Chapter 2: Assessment of the Pacific cod stock in the Gulf of Alaska

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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:

Changes in the input data

1. Federal and state catch data for 1997 – 2013 were updated and preliminary federal and state catch data for 2014 were included
2. Commercial federal and state fishery size composition data for 1997 – 2013 were updated, and preliminary commercial federal and state fishery size composition data for 2014 were included

Changes in the methodology

One of the models in this year's assessment is the 2013 final model. An alternative version of the 2013 model which uses the recruitment variability multiplier (sigmaR multiplier) for recent recruits is also presented.

Two additional models which differ significantly from the 2013 final model are also presented. These differences include:

- Using all of the GOA NMFS bottom trawl survey as a single source of data instead of being split into sub-27 and 27-plus, for the abundance estimates and the length- and age-composition data;
- Using 3 blocks of non-parametric or cubic spline-based survey selectivity-at-age instead of 12 blocks of double normal selectivity-at-age;
- Including the survey age data as conditional age-at-length data instead of age composition and mean size-at-age data; and
- Using the recruitment variability multiplier (sigmaR multiplier) for recent recruits

Summary of Results

Quantity	As estimated or *specified last* year for: 2014	2015	As estimated or *specified this* year for: 2015	2016
M (natural mortality rate)	0.38	0.38	0.38	0.38
Tier	3a	3a	3a	3a
Projected total (age 0+) biomass (t)	422,000	397,000	583,800	558,200
Female spawning biomass (t)				
Projected	120,100	111,500	155,400	150,400
Upper 95% confidence interval	142,800	132,500	215,400	210,400
Lower 95% confidence interval	97,500	90,500	95,400	90,400
$B_{100\%}$	227,800	227,800	316,500	316,500
$B_{40\%}$	91,100	91,100	126,600	126,600
$B_{35\%}$	79,700	79,700	110,700	110,700
F_{OFL}	0.69	0.69	0.626	0.626
$maxF_{ABC}$	0.54	0.54	0.502	0.502
F_{ABC}	0.54	0.54	0.502	0.502
OFL (t)	107,300	101,800	140,300	133,100
maxABC (t)	88,500	84,100	117,200	110,700
ABC (t)	88,500	84,100	117,200	110,700
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

Area apportionment

In 2012 the ABC for GOA Pacific cod was apportioned among regulatory areas using a Kalman filter approach based on trawl survey biomass estimates. In the 2013 assessment, the random effects model (which is similar to the Kalman filter approach, and was recommended in the Survey Average working group report which was presented to the Plan Team in September 2013) was used; this method was used for the ABC apportionment for 2014. The SSC concurred with this method in December 2013. Using this method with the trawl survey biomass estimates through 2013, the area-apportioned ABCs are:

	Western	Central	Eastern	Total
Random effects area apportionment (percent)	37.63	59.62	2.75	100.00
2015 ABC	44,102	69,875	3,223	117,200
2016 ABC	41,656	65,999	3,044	110,700

Responses to SSC and Plan Team Comments in General

SSC, December 2014: "*During public testimony, it was proposed that assessment authors should consider projecting the reference points for the future two years (e.g., 2014 and 2015) on the phase diagrams. It was suggested that this forecast would be useful to the public. The SSC agrees. The SSC appreciated this suggestion and asks the assessment authors to do so in the next assessment.*"
Response: This figure is included as Figure 2.26.

Responses to SSC and Plan Team Comments Specific to this Assessment

Plan Team, September 2014: "*The PT concurred with the author to bring forward three models to the November Plan Team meeting: Models P1, S1a, and S1b. These three models give a reasonable portrayal of stock dynamics. The major differences in the S1 models compared to the P1 model (last year's model) is the use of a conditional age at length key for survey data, treating bottom trawl survey data as one source (i.e. sub 27 and 27 plus size groups combined), and the inclusion a recruitment variability multiplier (sigma r multiplier) applied to recent recruitment estimates,. Model P1 omits the sub 27 survey data. Model S1b includes the use of splines to estimate selectivity curves.*"
Response: The three models have been brought forward, along with an additional model which is the 2013 model with the recruitment variability multiplier for recent recruits.

Plan Team, September 2014: ***"For all models, the Plan Team recommends that starting values for sample weights for compositional data (i.e. age and length data) be based on the number of hauls or trips rather than the number samples. These starting values should be the upper limit of sample weights."***
Response: The sample sizes for the fishery catch-at-length data are based on the number of hauls or trips; the sample sizes for the survey length and age composition data and conditional age-at-length data are the number of hauls.

Plan Team, September 2014: ***"The Plan Team recommends that the authors explore the use of the "10% selectivity rule" presented by Grant Thompson as the year class to start applying the sigma r multiplier."***
Response: Using the average of the survey selectivity-at-age curves from the 2013 model, the result of the "first age = round[(0.05/M) + A10%] calculation is 1.4, or age 1. However, in the two new models, the survey selectivity at age 2 is lower than selectivity at age 1 in most years, so age 2 was used as the cutoff. This change resulted in age-0 recruits being estimated through 2011, and the sigmaR multiplier being applied to the 2012, 2013, and 2014 age-0 recruits.

Plan Team, September 2014: ***"The Plan Team also recommends exploration of the use of longline survey data as an additional source of abundance index data for adult Pacific cod."***
Response: This exploration is still ongoing. Dana Hanselman provided a preliminary figure for this analysis, and is included as Figure 2.27.

SSC, October 2014: "*The assessment author presented 5 alternative models, and the Plan Team recommended that Models P1, S1a and S1b be brought forward to the November plan team meeting. Model P1 is last years' model. The S1 models differ in that they use conditional age at length for survey data and include a recruitment variability multiplier. Model S1b uses non-parametric selectivity functions (cubic splines). The Plan Team recommends that the starting values for composition sample weights be based on the number of hauls or trips, rather than the number of samples. The Plan Team also recommends the author explore the use of the 10% selectivity rule for determining the recruitment vector, and explore the use of the IPHC set-line survey data as an index for adult Pacific cod.* ***The SSC agrees with all the recommendations made by the Plan Team.***"
Response: The recommendations made by the Plan Team have been addressed.

Introduction

Pacific cod (*Gadus macrocephalus*) is a transoceanic species, occurring at depths from shoreline to 500 m. The southern limit of the species' distribution is about 34° N latitude, with a northern limit of about 63° N latitude. Pacific cod is distributed widely over Gulf of Alaska (GOA), as well as the eastern Bering Sea (EBS) and the Aleutian Islands (AI) area. Tagging studies (e.g., Shimada and Kimura 1994) have demonstrated significant migration both within and between the EBS, AI, and GOA. Recent research indicates the existence of discrete stocks in the EBS and AI (Canino et al. 2005, Cunningham et al. 2009, Canino et al. 2010, Spies 2012). Pacific cod is not known to exhibit any special life history characteristics that would require it to be assessed or managed differently from other groundfish stocks in the GOA. The Pacific cod stock in the GOA is managed as one stock.

Review of Life History

Pacific cod eggs are demersal and adhesive. Eggs hatch in about 15 to 20 days. Spawning takes place in the sublittoral-bathyal zone (40 to 290 m) near bottom. Eggs sink to the bottom after fertilization and are somewhat adhesive. Optimal temperature for incubation is 3° to 6°C, optimal salinity is 13 to 23 parts per thousand (ppt), and optimal oxygen concentration is from 2 to 3 ppm to saturation. Little is known about the optimal substrate type for egg incubation.

Little is known about the distribution of Pacific cod larvae, which undergo metamorphosis at about 25 to 35 mm. Larvae are epipelagic, occurring primarily in the upper 45 m of the water column shortly after hatching, moving downward in the water column as they grow.

Juveniles occur mostly over the inner continental shelf at depths of 60 to 150 m. Adults occur in depths from the shoreline to 500 m, although occurrence in depths greater than 300 m is fairly rare. Preferred substrate is soft sediment, from mud and clay to sand. Average depth of occurrence tends to vary directly with age for at least the first few years of life. However, in the GOA trawl survey, the percentage of fish residing in waters less than 100 m tends to increase with length beyond about 90 cm. The GOA trawl survey also indicates that fish occupying depths of 200-300 m are typically in the 40-90 cm size range.

It is conceivable that mortality rates, both fishing and natural, may vary with age in Pacific cod. In particular, very young fish likely have higher natural mortality rates than older fish (note that this may not be particularly important from the perspective of single-species stock assessment, so long as these higher natural mortality rates do not occur at ages or sizes that are present in substantial numbers in the data). For example, Leslie matrix analysis of a Pacific cod stock occurring off Korea estimated the instantaneous natural mortality rate of 0-year-olds at 910% per year (Jung et al. 2009). This may be compared to a mean estimate for age 0 Atlantic cod (*Gadus morhua*) in Newfoundland of 4.17% per day, with a 95% confidence interval ranging from about 3.31% to 5.03% (Gregory et al. in prep.); and age 0 Greenland cod (*Gadus ogac*) of 2.12% per day, with a 95% confidence interval ranging from about 1.56% to 2.68% (Robert Gregory and Corey Morris, *pers. commun.*).

Although little is known about the likelihood of age-dependent natural mortality in adult Pacific cod, it has been suggested that Atlantic cod may exhibit increasing natural mortality with age (Greer-Walker 1970).

At least one study (Ueda et al. 2006) indicates that age 2 Pacific cod may congregate more, relative to age 1 Pacific cod, in areas where trawling efficiency is reduced (e.g., areas of rough substrate), causing their selectivity to decrease. Also, Atlantic cod have been shown to dive in response to a passing vessel (Ona and Godø 1990), which may complicate attempts to estimate catchability or selectivity. It is not known whether Pacific cod undertake a similar response.

As noted above, Pacific cod are known to undertake seasonal migrations, the timing and duration of which may be variable (Savin 2008).

Fishery

During the two decades prior to passage of the Magnuson Fishery Conservation and Management Act (MFCMA) in 1976, the fishery for Pacific cod in the GOA was small, averaging around 3,000 t per year. Most of the catch during this period was taken by the foreign fleet, whose catches of Pacific cod were usually incidental to directed fisheries for other species. By 1976, catches had increased to 6,800 t. Catches of Pacific cod since 1991 are shown in Table 2.1; catches prior to that are listed in Thompson et al. (2011). Presently, the Pacific cod stock is exploited by a multiple-gear fishery, including trawl, longline, pot, and jig components. Trawl gear took the largest share of the catch in every year but one from 1991-2002, although pot gear has taken the largest single-gear share of the catch in each year since 2003 (not counting 2013, for which data are not yet complete). Figure 2.1 shows landings by gear and season since 1977. Table 2.1 shows the catch by jurisdiction and gear type.

The history of acceptable biological catch (ABC) and total allowable catch (TAC) levels is summarized and compared with the time series of aggregate commercial catches in Table 2.2. For the first year of management under the MFCMA (1977), the catch limit for GOA Pacific cod was established at slightly less than the 1976 total reported landings. During the period 1978-1981, catch limits varied between 34,800 and 70,000 t, settling at 60,000 t in 1982. Prior to 1981 these limits were assigned for "fishing years" rather than calendar years. In 1981 the catch limit was raised temporarily to 70,000 t and the fishing year was extended until December 31 to allow for a smooth transition to management based on calendar years, after which the catch limit returned to 60,000 t until 1986, when ABC began to be set on an annual basis. From 1986 (the first year in which an ABC was set) through 1996, TAC averaged about 83% of ABC and catch averaged about 81% of TAC. In 8 of those 11 years, TAC equaled ABC exactly. In 2 of those 11 years (1992 and 1996), catch exceeded TAC.

To understand the relationships between ABC, TAC, and catch for the period since 1997, it is important to understand that a substantial fishery for Pacific cod has been conducted during these years inside State of Alaska waters, mostly in the Western and Central Regulatory Areas. To accommodate the State-managed fishery, the Federal TAC was set well below ABC (15-25% lower) in each of those years. Thus, although total (Federal plus State) catch has exceeded the Federal TAC in all but three years since 1997, this is basically an artifact of the bi-jurisdictional nature of the fishery and is not evidence of overfishing. At no time since the separate State waters fishery began in 1997 has total catch exceeded ABC, and total catch has never exceeded OFL.

Changes in ABC over time are typically attributable to three factors: 1) changes in resource abundance, 2) changes in management strategy, and 3) changes in the stock assessment model. Assessments conducted prior to 1988 were based on survey biomass alone. From 1988-1993, the assessment was based on stock reduction analysis (Kimura et al. 1984). From 1994-2004, the assessment was conducted using the Stock Synthesis 1 modeling software (Methot 1986, 1990) with length-based data. The assessment was migrated to Stock Synthesis 2 (SS2) in 2005 (Methot 2005b), at which time age-based data began to enter the assessment. Several changes have been made to the model within the SS2 framework (renamed "Stock Synthesis," or SS3, in 2008) each year since then.

Historically, the majority of the GOA catch has come from the Central regulatory area. To some extent the distribution of effort within the GOA is driven by regulation, as catch limits within this region have been apportioned by area throughout the history of management under the MFCMA. Changes in area-specific allocation between years have usually been traceable to changes in biomass distributions estimated by Alaska Fisheries Science Center trawl surveys or management responses to local concerns. Currently the ABC is derived from the random effects model (which is similar to the Kalman filter approach. The complete history of allocation (in percentage terms) by regulatory area within the GOA is shown in Table 2.3.

The catches shown in Tables 2.1 and 2.2 include estimated discards (Table 2.4).

In addition to area allocations, GOA Pacific cod is also allocated on the basis of processor component (inshore/offshore) and season. The inshore component is allocated 90% of the TAC and the remainder is allocated to the offshore component. Within the Central and Western Regulatory Areas, 60% of each component's portion of the TAC is allocated to the A season (January 1 through June 10) and the remainder is allocated to the B season (June 11 through December 31, although the B season directed fishery does not open until September 1).

NMFS has also published the following rule to implement Amendment 83 to the GOA Groundfish FMP:

> "Amendment 83 allocates the Pacific cod TAC in the Western and Central regulatory areas of the GOA among various gear and operational sectors, and eliminates inshore and offshore allocations in these two regulatory areas. These allocations apply to both annual and seasonal limits of Pacific cod for the applicable sectors. These apportionments are discussed in detail in a subsequent section of this rule. Amendment 83 is intended to reduce competition among sectors and to support stability in the Pacific cod fishery. The final rule implementing Amendment 83 limits access to the Federal Pacific cod TAC fisheries prosecuted in State of Alaska (State) waters adjacent to the Western and Central regulatory areas in the GOA, otherwise known as parallel fisheries. Amendment 83 does not change the existing annual Pacific cod TAC allocation between the inshore and offshore processing components in the Eastern regulatory area of the GOA.
>
> "In the Central GOA, NMFS must allocate the Pacific cod TAC between vessels using jig gear, catcher vessels (CVs) less than 50 feet (15.24 meters) length overall using hook-and-line gear, CVs equal to or greater than 50 feet (15.24 meters) length overall using hook-and-line gear, catcher/processors (C/Ps) using hook-and-line gear, CVs using trawl gear, C/Ps using trawl gear, and vessels using pot gear. In the Western GOA, NMFS must allocate the Pacific cod TAC between vessels using jig gear, CVs using hook-and-line gear, C/Ps using hook-and-line gear, CVs using trawl gear, and vessels using pot gear. Table 3 lists the proposed amounts of these seasonal allowances. For the Pacific cod sector splits and associated management measures to become effective in the GOA at the beginning of the 2012 fishing year, NMFS published a final rule (76 FR 74670, December 1, 2011) and will revise the final 2012 harvest specifications (76 FR 11111, March 1, 2011)."
>
> "NMFS proposes to calculate of the 2012 and 2013 Pacific cod TAC allocations in the following manner. First, the jig sector would receive 1.5 percent of the annual Pacific cod TAC in the Western GOA and 1.0 percent of the annual Pacific cod TAC in the Central GOA, as required by proposed § 679.20(c)(7). The jig sector annual allocation would further be apportioned between the A (60 percent) and B (40 percent) seasons as required by § 679.20(a)(12)(i). Should the jig sector harvest 90 percent or more of its allocation in a given area during the fishing year, then this allocation would increase by one percent in the subsequent fishing year, up to six percent of the annual TAC. NMFS proposes to allocate the remainder of the annual Pacific cod TAC based on gear type, operation type, and vessel length overall in the Western and Central GOA seasonally as required by proposed § 679.20(a)(12)(A) and (B)."

The longline and trawl fisheries are also associated with a Pacific halibut mortality limit which sometimes constrains the magnitude and timing of harvests taken by these two gear types.

Data

This section describes data used in the current assessment model. It does not attempt to summarize all available data pertaining to Pacific cod in the GOA.

Data	Source	Type	Years included
Federal and state fishery catch, by gear type and month	AKFIN	metric tons	1977 – 2014
Federal fishery catch-at-length, by gear type and month	AKFIN / FMA	number, by cm bin	1977 – 2014
State fishery catch-at-length, by gear type and month	ADF&G	number, by cm bin	1997 – 2014
GOA NMFS bottom trawl survey biomass and abundance estimates	AFSC	metric tons, numbers	1984 – 2013
GOA NMFS bottom trawl survey length composition	AFSC	number, by cm bin	1984 – 2013
GOA NMFS bottom trawl survey age composition	AFSC	number, by age	1987 – 2011
GOA NMFS bottom trawl survey mean length-at-age	AFSC	mean value and number	1987 – 2011

Fishery

Catch Biomass

Catches for the period 1991-2014 are shown for the three main gear types in Table 2.7, with the catches for season 5 (Nov – Dec) of 2014 projected. This also shows gear-specific catches by "selectivity seasons," which are obtained from combinations of "catch seasons." The catch seasons are defined as January-February, March-April, May-August, September-October, and November-December. Three selectivity seasons are defined by combining catch seasons 1 and 2 into selectivity season 1, equating catch season 3 with selectivity season 2, and combining catch seasons 4 and 5 into selectivity season 3. The catch seasons used were the result of a statistical analysis described in the 2010 assessment (Thompson et al. 2010), and the selectivity seasons were chosen to correspond as closely as possible to the traditional seasons used in previous assessments (given the revised catch seasons). In years for which estimates of the distribution by gear or period were unavailable, proxies based on other years' distributions were used. Non-commercial catches for 2004 – 2013 are shown in Table 2.8.

Catch Size Composition

Fishery size compositions are presently available, by gear and season, for at least one gear type in every year from 1977 through the first part of 2014. Beginning with the 2010 assessment (Thompson et al. 2010), size composition data are based on 1-cm bins ranging from 4 to 120 cm. As the maximum percent of fish larger than 110 cm over each year-gear type-season is less than 0.5%, the upper limit of the length bins has been changed to 110 cm, with the 110-cm bin accounting for all fish 110 cm and larger.

Survey

Survey Age Composition

Age compositions from each survey except 1984 are available (note that the sample size for the 1987 was very small, however). The age compositions and actual sample sizes are shown in Table 2.9 and Fig. 2.7.

Survey Size Composition

For the last few assessments, the size composition data from the trawl surveys of the GOA conducted by the Alaska Fisheries Science Center have been partitioned into two length categories: fish smaller than 27 cm (the "sub-27" survey) and fish 27 cm and larger (the "27-plus" survey). The relative size compositions from 1984-2013 are shown for the sub-27 and the 27-plus survey in Table 2.10, using the same 1-cm length bins defined above for the fishery catch size compositions. Columns in this table sum to the actual number of fish measured in each year. The full size compositions are shown in Fig. 2.6.

Mean Size at Age

Mean size-at-age data are available for all of the years in which age compositions are available. These are shown in Table 2.11; the sample sizes are shown in Table 2.12.

Abundance Estimates

Estimates of total abundance (both in biomass and numbers of fish) obtained from the trawl surveys are shown in Table 2.13 and Fig. 2.3, together with their respective coefficients of variation. The abundance estimates by area are shown in Fig. 2.5.

The highest biomass ever observed by the survey was the 2009 estimate of 752,651 t, and the low point was the preceding (2007) estimate of 233,310 t. The 2009 biomass estimate represented a 223% increase over the 2007 estimate. The 2011 biomass estimate was down 33% from 2009, but still 115% above the 2007 estimate. The 2013 biomass estimate is a small increase (1%) from the 2011 estimate (Fig. 2.2). The biomass estimates by area are shown in Fig. 2.4.

In terms of population numbers, the record high was observed in 2009, when the population was estimated to include over 573 million fish. The 2005 estimate of 140 million fish was the low point in the time series. The 2009 abundance estimate represented a 199% increase over the 2007 estimate. The 2011 abundance estimate was a decrease of 39% from 2009, but still 81% above the 2007 estimate.

The 2013 total abundance estimate is a small decrease (3%) from the 2011 estimate, and the 2013 estimate has a lower coefficient of variation (CV), 0.151, than the 2011 estimate. The 2013 abundance estimate for fish 27 cm and above is a decrease of 24% from the 2011 estimate, with a lower CV, 0.139, than in 2011. The 2013 abundance estimate for fish less than 27 cm is an increase of over 800% from the 2011 estimate, with a higher CV, 0.437, than in 2011. The total, 27-plus, and sub-27 abundance estimates for 2013 are a decrease of at least 39% from the 2009 estimates.

Analytic Approach

Model Structure

History of Previous Model Structures Developed Under Stock Synthesis

Beginning with the 1994 SAFE report (Thompson and Zenger 1994), a model using the Stock Synthesis 1 (SS1) assessment program (Methot 1986, 1990, 1998, 2000) and based largely on length-structured data formed the primary analytical tool used to assess the GOA Pacific cod stock.

SS1 was a program that used the parameters of a set of equations governing the assumed dynamics of the stock (the “model parameters”) as surrogates for the parameters of statistical distributions from which the data were assumed to be drawn (the “distribution parameters”), and varies the model parameters systematically in the direction of increasing likelihood until a maximum is reached. The overall likelihood was the product of the likelihoods for each of the model components. In part because the overall likelihood could be a very small number, SS1 used the logarithm of the likelihood as the objective function. Each likelihood component was associated with a set of data assumed to be drawn from statistical distributions of the same general form (e.g., multinomial, lognormal, etc.). Typically, likelihood components were associated with data sets such as catch size (or age) composition, survey size (or age) composition, and survey abundance (either biomass or numbers, either relative or absolute).

SS1 permitted each data time series to be divided into multiple segments, resulting in a separate set of parameter estimates for each segment. In the base model for the GOA Pacific cod assessment, for example, possible differences in selectivity between the mostly foreign (also joint venture) and mostly domestic fisheries were accommodated by splitting the fishery size composition time series into pre-1987 and post-1986 segments during the era of SS1-based assessments.

Until 2010, each year was been partitioned into three seasons defined as January-May, June-August, and September-December (these seasonal boundaries were suggested by industry participants in the EBS fishery). Four fisheries were defined during the era of SS1-based assessments: The January-May trawl fishery, the June-December trawl fishery, the longline fishery, and the pot fishery.

Following a series of modifications from 1993 through 1997, the base model for GOA Pacific cod remained completely unchanged from 1997 through 2001. During the late 1990s, a number of attempts were made to estimate the natural mortality rate *M* and the shelf bottom trawl survey catchability coefficient *Q*, but these were not particularly successful and the Plan Team and SSC always opted to retain the base model in which *M* and *Q* were fixed at traditional values of 0.37 and 1.0, respectively.

A minor modification of the base model was suggested by the SSC in 2001, namely, that consideration be given to dividing the domestic era into pre-2000 and post-1999 segments. This modification was tested in the 2002 assessment (Thompson et al. 2002), where it was found to result in a statistically significant improvement in the model's ability to fit the data.

A major change took place in the 2005 assessment (Thompson and Dorn 2005), as the model was migrated to the newly developed Stock Synthesis 2 (SS2) program, which made use of the ADMB modeling architecture (Fournier et al. 2012) currently used in most age-structured assessments of BSAI and GOA groundfish. The move to SS2 facilitated improved estimation of model parameters as well as statistical characterization of the uncertainty associated with parameter estimates and derived quantities such as spawning biomass. Technical details of SS2 were described by Methot (2005a, 2007).

The 2006 assessment model (Thompson et al. 2006) was structured similarly to the 2005 assessment model; the primary change being external estimation of growth parameters.

A technical workshop was convened in April, 2007 to consider a wide range of issues pertaining to both the BSAI and GOA Pacific cod assessments (Thompson and Conners 2007).

The 2007 assessment model (Thompson et al. 2007b) for Pacific cod in the GOA was patterned after the model used in that year's assessment of the BSAI Pacific cod stock (Thompson et al. 2007a), with several changes as described in the assessment document. However, the 2007 assessment model was not accepted by the Plan Team or the SSC.

For the 2008 assessment, the recommended model for the GOA was based largely on the recommended model from the 2008 BSAI Pacific cod assessment. Among other things, this model used an explicit algorithm to determine which fleets (including surveys as well as fisheries) would be forced to exhibit asymptotic selectivity, and another explicit algorithm to determine which selectivity parameters would be allowed to vary periodically in "blocks" of years and to determine the appropriate block length for each such time-varying parameter. One other significant change in the recommended model from the 2008 GOA assessment, which was not shared by the BSAI assessment, was a substantial downweighting of the age composition data. This downweighting was instituted as a means of keeping the root mean squared error of the fit to the survey abundance data close to the sampling variability of those data.

The 2009 assessment (Thompson et al. 2009) featured a total of ten models reflecting a great many alternative assumptions and use or non-use of certain data, particularly age composition data. Relative to the 2008 assessment, the main changes in the model accepted by the Plan Team and SSC were as follow: 1) input standard deviations of all "dev" vectors were set iteratively by matching the standard deviations of the set of estimated "devs;" 2) the standard deviation of length at age was estimated outside the model as a linear function of mean length at age; 3) catchability for the pre-1996 trawl survey was estimated freely while catchability for the post-1993 trawl survey was fixed at the value that sets the average (weighted by numbers at length) of the product of catchability and selectivity for the 60-81 cm size range equal to the point estimate of 0.916 obtained by Nichol et al. (2007); 4) potential ageing bias was accounted for in the ageing error matrix by examining alternative bias values in increments of 0.1 for ages

2 and above, resulting in a positive bias of 0.4 years for these ages (age-specific bias values were also examined, but did not improve the fit significantly); 5) weighting of the age composition data was returned to its traditional level; 6) except for the parameter governing selectivity at age 0, all parameters of the selectivity function for the post-1993 years of the 27-plus trawl survey were allowed to vary in each survey year except for the most recent; and 7) cohort-specific growth devs were estimated for all years through 2008.

Many changes were made or considered in the 2010 stock assessment model (Thompson et al. 2010). Five models were presented preliminary assessment, as requested by the Plan Teams in May, with subsequent concurrence (given two minor modifications) by the SSC in June. Following review in September and October, three of these models, or modifications thereof, were requested by the Plan Teams or SSC to be included in the final assessment. Relative to the 2009 assessment, the main changes in the model that was ultimately accepted by the Plan Team and SSC in 2010 were as follow: 1) exclude the single record (each) of fishery age composition and mean length-at-age data, 2) use a finer length bin structure than previous models, and 3) re-evaluate the existing seasonal structure used in the model and revise it as appropriate, and 4) remove cohort-specific growth rates (these were introduced for the first time in the 2009 assessment). The new length bin structure consisted of 1-cm bins, replacing the combination of 3-cm and 5-cm bins used in previous assessments. The new seasonal structure consisted of five catch seasons defined as January-February, March-April, May-August, September-October, and November-December; and three selectivity seasons defined as January-April, May-August, and September-December; with spawning identified as occurring at the beginning of the second catch season (March).

Following a review by the Center for Independent Experts in 2011 that resulted in a total of 128 unique recommendations from the three reviewers, the 2011 stock assessment (Thompson et al. 2011) again considered several possible model changes. Three models were requested by the Plan Teams to be included in the final GOA assessment. The SSC concurred, and added one more model. The model that was ultimately accepted by the Team and SSC differed from the 2010 model in the following respects:

- The age corresponding to the *L1* parameter in the length-at-age equation was increased from 0 to 1.3333, to correspond to the age of a 1-year-old fish at the time of the survey, which is when the age data are collected. This change was adopted to prevent mean size at age from going negative (as sometimes happened in previous EBS Pacific cod models), and to facilitate comparison of estimated and observed length at age and variability in length at age.
- The parameters governing variability in length at age were re-tuned. This was necessitated by the change in the age corresponding to the *L1* parameter (above).
- A column for age 0 fish was added to the age composition and mean-size-at-age portions of the data file. Even though there are virtually no age 0 fish represented in these two portions of the data file, unless a column for age 0 is included, SS will interpret age 1 fish as being ages 0 and 1 combined, which can bias the estimates of year class strength.
- Ageing bias was estimated internally. To preserve a large value for the strength of the 1977 year class and to keep the mean recruitment from the pre-1977 environmental regime lower than the mean recruitment from the post-1976 environmental regime, ageing bias was constrained to be positive (this constraint ultimately proved to be binding only at the maximum age).

It should also be noted that, consistent with Plan Team policy adopted in 2010, quantities that were estimated iteratively in the 2009 assessment were not re-estimated in the 2010 assessment (with the exception of the parameters governing variability in length at age, for the reason listed above).

Model Structures Considered in This Year's Assessment

Stock Synthesis version 3.24S (Methot and Wetzel 2013; Methot 2013) was used to run all the model configurations in this analysis.

Two of the models in this year's assessment are based on the 2013 final model. The 2013 final model is the 2012 final model, and estimates age-0 recruits for 1977 – 2009 instead of for 1977 – 2011. This model (labeled "2013") is characterized by:

- Three gear types (trawl, longline, and pot), 5 seasons (Jan-Feb, Mar-Apr, May-Aug, Sept-Oct, and Nov-Dec), and three fishery selectivity "seasons" (Jan-Apr, May-Aug, and Sept-Dec);
- Time-varying fishery selectivity-at-length for all gears and seasons (3 – 7 blocks);
- All data for the sub-27 survey omitted;
- Two blocks for catchability for the 27-plus survey, 1984 – 1993 and 1996 – 2013, with the catchability for the latter period set to 1.0;
- Time-varying survey selectivity-at-age for the 27-plus survey (12 blocks); and
- Age-0 recruits estimated through 2009 and recruits for 2010 on set to the average for 1977 – 2009

The adjusted version of the 2013 model (labeled "2013 adj") estimates age-0 recruits through 2011 and uses the recruitment variability multiplier (sigmaR multiplier, value 4.0) for age-0 recruits for 2012, 2013, and 2014.

The additional two models (labeled "S1a" and "S1b") differ significantly from the 2013 final model by:

- Using the GOA NMFS bottom trawl survey as one source of data instead of being split into sub-27 and 27-plus, for the abundance estimates and the length- and age-composition data;
- Using 3 blocks of non-parametric (S1a) or cubic spline-based (S1b) survey selectivity-at-age instead of 12 blocks of double normal selectivity-at-age;
- Including the survey age data as conditional age-at-length data instead of age composition and mean size-at-age data; and
- Using the recruitment variability multiplier (sigmaR multiplier, value 4.0) for age-0 recruits for 2012, 2013, and 2014.

The author's preferred model configuration is Model S1a, with non-parametric survey selectivity-at-age.

Parameters Estimated Outside the Assessment Model

Natural Mortality

In the 1993 BSAI Pacific cod assessment (Thompson and Methot 1993), the natural mortality rate *M* was estimated using SS1 at a value of 0.37. All subsequent assessments of the BSAI and GOA Pacific cod stocks (except the 1995 GOA assessment) have used this value for *M*, until the 2007 assessments, at which time the BSAI assessment adopted a value of 0.34 and the GOA assessment adopted a value of 0.38. Both of these were accepted by the respective Plan Teams and the SSC. The new values were based on Equation 7 of Jensen (1996) and ages at 50% maturity reported by (Stark 2007; see "Maturity" subsection below). In response to a request from the SSC, the 2008 BSAI assessment included further discussion and justification for these values.

For historical completeness, other published estimates of *M* for Pacific cod are shown below:

Area	Author	Year	Value
Eastern Bering Sea	Low	1974	0.30-0.45
	Wespestad et al.	1982	0.70
	Bakkala and Wespestad	1985	0.45
	Thompson and Shimada	1990	0.29
	Thompson and Methot	1993	0.37
Gulf of Alaska	Thompson and Zenger	1993	0.27
	Thompson and Zenger	1995	0.50
British Columbia	Ketchen	1964	0.83-0.99
	Fournier	1983	0.65

The model in this assessment sets *M* independently at the SSC-approved value of 0.38.

Catchability

In the 2009 assessment (Thompson et al. 2009), catchability for the post-1993 27-plus trawl survey was estimated iteratively by matching the average (weighted by numbers at length) of the product of catchability and selectivity for the 60-81 cm size range equal to the point estimate of 0.916 obtained by Nichol et al. (2007). The current model configuration has catchability set to 1.0, per Plan Team request.

Variability in Estimated Age

Variability in estimated age in SS is based on the standard deviation of estimated age. Weighted least squares regression has been used in the past several assessments to estimate a linear relationship between standard deviation and age. The regression was recomputed in 2011, yielding an estimated intercept of 0.023 and an estimated slope of 0.072 (i.e, the standard deviation of estimated age was modeled as 0.023 + 0.072 × age), which gives a weighted R^2 of 0.88. This regression was retained in the present assessment.

Variability in Length at Age

The last few assessments have used a regression approach to estimate the parameters of the schedule of variability in length at age, based on the outside-the-model estimates of standard deviation of length at age and mean length at age from the survey age data (Thompson et al. 2009). The best fit was obtained by assuming that the standard deviation is a linear function of length at age. The regression was re-estimated in 2011 after updating with the most recent data, giving an intercept of 2.248 and a slope of 0.044. This regression was retained in the present assessment.

Use of this regression requires an iterative, "quasi-conditional" procedure for specifying the standard deviations of length at ages 0 and 20, because the regression is a function of length at age, and length at age is estimated conditionally (i.e., inside the model).

In the 2011 model, the age corresponding to the *L1* parameter in the length-at-age equation was increased from 0 to 1.3333 (to correspond to the age of a 1-year-old fish at the time of the survey, when the age data are collected). This made it necessary to re-do the iterative tuning process for this model.

Weight at Length

Season-specific parameters governing the weight-at-length schedule were estimated in the 2010 assessment (based on data through 2008), giving the following values:

Season:	Jan-Feb	Mar-Apr	May-Aug	Sep-Oct	Nov-Dec
α:	8.799×10^{-6}	8.013×10^{-6}	1.147×10^{-5}	1.791×10^{-5}	7.196×10^{-6}
β:	3.084	3.088	2.990	2.893	3.120
Samples:	36,566	29,753	6,950	9,352	2,957

The above parameters were retained in the present assessment.

Maturity

A detailed history and evaluation of parameter values used to describe the maturity schedule for BSAI Pacific cod was presented in the 2005 assessment (Thompson and Dorn 2005). A length-based maturity schedule was used for many years. The parameter values used for this schedule in the 2005 and 2006 assessments were set on the basis of a study by Stark (2007) at the following values: length at 50% maturity = 50 cm and slope of linearized logistic equation = –0.222. However, in 2007, changes in SS allowed for use of either a length-based or an age-based maturity schedule. Beginning with the 2007 assessment, the accepted model has used an age-based schedule with intercept = 4.3 years and slope = –1.963 (Stark 2007). The use of an age-based rather than a length-based schedule follows a recommendation from the maturity study's author (James Stark, ret., Alaska Fisheries Science Center, personal communication). The age-based parameters were retained in the present assessment.

Parameters Estimated Inside the Assessment Model

Parameters estimated conditionally (i.e., within individual SS runs, based on the data and the parameters estimated independently) in the model include the von Bertalanffy growth parameters, two ageing bias parameters, log mean recruitment before and since the 1976-1977 regime shift, annual recruitment deviations, initial fishing mortality, gear-season-and-block-specific fishery selectivity parameters, survey selectivity parameters, and pre-1996 catchability for the 27-plus or full survey.

The same functional form (pattern 24 for length-based selectivity, pattern 20 for age-based selectivity) used in Stock Synthesis to define the selectivity schedules in last year's assessment was used again this year in the models based on the 2013 final model. This functional form, the double normal, is constructed from two underlying and rescaled normal distributions, with a horizontal line segment joining the two peaks. This form uses the following six parameters (selectivity parameters are referenced by these numbers in several of the tables in this assessment):

1. Beginning of peak region (where the curve first reaches a value of 1.0)
2. Width of peak region (where the curve first departs from a value of 1.0)
3. Ascending "width" (equal to twice the variance of the underlying normal distribution)
4. Descending width
5. Initial selectivity (at minimum length/age)
6. Final selectivity (at maximum length/age)

All but the "beginning of peak region" parameter are transformed: The widths are log-transformed and the other parameters are logit-transformed.

Fishery selectivities are length-based and trawl survey selectivities are age-based in these models.

Uniform prior distributions are used for all parameters, except that *dev* vectors are constrained by input standard deviations ("sigma"), which imply a type of joint prior distribution. These input standard deviations were determined iteratively in the 2009 assessment (Thompson et al. 2009) by matching the standard deviations of the estimated *dev*s. The same input standard deviations were used in this assessment.

