Chapter 4.1: Assessment of the northern and southern rock sole (*Lepidopsetta polyxystra and bilineata*) stocks in the Gulf of Alaska for 2015

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Executive Summary

Summary of Changes in Assessment Inputs

Relative to last year's assessment, the following changes have been made in the current assessment:

New Input data

1. Fishery: 2013 and 2014 total shallow-water flatfish catch, total rock sole catch for 1993 – 2014, and fishery observer undifferentiated (U)/northern (N)/southern (S) rock sole catch-at-length for 1989 – 2014
2. Survey: 2013 N and S rock sole age composition and mean size-at-age from the NMFS GOA bottom trawl survey

Changes in assessment methodology

Stock Synthesis was used for all model configurations in this analysis.

Summary of Results

The biomass estimate from the 2013 GOA NMFS bottom trawl survey for northern rock sole was a slight increase (2.3%) from the estimate from the 2011 survey. The biomass estimate from the 2013 survey for southern rock sole was an increase of 9% from the estimate from the 2011 survey.

Stock Synthesis was used for all model configurations in this analysis; Stock Synthesis models have been presented at the September Groundfish Plan Team meetings in 2013 and 2014. The 2012 final model was a two-species two-sex mixed-fishery statistical catch-at-age population dynamics ADMB (ADMB Project, 2009) model. Due to the government shutdown in October 2013, the results of the 2012 model were used for the projections in the 2013 GOA northern and southern rock sole SAFE document.

Northern Rock Sole

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2014	2015	2015	2016
M (natural mortality rate)	0.2,0.275*	0.2, 0.275*	0.2,0.251*	0.2, 0.251*
Tier	3a	3a	3a	3a
Projected total (age 3+) biomass (t)	87,300	79,300	80,000	68,600
Projected Female spawning biomass	40,600	34,400	40,600	32,600
$B_{100\%}$	50,300	50,300	50,400	50,400
$B_{40\%}$	20,100	20,100	20,100	20,100

$B_{35\%}$	17,600	17,600	17,600	17,600
F_{OFL}	0.180	0.180	0.452	0.452
$maxF_{ABC}$	0.152	0.152	0.374	0.374
F_{ABC}	0.152	0.152	0.374	0.374
OFL (t)	11,000	9,700	17,000	14,200
maxABC (t)	9,400	8,300	14,300	11,900
ABC (t)	9,400	8,300	14,300	11,900
Status	As determined *last* year for: 2012	2013	As determined *this* year for: 2013	2014
Overfishing	no	n/a	no	n/a
Overfished	n/a	no	n/a	no
Approaching overfished	n/a	no	n/a	no

*Estimated in model for males

Southern Rock Sole

Quantity	As estimated or *specified last* year for: 2014	2015	As estimated or *recommended this* year for: 2015	2016
M (natural mortality rate)	0.2, 0.267*	0.2, 0.267*	0.2, 0.259*	0.2, 0.259*
Tier	3a	3a	3a	3a
Projected total (age 3+) biomass (t)	208,800	195,200	119,500	103,600
Projected Female spawning biomass	81,500	69,300	72,200	65,900
$B_{100\%}$	112,900	112,900	81,500	81,500
$B_{40\%}$	45,100	45,100	32,600	32,600
$B_{35\%}$	39,500	39,500	28,500	28,500
F_{OFL}	0.230	0.230	0.243	0.243
$maxF_{ABC}$	0.193	0.193	0.204	0.204
F_{ABC}	0.193	0.193	0.204	0.204
OFL (t)	21,400	18,900	19,600	16,600
maxABC (t)	18,200	16,000	16,700	14,100
ABC (t)	18,200	16,000	16,700	14,100
Status	As determined *last* year for: 2012	2013	As determined *this* year for: 2013	2014
Overfishing	no	n/a	no	n/a
Overfished	n/a	no	n/a	no
Approaching overfished	n/a	no	n/a	no

*Estimated in model for males

Responses to SSC and Plan Team Comments Specific to this Assessment

Plan Team, Sept. 2014: "*Empirical weight-at-age was not feasible, due to a lack of any data for estimating fishery weights-at-age. Instead conditional age-at-length (AAL) was calculated for survey data, allowing growth and growth variability parameters to be estimated internally in the assessment models.* ***The Plan Team recommends using the AAL approach for models to be considered in November.***"
Response: The survey age data were included in all model configurations as conditional age-at-length.

Plan Team, Sept. 2014: "*Investigating the use of length-based selectivity (rather than age-based) might also be helpful in understanding why CVs of length at age were found be quite low (<5%) for age-3 rock sole.*"
Response: Model configurations were run with selectivity-at-age or selectivity-at-length for the survey.

Plan Team, Sept. 2014: "***The Plan Team recommends using the number of hauls as initial values and continuing to explore weighting from there.***"
Response: The number of hauls or trips was used for sample sizes for fishery and survey length composition data, and for the survey conditional age-at-length data.

Plan Team, Sept. 2014: "***The Plan Team recommends estimating male natural mortality in models considered for November***."
Response: Male M was estimated in all model configurations.

Plan Team, Sept. 2014: "*Previous analyses have used 60% and 40% of the total rock sole catches in each of the species-specific assessments in order to recognize the variability in observed ratios.* ***The Plan Team recommends that values of 50:50 be used for the base case.***"
Response: The annual catches for the species-specific models was ½ of the annual total rock sole catch.

Plan Team, Sept. 2014: "***However, the Plan Team is still interested in the relative trends provided by those data, and recommends evaluating ADF&G survey data for model application (time permitting).***"
Response: This analysis is in process.

SSC, Oct. 2014: "*The assessment author responded to all of the recommendations from previous Plan Team meetings and comments from the SSC were addressed in some form. Progress on the stock structure template is underway. Notable changes to the assessment model include the use of conditional age-at-length (AAL) data to jointly estimate growth of male and female northern and southern rock sole. The Plan Team recommends using the AAL approach for models to be considered this November. The Plan Team also recommends down weighting the sample sizes for composition data using the number of hauls as the initial starting values for the iterative re-weighting procedures. Estimating natural mortality for males improved over all fits, and the Plan Team recommends estimating male natural mortality rates for November. The Plan Team also suggests exploring the use of length-based selectivity to investigate if the current age-based selectivity is a source of the low CVs in the estimated length-at-age for age-3 rock sole.* ***The SSC supports all of the above Plan Team recommendations.***"
Response: All of the Plan Team recommendations were addressed.

SSC, Oct. 2014: "*The major axis of uncertainty in this assessment is partitioning catches into species-specific (northern and southern rock sole) values. Catch data in the model date back to 1977, but ratios of northern and southern are only available from 1988 onwards, with no clear trends in the ratios. The Plan Team recommends a 50:50 ratio for splitting the catch in the base model, and if time permits a sensitivity analysis exploring 40:60 ratios in the historical period where ratio information is not available.* ***The SSC also supports this Plan Team recommendation.***"
Response: All of the Plan Team recommendations were addressed.

Introduction

Rock sole are demersal fish and can be found in shelf waters to 600 m (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). Adults of the northern rock sole are found from Puget Sound through the Bering Sea and Aleutian Islands to the Kuril Islands, while the southern rock sole is known 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. The northern rock sole spawns in midwinter and spring, and the 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 spawning began 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*), as these species are caught in the shallow-water flatfish fishery (Turnock et al., 2009).

Fishery

Rock sole are caught in the shallow-water flatfish fishery and are not targeted specifically, as they co-occur with several other species. The rock sole species were differentiated in survey data beginning in 1996, and were differentiated in the fishery observer data beginning in 1997. Data for more recent years have the species listed as northern (N), southern (S), or "undifferentiated" (U) rock sole as 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.

See the Chapter 4 for more information on the Gulf of Alaska shallow-water flatfish fishery

Data

This section describes data used in the current assessment model. It does not attempt to summarize all available data pertaining to northern and southern rock sole in the GOA.

Data	Source	Type	Years included
Fishery catch	AKFIN	metric tonnes	1977 – 2014
Fishery catch-at-length[a]	AKFIN / FMA	number, by cm bin	1989 – 2014
GOA NMFS bottom trawl survey biomass and abundance estimates[b]	AFSC	metric tonnes, numbers	1984 – 2013
GOA NMFS bottom trawl survey length composition[b]	AFSC	number, by cm bin	1984 – 2013
GOA NMFS bottom trawl survey age composition[b]	AFSC	number, by age	1984 – 2013
GOA NMFS bottom trawl survey mean length-at-age[b]	AFSC	mean value and number	1984 – 2013

[a]Species-specific fishery observer catch-at-length data are available for 1997 – 2014
[b]Species-specific survey data are available for 1996 – 2013

The survey data for 1984, 1987, 1990, and 1993 are for U rock sole; the survey data for N and S rock sole are specified by species from 1996 on, and the fishery observer length data for N and S rock sole are specified by species from 1997 on. The catch data are for U rock sole.

Fishery:

The fishery data available include total rock sole catch, retained and discarded, by year and area (Table 4.1.1, Figure 4.1.1); fishery observer species-specific extrapolated haul-level data (Table 4.1.2, Figure 4.1.2); and fishery observer catch-at-length data for 1989 through 2014 for U/N/S rock sole. The fishery observer data for N and S rock sole are separated out by species from 1997 on. Data for more recent years have the species listed as N, S, or U rock sole as adult northern and southern rock sole are difficult to differentiate visually (Orr and Matarese, 2000).

See the Chapter 4 for more information on the Gulf of Alaska shallow-water flatfish fishery

Survey:

The survey data available include NMFS GOA bottom trawl survey biomass and population estimates by area for 1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007, 2009, 2011, and 2013 (Table 4.1.3, Figures 4.1.3, 4.1.4, 4.1.5, and 4.1.6); survey numbers-at-length for all survey years; survey numbers-at-age for all survey years; survey samples with age and length; and survey estimates of mean length-at-age for all survey years. The survey data for 1984, 1987, 1990, and 1993 are for U rock sole; the survey data for N and S rock sole are separated out by species from 1996 on.

Analytic Approach

Model Structure

Three sets of Stock Synthesis model configurations were developed, for the undifferentiated, northern, and southern rock sole stocks. Stock Synthesis version 3.24S (Methot, 2013) was used. Technical details of Stock Synthesis are described by Methot and Wetzell (2013). All model configurations covered ages 0 to 30, were sex-specific, and estimated male natural mortality; female natural mortality was fixed at 0.2.

For the undifferentiated models configurations, the data were split into 3 groups to account for possible changes in the ratio of northern and southern rock sole. The data from the NMFS GOA bottom trawl survey have been divided into three periods, 1984 – 1993, 1996 – 2004, and 2005 on, with respect to catchability and selectivity. Catchability is set to 1.0 for the latter two survey periods and estimated for the first period, as Thompson et al. (2009) note that "the [NMFS GOA bottom trawl] survey used 30-minute tows during that period [1984-1993], but 15-minute tows thereafter [from 1996 on]".

All fishery catch-at-length data were used in model fitting; the three fishery selectivity curves correspond to three periods, 1977 – 1996, 1997 – 2005, and 2006 on, so that each period had at least 8 years of data. Survey length composition data for all survey years and survey conditional age-at-length data for 1990 on were used in model fitting. The conditional age-at-length data for 1984 and 1987 were not used, as Boldt and Zador (2009) state that "…the gears used by the Japanese vessels in the [NMFS GOA bottom trawl] surveys prior to 1990 were quite different from the survey gear used aboard American vessels in subsequent surveys and likely resulted in different catch rates for many of these groups."

For the species-specific model configurations, the species-specific survey data for 1996 on and the fishery length composition data for 1997 on were used as one period in all model configurations. Constant fishery and survey selectivity curves were estimated.

The sample sizes for the fishery and survey length composition data were the number of hauls or trips with U/N/S rock sole. The sample sizes for the survey conditional age-at-length data were the number of

samples in that length bin multiplied by the total number of hauls with U/N/S rock sole in that survey year divided by the total number of U/N/S rock sole samples in that survey year. This sample size adjustment results in the sum of the conditional age-at-length sample sizes for each survey year being the number of hauls in that survey year.

Parameters Estimated Outside the Assessment Model

The initial values for the growth and maturity parameters used in the model are from Stark and Somerton, 2002.

Northern rock sole

- Males: L_∞=382 mm, k=0.261, t_0=0.160;
- Females: L_∞=429 mm, k=0.236, t_0=0.387, L_{T50} = 328 mm.

Southern rock sole

- Males: L_∞=387 mm, k=0.182, t_0=-0.962;
- Females: L_∞=520 mm, k=0.120, t_0=-0.715, L_{T50} = 347 mm.

The value for natural mortality for U/N/S females was fixed at 0.2 in all model configurations.

See the Chapter 4 for more information on growth, maturity, and natural mortality for GOA northern and southern rock sole

Parameters Estimated Inside the Assessment Model

Parameters that were estimated in the model configurations included:

- median and initial age-0 recruitment;
- annual recruitment deviations;
- natural mortality for males;
- annual fishing mortality;
- initial fishing mortality;
- fishery selectivity-at-length by period and sex;
- survey catchability for the first survey period for U models;
- survey selectivity-at-age or selectivity-at-length by survey period and sex;
- length-at-age growth parameters by sex; and
- CVs for length-at-age at A_{min} (3.33333), by sex
- CVs for length-at-age at A_{max} (A_∞, corresponding to L_∞)

The stock-recruitment relationship is an average level of recruitment unrelated to stock size in all model configurations. Recruitment variability, σ_R, was fixed at 1.0. Catchability for the survey for 1996 on was fixed at 1.0.

Results

Model Evaluation

The model evaluation criteria included how well the model estimates fit to the survey estimates of biomass, the survey numbers-at-age, the annual U/N/S rock sole catch, the total negative log likelihood (NLL) value and its components, and that the model estimated the variance-covariance matrix.

Two model configurations are presented for each of the U/N/S stocks. The difference between the two configurations was the estimation of survey selectivity-at-age or selectivity-at-length. This difference was shown in model configurations which estimated survey selectivity-at-age fitting to the survey conditional age-at-length data better than to the fishery and survey length composition data relative to model configurations which estimated survey selectivity-at-length, and the reverse for model configurations which estimated survey selectivity-at-length (Table 4.1.4). This difference was also shown in the growth parameter and recruitment estimates, specifically in length-at-A_{min}, k, and R_0 (Tables 4.1.5 and 4.1.6).

The estimates of spawning biomass and age-0 were recruits were moderately higher in model configurations with survey selectivity-at-length than in the model configurations with survey selectivity-at-age for U (Figures 4.1.7 and 4.1.8) and S (Figures 4.1.13 and 4.1.14), and significantly higher for N (Figures 4.1.10 and 4.1.11). However, this difference did not result in significantly different fits to the survey indices (Figures 4.1.9, 4.1.12, and 4.1.15).

The model configurations which estimated survey selectivity-at-age were the preferred models, as the survey age data had more information about the age structure of the stocks than the other included data. The U and N model configurations with survey selectivity-at-age had lower NLL values than the corresponding model configurations with survey selectivity-at-length, although the S model configuration with survey selectivity-at-age had a slightly higher NLL than the corresponding model configuration with survey selectivity-at-length (Table 4.1.4).

Parameter estimates with standard deviations for the N and S model configurations with survey selectivity-at-age are in Table 4.1.12.

Time Series Results

The time series of spawning biomass and age-0 recruits for the U, N, and S model configurations with survey selectivity-at-age are in Figures 4.1.16 and 4.1.17, respectively. The corresponding time series for the U, N, and S model configurations with survey selectivity-at-length are in Figures 4.1.18 and 4.1.19.

The time series of spawning biomass and age-0 recruits, with standard deviations, for the N and S model configurations with survey selectivity-at-age are in Table 4.1.7. The estimates of numbers-at-age for northern rock sole are in Tables 4.1.8 and 4.1.9, and in Tables 4.1.10 and 4.1.11 for southern rock sole. Female maturity-at-age, survey selectivity-at-age and derived fishery selectivity-at-age for the N and S model configurations are in Table 4.1.13.

The time series of annual catches used for the N and S model configurations, which is half of the total annual rock sole catch, is in Figure 4.1.20.

Spawning biomass for N was stable over most of the historical period, with the highest value in 2007 and decreasing moderately through 2014 (Figure 4.1.21). Females are larger than males on average at all ages (Figure 4.1.22). Age-0 recruits are moderately variable for the recent period (Figure 4.1.23), with lower uncertainty on estimates for the 1990s and 2000s (Figure 4.1.24). The fit to the survey index is reasonable, given the uncertainty intervals (Figure 4.1.25). The fishery selectivity-at-length curves for females and males are in Figures 4.1.26 and 4.1.27, respectively; the survey selectivity-at-age curves for

females and males are in Figures 4.1.28 and 4.1.29, respectively. The derived fishery selectivity-at-age curves are asymptotic but do not reach full selectivity (Figure 4.1.30). The fits to the fishery and survey length composition data for females and males are in Figures 4.1.31, 4.1.32, 4.1.33, and 4.1.34. The summary fits to the fishery and survey length composition data for females and males are in Figures 4.1.35 and 4.1.36, respectively; the model configurations with survey selectivity-at-age aren't able to match the peak in the female and male survey length composition data as well as the model configurations with survey selectivity-at-length. The survey conditional age-at-length data for females and males and the estimated relationships are in Figures 4.1.37 and 4.1.38.

Spawning biomass for S has been more variable than that for N, with the highest value in 1990 and decreasing moderately through 2014 (Figure 4.1.39). Females are larger than males on average for ages 4 and older (Figure 4.1.40). Age-0 recruits were significantly lower than average in 2006 through 2009, and have increased through 2014 since the lowest level in 2006 (Figure 4.1.41), with lower uncertainty on estimates for the 1990s and 2000s (Figure 4.1.42). The fit to the survey index is reasonable, although few, if any, model configurations were able to estimate the 2009 value well (Figure 4.1.43). The fishery selectivity-at-length curves for males and females are in Figures 4.1.44 and 4.1.45, respectively; the survey selectivity-at-age curves for females and males are in Figures 4.1.46 and 4.1.47, respectively. The derived fishery selectivity-at-age curves are asymptotic, and are almost fully selected by age 30 for females (Figure 4.1.48). The fits to the fishery and survey length composition for females and males are in Figures 4.1.49, 4.1.50, 4.1.51, and 4.1.52; the model configurations with survey selectivity-at-age aren't able to match the peak in the female and male survey length composition data as well as the model configurations with survey selectivity-at-length. The survey conditional age-at-length data for females and males and the estimated relationships are in Figures 4.1.55 and 4.1.56.

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 1977-2013. Spawning was assumed to occur on 1 April and 15 July for northern and southern rock sole, respectively, and female spawning biomass was calculated using the mean weight-at-age at the time of spawning.

	Northern	**Southern**
SB_{2015}	40,600	65,900
$SB_{40\%}$	23,800	37,300
$SB_{35\%}$	20,800	32,600
F_{ABC}	0.374	0.204
ABC	14,300	16,700
F_{OFL}	0.452	0.243
OFL	17,000	19,600

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 2014 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2015 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total annual catch for 2014. 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 2015, are as follows ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

> *Scenario 1*: In all future years, F is set equal to *max* F_{ABC}. (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* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2015 recommended in the assessment to the *max* F_{ABC} for 2015. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)
>
> *Scenario 3*: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)
>
> *Scenario 4*: In all future years, F is set equal to the 2009-2013 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)
>
> *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 F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above its MSY level in 2014 and above its MSY level in 2027 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2015 and 2016, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished

condition. If the stock is expected to be above its MSY level in 2025 under this scenario, then the stock is not approaching an overfished condition.)

Simulation results indicate the northern (Table 4.1.14) and southern (Table 4.1.15) rock sole are not overfished currently and are not approaching an overfished condition.

The authors' recommendations for F_{ABC} and ABC for northern and southern rock sole for 2015 are 0.374 and 14,300 mt and 0.204 and 16,700 mt, respectively.

Ecosystem Considerations

See the Chapter 4 for information on ecosystem considerations for the Gulf of Alaska shallow-water flatfish fishery and stocks

Ecosystem Effects on the Stock

See the Chapter 4 for information on ecosystem considerations for the Gulf of Alaska shallow-water flatfish fishery and stocks

Fishery Effects on the Ecosystem

See the Chapter 4 for information on ecosystem considerations for the Gulf of Alaska shallow-water flatfish fishery and stocks

Data Gaps and Research Priorities

There is considerable uncertainty about the fractions, by mass, of the shallow-water flatfish catch that is northern or southern rock sole. The fishery observer program samples on average 20% of the shallow-water flatfish catch by mass (A'mar and Palsson, 2013), and U/N/S rock sole is on average 70-80% of the observed shallow-water flatfish catch by mass (A'mar and Palsson, 2013).

The increase in random fishery observer samples throughout the year and across the entire GOA may provide more information about the distribution of northern and southern rock sole during the year. The NMFS bottom trawl survey takes place in the summer, when southern rock sole are spawning, so that the distribution of northern and southern rock sole determined by the survey may not represent the distribution of northern and southern rock sole at different times. The annual shallow-water flatfish catches come primarily from INPFC area 630 (Figure 4.1.1); the fishery observer data for shallow-water flatfish come primarily from INPFC area 630 as well (A'mar and Palsson, 2013). However, the survey data suggest that, in the summer, northern rock sole are located primarily in INPFC area 610 (Figure 4.1.4) and southern rock sole are distributed more widely across the GOA (Figure 4.1.5).

Another research question is how well the northern and southern rock sole animals are differentiated by fishery observers and survey personnel. Future sampling and genetic analysis of tissue samples would provide more information on the rates of misidentification.

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Tables

Table 4.1.1 – Estimated catch (in metric tonnes) for shallow water flatfish (SWFF) and total rock sole catch from the Alaska Fisheries Information Network (AKFIN) (as of 2014-10-24).

Year	SWFF catch (AKFIN)	U/N/S rock sole catch (AKFIN)	% U/N/S rock sole
1991	5,224.6	0.1	-
1992	8,333.8	42.0	-
1993	9,113.7	8,112.1	89.0
1994	3,843.0	3,008.1	78.3
1995	5,436.9	3,923.9	72.2
1996	9,372.4	6,595.3	70.4
1997	7,779.6	5,466.8	70.3
1998	3,567.3	2,532.3	71.0
1999	2,578.4	1,765.4	68.5
2000	6,928.7	5,386.7	77.7
2001	6,163.3	4,771.7	77.4
2002	7,177.3	5,564.3	77.5
2003	4,648.5	3,554.6	76.5
2004	3,094.1	2,216.7	71.6
2005	4,805.1	4,130.5	86.0
2006	7,651.6	5,763.3	75.3
2007	8,692.3	6,727.4	77.4
2008	9,721.0	7,269.1	74.8
2009	8,485.4	6,538.7	77.1
2010	5,533.7	3,285.3	59.4
2011	3,998.2	3,094.4	77.4
2012	4,015.3	2,828.6	70.4
2013	5,521.8	4,057.7	73.5
2014	3,924.4	2,846.5	72.5

Table 4.1.2 – Totals of fishery observer extrapolated haul-level rock sole catch data (in metric tonnes), by species (as of 2014-10-24)

Year	U	N	S	Total		% U	% N	% S
1997	1,057.9	37.9	46.0	1,141.8		92.7	3.3	4.0
1998	135.7	171.7	223.0	530.4		25.6	32.4	42.0
1999	117.9	122.1	122.0	362.1		32.6	33.7	33.7
2000	220.8	359.8	328.8	909.4		24.3	39.6	36.2
2001	179.3	404.4	425.6	1,009.4		17.8	40.1	42.2
2002	247.5	551.0	335.3	1,133.8		21.8	48.6	29.6
2003	112.0	254.3	265.6	632.0		17.7	40.2	42.0
2004	91.6	84.8	225.6	401.9		22.8	21.1	56.1
2005	39.4	209.9	224.3	473.6		8.3	44.3	47.4
2006	79.2	492.3	177.5	748.9		10.6	65.7	23.7
2007	208.3	644.2	429.6	1,282.1		16.2	50.2	33.5
2008	213.2	551.5	610.3	1,374.9		15.5	40.1	44.4
2009	161.1	498.0	441.8	1,100.8		14.6	45.2	40.1
2010	56.8	374.6	368.2	799.6		7.1	46.8	46.0
2011	73.7	149.5	288.4	511.5		14.4	29.2	56.4
2012	115.5	374.0	703.1	1,192.7		9.7	31.4	59.0
2013	116.9	519.1	476.9	1,112.8		10.5	46.6	42.9
2014	27.7	535.2	148.4	711.3		3.9	75.2	20.9

Table 4.1.3 – GOA NMFS bottom trawl survey biomass (in mt) and population estimates

Year	Species	Total biomass	std dev	Total numbers	std dev
1984	U	137,623	12,208	404,285,245	43,401,215
1987	U	123,393	20,329	281,015,223	37,864,353
1990	U	156,032	19,472	329,427,129	40,836,229
1993	U	173,044	14,570	346,198,094	29,291,722
1996	N	78,845	9,930	208,492,467	30,477,247
1999	N	61,543	15,134	151,313,021	34,652,753
2001	N	64,809	9,887	140,508,433	17,513,605
2003	N	79,648	9,514	203,049,571	26,460,258
2005	N	91,459	10,123	216,801,482	23,769,367
2007	N	102,303	12,046	227,003,343	26,624,065
2009	N	95,846	16,068	257,075,774	51,973,203
2011	N	72,875	12,427	148,039,674	24,568,593
2013	N	74,586	13,587	152,326,011	31,004,369
1996	S	127,390	12,580	186,116,865	16,990,673
1999	S	106,235	10,580	154,084,268	15,292,879
2001	S	122,492	14,643	174,732,258	20,118,997
2003	S	126,819	12,480	199,376,622	15,983,336
2005	S	147,665	15,084	240,030,524	25,605,394
2007	S	161,617	11,764	256,910,791	19,144,732
2009	S	191,765	22,591	300,479,225	33,990,620
2011	S	120,573	10,318	174,623,722	15,912,209
2013	S	131,441	13,993	182,199,716	16,748,495

Table 4.1.4 – Negative log likelihood components

	N			S			U	
	sel-at-age	sel-at-length		sel-at-age	sel-at-length		sel-at-age	sel-at-length
Parameters	88	88		88	88		137	137
TOTAL	875.22	890.26		887.63	884.07		1024.65	1045.06
Survey	-14.05	-14.38		-12.05	-14.094		-20.07	-21.612
Fsh length comp	181.66	186.04		157.42	143.42		195.34	198.79
Srv length comp	49.40	29.52		46.90	31.002		51.79	29.96
Srv age comp	674.05	702.73		704.70	733.06		807.00	847.93
Recruitment	-19.22	-19.11		-14.64	-15.83		-13.90	-15.89

Table 4.1.5 – Growth parameter estimates for the northern and southern model configurations

Parameter	Northern rock sole			Southern rock sole	
	sel-at-age	sel-at-length		sel-at-age	sel-at-length
Female L-at-Amin	21.20	15.64		15.93	11.34
Female L-at-Amax	45.36	46.75		49.38	49.53
Female k	0.186	0.212		0.185	0.199
Female CV Amin	3.32	3.03		3.18	3.24
Female CV Amax	6.75	8.06		4.62	4.87
Male M	0.251	0.240		0.259	0.242
Male L-at-Amin	20.98	15.63		17.35	13.12
Male L-at-Amax	40.92	39.28		41.71	41.86
Male k	0.165	0.261		0.186	0.206
Male CV Amin	2.73	2.97		2.37	2.20
Male CV Amax	5.24	5.38		4.15	5.00
Ln(R_0)	11.69	12.08		12.24	12.49

Table 4.1.6 – Growth parameter estimates for the undifferentiated model configuration

Parameter	Early period			Middle period			Later period	
	sel-at-age	sel-at-length		sel-at-age	sel-at-length		sel-at-age	sel-at-length
Female L-at-Amin	19.67	14.45		20.40	15.33		20.20	14.74
Female L-at-Amax	45.12	44.36		49.22	49.87		50.48	50.57
Female k	0.162	0.203		0.168	0.188		0.146	0.170
Female CV Amin	3.35	3.43		-	-		-	-
Female CV Amax	5.32	5.44		-	-		-	-
Male M	0.252	0.241		-	-		-	-
Male L-at-Amin	20.24	15.91		19.56	15.22		19.92	14.69
Male L-at-Amax	40.35	37.75		43.39	42.14		42.13	41.15
Male k	0.133	0.200		0.160	0.210		0.168	0.219
Male CV Amin	2.70	2.92		-	-		-	-
Male CV Amax	4.72	4.72		-	-		-	-
Ln(R_0)	12.75	12.99		-	-		-	-
Q for early period	0.628	0.763		-	-		-	-

Table 4.1.7 – Estimated annual spawning biomass (in metric tonnes) and age-0 recruits (in thousands) with standard deviations by species

Year	Northern rock sole				Southern rock sole			
	Spawning	Std dev	Recruits	Std dev	Spawning	Std dev	Recruits	Std dev
1977	47,048	10,427	102,350	60,857	81,488	15,875	317,989	233,296
1978	46,387	10,495	116,089	70,761	80,717	16,238	315,856	234,054
1979	45,770	10,503	123,678	73,492	79,648	16,321	295,372	207,515
1980	45,094	10,448	105,466	60,207	78,232	16,143	289,087	196,409
1981	44,467	10,331	95,879	51,060	76,887	15,810	283,024	162,037
1982	43,745	10,154	88,141	45,021	75,862	15,413	183,873	102,279
1983	43,995	9,915	80,328	40,297	76,688	15,059	191,596	101,101
1984	44,153	9,593	95,615	46,850	78,622	14,721	241,865	120,305
1985	45,203	9,290	120,481	56,662	82,746	14,434	209,764	99,777
1986	46,634	8,967	120,420	57,565	88,421	14,202	156,658	76,373
1987	47,500	8,540	177,052	58,350	94,307	13,887	243,886	81,142
1988	47,156	8,010	91,379	37,128	98,916	13,365	138,686	55,297
1989	46,666	7,425	79,770	28,290	102,481	12,657	129,649	41,509
1990	45,524	6,821	85,202	25,057	103,579	11,810	113,972	34,666
1991	44,791	6,239	88,645	21,701	102,706	10,858	149,198	35,349
1992	44,950	5,720	71,357	17,387	100,941	9,838	132,177	31,853
1993	45,658	5,252	75,330	17,723	98,354	8,836	197,112	35,864
1994	46,633	4,852	97,506	20,945	95,055	7,880	150,482	30,092
1995	47,068	4,493	126,635	22,503	92,904	6,994	142,916	28,093
1996	46,052	4,115	124,967	21,443	89,963	6,189	182,390	33,524
1997	44,153	3,759	123,899	22,245	85,400	5,484	299,194	43,478
1998	42,529	3,462	182,307	27,374	80,638	4,880	342,941	45,705
1999	41,377	3,216	198,969	27,780	76,975	4,387	178,226	33,879
2000	40,716	3,020	116,889	20,237	74,257	3,997	126,687	27,445
2001	40,232	2,887	61,204	13,393	71,501	3,693	195,607	33,151
2002	41,105	2,828	65,240	14,293	69,701	3,475	184,420	34,622
2003	42,272	2,810	88,541	19,358	68,359	3,328	267,042	41,321
2004	44,679	2,831	168,061	29,507	68,795	3,255	189,328	34,758
2005	49,019	2,926	144,595	26,902	71,675	3,267	157,983	28,916
2006	52,795	3,066	86,407	18,722	75,599	3,345	54,767	14,256
2007	53,254	3,121	56,095	13,486	78,478	3,440	57,404	14,775
2008	50,799	3,072	56,542	14,714	79,062	3,500	80,470	20,736
2009	47,730	3,022	61,223	17,422	78,162	3,540	100,446	30,351
2010	46,383	3,110	90,320	28,781	77,590	3,630	160,540	58,103
2011	48,040	3,408	128,217	50,146	78,372	3,795	173,478	82,970
2012	49,408	3,701	85,851	47,797	78,981	3,993	161,186	93,011
2013	48,767	3,846	99,634	60,016	78,217	4,146	172,577	103,590
2014	46,199	3,867	100,098	60,453	74,865	4,190	173,650	104,608
2015	43,506	3,866	119,839	72,375	70,094	4,135	207,896	125,239

Table 4.1.8 – Numbers-at-age for northern rock sole females

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	51.2	39.5	32.2	26.7	22.2	18.4	15.2	12.4	10.1	8.2	6.7	5.4	4.3	3.5	3.0	2.4	1.9	1.5	1.2	1.0	3.7
1978	58.0	41.9	32.3	26.3	21.8	18.1	14.9	12.3	10.0	8.1	6.6	5.3	4.3	3.4	2.8	2.4	1.9	1.5	1.2	1.0	3.7
1979	61.8	47.5	34.3	26.5	21.5	17.8	14.7	12.1	9.9	8.1	6.5	5.3	4.2	3.4	2.7	2.2	1.9	1.5	1.2	1.0	3.7
1980	52.7	50.6	38.9	28.1	21.6	17.5	14.4	11.9	9.7	8.0	6.5	5.2	4.2	3.4	2.7	2.2	1.7	1.5	1.2	1.0	3.7
1981	47.9	43.2	41.4	31.8	22.9	17.6	14.2	11.7	9.6	7.8	6.4	5.2	4.2	3.3	2.7	2.1	1.7	1.4	1.2	1.0	3.7
1982	44.1	39.2	35.3	33.9	26.0	18.7	14.3	11.5	9.4	7.7	6.3	5.1	4.1	3.3	2.6	2.1	1.7	1.4	1.1	0.9	3.6
1983	40.2	36.1	32.1	28.9	27.7	21.2	15.2	11.7	9.4	7.6	6.2	5.1	4.1	3.3	2.7	2.1	1.7	1.4	1.1	0.9	3.7
1984	47.8	32.9	29.5	26.3	23.6	22.6	17.3	12.4	9.4	7.6	6.2	5.0	4.1	3.3	2.7	2.1	1.7	1.4	1.1	0.9	3.7
1985	60.2	39.1	26.9	24.2	21.5	19.3	18.5	14.1	10.1	7.7	6.1	5.0	4.1	3.3	2.7	2.2	1.7	1.4	1.1	0.9	3.7
1986	60.2	49.3	32.0	22.0	19.8	17.6	15.8	15.1	11.5	8.2	6.3	5.0	4.1	3.3	2.7	2.2	1.8	1.4	1.1	0.9	3.7
1987	88.5	49.3	40.4	26.2	18.0	16.2	14.4	12.9	12.3	9.4	6.7	5.1	4.1	3.3	2.7	2.2	1.8	1.4	1.1	0.9	3.8
1988	45.7	72.5	40.4	33.0	21.4	14.7	13.2	11.7	10.5	10.0	7.6	5.4	4.1	3.3	2.7	2.2	1.8	1.4	1.1	0.9	3.7
1989	39.9	37.4	59.3	33.0	27.0	17.5	12.0	10.8	9.5	8.5	8.1	6.2	4.4	3.3	2.7	2.2	1.8	1.4	1.2	0.9	3.8
1990	42.6	32.7	30.6	48.5	27.0	22.1	14.3	9.8	8.7	7.7	6.9	6.5	4.9	3.5	2.7	2.1	1.7	1.4	1.1	0.9	3.7
1991	44.3	34.9	26.7	25.0	39.7	22.0	17.9	11.6	7.9	7.0	6.2	5.5	5.2	3.9	2.8	2.1	1.7	1.4	1.1	0.9	3.7
1992	35.7	36.3	28.5	21.9	20.5	32.3	17.9	14.5	9.3	6.3	5.6	4.9	4.4	4.1	3.1	2.2	1.7	1.3	1.1	0.9	3.6
1993	37.7	29.2	29.7	23.3	17.8	16.6	26.1	14.4	11.6	7.4	5.0	4.4	3.9	3.4	3.2	2.4	1.7	1.3	1.0	0.8	3.5
1994	48.8	30.8	23.9	24.3	19.0	14.5	13.4	21.0	11.4	9.2	5.8	3.9	3.4	3.0	2.7	2.5	1.9	1.3	1.0	0.8	3.3
1995	63.3	39.9	25.2	19.6	19.8	15.5	11.8	10.9	17.0	9.2	7.4	4.7	3.1	2.8	2.4	2.1	2.0	1.5	1.1	0.8	3.3
1996	62.5	51.8	32.7	20.7	16.0	16.2	12.6	9.6	8.8	13.7	7.4	5.9	3.7	2.5	2.2	1.9	1.7	1.6	1.2	0.8	3.3
1997	61.9	51.2	42.4	26.7	16.9	13.0	13.1	10.2	7.6	7.0	10.8	5.9	4.7	2.9	2.0	1.7	1.5	1.3	1.2	0.9	3.2
1998	91.2	50.7	41.9	34.7	21.8	13.7	10.5	10.6	8.1	6.1	5.6	8.6	4.6	3.7	2.3	1.5	1.4	1.2	1.0	1.0	3.2
1999	99.5	74.6	41.5	34.3	28.4	17.8	11.2	8.6	8.6	6.6	4.9	4.5	6.9	3.7	3.0	1.9	1.2	1.1	0.9	0.8	3.4
2000	58.4	81.5	61.1	34.0	28.0	23.2	14.5	9.1	7.0	6.9	5.3	4.0	3.6	5.6	3.0	2.4	1.5	1.0	0.9	0.8	3.4
2001	30.6	47.9	66.7	50.0	27.7	22.8	18.8	11.7	7.3	5.6	5.5	4.2	3.2	2.9	4.4	2.4	1.9	1.2	0.8	0.7	3.2
2002	32.6	25.1	39.2	54.5	40.8	22.6	18.5	15.2	9.4	5.8	4.4	4.4	3.4	2.5	2.3	3.5	1.9	1.5	0.9	0.6	3.1
2003	44.3	26.7	20.5	32.0	44.5	33.2	18.3	14.9	12.2	7.5	4.6	3.5	3.5	2.7	2.0	1.8	2.7	1.5	1.2	0.7	2.9
2004	84.0	36.2	21.9	16.8	26.2	36.3	27.0	14.8	12.1	9.8	6.0	3.7	2.8	2.8	2.1	1.6	1.4	2.2	1.2	0.9	2.9
2005	72.3	68.8	29.7	17.9	13.7	21.4	29.6	22.0	12.1	9.8	7.9	4.9	3.0	2.3	2.2	1.7	1.3	1.1	1.8	0.9	3.1
2006	43.2	59.2	56.3	24.3	14.6	11.2	17.4	24.0	17.8	9.7	7.9	6.4	3.9	2.4	1.8	1.8	1.4	1.0	0.9	1.4	3.2
2007	28.0	35.4	48.4	46.1	19.8	11.9	9.1	14.0	19.3	14.2	7.8	6.3	5.1	3.1	1.9	1.4	1.4	1.1	0.8	0.7	3.6
2008	28.3	23.0	28.9	39.6	37.6	16.1	9.6	7.3	11.3	15.4	11.3	6.1	4.9	4.0	2.4	1.5	1.1	1.1	0.8	0.6	3.4
2009	30.6	23.1	18.8	23.7	32.3	30.6	13.0	7.8	5.8	9.0	12.2	8.9	4.8	3.9	3.1	1.9	1.2	0.9	0.9	0.7	3.1
2010	45.2	25.1	18.9	15.4	19.3	26.3	24.7	10.5	6.2	4.7	7.1	9.6	7.0	3.8	3.0	2.4	1.5	0.9	0.7	0.7	2.9
2011	64.1	37.0	20.5	15.5	12.6	15.8	21.4	20.1	8.5	5.0	3.8	5.7	7.7	5.6	3.0	2.4	2.0	1.2	0.7	0.5	2.9
2012	42.9	52.5	30.3	16.8	12.7	10.3	12.8	17.4	16.3	6.9	4.0	3.0	4.6	6.2	4.5	2.4	1.9	1.6	1.0	0.6	2.7
2013	49.8	35.1	43.0	24.8	13.7	10.3	8.4	10.4	14.1	13.2	5.6	3.3	2.4	3.7	5.0	3.6	2.0	1.6	1.3	0.8	2.7
2014	50.0	40.8	28.8	35.1	20.2	11.2	8.4	6.8	8.4	11.4	10.6	4.4	2.6	1.9	2.9	4.0	2.9	1.6	1.2	1.0	2.7

