. The green dot represents 1977 and the red dot represents 2017.

a)

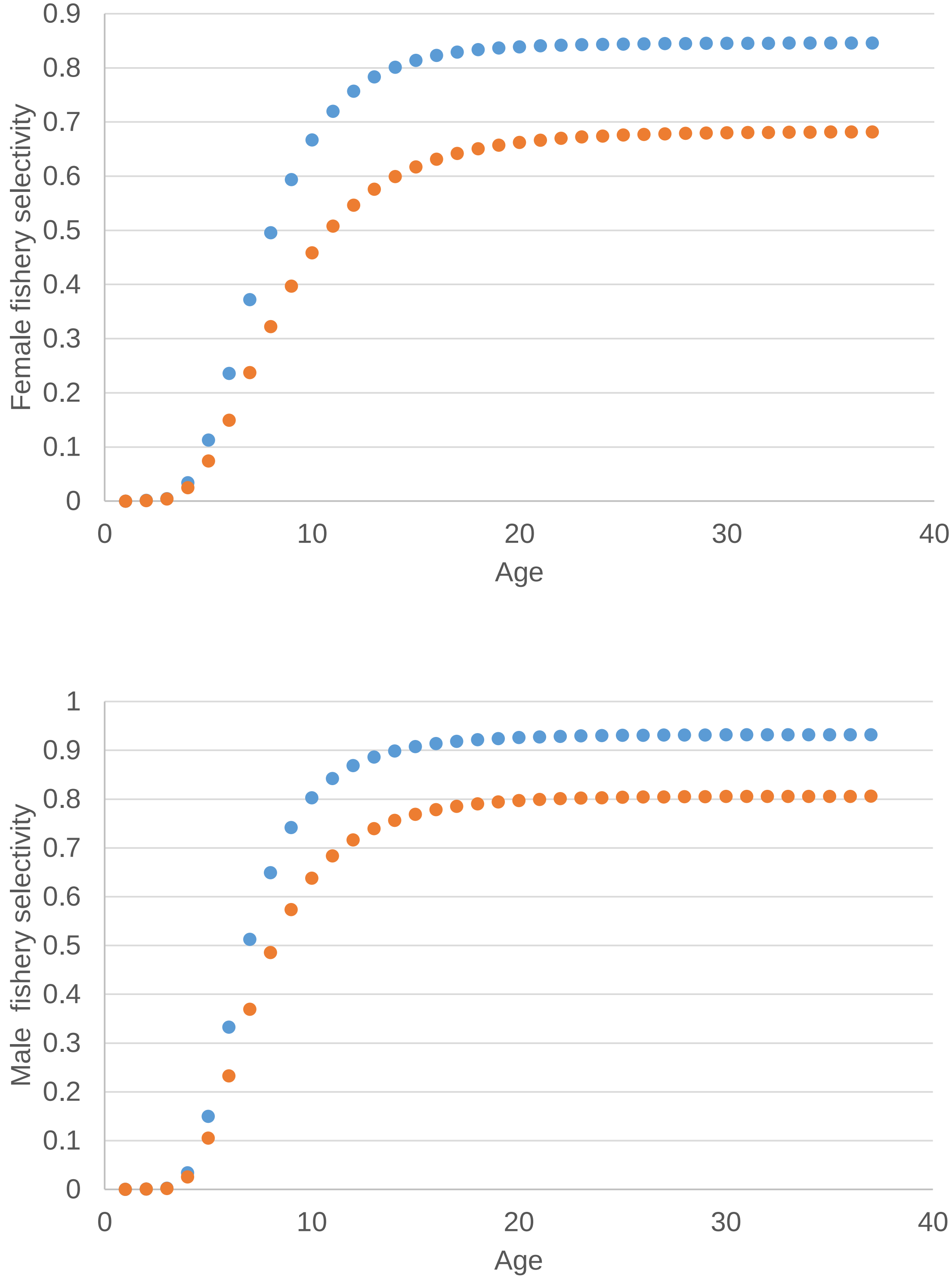


Figure 4.43 Northern rock sole derived age based fishery selectivity, a) female and b) male. The blue points represent the 2016 projection input and the orange points represent the 2017 input.