For all parameters estimated within individual SS runs, the estimator used is the mode of the logarithm of the joint posterior distribution, which is in turn calculated as the sum of the logarithms of the parameter-specific prior distributions and the logarithm of the likelihood function.

In addition to the above, the full set of year-, season-, and gear-specific fishing mortality rates are also estimated conditionally, but not in the same sense as the above parameters. The fishing mortality rates are determined exactly rather than estimated statistically because SS assumes that the input total catch data are true values rather than estimates, so the fishing mortality rates can be computed algebraically given the other parameter values and the input catch data.

Likelihood Components

The model includes likelihood components for trawl survey relative abundance, fishery and survey size composition, survey age composition, survey mean size at age, recruitment, parameter deviations, and "softbounds" (equivalent to an extremely weak prior distribution used to keep parameters from hitting bounds), initial (equilibrium) catch, and survey mean size at age.

In SS, emphasis factors are specified to determine which likelihood components receive the greatest attention during the parameter estimation process. As in previous assessments, all likelihood components were given an emphasis of 1.0 in the present assessment.

Use of Size Composition Data in Parameter Estimation

Size composition data are assumed to be drawn from a multinomial distribution specific to a particular year, gear, and season within the year. In the parameter estimation process, SS weights a given size composition observation (i.e., the size frequency distribution observed in a given year, gear, and season) according to the emphasis associated with the respective likelihood component and the sample size specified for the multinomial distribution from which the data are assumed to be drawn. In developing the model upon which SS was originally based, Fournier and Archibald (1982) suggested truncating the multinomial sample size at a value of 400 in order to compensate for contingencies which cause the sampling process to depart from the process that gives rise to the multinomial distribution. For many years, the Pacific cod assessments assumed a multinomial sample size equal to the square root of the true length sample size, rather than the true length sample size itself. Given the true length sample sizes observed in the GOA Pacific cod data, this procedure tended to give values somewhat below 400 while still providing SS with usable information regarding the appropriate effort to devote to fitting individual length samples.

Although the "square root rule" for specifying multinomial sample sizes gave reasonable values, the rule itself was largely *ad hoc*. In an attempt to move toward a more statistically based specification, the 2007 BSAI assessment (Thompson et al. 2007a) used the harmonic means from a bootstrap analysis of the available fishery length data from 1990-2006. The harmonic means were smaller than the actual sample sizes, but still ranged well into the thousands. A multinomial sample size in the thousands would likely overemphasize the size composition data. As a compromise, the harmonic means were rescaled proportionally in the 2007 BSAI assessment so that the average value (across all samples) was 300. However, the question then remained of what to do about years not covered by the bootstrap analysis (2007 and pre-1990) and what to do about the survey samples. The solution adopted in the 2007 BSAI assessment was based on the consistency of the ratios between the harmonic means (the raw harmonic means, not the rescaled harmonic means) and the actual sample sizes. For the years prior to 1999, the ratio was very consistently close to 0.16, and for the years after 1998, the ratio was very consistently close to 0.34.

This consistency was used to specify input sample sizes for size composition data in all GOA assessments since 2007 as follows: For fishery data, the sample sizes for length compositions from years prior to 1999 were tentatively set at 16% of the actual sample size, and the sample sizes for length compositions from 2007 were tentatively set at 34% of the actual sample size. For the trawl survey, sample sizes were tentatively set at 34% of the actual sample size. Then, all sample sizes were adjusted proportionally so that the average was 300. This method was used to adjust the samples sizes used for the size composition data for analyses performed through 2013.

For the models in this analysis, the number of hauls or trips was used as the sample size instead of the adjusted sample size. The sample sizes for the survey length composition data are the number of hauls in that survey year with cod present.

The fishery catch-at-length data did not have distinct haul or trip identifiers for all samples, so the adjusted sample size for each year, gear type, and season was the total number of samples multiplied by a scaling factor for each gear type and season. The scaling factor was calculated using the federal fishery observer catch-at-length data for 1987 – 2014. The scaling factor is the ratio of total number of hauls or trips to the total number of samples for each gear type and season.

Gear type	Season 1	Season 2	Season 3	Season 4	Season 5
Trawl	0.01805	0.01196	0.03219	0.02926	0.03326
Longline	0.03656	0.02212	0.04550	0.05066	0.05207
Pot	0.02901	0.01877	0.02946	0.04009	0.03467
Other	0.02844	0.04201	0.04424	0.04651	0.02402

The average of the new sample sizes for the fishery catch-at-length data is 185.

Use of Age Composition Data in Parameter Estimation

Like the size composition data, the age composition data are assumed to be drawn from a multinomial distribution specific to a particular gear, year, and season within the year. Input sample sizes for the multinomial distributions were computed by scaling the actual number of otoliths read in each year proportionally such that the average of the input sample sizes was equal to 300. This method was used to adjust the samples sizes used for the age composition data for analyses performed through 2013.

For the models in this analysis, the number of hauls was used as the sample size instead of the adjusted sample size. For the model configurations with survey age data used as conditional age-at-length data, the sample sizes for a given year sum to the number of hauls in that year.

To avoid double counting of the same data, all models ignore size composition data from each year in which survey age composition data or conditional age-at-length data are available.

Results

Model Evaluation

The 2013 final model and three additional models were evaluated, one of which was based on the 2013 final model, and two others which differed in which and how the survey data were used and the survey selectivity-at-age curves. The model evaluation criteria included the relative sizes of the likelihood components, and how well the model estimates fit to the survey indices, the survey age composition or conditional age-at-length data, reasonable curves for fishery sand survey selectivity, and that the model estimated the variance-covariance matrix.

All of the models fit to the same catch, fishery catch-at-length, and survey length composition data. The 2013 final model (“2013”), with recruits estimated through 2009, and the 2013 final model with recruits estimated through 2011 and the sigmaR multiplier used for recent recruits (“2013 adj”) fit to survey data from the 27-plus portion of the GOA NMFS bottom trawl survey. The two models which fit to the survey data as one source and conditional age-at-length survey data estimated 3 periods of non-parametric (“S1a”) or cubic spline-based (“S1b”) survey selectivity-at-age and used the sigmaR multipler for recent recruits.

Comparing and Contrasting the Models

The four models estimated similar patterns for spawning biomass, although the estimates from Models S1a and S1b were higher than those from the 2013 models (Fig. 2.8). The estimates of age-0 recruits

differed between the two sets of models for the first half of the historical period and were similar for the more recent period (Fig. 2.9); however, Models 2013 adj, S1a, and S1b estimated similar values for recent recruitment, as these three models included the sigmaR multiplier on recent recruits. All models fit to the survey indices reasonably well in the middle of the time series, and mediocre fit early and later in the time series, with Models S1a and S1b fitting slightly better to the early and later abundance estimates than the 2013 models (Fig. 2.10).

The two sets of models differed in their fits to their respective sets of survey data with respect to likelihood components (Table 2.14). The 2013 adj model had fewer parameters and a lower total negative log likelihood (NLL) than the 2013 final model. All models had similar fits to the fishery catch-at-length data, although there were differences between the two sets of models for the May-Aug trawl and Sept-Dec trawl data.

The growth parameter estimates also differed between the two sets of models. The 2013 models, which did not include any survey data for fish less than 27 cm, estimated a higher length-at-Amin (age 1.33333) and length-at-A∞ than Models S1a and S1b, with Models S1a and S1b estimating higher values for k than the 2013 models. Models S1a and S1b estimated the CV for length-at-Amin higher than the value used in the 2013 models, 3.13; the estimates of CV for length-at-A∞ for Models S1a and S1b were slightly higher than the value used in the 2013 models, 6.55.

Evaluation Criteria

Models S1a and S1b fit to the full survey abundance index better than the 2013 models fit to the 27-plus survey abundance index. All model configurations had reasonable fishery selectivity-at-length curves; the 2013 models had highly variable survey selectivity-at-age curves. All model configurations converged and produced variance-covariance matrices.

Selection of final model

The two new models, S1a and S1b, are preferred over the 2013 models, as the new models used all of the survey data, instead of data from the 27-plus portion only. The two new models also allowed for the estimation of more flexible survey selectivity-at-age curves and variability in the length-at-age relationship.

Model S1a, the new model with non-parametric survey selectivity-at-age, was selected as the preferred model, as it fit the data better than Model S1b, the new model with cubic spline-based survey selectivity-at-age, although the differences in the NLL components were small.

Final parameter estimates and associated schedules

The fixed and estimated parameters for Model S1a are listed in Table 2.15. Total biomass has decreased from a peak in 1980 to a low in 2008 and is increasing (Fig. 2.11); spawning biomass has a similar pattern with more uncertainty for the recent years (Fig. 2.12). Age-0 recruits had the highest value at the beginning of the time series and has had moderate variability around 290 million since then (Fig. 2.13). The estimates of full survey abundance estimates fit the data reasonably well in the early and middle survey years, and less well in the more recent years, due to the high estimate for 2009 (Fig. 2.14). There does not appear to be a strong relationship between spawning biomass and recruitment (Fig. 2.15). The fits to the survey conditional age-at-length data are good, with moderate variability where there are abundant data (Fig. 2.16). The fits to the survey length composition data are reasonable in most years, with small fish poorly estimated in 2007, 2009, and 2011 (Fig. 2.17); the 1984 survey length composition data were not used in model fitting (Fig. 2.18). The estimated length-at-age relationship is shown in Fig. 2.19.

Survey selectivity-at-age had a maximum at age 4 or 5, with the selectivity at age 1 larger than that of age 2 in most years (Fig. 2.20); fishery selectivity-at-length was more variable, both within and between seasons and gear types (Fig. 2.21). The fits to the fishery catch-at-length data were reasonable in most years, with poor fits to some years in the 1980s for the Jan-Apr trawl fishery (Figs. 2.22 and 2.23).

The seasonal length-at-age and weight-at-age schedules are in Table 2.16. Survey selectivity-at-age by time period is in Table 2.17.

Time Series Results

Definitions

The biomass estimates presented here will be defined in two ways: 1) age 0+ biomass, consisting of the biomass of all fish aged 0 years or greater in a given year; and 2) spawning biomass, consisting of the biomass of all spawning females in a given year. The recruitment estimates presented here will be defined as numbers of age-0 fish in a given year.

Biomass

Table 2.18 shows the time series of GOA Pacific cod female spawning biomass for the years 1977-2014 as estimated last year and this year. The estimated spawning biomass time series are accompanied by their respective standard deviations. Total and spawning biomass are shown in Figs. 2.11 and 2.12.

Recruitment and Numbers at Age

Table 2.19 shows the time series of GOA Pacific cod age-0 recruits for the years 1977-2013 as estimated last year and this year. The estimated recruitment time series are accompanied by their respective standard deviations (Fig. 2.13). Table 2.20 shows the numbers-at-age for 1977-2014.

Survey Data

Fig. 2.14 shows the fit to the full survey abundance estimates. Figure 2.16 shows the fit to the full survey conditional age-at-length data, Fig. 2.17 shows the fit to the full survey length composition data, and Fig. 2.18 shows the 1984 survey length composition data, which were not used in model fitting, and the estimated survey length composition.

Fishing Mortality

Table 2.21 shows the "effective" annual fishing mortality by age and year for ages 1-19 and years 1977-2013. The "effective" annual fishing mortality is $-\ln(N_{a+1,y+1}/N_{a,y})-M$.

Retrospective analysis

Estimates of spawning biomass for Model S1a with the 2013 survey age data included with an ending year of 2005 through 2014 are very similar for 1984 through 2000, and have a consistent downward adjustment for the recent years as more data are included (Fig. 2.24). Relative differences in estimates of spawning biomass show the same pattern for the more recent years (Fig. 2.25).

Harvest Recommendations

Amendment 56 Reference Points

Amendment 56 to the GOA Groundfish Fishery Management Plan (FMP) defines the "overfishing level" (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater. Because reliable estimates of reference points related to maximum sustainable yield (MSY) are currently not available but reliable estimates of reference points related to spawning per recruit are available, Pacific cod in the GOA have generally been managed under Tier 3 of Amendment 56. Tier 3 uses the following reference points:

$B_{40\%}$, equal to 40% of the equilibrium spawning biomass that would be obtained in the absence of fishing; $F_{35\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 35% of the level that would be obtained in the absence of fishing; and $F_{40\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 40% of the level that would be obtained in the absence of fishing. The following formulae apply under Tier 3:

3a) Stock status: $B/B_{40\%} > 1$

$F_{OFL} = F_{35\%}$

$F_{ABC} \leq F_{40\%}$

3b) Stock status: $0.05 < B/B_{40\%} \leq 1$

$F_{OFL} = F_{35\%} \times (B/B_{40\%} - 0.05) \times 1/0.95$

$F_{ABC} \leq F_{40\%} \times (B/B_{40\%} - 0.05) \times 1/0.95$

3c) Stock status: $B/B_{40\%} \leq 0.05$

$F_{OFL} = 0$

$F_{ABC} = 0$

Other useful biomass reference points which can be calculated using this assumption are $B_{100\%}$ and $B_{35\%}$, defined analogously to $B_{40\%}$. These reference points are estimated as follows, based on this year's model, Model S1a:

Reference point:	$B_{35\%}$	$B_{40\%}$	$B_{100\%}$
Spawning biomass:	110,700 t	126,600 t	316,500 t

For a stock exploited by multiple gear types, estimation of $F_{35\%}$ and $F_{40\%}$ requires an assumption regarding the apportionment of fishing mortality among those gear types. For this assessment, the apportionment was based on this year's model's estimates of fishing mortality by gear for the five most recent complete years of data (2009-2013). The average fishing mortality rates for those years implied that total fishing mortality was divided among the three main gear types according to the following percentages: trawl 21%, longline 24%, and pot 55%. This apportionment results in estimates of $F_{35\%}$ and $F_{40\%}$ equal to 0.626 and 0.502, respectively.

Specification of OFL and Maximum Permissible ABC

Spawning biomass for 2015 is estimated by this year's model to be 155,400 t. This is well above the $B_{40\%}$ value of 126,600 t, thereby placing Pacific cod in sub-tier "a" of Tier 3. Given this, the model estimates OFL, maximum permissible ABC, and the associated fishing mortality rates for 2015 and 2016 as follows (2016 values are predicated on the assumption that 2015 catch will equal 2015 maximum permissible ABC):

Units	Year	Overfishing Level (OFL)	Maximum Permissible ABC
Harvest amount	2015	140,300 t	117,200 t
Harvest amount	2016	133,100 t	110,700 t
Fishing mortality rate	2015	0.626	0.502
Fishing mortality rate	2016	0.626	0.502

The age 0+ biomass projections for 2015 and 2016 from this year's model are 583,800 t and 558,200 t, respectively.

ABC Recommendation

Since 2008 the GOA Plan Team and SSC recommended setting the ABC at the maximum permissible level under Tier 3.

Following this practice, this year's ABC recommendations for 2015 and 2016 are at their respective maximum permissible levels of 117,200 t and 110,700 t.

Area Allocation of Harvests

For the past several years, ABC has been allocated among regulatory areas on the basis of the three most recent surveys. The previous proportions based on the 2009-2013 surveys were 33% Western, 64% Central, and 3% Eastern. In the 2013 assessment, the random effects model was used for the 2014 ABC apportionment. Using this method with the trawl survey biomass estimates through 2013, the area-apportioned ABCs are:

	Western	Central	Eastern	Total
Random effects area apportionment (percent)	37.63	59.61	2.75	100.00
2015 ABC	44,102	69,863	3,223	117,200
2016 ABC	41,656	65,988	3,044	110,700

Standard Harvest and Recruitment Scenarios and Projection Methodology

A standard set of projections is required for each stock managed under Tiers 1, 2, or 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 a vector of 2014 estimated numbers at age. 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 rates, 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 TACs for 2015 and 2016, are as follow ("*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 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 4: In all future years, the upper bound on F_{ABC} is set at $F_{60\%}$. (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 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 follow (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 1) above its MSY level in 2014, or 2) above 1/2 of its MSY level in 2014 and expected to be above its MSY level in 2024 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 2027 under this scenario, then the stock is not approaching an overfished condition.)

Projections and Status Determination

Projections corresponding to the standard scenarios are shown for this year's model in Table 2.22 (note that Scenarios 1 and 2 are identical in this case, because the recommended ABC is equal to the maximum permissible ABC).

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. While Scenario 6 gives the best estimate of OFL for 2015, it does not provide the best estimate of OFL for 2016, because the mean 2016 catch under Scenario 6 is predicated on the 2015 catch being equal to the 2015 OFL, whereas the actual 2015 catch will likely be less than the 2015 OFL.

Under the MSFCMA, the Secretary of Commerce is required to report on the status of each U.S. fishery with respect to overfishing. This report involves the answers to three questions: 1) Is the stock being subjected to overfishing? 2) Is the stock currently overfished? 3) Is the stock approaching an overfished condition?

Is the stock being subjected to overfishing? The official catch estimate for the most recent complete year (2013) is 68,593 t. This is less than the 2013 OFL of 107,300 t. Therefore, the stock is not being subjected to overfishing.

Harvest Scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be *overfished*. Any stock that is expected to fall below its MSST in the next two years is defined to be *approaching* an overfished condition. Harvest Scenarios #6 and #7 are used in these determinations as follows:

Is the stock currently overfished? This depends on the stock's estimated spawning biomass in 2014:

a. If spawning biomass for 2014 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.

b. If spawning biomass for 2014 is estimated to be above $B_{35\%}$ the stock is above its MSST.

c. If spawning biomass for 2014 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 2.22). If the mean spawning biomass for 2024 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the stock approaching an overfished condition? This is determined by referring to harvest Scenario #7 (Table 2.22):

a. If the mean spawning biomass for 2017 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2017 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2017 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2027. If the mean spawning biomass for 2027 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

Based on the above criteria and Table 2.22, the stock is not overfished and is not approaching an overfished condition.

Biological reference points, spawning biomass, and ABC values from the current SAFE document and previous GOA Pacific cod SAFE documents for 2001 – 2014 are listed in Table 2.23.

Ecosystem Considerations

Ecosystem Effects on the Stock

A primary ecosystem phenomenon affecting the Pacific cod stock seems to be the occurrence of periodic "regime shifts," in which central tendencies of key variables in the physical environment change on a scale spanning several years to a few decades (Boldt (ed.), 2005). One well-documented example of such a regime shift occurred in 1977, and shifts occurring in 1989 and 1999 have also been suggested (e.g., Hare and Mantua 2000). In the present assessment, an attempt was made to estimate the change in median recruitment of GOA Pacific cod associated with the 1977 regime shift. According to this year's model, pre-1977 median recruitment was only about 32% of post-1976 median recruitment. Establishing a link between environment and recruitment within a particular regime is more difficult. In the 2004 assessment (Thompson et al. 2004), for example, the correlations between age 1 recruits spawned since 1977 and monthly values of the Pacific Decadal Oscillation (Mantua et al. 1997) were computed and found to be very weak.

The prey and predators of Pacific cod have been described or reviewed by Albers and Anderson (1985), Livingston (1989, 1991), Lang et al. (2003), Westrheim (1996), and Yang (2004). The composition of Pacific cod prey varies to some extent by time and area. In terms of percent occurrence, some of the most important items in the diet of Pacific cod in the BSAI and GOA have been polychaetes, amphipods, and crangonid shrimp. In terms of numbers of individual organisms consumed, some of the most important dietary items have been euphausids, miscellaneous fishes, and amphipods. In terms of weight of organisms consumed, some of the most important dietary items have been walleye pollock, fishery offal, yellowfin sole, and crustaceans. Small Pacific cod feed mostly on invertebrates, while large Pacific cod are mainly piscivorous. Predators of Pacific cod include Pacific cod, halibut, salmon shark, northern fur seals, Steller sea lions, harbor porpoises, various whale species, and tufted puffin. Major trends in the most important prey or predator species could be expected to affect the dynamics of Pacific cod to some extent.

Fishery Effects on the Ecosystem

Potentially, fisheries for Pacific cod can have effects on other species in the ecosystem through a variety of mechanisms, for example by relieving predation pressure on shared prey species (i.e., species which serve as prey for both Pacific cod and other species), by reducing prey availability for predators of Pacific cod, by altering habitat, by imposing bycatch mortality, or by "ghost fishing" caused by lost fishing gear.

Incidental Catch of Nontarget Species

Incidental catches of nontarget species in each year 2005-2014 are shown Table 2.6. In terms of average catch over the time series, only sea stars account for more than 250 t per year.

Steller Sea Lions

Sinclair and Zeppelin (2002) showed that Pacific cod was one of the four most important prey items of Steller sea lions in terms of frequency of occurrence averaged over years, seasons, and sites, and was especially important in winter. Pitcher (1981) and Calkins (1998) also showed Pacific cod to be an important winter prey item in the GOA and BSAI, respectively. Furthermore, the size ranges of Pacific cod harvested by the fisheries and consumed by Steller sea lions overlap, and the fishery operates to some extent in the same geographic areas used by Steller sea lion as foraging grounds (Livingston (ed.), 2002).

The Fisheries Interaction Team of the Alaska Fisheries Science Center has been engaged in research to determine the effectiveness of recent management measures designed to mitigate the impacts of the Pacific cod fisheries (among others) on Steller sea lions. Results from studies conducted in 2002-2003 were summarized by Conners et al. (2004). These studies included a tagging feasibility study, which may evolve into an ongoing research effort capable of providing information on the extent and rate to which Pacific cod move in and out of various portions of Steller sea lion critical habitat. Nearly 6,000 cod with spaghetti tags were released, of which approximately 1,000 had been returned as of September 2003.

Seabirds

The following is a summary of information provided by Livingston (ed., 2002): In both the BSAI and GOA, the northern fulmar (*Fulmarus glacialis*) comprises the majority of seabird bycatch, which occurs primarily in the longline fisheries, including the hook and line fishery for Pacific cod (Tables 2.30b and 2.30b). Shearwater (*Puffinus* spp.) distribution overlaps with the Pacific cod longline fishery in the Bering Sea, and with trawl fisheries in general in both the Bering Sea and GOA. Black-footed albatross (*Phoebastria nigripes*) is taken in much greater numbers in the GOA longline fisheries than the Bering Sea longline fisheries, but is not taken in the trawl fisheries. The distribution of Laysan albatross (*Phoebastria immutabilis*) appears to overlap with the longline fisheries in the central and western Aleutians. The distribution of short-tailed albatross (*Phoebastria albatrus*) also overlaps with the Pacific cod longline fishery along the Aleutian chain, although the majority of the bycatch has taken place along the northern portion of the Bering Sea shelf edge (in contrast, only two takes have been recorded in the GOA). Some success has been obtained in devising measures to mitigate fishery-seabird interactions. For example, on vessels larger than 60 ft. LOA, paired streamer lines of specified performance and material standards have been found to reduce seabird incidental take significantly.

Fishery Usage of Habitat

The following is a summary of information provided by Livingston (ed., 2002): The longline and trawl fisheries for Pacific cod each comprise an important component of the combined fisheries associated with the respective gear type in each of the three major management regions (BS, AI, and GOA). Looking at each gear type in each region as a whole (i.e., aggregating across all target species) during the period 1998-2001, the total number of observed sets was as follows:

Gear	BS	AI	GOA
Trawl	240,347	43,585	68,436
Longline	65,286	13,462	7,139

In the BS, both longline and trawl effort was concentrated north of False Pass (Unimak Island) and along the shelf edge represented by the boundary of areas 513, 517 (in addition, longline effort was concentrated along the shelf edge represented by the boundary of areas 521-533). In the AI, both longline and trawl effort were dispersed over a wide area along the shelf edge. The catcher vessel longline fishery in the AI occurred primarily over mud bottoms. Longline catcher-processors in the AI tended to fish more over rocky bottoms. In the GOA, fishing effort was also dispersed over a wide area along the shelf, though pockets of trawl effort were located near Chirikof, Cape Barnabus, Cape Chiniak and Marmot

Flats. The GOA longline fishery for Pacific cod generally took place over gravel, cobble, mud, sand, and rocky bottoms, in depths of 25 fathoms to 140 fathoms.

Impacts of the Pacific cod fisheries on essential fish habitat were further analyzed in an environmental impact statement by NMFS (2005).

Data Gaps and Research Priorities

Understanding of the above ecosystem considerations would be improved if future research were directed toward closing certain data gaps. Such research would have several foci, including the following: 1) ecology of the Pacific cod stock, including spatial dynamics, trophic and other interspecific relationships, and the relationship between climate and recruitment; 2) behavior of the Pacific cod fishery, including spatial dynamics; 3) determinants of trawl survey catchability and selectivity; 4) age determination; 5) ecology of species taken as bycatch in the Pacific cod fisheries, including estimation of biomass, carrying capacity, and resilience; and 6) ecology of species that interact with Pacific cod, including estimation of biomass, carrying capacity, and resilience.

Acknowledgements

Jon Short and Delsa Anderl provided age data. Sonya Elmejjati (ADF&G) and Elisa Russ (ADF&G) provided size composition data from the State of Alaska-managed Pacific cod fishery. Rick Methot developed the Stock Synthesis software used to conduct this assessment, and Ian Taylor developed the R package r4ss and answered numerous questions about the software. Jim Ianelli and Peter Hulson provided the random effects model area apportion values. Grant Thompson and the GOA Groundfish Plan Team provided reviews of this assessment. Many NMFS survey personnel and countless fishery observers collected most of the raw data that were used in this assessment.

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Tables

Table 2.1. Catch (t) for 1991 through 2014 by jurisdiction and gear type (as of 2014-10-14)

	Federal					State				
Year	Trawl	Longline	Pot	Other	Subtotal	Longline	Pot	Other	Subtotal	Total
1991	58,093	7,656	10,464	115	76,328	0	0	0	0	76,328
1992	54,593	15,675	10,154	325	80,747	0	0	0	0	80,747
1993	37,806	8,963	9,708	11	56,488	0	0	0	0	56,488
1994	31,447	6,778	9,161	100	47,485	0	0	0	0	47,485
1995	41,875	10,978	16,055	77	68,985	0	0	0	0	68,985
1996	45,991	10,196	12,040	53	68,280	0	0	0	0	68,280
1997	48,406	10,978	9,065	26	68,476	0	7,224	1,319	8,542	77,018
1998	41,570	10,012	10,510	29	62,121	0	9,088	1,316	10,404	72,525
1999	37,167	12,363	19,015	70	68,614	0	12,075	1,096	13,171	81,785
2000	25,443	11,660	17,351	54	54,508	0	10,388	1,643	12,031	66,560
2001	24,383	9,910	7,171	155	41,619	0	7,836	2,084	9,920	51,542
2002	19,810	14,666	7,694	176	42,345	0	10,423	1,714	12,137	54,483
2003	18,885	9,525	12,740	161	41,311	60	7,966	3,242	11,267	52,579
2004	17,513	10,329	14,965	400	43,206	51	10,602	2,765	13,418	56,625
2005	14,549	5,732	14,749	203	35,234	26	9,653	2,673	12,351	47,585
2006	13,131	10,228	14,795	118	38,272	47	8,890	646	9,582	47,854
2007	14,774	11,512	13,477	40	39,803	165	10,886	574	11,625	51,428
2008	20,293	12,125	11,230	62	43,710	233	13,438	1,568	15,239	58,949
2009	13,981	13,879	11,573	199	39,632	503	10,295	2,500	13,298	52,931
2010	21,791	16,463	20,114	427	58,795	583	14,604	4,045	19,231	78,027
2011	16,365	16,377	29,228	721	62,691	857	16,668	4,625	22,150	84,841
2012	20,182	14,477	21,239	722	56,620	852	15,937	4,613	21,402	78,022
2013	21,694	12,975	17,011	476	52,156	980	14,154	1,303	16,437	68,593
2014	24,953	11,224	16,031	1,029	53,237	846	17,453	2,853	21,151	74,388

Table 2.2 History of Pacific cod catch (t, includes catch from State waters), Federal TAC (does not include State guideline harvest level), ABC, and OFL. ABC was not used in management of GOA groundfish prior to 1986. Catch for 2014 is current through 2014-10-14. The values in the column labeled "TAC" correspond to "optimum yield" for the years 1980-1986, "target quota" for the year 1987, and true TAC for the years 1988-present. The ABC value listed for 1987 is the upper bound of the range. Source: NPFMC staff.

Year	Catch	TAC	ABC	OFL
1980	35,345	60,000	-	-
1981	36,131	70,000	-	-
1982	29,465	60,000	-	-
1983	36,540	60,000	-	-
1984	23,898	60,000	-	-
1985	14,428	60,000		-
1986	25,012	75,000	136,000	-
1987	32,939	50,000	125,000	-
1988	33,802	80,000	99,000	-
1989	43,293	71,200	71,200	-
1990	72,517	90,000	90,000	-
1991	76,328	77,900	77,900	-
1992	80,747	63,500	63,500	87,600
1993	56,488	56,700	56,700	78,100
1994	47,485	50,400	50,400	71,100
1995	68,985	69,200	69,200	126,000
1996	68,280	65,000	65,000	88,000
1997	77,018	69,115	81,500	180,000
1998	72,525	66,060	77,900	141,000
1999	81,785	67,835	84,400	134,000
2000	66,560	59,800	76,400	102,000
2001	51,542	52,110	67,800	91,200
2002	54,483	44,230	57,600	77,100
2003	52,579	40,540	52,800	70,100
2004	56,625	48,033	62,810	102,000
2005	47,585	44,433	58,100	86,200
2006	47,854	52,264	68,859	95,500
2007	51,428	52,264	68,859	97,600
2008	58,949	50,269	64,493	88,660
2009	52,931	41,807	55,300	66,000
2010	78,027	59,563	79,100	94,100
2011	84,841	65,100	86,800	102,600
2012	78,022	65,700	87,600	104,000
2013	68,593	60,600	88,500	107,300
2014	74,388	-	117,200	140,300

Table 2.3. History of GOA Pacific cod allocations by regulatory area (in percent)

Year(s)	Western	Central	Eastern
1977-1985	28	56	16
1986	40	44	16
1987	27	56	17
1988-1989	19	73	8
1990	33	66	1
1991	33	62	5
1992	37	61	2
1993-1994	33	62	5
1995-1996	29	66	5
1997-1999	35	63	2
2000-2001	36	57	7
2002	39	55	6
2002	38	56	6
2003	39	55	6
2003	38	56	6
2004	36	57	7
2004	35.3	56.5	8.2
2005	36	57	7
2005	35.3	56.5	8.2
2006	39	55	6
2006	38.54	54.35	7.11
2007	39	55	6
2007	38.54	54.35	7.11
2008	39	57	4
2008	38.69	56.55	4.76
2009	39	57	4
2009	38.69	56.55	4.76
2010	35	62	3
2010	34.86	61.75	3.39
2011	35	62	3
2011	35	62	3
2012	35	62	3
2012	32	65	3
2013	38	60	3
2014	38	60	3

Table 2.4 Estimated retained-and discarded GOA Pacific cod from federal waters (source: AKFIN; as of 2014-11-07)

Year	Discarded	Retained	Grand Total
1991	1,429	74,899	76,328
1992	3,873	76,199	80,073
1993	5,844	49,865	55,709
1994	3,109	43,540	46,649
1995	3,525	64,560	68,085
1996	7,534	60,530	68,064
1997	4,783	63,057	67,840
1998	1,709	59,811	61,520
1999	1,617	66,311	67,928
2000	1,362	52,904	54,266
2001	1,904	39,715	41,619
2002	3,715	38,631	42,345
2003	2,483	50,096	52,579
2004	1,269	55,355	56,625
2005	1,044	46,541	47,585
2006	1,840	46,014	47,854
2007	1,441	49,988	51,428
2008	3,308	55,720	59,027
2009	3,944	49,252	53,196
2010	2,870	75,444	78,314
2011	2,074	83,170	85,244
2012	972	77,050	78,022
2013	4,632	63,961	68,593
2014	4,692	75,166	79,858

Table 2.5 – Groundfish bycatch, discarded and retained, for GOA Pacific cod as target species (AKFIN; as of 2014-10-09)

	2009		2010		2011		2012		2013		2014	
	D	R	D	R	D	R	D	R	D	R	D	R
Arrowtooth Flounder	644.9	109.0	322.0	66.6	310.4	268.8	332.7	498.9	885.3	575.9	816.7	476.4
Atka Mackerel	46.5	0.9	57.1	0.1	16.6	0.2	12.4	1.9	21.4	0.1	1.4	0.0
Flathead Sole	25.3	95.0	41.1	33.2	19.2	149.7	52.3	157.5	249.4	178.5	116.4	175.9
GOA Deep Water Flatfish	1.5	0.4	12.6	1.3	8.5	3.8	0.2	3.1	18.3	5.6	0.8	8.7
GOA Demersal Shelf Rockfish		2.0		1.8		3.0		0.5		1.7		1.4
GOA Dusky Rockfish							23.1	9.4	17.4	6.5	2.8	39.1
GOA Pelagic Shelf Rockfish	32.7	11.2	12.8	14.8	10.0	7.5						
GOA Rex Sole	0.0	66.3	8.9	6.8	8.6	31.6	27.8	109.9	17.5	95.1	11.9	72.5
GOA Rougheye Rockfish	4.0	3.3	4.9	2.6	0.9	5.1	0.4	4.3	0.4	5.0	0.4	4.2
GOA Shallow Water Flatfish	43.5	204.9	161.5	517.3	127.7	816.3	125.1	686.3	173.7	792.0	292.6	511.8
GOA Shortraker Rockfish	3.5	4.0	4.7	3.7	3.8	4.1	2.0	4.0	1.3	4.7	0.4	4.5
GOA Skate, Big	211.0	339.2	333.9	613.6	299.0	662.5	83.3	671.6	227.1	422.7	463.8	179.0
GOA Skate, Longnose	115.9	208.8	175.4	255.0	144.4	230.1	9.3	317.3	114.8	320.4	68.2	223.7
GOA Skate, Other	623.6	65.8	919.1	158.1	605.2	195.0	584.6	119.3	899.1	11.0	669.5	58.7
GOA Thornyhead Rockfish	0.4	7.4	0.6	5.4	0.7	7.0	0.3	2.7	5.0	4.1	0.2	10.5
Halibut									182.5	36.6	136.4	23.7
Northern Rockfish	10.8	13.9	13.9	4.7	8.2	8.2	26.8	24.0	48.1	61.9	2.0	58.7
Octopus					482.1	379.4	135.0	273.1	108.8	211.7	258.0	313.3
Other Rockfish	23.7	11.8	19.8	10.1	20.1	33.5	6.9	38.6	28.7	38.6	9.2	25.2
Other Species	498.1	264.1	596.9	233.4								
Pacific Ocean Perch	4.4	38.2	0.2	8.5	1.3	18.5	7.5	45.8	7.0	5.3	0.3	14.2
Pollock	123.2	353.2	205.5	423.7	47.5	503.7	710.4	970.5	109.6	750.4	82.4	1186.9
Sablefish	25.5	19.1	46.9	72.8	49.4	60.3	0.4	23.1	73.7	16.4	6.4	33.7
Sculpin					332.9	10.3	414.4	42.2	481.1	4.7	368.7	6.1
Shark					90.7	0.7	18.8	0.6	66.1	0.1	66.7	0.2
Squid									0.2			
Total	2,937.8	2,433.4	2,587.1	3,399.3	2,573.7	4,004.8	3,736.5	3,549.7	3,375.1	3,428.4	2,937.8	2,433.4

Table 2.6 - Incidental catch (t) of non-target species groups by GOA Pacific cod fisheries, 2004-2013 (as of 2014-10-09)

Species/group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Benthic urochordata	0.0	0.0	0.0	0.6	3.0	0.0	0.2	0.0	0.0	0.1
Birds	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.1
Bivalves	1.3	2.1	1.2	1.7	4.2	2.7	6.2	1.7	2.0	1.4
Brittle star unidentified	0.2	0.1	0.3	0.1	0.0	0.1	2.1	0.0	0.1	0.0
Capelin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corals Bryozoans	0.0	0.1	0.2	0.0	1.7	0.0	0.7	4.0	0.1	0.9
Dark Rockfish	0.0	0.0	0.0	0.3	2.7	12.4	2.5	1.5	1.1	1.8
Eelpouts	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.3	0.2	0.1
Eulachon	0.0	2.4	0.0	0.1	0.0	0.6	0.0	0.0	0.0	0.3
Giant Grenadier	0.0	21.9	81.5	31.0	51.3	142.7	60.4	175.8	144.5	142.4
Greenlings	1.5	3.7	0.8	7.1	1.3	0.8	0.8	1.9	1.2	0.4
Grenadier	0.0	0.6	0.0	66.0	6.6	11.3	8.2	0.0	24.1	22.6
Gunnels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hermit crab unidentified	0.4	0.5	1.7	2.9	3.9	2.1	0.8	0.8	1.8	0.4
Invertebrate unidentified	0.0	12.6	1.6	1.3	0.1	1.6	9.1	4.5	0.4	0.5
Misc crabs	1.7	0.7	6.6	2.4	1.5	3.4	2.5	2.2	2.9	2.9
Misc crustaceans	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
Misc fish	152.5	176.0	539.4	210.5	99.0	89.0	134.2	224.3	91.9	132.6
Misc inverts (worms etc)	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other osmerids	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Pacific Sand lance	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Pandalid shrimp	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Polychaete unidentified	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scypho jellies	1.1	4.6	0.1	0.4	0.2	11.1	0.8	0.6	1.8	0.9
Sea anemone unidentified	0.7	0.3	5.1	6.0	6.6	7.2	8.8	6.0	7.7	4.0
Sea pens whips	0.0	3.2	1.0	0.0	3.3	3.9	1.4	0.8	2.5	1.7
Sea star	937.7	703.5	299.0	316.5	471.9	871.0	718.0	462.5	553.2	545.9
Snails	4.8	2.9	0.8	0.9	2.5	0.7	1.3	3.7	2.6	25.0
Sponge unidentified	1.0	1.2	0.0	1.1	1.6	0.7	0.5	0.4	0.5	0.4
Stichaeidae	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.1	0.0
Surf smelt	0.4	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
urchins dollars cucumbers	1.1	1.0	3.2	0.5	1.3	0.5	2.2	3.6	1.3	1.1

Table 2.7 Catch (t) of Pacific cod by year, gear, and season for the years 1991-2014 as configured in the stock assessment models (as of 2014-10-14) values for 2014 season 5 (Nov – Dec) were estimated given the average fraction of catch in season 5 for 2003 – 2012 (0.0337) and the average fraction of each gear type in season 5 for 2004 – 2013 (0.1089, 0.3490, 0.5421, for trawl, longline, and pot, respectively).