Table 4.1.9 – Numbers-at-age for northern rock sole males

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	51.2	37.5	29.0	22.9	18.1	14.2	11.1	8.6	6.7	5.1	3.9	3.0	2.2	1.7	1.4	1.1	0.8	0.6	0.4	0.3	1.0
1978	58.0	39.8	29.2	22.6	17.7	14.0	11.0	8.5	6.6	5.0	3.9	2.9	2.2	1.7	1.3	1.1	0.8	0.6	0.4	0.3	1.0
1979	61.8	45.1	31.0	22.7	17.5	13.7	10.8	8.4	6.5	5.0	3.8	2.9	2.2	1.7	1.3	1.0	0.8	0.6	0.4	0.3	1.0
1980	52.7	48.1	35.1	24.1	17.6	13.5	10.6	8.2	6.4	4.9	3.8	2.9	2.2	1.6	1.2	0.9	0.7	0.6	0.4	0.3	1.0
1981	47.9	41.0	37.4	27.3	18.7	13.6	10.4	8.1	6.3	4.8	3.7	2.8	2.2	1.6	1.2	0.9	0.7	0.5	0.4	0.3	1.0
1982	44.1	37.3	31.9	29.1	21.2	14.4	10.5	8.0	6.2	4.7	3.7	2.8	2.1	1.6	1.2	0.9	0.7	0.5	0.4	0.3	1.0
1983	40.2	34.3	29.0	24.8	22.6	16.4	11.2	8.1	6.2	4.7	3.7	2.8	2.1	1.6	1.2	0.9	0.7	0.5	0.4	0.3	1.0
1984	47.8	31.2	26.7	22.5	19.3	17.5	12.7	8.6	6.2	4.7	3.6	2.8	2.1	1.6	1.2	0.9	0.7	0.5	0.4	0.3	1.0
1985	60.2	37.2	24.3	20.7	17.5	14.9	13.6	9.8	6.6	4.8	3.6	2.8	2.1	1.6	1.2	0.9	0.7	0.5	0.4	0.3	1.0
1986	60.2	46.9	28.9	18.9	16.1	13.6	11.6	10.5	7.6	5.1	3.7	2.8	2.1	1.6	1.3	1.0	0.7	0.6	0.4	0.3	1.0
1987	88.5	46.8	36.4	22.5	14.7	12.5	10.6	9.0	8.1	5.9	4.0	2.9	2.2	1.7	1.3	1.0	0.7	0.6	0.4	0.3	1.0
1988	45.7	68.9	36.4	28.3	17.5	11.4	9.7	8.1	6.9	6.2	4.5	3.0	2.2	1.6	1.3	1.0	0.7	0.6	0.4	0.3	1.0
1989	39.9	35.5	53.6	28.3	22.0	13.6	8.8	7.5	6.3	5.3	4.8	3.5	2.3	1.7	1.3	1.0	0.7	0.6	0.4	0.3	1.0
1990	42.6	31.0	27.6	41.6	22.0	17.1	10.5	6.8	5.7	4.8	4.1	3.6	2.6	1.8	1.3	1.0	0.7	0.6	0.4	0.3	1.0
1991	44.3	33.1	24.1	21.5	32.3	17.0	13.1	8.0	5.2	4.4	3.6	3.1	2.7	2.0	1.3	0.9	0.7	0.5	0.4	0.3	1.0
1992	35.7	34.5	25.8	18.8	16.7	25.0	13.1	10.0	6.1	3.9	3.3	2.7	2.3	2.1	1.5	1.0	0.7	0.5	0.4	0.3	1.0
1993	37.7	27.8	26.8	20.0	14.5	12.9	19.1	9.9	7.6	4.6	2.9	2.4	2.0	1.7	1.5	1.1	0.7	0.5	0.4	0.3	0.9
1994	48.8	29.3	21.6	20.8	15.5	11.2	9.8	14.5	7.4	5.6	3.4	2.1	1.8	1.5	1.2	1.1	0.8	0.5	0.4	0.3	0.9
1995	63.3	37.9	22.8	16.8	16.2	12.0	8.6	7.6	11.1	5.7	4.3	2.6	1.6	1.3	1.1	0.9	0.8	0.6	0.4	0.3	0.9
1996	62.5	49.2	29.5	17.7	13.0	12.5	9.3	6.6	5.8	8.4	4.3	3.2	1.9	1.2	1.0	0.8	0.7	0.6	0.4	0.3	0.9
1997	61.9	48.6	38.3	22.9	13.7	10.0	9.6	7.0	5.0	4.3	6.3	3.2	2.4	1.4	0.9	0.7	0.6	0.5	0.5	0.3	0.8
1998	91.2	48.2	37.8	29.8	17.8	10.6	7.7	7.3	5.3	3.8	3.2	4.7	2.4	1.8	1.0	0.7	0.5	0.4	0.4	0.3	0.9
1999	99.5	70.9	37.5	29.4	23.1	13.8	8.2	5.9	5.6	4.1	2.9	2.5	3.6	1.8	1.3	0.8	0.5	0.4	0.3	0.3	0.9
2000	58.4	77.4	55.1	29.1	22.8	17.9	10.7	6.3	4.6	4.3	3.1	2.2	1.9	2.7	1.4	1.0	0.6	0.4	0.3	0.3	0.9
2001	30.6	45.5	60.2	42.9	22.6	17.6	13.8	8.1	4.8	3.4	3.2	2.3	1.6	1.4	2.0	1.0	0.8	0.4	0.3	0.2	0.9
2002	32.6	23.8	35.4	46.8	33.2	17.5	13.5	10.5	6.2	3.6	2.6	2.4	1.7	1.2	1.0	1.5	0.8	0.6	0.3	0.2	0.8
2003	44.3	25.4	18.5	27.5	36.3	25.7	13.4	10.3	8.0	4.6	2.7	1.9	1.8	1.3	0.9	0.8	1.1	0.6	0.4	0.2	0.7
2004	84.0	34.4	19.7	14.4	21.3	28.1	19.8	10.3	7.9	6.1	3.5	2.0	1.5	1.4	1.0	0.7	0.6	0.8	0.4	0.3	0.7
2005	72.3	65.4	26.8	15.3	11.2	16.5	21.7	15.3	7.9	6.1	4.6	2.7	1.6	1.1	1.0	0.7	0.5	0.4	0.6	0.3	0.8
2006	43.2	56.2	50.8	20.8	11.9	8.7	12.8	16.7	11.7	6.0	4.6	3.5	2.0	1.2	0.8	0.8	0.6	0.4	0.3	0.5	0.8
2007	28.0	33.6	43.7	39.5	16.1	9.2	6.7	9.7	12.7	8.8	4.5	3.4	2.6	1.5	0.9	0.6	0.6	0.4	0.3	0.2	1.0
2008	28.3	21.8	26.1	34.0	30.6	12.5	7.1	5.1	7.4	9.5	6.6	3.4	2.6	1.9	1.1	0.6	0.5	0.4	0.3	0.2	0.9
2009	30.6	22.0	17.0	20.3	26.3	23.6	9.5	5.4	3.8	5.5	7.1	4.9	2.5	1.9	1.4	0.8	0.5	0.3	0.3	0.2	0.8
2010	45.2	23.8	17.1	13.2	15.7	20.3	18.1	7.3	4.0	2.9	4.1	5.3	3.6	1.8	1.4	1.0	0.6	0.3	0.2	0.2	0.7
2011	64.1	35.1	18.5	13.3	10.2	12.2	15.7	13.9	5.6	3.1	2.2	3.1	4.0	2.7	1.4	1.0	0.8	0.5	0.3	0.2	0.7
2012	42.9	49.9	27.3	14.4	10.3	7.9	9.4	12.1	10.7	4.3	2.4	1.7	2.4	3.0	2.1	1.1	0.8	0.6	0.3	0.2	0.7
2013	49.8	33.4	38.8	21.2	11.2	8.0	6.1	7.3	9.3	8.2	3.3	1.8	1.3	1.8	2.3	1.6	0.8	0.6	0.5	0.3	0.7
2014	50.0	38.7	26.0	30.1	16.5	8.7	6.2	4.7	5.5	7.1	6.2	2.5	1.4	1.0	1.4	1.7	1.2	0.6	0.4	0.3	0.7

Table 4.1.10 – Numbers-at-age for southern rock sole females

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	159.0	102.2	66.3	50.0	37.2	30.4	25.7	22.2	20.3	16.2	12.6	10.0	8.1	6.6	5.9	4.7	3.8	3.1	2.5	2.0	8.2
1978	157.9	130.2	83.7	54.3	40.9	30.4	24.8	21.0	18.0	16.5	13.1	10.1	8.0	6.5	5.3	4.7	3.8	3.1	2.5	2.0	8.2
1979	147.7	129.3	106.6	68.5	44.4	33.4	24.8	20.2	17.0	14.6	13.3	10.6	8.2	6.5	5.3	4.3	3.8	3.1	2.5	2.0	8.2
1980	144.5	120.9	105.9	87.2	56.1	36.3	27.3	20.2	16.4	13.8	11.8	10.7	8.5	6.6	5.2	4.2	3.4	3.0	2.5	2.0	8.1
1981	141.5	118.3	99.0	86.6	71.4	45.8	29.6	22.2	16.4	13.3	11.2	9.5	8.7	6.9	5.3	4.2	3.4	2.8	2.4	2.0	8.1
1982	91.9	115.9	96.9	81.0	70.9	58.3	37.4	24.1	18.0	13.3	10.7	9.0	7.7	7.0	5.5	4.3	3.4	2.7	2.2	2.0	8.1
1983	95.8	75.3	94.9	79.3	66.3	58.0	47.7	30.5	19.7	14.7	10.8	8.8	7.3	6.3	5.7	4.5	3.5	2.7	2.2	1.8	8.2
1984	120.9	78.4	61.6	77.7	64.9	54.2	47.4	38.9	24.9	16.0	11.9	8.8	7.1	5.9	5.1	4.6	3.6	2.8	2.2	1.8	8.1
1985	104.9	99.0	64.2	50.4	63.6	53.1	44.4	38.7	31.8	20.3	13.0	9.7	7.2	5.8	4.8	4.1	3.7	3.0	2.3	1.8	8.0
1986	78.3	85.9	81.1	52.6	41.3	52.0	43.5	36.3	31.7	26.0	16.6	10.7	7.9	5.8	4.7	3.9	3.4	3.1	2.4	1.9	8.0
1987	121.9	64.1	70.3	66.4	43.0	33.8	42.6	35.6	29.7	25.9	21.2	13.5	8.7	6.5	4.8	3.9	3.2	2.8	2.5	2.0	8.1
1988	69.3	99.8	52.5	57.6	54.3	35.2	27.6	34.8	29.0	24.2	21.1	17.3	11.0	7.1	5.3	3.9	3.1	2.6	2.2	2.0	8.2
1989	64.8	56.8	81.7	43.0	47.1	44.5	28.8	22.6	28.4	23.7	19.7	17.2	14.1	9.0	5.8	4.3	3.2	2.5	2.1	1.8	8.3
1990	57.0	53.1	46.5	66.9	35.2	38.5	36.3	23.5	18.4	23.1	19.2	16.0	13.9	11.4	7.3	4.7	3.5	2.6	2.1	1.7	8.2
1991	74.6	46.7	43.5	38.0	54.8	28.8	31.5	29.6	19.1	15.0	18.7	15.6	13.0	11.3	9.2	5.9	3.8	2.8	2.1	1.7	8.0
1992	66.1	61.1	38.2	35.6	31.1	44.8	23.5	25.6	24.1	15.5	12.1	15.2	12.6	10.5	9.1	7.4	4.7	3.0	2.3	1.7	7.8
1993	98.6	54.1	50.0	31.3	29.1	25.4	36.5	19.1	20.8	19.5	12.5	9.7	12.2	10.1	8.4	7.3	6.0	3.8	2.4	1.8	7.6
1994	75.2	80.7	44.3	40.9	25.6	23.8	20.7	29.6	15.4	16.7	15.6	10.0	7.8	9.7	8.1	6.7	5.8	4.7	3.0	1.9	7.5
1995	71.5	61.6	66.1	36.3	33.5	20.9	19.4	16.9	24.1	12.6	13.6	12.7	8.1	6.3	7.9	6.5	5.4	4.7	3.8	2.4	7.6
1996	91.2	58.5	50.4	54.1	29.7	27.4	17.1	15.8	13.8	19.6	10.2	11.0	10.3	6.6	5.1	6.4	5.3	4.4	3.8	3.1	8.1
1997	149.6	74.7	47.9	41.3	44.2	24.2	22.3	13.9	12.8	11.1	15.8	8.2	8.8	8.2	5.3	4.1	5.1	4.2	3.5	3.0	8.9
1998	171.5	122.5	61.1	39.2	33.8	36.1	19.8	18.1	11.2	10.4	8.9	12.7	6.6	7.1	6.6	4.2	3.3	4.1	3.4	2.8	9.6
1999	89.1	140.4	100.3	50.0	32.1	27.6	29.5	16.1	14.8	9.1	8.4	7.3	10.3	5.3	5.7	5.3	3.4	2.6	3.3	2.7	10.0
2000	63.3	73.0	114.9	82.1	41.0	26.3	22.6	24.1	13.2	12.0	7.5	6.8	5.9	8.4	4.3	4.7	4.3	2.8	2.2	2.7	10.4
2001	97.8	51.9	59.7	94.1	67.2	33.5	21.4	18.3	19.5	10.6	9.7	6.0	5.5	4.7	6.7	3.5	3.7	3.5	2.2	1.7	10.4
2002	92.2	80.1	42.5	48.9	77.0	54.9	27.3	17.4	14.9	15.8	8.6	7.8	4.8	4.4	3.8	5.4	2.8	3.0	2.8	1.8	9.7
2003	133.5	75.5	65.6	34.8	40.0	62.9	44.7	22.2	14.1	12.0	12.7	6.9	6.3	3.9	3.5	3.0	4.3	2.2	2.4	2.2	9.2
2004	94.7	109.3	61.8	53.7	28.4	32.7	51.3	36.4	18.0	11.4	9.7	10.3	5.6	5.1	3.1	2.8	2.4	3.5	1.8	1.9	9.2
2005	79.0	77.5	89.5	50.6	43.9	23.3	26.7	41.9	29.7	14.7	9.3	7.9	8.4	4.5	4.1	2.5	2.3	2.0	2.8	1.4	9.0
2006	27.4	64.7	63.4	73.3	41.4	35.9	19.0	21.8	34.0	24.1	11.9	7.5	6.4	6.7	3.6	3.3	2.0	1.9	1.6	2.3	8.4
2007	28.7	22.4	52.9	51.9	59.9	33.8	29.3	15.4	17.6	27.5	19.4	9.5	6.0	5.1	5.4	2.9	2.6	1.6	1.5	1.3	8.5
2008	40.2	23.5	18.4	43.3	42.5	49.0	27.6	23.8	12.5	14.2	22.1	15.6	7.6	4.8	4.1	4.3	2.3	2.1	1.3	1.2	7.8
2009	50.2	32.9	19.2	15.0	35.4	34.7	39.9	22.3	19.2	10.0	11.4	17.7	12.4	6.1	3.8	3.3	3.4	1.8	1.7	1.0	7.1
2010	80.3	41.1	27.0	15.7	12.3	29.0	28.3	32.4	18.1	15.5	8.1	9.1	14.2	9.9	4.9	3.1	2.6	2.7	1.5	1.3	6.5
2011	86.7	65.7	33.7	22.1	12.9	10.0	23.6	23.0	26.3	14.7	12.6	6.5	7.4	11.5	8.0	3.9	2.5	2.1	2.2	1.2	6.3
2012	80.6	71.0	53.8	27.6	18.1	10.5	8.2	19.3	18.8	21.4	11.9	10.2	5.3	6.0	9.3	6.5	3.2	2.0	1.7	1.8	6.1
2013	86.3	66.0	58.1	44.0	22.6	14.8	8.6	6.7	15.7	15.2	17.4	9.7	8.2	4.3	4.9	7.5	5.3	2.6	1.6	1.4	6.3
2014	86.8	70.6	54.0	47.6	36.0	18.4	12.1	7.0	5.4	12.7	12.3	14.0	7.8	6.6	3.5	3.9	6.0	4.2	2.1	1.3	6.2

Table 4.1.11 – Numbers-at-age for southern rock sole males

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	159.0	96.3	58.9	41.8	29.4	22.6	18.0	14.6	12.6	9.4	6.9	5.1	3.9	3.0	2.5	1.9	1.4	1.1	0.8	0.6	2.0
1978	157.9	122.7	74.3	45.5	32.3	22.6	17.4	13.8	11.1	9.5	7.1	5.2	3.9	3.0	2.3	1.9	1.4	1.1	0.8	0.6	2.0
1979	147.7	121.9	94.7	57.3	35.1	24.8	17.4	13.3	10.5	8.5	7.3	5.4	3.9	2.9	2.2	1.7	1.4	1.1	0.8	0.6	1.9
1980	144.5	114.0	94.0	73.0	44.2	27.0	19.1	13.3	10.1	8.0	6.4	5.5	4.1	3.0	2.2	1.7	1.3	1.1	0.8	0.6	1.9
1981	141.5	111.5	87.9	72.5	56.3	34.0	20.7	14.6	10.1	7.7	6.1	4.9	4.2	3.1	2.3	1.7	1.3	1.0	0.8	0.6	1.9
1982	91.9	109.2	86.1	67.8	55.9	43.3	26.1	15.8	11.1	7.7	5.8	4.6	3.7	3.2	2.4	1.7	1.3	1.0	0.7	0.6	1.9
1983	95.8	70.9	84.3	66.4	52.3	43.1	33.4	20.1	12.2	8.5	5.9	4.5	3.5	2.8	2.4	1.8	1.3	1.0	0.7	0.6	2.0
1984	120.9	73.9	54.7	65.0	51.2	40.3	33.2	25.6	15.4	9.3	6.5	4.5	3.4	2.7	2.2	1.8	1.4	1.0	0.7	0.6	1.9
1985	104.9	93.3	57.0	42.2	50.1	39.5	31.1	25.5	19.7	11.8	7.1	5.0	3.5	2.6	2.1	1.7	1.4	1.1	0.8	0.6	1.9
1986	78.3	80.9	72.0	44.0	32.6	38.7	30.4	23.9	19.6	15.2	9.1	5.5	3.8	2.7	2.0	1.6	1.3	1.1	0.8	0.6	1.9
1987	121.9	60.4	62.4	55.6	34.0	25.1	29.8	23.5	18.4	15.1	11.7	7.0	4.2	3.0	2.0	1.6	1.2	1.0	0.8	0.6	1.9
1988	69.3	94.1	46.6	48.2	42.9	26.2	19.3	22.9	18.0	14.1	11.6	8.9	5.4	3.2	2.3	1.6	1.2	0.9	0.7	0.6	1.9
1989	64.8	53.5	72.6	36.0	37.2	33.0	20.2	14.9	17.6	13.8	10.9	8.9	6.9	4.1	2.5	1.7	1.2	0.9	0.7	0.6	2.0
1990	57.0	50.0	41.3	56.0	27.8	28.6	25.4	15.5	11.4	13.5	10.6	8.3	6.8	5.2	3.1	1.9	1.3	0.9	0.7	0.5	1.9
1991	74.6	44.0	38.6	31.9	43.2	21.4	22.0	19.5	11.8	8.7	10.3	8.1	6.3	5.2	4.0	2.4	1.4	1.0	0.7	0.5	1.9
1992	66.1	57.6	33.9	29.8	24.6	33.3	16.4	16.9	14.9	9.0	6.6	7.8	6.1	4.8	3.9	3.0	1.8	1.1	0.8	0.5	1.8
1993	98.6	51.0	44.4	26.2	23.0	18.9	25.5	12.5	12.8	11.3	6.8	5.0	5.9	4.6	3.6	3.0	2.3	1.4	0.8	0.6	1.8
1994	75.2	76.0	39.3	34.3	20.2	17.7	14.5	19.4	9.5	9.7	8.5	5.1	3.8	4.4	3.5	2.7	2.2	1.7	1.0	0.6	1.8
1995	71.5	58.1	58.7	30.4	26.4	15.5	13.6	11.1	14.9	7.3	7.4	6.5	3.9	2.9	3.4	2.6	2.1	1.7	1.3	0.8	1.8
1996	91.2	55.1	44.8	45.3	23.4	20.4	11.9	10.4	8.5	11.4	5.5	5.6	4.9	3.0	2.2	2.6	2.0	1.6	1.3	1.0	2.0
1997	149.6	70.4	42.5	34.6	34.9	18.0	15.6	9.1	7.9	6.4	8.6	4.2	4.2	3.7	2.2	1.6	1.9	1.5	1.2	1.0	2.2
1998	171.5	115.4	54.3	32.8	26.6	26.9	13.8	11.9	6.9	6.0	4.9	6.5	3.2	3.2	2.8	1.7	1.2	1.5	1.1	0.9	2.4
1999	89.1	132.3	89.1	41.9	25.3	20.5	20.7	10.6	9.1	5.3	4.6	3.7	4.9	2.4	2.4	2.1	1.3	0.9	1.1	0.9	2.5
2000	63.3	68.8	102.1	68.7	32.3	19.5	15.8	15.9	8.1	7.0	4.1	3.5	2.8	3.8	1.8	1.9	1.6	1.0	0.7	0.8	2.6
2001	97.8	48.9	53.1	78.8	53.0	24.9	15.0	12.1	12.1	6.2	5.3	3.1	2.6	2.1	2.8	1.4	1.4	1.2	0.7	0.5	2.6
2002	92.2	75.5	37.7	40.9	60.7	40.8	19.1	11.4	9.2	9.2	4.7	4.0	2.3	2.0	1.6	2.1	1.0	1.1	0.9	0.6	2.3
2003	133.5	71.1	58.2	29.1	31.6	46.7	31.2	14.5	8.7	6.9	6.9	3.5	3.0	1.7	1.5	1.2	1.6	0.8	0.8	0.7	2.2
2004	94.7	103.0	54.9	44.9	22.4	24.3	35.9	23.9	11.1	6.6	5.3	5.3	2.7	2.3	1.3	1.1	0.9	1.2	0.6	0.6	2.2
2005	79.0	73.0	79.5	42.4	34.7	17.3	18.7	27.6	18.4	8.5	5.1	4.0	4.0	2.0	1.7	1.0	0.9	0.7	0.9	0.5	2.1
2006	27.4	61.0	56.4	61.3	32.7	26.7	13.3	14.3	21.0	14.0	6.5	3.8	3.1	3.0	1.5	1.3	0.8	0.7	0.5	0.7	2.0
2007	28.7	21.1	47.0	43.5	47.3	25.1	20.5	10.1	10.9	15.9	10.6	4.9	2.9	2.3	2.3	1.2	1.0	0.6	0.5	0.4	2.0
2008	40.2	22.1	16.3	36.3	33.5	36.4	19.2	15.6	7.7	8.2	12.0	7.9	3.7	2.2	1.7	1.7	0.9	0.7	0.4	0.4	1.8
2009	50.2	31.0	17.1	12.6	28.0	25.8	27.8	14.6	11.8	5.8	6.2	9.0	6.0	2.7	1.6	1.3	1.3	0.7	0.6	0.3	1.6
2010	80.3	38.8	24.0	13.2	9.7	21.5	19.7	21.2	11.1	8.9	4.4	4.7	6.8	4.5	2.1	1.2	1.0	1.0	0.5	0.4	1.5
2011	86.7	61.9	29.9	18.5	10.2	7.5	16.5	15.1	16.2	8.5	6.8	3.3	3.5	5.2	3.4	1.6	0.9	0.7	0.7	0.4	1.4
2012	80.6	66.9	47.8	23.1	14.3	7.8	5.7	12.7	11.6	12.4	6.5	5.2	2.5	2.7	3.9	2.6	1.2	0.7	0.6	0.6	1.4
2013	86.3	62.2	51.6	36.9	17.8	11.0	6.0	4.4	9.7	8.9	9.5	4.9	4.0	1.9	2.1	3.0	2.0	0.9	0.5	0.4	1.5
2014	86.8	66.6	48.0	39.8	28.4	13.7	8.4	4.6	3.4	7.4	6.7	7.2	3.7	3.0	1.5	1.6	2.3	1.5	0.7	0.4	1.4

Table 4.1.12 – Parameter estimates for the northern and southern model configurations

	Northern rock sole			Southern rock sole	
Label	**Value**	**Std Dev**		**Value**	**Std Dev**
NatM females	0.2	-		0.2	-
L_at_Amin females	21.2026	0.684352		15.9336	0.82161
L_at_Amax females	45.3603	1.07436		49.3793	0.616781
VonBert_K females	0.186109	0.01764		0.185096	0.010141
CV_young females	3.31867	0.299856		3.178	0.309287
CV_old females	6.75109	0.304511		4.62328	0.200653
NatM males	0.251293	0.008393		0.259282	0.006388
L_at_Amin males	20.9763	0.534806		17.3469	0.736351
L_at_Amax males	40.9238	1.35756		41.714	0.728567
VonBert_K males	0.164977	0.022107		0.186291	0.016498
CV_young males	2.73327	0.208262		2.37313	0.249195
CV_old males	5.24477	0.286135		4.15062	0.238403
SR_LN(R0)	11.6939	0.068833		12.2448	0.053817
SR_R1_offset	-0.00914	0.131678		0.017224	0.129415
Early_InitAge_13	-0.00017	0.599936		-0.00261	0.599171
Early_InitAge_12	-0.00022	0.599911		-0.00316	0.598988
Early_InitAge_11	-0.00029	0.599875		-0.00382	0.598762
Early_InitAge_10	-0.0005	0.599788		0.022194	0.605992
Early_InitAge_9	-0.00096	0.599606		0.071021	0.616383
Early_InitAge_8	-0.00199	0.599222		0.094955	0.619794
Early_InitAge_7	-0.00439	0.5984		-0.01637	0.589697
Early_InitAge_6	-0.00904	0.596882		-0.06765	0.578779
Early_InitAge_5	-0.01774	0.594217		-0.09709	0.571203
Early_InitAge_4	-0.02881	0.590568		-0.08971	0.569678
Early_InitAge_3	-0.03936	0.58604		0.010438	0.590324
Early_InitAge_2	-0.04593	0.581786		0.100294	0.605002
Early_InitAge_1	-0.03389	0.581493		0.339374	0.663698
Main_RecrDev_1977	0.022255	0.57959		0.604976	0.723463
Main_RecrDev_1978	0.148209	0.597521		0.598245	0.737747
Main_RecrDev_1979	0.21153	0.585849		0.531195	0.700286
Main_RecrDev_1980	0.052239	0.562936		0.509689	0.67803
Main_RecrDev_1981	-0.04306	0.525342		0.488491	0.573372
Main_RecrDev_1982	-0.12721	0.504258		0.057207	0.55077
Main_RecrDev_1983	-0.22002	0.494855		0.098347	0.523972
Main_RecrDev_1984	-0.04582	0.486349		0.331341	0.500312
Main_RecrDev_1985	0.185347	0.47132		0.188941	0.47601
Main_RecrDev_1986	0.18484	0.47534		-0.10298	0.483207
Main_RecrDev_1987	0.570296	0.337145		0.33966	0.340135

Main_RecrDev_1988	-0.09114	0.403107		-0.22483	0.397225
Main_RecrDev_1989	-0.227	0.353601		-0.29221	0.321507
Main_RecrDev_1990	-0.16113	0.295025		-0.42109	0.302582
Main_RecrDev_1991	-0.12151	0.245525		-0.15177	0.236476
Main_RecrDev_1992	-0.33845	0.238648		-0.2729	0.239526
Main_RecrDev_1993	-0.28427	0.2299		0.126734	0.184071
Main_RecrDev_1994	-0.02623	0.213848		-0.1432	0.198327
Main_RecrDev_1995	0.235165	0.174116		-0.19479	0.192673
Main_RecrDev_1996	0.221902	0.167099		0.04911	0.179059
Main_RecrDev_1997	0.213322	0.172528		0.544052	0.143575
Main_RecrDev_1998	0.599544	0.145812		0.680518	0.134949
Main_RecrDev_1999	0.687002	0.135942		0.026012	0.188327
Main_RecrDev_2000	0.155078	0.168614		-0.31532	0.212905
Main_RecrDev_2001	-0.49194	0.21042		0.119069	0.166573
Main_RecrDev_2002	-0.42807	0.209869		0.060176	0.18321
Main_RecrDev_2003	-0.12268	0.208832		0.430365	0.151311
Main_RecrDev_2004	0.51818	0.166364		0.086442	0.179734
Main_RecrDev_2005	0.367787	0.177268		-0.09456	0.177344
Main_RecrDev_2006	-0.14708	0.205159		-1.15395	0.249997
Main_RecrDev_2007	-0.5791	0.224883		-1.10693	0.24409
Main_RecrDev_2008	-0.57116	0.243291		-0.76915	0.242677
Main_RecrDev_2009	-0.49163	0.265215		-0.54742	0.28619
Main_RecrDev_2010	-0.10279	0.298082		-0.0785	0.346107
Main_RecrDev_2011	0.247579	0.374031		-0.00099	0.462219
Late_RecrDev_2012	-0.15354	0.553238		-0.07448	0.575175
Late_RecrDev_2013	-0.00465	0.598423		-0.0062	0.597857
Late_RecrDev_2014	0	0.6		0	0.6
ForeRecr_2015	0	0.6		0	0.6
Initial F	0.044336	0.011291		0.018281	0.003698
P_1_Fishery	54.3191	3.1114		50.7714	2.18457
P_2_Fishery	-1.34075	1.70605		2.21138	30.3393
P_3_Fishery	5.75341	0.158167		5.6192	0.141964
P_4_Fishery	-2.047	32.2319		0.202653	216.869
P_5_Fishery	-10	-		-10	-
P_6_Fishery	1.40235	2.51311		3.56799	97.2086
Male_Peak_Fishery	-12.7845	2.29871		-12.5325	1.86741
Male_Ascend_Fishery	-0.98505	0.155589		-1.0806	0.156653
Male_Descend_Fishery	7.77284	101.784		-0.00144	335.388
Male_Final_Fishery	6.43189	65.3279		0.000425	223.592
Male_Scale_Fishery	1	-		1	-
P_1_Survey	5.3466	0.427369		7.23931	0.476064

P_2_Survey	0.0759	0.574559		1.85494	0.335075
P_3_Survey	1.15328	0.288257		1.78778	0.252216
P_4_Survey	3.21324	1.77916		-4.59863	9.87062
P_5_Survey	-10	-		-10	-
P_6_Survey	-2.71721	3.03098		-8.76529	26.6482
Male_Peak_Survey	-1.00301	0.444775		-1.44857	0.508626
Male_Ascend_Survey	-0.81168	0.360871		-0.83543	0.317157
Male_Descend_Survey	0.222465	2.13557		8.82626	5.2325
Male_Final_Survey	0.748486	5.62296		-0.38918	94.4618
Male_Scale_Survey	1	-		1	-

Table 4.1.13 – Maturity-at-age (fixed), estimated survey selectivity-at-age, and derived fishery selectivity-at-age for males and females for the northern and southern model configurations with survey selectivity-at-age

	Northern						Southern				
Age	Maturity	Srv F	Srv M	Fsh F	Fsh M		Maturity	Srv F	Srv M	Fsh F	Fsh M
0	0	0.000	0.000	0.000	0.000		0	0.000	0.000	0.000	0.000
1	0	0.002	0.000	0.006	0.002		0	0.001	0.000	0.004	0.002
2	0	0.029	0.020	0.017	0.012		0	0.010	0.004	0.010	0.007
3	0	0.176	0.277	0.043	0.047		0	0.049	0.050	0.027	0.031
4	0	0.564	0.920	0.093	0.112		0	0.173	0.290	0.081	0.110
5	0.02	0.963	1.000	0.159	0.205		0.01	0.432	0.786	0.171	0.249
6	0.24	1.000	1.000	0.234	0.311		0.04	0.773	0.999	0.285	0.416
7	0.72	1.000	1.000	0.309	0.416		0.15	0.991	1.000	0.404	0.573
8	0.93	1.000	1.000	0.379	0.510		0.37	1.000	1.000	0.516	0.697
9	0.98	1.000	1.000	0.439	0.589		0.63	1.000	1.000	0.611	0.786
10	0.99	1.000	1.000	0.491	0.652		0.82	1.000	1.000	0.688	0.847
11	1	1.000	1.000	0.534	0.702		0.91	1.000	1.000	0.748	0.888
12	1	1.000	1.000	0.569	0.741		0.96	1.000	1.000	0.793	0.915
13	1	1.000	1.000	0.597	0.772		0.98	1.000	1.000	0.828	0.934
14	1	1.000	1.000	0.620	0.796		0.99	1.000	1.000	0.854	0.946
15	1	1.000	1.000	0.639	0.814		0.99	1.000	1.000	0.874	0.955
16	1	1.000	1.000	0.654	0.829		0.99	1.000	1.000	0.889	0.962
17	1	1.000	1.000	0.666	0.841		1	1.000	1.000	0.901	0.966
18	1	1.000	1.000	0.676	0.851		1	1.000	1.000	0.910	0.970
19	1	0.989	0.971	0.684	0.859		1	1.000	1.000	0.917	0.973
20	1	0.915	0.891	0.691	0.865		1	1.000	1.000	0.922	0.975
21	1	0.785	0.775	0.696	0.871		1	1.000	1.000	0.927	0.976
22	1	0.628	0.641	0.700	0.875		1	1.000	1.000	0.930	0.978
23	1	0.470	0.508	0.704	0.878		1	1.000	1.000	0.933	0.979
24	1	0.332	0.390	0.707	0.881		1	1.000	1.000	0.935	0.979
25	1	0.227	0.296	0.709	0.884		1	1.000	1.000	0.937	0.980
26	1	0.154	0.226	0.711	0.886		1	1.000	1.000	0.939	0.981
27	1	0.108	0.179	0.713	0.888		1	0.049	0.985	0.940	0.981
28	1	0.082	0.149	0.715	0.889		1	0.000	0.818	0.941	0.981
29	1	0.068	0.132	0.716	0.890		1	0.000	0.481	0.942	0.982
30	1	0.062	0.123	0.717	0.892		1	0.000	0.000	0.943	0.982

Table 4.1.14 – Results for the projections scenarios for northern rock sole

Scenarios 1 and 2, Maximum tier 3 ABC harvest permissible						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	14,802	17,549	1,600	44,538	0.037	86,708
2015	14,393	17,065	14,393	40,685	0.374	84,233
2016	11,985	14,220	11,985	32,667	0.374	72,279
2017	10,355	12,297	10,355	27,817	0.374	65,151
2018	9,286	11,036	9,286	25,142	0.374	61,207
2019	8,610	10,239	8,610	23,029	0.374	58,390
2020	8,205	9,763	8,205	21,614	0.374	56,577
2021	7,980	9,497	7,980	20,814	0.374	55,520
2022	7,765	9,224	7,765	20,495	0.369	55,032
2023	7,628	9,062	7,628	20,435	0.364	54,869
2024	7,543	8,963	7,543	20,480	0.361	54,877
2025	7,512	8,928	7,512	20,459	0.360	54,886
2026	7,504	8,917	7,504	20,381	0.360	54,875
2027	7,493	8,905	7,493	20,277	0.360	54,836
Scenario 3, F_{ABC} at average F over the past 5 years						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	1,850	17,549	1,600	44,538	0.037	86,708
2015	1,798	17,065	1,798	41,917	0.043	84,233
2016	1,757	16,688	1,757	39,757	0.043	82,318
2017	1,731	16,471	1,731	39,028	0.043	82,050
2018	1,720	16,386	1,720	39,376	0.043	82,926
2019	1,721	16,406	1,721	39,413	0.043	83,460
2020	1,730	16,505	1,730	39,513	0.043	83,984
2021	1,745	16,658	1,745	39,817	0.043	84,614
2022	1,762	16,831	1,762	40,341	0.043	85,406
2023	1,780	16,998	1,780	40,905	0.043	86,170
2024	1,795	17,138	1,795	41,430	0.043	86,861
2025	1,807	17,247	1,807	41,769	0.043	87,362
2026	1,816	17,331	1,816	41,961	0.043	87,711
2027	1,823	17,398	1,823	42,056	0.043	87,938
Scenario 4, $F_{ABC} = F_{60\%}$						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	7,315	17,549	1,600	44,538	0.037	86,708
2015	7,112	17,065	7,112	41,418	0.176	84,233
2016	6,509	15,641	6,509	36,732	0.176	78,066
2017	6,069	14,608	6,069	34,011	0.176	74,538
2018	5,761	13,890	5,761	32,741	0.176	72,862
2019	5,557	13,419	5,557	31,501	0.176	71,424
2020	5,433	13,134	5,433	30,605	0.176	70,428

2021	5,366	12,983	5,366	30,119	0.176	69,868
2022	5,334	12,913	5,334	29,999	0.176	69,705
2023	5,319	12,880	5,319	30,037	0.176	69,696
2024	5,308	12,856	5,308	30,122	0.176	69,753
2025	5,298	12,830	5,298	30,102	0.176	69,741
2026	5,286	12,803	5,286	30,004	0.176	69,685
2027	5,278	12,782	5,278	29,871	0.176	69,595
Scenario 5, No fishing (F_{ABC} = 0)						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	0	17,549	1,600	44,538	0.037	86,708
2015	0	17,065	0	42,079	0.000	84,233
2016	0	17,044	0	40,791	0.000	83,761
2017	0	17,137	0	40,822	0.000	84,722
2018	0	17,318	0	41,850	0.000	86,661
2019	0	17,568	0	42,477	0.000	88,102
2020	0	17,866	0	43,085	0.000	89,398
2021	0	18,191	0	43,830	0.000	90,690
2022	0	18,515	0	44,739	0.000	92,055
2023	0	18,814	0	45,643	0.000	93,317
2024	0	19,070	0	46,466	0.000	94,440
2025	0	19,280	0	47,065	0.000	95,314
2026	0	19,450	0	47,480	0.000	95,981
2027	0	19,593	0	47,767	0.000	96,476
Scenario 6, Whether N rock sole are overfished – $SB_{35\%}$ = 17,600						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	17,549	17,549	1,600	44,538	0.037	86,708
2015	17,065	17,065	17,065	40,399	0.452	84,233
2016	13,703	13,703	13,703	31,201	0.452	70,167
2017	11,516	11,516	11,516	25,734	0.452	61,960
2018	10,134	10,134	10,134	22,741	0.452	57,483
2019	9,291	9,291	9,291	20,494	0.452	54,438
2020	8,346	8,346	8,346	19,080	0.426	52,553
2021	7,932	7,932	7,932	18,490	0.412	51,836
2022	7,869	7,869	7,869	18,422	0.410	51,797
2023	7,895	7,895	7,895	18,532	0.410	51,926
2024	7,904	7,904	7,904	18,663	0.410	52,065
2025	7,891	7,891	7,891	18,677	0.410	52,112
2026	7,884	7,884	7,884	18,617	0.411	52,116
2027	7,873	7,873	7,873	18,526	0.410	52,085
Scenario 7, Whether N rock sole are approaching overfished condition						
Year	ABC	OFL	Catch	SSB	F	Total Bio

2014	17,549	17,549	1,600	44,538	0.037	86,708
2015	17,065	17,065	14,393	40,685	0.374	84,233
2016	14,220	14,220	11,985	32,667	0.374	72,279
2017	12,297	12,297	12,297	27,629	0.452	65,151
2018	10,679	10,679	10,679	24,111	0.452	59,697
2019	9,667	9,667	9,667	21,467	0.452	55,952
2020	8,873	8,873	8,873	19,734	0.442	53,569
2021	8,192	8,192	8,192	18,830	0.420	52,300
2022	7,979	7,979	7,979	18,582	0.413	51,971
2023	7,933	7,933	7,933	18,595	0.411	51,963
2024	7,911	7,911	7,911	18,677	0.411	52,046
2025	7,885	7,885	7,885	18,671	0.410	52,077
2026	7,875	7,875	7,875	18,605	0.410	52,084
2027	7,864	7,864	7,864	18,514	0.410	52,061

Table 4.1.15 – Results for the projections scenarios for southern rock sole

Scenarios 1 and 2, Maximum tier 3 ABC harvest permissible						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	17,597	20,705	1,600	72,243	0.017	127,883
2015	16,727	19,683	16,727	65,942	0.204	123,971
2016	14,177	16,690	14,177	52,717	0.204	107,544
2017	12,500	14,725	12,500	43,009	0.204	96,350
2018	11,471	13,520	11,471	36,712	0.204	89,392
2019	10,895	12,847	10,895	33,111	0.204	85,746
2020	10,183	11,963	10,183	31,257	0.195	84,151
2021	9,934	11,679	9,934	30,529	0.190	83,869
2022	10,036	11,800	10,036	30,476	0.189	84,355
2023	10,258	12,068	10,258	30,812	0.191	85,082
2024	10,418	12,262	10,418	31,346	0.192	85,926
2025	10,505	12,370	10,505	31,901	0.192	86,771
2026	10,589	12,471	10,589	32,306	0.192	87,452
2027	10,698	12,599	10,698	32,511	0.193	87,912
Scenario 3, F_{ABC} at average F over the past 5 years						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	1,730	20,705	1,600	72,243	0.017	127,883
2015	1,643	19,683	1,643	67,624	0.019	123,971
2016	1,583	18,988	1,583	62,560	0.019	119,990
2017	1,552	18,649	1,552	58,482	0.019	117,432
2018	1,546	18,605	1,546	56,075	0.019	116,520
2019	1,559	18,787	1,559	55,344	0.019	117,344
2020	1,587	19,133	1,587	55,755	0.019	119,287
2021	1,624	19,592	1,624	56,734	0.019	121,591
2022	1,666	20,103	1,666	58,073	0.019	124,132
2023	1,708	20,609	1,708	59,652	0.019	126,675
2024	1,746	21,067	1,746	61,381	0.019	129,248
2025	1,780	21,462	1,780	63,099	0.019	131,722
2026	1,808	21,801	1,808	64,595	0.019	133,883
2027	1,833	22,098	1,833	65,789	0.019	135,657
Scenario 4, $F_{ABC} = F_{60\%}$						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	8,973	20,705	1,600	72,243	0.017	127,883
2015	8,527	19,683	8,527	66,879	0.100	123,971
2016	7,760	17,936	7,760	58,020	0.100	114,293
2017	7,251	16,785	7,251	51,063	0.100	107,414
2018	6,949	16,108	6,949	46,460	0.100	103,189
2019	6,802	15,786	6,802	43,964	0.100	101,363
2020	6,767	15,718	6,767	42,874	0.100	101,083