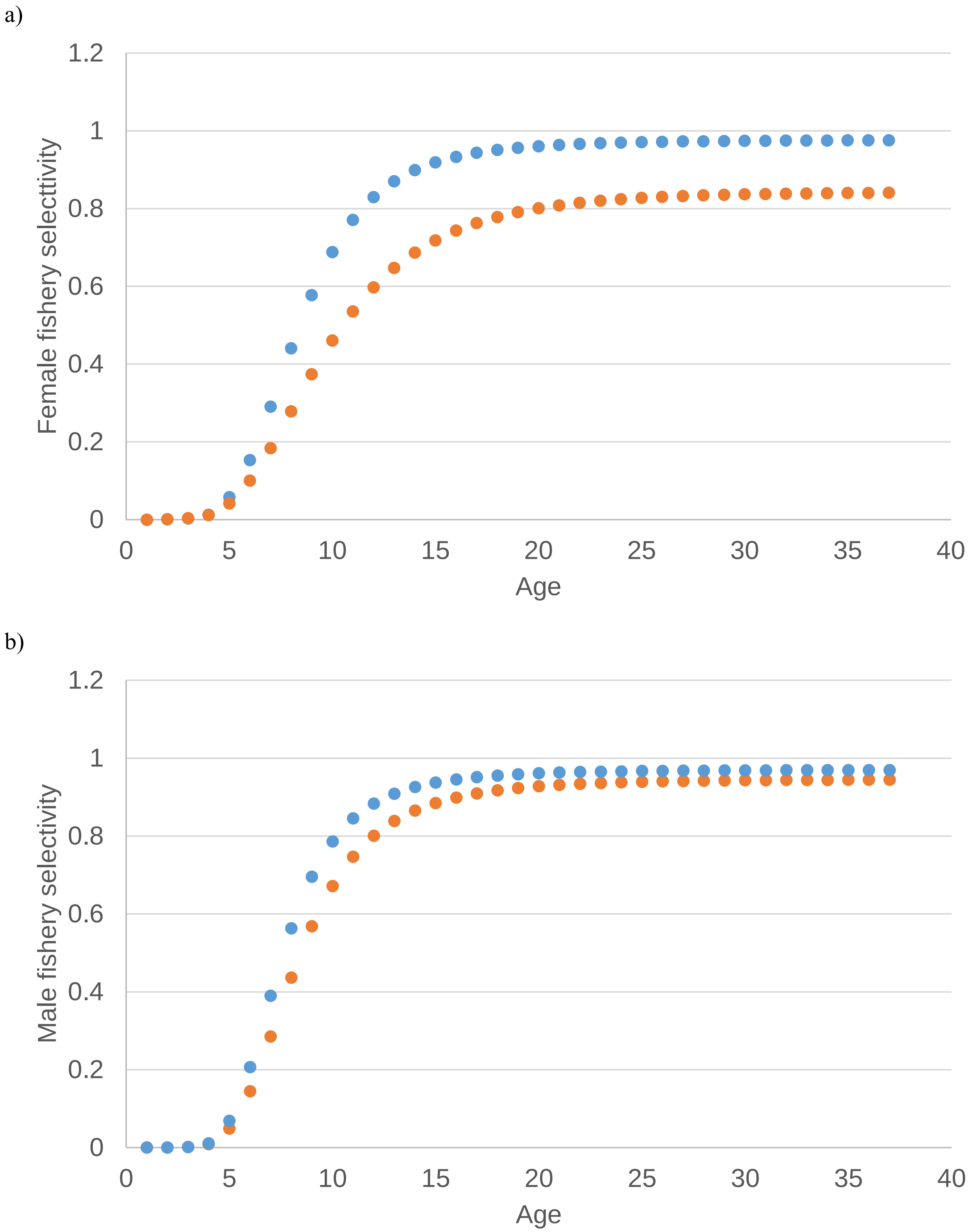


Figure 4.44 Southern rock sole derived age based fishery selectivity, a) female and b) male. The blue points represent the 2016 projection input and the orange points represent the 2017 input.