	Trawl				Longline				Pot			
Year	Jan-Apr	May-Aug	Sep-Dec	Total	Jan-Apr	May-Aug	Sep-Dec	Total	Jan-Apr	May-Aug	Sep-Dec	Total
1991	55,862	778	1,493	58,133	7,052	540	72	7,664	9,413	183	934	10,530
1992	51,479	1,828	1,500	54,807	12,545	966	2,243	15,754	9,698	19	470	10,187
1993	33,637	2,625	1,551	37,813	7,999	784	181	8,964	9,384	326	0	9,710
1994	29,150	1,433	877	31,460	6,431	299	52	6,782	8,714	33	496	9,243
1995	38,198	1,117	2,597	41,912	10,553	214	227	10,994	15,410	76	592	16,078
1996	40,506	4,023	1,494	46,023	9,885	215	106	10,206	12,025	27	0	12,052
1997	40,407	1,970	6,044	48,421	10,213	390	379	10,982	13,411	2,356	1,848	17,615
1998	34,372	4,014	3,200	41,586	9,307	444	264	10,015	17,652	2,137	1,136	20,925
1999	30,122	1,520	5,550	37,192	11,808	403	158	12,369	22,793	6,859	2,572	32,224
2000	21,579	3,148	750	25,477	11,401	170	107	11,678	25,768	2,938	699	29,405
2001	14,522	2,753	7,228	24,503	9,644	135	142	9,921	12,275	2,885	1,958	17,118
2002	14,466	4,069	1,309	19,844	11,410	161	3,159	14,730	13,049	2,288	4,573	19,910
2003	10,796	3,780	5,271	19,847	8,932	579	765	10,276	19,399	0	3,057	22,456
2004	9,221	2,429	6,400	18,050	8,259	268	2,046	10,573	23,334	276	4,392	28,002
2005	9,658	2,131	3,159	14,948	3,838	174	1,875	5,887	21,361	250	5,139	26,749
2006	10,028	2,081	1,332	13,441	6,156	251	3,948	10,355	21,417	261	2,381	24,059
2007	9,613	2,357	3,127	15,097	7,094	401	4,262	11,757	20,030	546	3,997	24,574
2008	11,157	4,108	6,118	21,382	9,312	642	2,618	12,572	20,394	0	4,600	24,994
2009	6,877	4,616	3,879	15,372	9,609	1,372	3,954	14,935	19,027	0	3,596	22,624
2010	11,007	5,096	7,728	23,830	11,667	774	5,129	17,571	30,986	1	5,638	36,626
2011	9,570	1,940	5,733	17,244	10,248	1,229	6,301	17,779	36,953	102	12,764	49,819
2012	15,875	1,531	2,789	20,182	11,692	336	3,301	15,328	27,991	0	9,185	39,280
2013	14,646	1,953	5,096	21,694	9,577	2,061	2,318	13,955	24,771	0	6,393	29,044
2014	16,012	5,651	6,157	29,868	10,308	801	4,673	16,318	28,265	101	7,076	36,722

Table 2.8 – Noncommercial fishery catch (in t); total source amounts less than 1 mt were omitted (AFSC for GOA bottom trawl survey values; AKFIN for other values, as of 2014-11-03)

Source	2005	2006	2007	2008	2009	2010	2011	2012	2013
Annual Longline Survey	13.88	18.10	17.33	16.71	30.99	33.22	27.07	30.50	22.73
Golden King Crab Pot Survey	0.15	0.43	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Gulf of Alaska Bottom Trawl Survey	20.73	0.00	18.35	0.00	53.11	0.00	29.37	0.00	26.22
IPHC Annual Longline Survey	0.00	0.00	0.00	0.00	0.00	142.30	124.36	85.60	123.20
Large-Mesh Trawl Survey	1.13	0.64	1.03	0.21	0.96	11.70	17.01	20.50	18.58
Sablefish Longline Survey	0.63	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shumigans Acoustic Survey	0.00	0.00	0.00	0.00	0.00	1.03	0.00	0.00	0.00
Small-Mesh Trawl Survey	0.25	0.27	0.11	0.00	0.00	1.89	1.65	2.66	1.68
Sport Fishery	0.00	0.00	0.00	0.00	0.00	113.66	155.53	143.76	131.13

Table 2.9 Age compositions observed by the sub-27 and 27-plus GOA bottom trawl survey, 1987-2011. Nact = actual sample size (these values get rescaled so that the average across the combined sub-27 and 27-plus age compositions equals 300; the 27-plus age compositions only are rescaled in models omitting the sub-27 data). The record for 1987 is shaded to indicate that these data are ignored in the fitting process due to very low sample size.

Year	Nact	0	1	2	3	4	5	6	7	8	9	10	11	12+
1987	28	0.000	0.921	0.078	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	20	0.000	0.995	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	110	0.000	0.981	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	100	0.000	0.951	0.049	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	98	0.000	0.971	0.029	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2001	125	0.000	0.919	0.081	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	57	0.000	0.895	0.105	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2005	65	0.000	0.870	0.130	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2007	93	0.000	0.997	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2009	83	0.000	0.937	0.053	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2011	66	0.000	0.981	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Year	Nact	0	1	2	3	4	5	6	7	8	9	10	11	12+
1987	110	0.000	0.006	0.248	0.253	0.251	0.157	0.055	0.019	0.009	0.002	0.001	0.000	0.000
1990	473	0.000	0.002	0.078	0.261	0.253	0.200	0.120	0.049	0.025	0.008	0.002	0.000	0.000
1993	750	0.000	0.004	0.102	0.242	0.288	0.202	0.112	0.030	0.016	0.004	0.001	0.000	0.000
1996	671	0.000	0.002	0.064	0.180	0.216	0.222	0.201	0.093	0.016	0.005	0.001	0.001	0.000
1999	584	0.000	0.001	0.052	0.173	0.239	0.278	0.161	0.058	0.026	0.009	0.002	0.001	0.000
2001	626	0.000	0.013	0.115	0.251	0.223	0.168	0.131	0.066	0.023	0.007	0.003	0.000	0.001
2003	654	0.000	0.001	0.032	0.188	0.275	0.285	0.133	0.052	0.027	0.004	0.001	0.001	0.001
2005	471	0.000	0.000	0.075	0.125	0.224	0.289	0.170	0.045	0.034	0.019	0.012	0.003	0.003
2007	378	0.000	0.018	0.279	0.295	0.156	0.110	0.039	0.023	0.014	0.027	0.022	0.002	0.014
2009	463	0.000	0.000	0.100	0.337	0.316	0.174	0.052	0.011	0.007	0.002	0.001	0.000	0.000
2011	753	0.000	0.001	0.106	0.415	0.291	0.148	0.034	0.005	0.001	0.000	0.000	0.000	0.000

Table 2.10 – Relative sub-27 and 27-plus size composition from the 1984 – 2013 bottom trawl surveys (in 1-cm bins from 4 to 110 cm)

Year	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007	2009	2011	2013
N	36	26	16	56	63	25	67	15	26	90	74	24	80
4	0	0	0	0	0	0	1	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	5	0	1	0	1
6	5	0	6	9	0	0	0	1	0	0	1	0	1
7	45	0	18	5	0	0	0	0	0	0	0	1	0
8	100	12	21	1	3	0	0	0	1	0	2	0	2
9	117	25	46	0	0	0	1	0	0	0	0	0	0
10	65	47	21	0	0	0	0	0	0	0	1	0	1
11	26	25	0	0	0	1	4	0	0	2	4	1	2
12	4	17	1	1	6	3	8	0	1	3	16	1	16
13	2	2	0	11	15	2	12	1	3	6	60	6	47
14	1	1	0	17	44	12	29	4	5	33	138	5	47
15	0	4	0	36	77	13	33	3	20	75	151	7	59
16	9	10	3	122	99	22	36	15	27	137	131	33	72
17	5	27	6	218	110	35	48	14	39	191	113	43	115
18	11	52	5	156	132	43	77	14	45	223	139	52	163
19	21	57	17	124	123	50	102	31	59	238	130	53	171
20	26	70	25	62	138	61	117	33	55	194	115	52	134
21	32	54	25	59	106	53	138	39	71	168	116	70	135
22	43	39	23	60	119	64	134	44	65	131	126	45	156
23	37	37	40	61	103	53	174	33	43	127	93	44	138
24	51	34	35	78	95	35	190	24	47	111	75	38	146
25	66	18	23	79	69	31	151	34	33	94	66	31	127
26	69	9	13	49	61	34	138	28	27	119	42	14	121
Year	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007	2009	2011	2013
N	895	946	537	789	519	356	333	422	305	350	783	552	414
27	100	13	20	54	42	28	97	32	33	104	72	13	105
28	101	30	11	51	30	24	91	22	20	81	91	13	93
29	92	47	14	42	20	21	73	21	11	73	163	27	88
30	115	91	19	57	19	37	70	22	23	65	209	18	66
31	134	131	43	68	25	34	70	25	31	65	202	37	61
32	154	168	45	90	47	57	62	37	46	78	211	65	55
33	181	203	62	117	52	75	79	54	51	87	212	76	39
34	176	257	74	120	52	92	74	74	64	89	257	100	48
35	185	277	81	136	64	91	71	93	72	87	283	113	70
36	184	301	67	143	89	101	78	113	87	126	299	120	56
37	196	335	86	144	100	109	71	119	76	128	330	130	76
38	189	371	115	179	127	104	94	149	95	165	302	146	75
39	186	394	106	204	163	114	111	161	82	155	361	157	106
40	214	461	152	274	171	105	106	204	83	195	384	179	132
41	234	403	130	325	193	137	124	198	116	182	393	301	164
42	247	350	172	398	199	142	119	225	87	209	438	336	211
43	277	365	158	404	189	181	133	255	103	226	437	406	214
44	335	332	207	452	209	165	133	312	90	215	474	392	247
45	420	305	213	424	205	179	148	294	104	211	493	423	277
46	492	302	223	405	193	195	140	254	99	227	501	422	241
47	579	359	233	419	194	178	158	234	103	178	488	402	220
48	705	469	328	432	173	209	164	274	115	207	471	356	236
49	786	584	311	373	203	176	176	250	117	179	503	391	241
50	854	680	394	426	193	213	162	266	132	178	503	359	228
51	900	781	344	439	190	169	195	236	138	132	486	337	213
52	886	794	354	538	222	209	172	279	161	140	563	333	212
53	866	818	359	519	222	210	167	260	201	134	539	370	201
54	871	787	386	593	246	238	188	278	246	156	555	439	218
55	835	820	379	623	274	240	178	314	246	166	534	406	295
56	806	744	420	584	272	243	169	277	262	169	564	417	280
57	720	676	471	511	347	284	177	312	253	211	476	432	315
58	705	665	436	559	358	287	194	286	276	225	512	415	343
59	625	644	487	558	353	280	188	307	272	212	411	391	329
60	554	604	472	528	414	262	194	265	257	194	397	373	342
61	482	576	463	490	471	245	214	253	219	228	349	324	344
62	374	529	398	482	458	226	178	212	241	193	337	362	316
63	369	506	361	426	443	191	238	218	185	188	312	291	275

Table 2.10 – Relative sub-27 and 27-plus size composition from the 1984 – 2013 bottom trawl surveys (in 1-cm bins from 4 to 110 cm)

Year	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007	2009	2011	2013
N	36	26	16	56	63	25	67	15	26	90	74	24	80
64	264	488	344	376	418	182	211	181	179	171	294	284	241
65	210	418	315	385	412	171	203	158	146	142	252	211	226
66	185	341	252	388	407	156	167	155	148	144	252	197	189
67	173	302	208	360	350	132	148	120	116	125	189	149	178
68	137	256	173	328	274	128	133	117	114	110	190	150	127
69	127	224	147	280	260	122	122	92	97	106	134	94	112
70	101	190	161	261	238	97	129	89	81	73	114	84	92
71	77	158	114	188	179	75	86	73	71	63	87	61	68
72	83	138	108	179	122	74	94	72	47	77	102	62	60
73	90	104	78	143	113	66	58	67	46	55	70	34	56
74	57	101	57	127	112	51	67	50	34	46	56	24	38
75	76	83	54	89	75	34	50	48	36	56	56	28	28
76	81	72	49	96	71	34	45	39	38	33	52	30	16
77	60	52	43	81	58	31	38	36	23	37	38	18	11
78	69	47	45	53	41	28	26	36	23	26	32	12	10
79	80	86	35	54	52	22	20	36	11	14	16	12	14
80	91	31	26	41	36	10	34	26	22	16	19	15	11
81	48	20	25	41	42	10	24	24	19	10	17	8	7
82	57	26	31	35	30	16	17	27	13	7	21	8	6
83	41	31	23	22	15	11	18	16	12	11	9	4	5
84	32	20	28	21	21	5	12	14	21	5	9	10	7
85	31	26	17	23	21	11	8	11	11	3	7	2	3
86	24	23	20	16	17	3	11	9	5	2	7	4	2
87	28	17	19	12	12	3	6	10	10	6	7	4	1
88	20	16	21	13	12	2	11	4	9	2	4	3	2
89	17	16	28	21	10	8	6	4	10	4	3	3	2
90	22	7	15	6	15	1	5	6	18	3	2	2	1
91	16	9	15	6	19	2	9	6	12	1	0	2	2
92	14	9	5	7	11	0	6	3	12	2	4	1	1
93	10	8	4	10	7	3	6	1	12	4	2	0	1
94	7	6	7	6	3	0	6	0	6	2	5	0	0
95	6	10	3	9	11	1	6	2	13	6	2	1	0
96	4	5	7	4	5	0	6	1	13	1	2	2	0
97	3	3	4	4	5	2	4	1	11	2	1	0	2
98	5	3	4	5	3	2	3	1	12	2	0	0	1
99	1	6	1	4	2	3	2	0	10	0	3	0	0
100	3	2	1	7	5	2	6	0	6	1	1	0	1
101	1	2	3	4	2	0	2	0	7	1	1	0	0
102	1	3	3	3	3	1	2	0	2	1	2	0	1
103	0	1	2	1	2	0	2	0	5	3	0	0	0
104	0	0	0	1	3	0	1	0	6	2	0	0	0
105	0	3	1	1	2	0	1	0	4	0	1	0	0
106	0	0	0	0	0	0	0	0	1	1	0	0	0
107	0	0	0	1	1	0	0	0	0	1	0	0	0
108	0	0	0	0	0	0	0	0	0	0	0	1	0
109	0	1	0	0	0	0	0	0	0	1	0	0	0
110+	1	1	0	0	0	0	0	0	0	1	0	0	1

Table 2.11 – Mean size-at-age (in cm) observed by the sub-27 and 27-plus GOA bottom trawl survey, 1987-2011

Year	0	1	2	3	4	5	6	7	8	9	10	11	12+
1987	0.000	20.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.000	21.835	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	0.000	20.384	25.652	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	0.000	20.440	25.366	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	0.000	20.571	26.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2001	0.000	21.141	25.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	0.000	21.131	25.041	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2005	0.000	18.941	24.493	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2007	0.000	17.383	26.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2009	0.000	19.794	24.898	25.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2011	0.000	20.829	25.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Year	0	1	2	3	4	5	6	7	8	9	10	11	12+
1987	0.000	0.000	34.251	43.215	52.832	59.235	64.794	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.000	27.262	35.068	45.917	53.472	59.940	65.134	70.773	77.170	83.949	89.101	98.223	102.518
1993	0.000	27.547	34.306	44.040	52.123	58.893	65.611	70.367	74.692	87.551	94.429	97.411	0.000
1996	0.000	27.101	32.319	41.564	52.395	59.236	64.132	68.530	75.524	82.825	93.850	97.313	85.989
1999	0.000	27.361	32.955	41.050	48.717	58.167	64.406	71.194	71.791	77.824	80.160	83.688	0.000
2001	0.000	27.444	32.840	42.651	52.148	58.807	65.611	70.623	74.937	84.301	86.745	85.000	78.723
2003	0.000	29.298	32.645	43.834	48.972	57.854	64.947	71.741	75.490	84.096	83.477	75.670	75.965
2005	0.000	0.000	33.353	41.202	51.274	57.144	62.322	68.165	78.232	90.879	95.862	95.153	91.745
2007	0.000	27.470	35.212	43.362	55.483	59.665	63.519	70.055	69.838	98.805	103.660	92.826	0.000
2009	0.000	27.000	33.708	44.697	55.494	61.956	65.694	74.054	74.209	84.884	92.512	0.000	0.000
2011	0.000	27.000	35.708	44.863	53.947	62.018	65.501	75.620	83.818	0.000	93.530	0.000	106.283

Table 2.12 – Sample sizes of fish for the mean size-at-age observed by the sub-27 and 27-plus GOA bottom trawl survey, 1987-2011

Year	0	1	2	3	4	5	6	7	8	9	10	11	12+
1987	0	28	0	0	0	0	0	0	0	0	0	0	0
1990	0	20	0	0	0	0	0	0	0	0	0	0	0
1993	0	108	2	0	0	0	0	0	0	0	0	0	0
1996	0	92	8	0	0	0	0	0	0	0	0	0	0
1999	0	95	3	0	0	0	0	0	0	0	0	0	0
2001	0	113	8	0	0	0	0	0	0	0	0	0	0
2003	0	52	5	0	0	0	0	0	0	0	0	0	0
2005	0	50	15	0	0	0	0	0	0	0	0	0	0
2007	0	92	1	0	0	0	0	0	0	0	0	0	0
2009	0	77	5	1	0	0	0	0	0	0	0	0	0
2011	0	65	1	0	0	0	0	0	0	0	0	0	0
Year	0	1	2	3	4	5	6	7	8	9	10	11	12+
1987	0	0	20	56	22	11	1	0	0	0	0	0	0
1990	0	3	50	95	81	78	59	41	36	20	7	2	1
1993	0	9	90	116	113	113	117	66	53	23	10	2	0
1996	0	2	45	146	123	100	107	92	34	17	3	1	1
1999	0	1	26	76	119	136	103	58	29	11	5	2	0
2001	0	9	87	120	106	81	84	64	34	15	8	3	1
2003	0	2	37	114	134	126	86	60	39	10	1	2	2
2005	0	0	64	87	83	78	84	39	21	6	4	1	1
2007	0	5	47	86	73	65	34	36	25	4	1	2	0
2009	0	1	60	120	105	86	47	19	16	5	4	0	0
2011	0	1	102	189	178	175	76	25	5	0	1	0	1

Table 2.13 Pacific cod abundance measured in biomass (t) and numbers of fish (1000s), as assessed by the GOA bottom trawl survey. Point estimates are shown along with coefficients of variation. The two right-hand sections show the total abundance divided into fish 27 cm or larger and fish smaller than 27 cm (totals are very slightly different in the first four years due to exclusion of tows with no length data from the strata extrapolations).

	All lengths				27-plus		Sub-27cm	
Year	Biomass(t)	CV	Abundance	CV	Abundance	CV	Abundance	CV
1984	550,971	0.145	320,525	0.156	296,057	0.175	19,526	0.596
1987	394,987	0.129	247,020	0.185	238,165	0.234	6,772	0.374
1990	416,788	0.152	212,132	0.208	193,577	0.243	14,739	0.412
1993	409,848	0.178	231,963	0.190	214,244	0.210	17,021	0.372
1996	538,154	0.198	319,068	0.215	234,528	0.172	84,540	0.615
1999	306,413	0.126	166,584	0.112	157,019	0.118	9,565	0.272
2001	257,614	0.202	158,424	0.180	137,041	0.203	21,384	0.270
2003	297,402	0.149	159,749	0.129	153,895	0.134	5,854	0.231
2005	308,091	0.258	139,852	0.208	127,282	0.221	12,570	0.388
2007	233,310	0.138	192,025	0.175	134,261	0.163	57,764	0.425
2009	752,651	0.296	573,509	0.286	422,370	0.239	151,139	0.867
2011	500,975	0.135	348,060	0.177	339,410	0.178	8,650	0.347
2013	506,362	0.148	337,992	0.151	257,315	0.139	80,677	0.437

Table 2.14. Number of parameters, negative log-likelihoods, and growth parameters for all model configurations (smaller indicates better fit to data).

	2013 model	2013 model with adj	Non-parametric srv sel	Splines srv sel
Number of parameters	254	249	230	213
Likelihood components (-ln)				
Survey indices	-1.61	-1.99	-14.01	-12.15
Length compositions	2095.25	2089.93	2202.93	2206.40
Age compositions	56.78	56.48	415.39	418.49
Size-at-age	398.85	396.00	-	-
Recruitment	-21.67	-24.90	-17.52	-17.75
Forecast recruitment	-	4.49	4.22	5.37
27-plus survey indices	-1.61	-1.99	-	-
Full survey indices	-	-	-14.01	-12.14
Total	2527.66	2520.06	2591.09	2600.41
Length composition likelihoods (-ln)				
Jan-Apr Trawl	298.13	294.52	299.84	298.54
Jan-Apr LL	150.88	147.09	140.98	141.14
Jan-Apr Pot	223.57	222.95	212.43	212.96
May-Aug Trawl	452.74	453.65	438.86	438.33
May-Aug LL	136.67	137.26	133.87	134.10
May-Aug Pot	336.42	337.93	334.27	334.10
Sep-Dec Trawl	267.44	267.20	271.28	271.14
Sep-Dec LL	45.78	46.09	45.35	45.41
Sep-Dec Pot	168.59	169.05	168.04	168.86
27-plus survey	15.04	14.18	-	-
Full survey	-	-	158.02	161.83
Age compositions likelihoods (-ln)				
Age 27-plus survey	56.78	56.48	-	-
Age full survey	-	-	415.39	418.49
Mean size-at-age likelihoods (-ln)				
Age 27-plus survey	398.85	396.00	-	-
Growth parameters				
Length-at-Amin	26.32	26.40	23.34	23.37
Length-at-A∞	98.33	98.68	94.28	94.25
k	0.181	0.180	0.201	0.201
CV for L-at-Amin	-	-	4.601	4.590
CV for L-at-A∞	-	-	6.775	6.805
ln(R0)	12.50	12.49	12.64	12.66

Table 2.15 – Parameter values, estimates, and standard deviations from Model S1a

Parameter	Value	Std Dev
M	0.38	_
L_at_Amin	23.3392	0.276908
L_at_Amax	94.283	0.81592
VonBert_K	0.201426	0.004298
CV_young	4.6016	0.134811
CV_old	6.77542	0.217853
Wtlen_1	8.84E-06	_
Wtlen_2	3.07181	_
Mat-at-50%	4.35	_
Mat_slope	-1.9632	_
Eggs/kg	1	_
AgeKeyParm1	1	_
AgeKeyParm2	0.111997	0.046143
AgeKeyParm3	9.50E-09	_
AgeKeyParm4	0	_
AgeKeyParm5	0.096	_
AgeKeyParm6	1.471	_
AgeKeyParm7	0	_
SR_LN(R0)	12.6438	0.06622
SR_BH_steep	1	_
SR_sigmaR	0.41	_
SR_R1_offset	0.069359	0.134755
Early_InitAge_13	-0.15814	0.381102
Early_InitAge_12	-0.19247	0.375512
Early_InitAge_11	-0.21966	0.370966
Early_InitAge_10	-0.23094	0.368343
Early_InitAge_9	-0.19969	0.370475
Early_InitAge_8	-0.09602	0.380637
Early_InitAge_7	0.111669	0.403327
Early_InitAge_6	0.37487	0.424365
Early_InitAge_5	0.502522	0.429912
Early_InitAge_4	1.49303	0.186194
Early_InitAge_3	-0.05908	0.296458
Early_InitAge_2	0.115144	0.191489
Early_InitAge_1	-0.53208	0.233706
Main_RecrDev_1977	1.66695	0.082256
Main_RecrDev_1978	-0.33959	0.221603
Main_RecrDev_1979	0.109951	0.106422
Main_RecrDev_1980	0.148782	0.08298

Main_RecrDev_1981	-0.08276	0.086461
Main_RecrDev_1982	0.066854	0.101395
Main_RecrDev_1983	-0.64218	0.171643
Main_RecrDev_1984	0.347582	0.139732
Main_RecrDev_1985	0.405736	0.119728
Main_RecrDev_1986	-0.44928	0.167252
Main_RecrDev_1987	0.17022	0.092666
Main_RecrDev_1988	0.115401	0.090243
Main_RecrDev_1989	0.117136	0.096423
Main_RecrDev_1990	0.383753	0.081494
Main_RecrDev_1991	0.063184	0.092826
Main_RecrDev_1992	-0.08382	0.101433
Main_RecrDev_1993	0.174726	0.081197
Main_RecrDev_1994	-0.06025	0.092771
Main_RecrDev_1995	0.271541	0.075958
Main_RecrDev_1996	-0.17702	0.090785
Main_RecrDev_1997	-0.29728	0.095106
Main_RecrDev_1998	-0.4744	0.096587
Main_RecrDev_1999	-0.13331	0.0838
Main_RecrDev_2000	-0.05287	0.079195
Main_RecrDev_2001	-0.34987	0.090695
Main_RecrDev_2002	-0.79237	0.113135
Main_RecrDev_2003	-0.42731	0.083729
Main_RecrDev_2004	-0.56617	0.094033
Main_RecrDev_2005	-0.15573	0.081475
Main_RecrDev_2006	0.208225	0.076683
Main_RecrDev_2007	0.119829	0.093486
Main_RecrDev_2008	0.465838	0.095318
Main_RecrDev_2009	0.246061	0.133346
Main_RecrDev_2010	-0.21078	0.16739
Main_RecrDev_2011	0.213214	0.225457
Late_RecrDev_2012	0.595512	0.16214
Late_RecrDev_2013	0.0038	0.203673
Late_RecrDev_2014	0	0.205
ForeRecr_2015	0	0.41
InitF_1Jan-Apr_Trawl_Fishery	0.036569	0.005865
InitF_2May-Aug_Trawl_Fishery	0	_
InitF_3Sep-Dec_Trawl_Fishery	0	_
InitF_4Jan-Apr_Longline_Fishery	0	_
InitF_5May-Aug_Longline_Fishery	0	_
InitF_6Sep-Dec_Longline_Fishery	0	_

InitF_7Jan-Apr_Pot_Fishery	0	_
InitF_8May-Aug_Pot_Fishery	0	_
InitF_9Sep-Dec_Pot_Fishery	0	_
Q_envlink_10_Trawl_Survey	0.356455	0.25064
LnQ_base_10_Trawl_Survey	0	_
SizeSel_1P_1_Jan-Apr_Trawl_Fishery	0	_
SizeSel_1P_2_Jan-Apr_Trawl_Fishery	0	_
SizeSel_1P_3_Jan-Apr_Trawl_Fishery	0	_
SizeSel_1P_4_Jan-Apr_Trawl_Fishery	0	_
SizeSel_1P_5_Jan-Apr_Trawl_Fishery	-10	_
SizeSel_1P_6_Jan-Apr_Trawl_Fishery	10	_
SizeSel_2P_1_May-Aug_Trawl_Fishery	0	_
SizeSel_2P_2_May-Aug_Trawl_Fishery	-7	_
SizeSel_2P_3_May-Aug_Trawl_Fishery	0	_
SizeSel_2P_4_May-Aug_Trawl_Fishery	4.68513	0.314994
SizeSel_2P_5_May-Aug_Trawl_Fishery	-10	_
SizeSel_2P_6_May-Aug_Trawl_Fishery	0	_
SizeSel_3P_1_Sep-Dec_Trawl_Fishery	0	_
SizeSel_3P_2_Sep-Dec_Trawl_Fishery	0	_
SizeSel_3P_3_Sep-Dec_Trawl_Fishery	0	_
SizeSel_3P_4_Sep-Dec_Trawl_Fishery	4.37269	0.354623
SizeSel_3P_5_Sep-Dec_Trawl_Fishery	-10	_
SizeSel_3P_6_Sep-Dec_Trawl_Fishery	-1.51788	0.265191
SizeSel_4P_1_Jan-Apr_Longline_Fishery	0	_
SizeSel_4P_2_Jan-Apr_Longline_Fishery	0	_
SizeSel_4P_3_Jan-Apr_Longline_Fishery	0	_
SizeSel_4P_4_Jan-Apr_Longline_Fishery	3.96351	0.258395
SizeSel_4P_5_Jan-Apr_Longline_Fishery	-10	_
SizeSel_4P_6_Jan-Apr_Longline_Fishery	0	_
SizeSel_5P_1_May-Aug_Longline_Fishery	0	_
SizeSel_5P_2_May-Aug_Longline_Fishery	-7	_
SizeSel_5P_3_May-Aug_Longline_Fishery	0	_
SizeSel_5P_4_May-Aug_Longline_Fishery	4.82853	0.291221
SizeSel_5P_5_May-Aug_Longline_Fishery	-10	_
SizeSel_5P_6_May-Aug_Longline_Fishery	0	_
SizeSel_6P_1_Sep-Dec_Longline_Fishery	0	_
SizeSel_6P_2_Sep-Dec_Longline_Fishery	-7	_
SizeSel_6P_3_Sep-Dec_Longline_Fishery	0	_
SizeSel_6P_4_Sep-Dec_Longline_Fishery	0	_
SizeSel_6P_5_Sep-Dec_Longline_Fishery	-10	_
SizeSel_6P_6_Sep-Dec_Longline_Fishery	0	_

SizeSel_7P_1_Jan-Apr_Pot_Fishery	0	_
SizeSel_7P_2_Jan-Apr_Pot_Fishery	-7	_
SizeSel_7P_3_Jan-Apr_Pot_Fishery	0	_
SizeSel_7P_4_Jan-Apr_Pot_Fishery	0	_
SizeSel_7P_5_Jan-Apr_Pot_Fishery	-10	_
SizeSel_7P_6_Jan-Apr_Pot_Fishery	0	_
SizeSel_8P_1_May-Aug_Pot_Fishery	0	_
SizeSel_8P_2_May-Aug_Pot_Fishery	-7	_
SizeSel_8P_3_May-Aug_Pot_Fishery	0	_
SizeSel_8P_4_May-Aug_Pot_Fishery	4.76334	0.477814
SizeSel_8P_5_May-Aug_Pot_Fishery	-10	_
SizeSel_8P_6_May-Aug_Pot_Fishery	-1.07732	0.440272
SizeSel_9P_1_Sep-Dec_Pot_Fishery	0	_
SizeSel_9P_2_Sep-Dec_Pot_Fishery	-7	_
SizeSel_9P_3_Sep-Dec_Pot_Fishery	0	_
SizeSel_9P_4_Sep-Dec_Pot_Fishery	4.46758	0.246737
SizeSel_9P_5_Sep-Dec_Pot_Fishery	-10	_
SizeSel_9P_6_Sep-Dec_Pot_Fishery	0	_
AgeSel_10P_1_Trawl_Survey	-2	_
AgeSel_10P_2_Trawl_Survey	3	_
AgeSel_10P_3_Trawl_Survey	-1	_
AgeSel_10P_4_Trawl_Survey	2	_
AgeSel_10P_5_Trawl_Survey	0	_
AgeSel_10P_6_Trawl_Survey	0	_
AgeSel_10P_7_Trawl_Survey	0	_
AgeSel_10P_8_Trawl_Survey	-1	_
AgeSel_10P_9_Trawl_Survey	-1	_
AgeSel_10P_10_Trawl_Survey	-1	_
AgeSel_10P_11_Trawl_Survey	-1	_
AgeSel_10P_12_Trawl_Survey	-1	_
AgeSel_10P_13_Trawl_Survey	-1	_
AgeSel_10P_14_Trawl_Survey	-2	_
AgeSel_10P_15_Trawl_Survey	-999	_
AgeSel_10P_16_Trawl_Survey	-999	_
AgeSel_10P_17_Trawl_Survey	-999	_
AgeSel_10P_18_Trawl_Survey	-999	_
AgeSel_10P_19_Trawl_Survey	-999	_
AgeSel_10P_20_Trawl_Survey	-999	_
AgeSel_10P_21_Trawl_Survey	-999	_
SizeSel_1P_1_Jan-Apr_Trawl_Fishery_1977	49.7199	3.13875
SizeSel_1P_1_Jan-Apr_Trawl_Fishery_1990	71.8043	1.195

SizeSel_1P_1_Jan-Apr_Trawl_Fishery_1995	74.259	1.07005
SizeSel_1P_1_Jan-Apr_Trawl_Fishery_2000	64.954	2.07086
SizeSel_1P_1_Jan-Apr_Trawl_Fishery_2005	69.3073	2.24715
SizeSel_1P_3_Jan-Apr_Trawl_Fishery_1977	4.16956	0.6253
SizeSel_1P_3_Jan-Apr_Trawl_Fishery_1990	5.82206	0.074596
SizeSel_1P_3_Jan-Apr_Trawl_Fishery_1995	5.87337	0.062162
SizeSel_1P_3_Jan-Apr_Trawl_Fishery_2000	5.6082	0.168419
SizeSel_1P_3_Jan-Apr_Trawl_Fishery_2005	5.84029	0.146064
SizeSel_2P_1_May-Aug_Trawl_Fishery_1977	53.852	1.25039
SizeSel_2P_1_May-Aug_Trawl_Fishery_1985	60.7856	1.21886
SizeSel_2P_1_May-Aug_Trawl_Fishery_1990	65.7192	1.04849
SizeSel_2P_1_May-Aug_Trawl_Fishery_2000	66.538	2.18554
SizeSel_2P_1_May-Aug_Trawl_Fishery_2005	67.8111	1.70648
SizeSel_2P_3_May-Aug_Trawl_Fishery_1977	4.50398	0.216443
SizeSel_2P_3_May-Aug_Trawl_Fishery_1985	5.18616	0.162178
SizeSel_2P_3_May-Aug_Trawl_Fishery_1990	5.10549	0.121318
SizeSel_2P_3_May-Aug_Trawl_Fishery_2000	5.75359	0.197442
SizeSel_2P_3_May-Aug_Trawl_Fishery_2005	5.91311	0.123724
SizeSel_2P_6_May-Aug_Trawl_Fishery_1977	-0.4555	0.285036
SizeSel_2P_6_May-Aug_Trawl_Fishery_1985	-1.44503	0.350824
SizeSel_2P_6_May-Aug_Trawl_Fishery_1990	-2.73456	0.777645
SizeSel_2P_6_May-Aug_Trawl_Fishery_2000	-1.12725	0.856166
SizeSel_2P_6_May-Aug_Trawl_Fishery_2005	-1.75893	1.00035
SizeSel_3P_1_Sep-Dec_Trawl_Fishery_1977	46.0044	4.90329
SizeSel_3P_1_Sep-Dec_Trawl_Fishery_1980	55.6161	1.64726
SizeSel_3P_1_Sep-Dec_Trawl_Fishery_1985	58.5631	1.6486
SizeSel_3P_1_Sep-Dec_Trawl_Fishery_1990	58.5454	3.24445
SizeSel_3P_1_Sep-Dec_Trawl_Fishery_1995	71.4395	1.41829
SizeSel_3P_1_Sep-Dec_Trawl_Fishery_2000	68.7713	1.59347
SizeSel_3P_1_Sep-Dec_Trawl_Fishery_2005	69.1546	1.27583
SizeSel_3P_2_Sep-Dec_Trawl_Fishery_1977	-3.69427	7.32648
SizeSel_3P_2_Sep-Dec_Trawl_Fishery_1980	-6	_
SizeSel_3P_2_Sep-Dec_Trawl_Fishery_1985	-7	_
SizeSel_3P_2_Sep-Dec_Trawl_Fishery_1990	-0.10989	0.259243
SizeSel_3P_2_Sep-Dec_Trawl_Fishery_1995	-7	_
SizeSel_3P_2_Sep-Dec_Trawl_Fishery_2000	-7	_
SizeSel_3P_2_Sep-Dec_Trawl_Fishery_2005	-7	_
SizeSel_3P_3_Sep-Dec_Trawl_Fishery_1977	3.79957	0.897482
SizeSel_3P_3_Sep-Dec_Trawl_Fishery_1980	5.12747	0.249784
SizeSel_3P_3_Sep-Dec_Trawl_Fishery_1985	5.51063	0.199755
SizeSel_3P_3_Sep-Dec_Trawl_Fishery_1990	5.11796	0.333539