2021	6,809	15,825	6,809	42,556	0.100	101,482
2022	6,895	16,030	6,895	42,751	0.100	102,353
2023	6,994	16,261	6,994	43,306	0.100	103,418
2024	7,085	16,472	7,085	44,095	0.100	104,656
2025	7,159	16,644	7,159	44,940	0.100	105,923
2026	7,221	16,784	7,221	45,636	0.100	107,004
2027	7,274	16,908	7,274	46,115	0.100	107,830
Scenario 5, No fishing (F_{ABC} = 0)						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	0	20,705	1,600	72,243	0.017	127,883
2015	0	19,683	0	67,796	0.000	123,971
2016	0	19,240	0	63,656	0.000	121,354
2017	0	19,113	0	60,344	0.000	119,924
2018	0	19,248	0	58,579	0.000	119,956
2019	0	19,585	0	58,409	0.000	121,596
2020	0	20,068	0	59,329	0.000	124,270
2021	0	20,648	0	60,772	0.000	127,235
2022	0	21,270	0	62,538	0.000	130,377
2023	0	21,878	0	64,511	0.000	133,472
2024	0	22,431	0	66,608	0.000	136,552
2025	0	22,914	0	68,671	0.000	139,495
2026	0	23,332	0	70,488	0.000	142,084
2027	0	23,701	0	71,977	0.000	144,245
Scenario 6, Whether S rock sole are overfished – $SB_{35\%}$ = 28,500						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	20,705	20,705	1,600	72,243	0.017	127,883
2015	19,683	19,683	19,683	65,589	0.243	123,971
2016	16,242	16,242	16,242	50,835	0.243	105,122
2017	14,024	14,024	14,024	40,309	0.243	92,591
2018	12,682	12,682	12,682	33,616	0.243	84,932
2019	10,955	10,955	10,955	29,903	0.222	80,913
2020	10,201	10,201	10,201	28,356	0.209	79,816
2021	10,109	10,109	10,109	27,914	0.206	80,014
2022	10,349	10,349	10,349	28,069	0.207	80,826
2023	10,732	10,732	10,732	28,537	0.211	81,744
2024	11,070	11,070	11,070	29,114	0.215	82,635
2025	11,229	11,229	11,229	29,620	0.216	83,374
2026	11,305	11,305	11,305	29,927	0.217	83,882
2027	11,394	11,394	11,394	30,032	0.219	84,180
Scenario 7, Whether S rock sole are approaching overfished condition						
Year	ABC	OFL	Catch	SSB	F	Total Bio

2014	20,705	20,705	1,600	72,243	0.017	127,883
2015	19,683	19,683	16,727	65,942	0.204	123,971
2016	16,690	16,690	14,177	52,717	0.204	107,544
2017	14,725	14,725	14,725	42,779	0.243	96,350
2018	13,198	13,198	13,198	35,453	0.243	87,670
2019	11,794	11,794	11,794	31,233	0.232	82,898
2020	10,670	10,670	10,670	29,155	0.216	80,906
2021	10,366	10,366	10,366	28,374	0.210	80,567
2022	10,474	10,474	10,474	28,307	0.209	81,058
2023	10,777	10,777	10,777	28,638	0.212	81,796
2024	11,072	11,072	11,072	29,137	0.215	82,602
2025	11,216	11,216	11,216	29,607	0.216	83,312
2026	11,288	11,288	11,288	29,901	0.217	83,821
2027	11,379	11,379	11,379	30,006	0.218	84,131

Figures

Figure 4.1.1 – Total catch of rock sole by area (as of 2014-10-24)

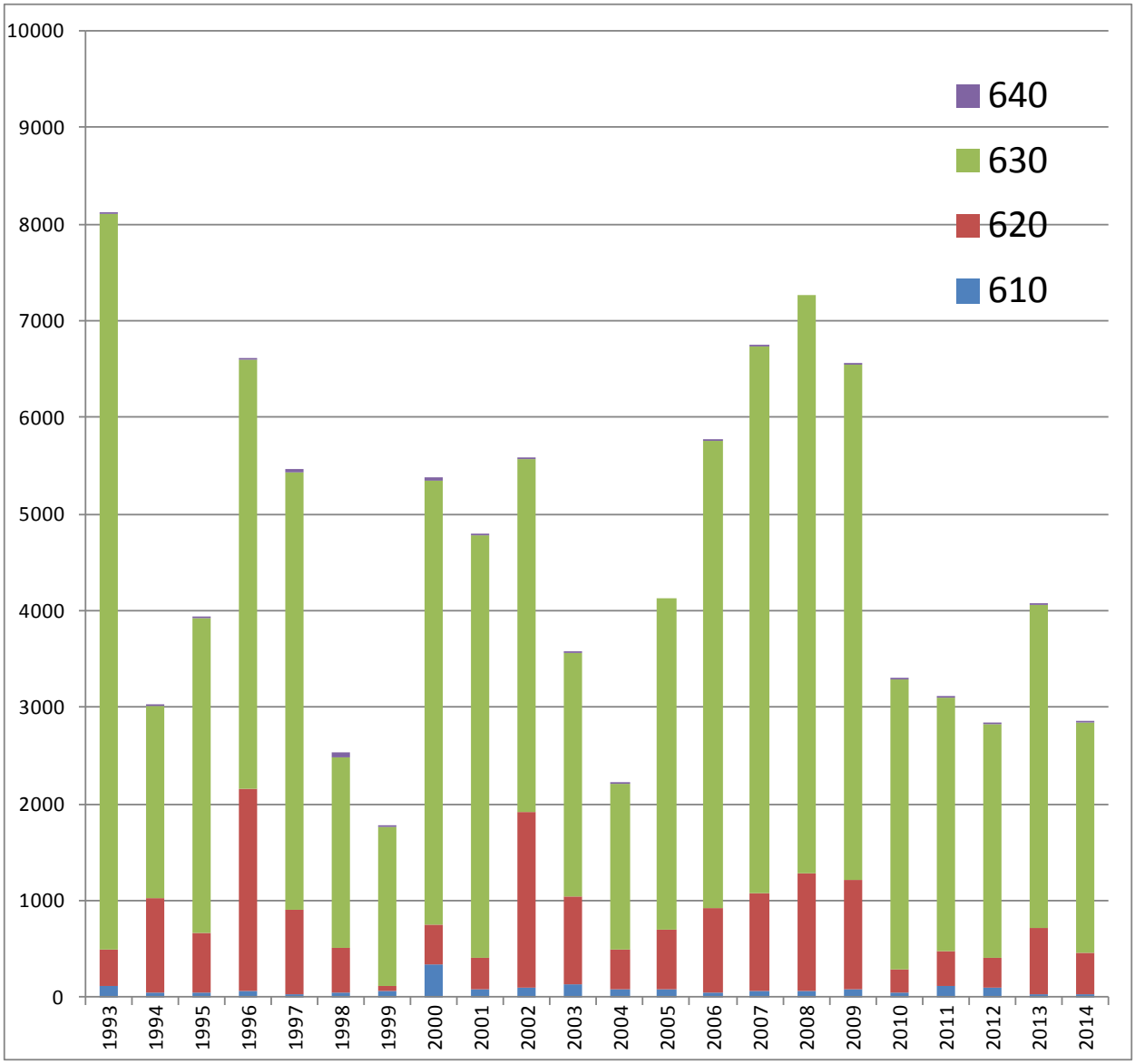


Figure 4.1.2 – Percent of the observed rock sole catch that is U/N/S rock sole (based on fishery observer extrapolated haul-level data; as of 2014-10-24)

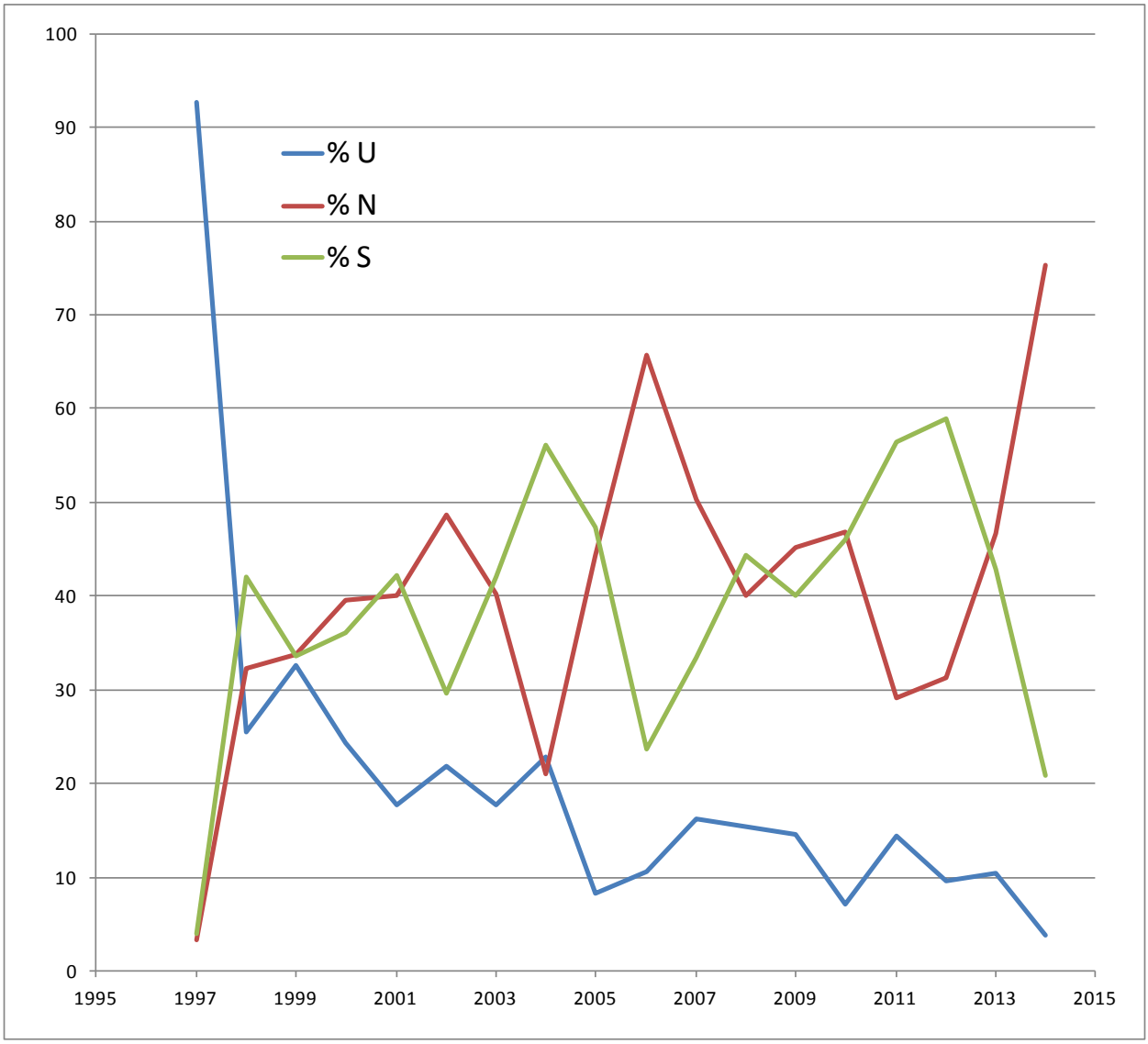


Figure 4.1.3 – GOA NMFS bottom trawl survey estimates for U rock sole by area

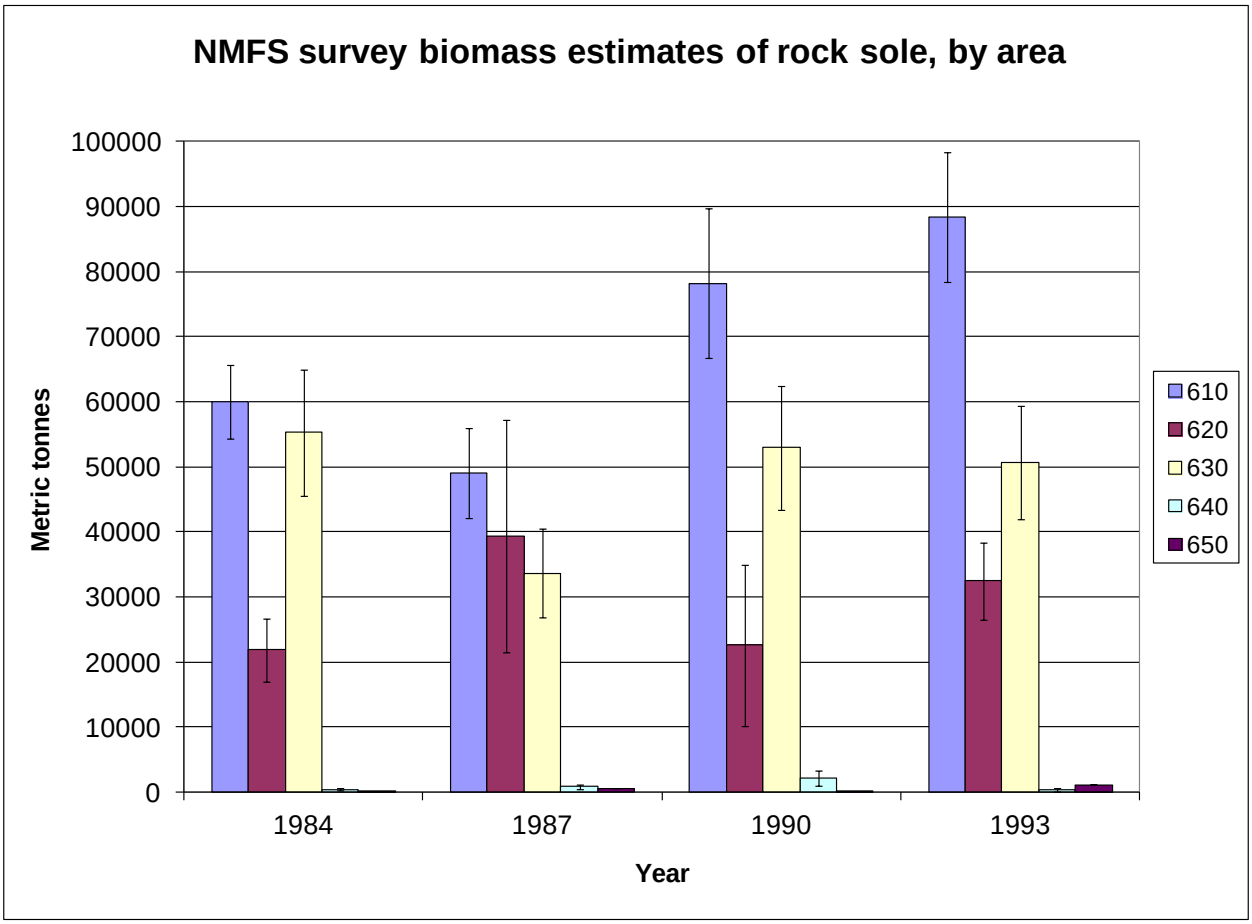


Figure 4.1.4 – GOA NMFS bottom trawl survey estimates for N rock sole by area

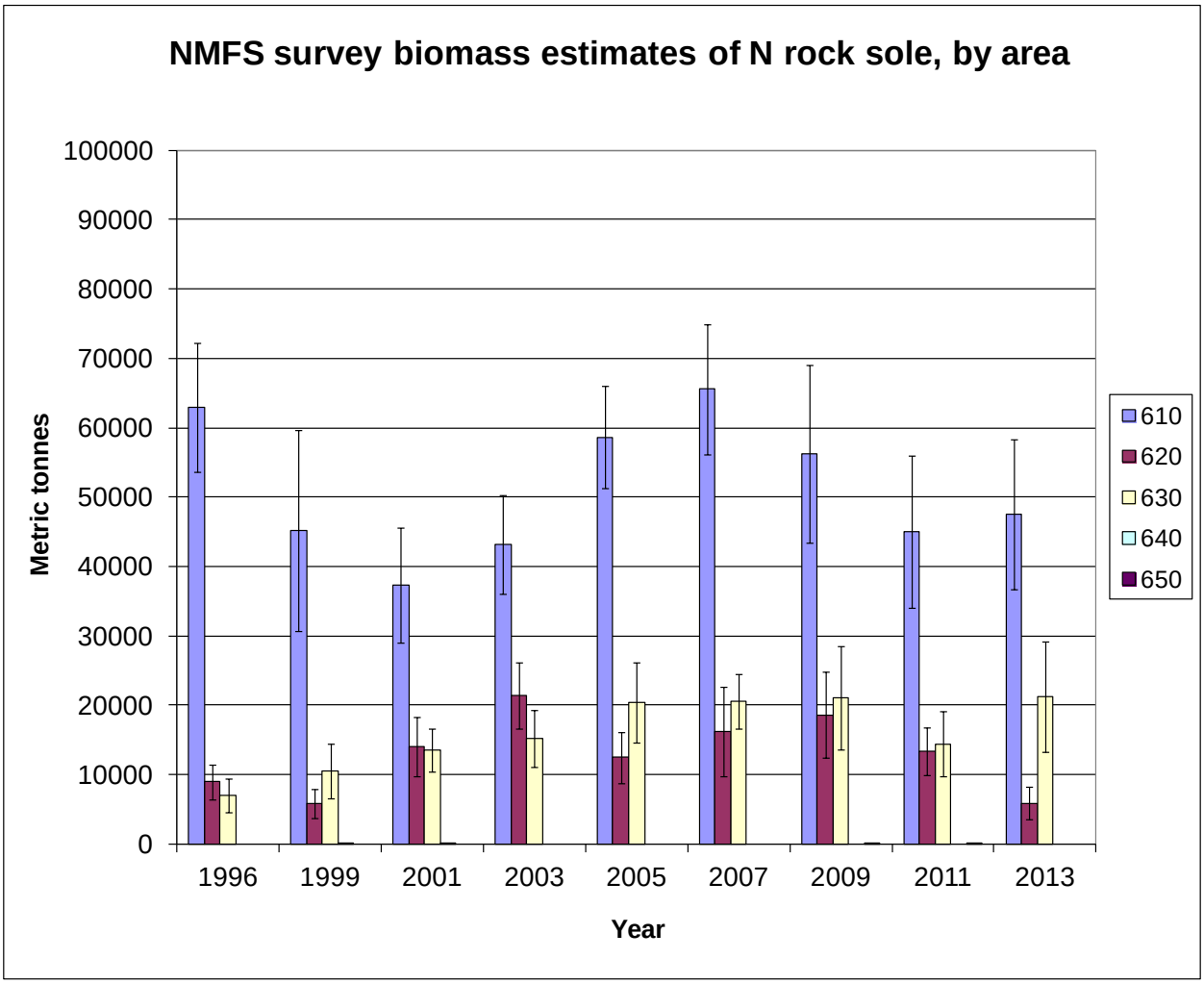


Figure 4.1.5 – GOA NMFS bottom trawl survey estimates for S rock sole by area

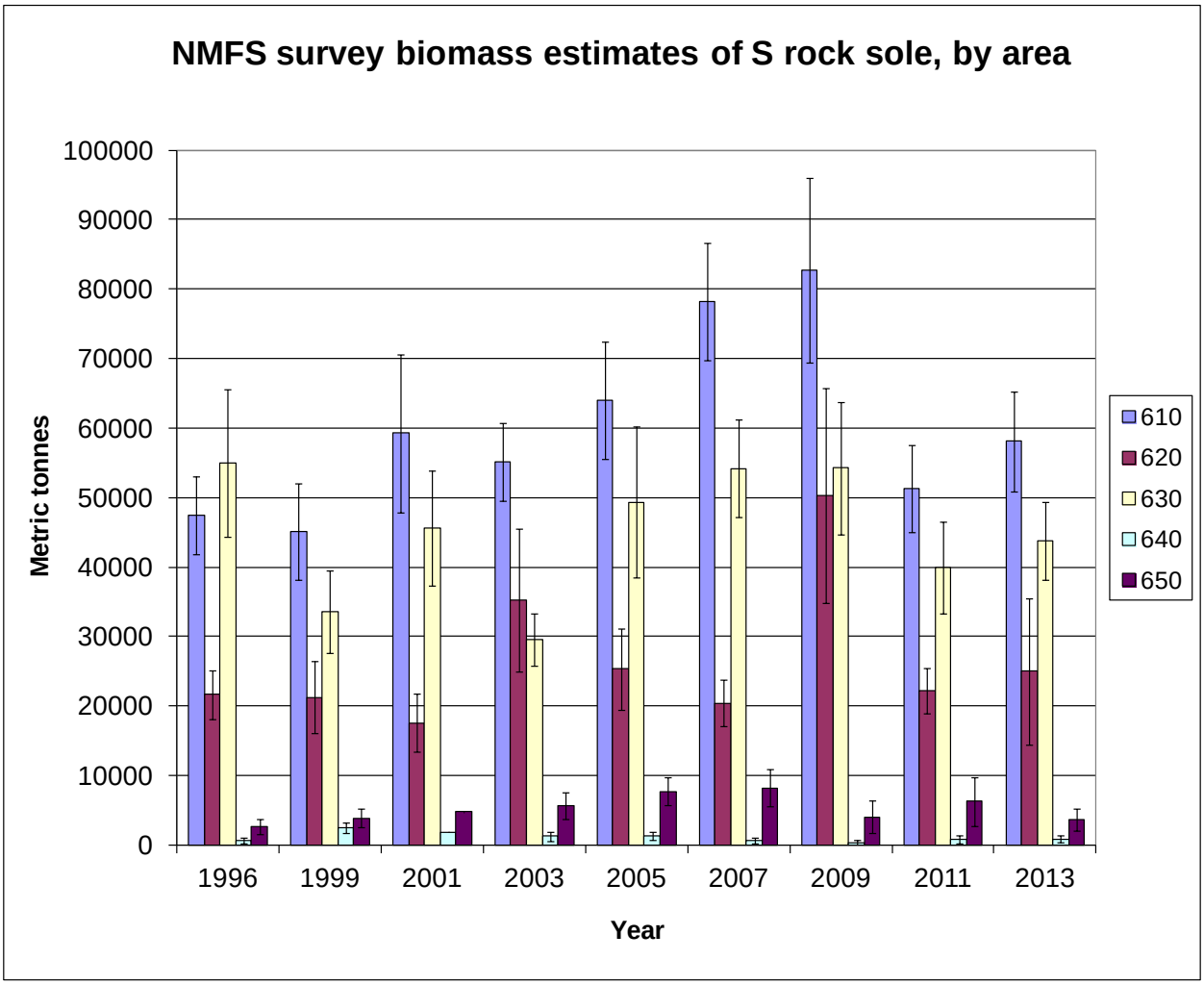


Figure 4.1.6 – GOA NMFS bottom trawl survey estimates for U/N/S rock sole

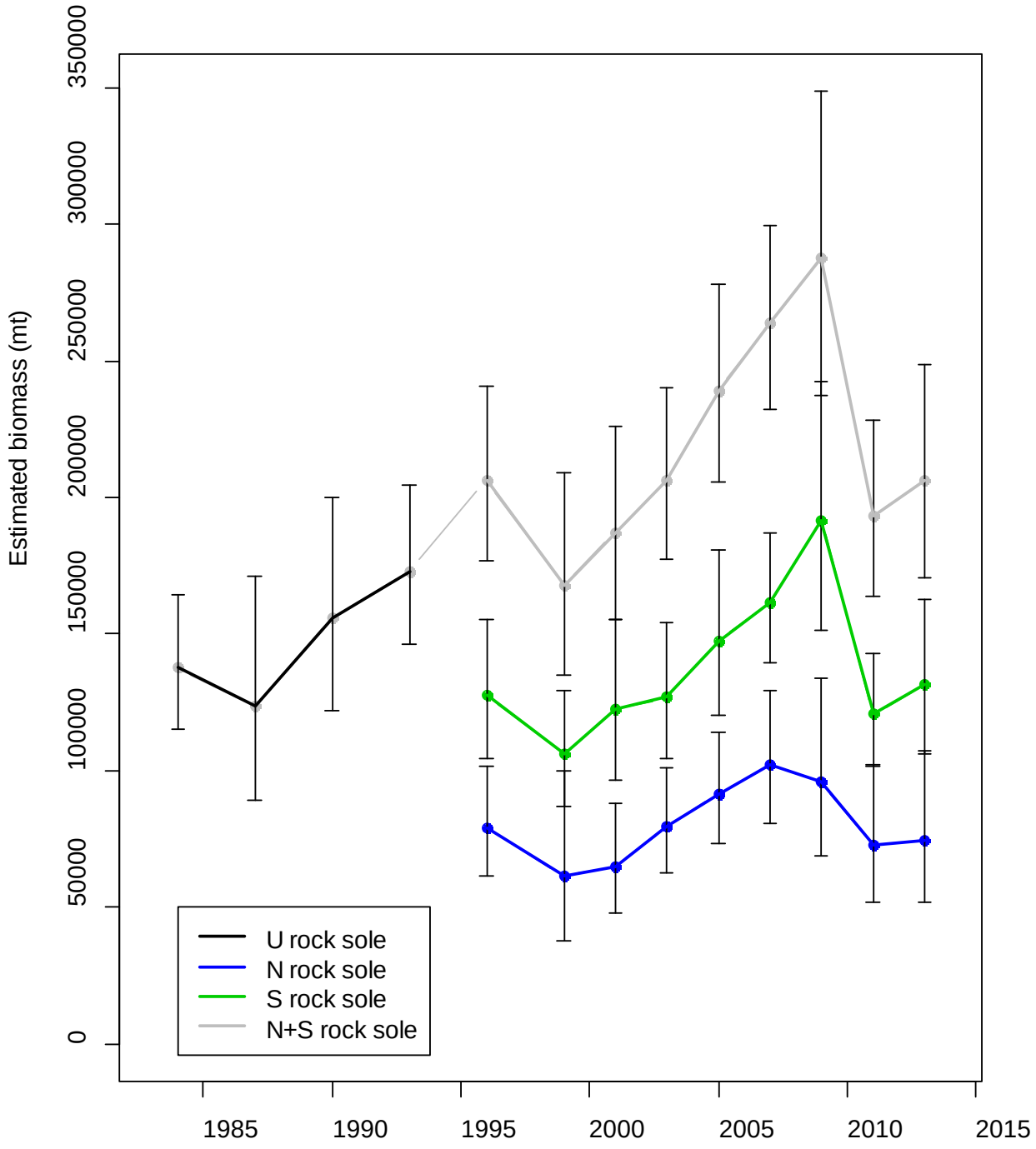


Figure 4.1.7 – Spawning biomass for U model configurations with survey selectivity-at-age and -at-length

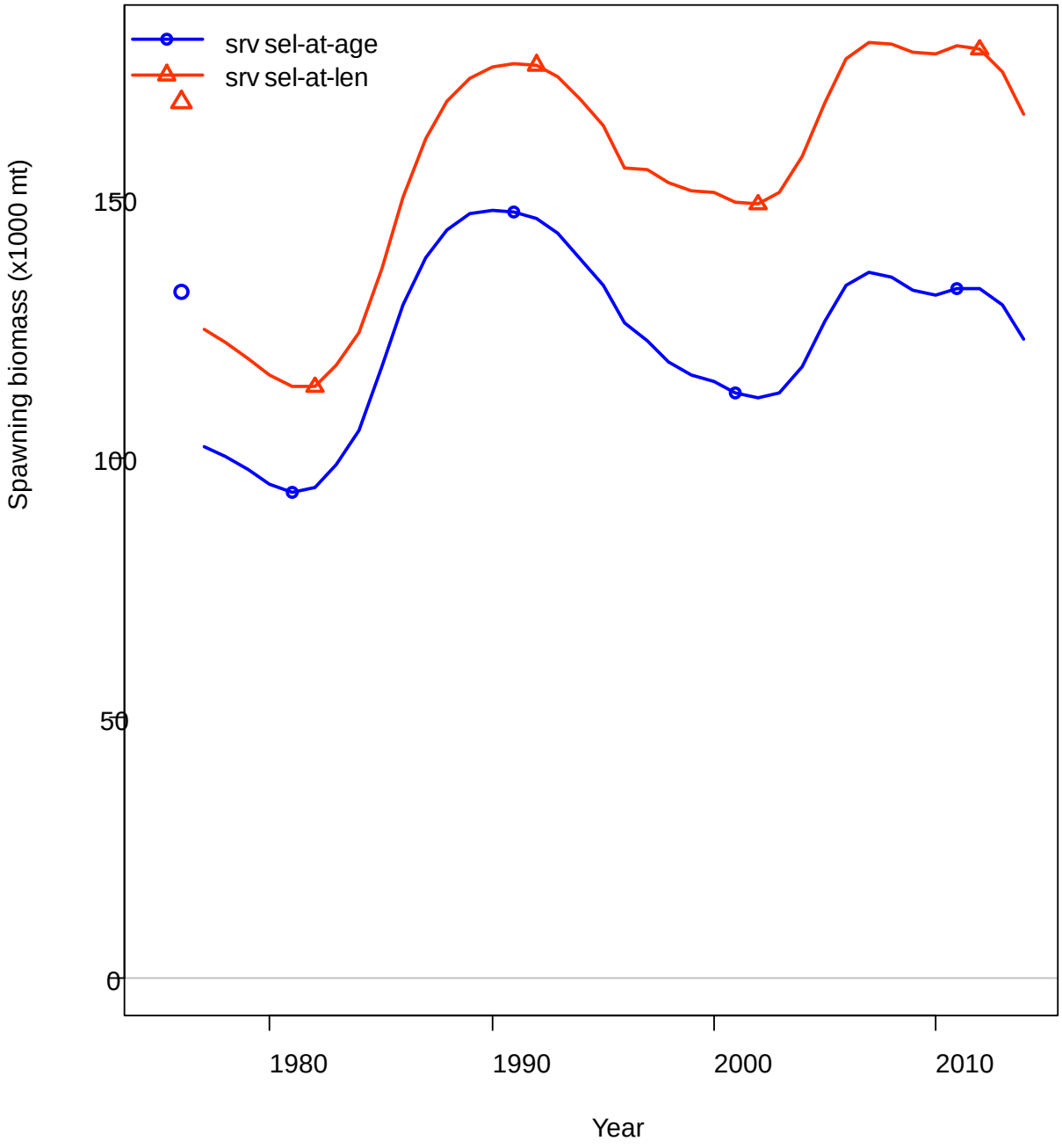


Figure 4.1.8 – Age-0 recruits for U model configurations with survey selectivity-at-age and -at-length

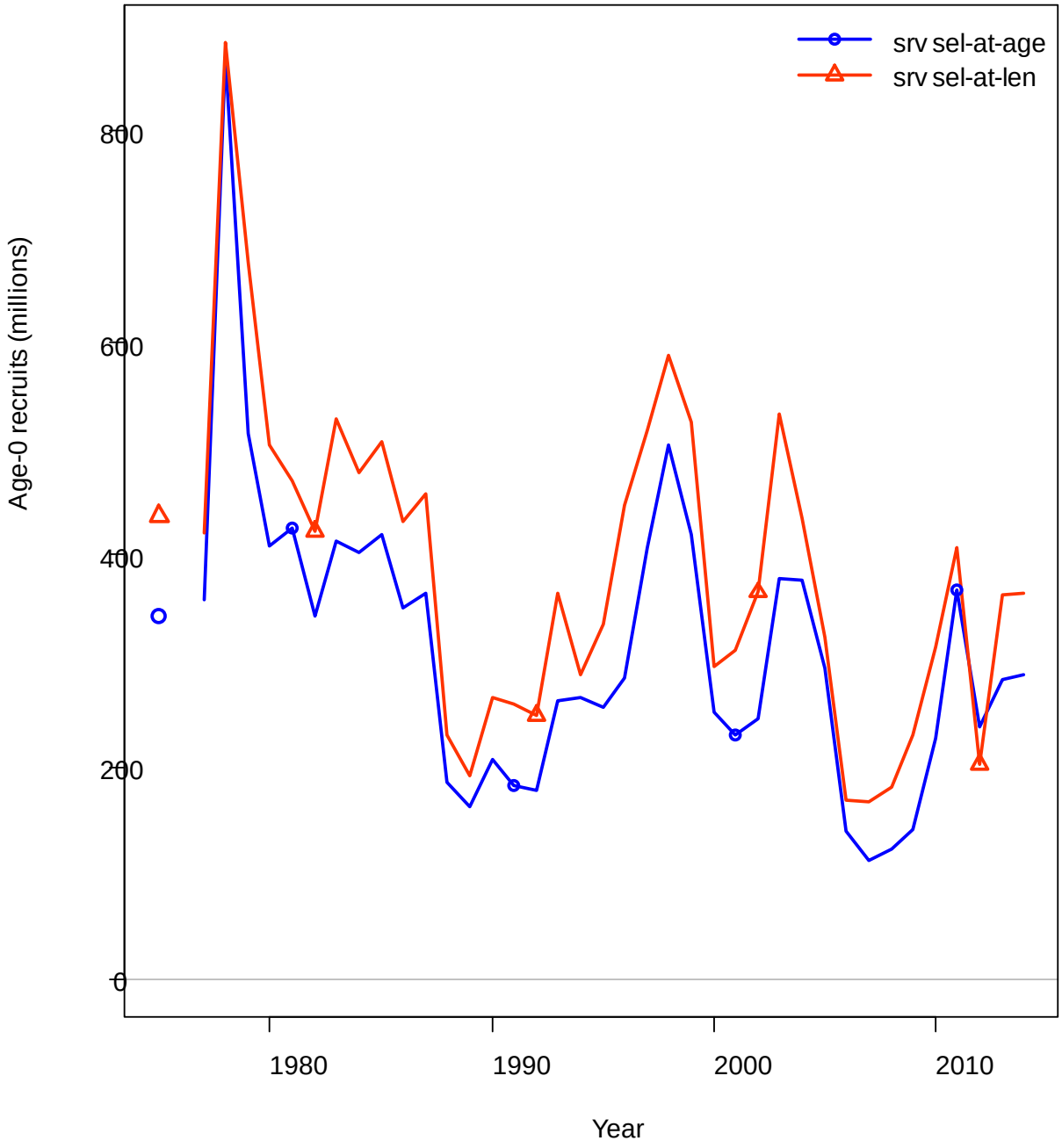


Figure 4.1.9 – Bottom trawl survey index for U model configurations with survey selectivity-at-age and -at-length

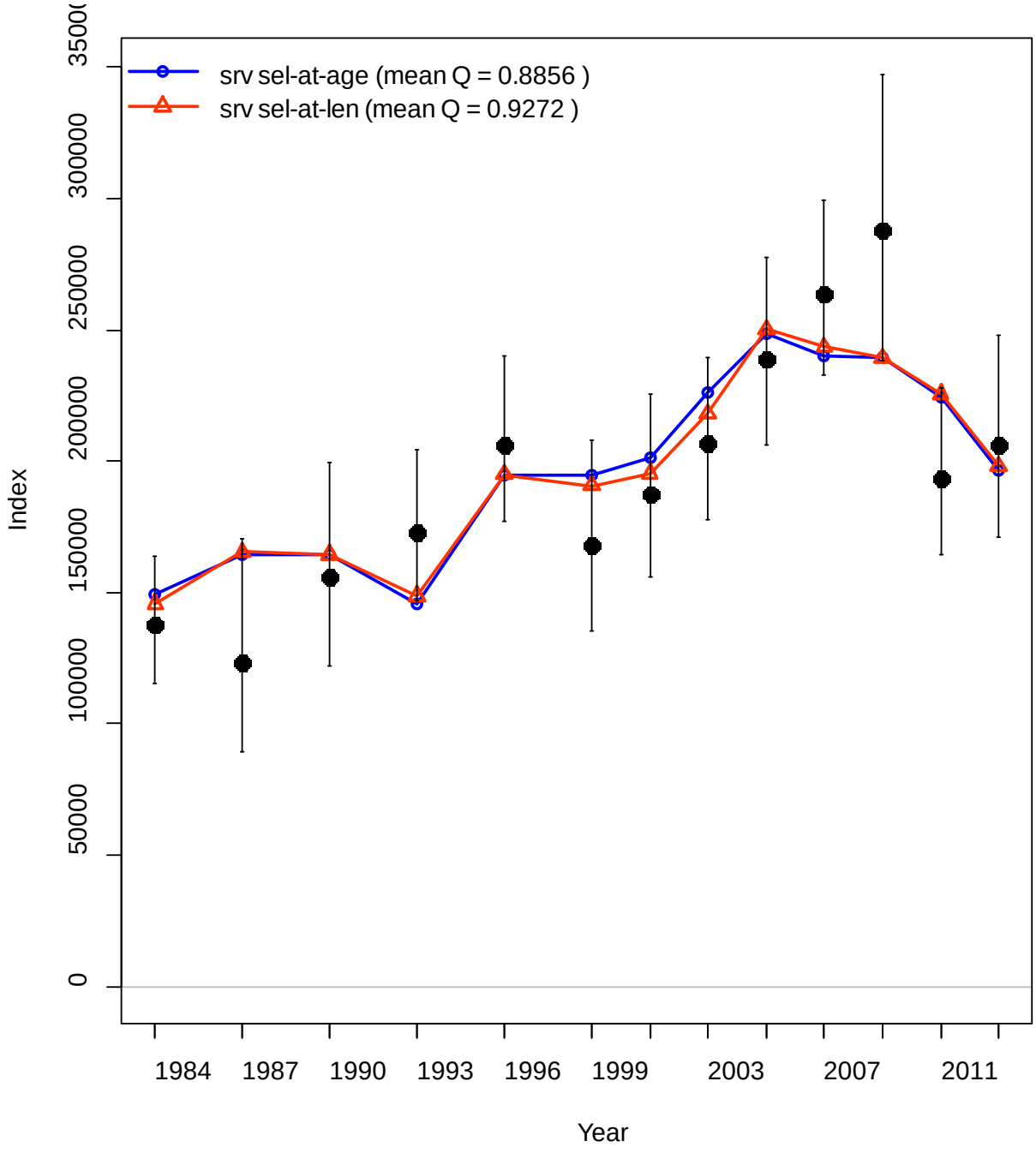


Figure 4.1.10 – Spawning biomass for N model configurations with survey selectivity-at-age and -at-length

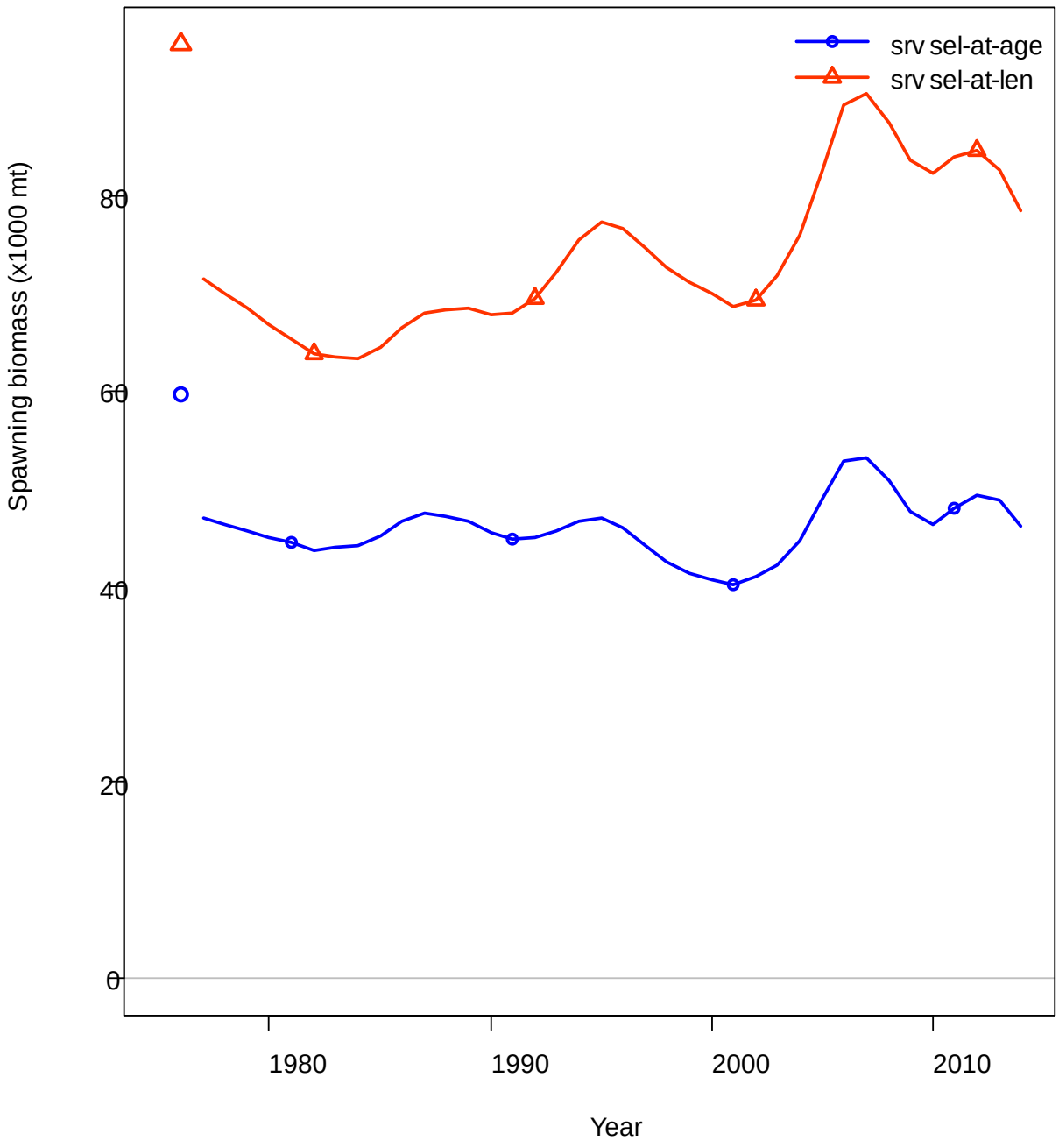


Figure 4.1.11 – Age-0 recruits for N model configurations with survey selectivity-at-age and -at-length

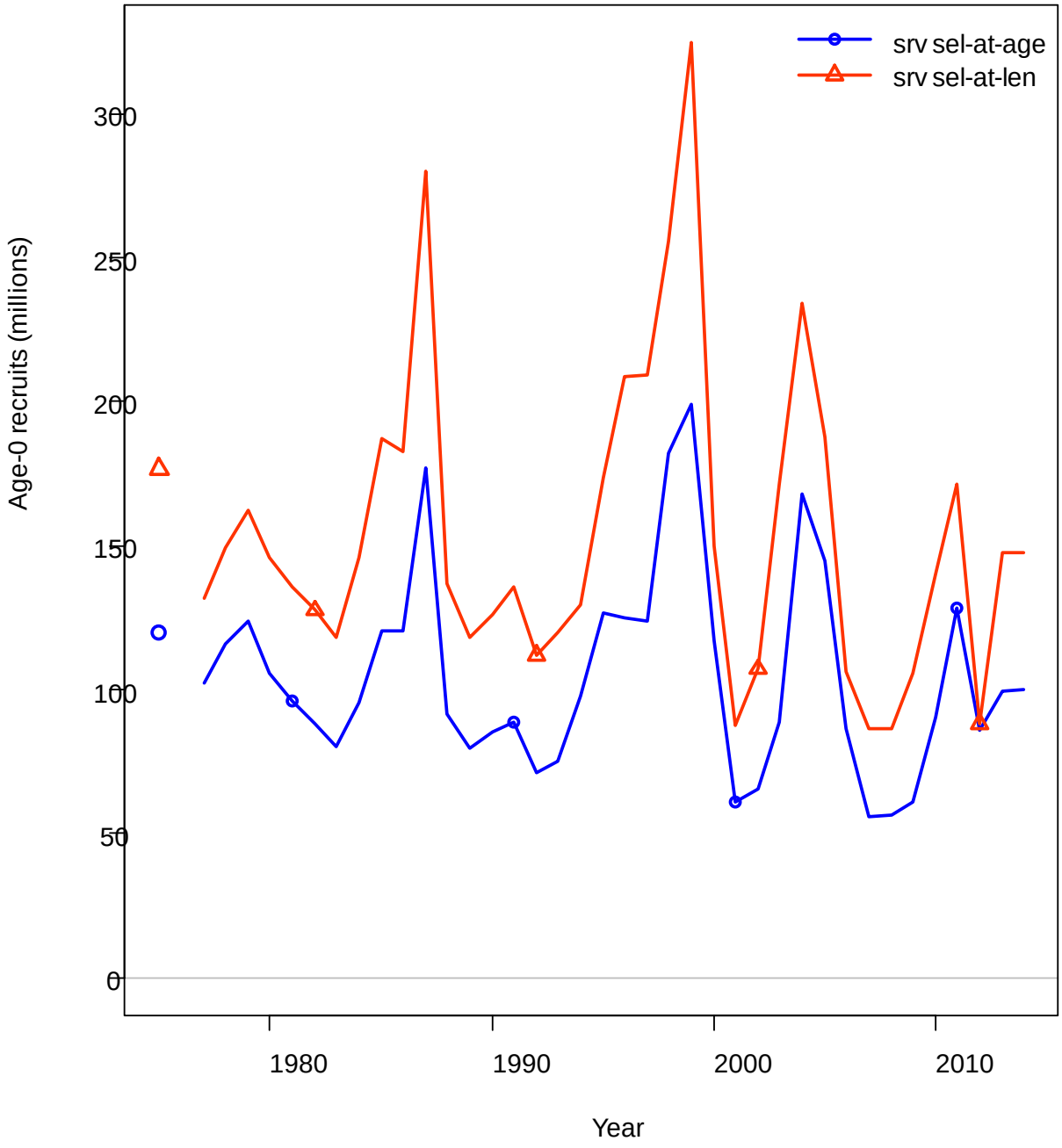


Figure 4.1.12 – Bottom trawl survey index for N model configurations with survey selectivity-at-age and -at-length

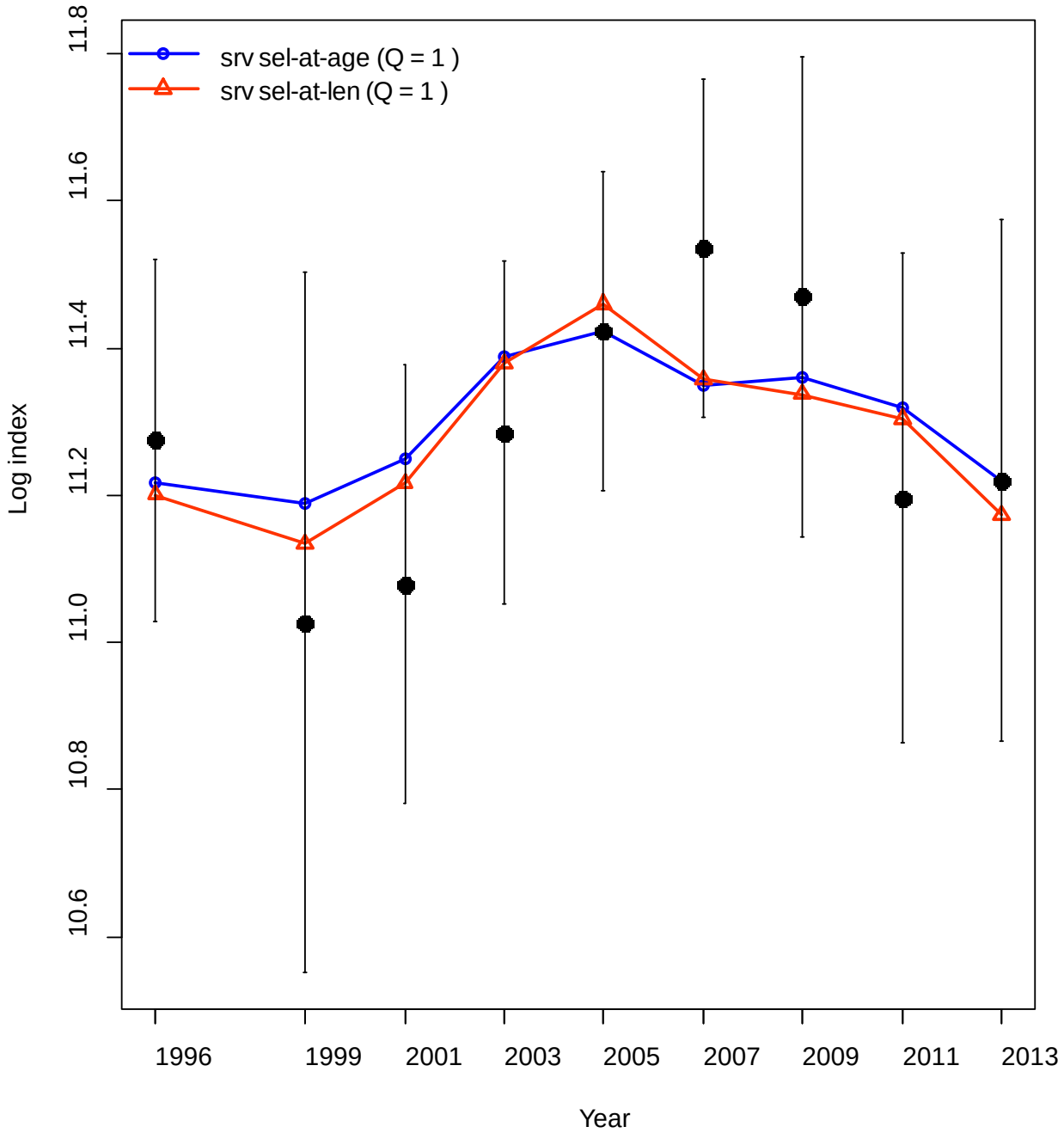


Figure 4.1.13 – Spawning biomass for S model configurations with survey selectivity-at-age and -at-length

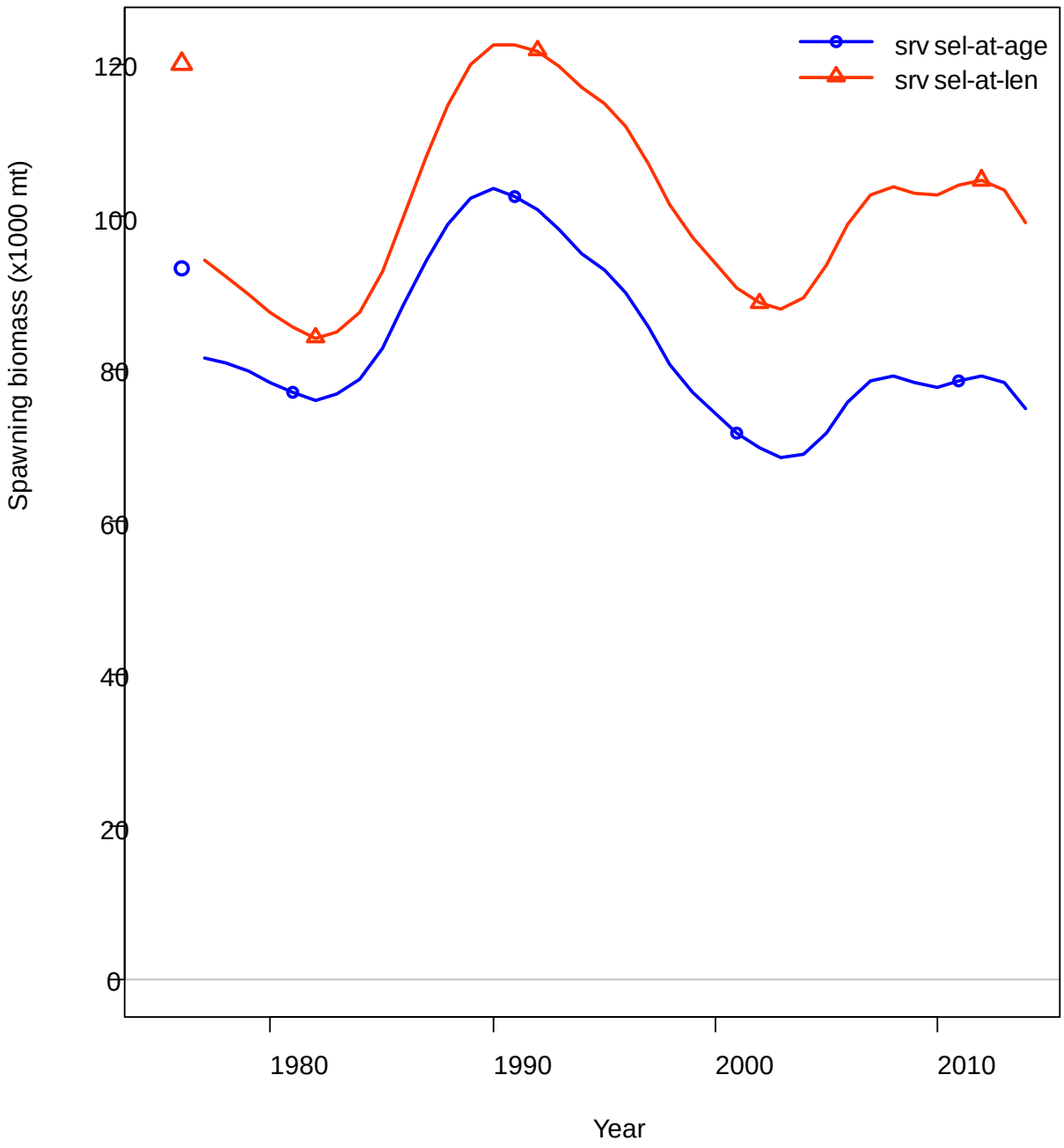


Figure 4.1.14 – Age-0 recruits for S model configurations with survey selectivity-at-age and -at-length

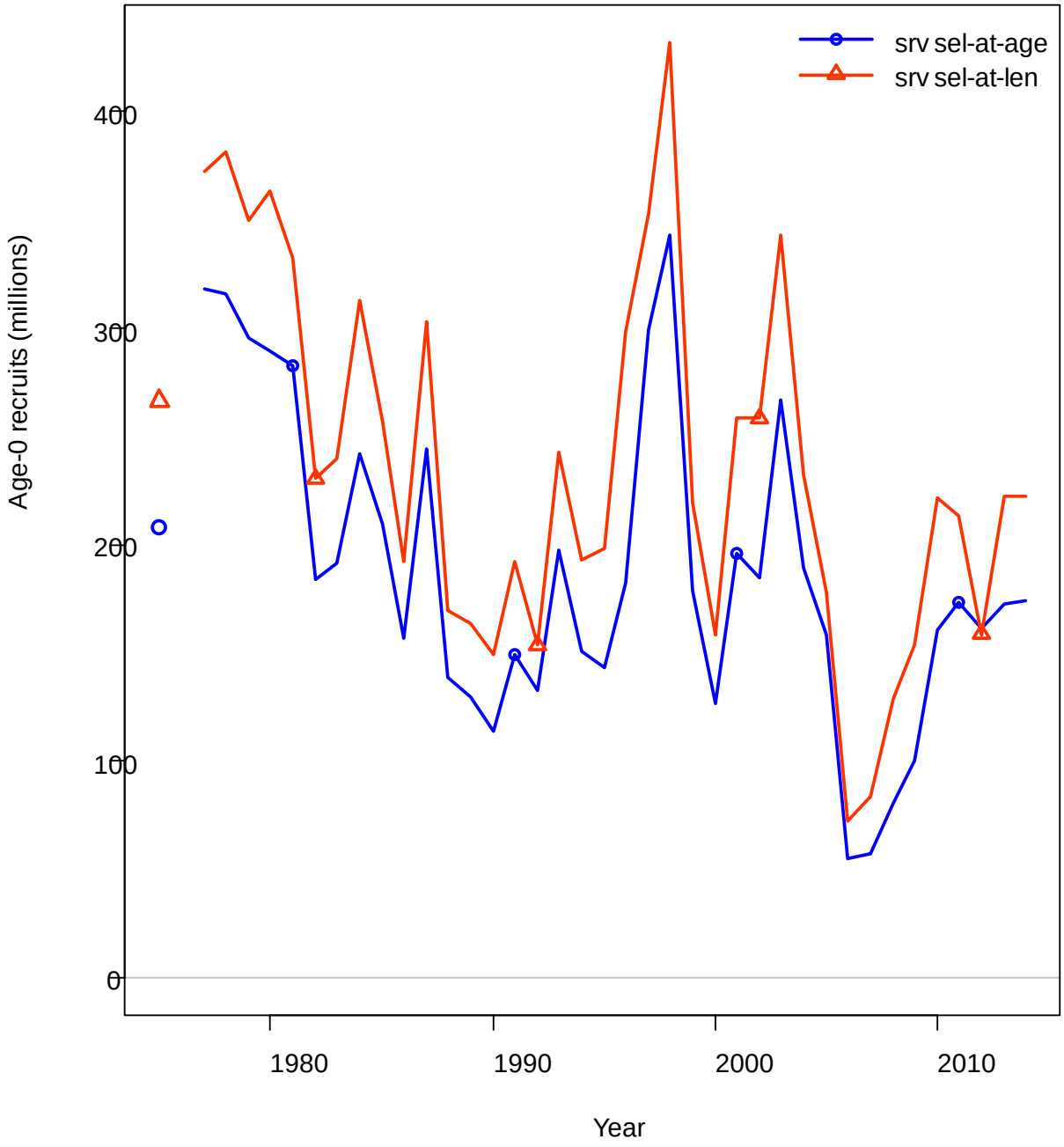


Figure 4.1.15 – Bottom trawl survey index for S model configurations with survey selectivity-at-age and -at-length

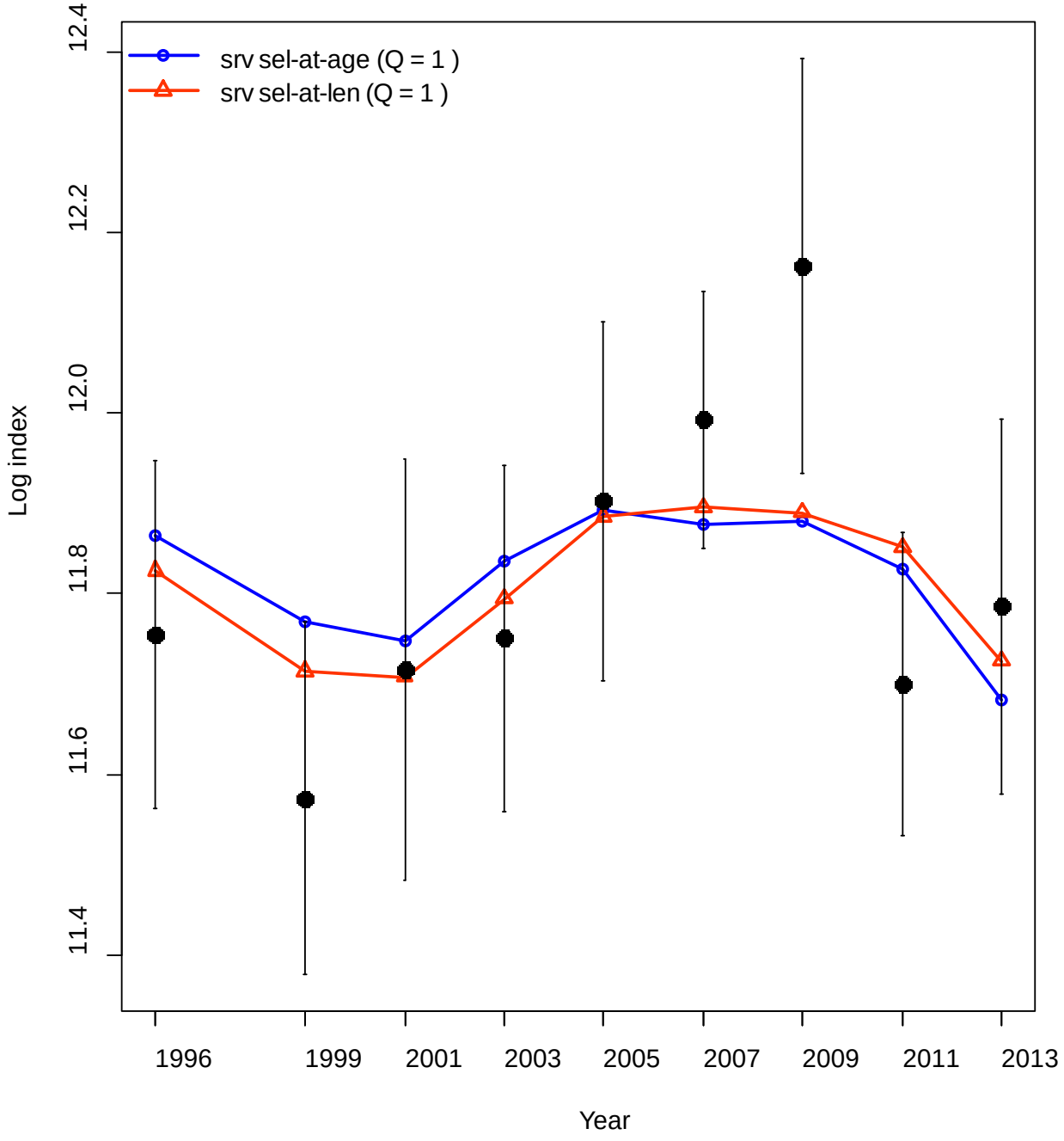


Figure 4.1.16 – Spawning biomass for U, N, and S model configurations with survey selectivity-at-age

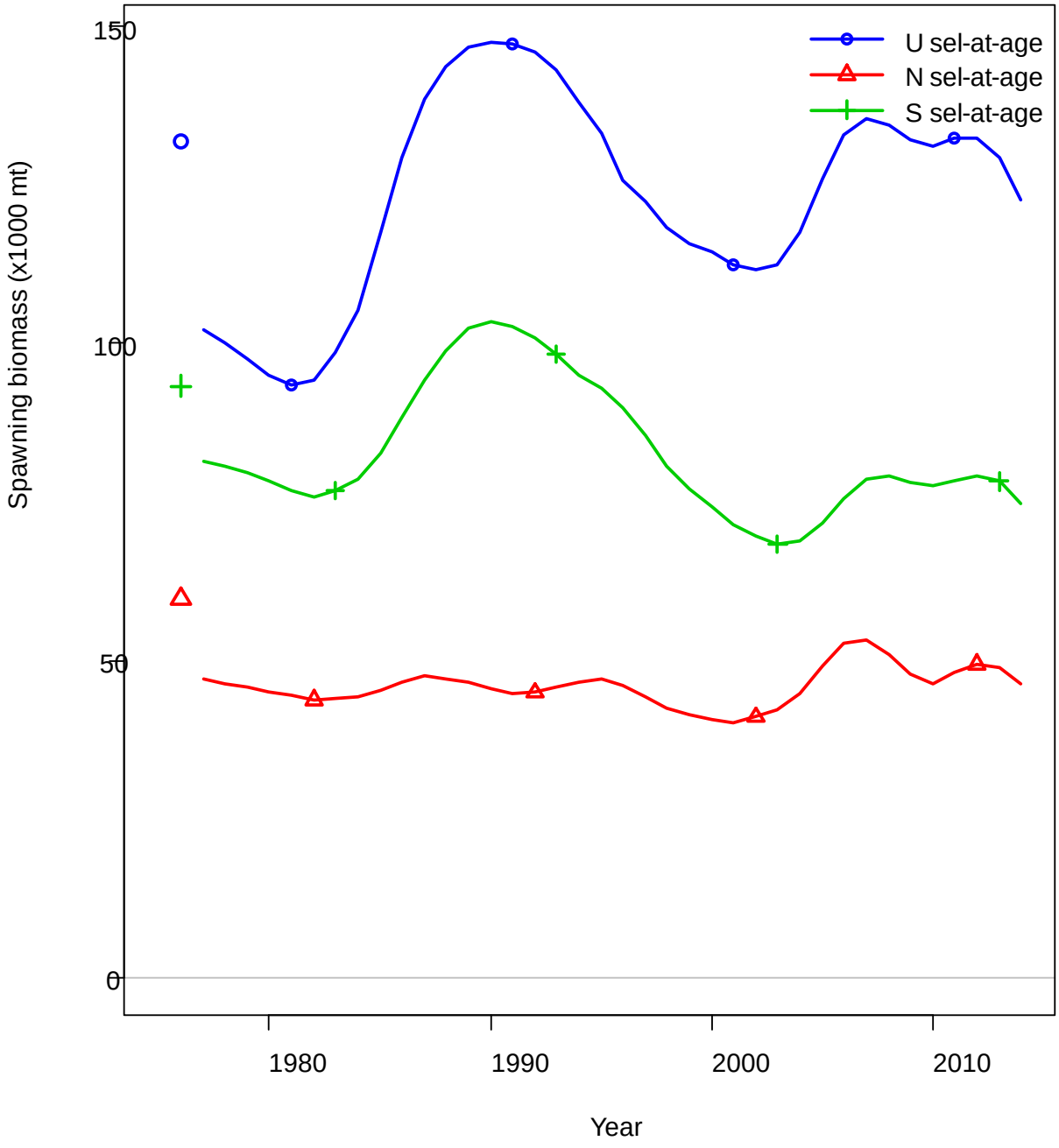


Figure 4.1.17 – Age-0 recruits for U, N, and S model configurations with survey selectivity-at-age

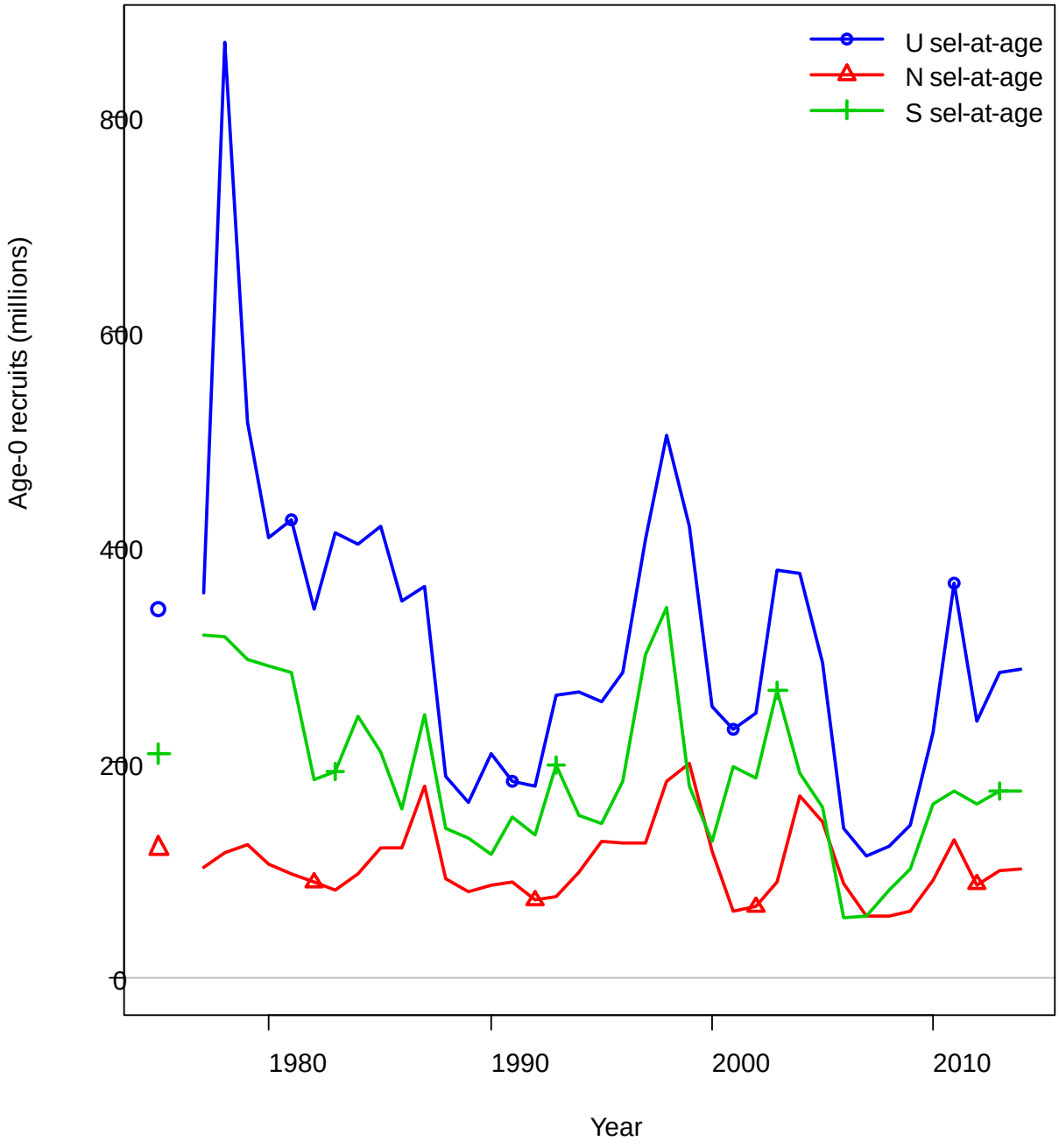


Figure 4.1.18 – Spawning biomass for U, N, and S model configurations with survey selectivity-at-length

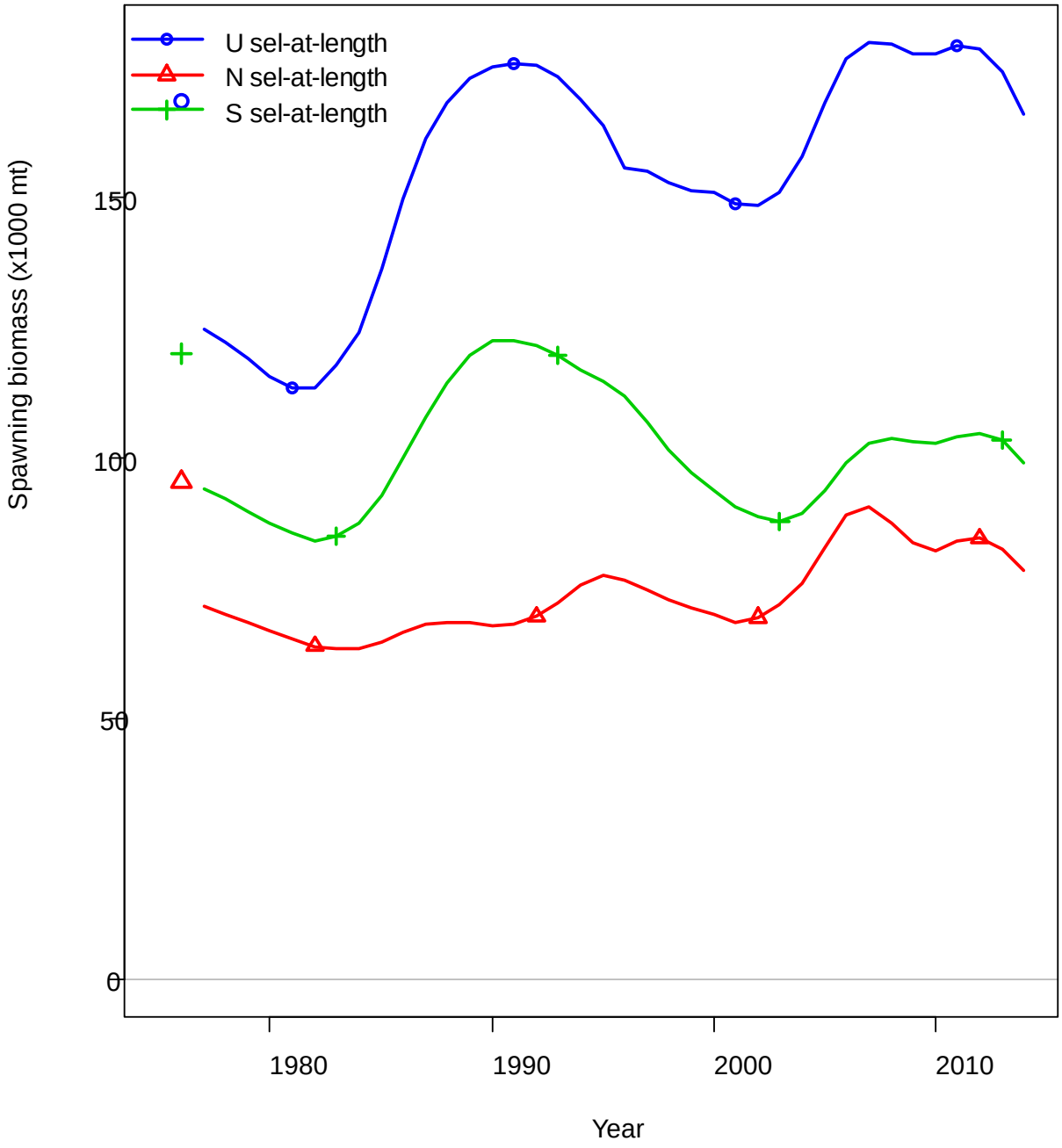


Figure 4.1.19 – Age-0 recruits for U, N, and S model configurations with survey selectivity-at-length

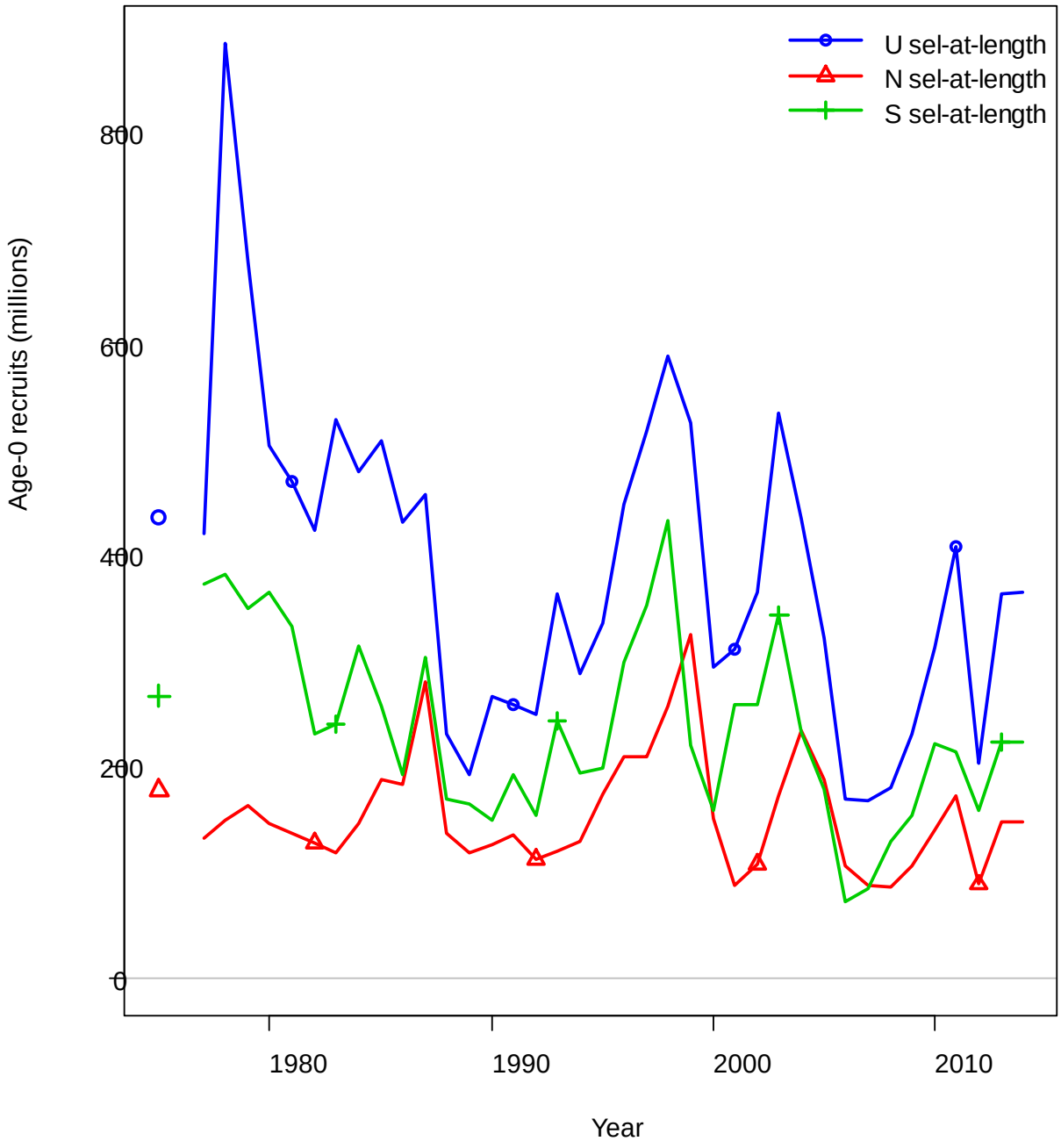


Figure 4.1.20 – Annual catch for northern and southern rock sole (half of total annual rock sole catch)

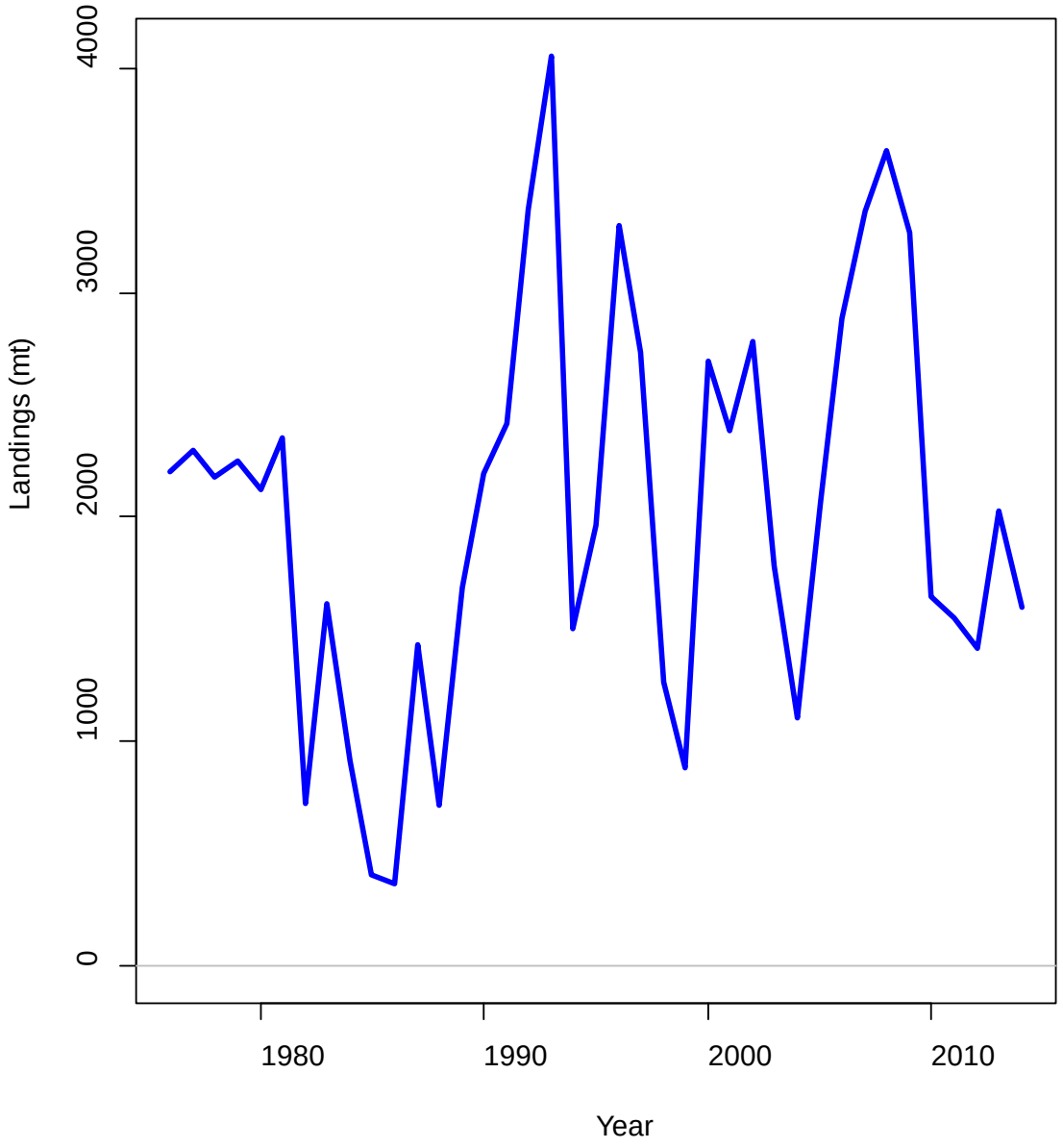


Figure 4.1.21 – Spawning biomass for N model configuration with survey selectivity-at-age

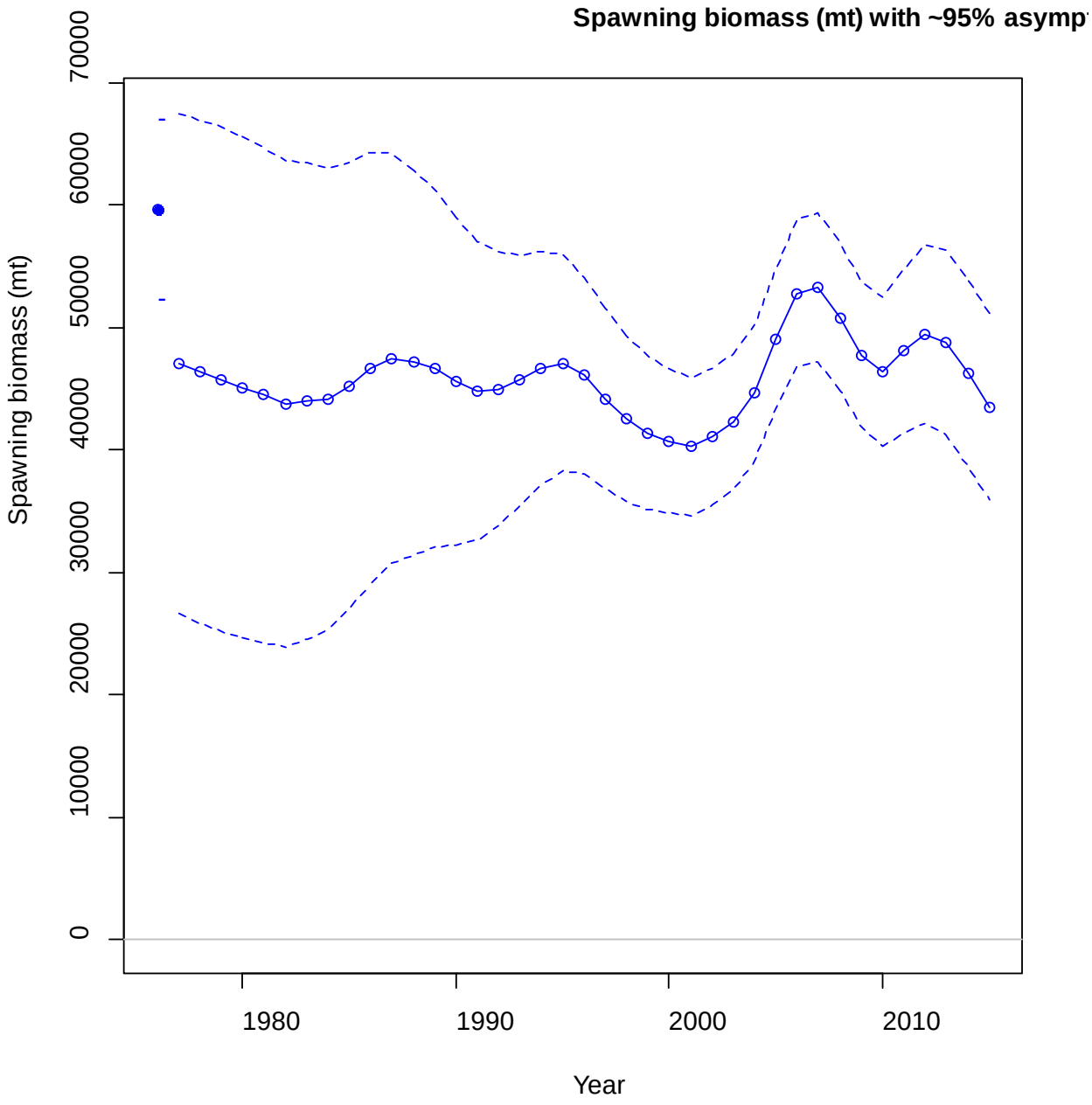


Figure 4.1.22 – Length-at-age for N model configuration with survey selectivity-at-age