SizeSel_3P_3_Sep-Dec_Trawl_Fishery_1995	6.16025	0.100253
SizeSel_3P_3_Sep-Dec_Trawl_Fishery_2000	5.88234	0.137355
SizeSel_3P_3_Sep-Dec_Trawl_Fishery_2005	5.7565	0.09604
SizeSel_4P_1_Jan-Apr_Longline_Fishery_1977	54.4347	0.783219
SizeSel_4P_1_Jan-Apr_Longline_Fishery_1985	61.8309	1.33874
SizeSel_4P_1_Jan-Apr_Longline_Fishery_1990	69.3193	0.887452
SizeSel_4P_1_Jan-Apr_Longline_Fishery_1995	72.2259	0.746895
SizeSel_4P_1_Jan-Apr_Longline_Fishery_2000	67.6821	1.03
SizeSel_4P_1_Jan-Apr_Longline_Fishery_2005	68.2574	0.508115
SizeSel_4P_2_Jan-Apr_Longline_Fishery_1977	-0.36988	0.133843
SizeSel_4P_2_Jan-Apr_Longline_Fishery_1985	-0.99007	0.196166
SizeSel_4P_2_Jan-Apr_Longline_Fishery_1990	-7	_
SizeSel_4P_2_Jan-Apr_Longline_Fishery_1995	-7	_
SizeSel_4P_2_Jan-Apr_Longline_Fishery_2000	-3.73448	2.18653
SizeSel_4P_2_Jan-Apr_Longline_Fishery_2005	-7	_
SizeSel_4P_3_Jan-Apr_Longline_Fishery_1977	4.3904	0.117486
SizeSel_4P_3_Jan-Apr_Longline_Fishery_1985	5.10816	0.118841
SizeSel_4P_3_Jan-Apr_Longline_Fishery_1990	5.2821	0.077346
SizeSel_4P_3_Jan-Apr_Longline_Fishery_1995	5.37007	0.063579
SizeSel_4P_3_Jan-Apr_Longline_Fishery_2000	5.05511	0.09891
SizeSel_4P_3_Jan-Apr_Longline_Fishery_2005	5.04249	0.048854
SizeSel_4P_6_Jan-Apr_Longline_Fishery_1977	-0.223	0.290025
SizeSel_4P_6_Jan-Apr_Longline_Fishery_1985	0.972233	0.329056
SizeSel_4P_6_Jan-Apr_Longline_Fishery_1990	1.41469	0.475192
SizeSel_4P_6_Jan-Apr_Longline_Fishery_1995	0.549834	0.312357
SizeSel_4P_6_Jan-Apr_Longline_Fishery_2000	-0.48297	0.237829
SizeSel_4P_6_Jan-Apr_Longline_Fishery_2005	-0.5524	0.206889
SizeSel_5P_1_May-Aug_Longline_Fishery_1977	54.3418	1.77318
SizeSel_5P_1_May-Aug_Longline_Fishery_1980	55.5032	0.689374
SizeSel_5P_1_May-Aug_Longline_Fishery_1990	69.3543	1.86694
SizeSel_5P_1_May-Aug_Longline_Fishery_2000	69.8589	1.37671
SizeSel_5P_3_May-Aug_Longline_Fishery_1977	4.27944	0.297868
SizeSel_5P_3_May-Aug_Longline_Fishery_1980	4.30932	0.119451
SizeSel_5P_3_May-Aug_Longline_Fishery_1990	4.99503	0.232409
SizeSel_5P_3_May-Aug_Longline_Fishery_2000	4.98389	0.148265
SizeSel_5P_6_May-Aug_Longline_Fishery_1977	0.143932	0.455827
SizeSel_5P_6_May-Aug_Longline_Fishery_1980	-0.96208	0.183823
SizeSel_5P_6_May-Aug_Longline_Fishery_1990	-1.71766	1.03808
SizeSel_5P_6_May-Aug_Longline_Fishery_2000	0.215815	0.657286
SizeSel_6P_1_Sep-Dec_Longline_Fishery_1977	56.1806	1.20256
SizeSel_6P_1_Sep-Dec_Longline_Fishery_1980	55.8547	0.310692

SizeSel_6P_1_Sep-Dec_Longline_Fishery_1990	67.1705	0.502632
SizeSel_6P_3_Sep-Dec_Longline_Fishery_1977	4.41105	0.172616
SizeSel_6P_3_Sep-Dec_Longline_Fishery_1980	4.30241	0.053122
SizeSel_6P_3_Sep-Dec_Longline_Fishery_1990	4.91013	0.052672
SizeSel_6P_4_Sep-Dec_Longline_Fishery_1977	9	_
SizeSel_6P_4_Sep-Dec_Longline_Fishery_1980	4.36572	0.105177
SizeSel_6P_4_Sep-Dec_Longline_Fishery_1990	4.13569	0.265056
SizeSel_6P_6_Sep-Dec_Longline_Fishery_1977	-8.3507	32.9364
SizeSel_6P_6_Sep-Dec_Longline_Fishery_1980	-1.67498	0.093792
SizeSel_6P_6_Sep-Dec_Longline_Fishery_1990	-0.79684	0.196577
SizeSel_7P_1_Jan-Apr_Pot_Fishery_1977	68.1684	0.454695
SizeSel_7P_1_Jan-Apr_Pot_Fishery_1995	70.9519	0.445977
SizeSel_7P_1_Jan-Apr_Pot_Fishery_2000	66.9739	0.597186
SizeSel_7P_1_Jan-Apr_Pot_Fishery_2005	67.0488	0.490147
SizeSel_7P_3_Jan-Apr_Pot_Fishery_1977	4.78643	0.055217
SizeSel_7P_3_Jan-Apr_Pot_Fishery_1995	4.94547	0.046664
SizeSel_7P_3_Jan-Apr_Pot_Fishery_2000	4.89805	0.067174
SizeSel_7P_3_Jan-Apr_Pot_Fishery_2005	4.73899	0.054229
SizeSel_7P_4_Jan-Apr_Pot_Fishery_1977	4.52016	0.185615
SizeSel_7P_4_Jan-Apr_Pot_Fishery_1995	4.20759	0.250571
SizeSel_7P_4_Jan-Apr_Pot_Fishery_2000	4.38012	0.273516
SizeSel_7P_4_Jan-Apr_Pot_Fishery_2005	4.19389	0.259778
SizeSel_7P_6_Jan-Apr_Pot_Fishery_1977	-2.01946	0.259921
SizeSel_7P_6_Jan-Apr_Pot_Fishery_1995	-0.79048	0.200859
SizeSel_7P_6_Jan-Apr_Pot_Fishery_2000	-0.85905	0.212626
SizeSel_7P_6_Jan-Apr_Pot_Fishery_2005	-0.40414	0.202777
SizeSel_8P_1_May-Aug_Pot_Fishery_1977	64.3107	1.61053
SizeSel_8P_1_May-Aug_Pot_Fishery_1995	67.6337	1.07985
SizeSel_8P_1_May-Aug_Pot_Fishery_2000	64.7851	1.28665
SizeSel_8P_3_May-Aug_Pot_Fishery_1977	4.42487	0.274312
SizeSel_8P_3_May-Aug_Pot_Fishery_1995	4.54768	0.165683
SizeSel_8P_3_May-Aug_Pot_Fishery_2000	4.27059	0.249282
SizeSel_9P_1_Sep-Dec_Pot_Fishery_1977	71.1912	0.986786
SizeSel_9P_1_Sep-Dec_Pot_Fishery_1995	71.272	1.12332
SizeSel_9P_1_Sep-Dec_Pot_Fishery_2000	64.9272	0.924086
SizeSel_9P_1_Sep-Dec_Pot_Fishery_2005	65.1577	0.589455
SizeSel_9P_3_Sep-Dec_Pot_Fishery_1977	5.29679	0.097451
SizeSel_9P_3_Sep-Dec_Pot_Fishery_1995	5.34695	0.110862
SizeSel_9P_3_Sep-Dec_Pot_Fishery_2000	4.88804	0.115761
SizeSel_9P_3_Sep-Dec_Pot_Fishery_2005	4.67637	0.075919
SizeSel_9P_6_Sep-Dec_Pot_Fishery_1977	-1.30375	0.414697

SizeSel_9P_6_Sep-Dec_Pot_Fishery_1995	-0.41457	0.464178
SizeSel_9P_6_Sep-Dec_Pot_Fishery_2000	-0.69647	0.304153
SizeSel_9P_6_Sep-Dec_Pot_Fishery_2005	-0.9052	0.253861
AgeSel_10P_1_Trawl_Survey_1977	-1000	_
AgeSel_10P_1_Trawl_Survey_1996	-1000	_
AgeSel_10P_1_Trawl_Survey_2005	-1000	_
AgeSel_10P_2_Trawl_Survey_1977	3.19651	0.997817
AgeSel_10P_2_Trawl_Survey_1996	7.83407	6.30736
AgeSel_10P_2_Trawl_Survey_2005	5.84925	2.36511
AgeSel_10P_3_Trawl_Survey_1977	0.039936	0.352043
AgeSel_10P_3_Trawl_Survey_1996	-0.35766	0.219491
AgeSel_10P_3_Trawl_Survey_2005	-0.1027	0.201135
AgeSel_10P_4_Trawl_Survey_1977	0.949177	0.356349
AgeSel_10P_4_Trawl_Survey_1996	1.29109	0.229264
AgeSel_10P_4_Trawl_Survey_2005	1.37699	0.203529
AgeSel_10P_5_Trawl_Survey_1977	1.02381	0.354691
AgeSel_10P_5_Trawl_Survey_1996	0.446728	0.195477
AgeSel_10P_5_Trawl_Survey_2005	0.132959	0.145057
AgeSel_10P_6_Trawl_Survey_1977	-0.50738	0.446408
AgeSel_10P_6_Trawl_Survey_1996	0.167843	0.163289
AgeSel_10P_6_Trawl_Survey_2005	0	_
AgeSel_10P_7_Trawl_Survey_1977	0.018839	0.436564
AgeSel_10P_7_Trawl_Survey_1996	-0.29082	0.196845
AgeSel_10P_7_Trawl_Survey_2005	-0.57732	0.237381
AgeSel_10P_8_Trawl_Survey_1977	-0.0013	0.044312
AgeSel_10P_8_Trawl_Survey_1996	-0.00561	0.161202
AgeSel_10P_8_Trawl_Survey_2005	-0.00091	0.031864
AgeSel_10P_9_Trawl_Survey_1977	-0.6378	0.536751
AgeSel_10P_9_Trawl_Survey_1996	-0.60489	0.388304
AgeSel_10P_9_Trawl_Survey_2005	-1.08722	0.566615
AgeSel_10P_10_Trawl_Survey_1977	-0.5064	0.706934
AgeSel_10P_10_Trawl_Survey_1996	-0.93429	0.681268
AgeSel_10P_10_Trawl_Survey_2005	-1.23135	0.613485
AgeSel_10P_11_Trawl_Survey_1977	-1.78459	1.8189
AgeSel_10P_11_Trawl_Survey_1996	-0.59196	0.798974
AgeSel_10P_11_Trawl_Survey_2005	-0.0009	0.031727
AgeSel_10P_12_Trawl_Survey_1977	-3.41416	13.21
AgeSel_10P_12_Trawl_Survey_1996	-8.3954	33.212
AgeSel_10P_12_Trawl_Survey_2005	-3.5727	9.30729
AgeSel_10P_13_Trawl_Survey_1977	-0.80874	14.102
AgeSel_10P_13_Trawl_Survey_1996	-5.17895	102.99

AgeSel_10P_13_Trawl_Survey_2005	-0.6585	9.56022
AgeSel_10P_14_Trawl_Survey_1977	-0.76982	3.73773
AgeSel_10P_14_Trawl_Survey_1996	-5.0007	111.757
AgeSel_10P_14_Trawl_Survey_2005	-0.01	_

Table 2.16 – Schedules of estimated population length (cm) and weight (kg) by season and age from Model S1a. Season 1=Jan-Feb, Season 2=Mar-Apr, Season 3=May-Aug, Season 4=Sep-Oct, Season 5=Nov-Dec. Lengths and weights correspond to season mid-points.

	Length, in cm					Mass, in kg				
Age	1	2	3	4	5	1	2	3	4	5
0	0.50	1.93	6.21	10.49	13.35	0.001	0.002	0.007	0.025	0.033
1	16.20	19.06	23.34	26.82	29.05	0.060	0.086	0.158	0.264	0.288
2	31.20	33.29	36.28	39.13	40.95	0.385	0.431	0.560	0.759	0.813
3	42.71	44.41	46.86	49.19	50.68	0.986	1.025	1.182	1.452	1.559
4	52.12	53.51	55.51	57.42	58.64	1.801	1.804	1.946	2.257	2.441
5	59.81	60.95	62.59	64.14	65.14	2.738	2.681	2.774	3.098	3.375
6	66.10	67.03	68.37	69.64	70.46	3.713	3.585	3.603	3.922	4.301
7	71.24	72.00	73.10	74.14	74.80	4.667	4.461	4.392	4.693	5.175
8	75.45	76.07	76.96	77.81	78.36	5.561	5.278	5.117	5.392	5.974
9	78.88	79.39	80.12	80.82	81.26	6.372	6.016	5.766	6.011	6.686
10	81.69	82.11	82.71	83.27	83.64	7.093	6.669	6.335	6.552	7.310
11	83.99	84.33	84.82	85.28	85.58	7.721	7.238	6.828	7.016	7.849
12	85.87	86.14	86.54	86.92	87.17	8.262	7.726	7.249	7.411	8.309
13	87.40	87.63	87.96	88.27	88.47	8.723	8.142	7.606	7.745	8.698
14	88.66	88.84	89.11	89.36	89.53	9.112	8.493	7.906	8.025	9.025
15	89.68	89.84	90.05	90.26	90.39	9.438	8.786	8.157	8.258	9.298
16	90.52	90.65	90.83	91.00	91.10	9.711	9.032	8.366	8.452	9.526
17	91.21	91.31	91.46	91.60	91.68	9.938	9.235	8.539	8.613	9.714
18	91.77	91.85	91.97	92.09	92.16	10.125	9.404	8.682	8.745	9.870
19	92.23	92.30	92.39	92.49	92.55	10.280	9.543	8.801	8.855	9.998
20	92.96	93.00	93.06	93.12	93.16	10.529	9.768	8.991	9.031	10.205

Table 2.17 – Schedule of estimated full survey selectivity-at-age from Model S1a

Age	1984 – 1993	1996 – 2003	2005 – 2013
0	0.005	0.000	0.001
1	0.134	0.213	0.245
2	0.139	0.149	0.221
3	0.359	0.541	0.876
4	1.000	0.845	1.000
5	0.602	1.000	1.000
6	0.614	0.748	0.561
7	0.613	0.743	0.561
8	0.324	0.406	0.189
9	0.195	0.160	0.055
10	0.033	0.088	0.055
11	0.001	0.000	0.002
12	0.000	0.000	0.001
13	0.000	0.000	0.001
14	0.000	0.000	0.001
15	0.000	0.000	0.001
16	0.000	0.000	0.001
17	0.000	0.000	0.001
18	0.000	0.000	0.001
19	0.000	0.000	0.001
20	0.000	0.000	0.001

Table 2.18 – Estimated female spawning biomass (t) from the 2013 assessment and this year's assessment from Model S1a

	Last year		**This year**	
Year	Spawning Biomass	Standard Deviation	Spawning Biomass	Standard Deviation
1977	186,808	22,033	417,262	64,250
1978	227,088	24,465	514,875	74,306
1979	239,480	24,638	528,010	73,382
1980	238,081	23,167	502,250	67,096
1981	252,175	22,457	510,750	64,125
1982	285,659	23,310	561,345	65,805
1983	285,396	22,223	539,730	60,570
1984	262,246	19,764	486,303	53,334
1985	244,848	17,150	438,862	46,804
1986	234,405	14,690	396,007	40,714
1987	226,094	12,560	355,515	35,200
1988	211,026	10,710	319,025	30,626
1989	202,045	9,314	306,546	28,269
1990	192,004	8,352	290,091	26,221
1991	172,390	7,469	260,199	23,940
1992	151,710	6,845	235,414	22,712
1993	144,063	6,517	226,204	22,314
1994	146,202	6,376	229,276	22,529
1995	155,479	6,310	239,934	22,819
1996	150,300	6,055	231,890	22,279
1997	141,547	5,699	220,810	21,694
1998	128,100	5,432	207,654	21,495
1999	122,142	5,347	202,477	21,597
2000	110,458	5,322	192,391	21,775
2001	109,422	5,207	186,894	20,940
2002	102,436	4,930	174,210	19,679
2003	90,860	4,669	158,567	18,548
2004	87,923	4,641	153,702	18,120
2005	87,611	4,751	150,557	17,715
2006	83,399	4,696	140,153	16,594
2007	79,240	4,581	127,838	15,217
2008	73,601	4,632	115,273	14,245
2009	73,230	5,096	109,778	14,049
2010	81,752	6,434	115,966	15,256
2011	95,863	8,938	129,024	17,827
2012	116,606	12,808	147,788	21,528
2013	146,930	18,109	173,781	26,328
2014	*147,000*		183,784	30,013
2015			*175,464*	

Table 2.19 – Estimated age-0 recruits (000's) from the 2013 assessment and this year's assessment from Model S1a

	Last year		**This year**	
Year	Age-0	Std. Dev	Age-0	Std. Dev
1977	756,157	53,618	1,508,670	166,531
1978	238,560	25,328	202,845	45,570
1979	173,783	14,582	317,978	39,722
1980	209,123	13,140	330,569	36,194
1981	204,331	12,984	262,242	28,787
1982	256,862	17,289	304,565	36,760
1983	182,726	16,137	149,883	27,381
1984	188,096	17,224	403,273	61,991
1985	319,968	17,552	427,420	54,495
1986	175,593	12,358	181,773	31,939
1987	228,726	12,044	337,732	36,908
1988	240,174	11,897	319,716	34,500
1989	230,335	12,418	320,271	37,262
1990	293,018	13,264	418,127	42,785
1991	241,917	11,354	303,450	32,348
1992	204,391	10,644	261,965	31,346
1993	223,157	10,273	339,257	34,955
1994	215,464	9,911	268,213	29,790
1995	227,150	9,706	373,745	38,943
1996	202,627	8,640	238,654	24,452
1997	156,086	7,279	211,612	24,564
1998	127,597	6,645	177,263	20,136
1999	169,207	7,825	249,317	27,191
2000	205,053	9,113	270,200	27,556
2001	156,483	7,441	200,770	20,803
2002	121,066	6,571	128,980	16,534
2003	148,323	7,457	185,809	18,991
2004	143,264	8,123	161,719	18,699
2005	206,195	12,227	243,789	26,509
2006	294,212	19,619	350,814	38,031
2007	298,706	23,992	321,135	37,887
2008	393,735	39,315	453,897	58,116
2009	399,022	47,592	364,342	56,371
2010	246,927	35,982	230,731	42,984
2011	293,917	62,757	352,569	86,650
2012			516,742	92,639
2013			285,954	61,298
Average	239,199	(1977 – 2011)	323,675	(1977 – 2013)

Table 2.20 – Estimated numbers-at-age (millions) at the time of spawning (middle of season 2) from Model S1a

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	1,461,640	118,824	155,222	89,142	286,870	72,442	43,339	22,641	12,504	7,662	5,048	3,470	2,424	1,705	1,477	1,004	682	464	315	214	455
1978	196,522	999,559	81,253	106,009	60,754	195,381	49,344	29,526	15,428	8,522	5,223	3,442	2,367	1,653	1,163	1,007	685	465	316	215	456
1979	308,067	134,394	683,455	55,371	71,820	41,090	132,255	33,431	20,018	10,465	5,784	3,546	2,338	1,608	1,123	790	685	465	316	215	456
1980	320,265	210,675	91,885	465,023	37,341	48,278	27,640	89,061	22,535	13,506	7,067	3,908	2,398	1,581	1,088	760	535	463	315	214	455
1981	254,068	219,017	144,034	62,500	311,065	24,751	32,143	18,515	59,881	15,183	9,111	4,771	2,640	1,621	1,069	736	514	362	313	213	453
1982	295,072	173,747	149,723	97,833	41,613	205,022	16,413	21,481	12,431	40,301	10,232	6,145	3,220	1,783	1,094	722	497	347	244	212	450
1983	145,211	201,788	118,778	101,679	65,112	27,423	135,930	10,964	14,412	8,360	27,140	6,897	4,145	2,173	1,203	739	487	335	235	165	447
1984	390,703	99,304	137,934	80,470	66,937	42,243	17,945	89,921	7,300	9,628	5,595	18,186	4,625	2,781	1,458	808	496	327	225	158	411
1985	414,097	267,186	67,885	93,791	53,864	44,409	28,124	12,009	60,367	4,909	6,481	3,769	12,256	3,118	1,875	983	545	335	221	152	384
1986	176,107	283,185	182,641	46,197	63,141	35,971	29,637	18,811	8,050	40,530	3,299	4,359	2,536	8,250	2,099	1,262	662	367	225	149	361
1987	327,204	120,432	193,546	124,094	30,927	41,824	23,856	19,754	12,586	5,398	27,216	2,217	2,931	1,706	5,550	1,412	849	446	247	152	343
1988	309,750	223,762	82,235	130,280	81,099	19,807	26,840	15,487	12,953	8,305	3,575	18,056	1,473	1,948	1,134	3,690	939	565	296	164	329
1989	310,288	211,826	152,816	55,377	85,561	52,351	12,770	17,429	10,130	8,514	5,475	2,360	11,934	974	1,289	750	2,442	622	374	196	326
1990	405,093	212,190	144,747	103,521	36,273	53,945	32,535	7,970	10,973	6,422	5,421	3,494	1,509	7,634	623	825	481	1,564	398	240	335
1991	293,991	277,018	144,910	97,690	67,130	22,147	31,550	18,827	4,651	6,489	3,840	3,269	2,119	919	4,661	381	506	295	960	245	353
1992	253,799	201,042	189,196	97,927	63,764	41,532	13,113	18,326	10,916	2,709	3,799	2,257	1,926	1,251	543	2,759	226	299	175	569	354
1993	328,682	173,559	137,363	128,283	64,575	40,123	25,118	7,803	10,913	6,543	1,634	2,303	1,373	1,174	764	332	1,687	138	183	107	566
1994	259,853	224,768	118,600	93,246	85,038	41,147	24,737	15,289	4,757	6,693	4,037	1,013	1,431	855	732	477	207	1,054	86	115	421
1995	362,095	177,699	153,597	80,534	61,850	54,161	25,281	14,955	9,235	2,888	4,087	2,476	623	882	528	453	295	128	653	53	332
1996	231,215	247,616	121,410	104,178	53,227	39,061	32,754	14,936	8,791	5,449	1,714	2,436	1,481	374	530	317	272	178	77	393	232
1997	205,016	158,115	169,181	82,326	68,683	33,382	23,395	19,175	8,716	5,157	3,217	1,017	1,451	884	224	317	190	163	107	46	375
1998	171,738	140,199	108,008	114,538	53,922	42,366	19,466	13,278	10,863	4,982	2,978	1,873	596	853	521	132	188	113	97	63	250
1999	241,546	117,442	95,792	73,215	75,168	33,300	24,745	11,097	7,580	6,273	2,911	1,757	1,112	355	510	313	79	113	68	58	189
2000	261,777	165,179	80,191	64,549	47,084	44,979	18,901	13,862	6,293	4,380	3,685	1,730	1,052	670	215	309	190	48	69	41	150
2001	194,512	179,016	112,853	54,307	42,378	29,522	27,388	11,483	8,516	3,914	2,750	2,328	1,097	669	426	137	197	121	31	44	122
2002	124,960	133,016	122,268	76,188	35,235	25,988	17,502	16,227	6,912	5,214	2,427	1,720	1,463	692	423	270	87	125	77	19	105
2003	180,017	85,454	90,879	82,615	49,154	21,156	14,934	10,053	9,512	4,138	3,171	1,491	1,063	908	430	263	168	54	78	48	78
2004	156,678	123,104	58,378	61,353	53,203	29,522	12,196	8,615	5,922	5,728	2,533	1,962	928	665	569	270	166	106	34	49	79
2005	236,190	107,144	84,101	39,490	39,817	32,277	17,154	7,071	5,087	3,567	3,501	1,563	1,218	578	415	356	169	104	66	21	81
2006	339,879	161,517	73,205	56,933	25,636	24,072	18,626	9,871	4,145	3,042	2,165	2,145	963	753	359	258	221	105	64	41	63
2007	311,125	232,424	110,356	49,552	36,923	15,464	13,842	10,674	5,763	2,469	1,839	1,321	1,317	593	465	222	159	137	65	40	65
2008	439,749	212,759	158,755	74,445	31,602	21,386	8,391	7,468	5,904	3,277	1,433	1,082	783	784	355	278	133	96	82	39	63
2009	352,985	300,720	145,348	107,136	47,415	18,192	11,485	4,479	4,100	3,346	1,902	845	644	469	472	214	168	80	58	50	62
2010	223,539	241,385	205,392	97,870	67,426	26,587	9,459	5,943	2,390	2,261	1,891	1,092	490	376	275	277	126	99	47	34	66
2011	341,579	152,865	164,894	138,437	61,669	37,720	13,737	4,862	3,157	1,316	1,279	1,088	635	287	221	162	163	74	59	28	59
2012	500,635	233,584	104,410	111,227	87,940	35,193	20,025	7,255	2,642	1,770	755	744	639	375	170	131	96	97	44	35	52
2013	277,041	342,355	159,588	70,684	72,224	53,052	20,167	11,403	4,205	1,563	1,062	457	454	391	230	104	81	59	60	27	54
2014	275,990	189,451	233,877	107,932	45,762	43,391	30,246	11,413	6,565	2,470	932	640	277	276	238	140	64	49	36	37	50

Table 2.21 – Estimates of "effective" fishing mortality (= $-\ln(N_{a+1,y+1}/N_{a,y})-M$) at age (a) and year (y) from Model S1a

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1977	0.000	0.000	0.001	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1978	0.000	0.002	0.008	0.010	0.010	0.009	0.008	0.008	0.007	0.007	0.007	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
1979	0.000	0.002	0.008	0.012	0.012	0.011	0.010	0.009	0.009	0.008	0.008	0.008	0.007	0.007	0.007	0.007	0.007	0.007	0.007
1980	0.000	0.004	0.021	0.033	0.030	0.024	0.020	0.018	0.017	0.016	0.015	0.015	0.014	0.014	0.014	0.013	0.013	0.013	0.013
1981	0.000	0.005	0.024	0.036	0.030	0.023	0.018	0.016	0.015	0.014	0.013	0.013	0.012	0.012	0.012	0.012	0.012	0.012	0.012
1982	0.000	0.005	0.023	0.034	0.029	0.022	0.018	0.015	0.014	0.013	0.013	0.012	0.012	0.012	0.012	0.011	0.011	0.011	0.011
1983	0.000	0.006	0.033	0.050	0.042	0.032	0.025	0.022	0.021	0.019	0.019	0.018	0.018	0.017	0.017	0.017	0.017	0.017	0.017
1984	0.000	0.004	0.020	0.031	0.028	0.023	0.020	0.018	0.017	0.016	0.015	0.015	0.014	0.014	0.014	0.014	0.013	0.013	0.013
1985	0.000	0.002	0.009	0.016	0.018	0.016	0.014	0.013	0.012	0.012	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.010	0.010
1986	0.000	0.004	0.018	0.033	0.035	0.031	0.027	0.025	0.023	0.022	0.021	0.021	0.020	0.020	0.020	0.020	0.020	0.020	0.020
1987	0.001	0.010	0.036	0.057	0.056	0.045	0.035	0.029	0.026	0.024	0.023	0.022	0.022	0.022	0.021	0.021	0.021	0.021	0.021
1988	0.000	0.006	0.029	0.050	0.053	0.047	0.039	0.034	0.031	0.029	0.028	0.027	0.027	0.027	0.027	0.027	0.026	0.026	0.026
1989	0.000	0.005	0.035	0.065	0.071	0.062	0.053	0.046	0.042	0.040	0.039	0.038	0.038	0.037	0.037	0.037	0.037	0.037	0.037
1990	0.000	0.005	0.027	0.072	0.112	0.128	0.125	0.115	0.105	0.098	0.093	0.089	0.087	0.085	0.083	0.082	0.082	0.081	0.080
1991	0.000	0.003	0.019	0.060	0.110	0.140	0.149	0.146	0.141	0.137	0.134	0.132	0.131	0.130	0.129	0.128	0.128	0.128	0.127
1992	0.000	0.003	0.021	0.069	0.127	0.162	0.170	0.165	0.158	0.153	0.149	0.146	0.144	0.143	0.142	0.142	0.141	0.141	0.140
1993	0.000	0.002	0.015	0.050	0.093	0.118	0.123	0.118	0.112	0.107	0.103	0.101	0.099	0.098	0.097	0.097	0.096	0.096	0.095
1994	0.000	0.001	0.011	0.038	0.073	0.094	0.099	0.096	0.091	0.087	0.084	0.082	0.081	0.080	0.080	0.079	0.079	0.079	0.078
1995	0.000	0.002	0.014	0.048	0.097	0.134	0.149	0.148	0.142	0.136	0.131	0.128	0.126	0.124	0.123	0.122	0.122	0.122	0.121
1996	0.000	0.002	0.015	0.051	0.099	0.135	0.148	0.147	0.142	0.136	0.132	0.129	0.127	0.126	0.125	0.124	0.124	0.123	0.123
1997	0.000	0.004	0.020	0.063	0.120	0.161	0.175	0.172	0.163	0.155	0.149	0.145	0.142	0.140	0.139	0.138	0.138	0.137	0.136
1998	0.000	0.003	0.017	0.058	0.117	0.160	0.173	0.168	0.158	0.149	0.142	0.137	0.134	0.132	0.130	0.129	0.128	0.128	0.127
1999	0.000	0.003	0.019	0.068	0.141	0.192	0.207	0.198	0.184	0.170	0.160	0.154	0.149	0.146	0.144	0.142	0.141	0.140	0.139
2000	0.000	0.003	0.021	0.074	0.137	0.164	0.157	0.139	0.123	0.112	0.105	0.100	0.097	0.096	0.095	0.094	0.093	0.093	0.092
2001	0.000	0.005	0.025	0.072	0.120	0.137	0.128	0.112	0.098	0.088	0.082	0.078	0.076	0.074	0.073	0.072	0.072	0.072	0.071
2002	0.000	0.004	0.027	0.084	0.141	0.160	0.150	0.131	0.114	0.104	0.097	0.093	0.090	0.088	0.087	0.086	0.086	0.086	0.085
2003	0.000	0.005	0.027	0.082	0.142	0.165	0.155	0.134	0.115	0.102	0.094	0.089	0.086	0.084	0.083	0.082	0.081	0.081	0.080
2004	0.000	0.005	0.029	0.091	0.158	0.184	0.171	0.146	0.124	0.110	0.100	0.095	0.091	0.089	0.087	0.086	0.085	0.085	0.084

2005	0.000	0.003	0.021	0.073	0.133	0.159	0.150	0.131	0.115	0.104	0.097	0.093	0.090	0.089	0.088	0.087	0.086	0.086	0.085
2006	0.000	0.003	0.021	0.075	0.143	0.172	0.164	0.144	0.127	0.115	0.108	0.103	0.101	0.099	0.098	0.097	0.096	0.096	0.096
2007	0.000	0.004	0.029	0.099	0.180	0.213	0.200	0.174	0.152	0.137	0.128	0.122	0.119	0.116	0.115	0.114	0.113	0.113	0.112
2008	0.000	0.006	0.038	0.121	0.218	0.257	0.243	0.211	0.184	0.165	0.153	0.146	0.142	0.139	0.137	0.136	0.135	0.134	0.133
2009	0.000	0.005	0.030	0.104	0.192	0.231	0.218	0.188	0.163	0.145	0.134	0.128	0.124	0.121	0.119	0.118	0.117	0.117	0.116
2010	0.000	0.006	0.038	0.134	0.250	0.301	0.285	0.248	0.215	0.192	0.178	0.170	0.165	0.161	0.159	0.158	0.156	0.156	0.155
2011	0.000	0.004	0.035	0.129	0.243	0.290	0.273	0.235	0.204	0.183	0.169	0.161	0.157	0.153	0.151	0.150	0.149	0.148	0.148
2012	0.000	0.004	0.028	0.101	0.190	0.229	0.219	0.193	0.171	0.156	0.147	0.141	0.137	0.135	0.134	0.133	0.132	0.132	0.131
2013	0.000	0.004	0.024	0.083	0.151	0.180	0.172	0.152	0.135	0.123	0.115	0.111	0.108	0.106	0.105	0.104	0.104	0.103	0.103

Table 2.22 – Results for the projection scenarios from Model S1a. ABC, OFL, Catch, Female Spawning Stock Biomass (SSB), and Total Biomass (Total Bio) in metric tons. Fishing mortality (F) is also presented.