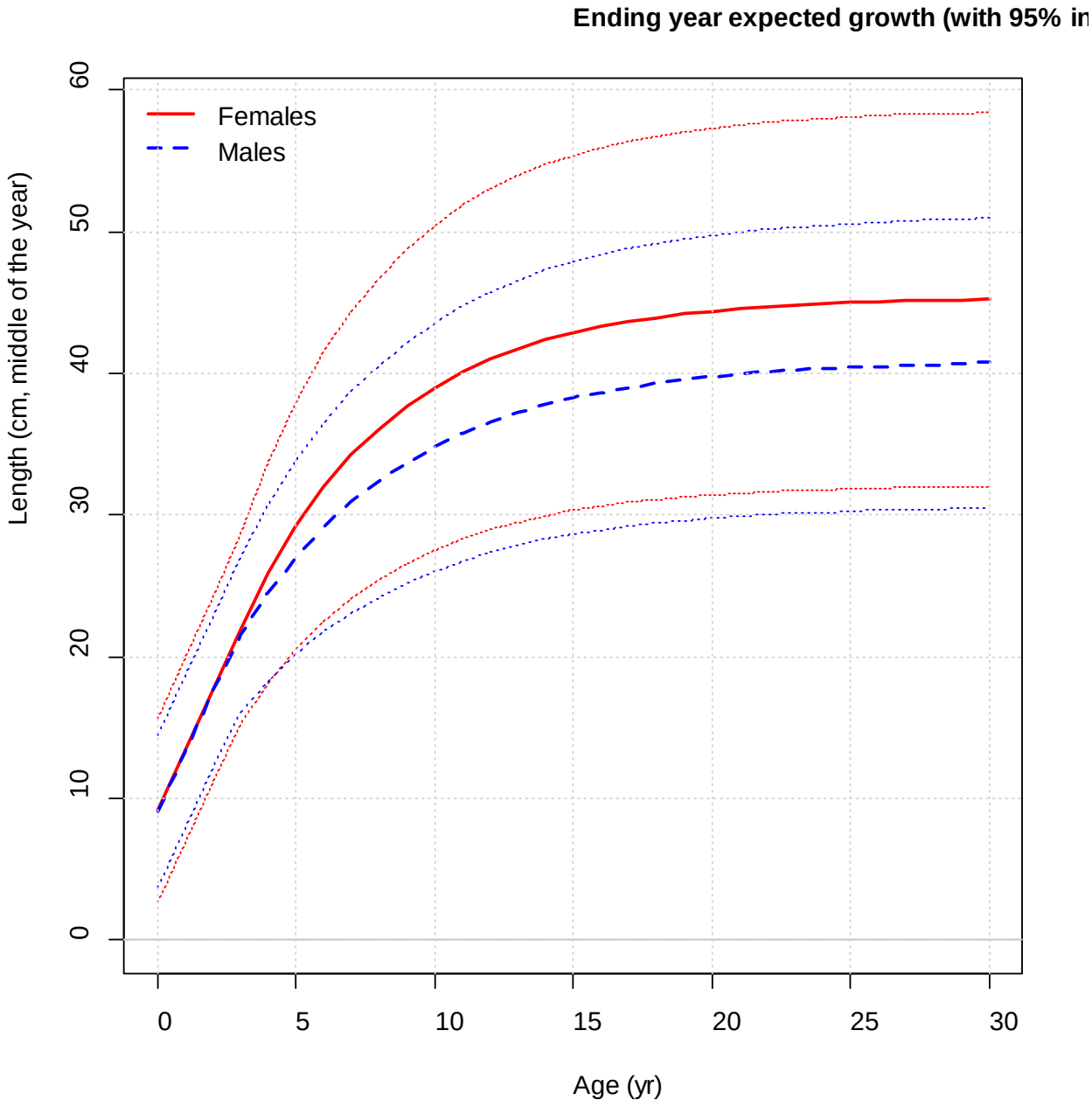


Figure 4.1.23 – Age-0 recruits for N model configuration with survey selectivity-at-age

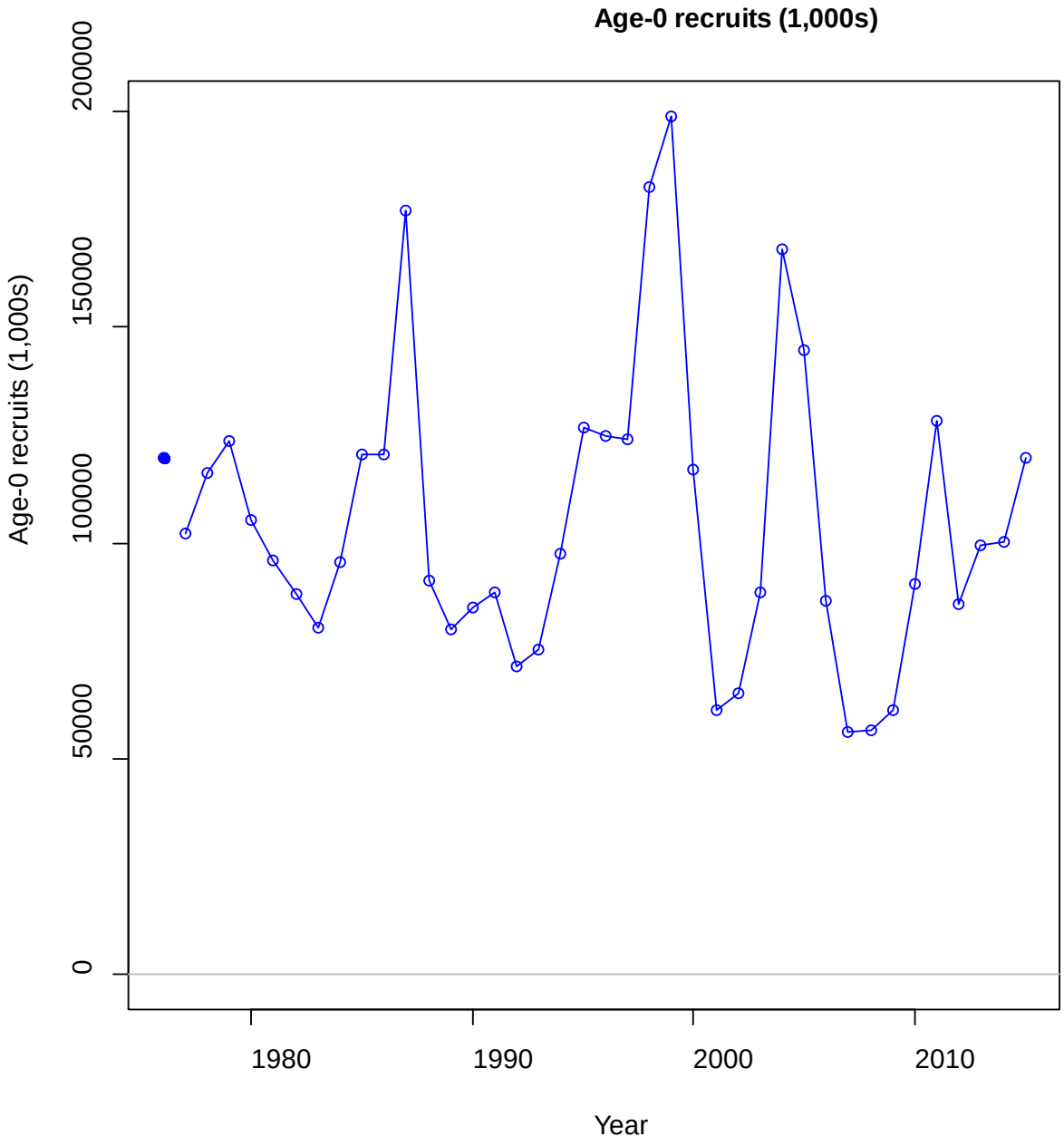


Figure 4.1.24 – Age-0 recruits with uncertainty intervals for N model configuration with survey selectivity-at-age

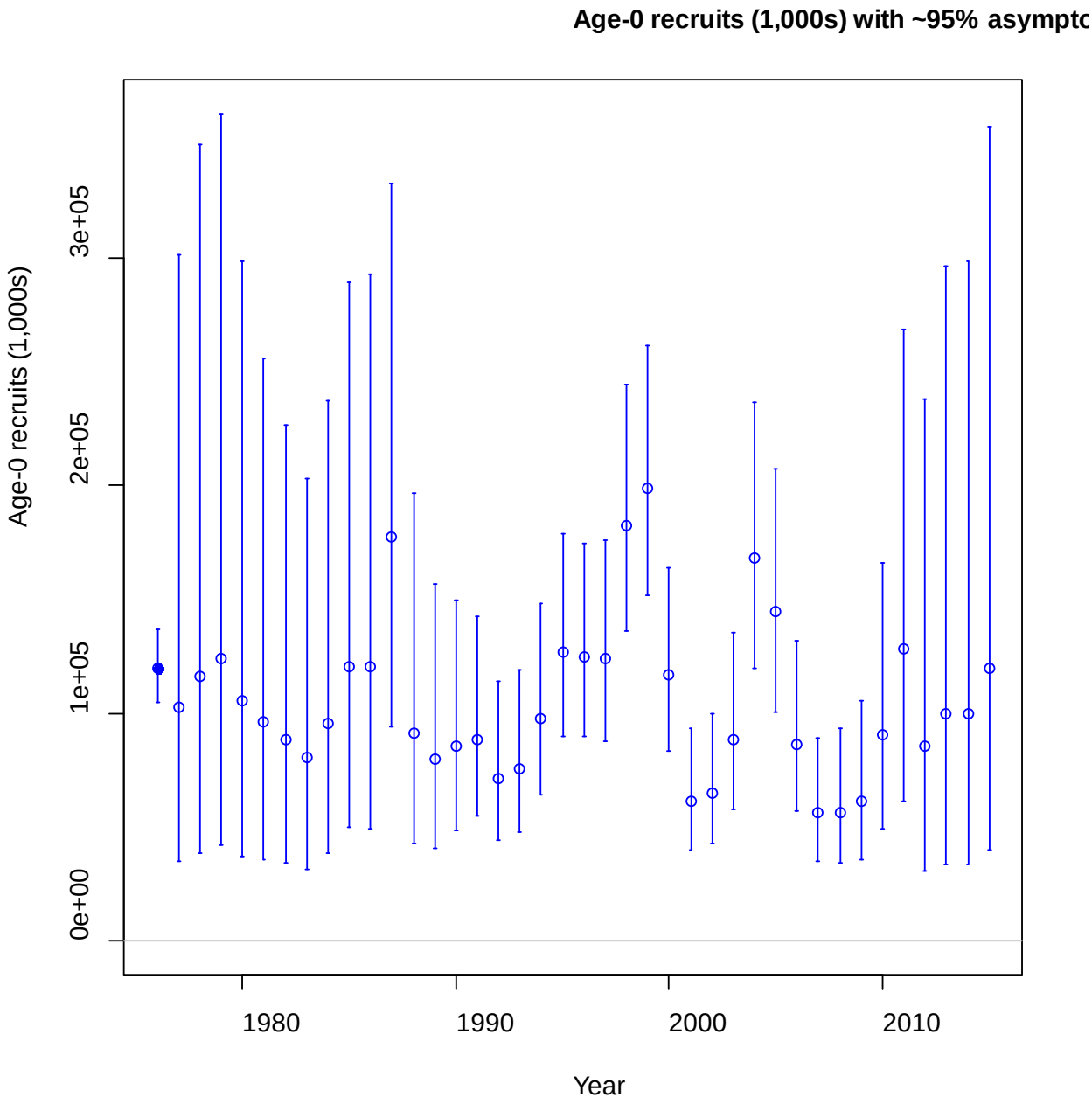


Figure 4.1.25 – Bottom trawl survey index for N model configuration with survey selectivity-at-age

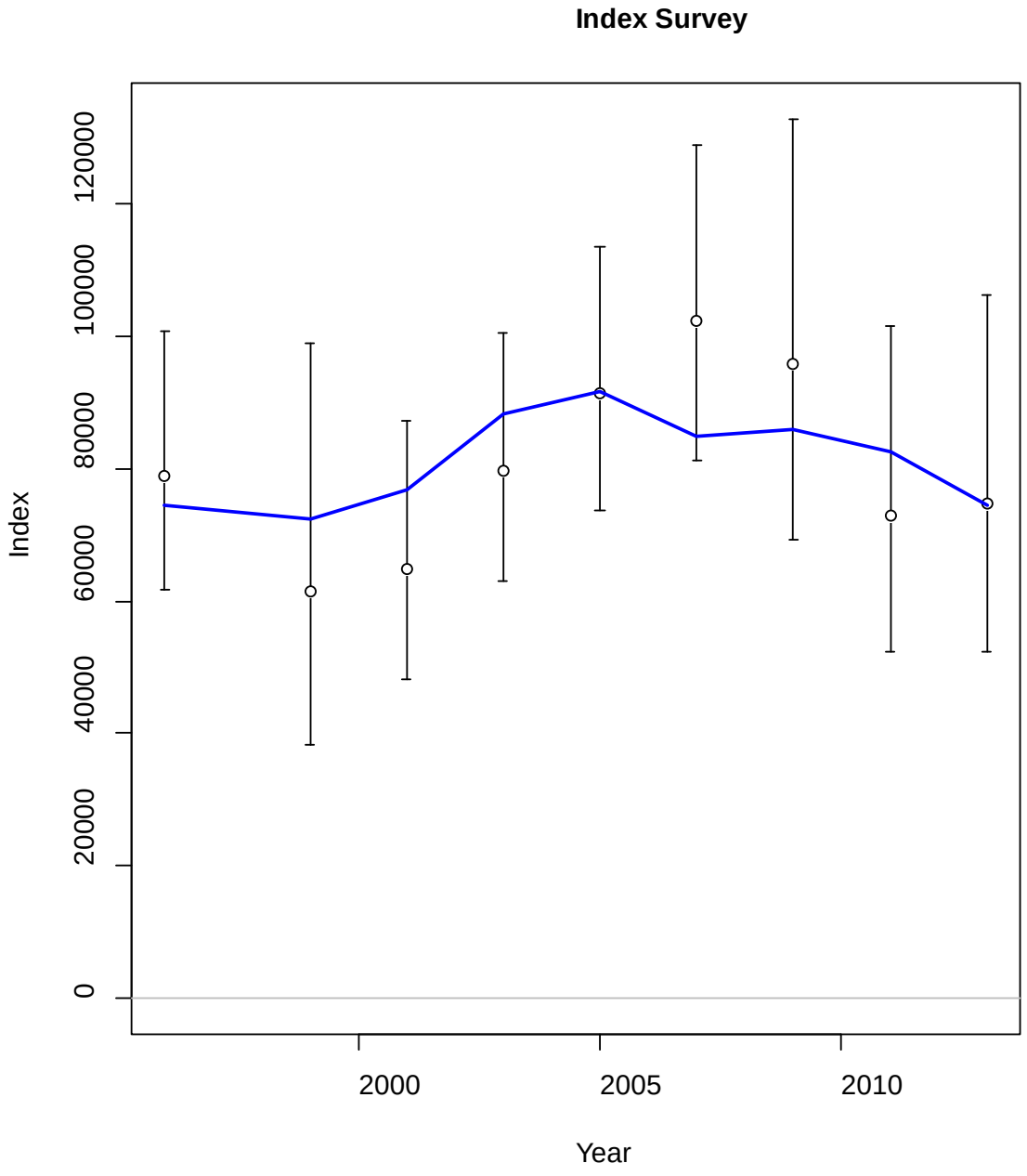


Figure 4.1.26 – Female fishery selectivity-at-length for N model configuration with survey selectivity-at-age

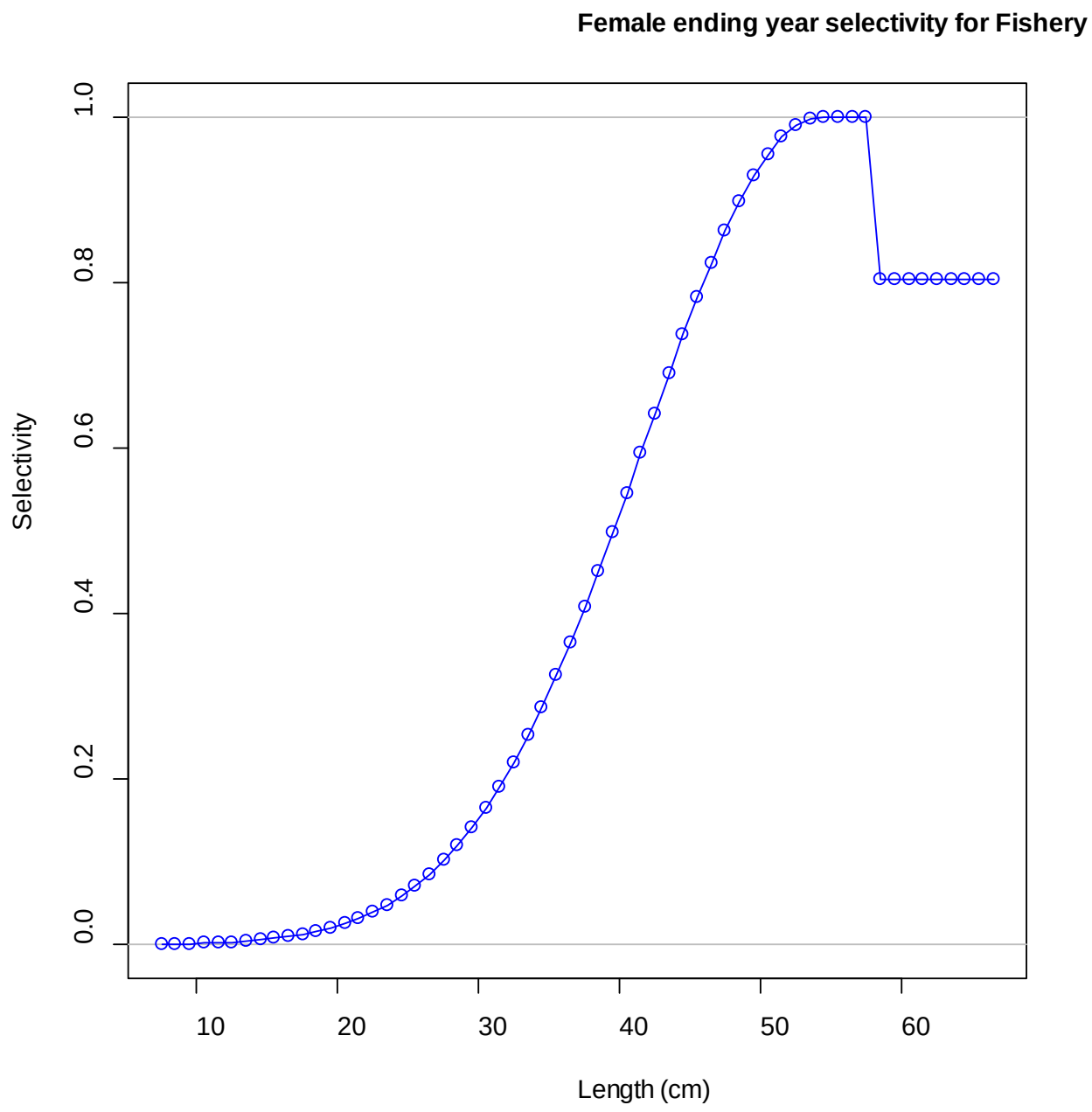


Figure 4.1.27 – Male fishery selectivity-at-length for N model configuration with survey selectivity-at-age

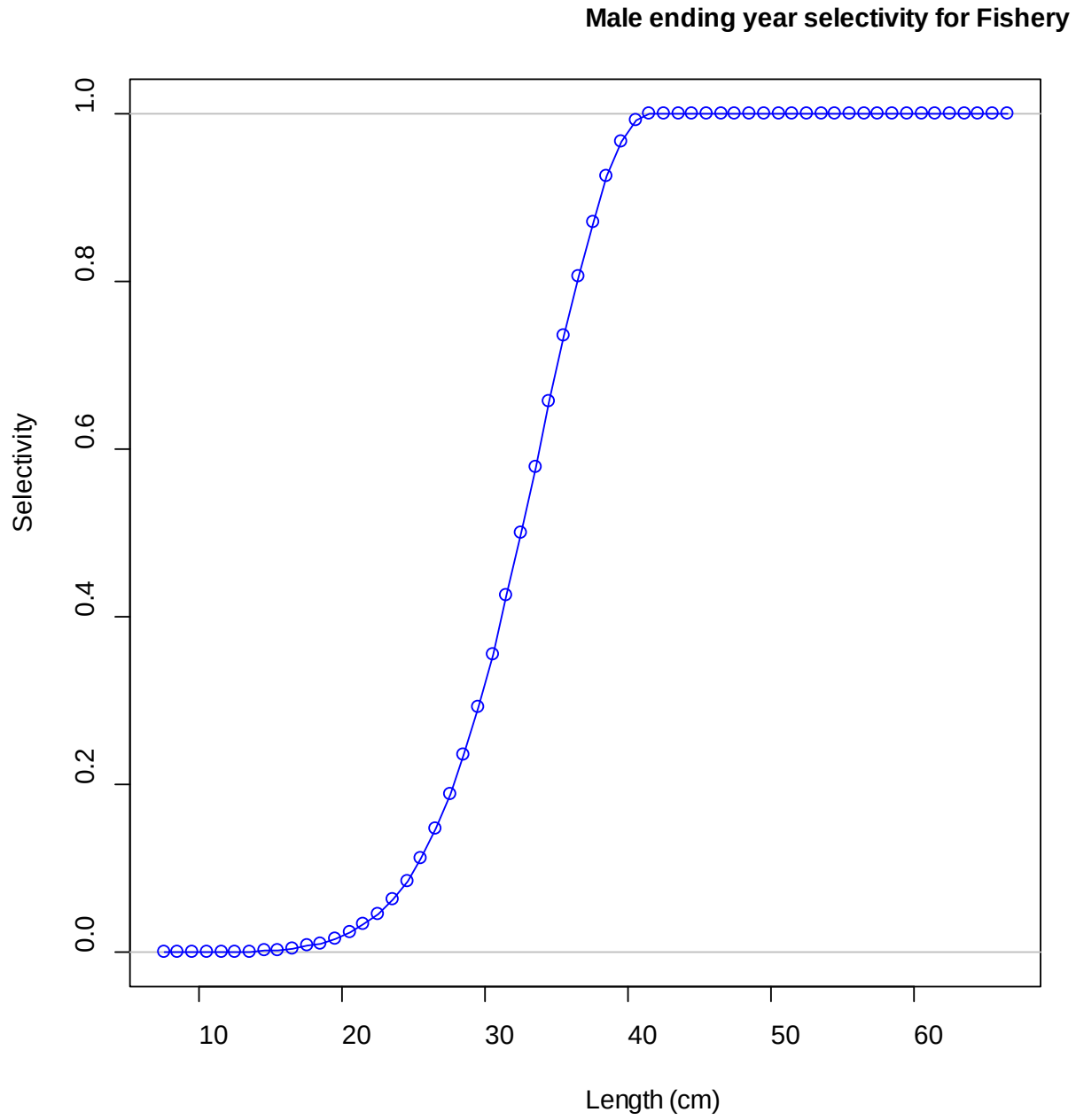


Figure 4.1.28 – Female survey selectivity-at-age for N model configuration with survey selectivity-at-age

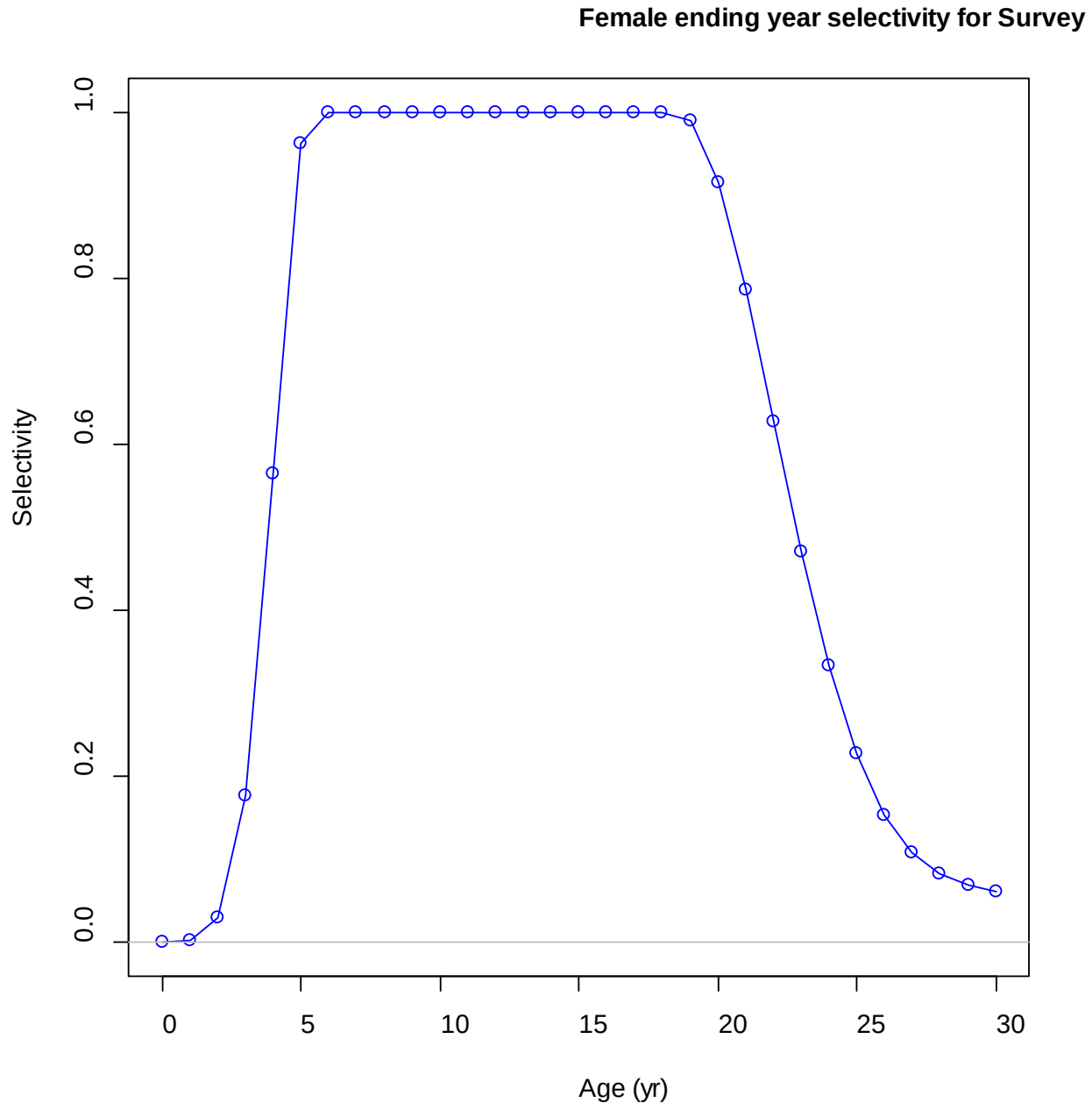


Figure 4.1.29 – Male survey selectivity-at-age for N model configuration with survey selectivity-at-age

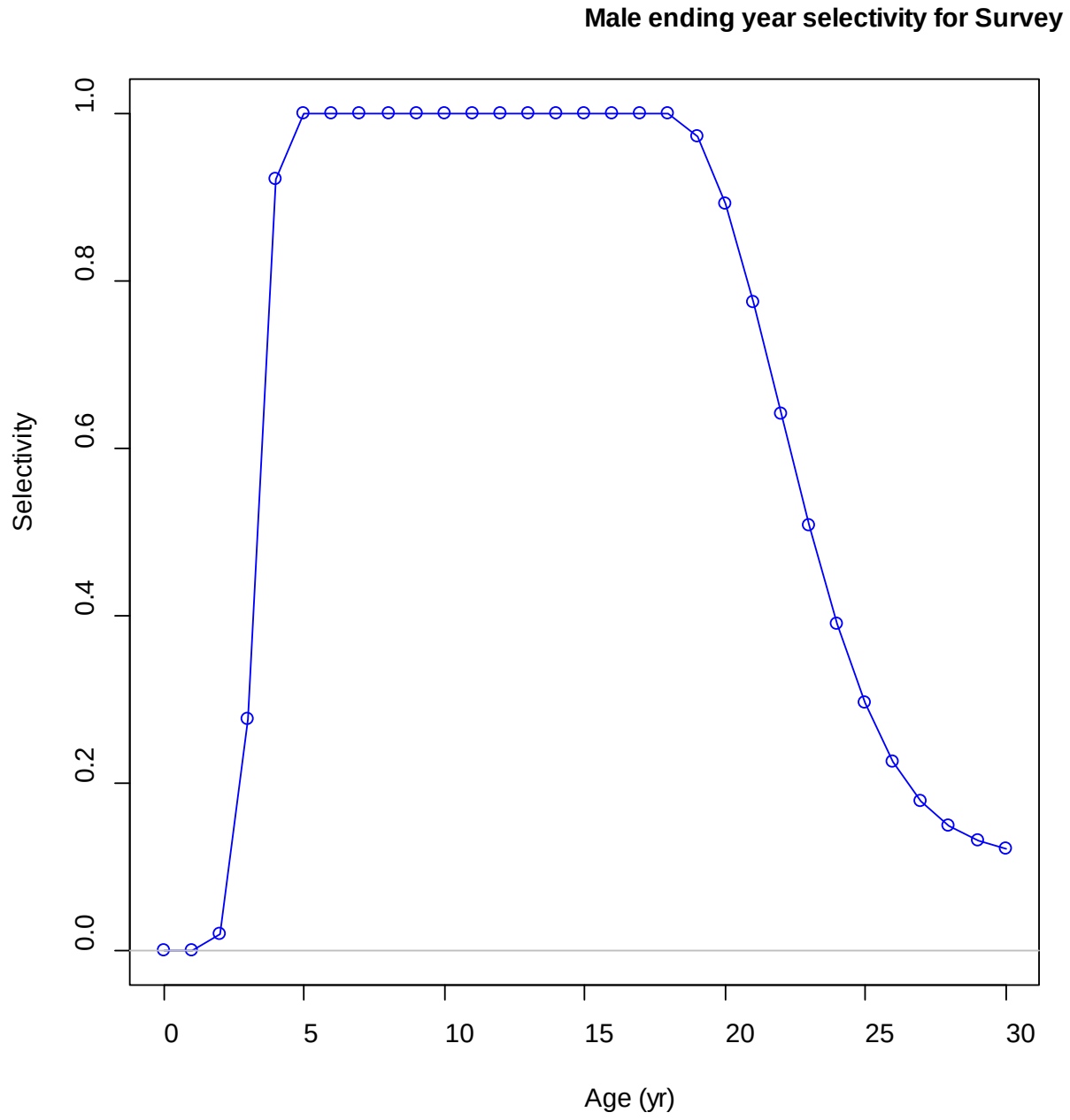


Figure 4.1.30 – Derived female and male fishery selectivity-at-age for N model configuration with survey selectivity-at-age

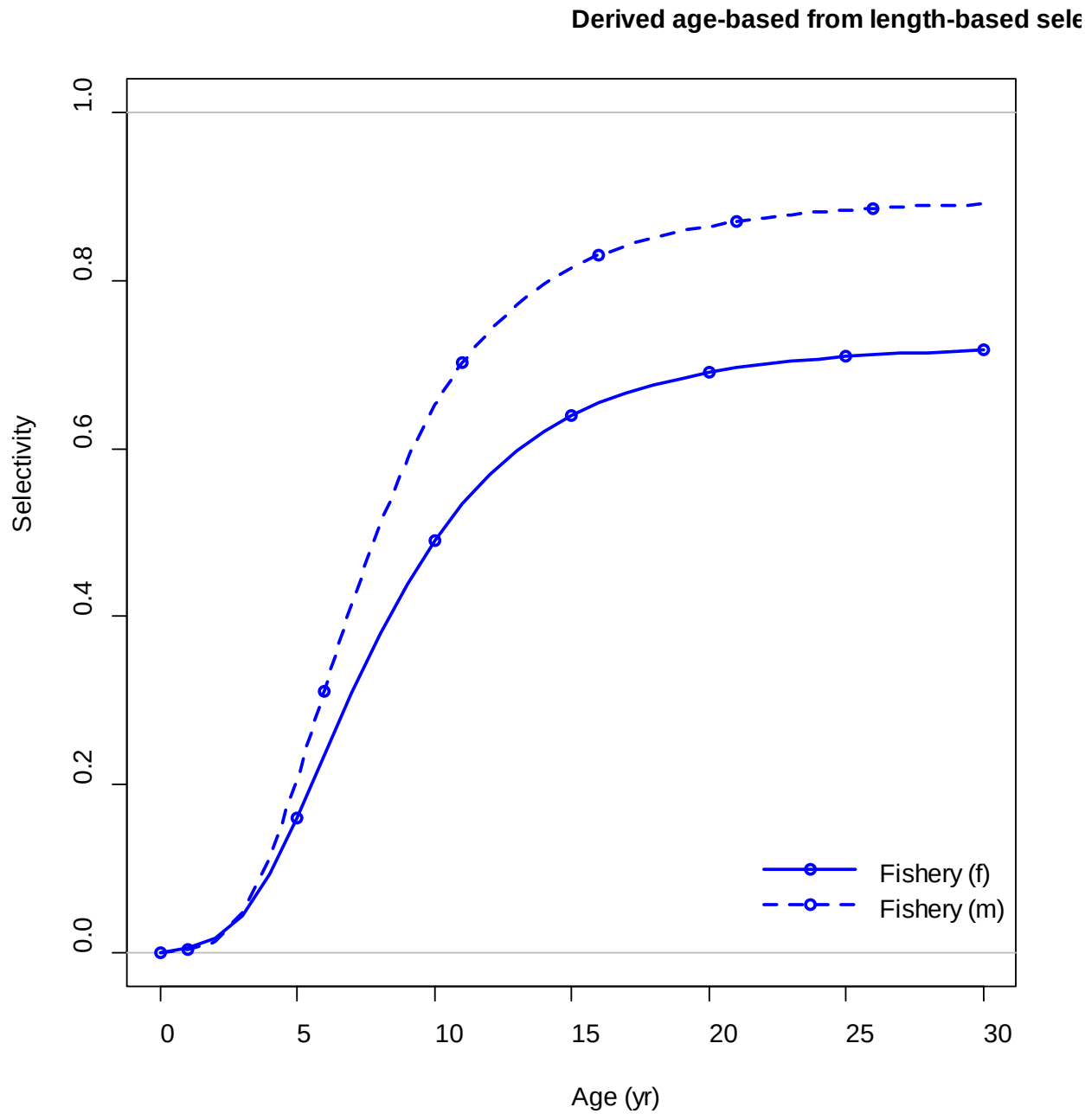


Figure 4.1.31 – Female fishery length compositions for N model configuration with survey selectivity-at-age

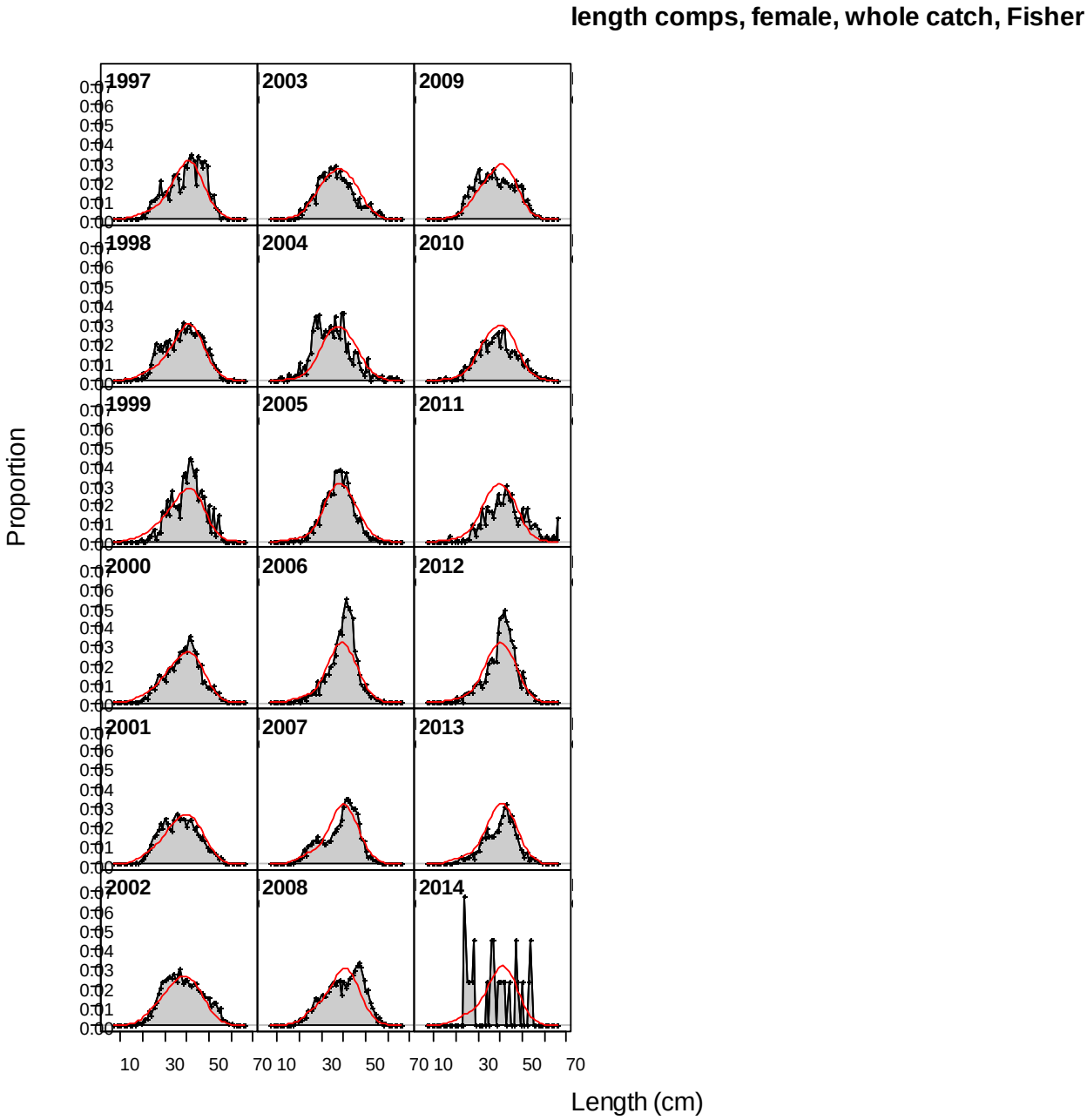


Figure 4.1.32 – Male fishery length compositions for N model configuration with survey selectivity-at-age

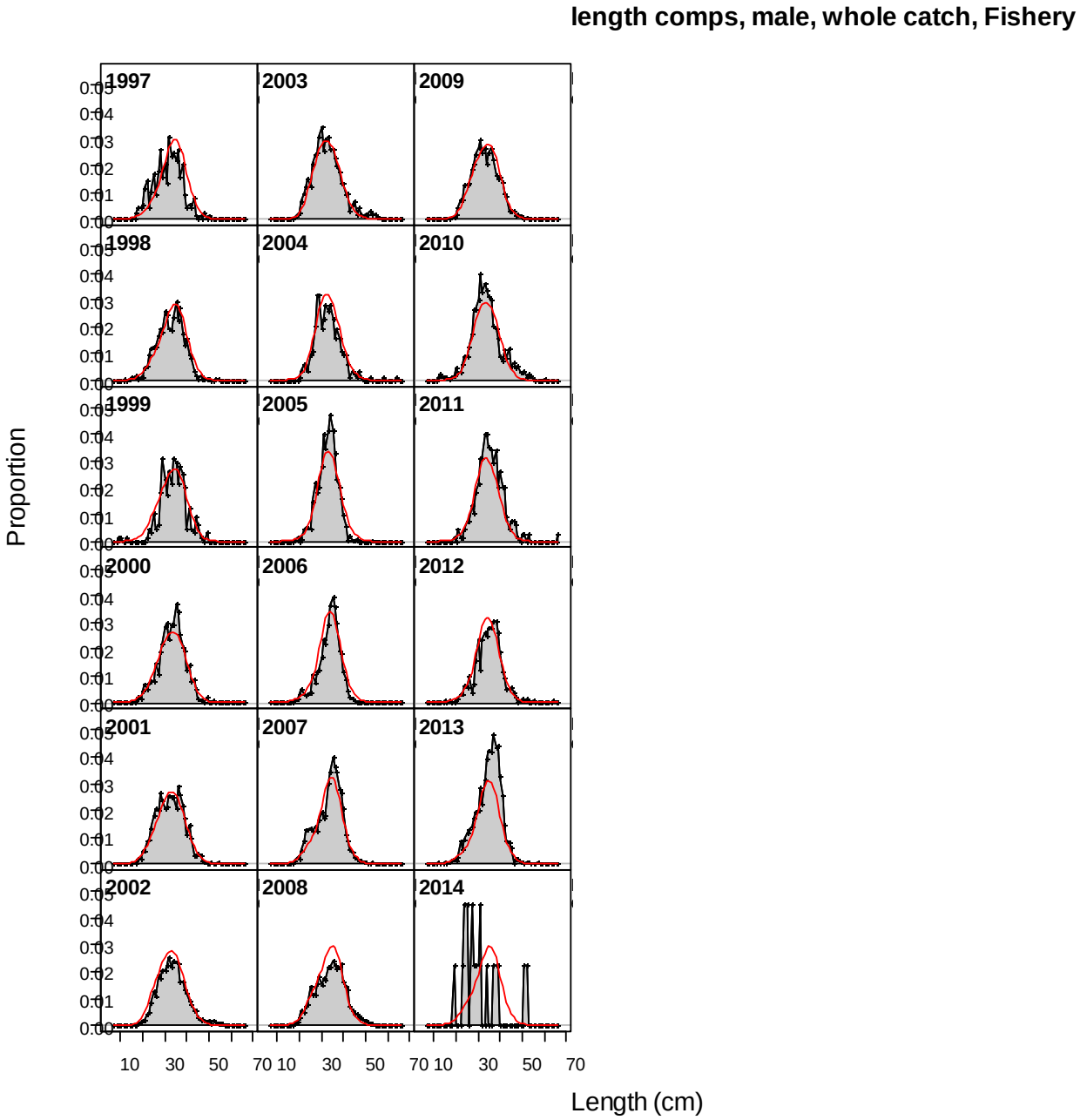


Figure 4.1.33 – Female survey length composition for N model configuration with survey selectivity-at-age