Scenarios 1 and 2, Maximum tier 3 ABC harvest permissible						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	121,847	145,783	82,908	165,670	0.321	585,479
2015	117,211	140,342	117,211	155,441	0.502	583,864
2016	110,799	133,133	110,799	150,466	0.502	558,273
2017	113,542	136,286	113,542	154,334	0.502	545,916
2018	107,605	128,850	107,605	142,594	0.502	516,949
2019	97,622	116,535	97,622	130,872	0.497	493,401
2020	90,869	108,604	90,869	127,701	0.474	485,089
2021	90,930	108,775	90,930	128,959	0.467	485,433
2022	91,674	109,646	91,674	129,976	0.465	485,234
2023	91,378	109,288	91,378	128,612	0.468	482,608
2024	90,661	108,375	90,661	127,268	0.471	481,520
2025	89,887	107,469	89,887	126,837	0.468	482,686
2026	90,288	108,063	90,288	127,418	0.468	486,003
2027	91,585	109,664	91,585	128,947	0.469	490,241
Scenario 3, F_{ABC} at average F over the past 5 years						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	65,152	145,783	82,908	165,670	0.321	585,479
2015	62,586	140,342	62,586	160,420	0.246	583,864
2016	67,208	151,830	67,208	176,185	0.246	609,394
2017	74,196	166,971	74,196	194,532	0.246	630,270
2018	75,593	168,756	75,593	193,227	0.246	624,950
2019	72,474	161,933	72,474	185,914	0.246	612,517
2020	70,218	157,473	70,218	182,878	0.246	605,669
2021	69,793	156,572	69,793	182,643	0.246	602,562
2022	69,868	156,580	69,868	182,646	0.246	599,832
2023	69,366	155,247	69,366	180,711	0.246	595,729
2024	68,590	153,503	68,590	178,842	0.246	593,496
2025	68,140	152,575	68,140	177,937	0.246	593,751
2026	68,170	152,640	68,170	178,076	0.246	596,083
2027	68,679	153,577	68,679	179,483	0.246	599,940
Scenario 4, $F_{ABC} = F_{60\%}$						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	59,848	145,783	82,908	165,670	0.321	585,479
2015	57,485	140,342	57,485	160,851	0.224	583,864
2016	62,440	153,594	62,440	178,649	0.224	614,200
2017	69,434	170,093	69,434	198,677	0.224	638,827
2018	71,243	173,045	71,243	198,764	0.224	636,581
2019	68,673	166,932	68,673	192,298	0.224	626,112

2020	66,671	162,696	66,671	189,643	0.224	620,177
2021	66,288	161,921	66,288	189,582	0.224	617,476
2022	66,376	161,975	66,376	189,695	0.224	614,989
2023	65,938	160,664	65,938	187,833	0.224	611,047
2024	65,228	158,957	65,228	185,977	0.224	608,858
2025	64,800	158,059	64,800	185,049	0.224	609,069
2026	64,814	158,134	64,814	185,159	0.224	611,340
2027	65,275	159,107	65,275	186,553	0.224	615,166
Scenario 5, No fishing (F_{ABC} = 0)						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	0	145,783	82,908	165,670	0.321	585,479
2015	0	140,342	0	165,375	0.000	583,864
2016	0	173,665	0	207,097	0.000	668,692
2017	0	208,477	0	250,340	0.000	743,768
2018	0	229,102	0	272,490	0.000	789,072
2019	0	236,503	0	283,148	0.000	816,632
2020	0	239,660	0	291,776	0.000	836,146
2021	0	242,768	0	299,007	0.000	849,764
2022	0	245,527	0	304,178	0.000	858,434
2023	0	246,448	0	305,913	0.000	862,427
2024	0	246,110	0	306,279	0.000	865,276
2025	0	245,679	0	306,519	0.000	868,184
2026	0	245,947	0	307,199	0.000	871,783
2027	0	247,228	0	308,986	0.000	876,462
Scenario 6, Whether Pacific cod are overfished – $SB_{35\%}$ = 110,700						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	145,783	145,783	82,908	165,670	0.321	585,479
2015	140,342	140,342	140,342	153,102	0.626	583,864
2016	125,338	125,338	125,338	139,970	0.626	536,837
2017	124,742	124,742	124,742	139,487	0.626	514,014
2018	113,855	113,855	113,855	125,448	0.619	479,282
2019	95,368	95,368	95,368	114,715	0.561	456,071
2020	93,558	93,558	93,558	114,804	0.548	456,282
2021	95,915	95,915	95,915	117,018	0.548	459,204
2022	96,974	96,974	96,974	117,942	0.548	458,862
2023	96,049	96,049	96,049	116,386	0.550	455,714
2024	94,789	94,789	94,789	115,183	0.550	454,814
2025	94,402	94,402	94,402	115,021	0.549	456,659
2026	95,275	95,275	95,275	115,659	0.551	460,170
2027	96,966	96,966	96,966	117,027	0.554	464,097
Scenario 7, Whether Pacific cod is approaching overfished condition						

Year	ABC	OFL	Catch	SSB	F	Total Bio
2014	145,783	145,783	82,908	165,670	0.321	585,479
2015	140,342	140,342	117,211	155,441	0.502	583,864
2016	133,133	133,133	110,799	150,466	0.502	558,273
2017	136,286	136,286	136,286	152,162	0.626	545,916
2018	120,870	120,870	120,870	131,958	0.626	495,491
2019	99,218	99,218	99,218	117,325	0.573	462,674
2020	94,277	94,277	94,277	115,469	0.551	457,825
2021	95,996	95,996	95,996	117,189	0.548	459,566
2022	96,975	96,975	96,975	117,996	0.548	458,972
2023	96,045	96,045	96,045	116,407	0.550	455,756
2024	94,788	94,788	94,788	115,193	0.550	454,833
2025	94,402	94,402	94,402	115,025	0.549	456,667
2026	95,275	95,275	95,275	115,660	0.551	460,173
2027	96,966	96,966	96,966	117,028	0.554	464,098

Table 2.23 – Biological reference points from GOA Pacific cod SAFE documents for years 2001 – 2014

Year	$SB_{100\%}$	$SB_{40\%}$	$F_{40\%}$	SB_{y+1}	ABC_{y+1}
2001	212,000	85,000	0.41	82,000	57,600
2002	226,000	90,300	0.35	88,300	52,800
2003	222,000	88,900	0.34	103,000	62,810
2004	211,000	84,400	0.31	91,700	58,100
2005	329,000	132,000	0.56	165,000	68,859
2006	259,000	103,000	0.46	136,000	68,859
2007	302,000	121,000	0.49	108,000	66,493
2008	255,500	102,200	0.52	88,000	55,300
2009	291,500	116,600	0.49	117,600	79,100
2010	256,300	102,500	0.42	124,100	86,800
2011	261,000	104,000	0.44	121,000	87,600
2012	234,800	93,900	0.49	111,000	80,800
2013	227,800	91,100	0.54	120,100	88,500
2014	*316,500*	*126,600*	*0.50*	*155,400*	*117,200*

Figures

Fig. 2.1 – Fishery catches by season and gear (AKFIN; as of 2014-10-14)

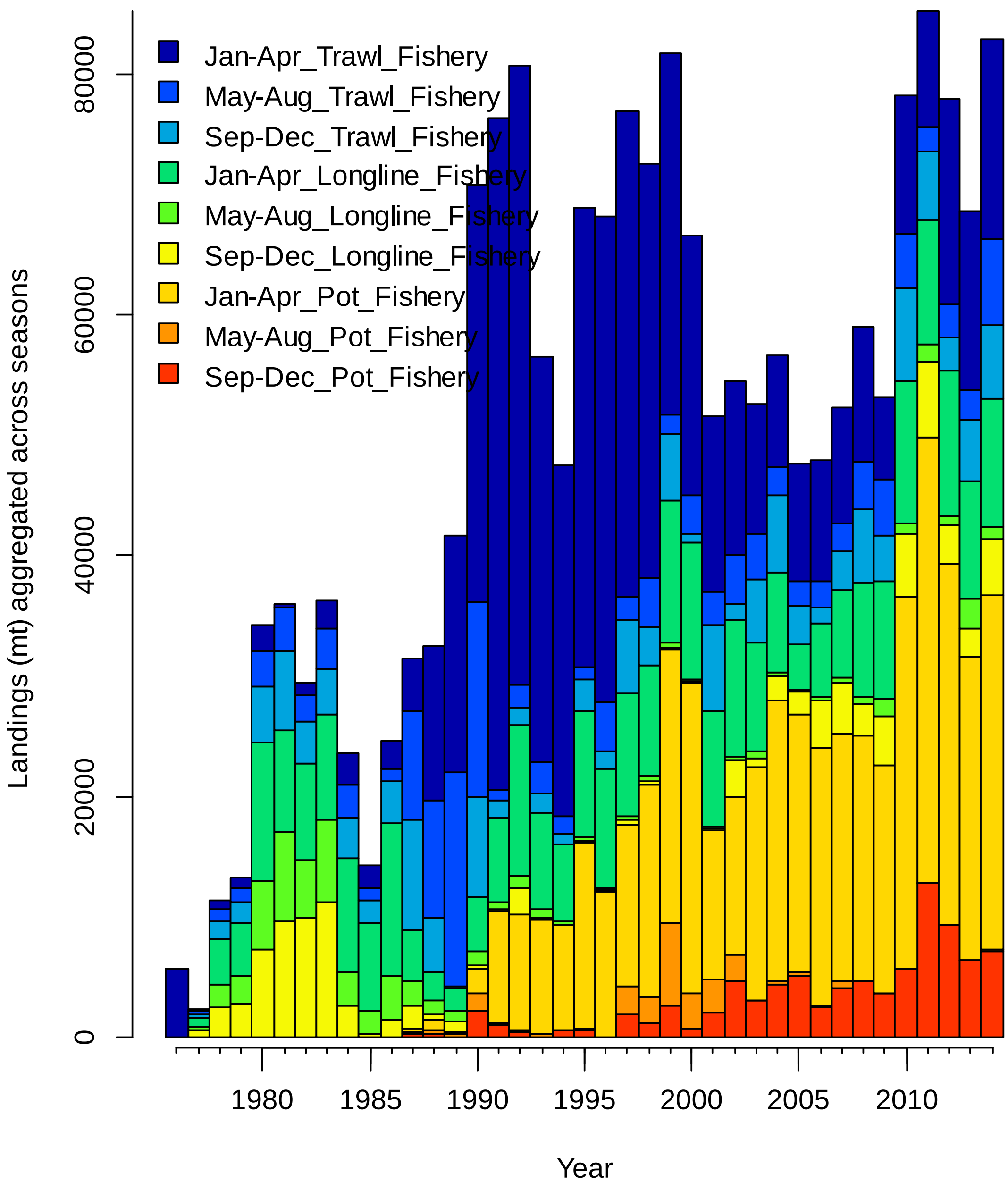


Fig. 2.2 – GOA NMFS bottom trawl survey biomass estimates for Pacific cod, with 95% confidence interval

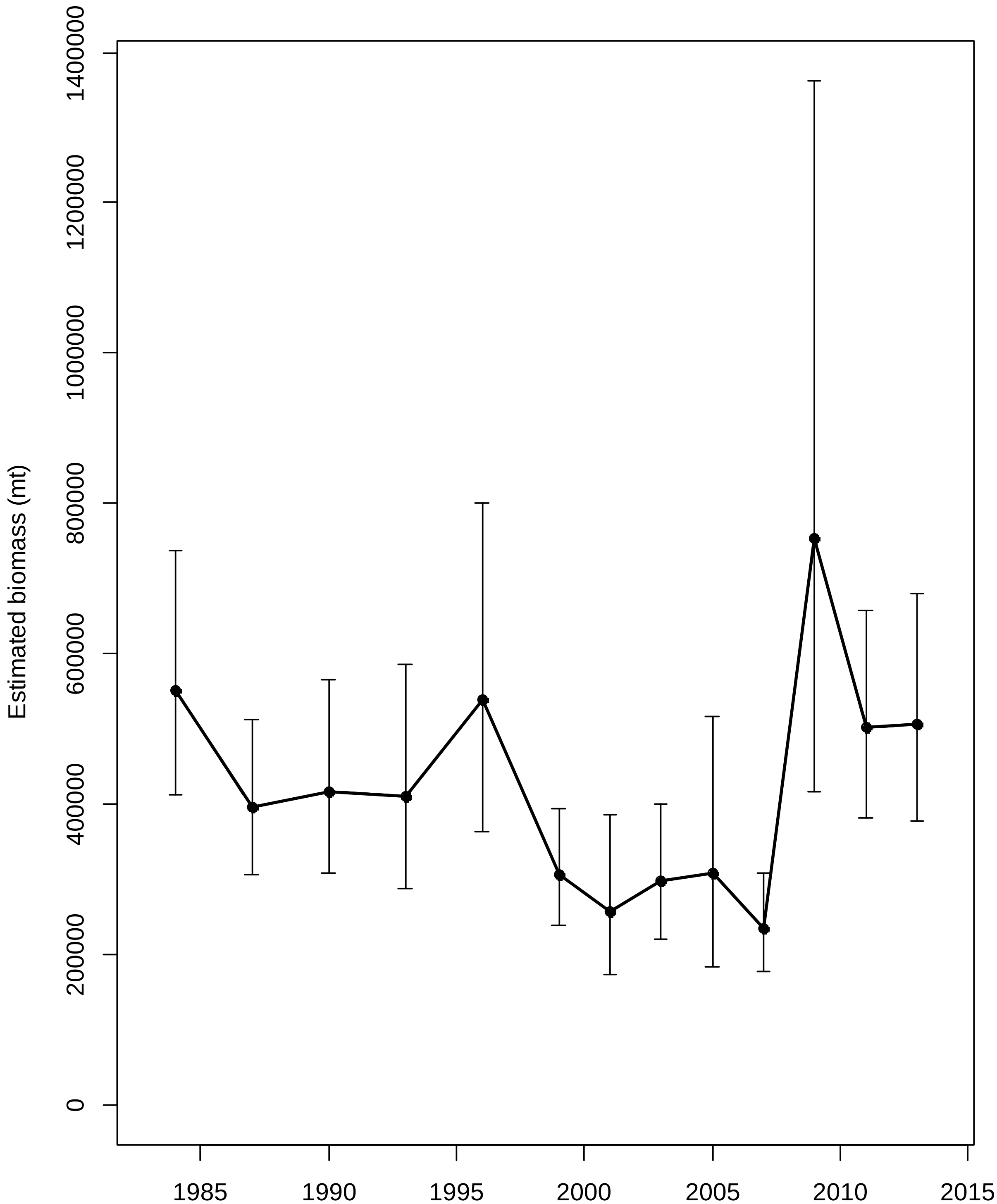


Fig. 2.3 – GOA NMFS survey abundance estimates for Pacific cod, with 95% confidence interval

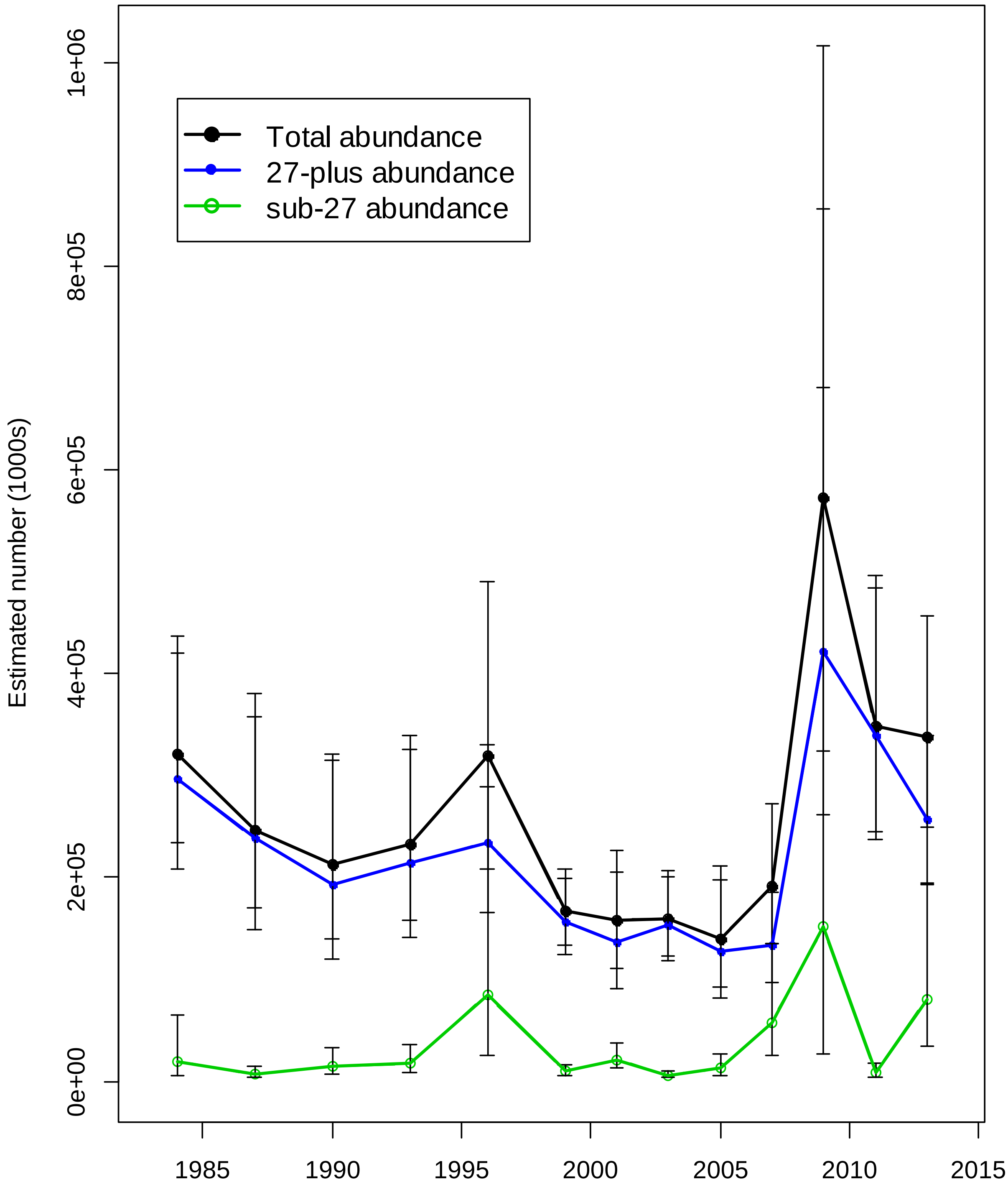


Fig. 2.4 – GOA NMFS bottom trawl survey biomass estimates by area (in t)

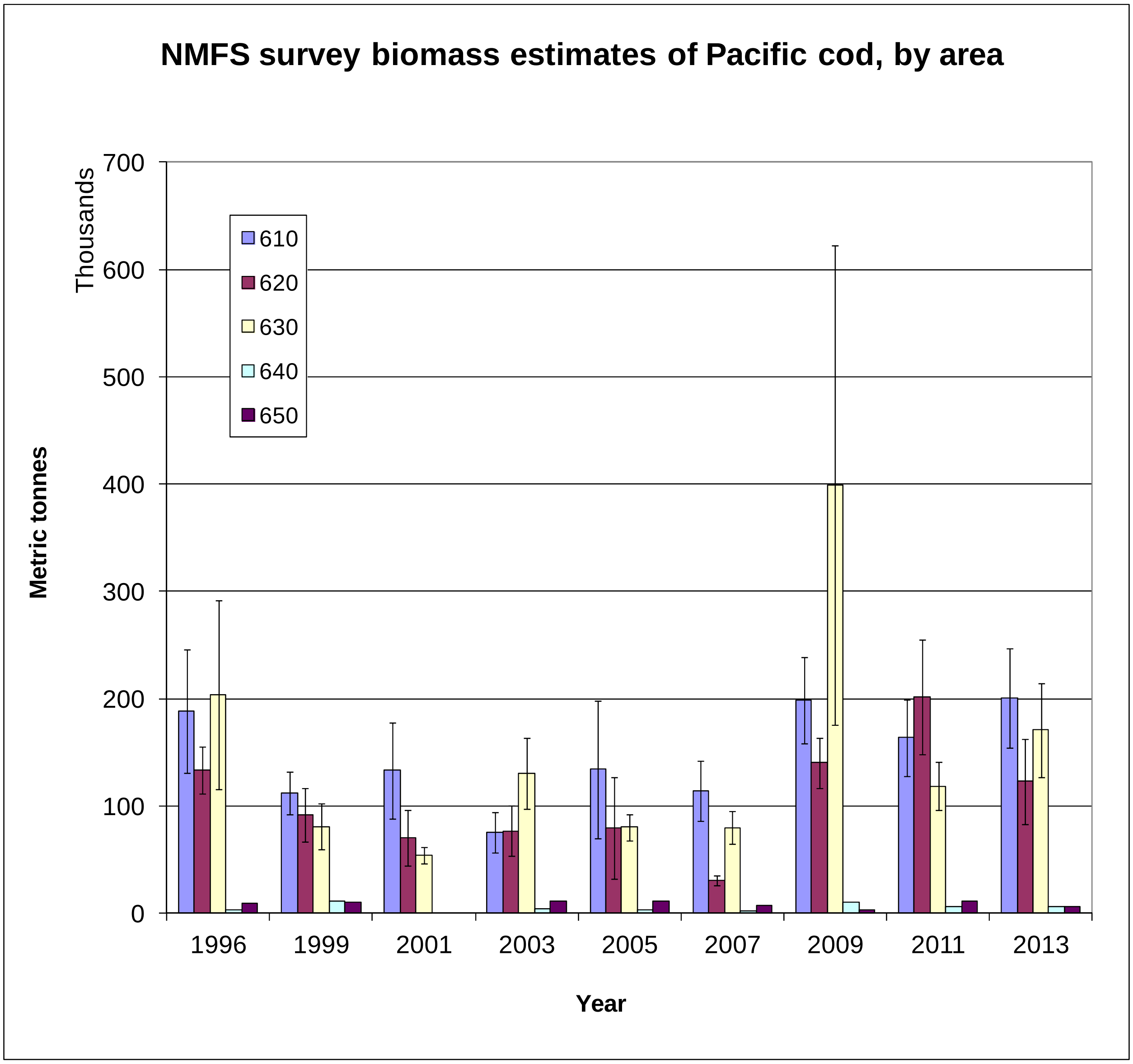


Fig. 2.5 – GOA NMFS bottom trawl survey abundance estimates by area (in numbers)

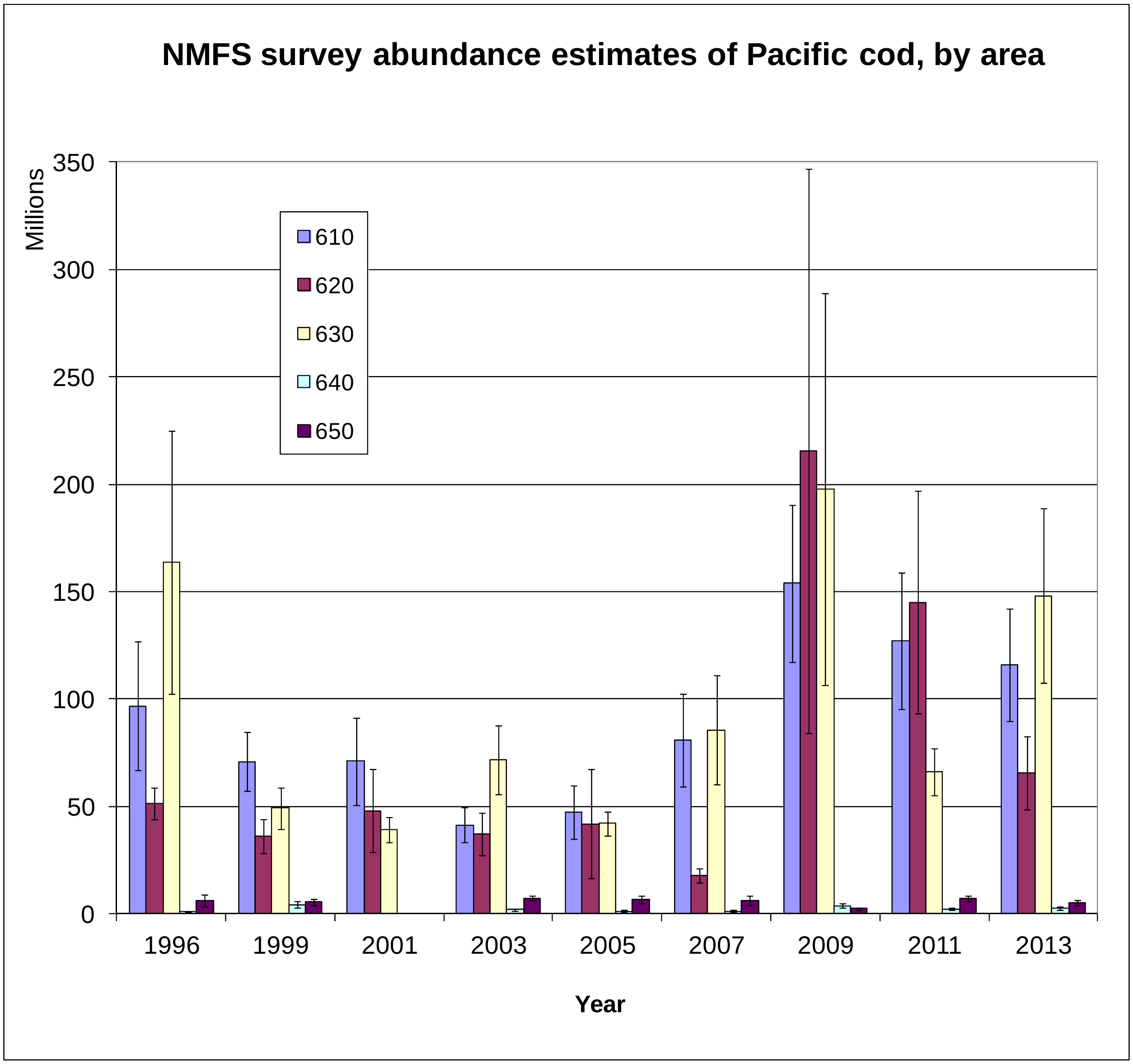


Fig. 2.6 – GOA NMFS bottom trawl population length composition estimates for Pacific cod, by cm

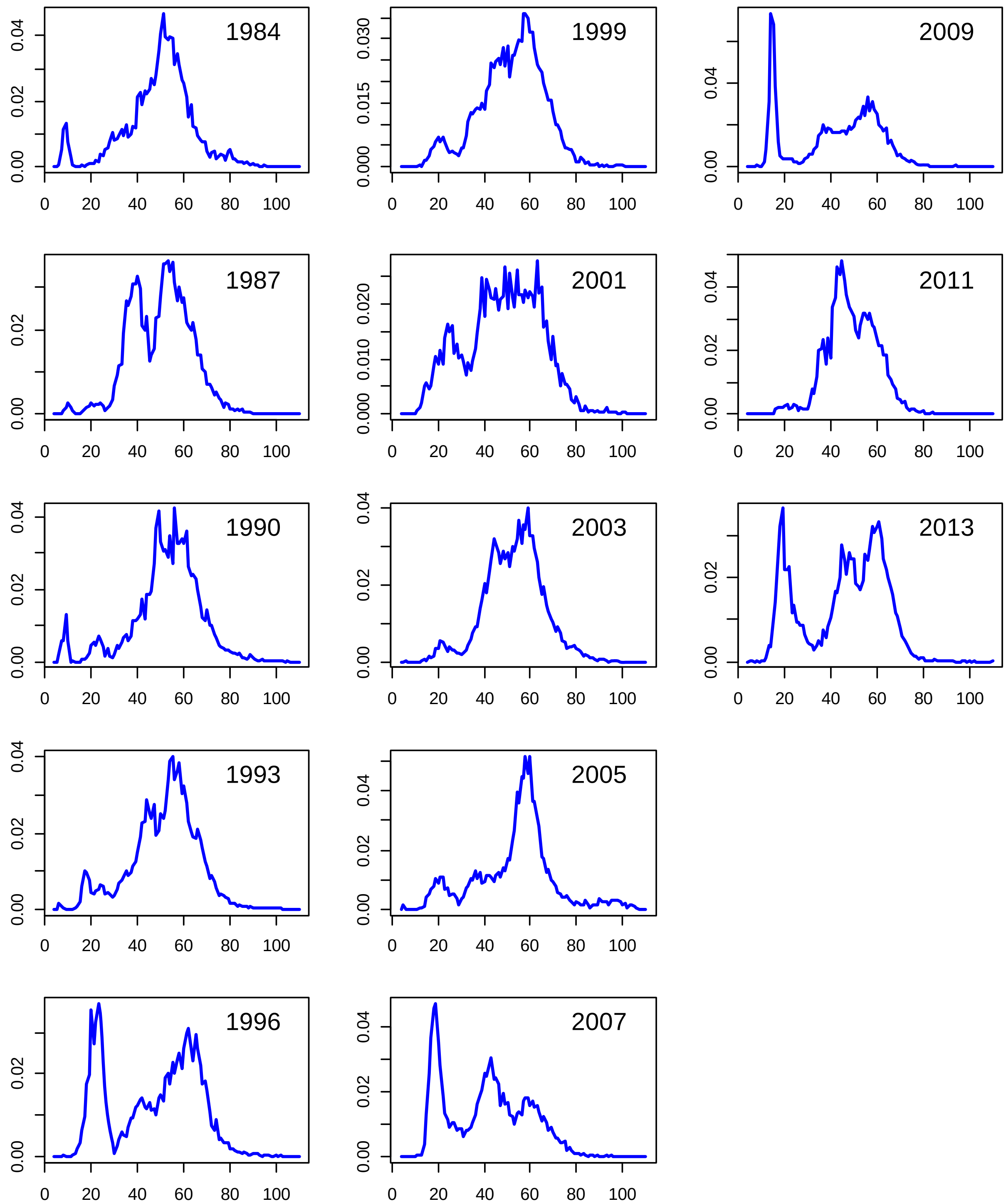


Fig. 2.7 – GOA NMFS bottom trawl population age composition estimates for Pacific cod

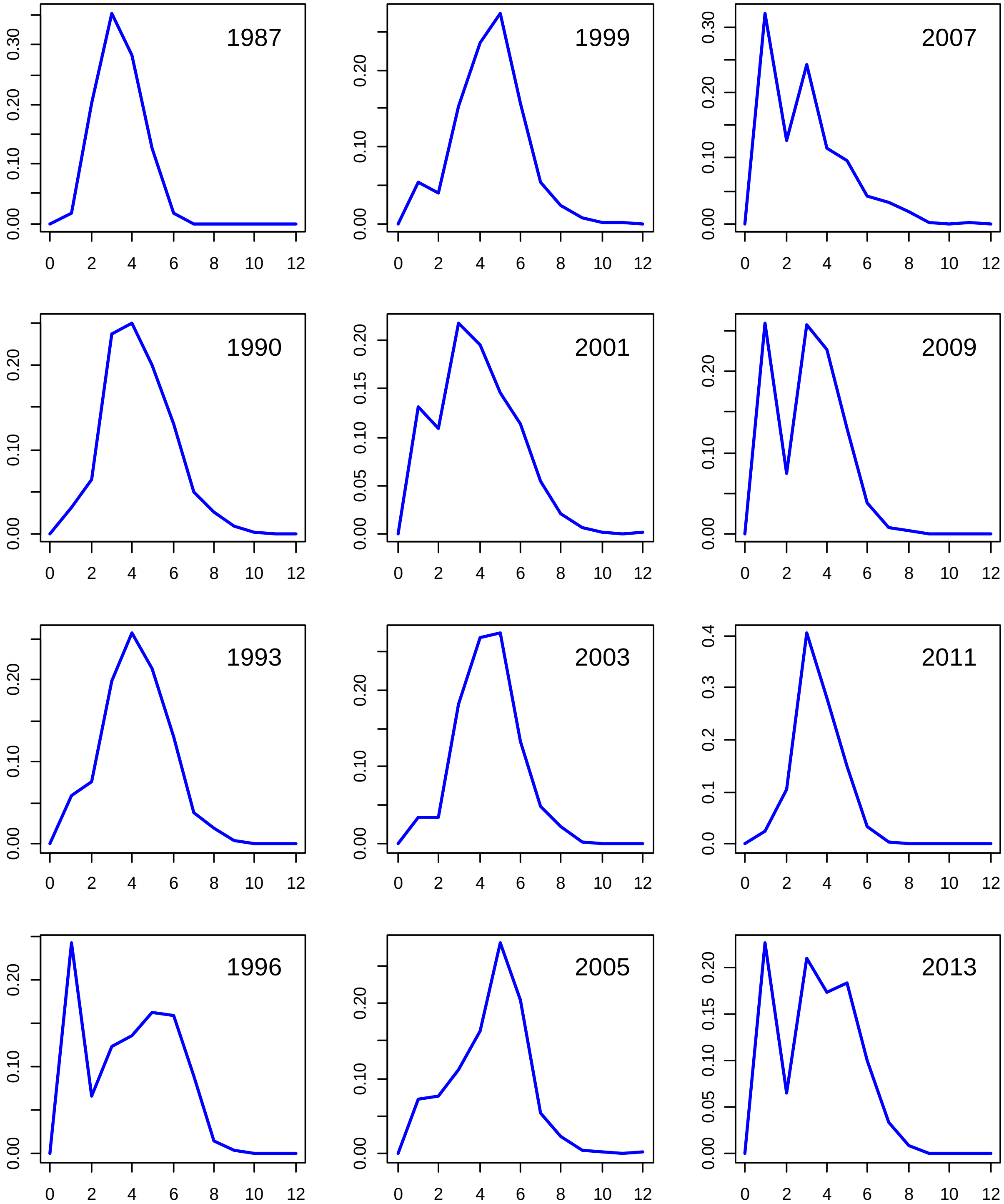


Fig. 2.8 – Estimates of spawning biomass for the 4 models evaluated

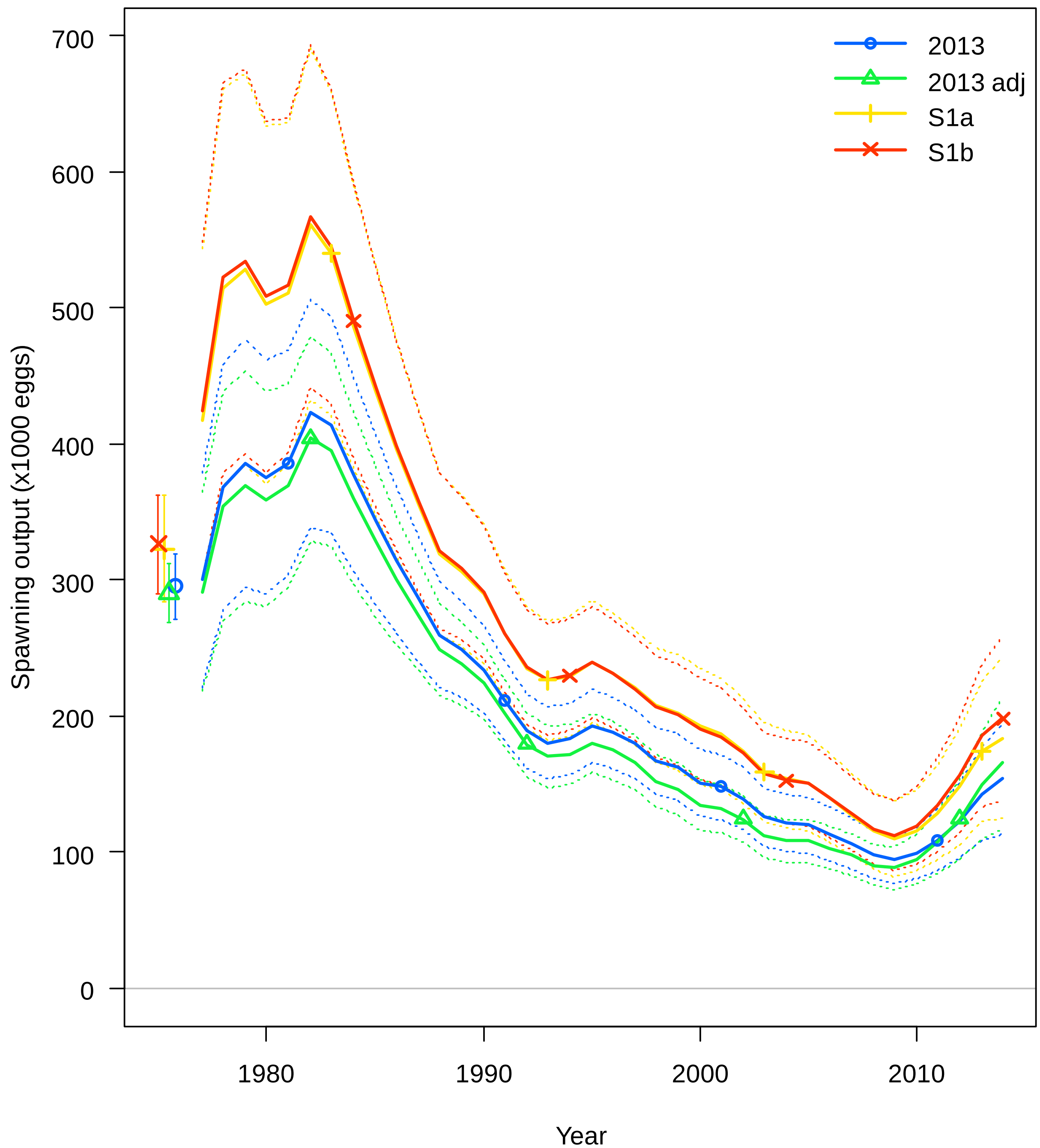


Fig. 2.9 – Estimates of age-0 recruits (billions) for the 4 models evaluated

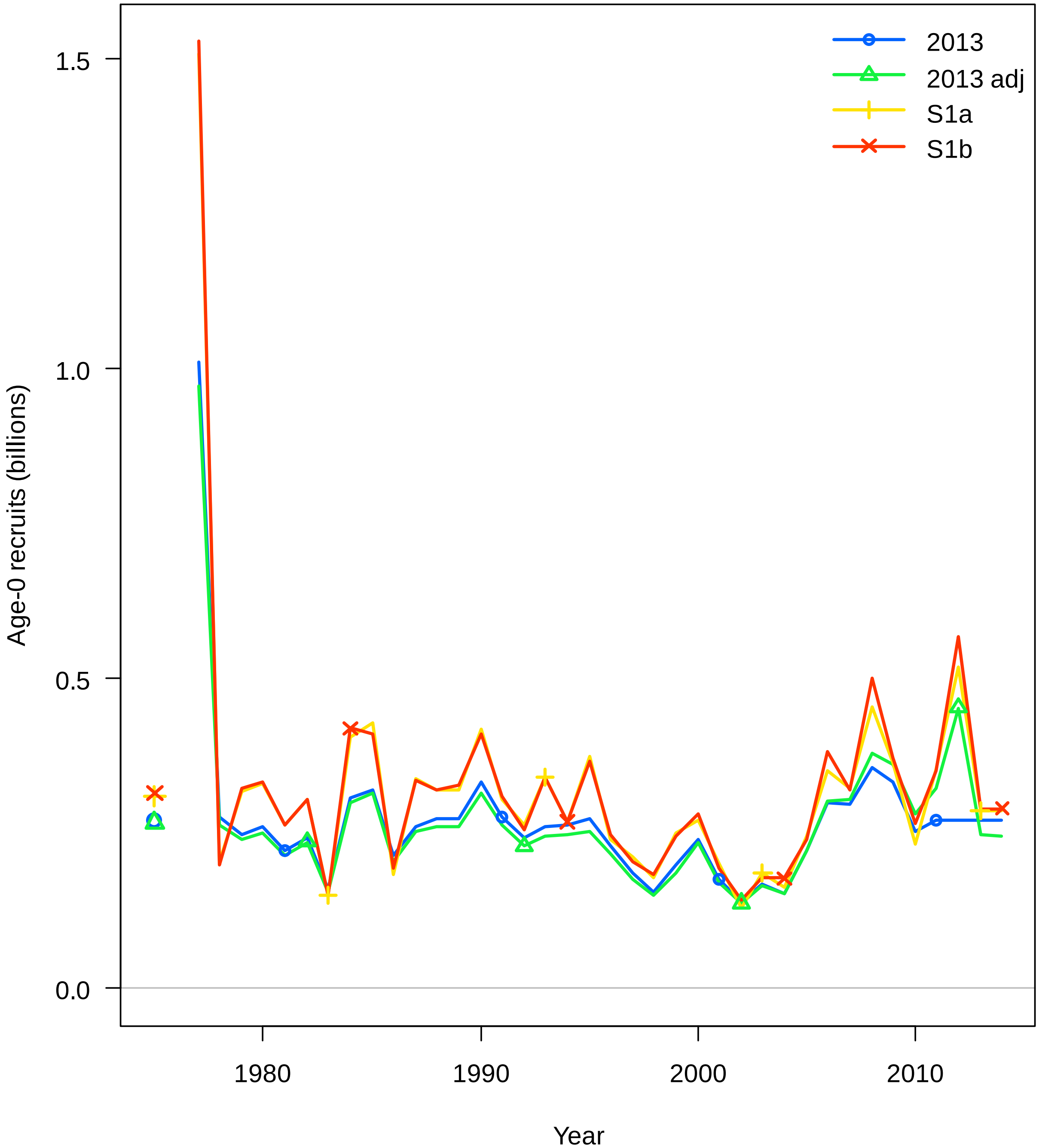


Fig. 2.10 – Fits (solid lines) to the 27-plus survey abundance estimates (solid circles, with 95% confidence intervals) for the 2013 models, and the full survey abundance estimates (solid circles, with 95% confidence intervals) for Models S1a and S1b

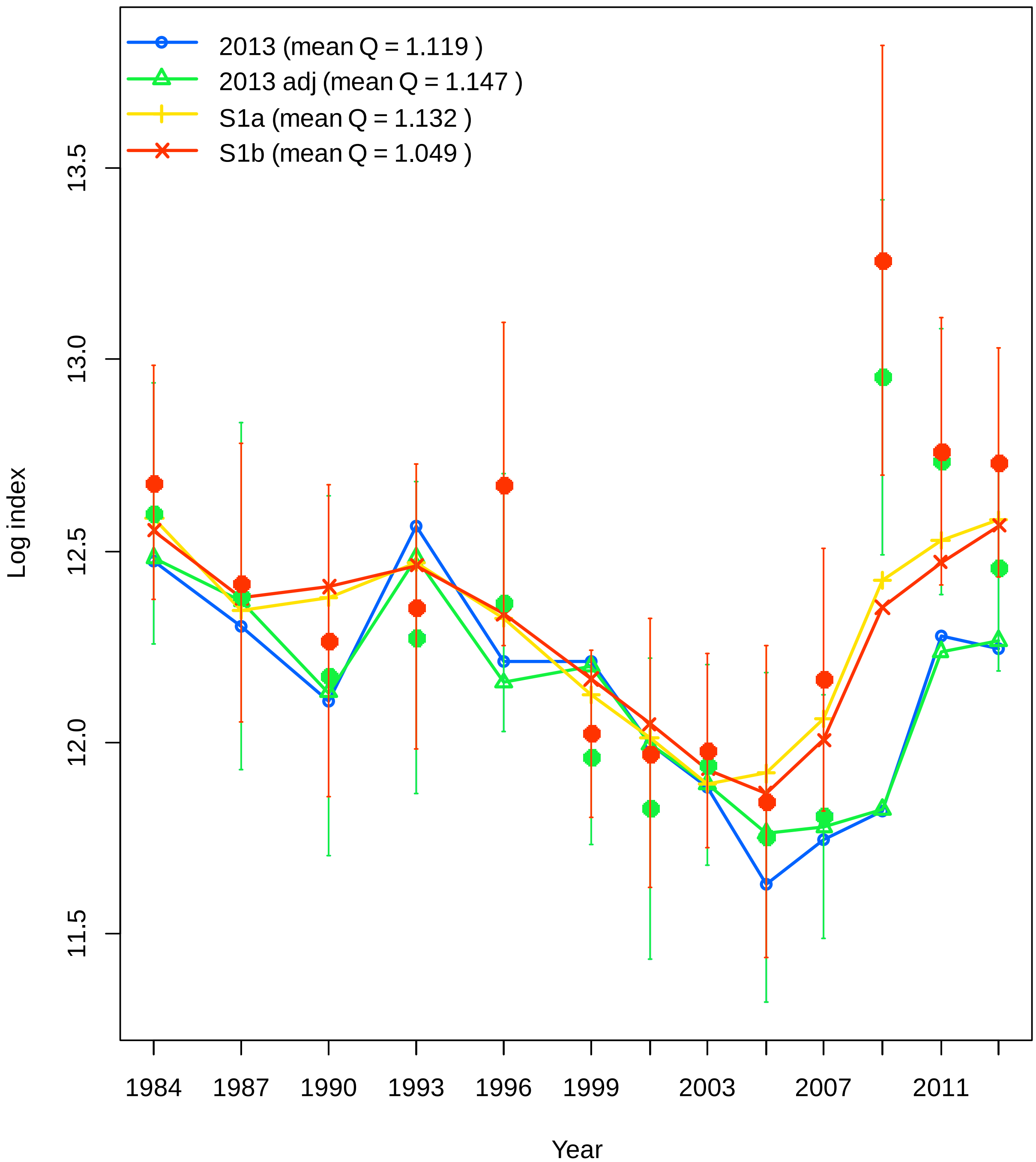


Fig. 2.11 – Estimates of total (age 0+) biomass from Model S1a

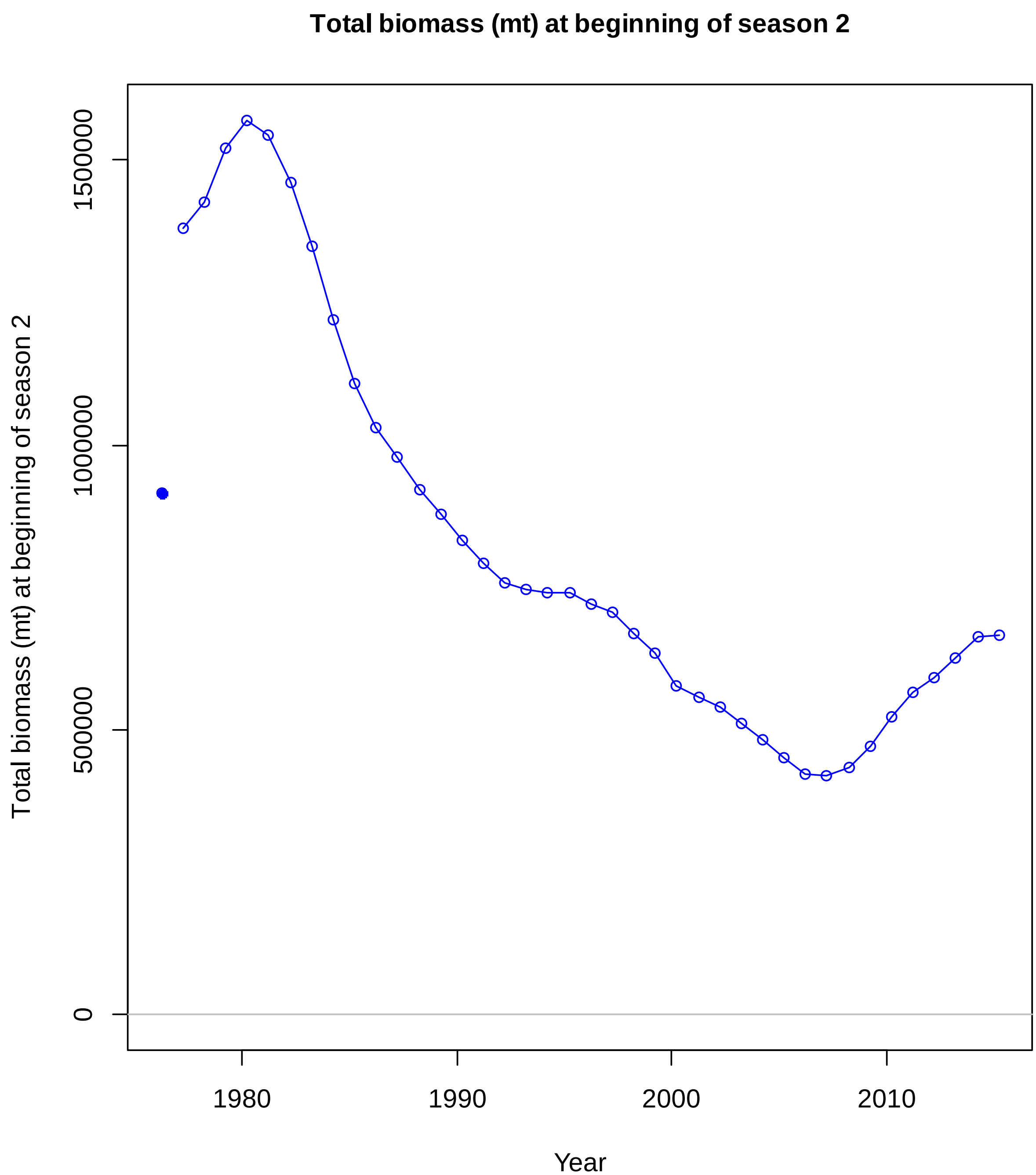


Fig. 2.12 – Estimates of female spawning biomass from Model S1a

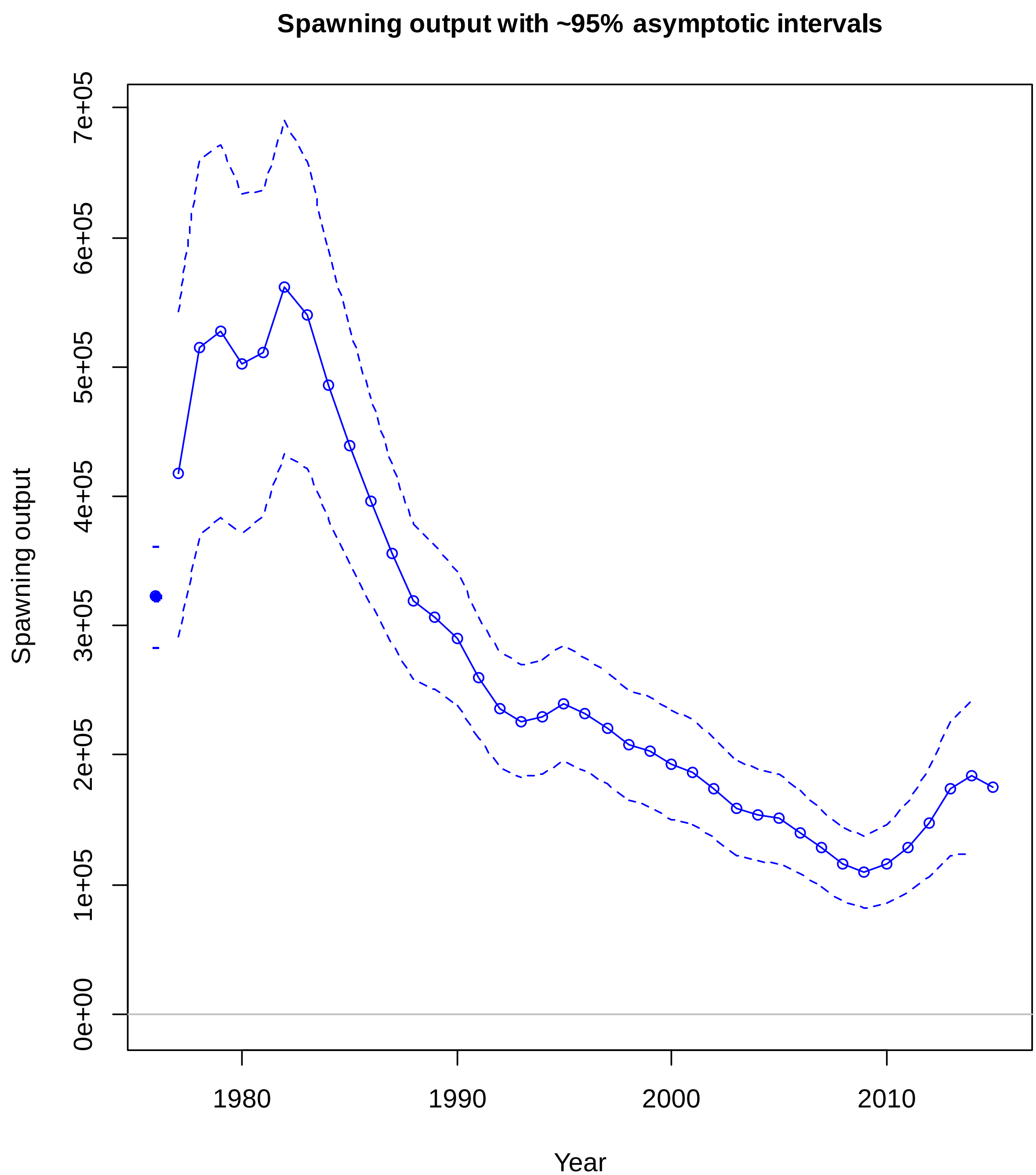


Fig. 2.13 – Estimates of age-0 recruits from Model S1a

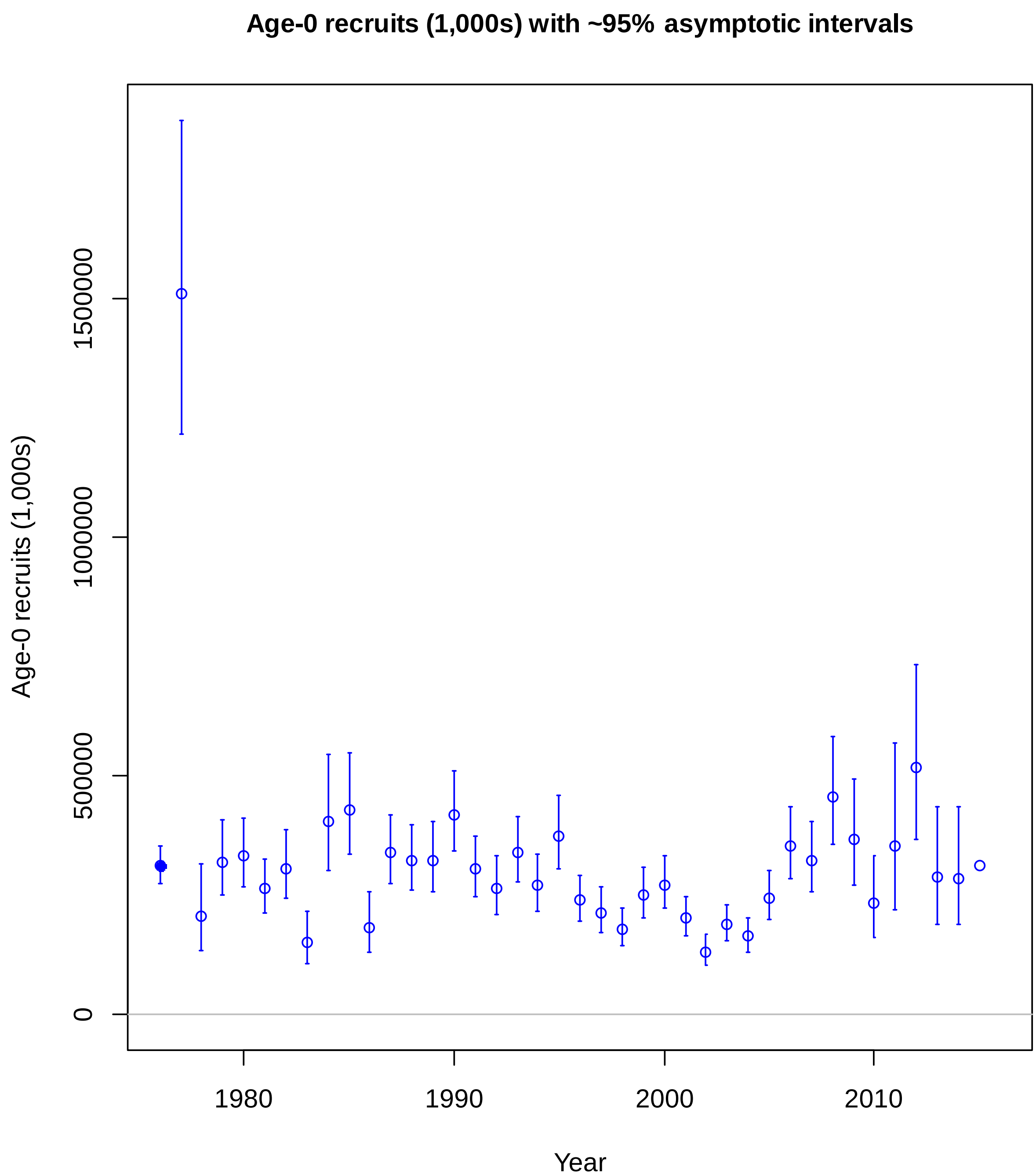
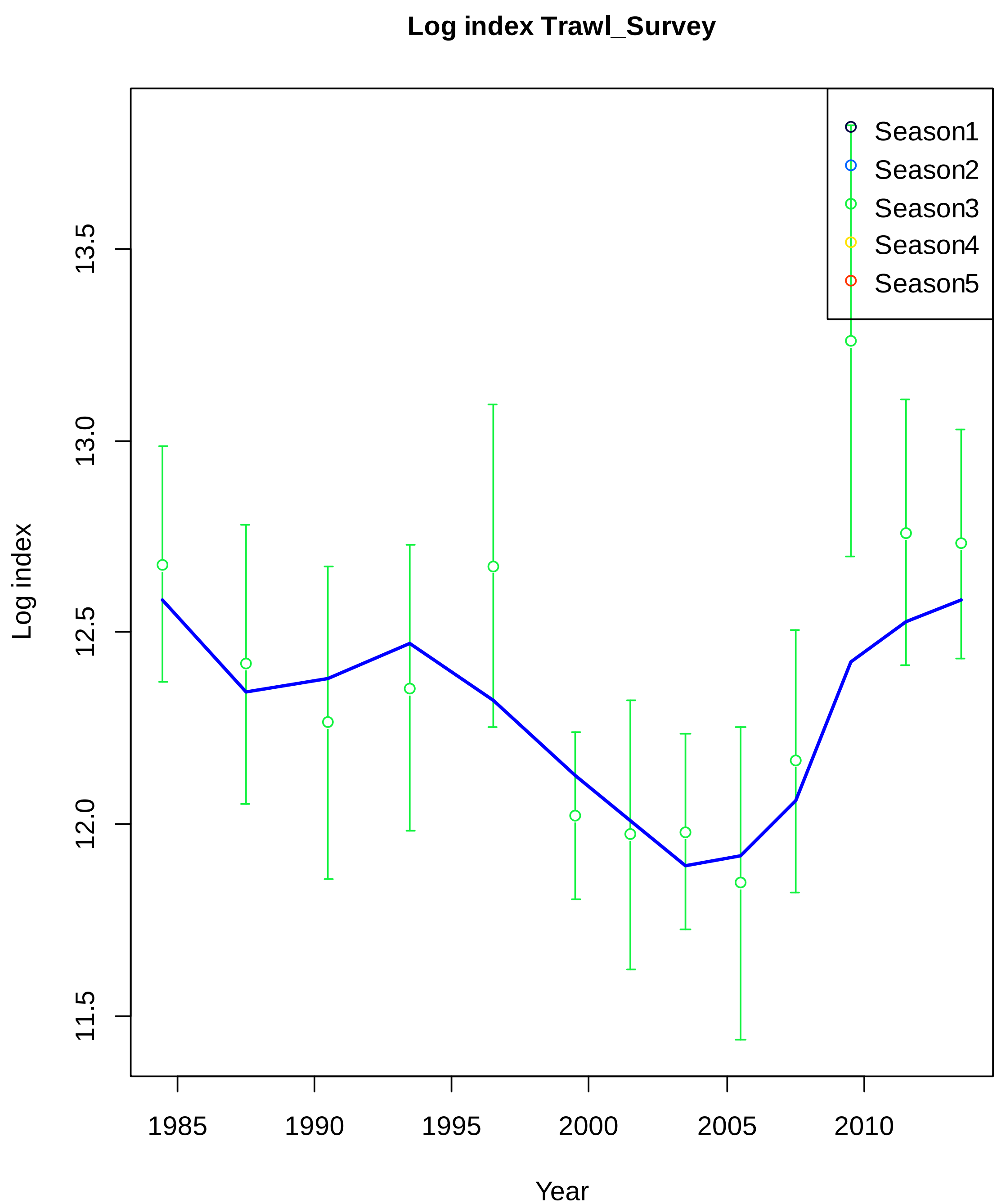


Fig. 2.14 – Fit (solid line) to the abundance estimates (open circles) from the GOA NMFS bottom trawl survey with 95% confidence intervals from Model S1a



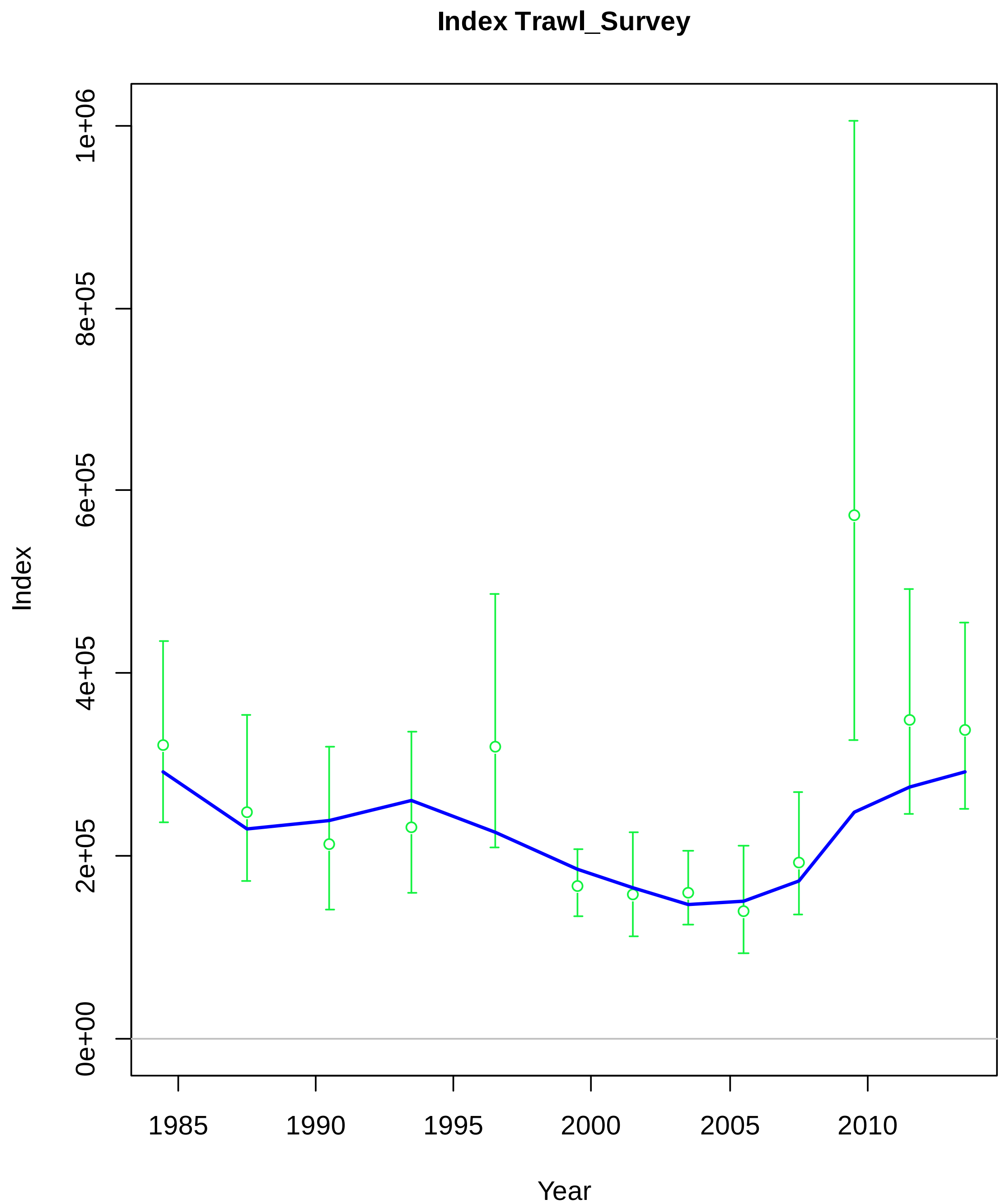

Index Trawl_Survey
Index
1e+06
8e+05
6e+05
4e+05
2e+05
0e+00
1985
1990
1995
2000
2005
2010
Year

Fig. 2.15 – Estimates of spawning biomass (t) and age-0 recruits from Model S1a; the solid black line is the median, and the solid green line is the bias-adjusted median

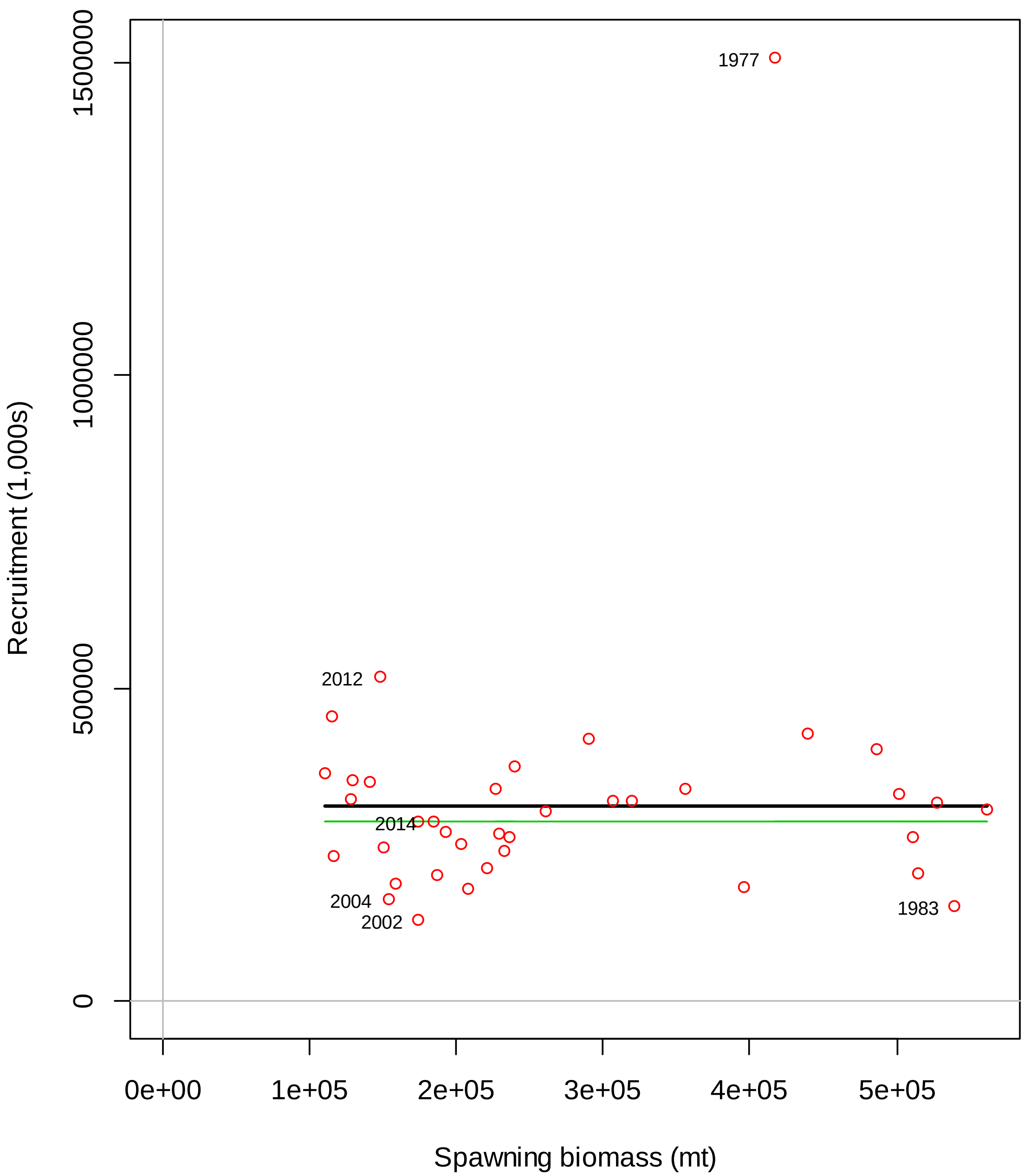
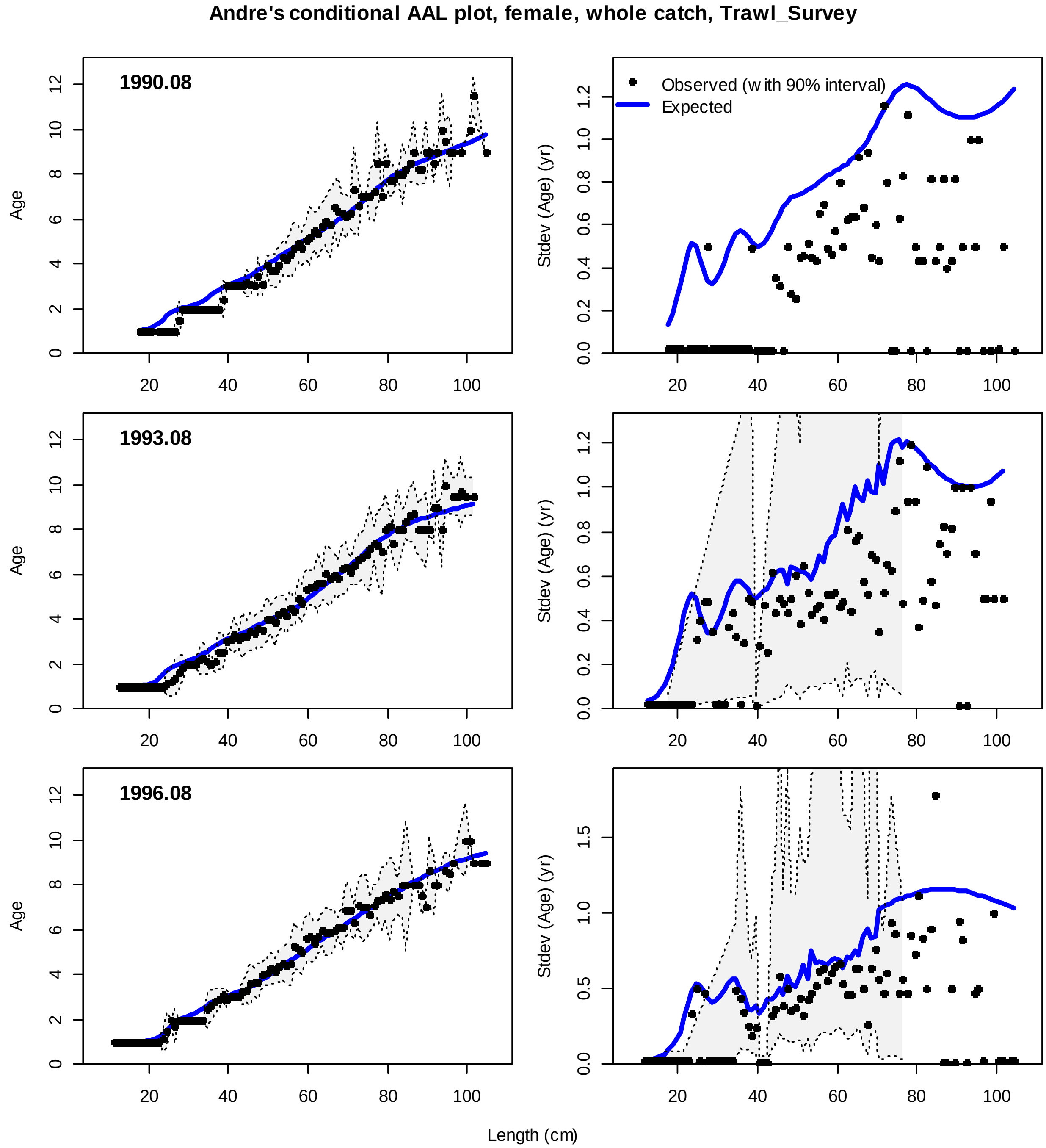
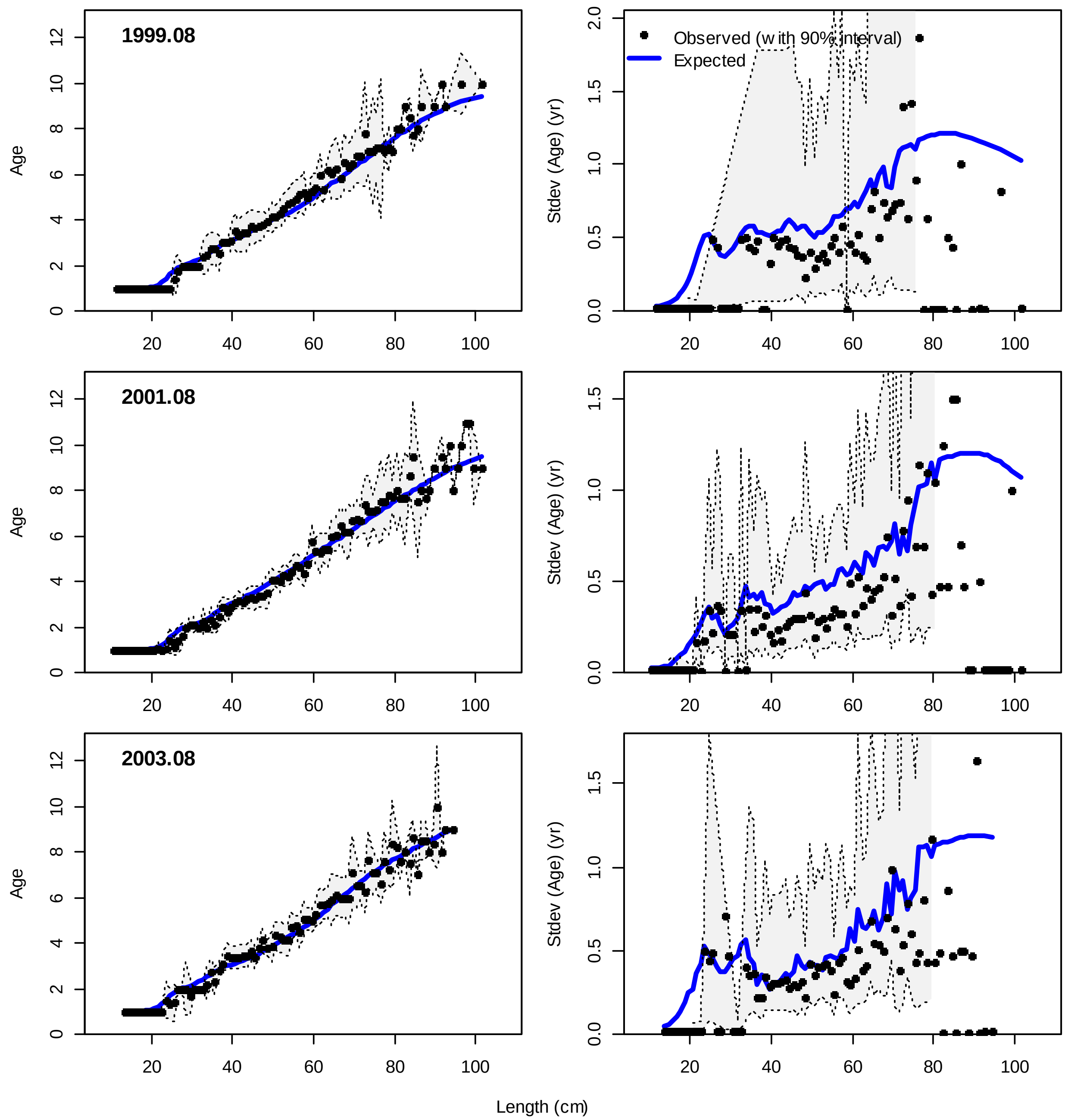
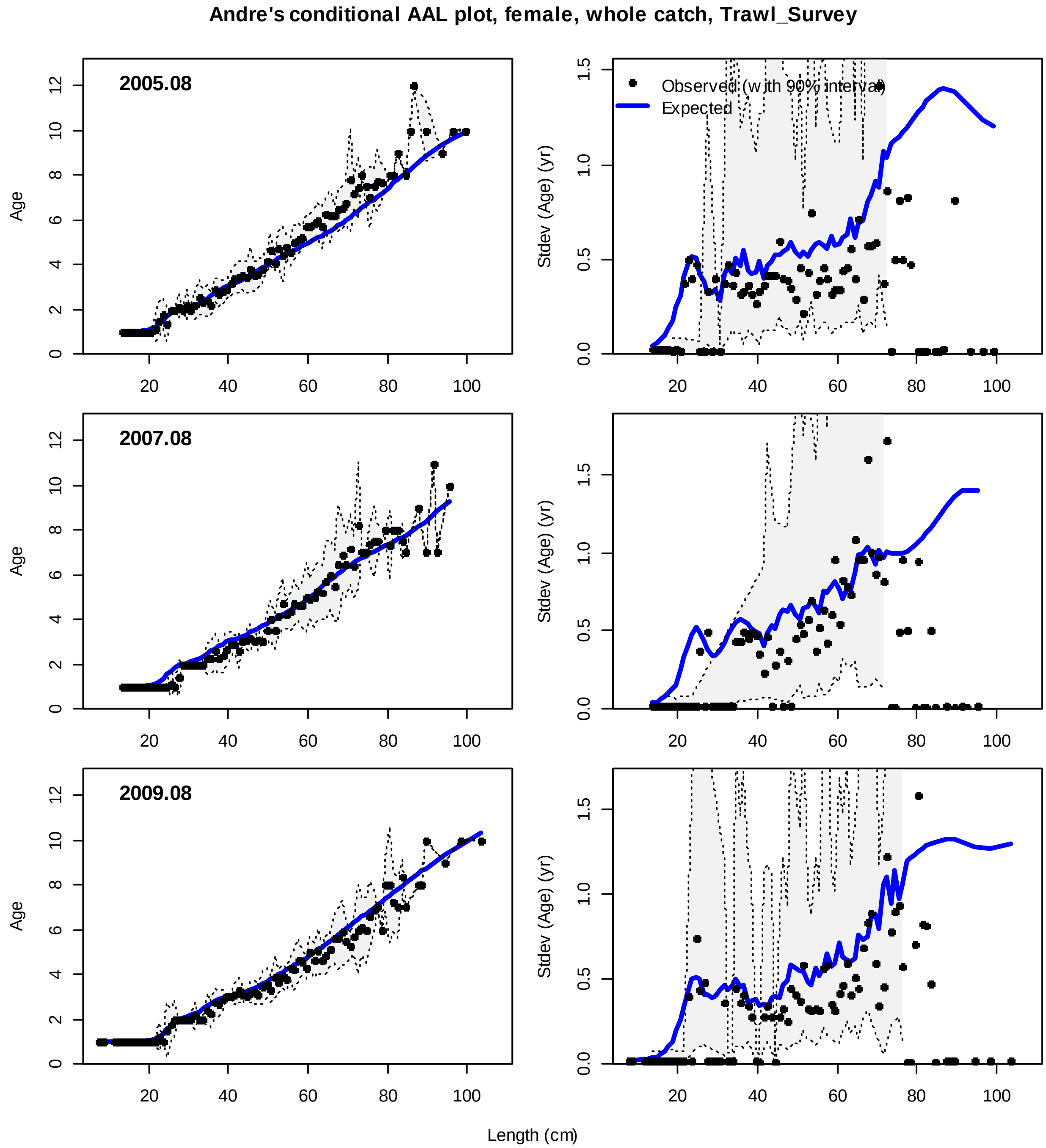