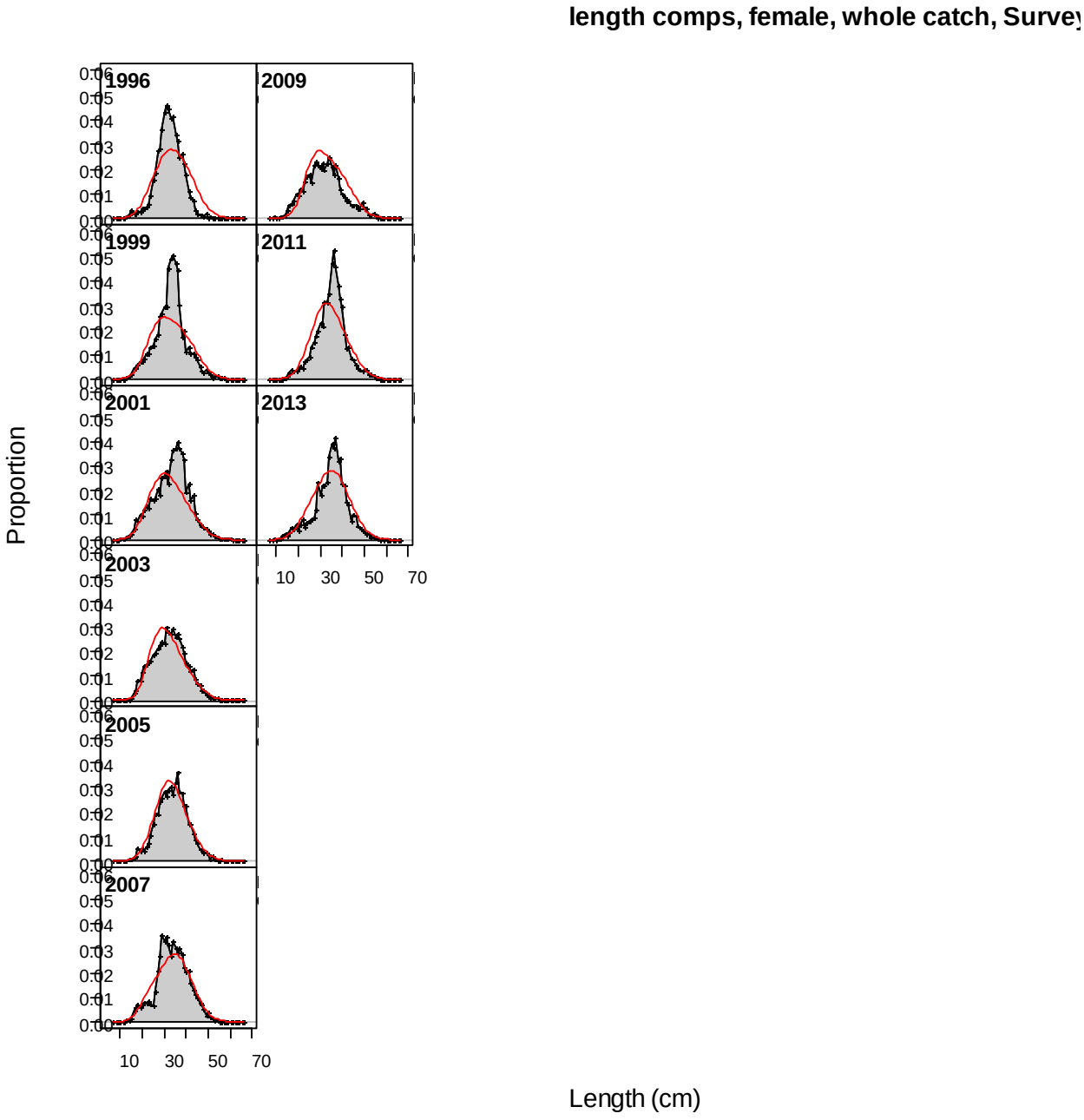


Figure 4.1.34 – Male survey length composition for N model configuration with survey selectivity-at-age

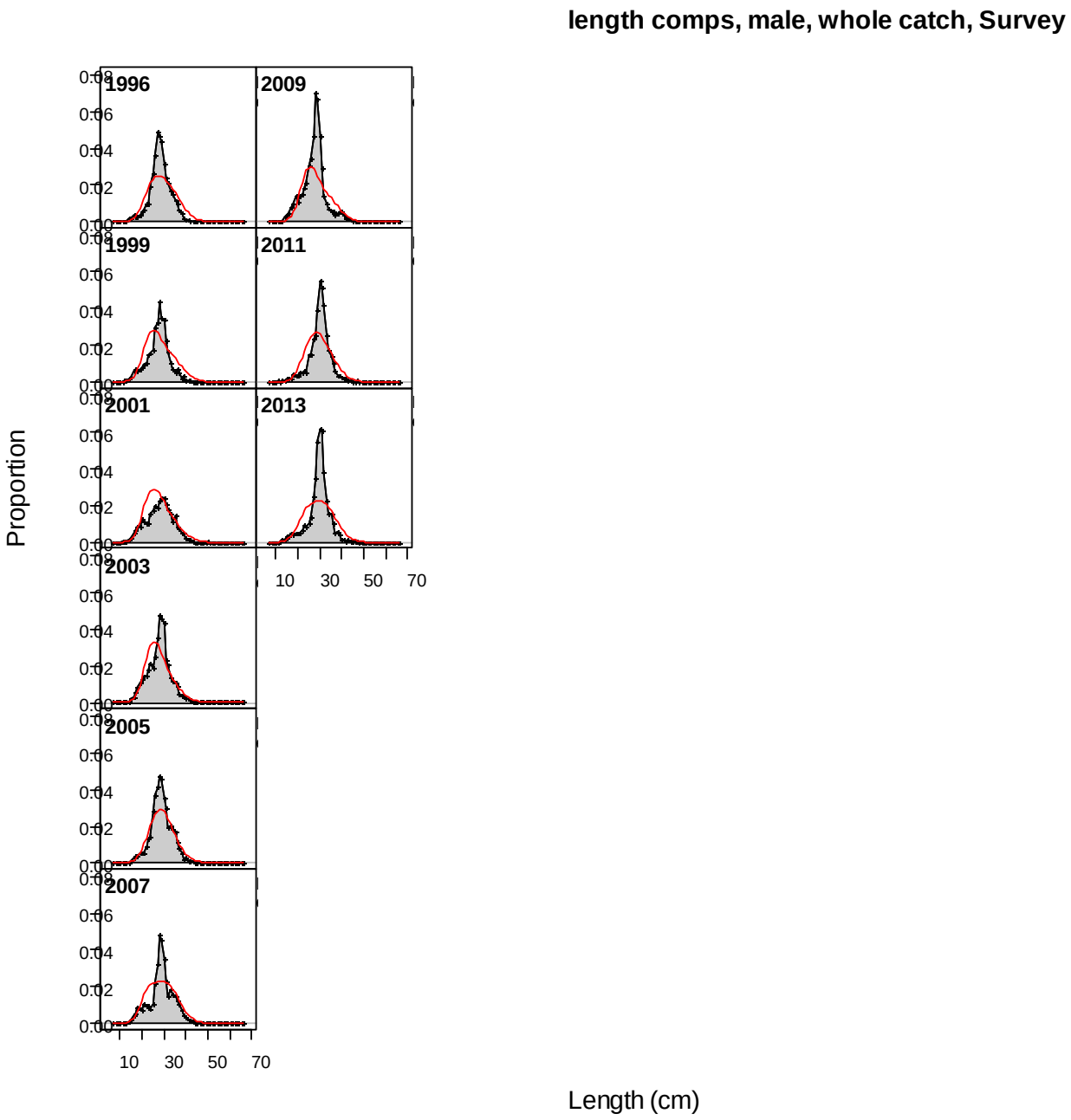


Figure 4.1.35 – Summary female fishery and survey length composition for N model configuration with survey selectivity-at-age

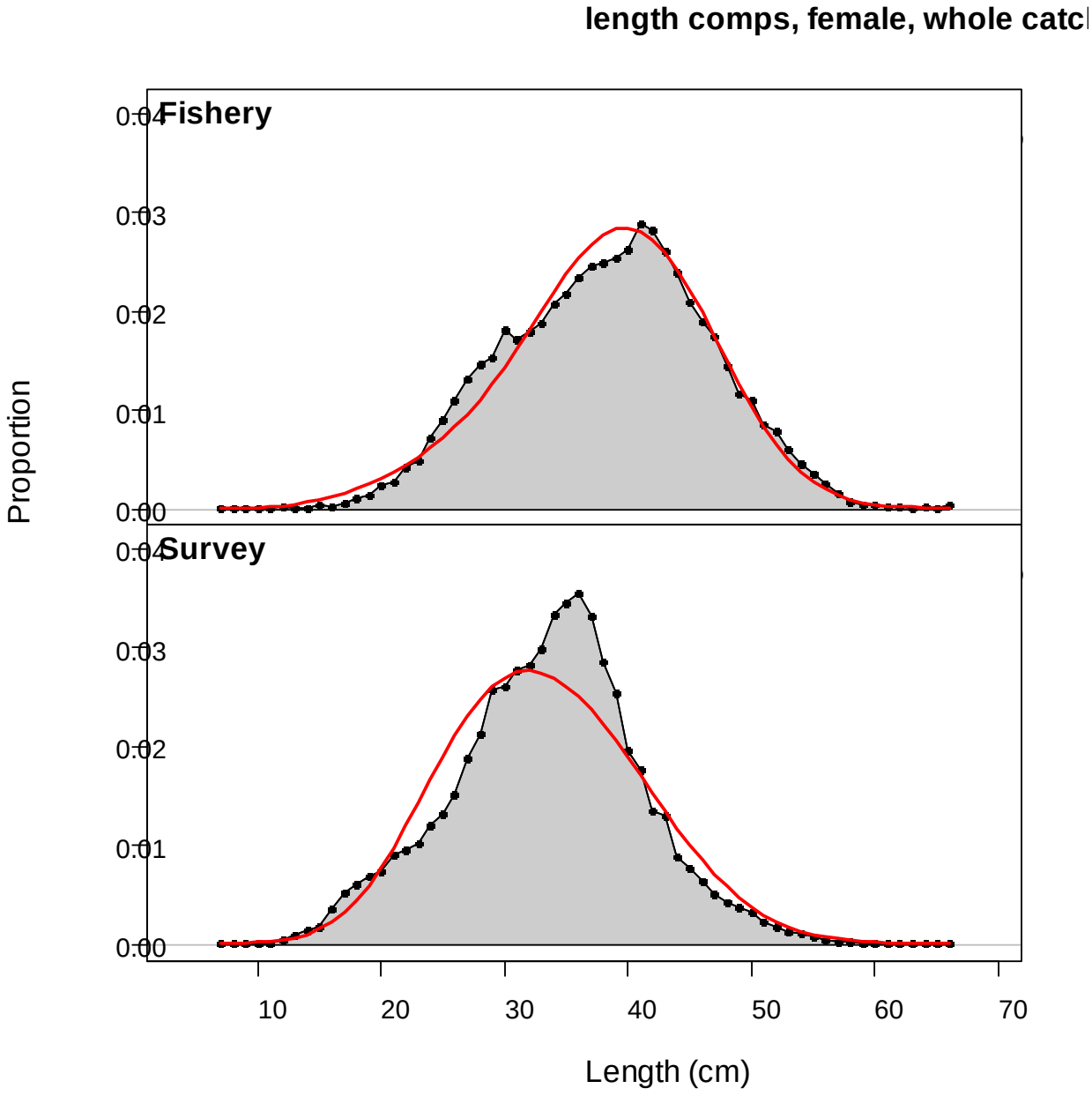


Figure 4.1.36 – Summary male fishery and survey length composition for N model configuration with survey selectivity-at-age

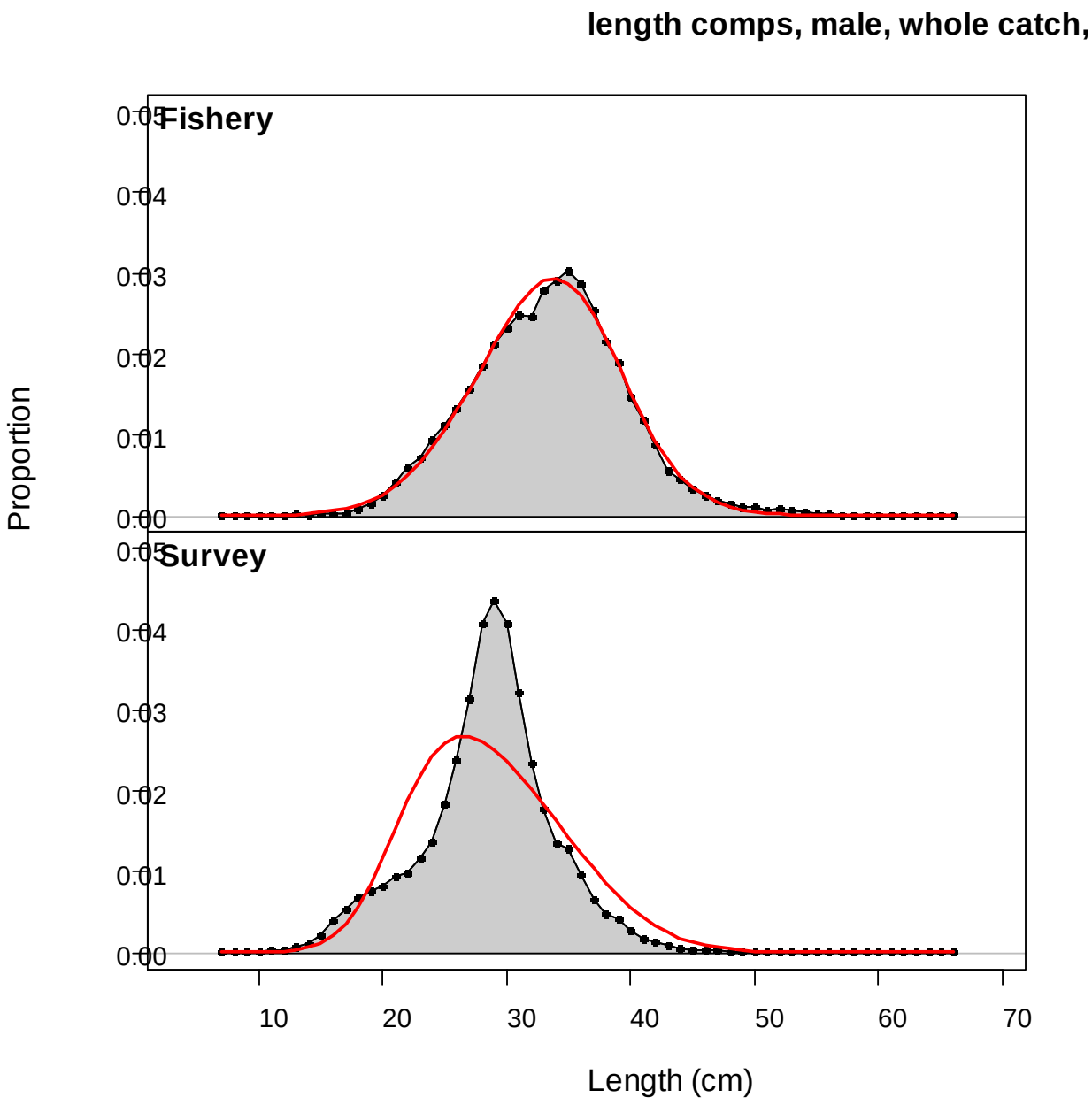
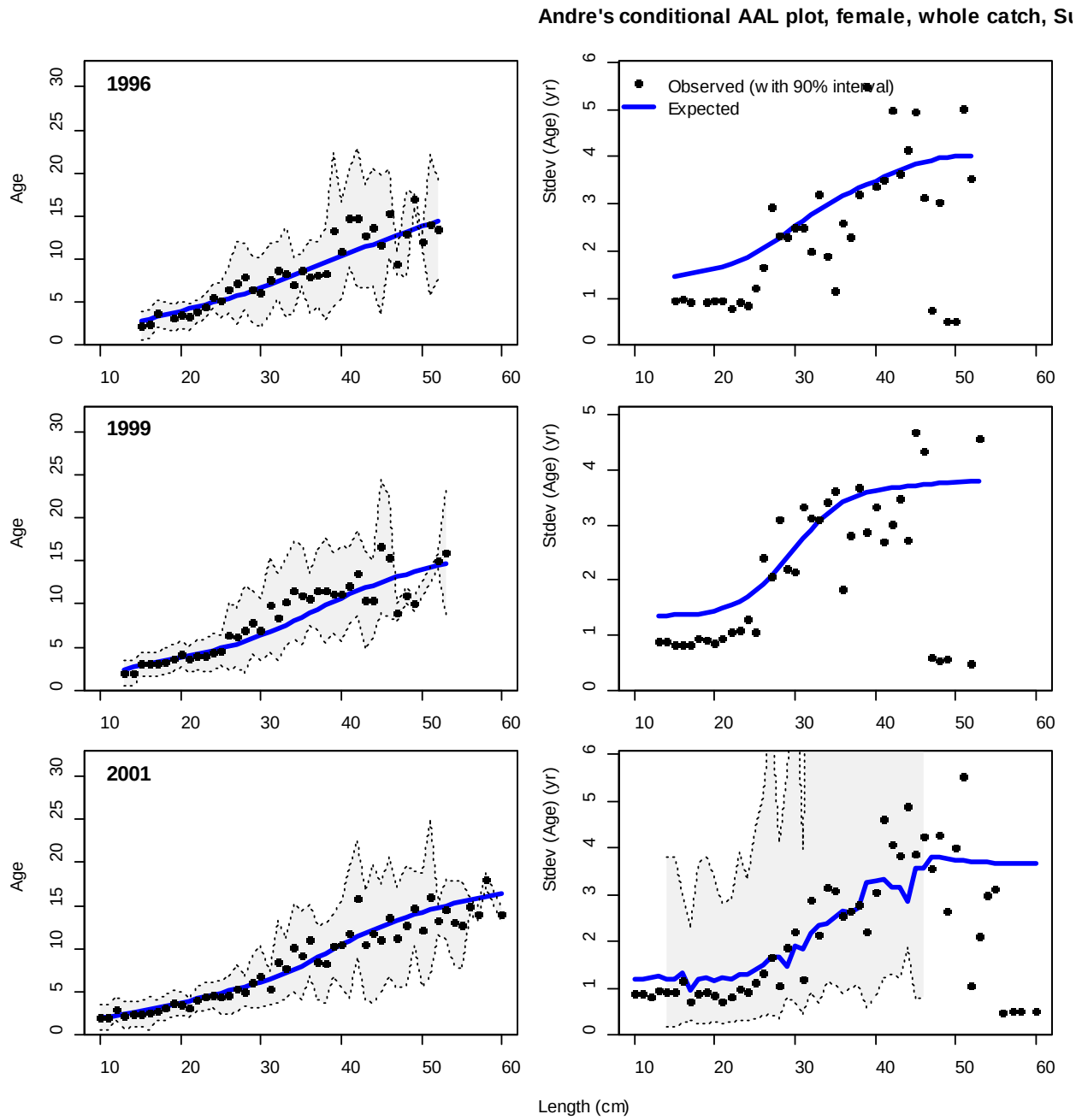
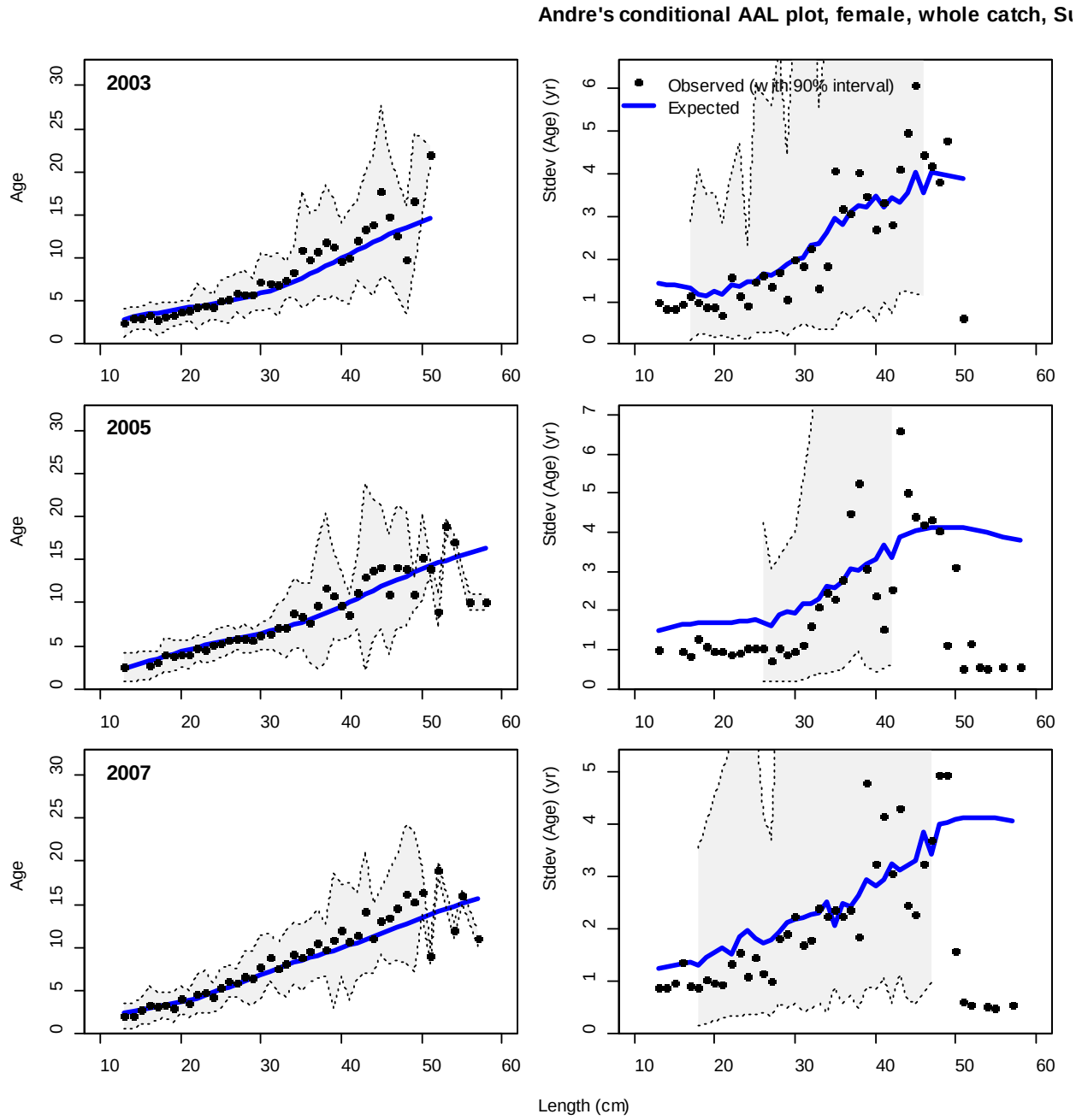


Figure 4.1.37 – Female survey conditional age-at-length for N model configuration with survey selectivity-at-age




Andre's conditional AAL plot, female, whole catch, Su
2003
2005
2007
Age
Stdev (Age) (yr)
Observed (with 90% interval)
Expected
Length (cm)

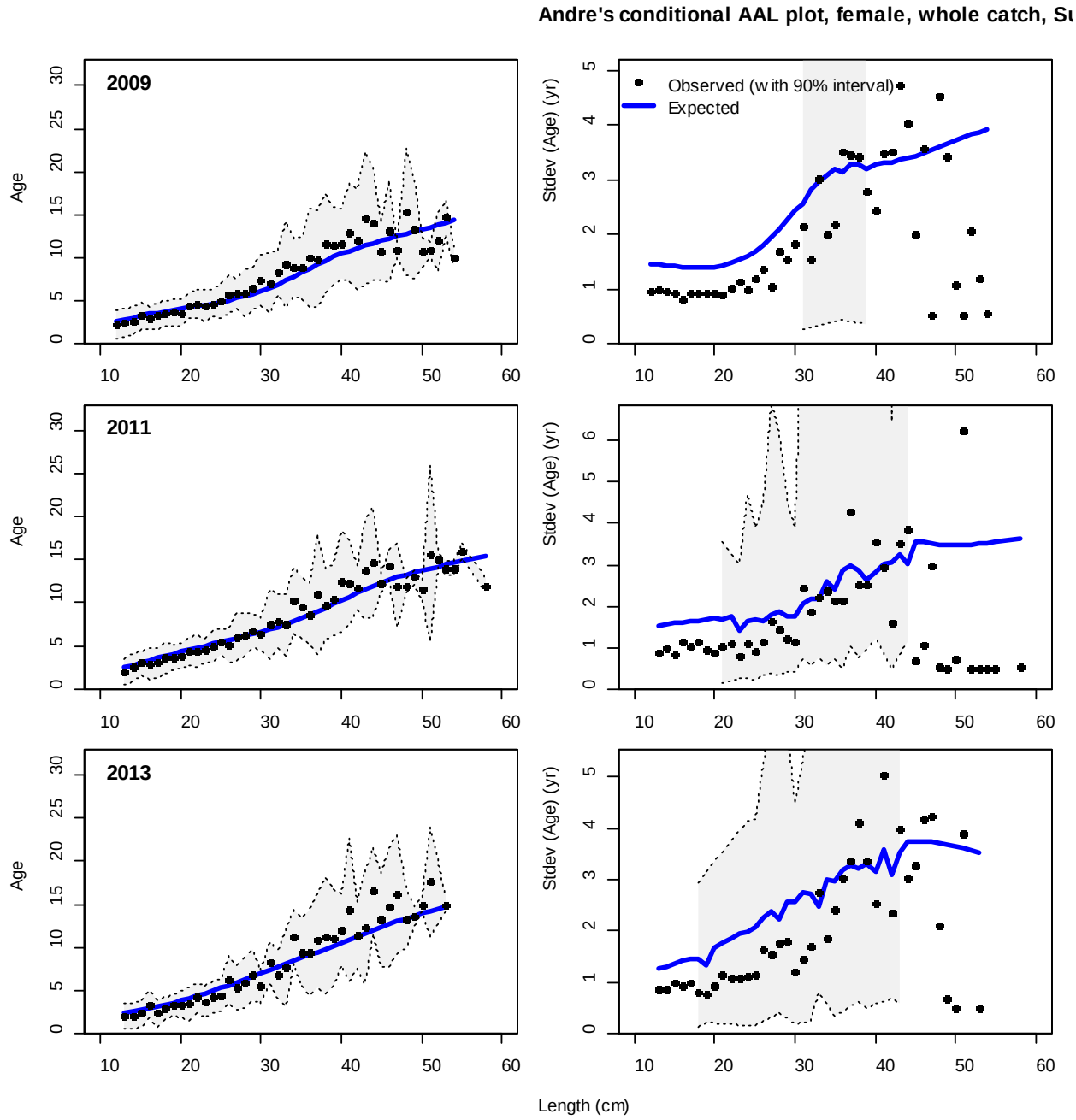
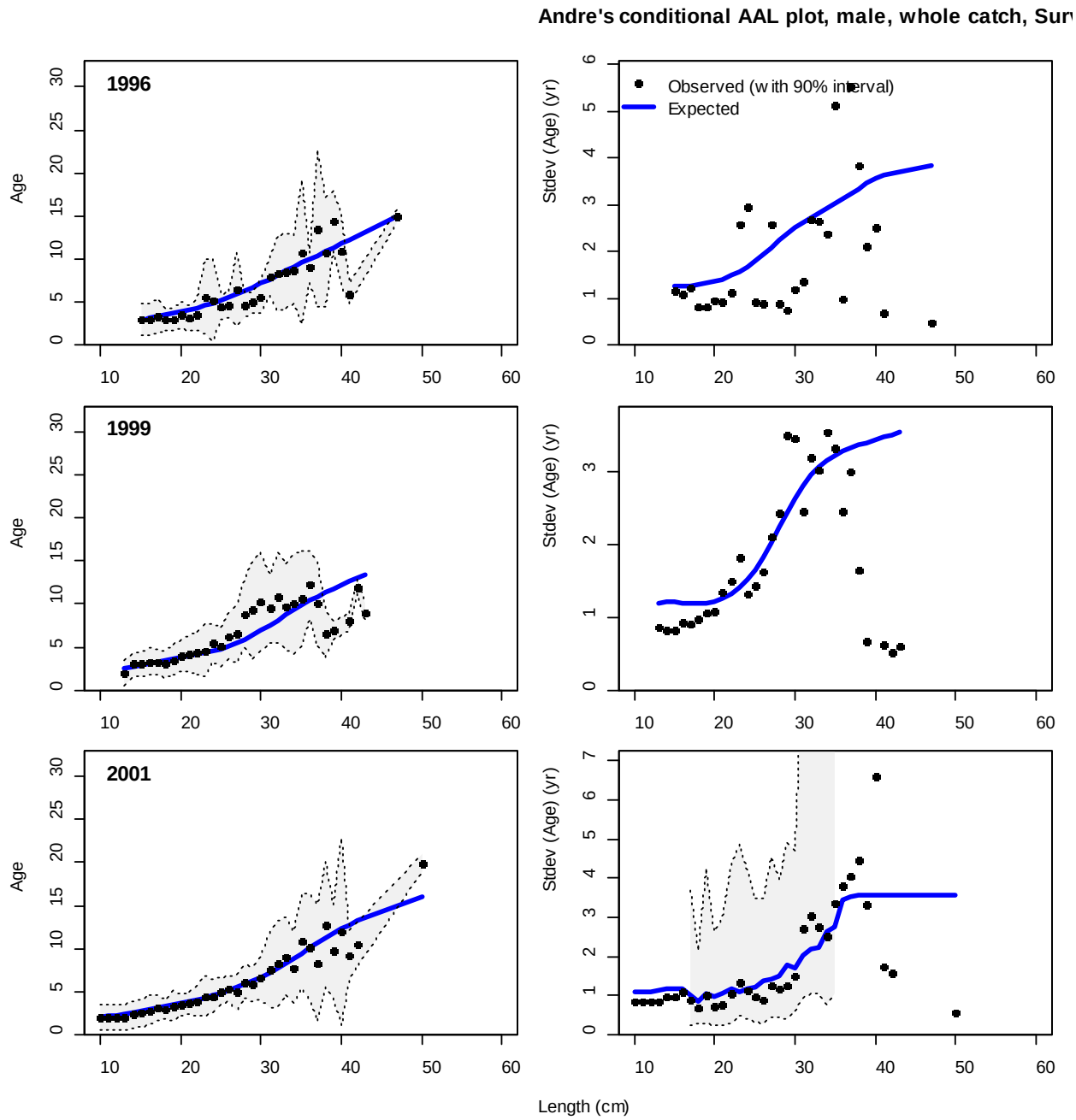
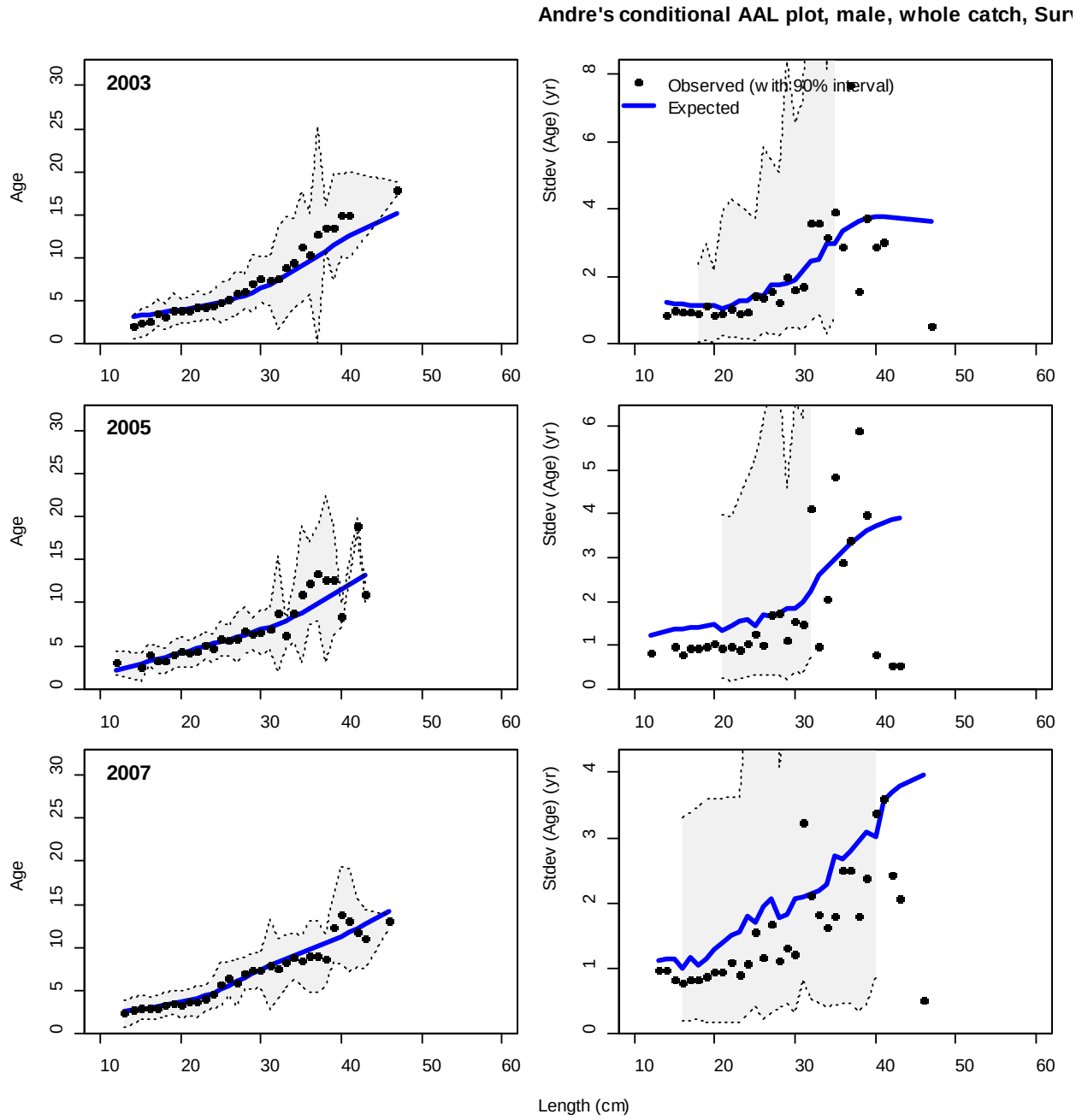

Andre's conditional AAL plot, female, whole catch, Su
2009
2011
2013
Age
Stdev (Age) (yr)
Observed (with 90% interval)
Expected
Length (cm)

Figure 4.1.38 – Male survey conditional age-at-length for N model configuration with survey selectivity-at-age




Andre's conditional AAL plot, male, whole catch, Sur
2003
2005
2007
Age
Stdev (Age) (yr)
Observed (with 90% interval)
Expected
Length (cm)

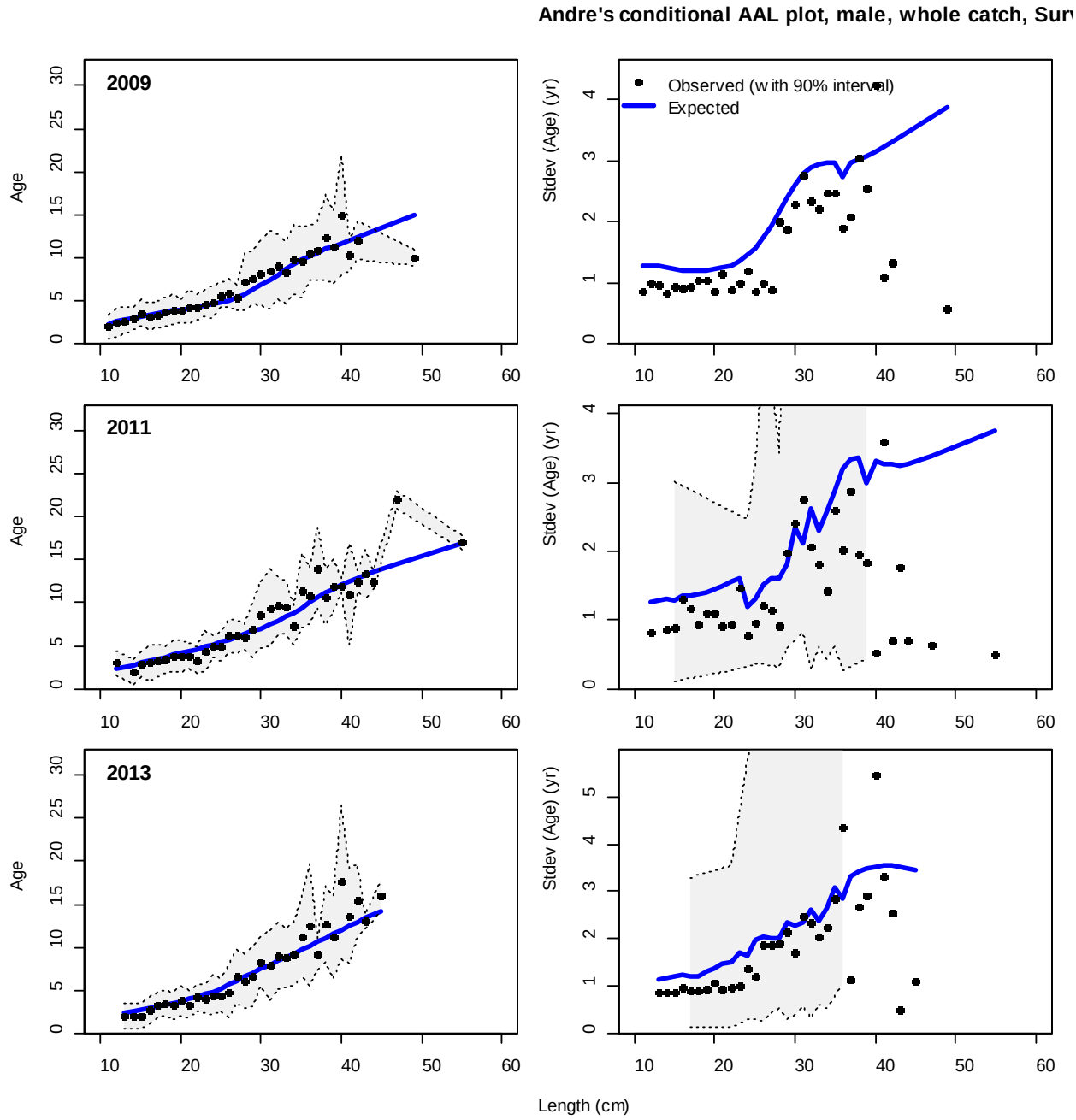

Andre's conditional AAL plot, male, whole catch, Sur
2009
2011
2013
Age
Stdev (Age) (yr)
Observed (with 90% interval)
Expected
Length (cm)

Figure 4.1.39 – Spawning biomass for S model configuration with survey selectivity-at-age