Fig. 2.16 – Fit to the age composition data from the GOA NMFS bottom trawl survey from Model S1a



Andre's conditional AAL plot, female, whole catch, Trawl_Survey




Andre's conditional AAL plot, female, whole catch, Trawl_Survey
2005.08
2007.08
2009.08
Age
Stdev (Age) (yr)
Observed (with 90% interval)
Expected
Length (cm)

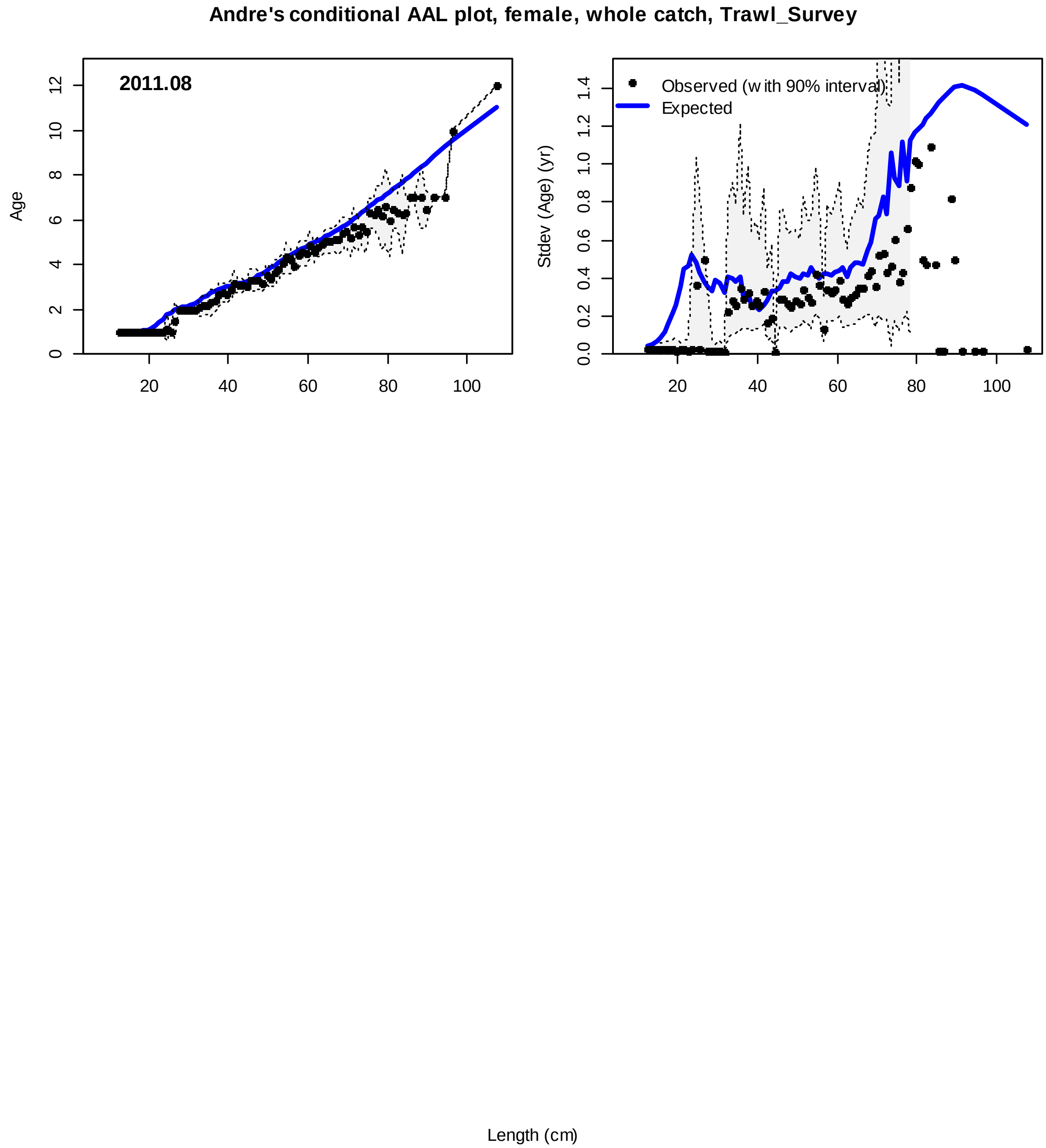

Andre's conditional AAL plot, female, whole catch, Trawl_Survey
2011.08
Age
Stdev (Age) (yr)
Observed (with 90% interval)
Expected
Length (cm)

Fig. 2.17 – Fit (solid line) to the length composition data from the GOA NMFS bottom trawl survey from Model S1a

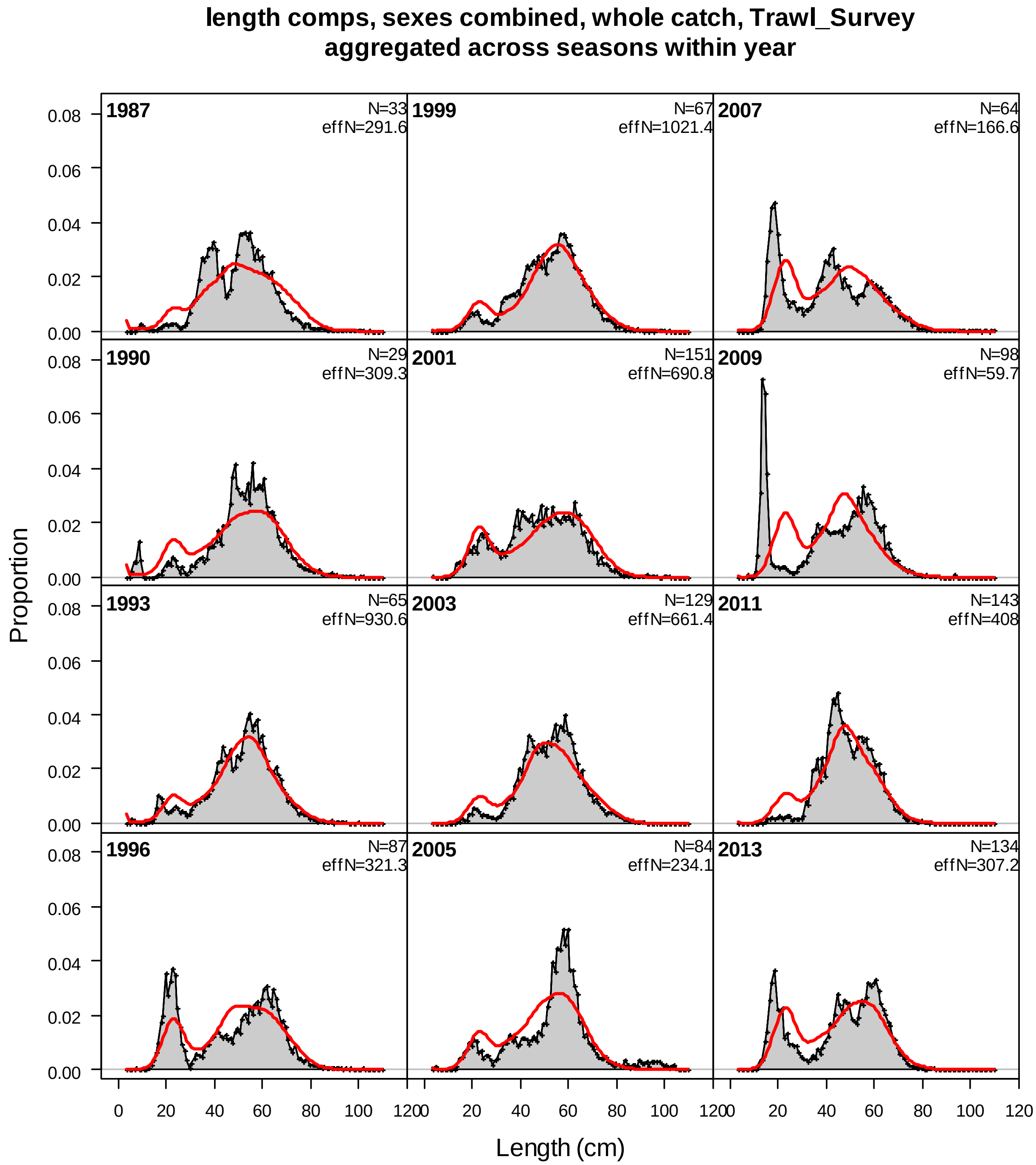


Fig. 2.18 – Estimates of (solid line) and length composition data for the GOA NMFS bottom trawl survey from Model S1a. The 1984 survey length composition data were not used in model fitting, hence "ghost length comps."

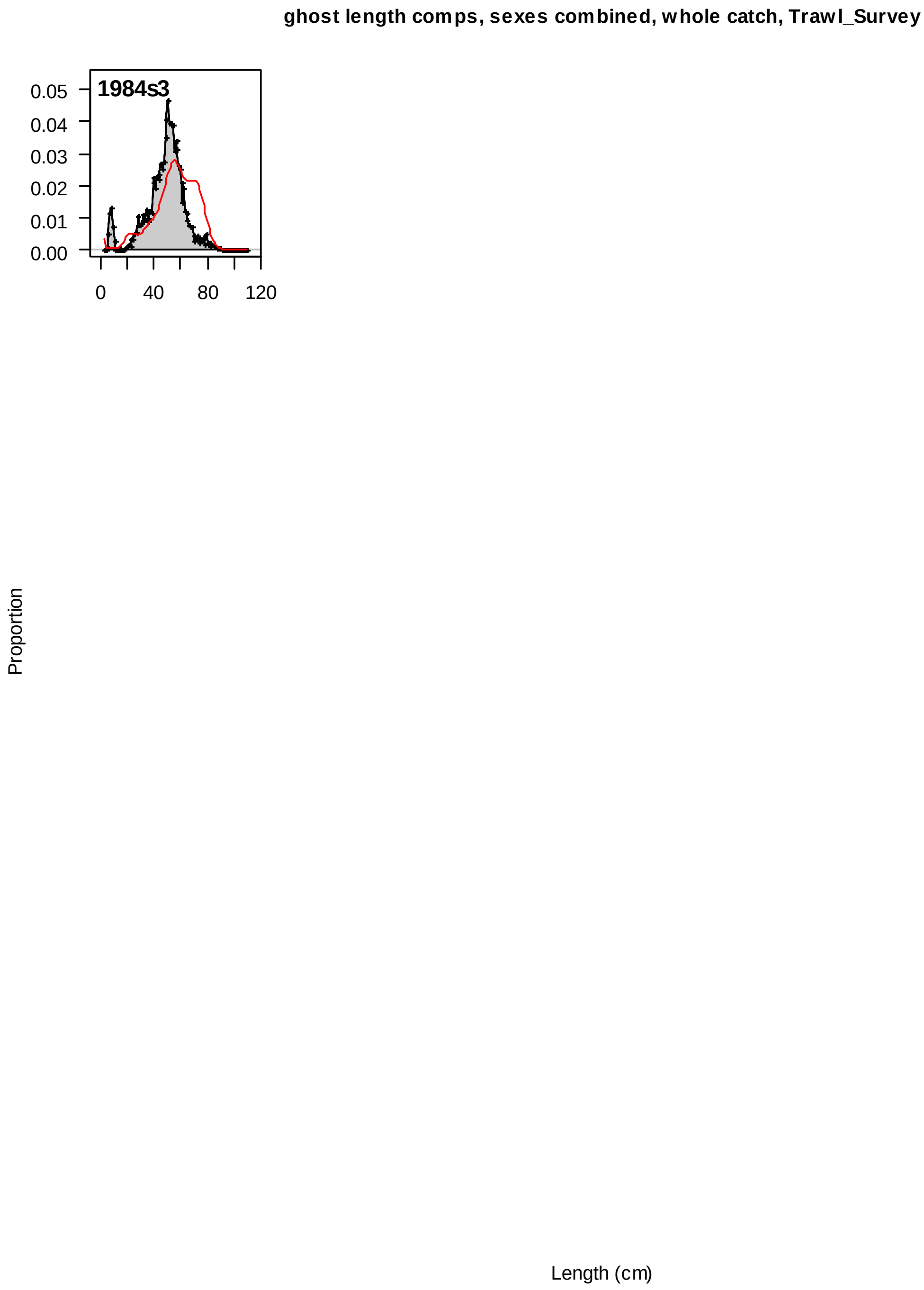


Fig. 2.19 – Estimated length-at-age (cm) from Model S1a

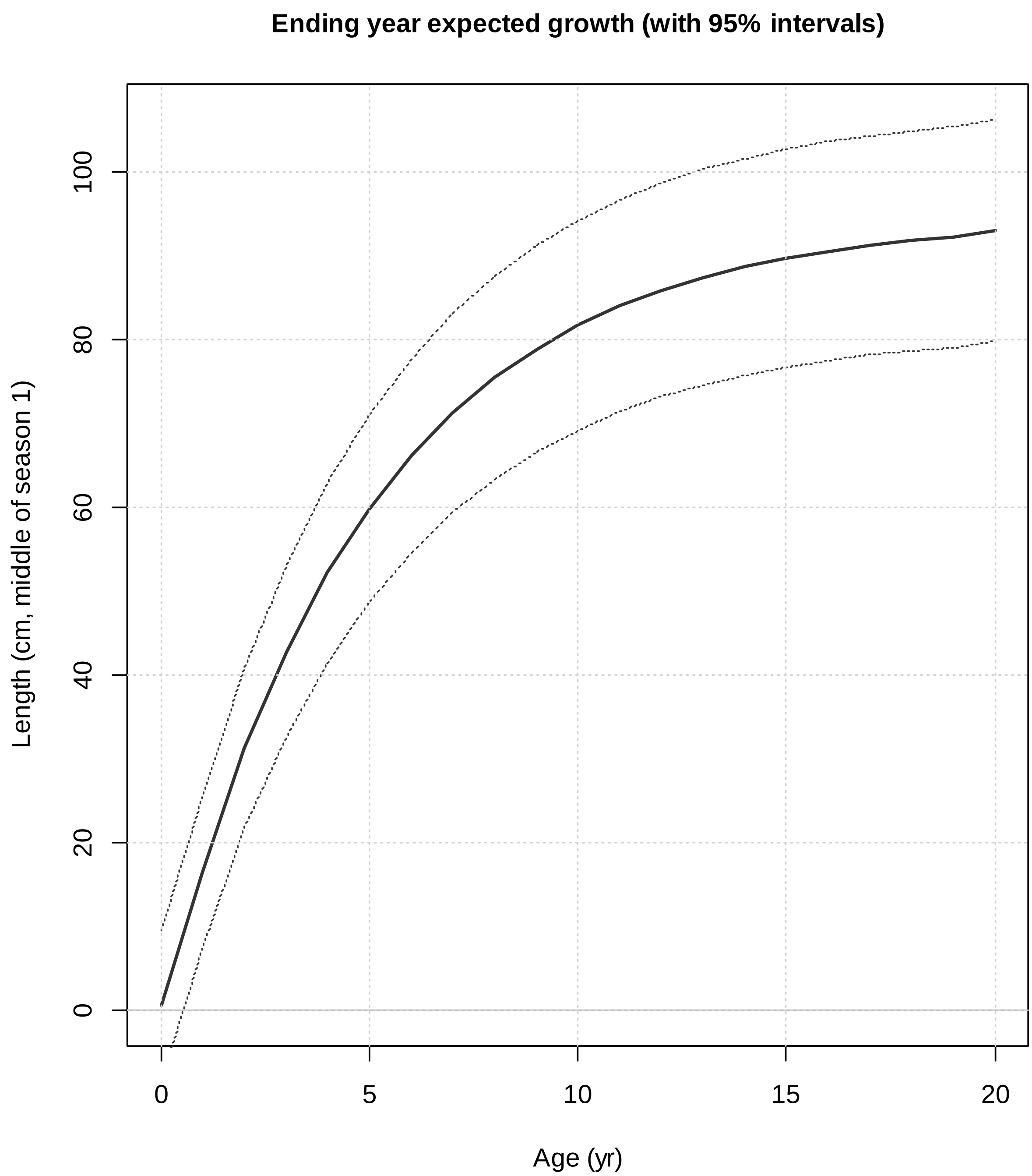


Fig. 2.20 – Estimate trawl survey selectivity-at-age from Model S1a

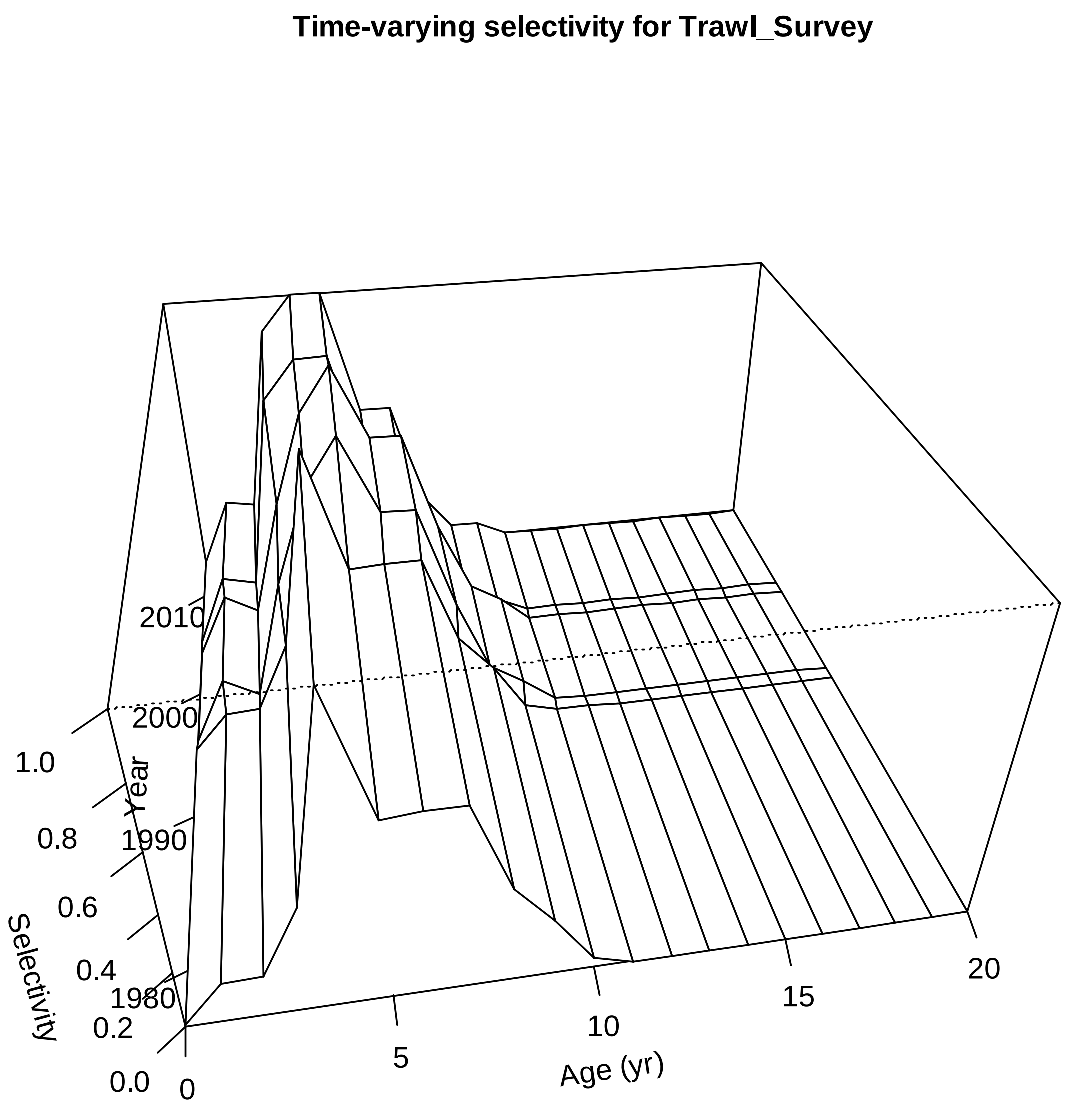
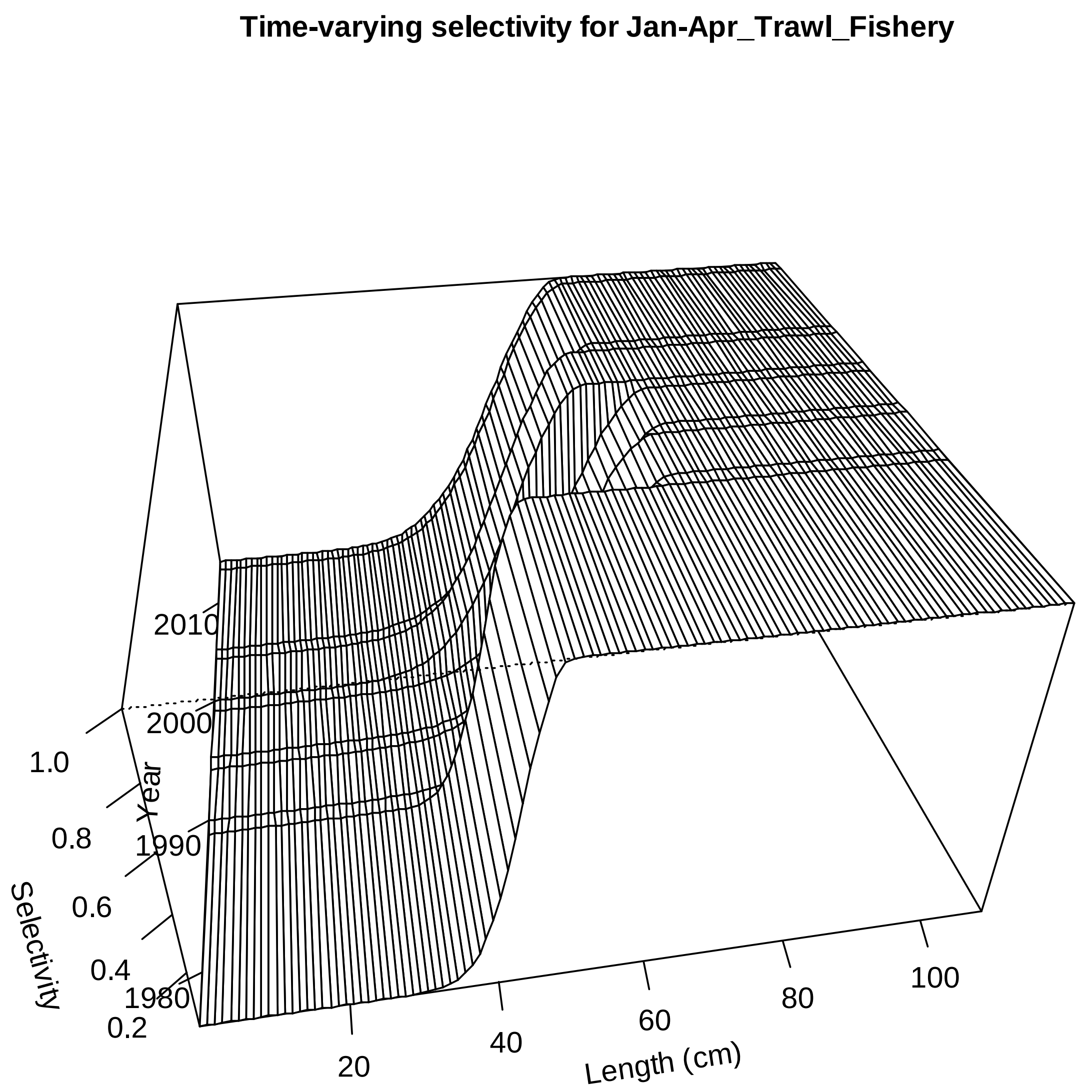
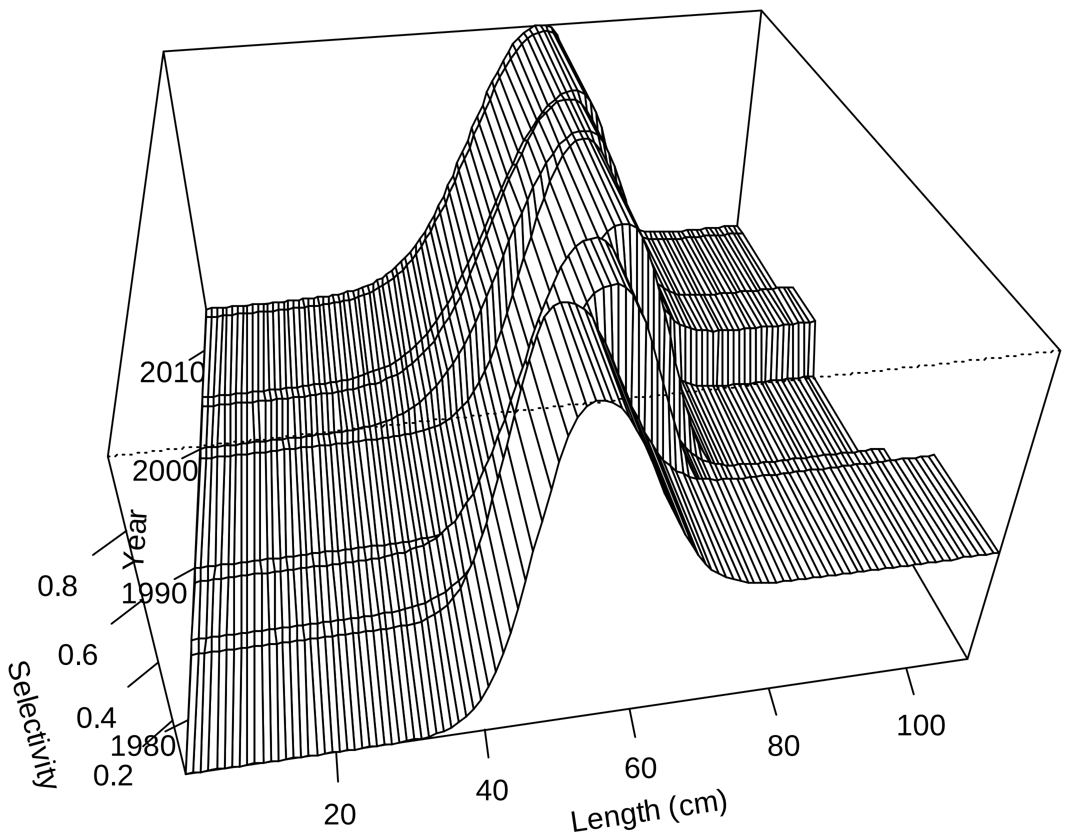
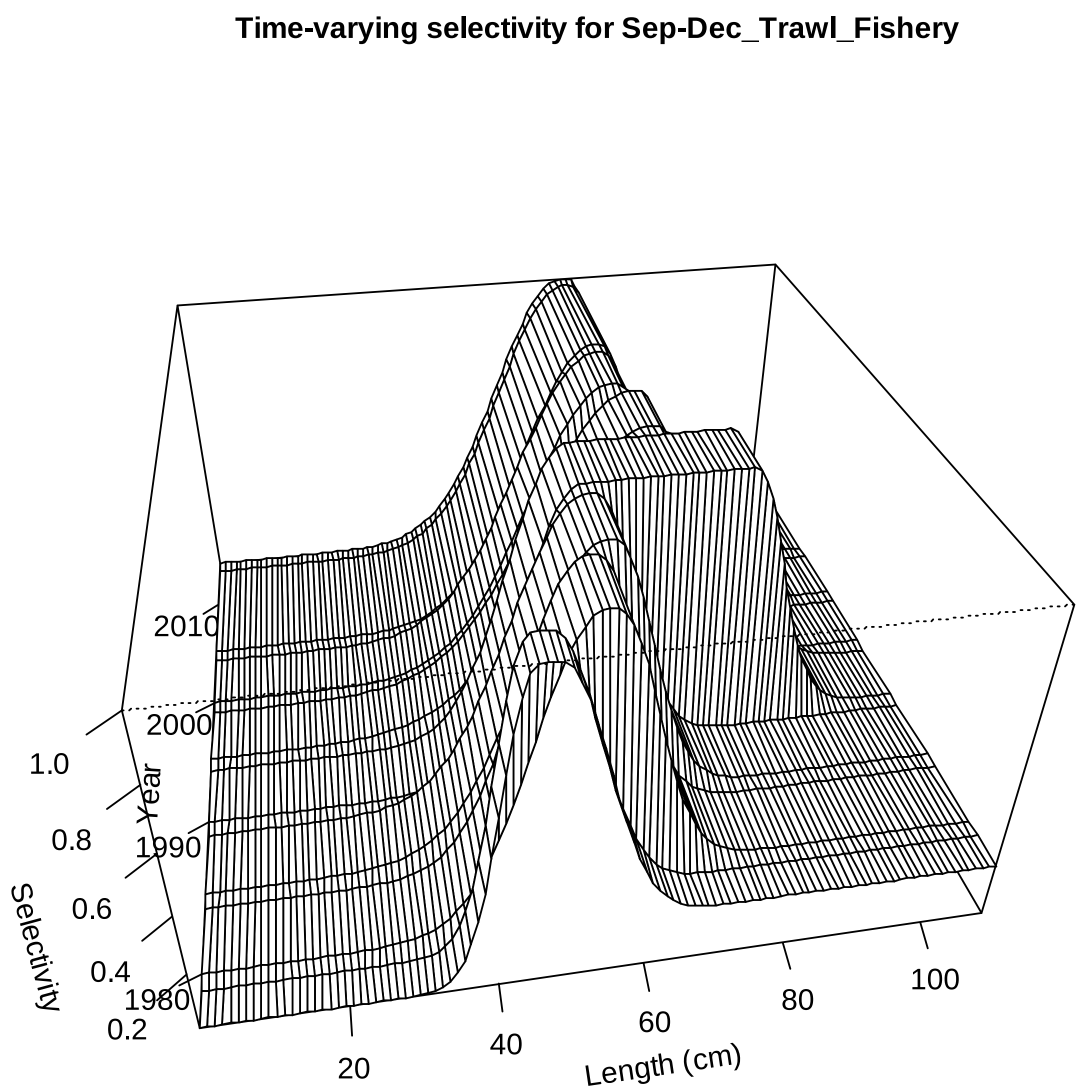


Fig. 2.21 – Fishery selectivity-at-length curves by gear and season from Model S1a

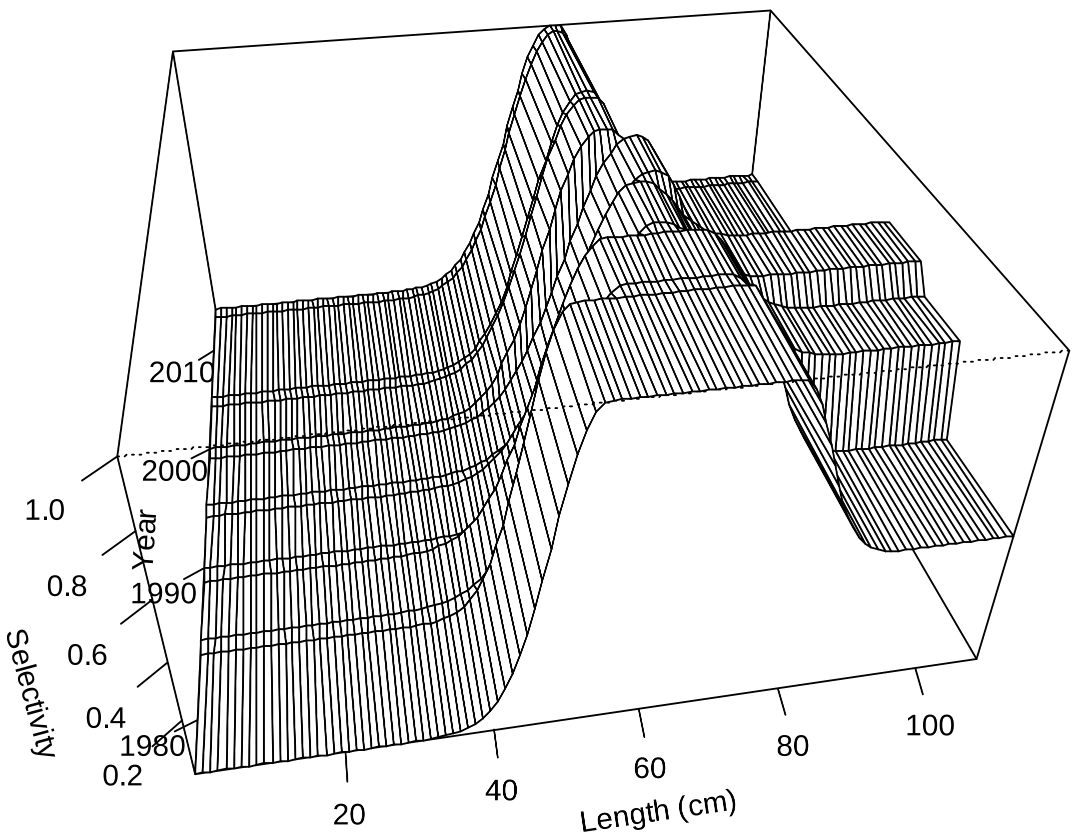


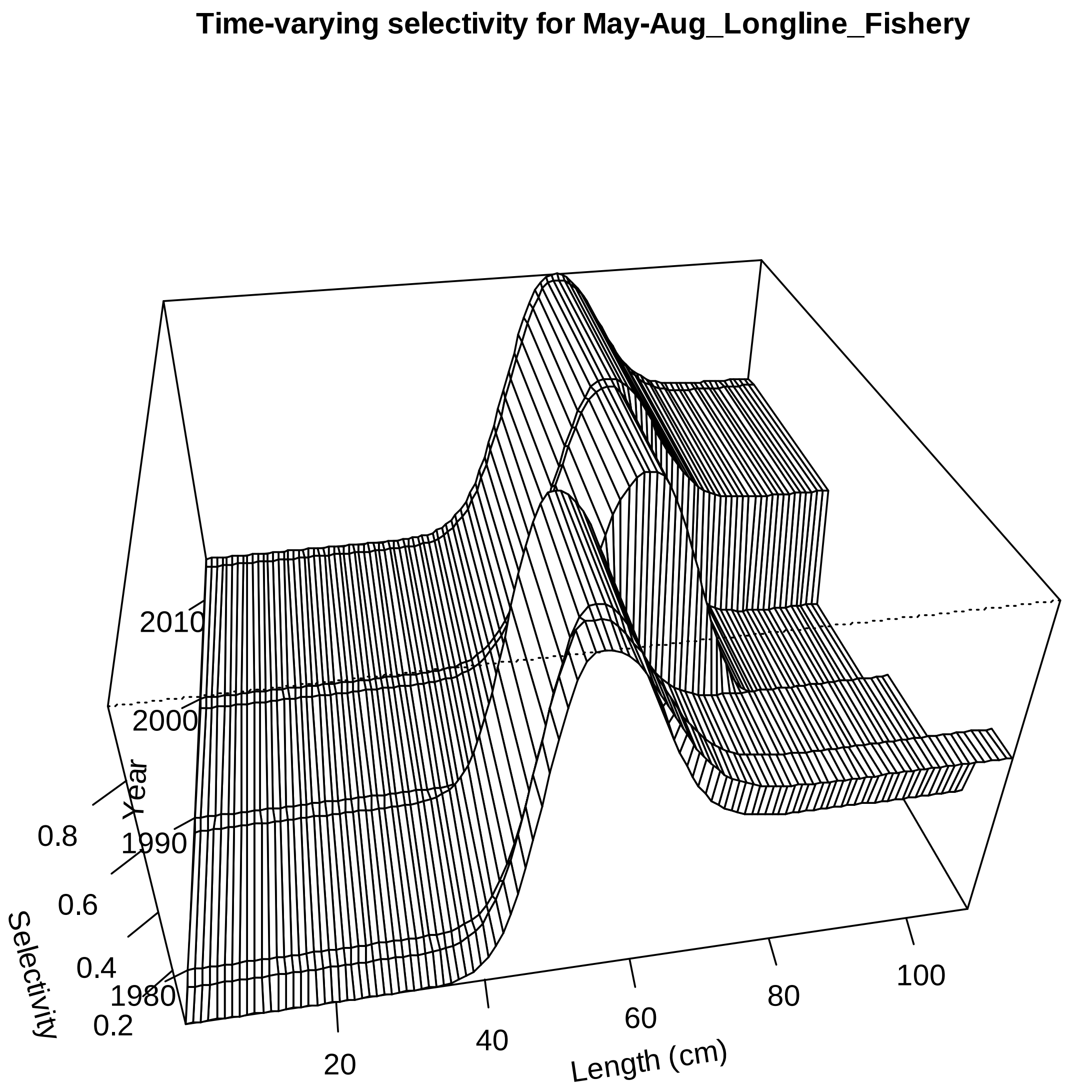
Time-varying selectivity for May-Aug_Trawl_Fishery