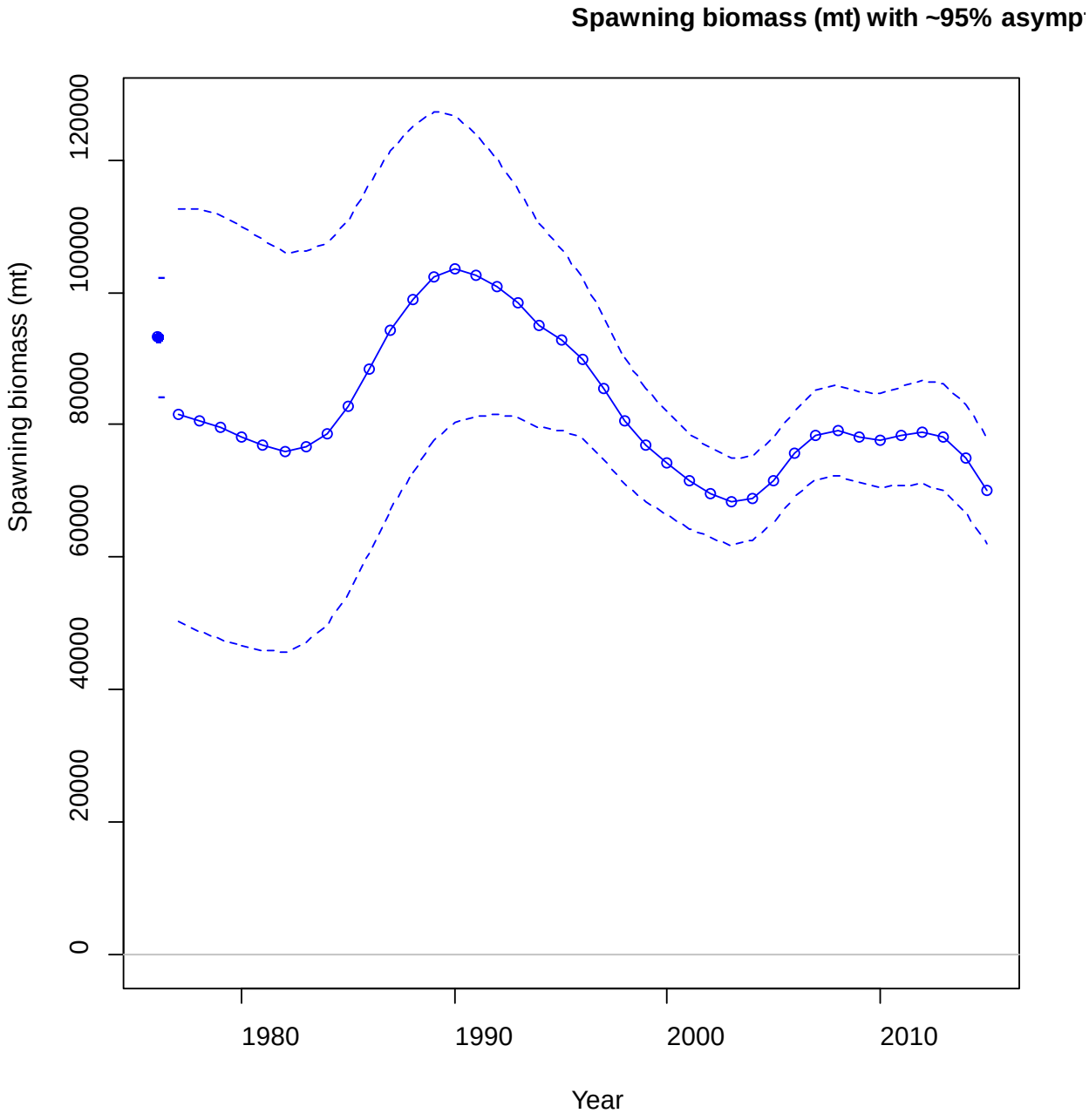


Figure 4.1.40 – Length-at-age for S model configuration with survey selectivity-at-age

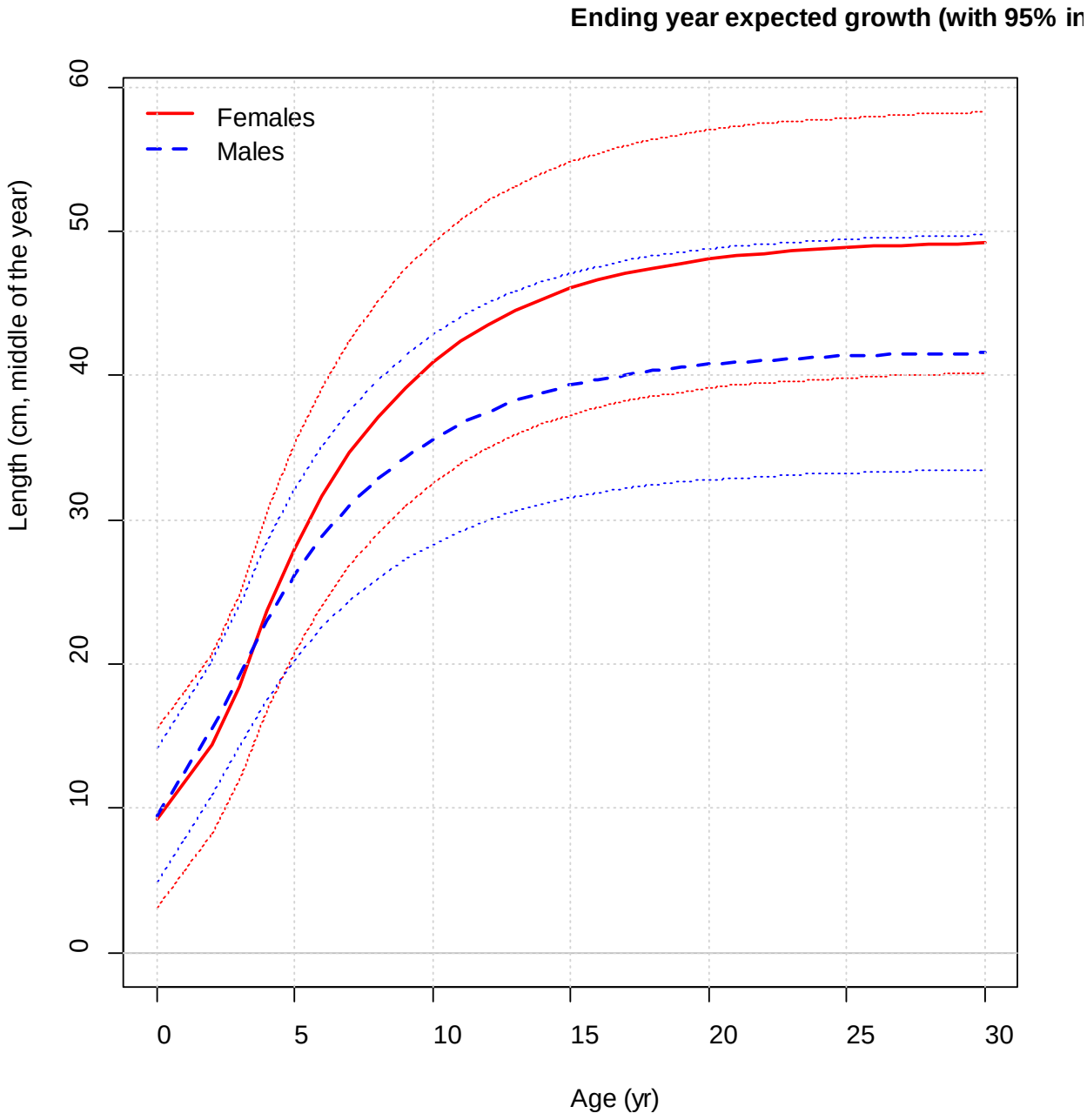


Figure 4.1.41 – Age-0 recruits for S model configuration with survey selectivity-at-age

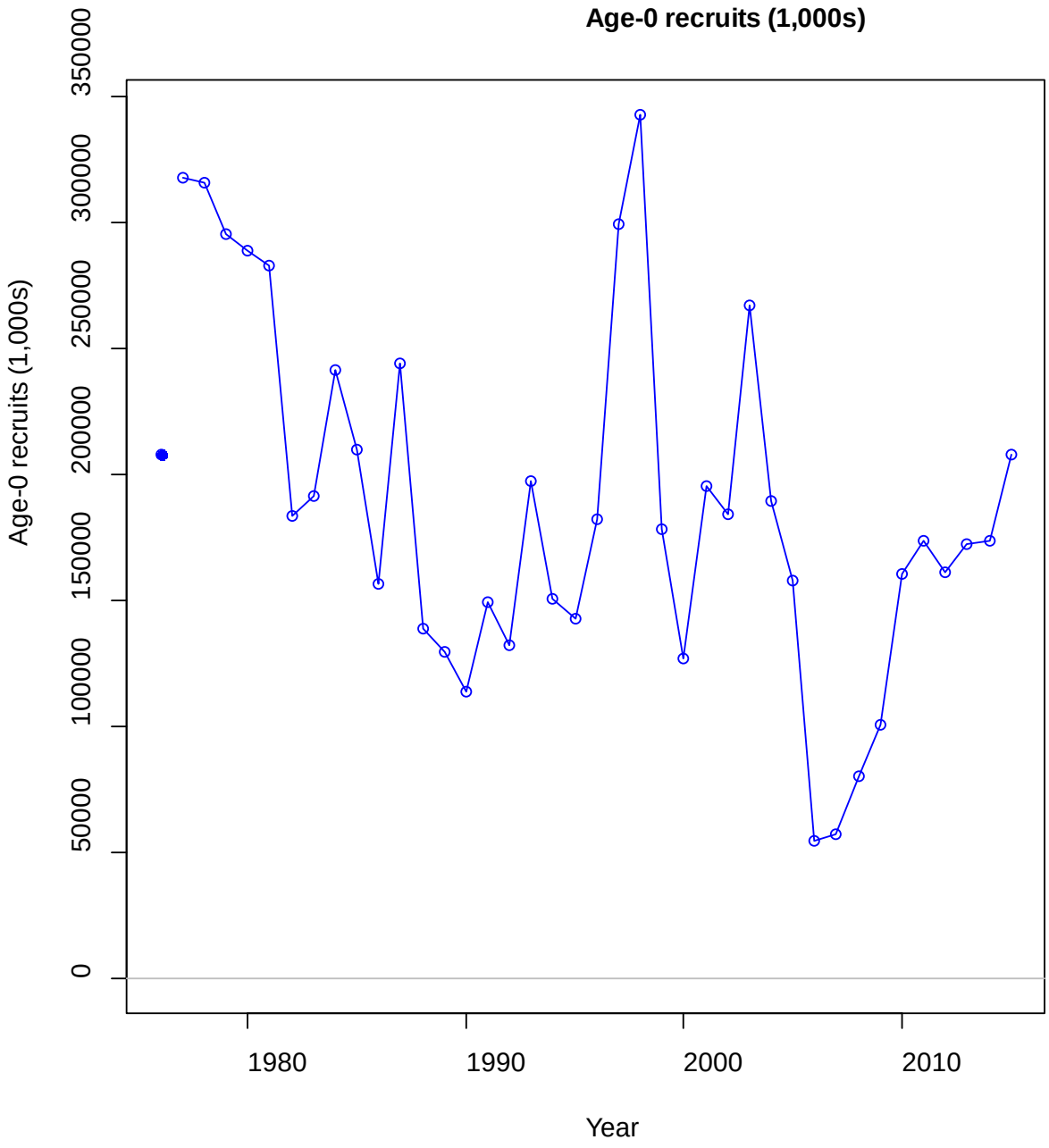


Figure 4.1.42 – Age-0 recruits with uncertainty intervals for S model configuration with survey selectivity-at-age

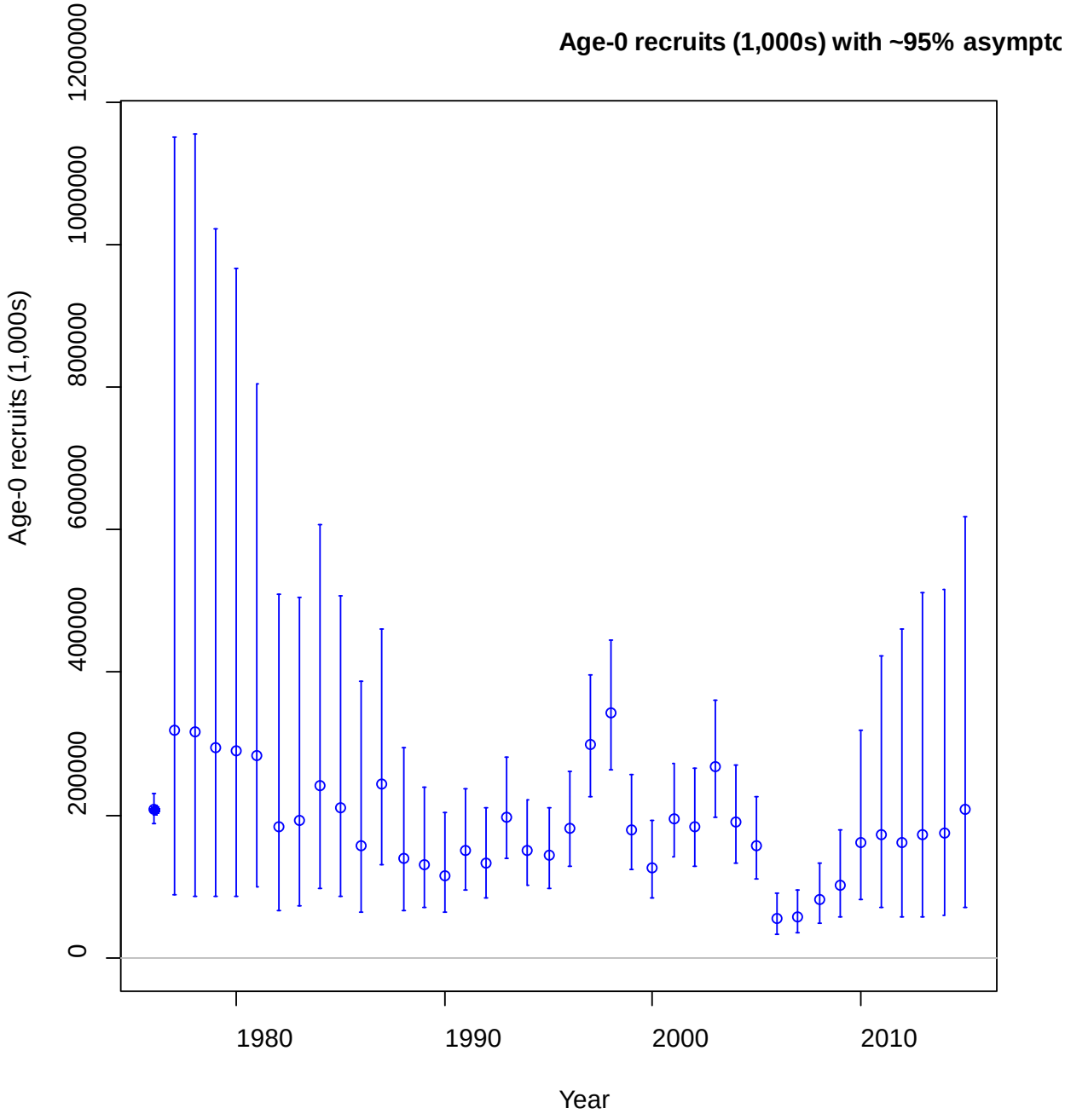


Figure 4.1.43 – Bottom trawl survey index for S model configuration with survey selectivity-at-age

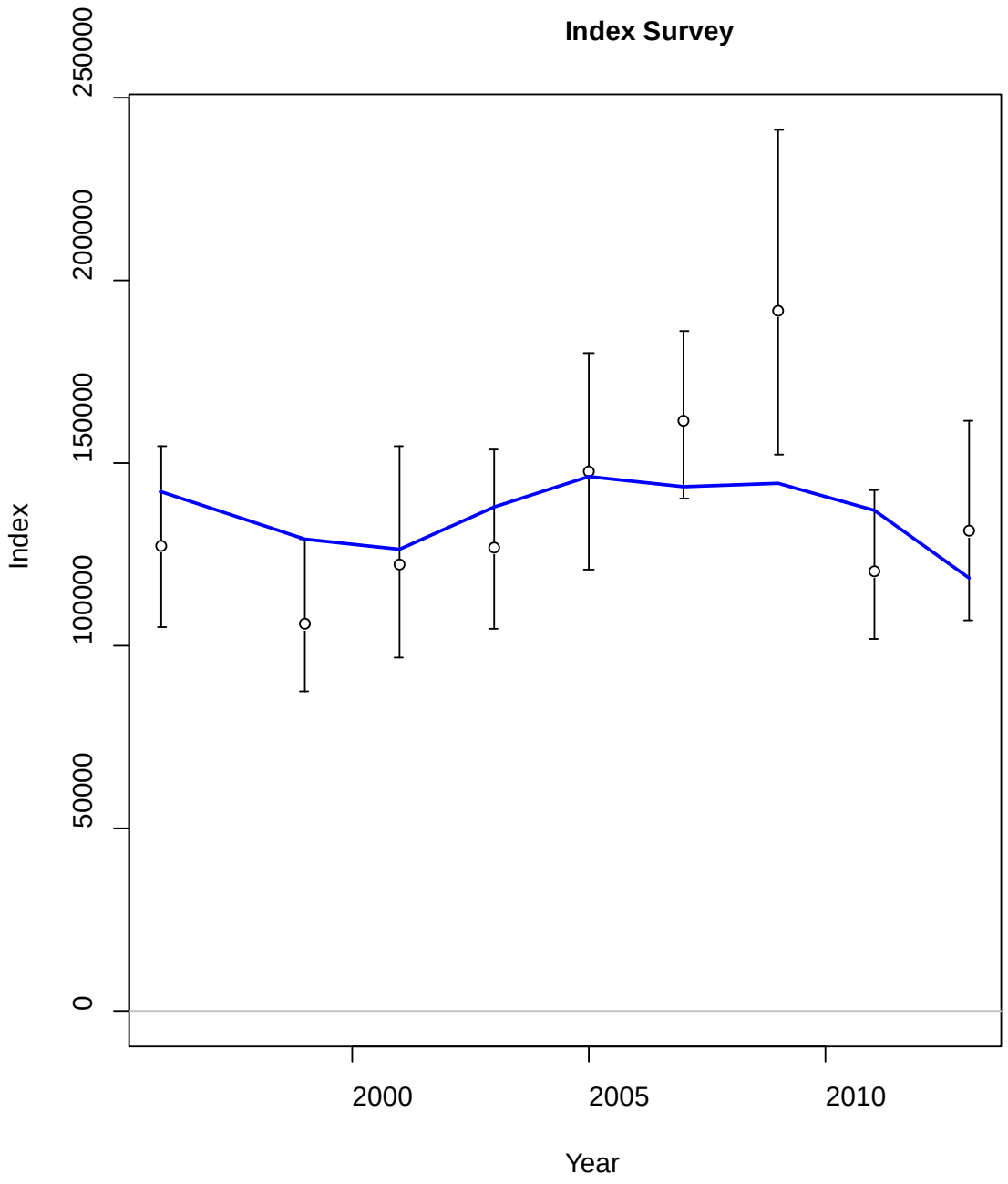


Figure 4.1.44 – Female fishery selectivity-at-length for S model configuration with survey selectivity-at-age

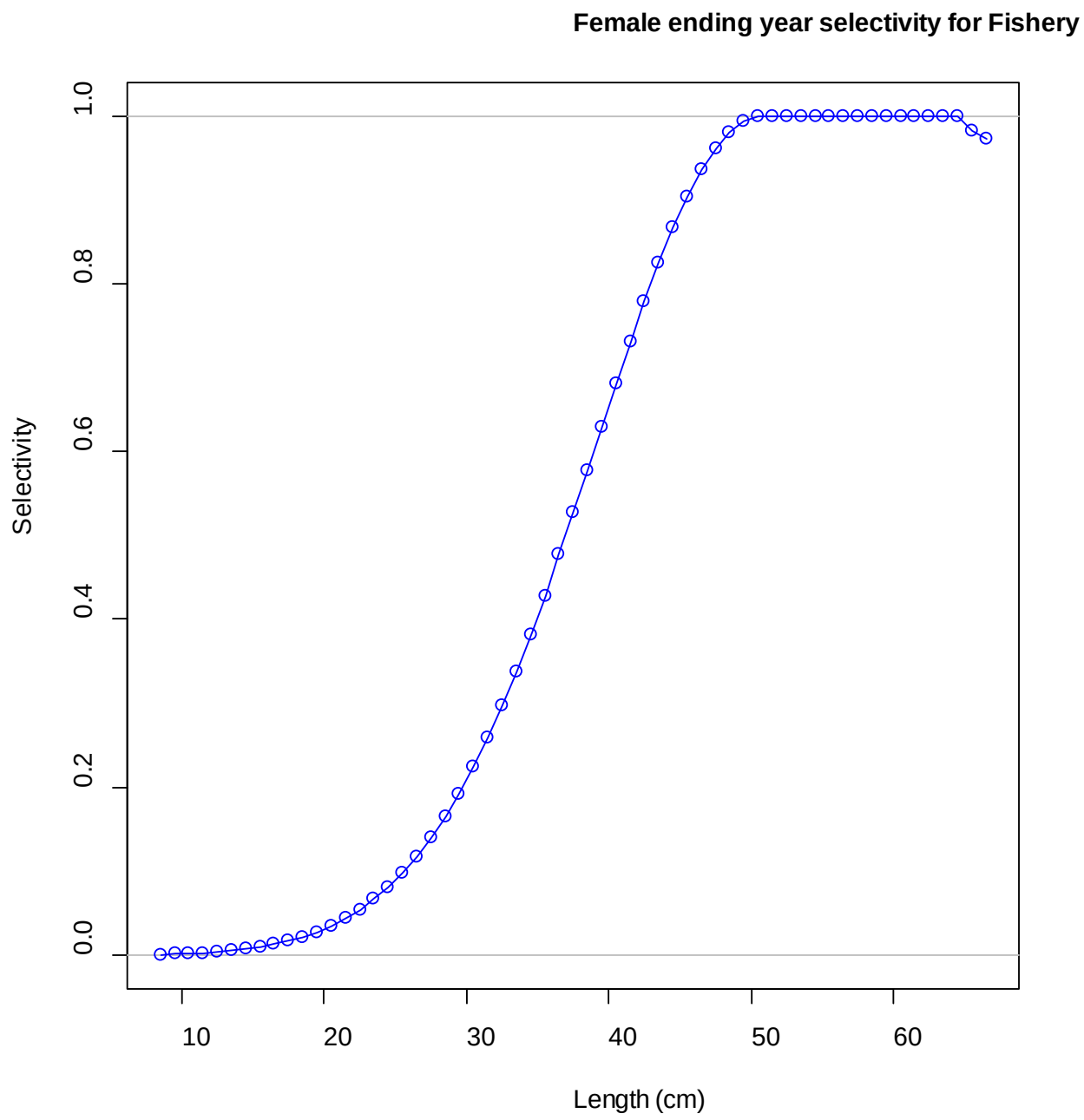


Figure 4.1.45 – Male fishery selectivity-at-length for S model configuration with survey selectivity-at-age

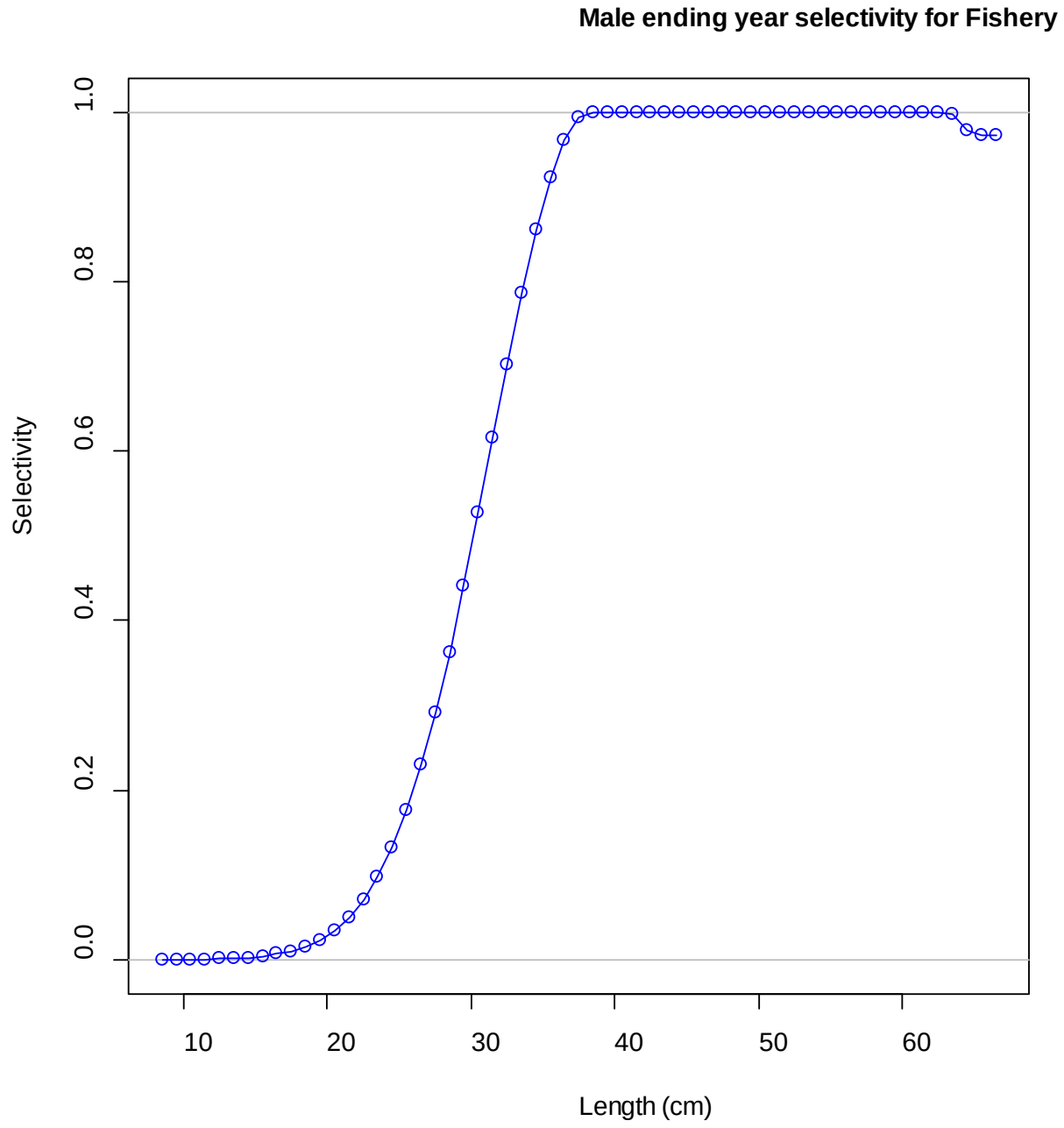


Figure 4.1.46 – Female survey selectivity-at-age for S model configuration with survey selectivity-at-age

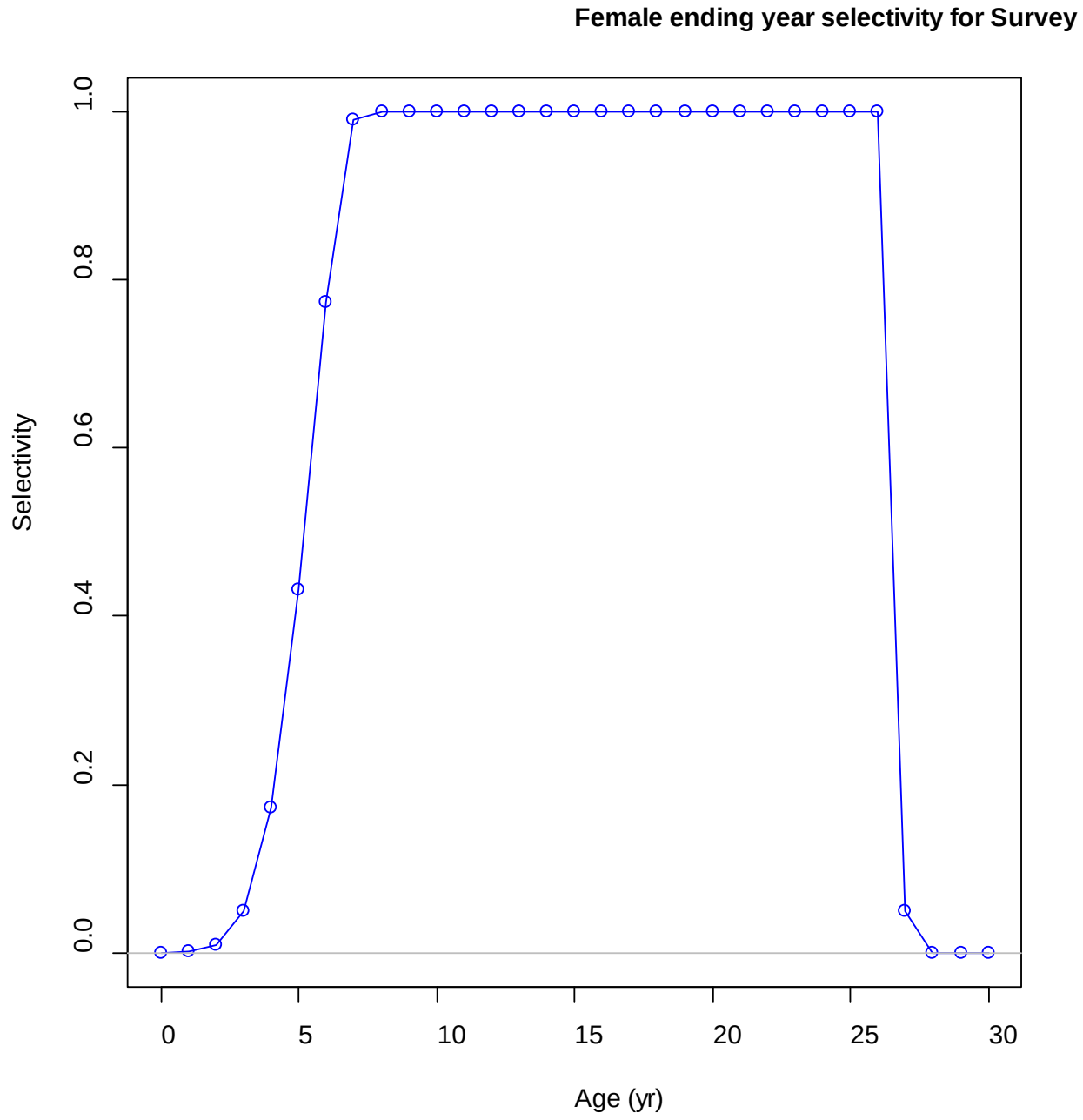


Figure 4.1.47 – Male survey selectivity-at-age for S model configuration with survey selectivity-at-age

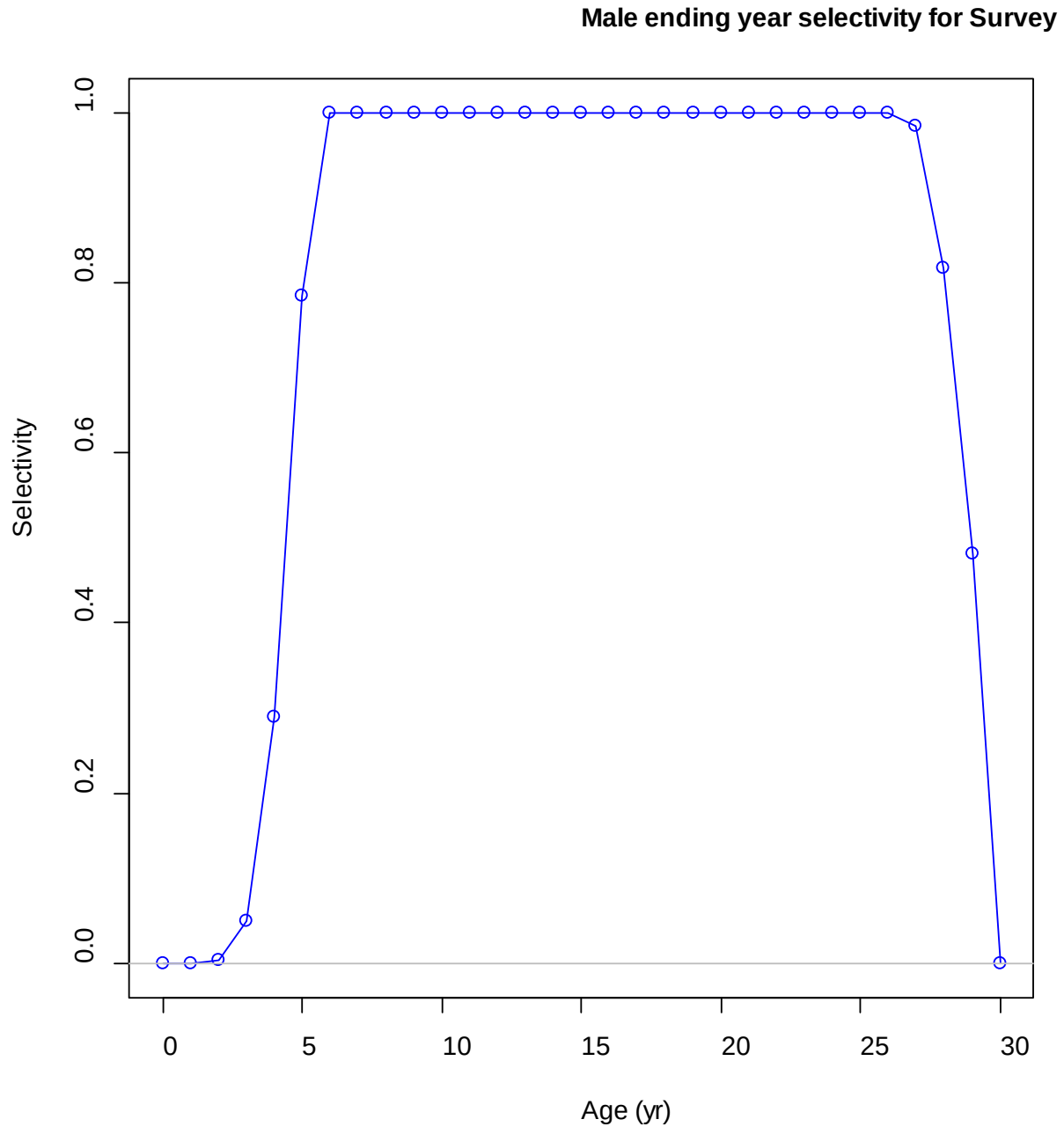


Figure 4.1.48 – Derived female and male fishery selectivity-at-age for S model configuration with survey selectivity-at-age

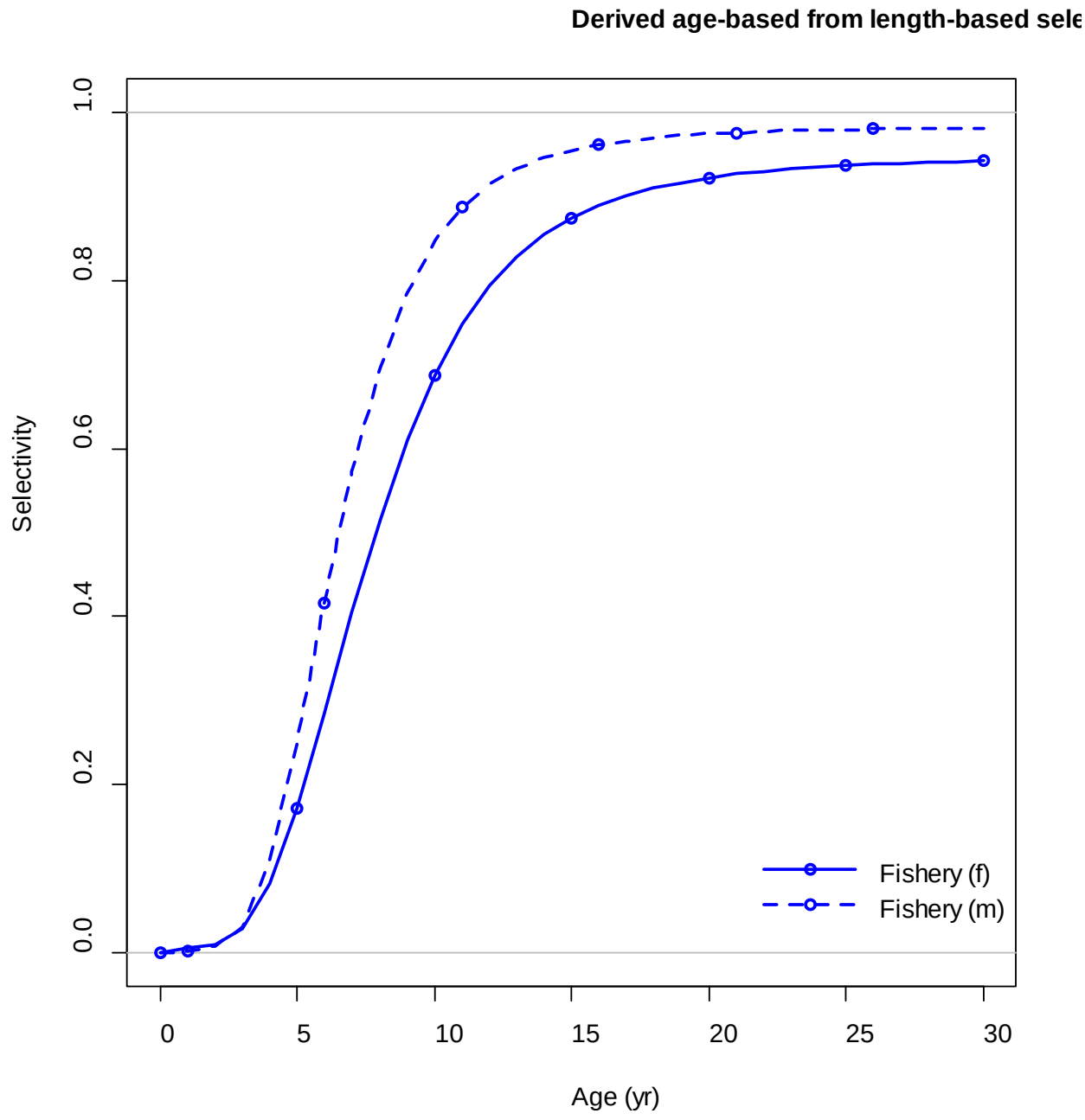


Figure 4.1.49 – Female fishery length composition for S model configuration with survey selectivity-at-age

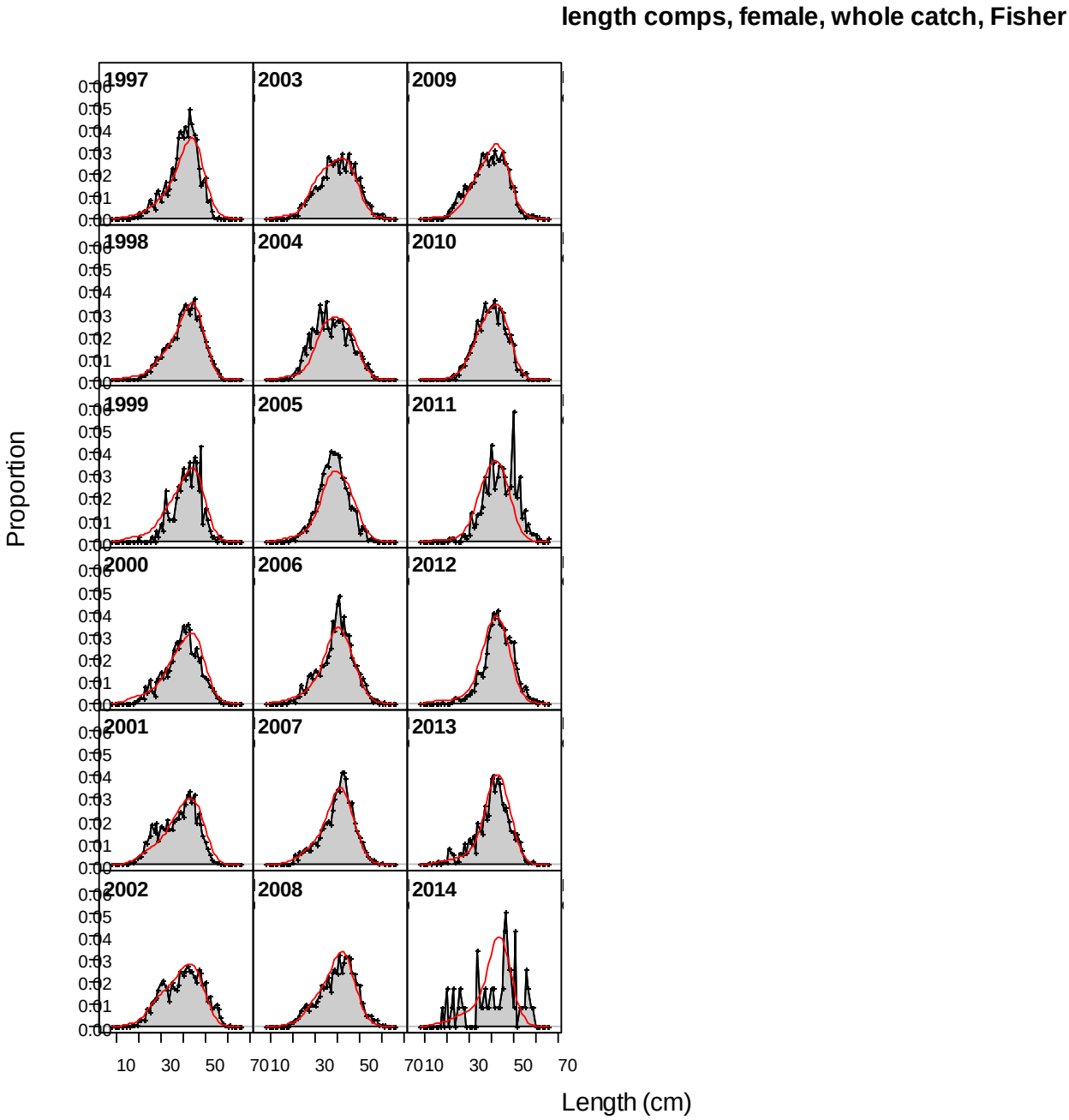


Figure 4.1.50 – Male fishery length composition for S model configuration with survey selectivity-at-age

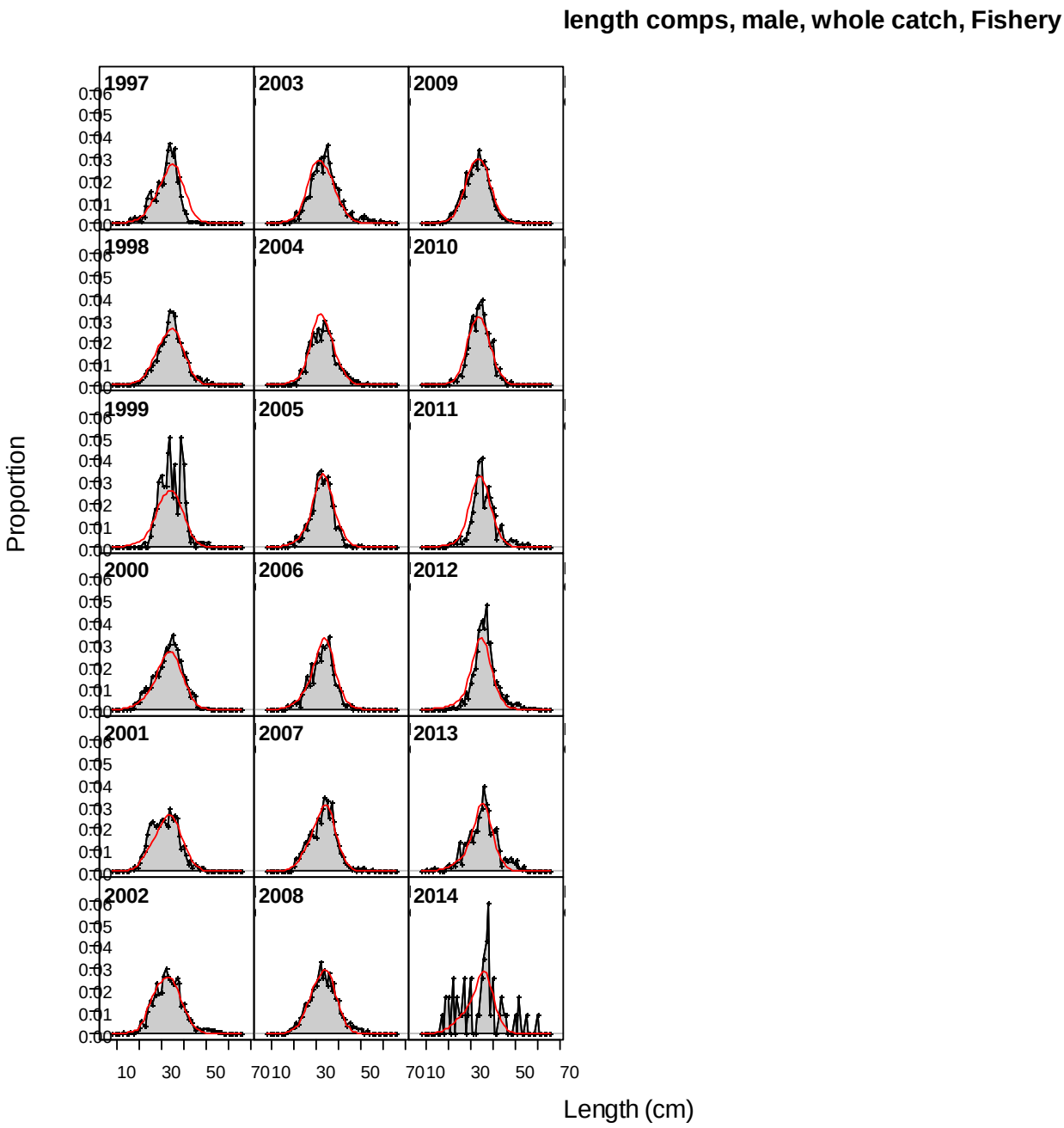


Figure 4.1.51 – Female survey length composition for S model configuration with survey selectivity-at-age

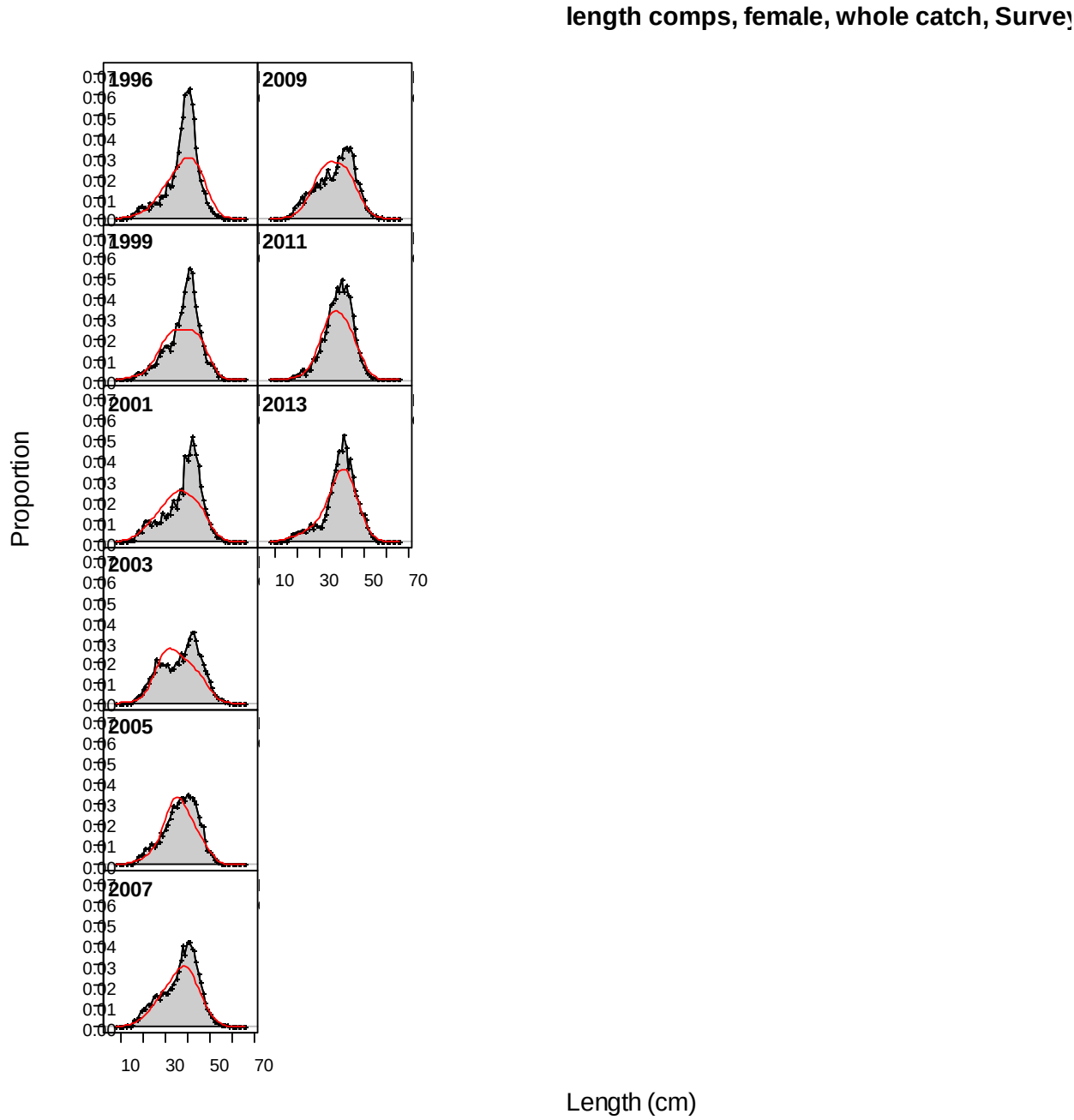


Figure 4.1.52 – Male survey length composition for S model configuration with survey selectivity-at-age

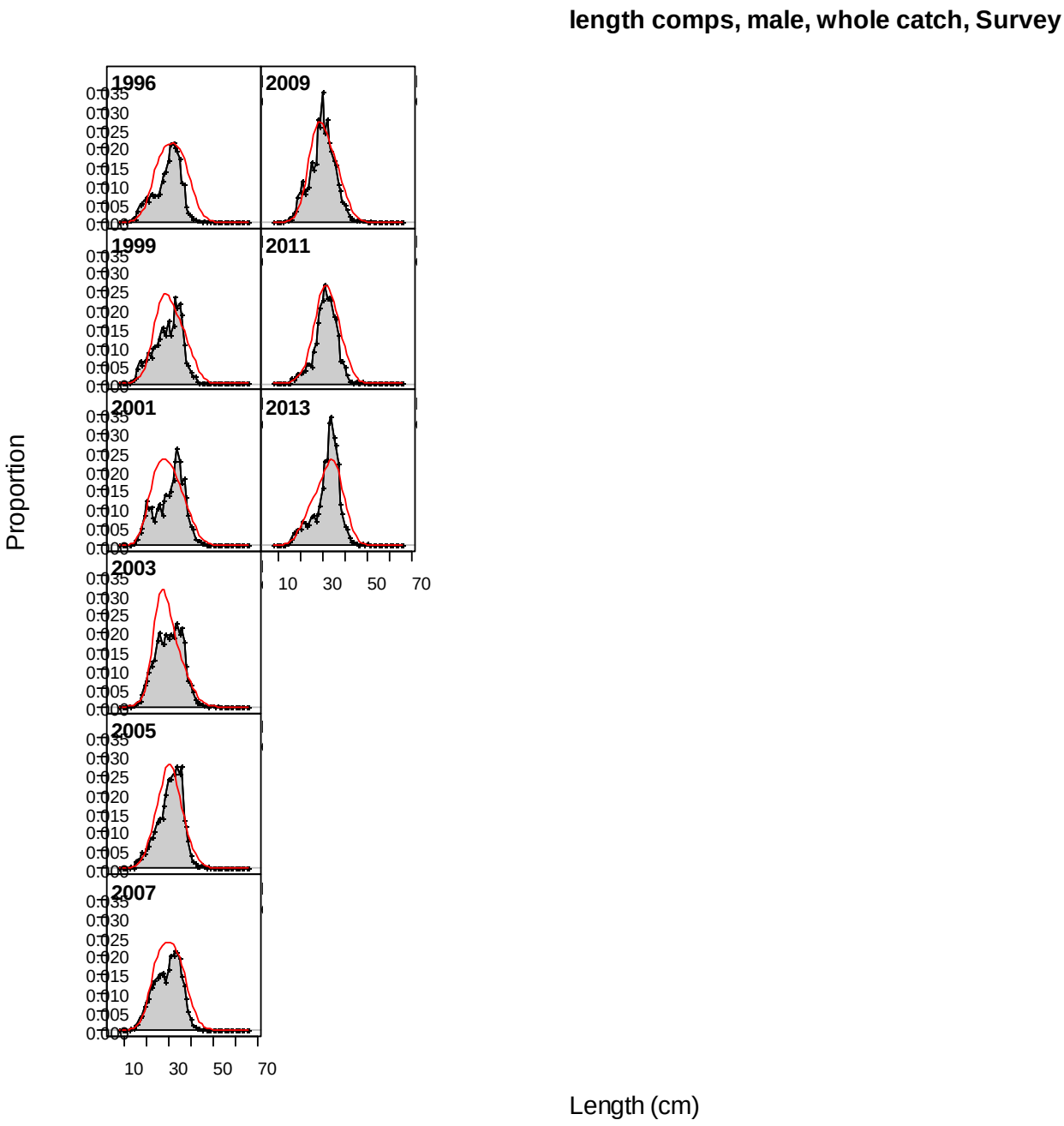


Figure 4.1.53 – Summary female fishery and survey length composition for S model configuration with survey selectivity-at-age

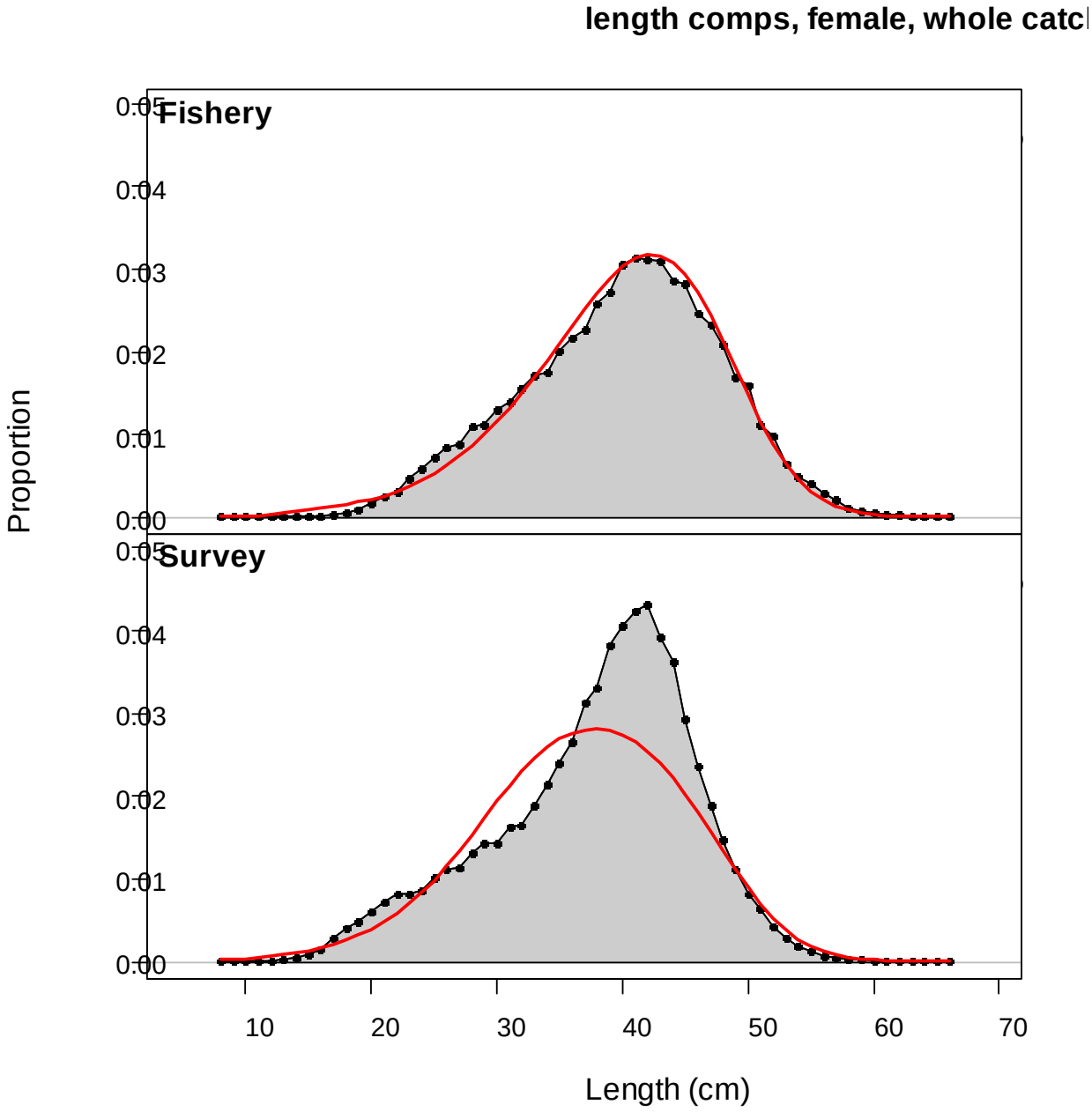


Figure 4.1.54 – Summary male fishery and survey length composition for S model configuration with survey selectivity-at-age

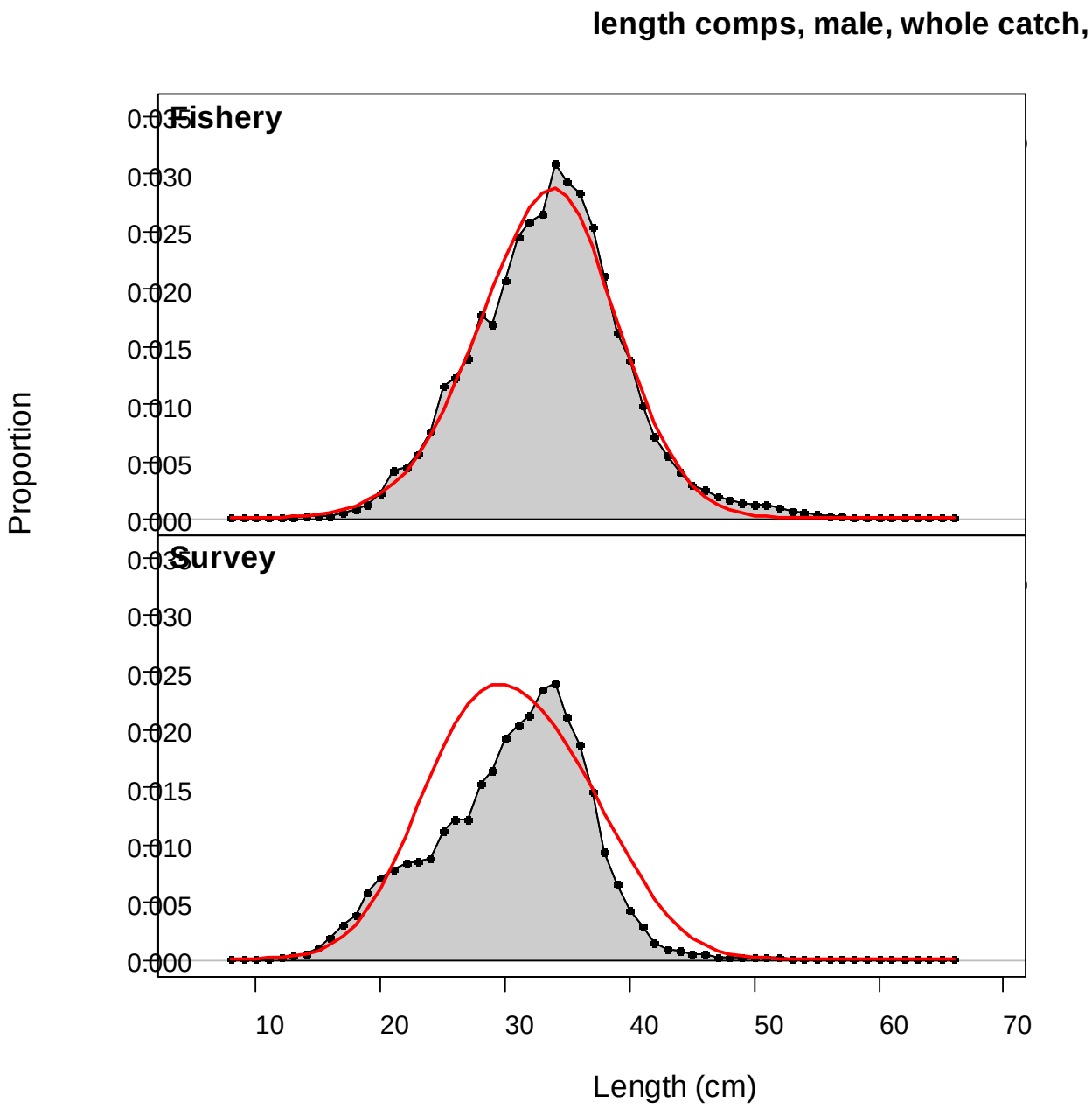
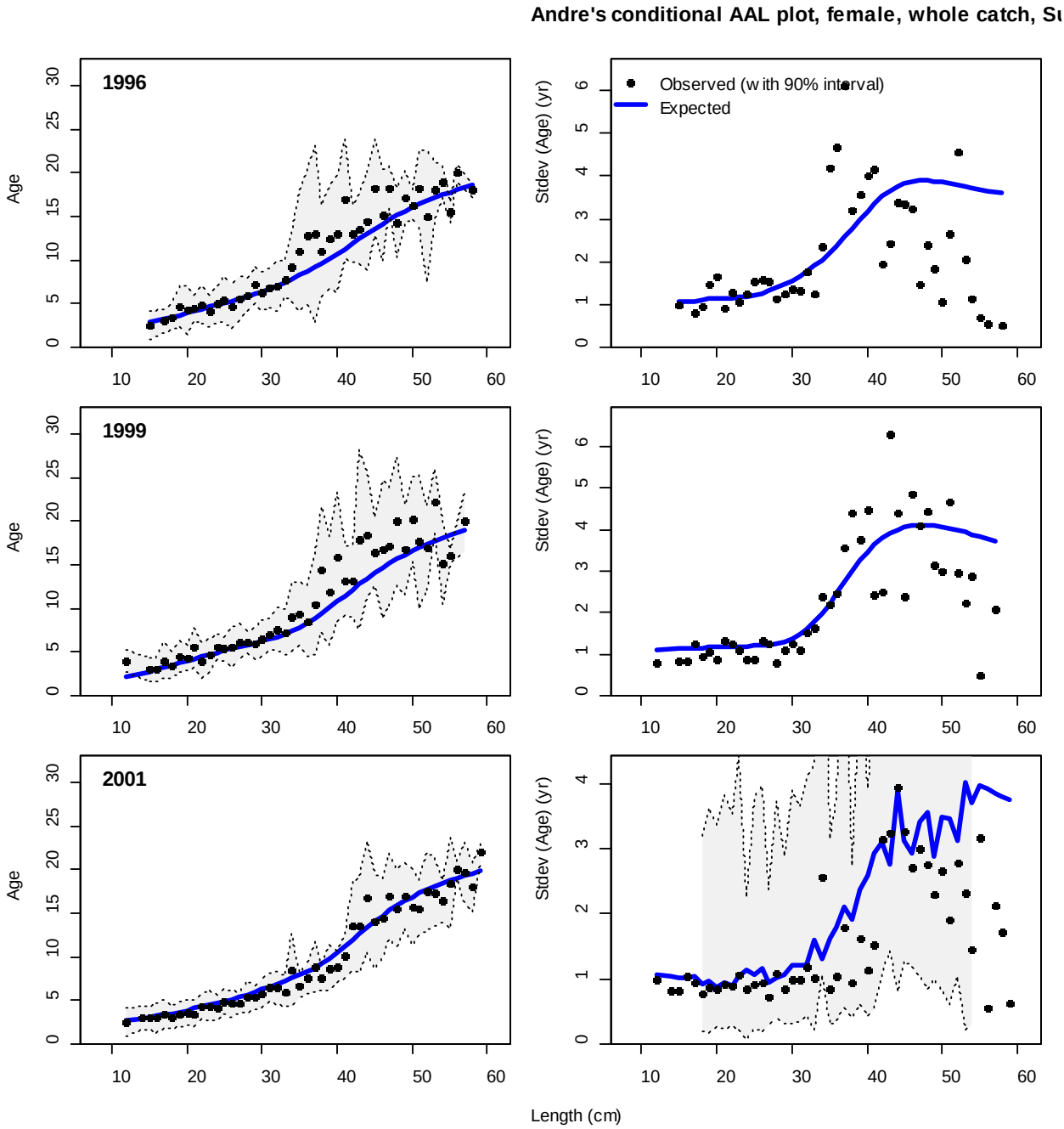
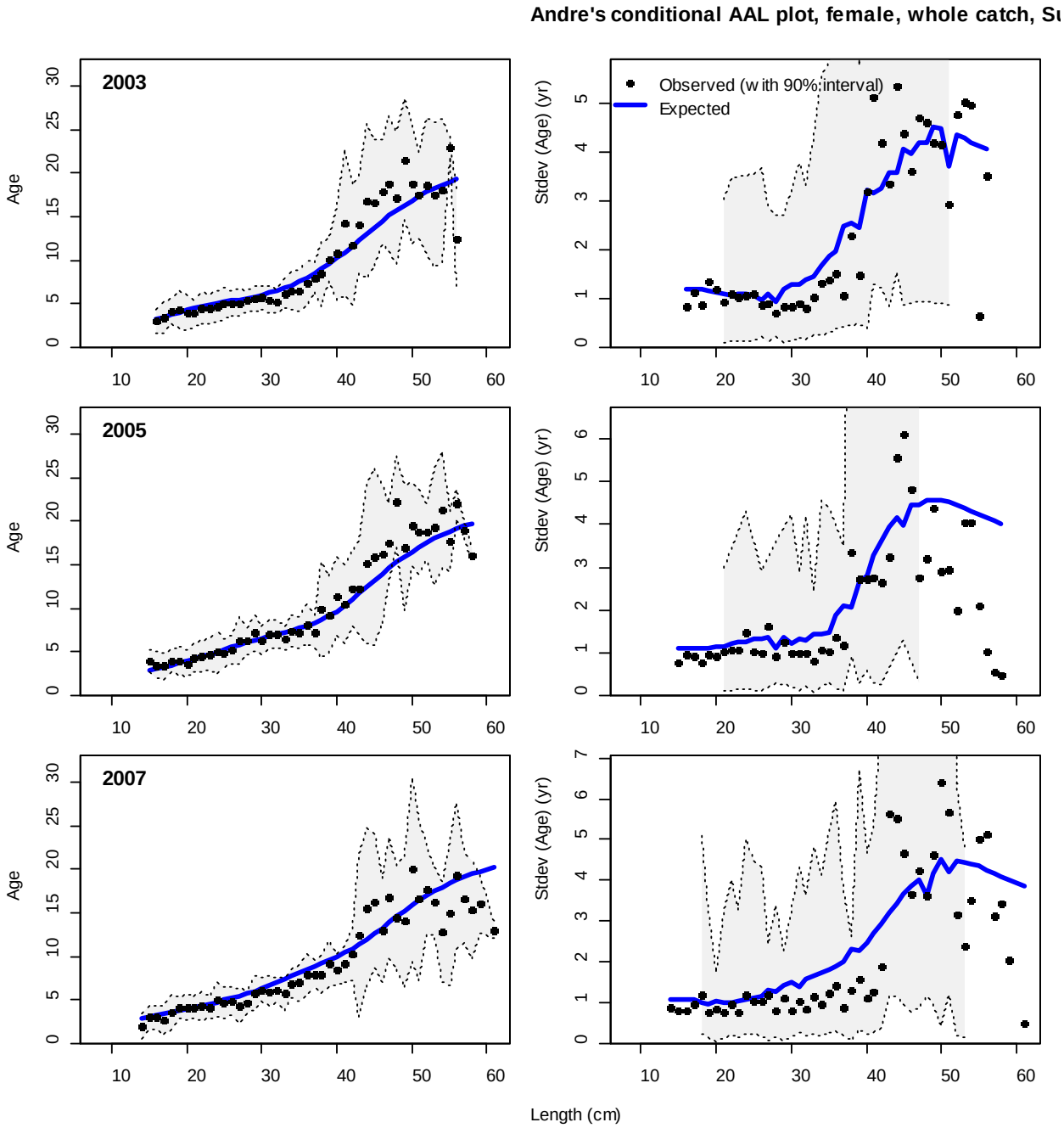


Figure 4.1.55 – Female survey conditional age-at-length for S model configuration with survey selectivity-at-age




Andre's conditional AAL plot, female, whole catch, Su
2003
2005
2007
Age
Stdev (Age) (yr)
Observed (with 90% interval)
Expected
Length (cm)

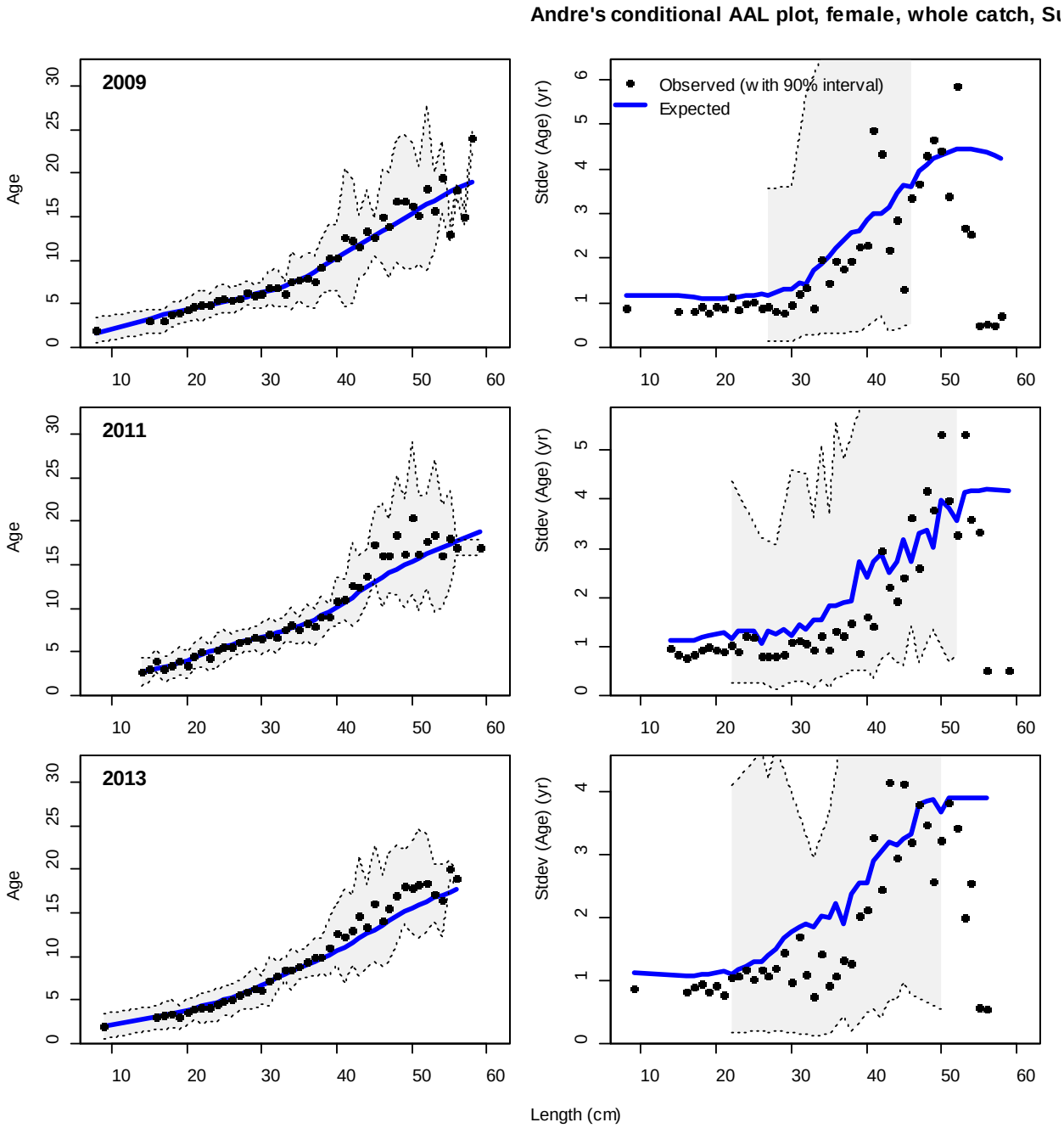
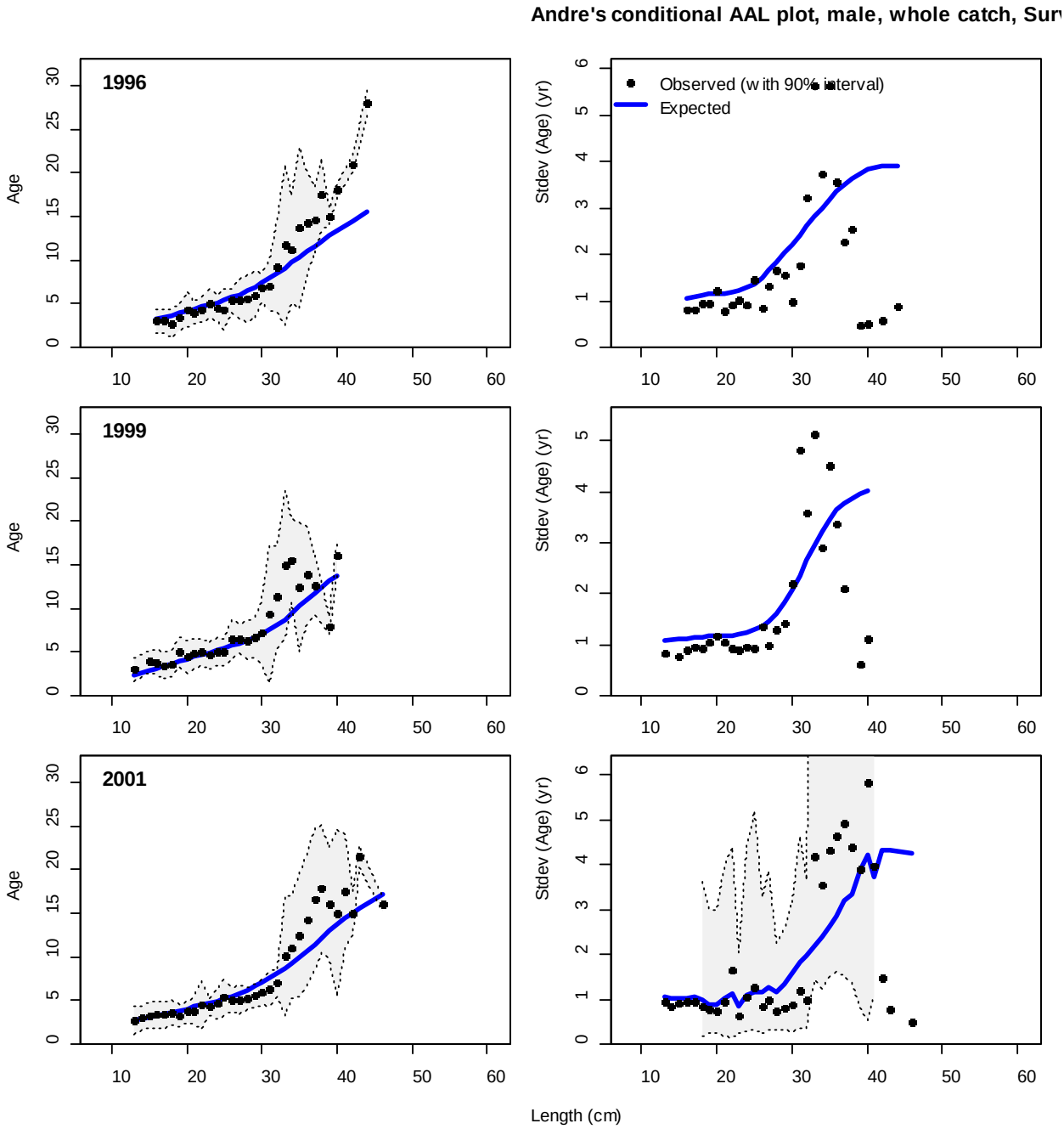
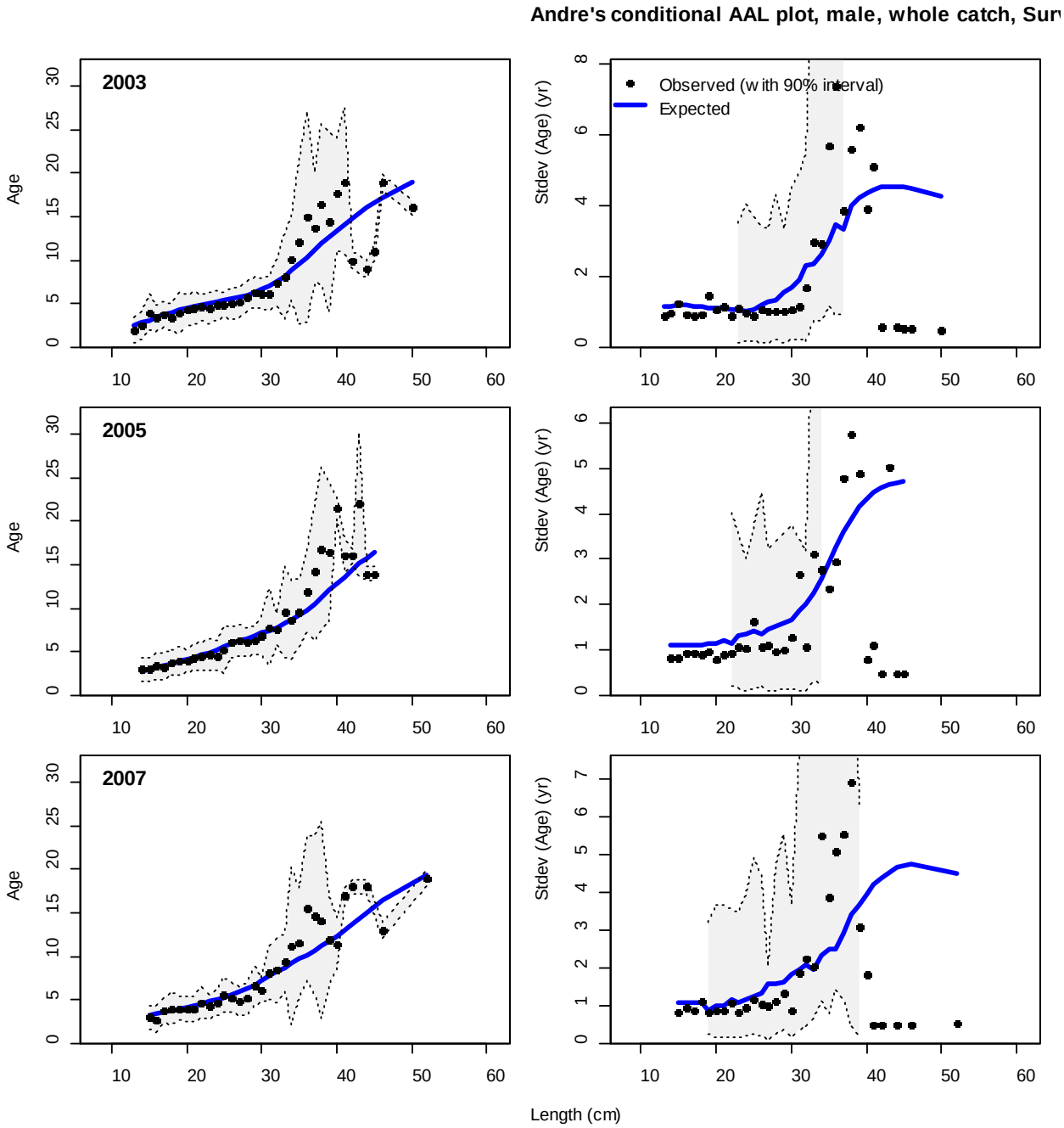
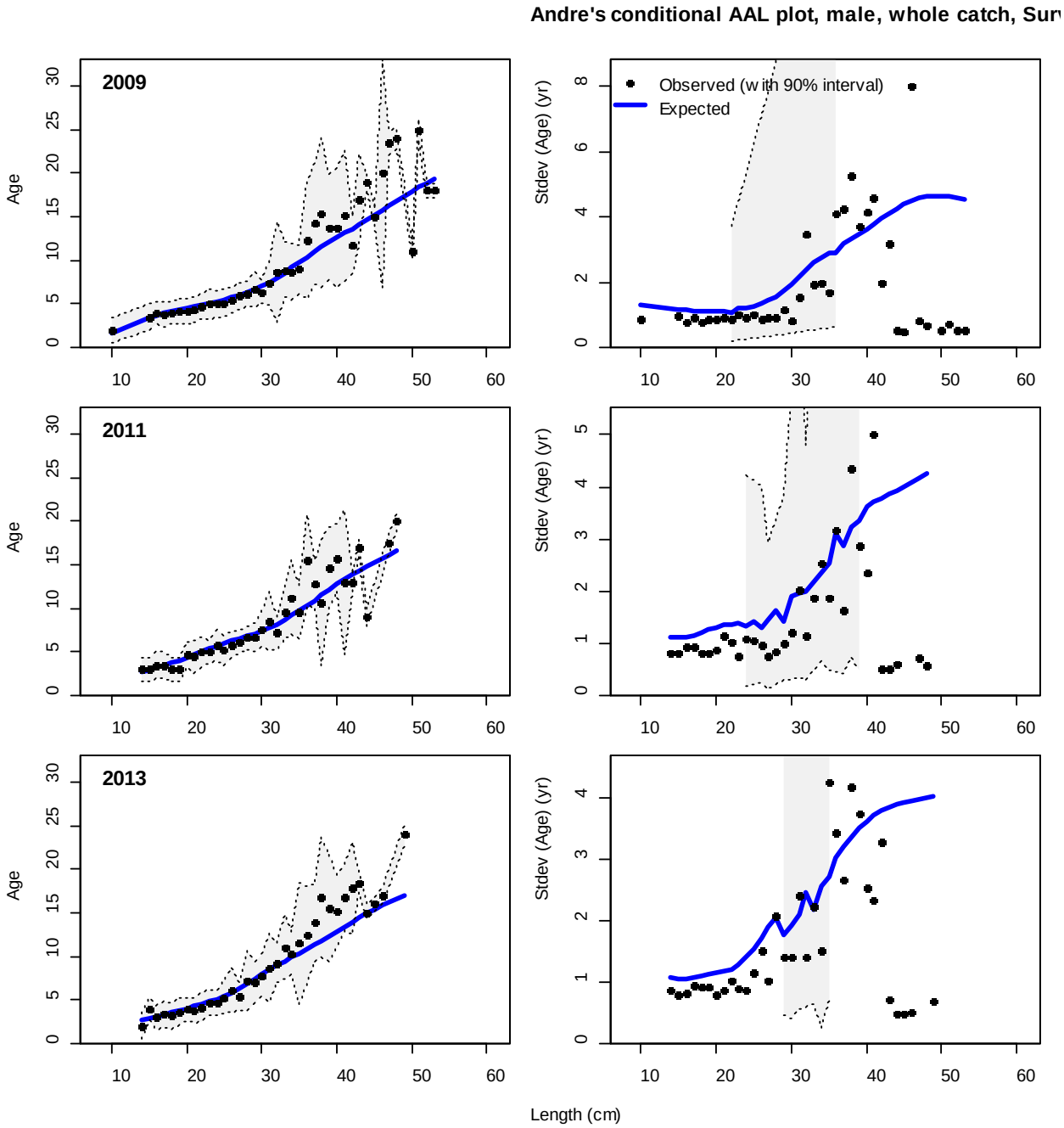

Andre's conditional AAL plot, female, whole catch, Su
2009
2011
2013
Age
Stdev (Age) (yr)
Observed (with 90% interval)
Expected
Length (cm)

Figure 4.1.56 – Male survey conditional age-at-length for S model configuration with survey selectivity-at-age




Andre's conditional AAL plot, male, whole catch, Sur
2003
2005
2007
Age
Stdev (Age) (yr)
Observed (with 90% interval)
Expected
Length (cm)


Andre's conditional AAL plot, male, whole catch, Sur
2009
2011
2013
Age
Stdev (Age) (yr)
Observed (with 90% interval)
Expected
Length (cm)

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