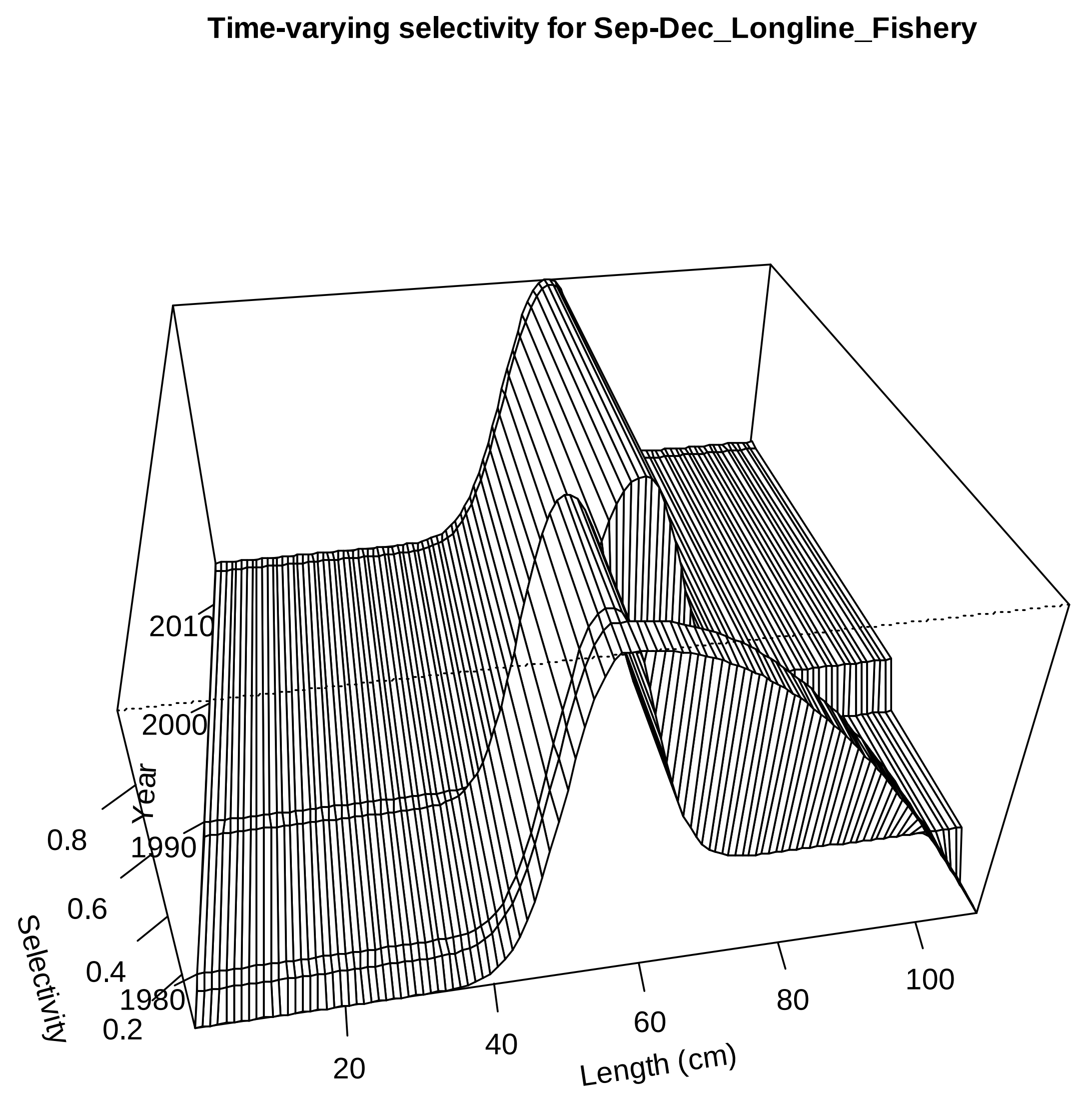


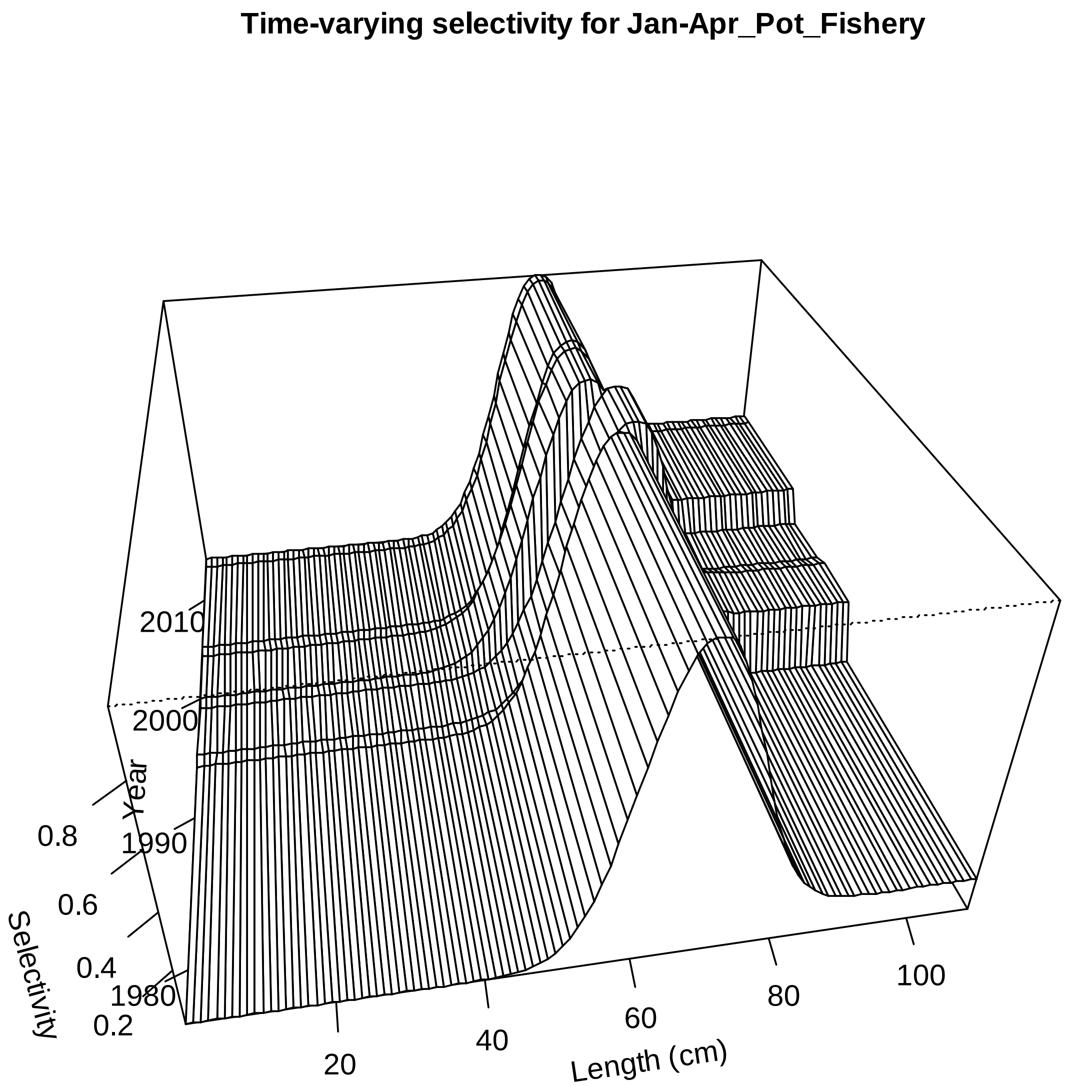

Time-varying selectivity for Sep-Dec_Trawl_Fishery
2010
2000
1990
1980
Year
1.0
0.8
0.6
0.4
0.2
Selectivity
20
40
60
80
100
Length (cm)

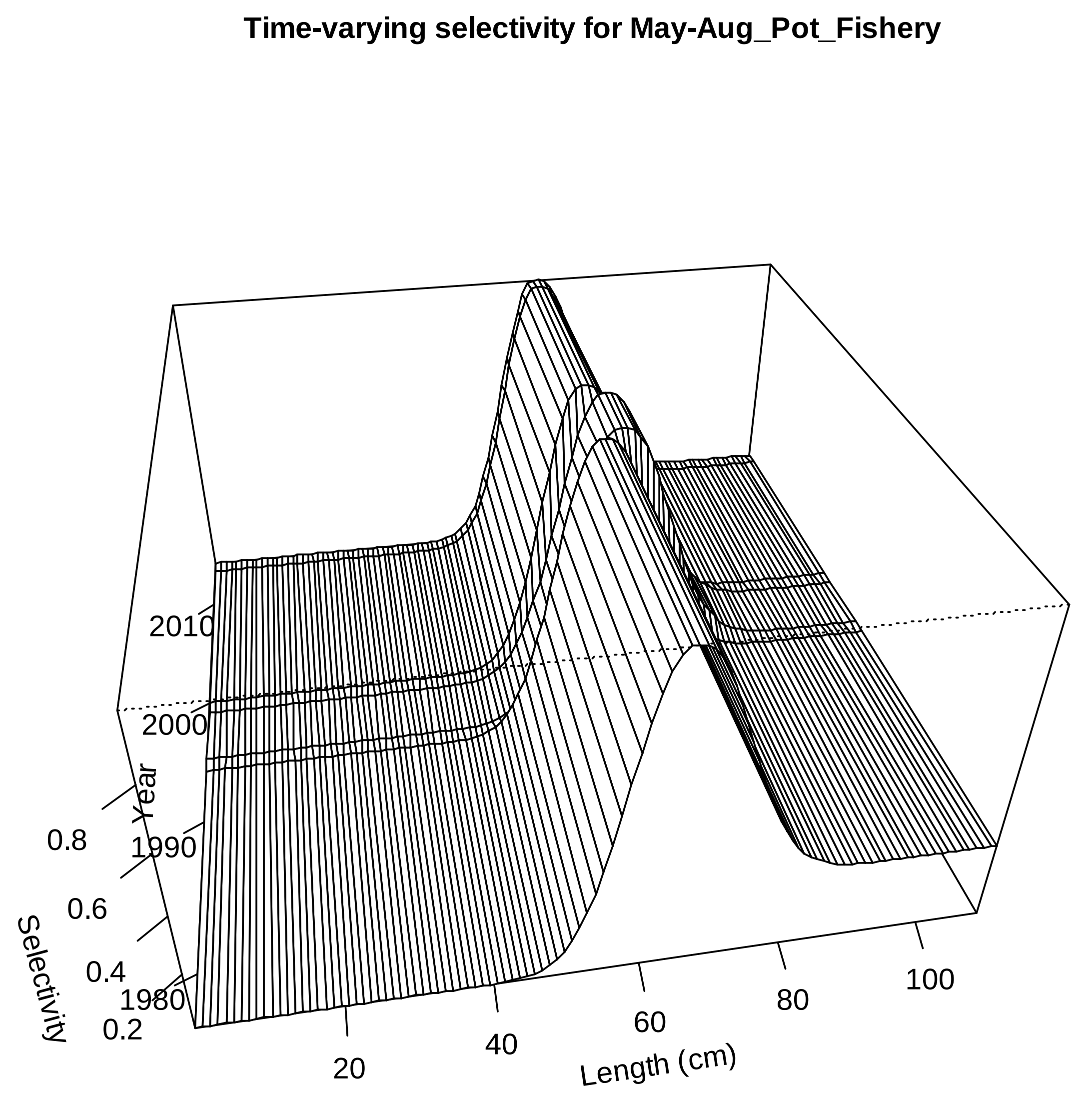
Time-varying selectivity for Jan-Apr_Longline_Fishery




Time-varying selectivity for May-Aug_Longline_Fishery
0.2
0.4
0.6
0.8
Selectivity
1980
1990
2000
2010
Year
20
40
60
80
100
Length (cm)


Time-varying selectivity for Sep-Dec_Longline_Fishery
Selectivity
0.2
0.4
0.6
0.8
Year
1980
1990
2000
2010
Length (cm)
20
40
60
80
100


Time-varying selectivity for Jan-Apr_Pot_Fishery
Selectivity
0.2
0.4
0.6
0.8
Year
1980
1990
2000
2010
Length (cm)
20
40
60
80
100


Time-varying selectivity for May-Aug_Pot_Fishery
2010
2000
1990
1980
Year
0.8
0.6
0.4
0.2
Selectivity
20
40
60
80
100
Length (cm)

Time-varying selectivity for Sep-Dec_Pot_Fishery

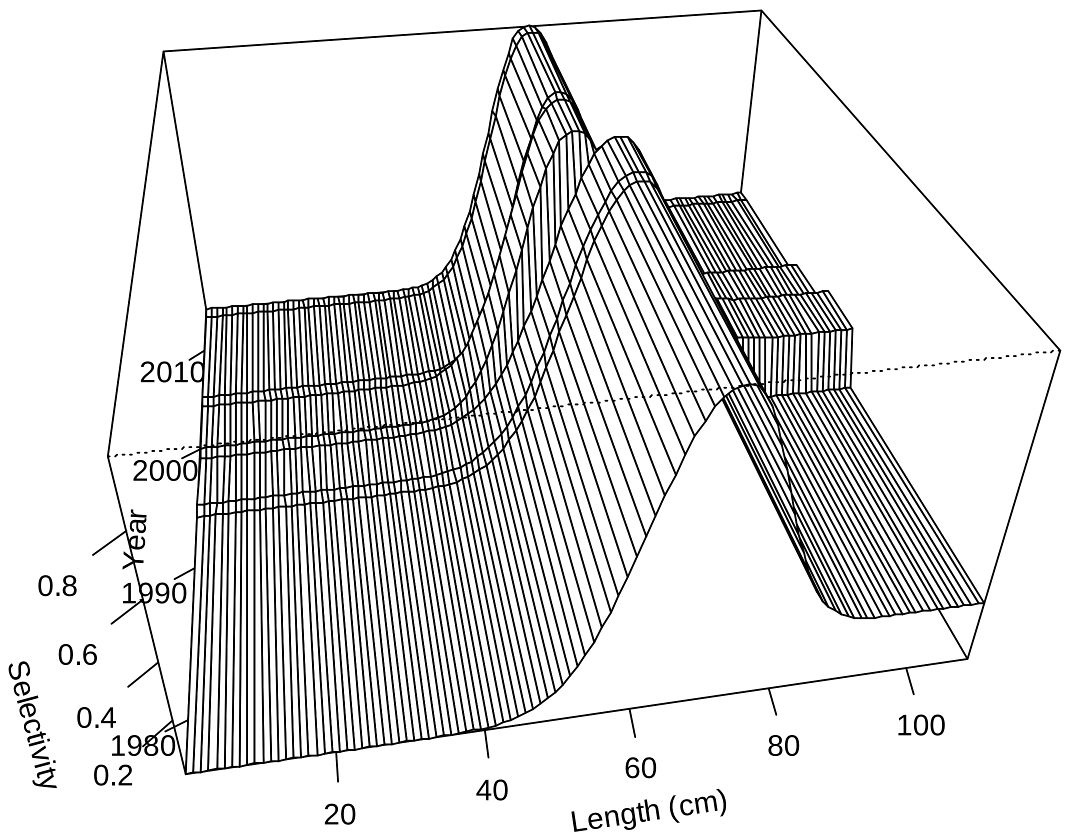


Fig. 2.22 – Summary of fits (solid lines) to fishery and survey length composition data, for season-gear groupings from Model S1a

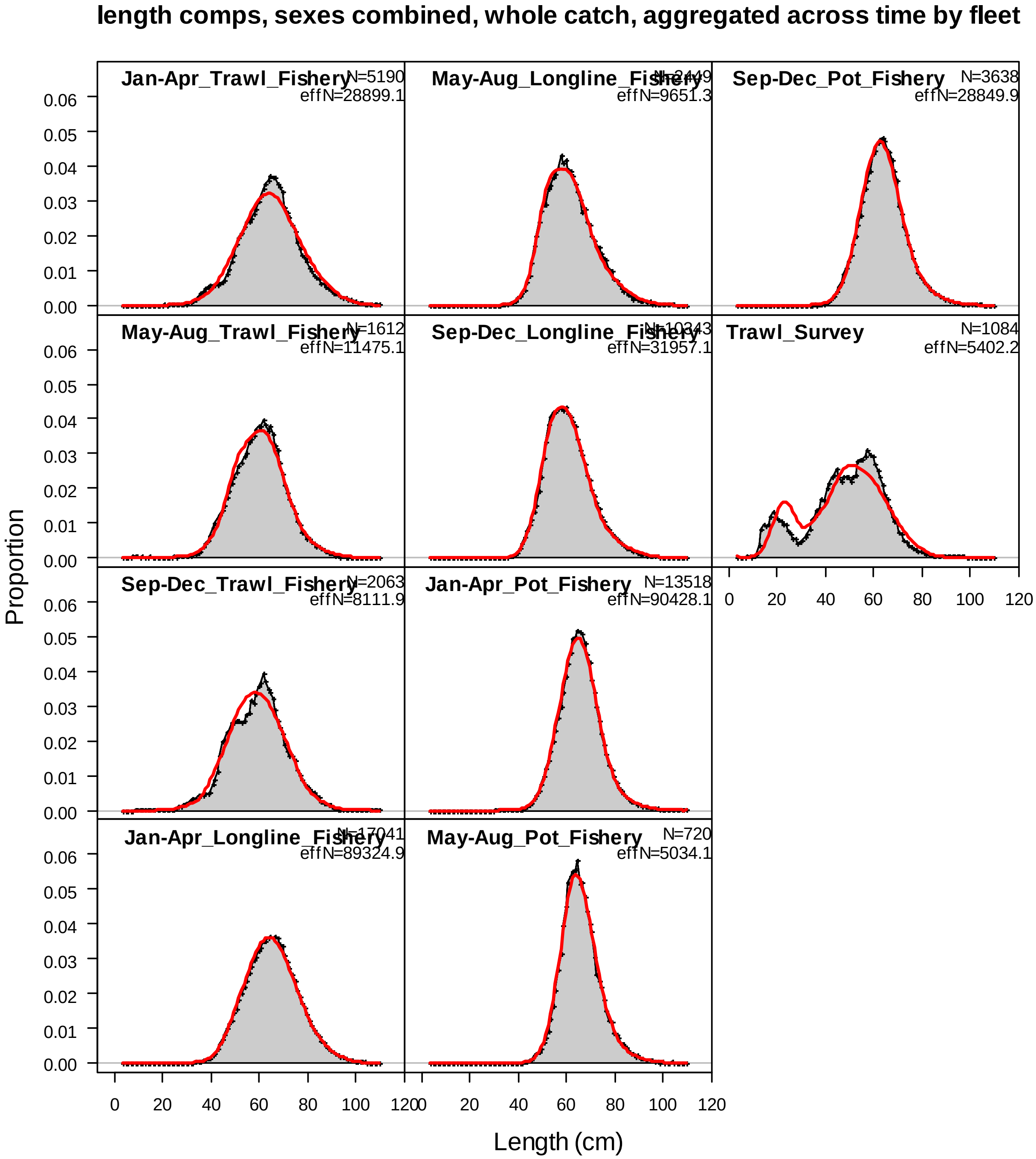
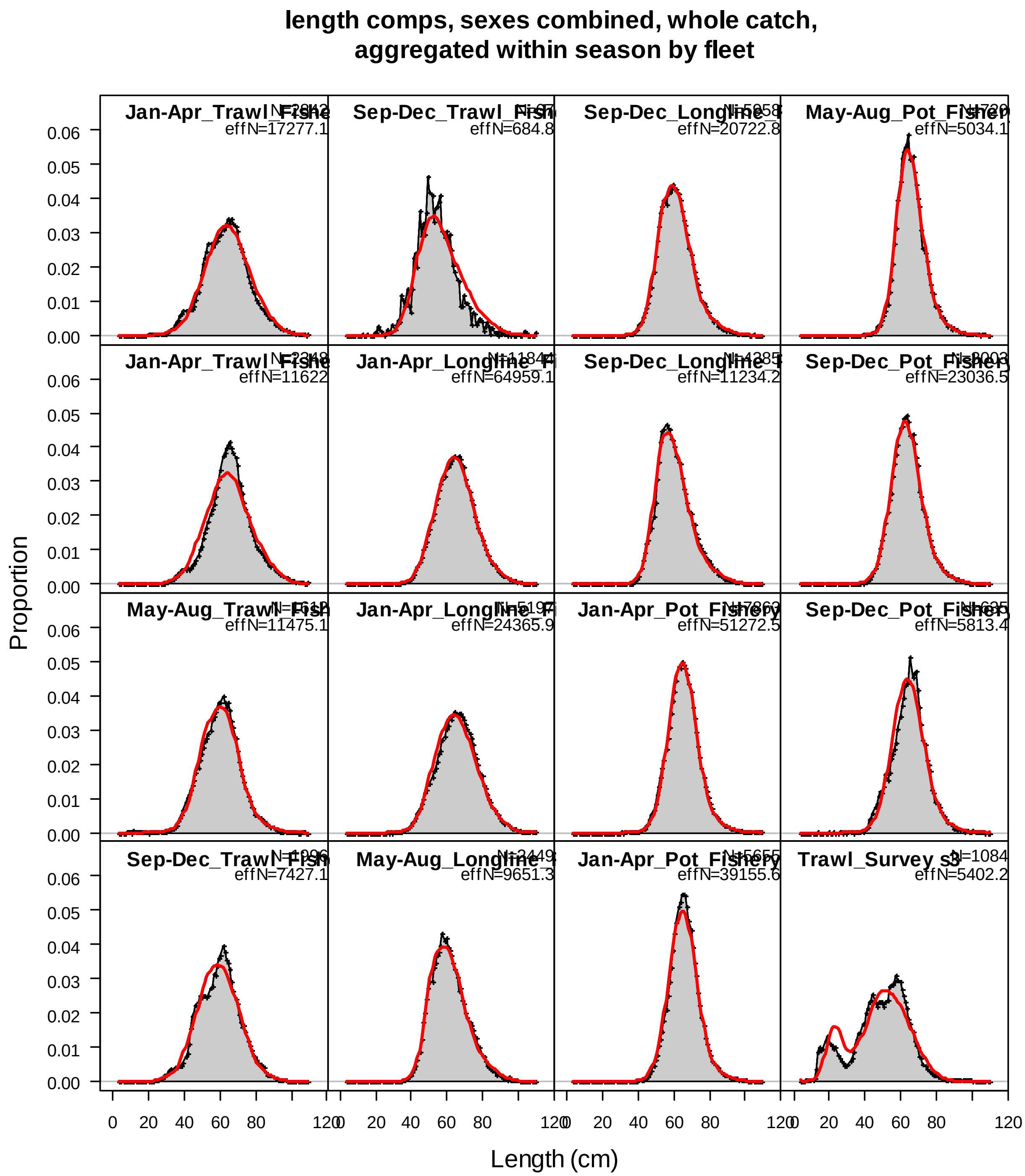
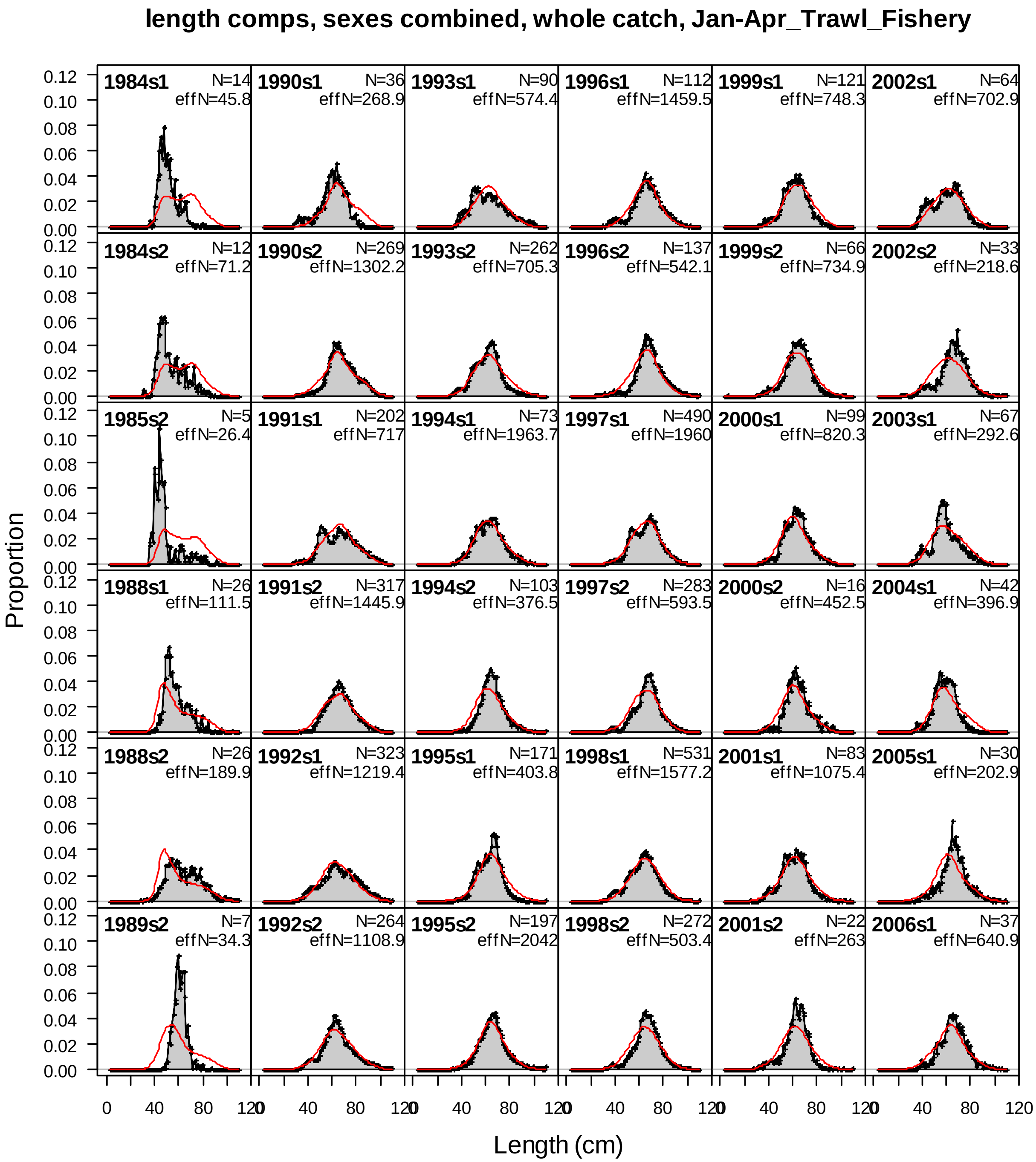
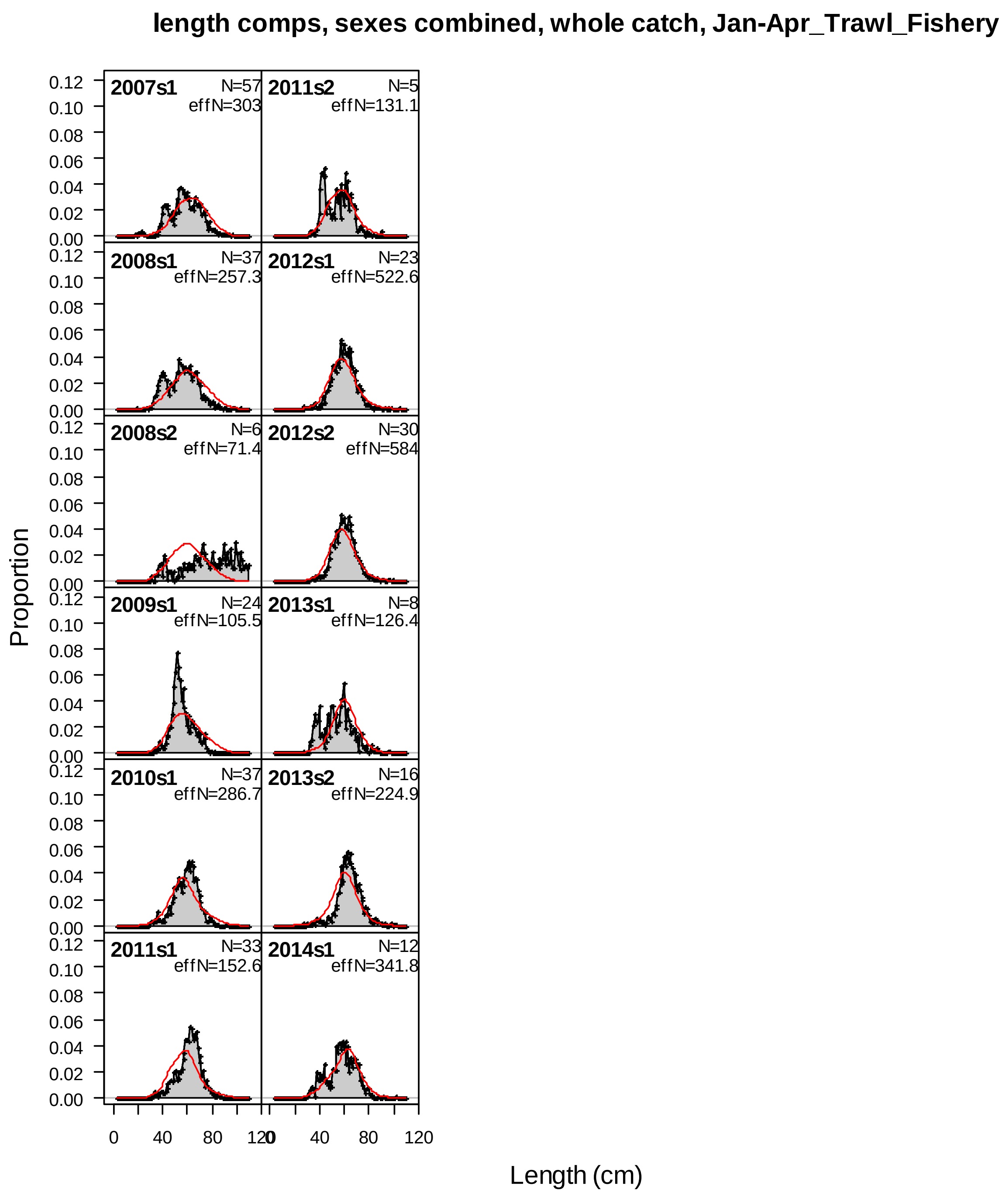
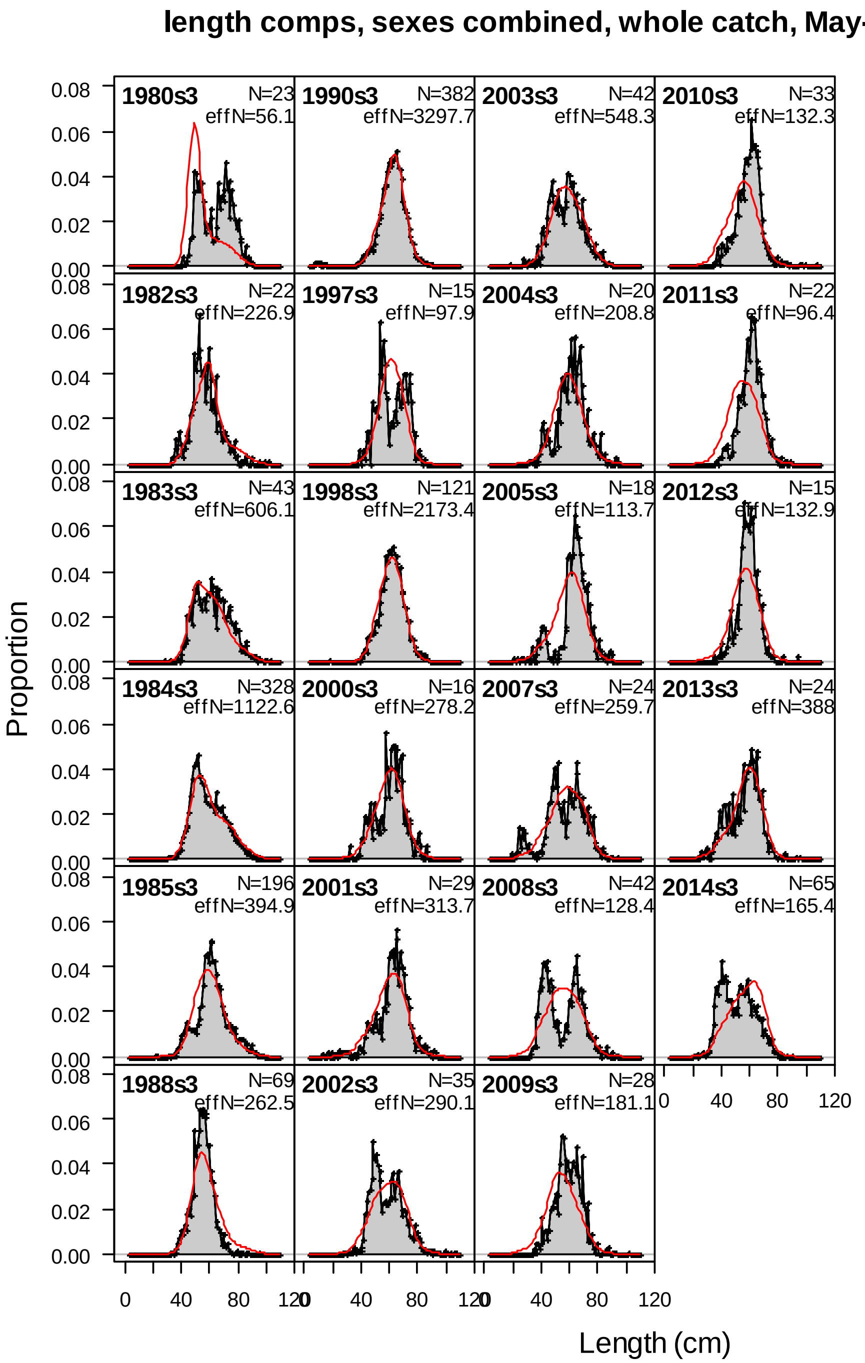


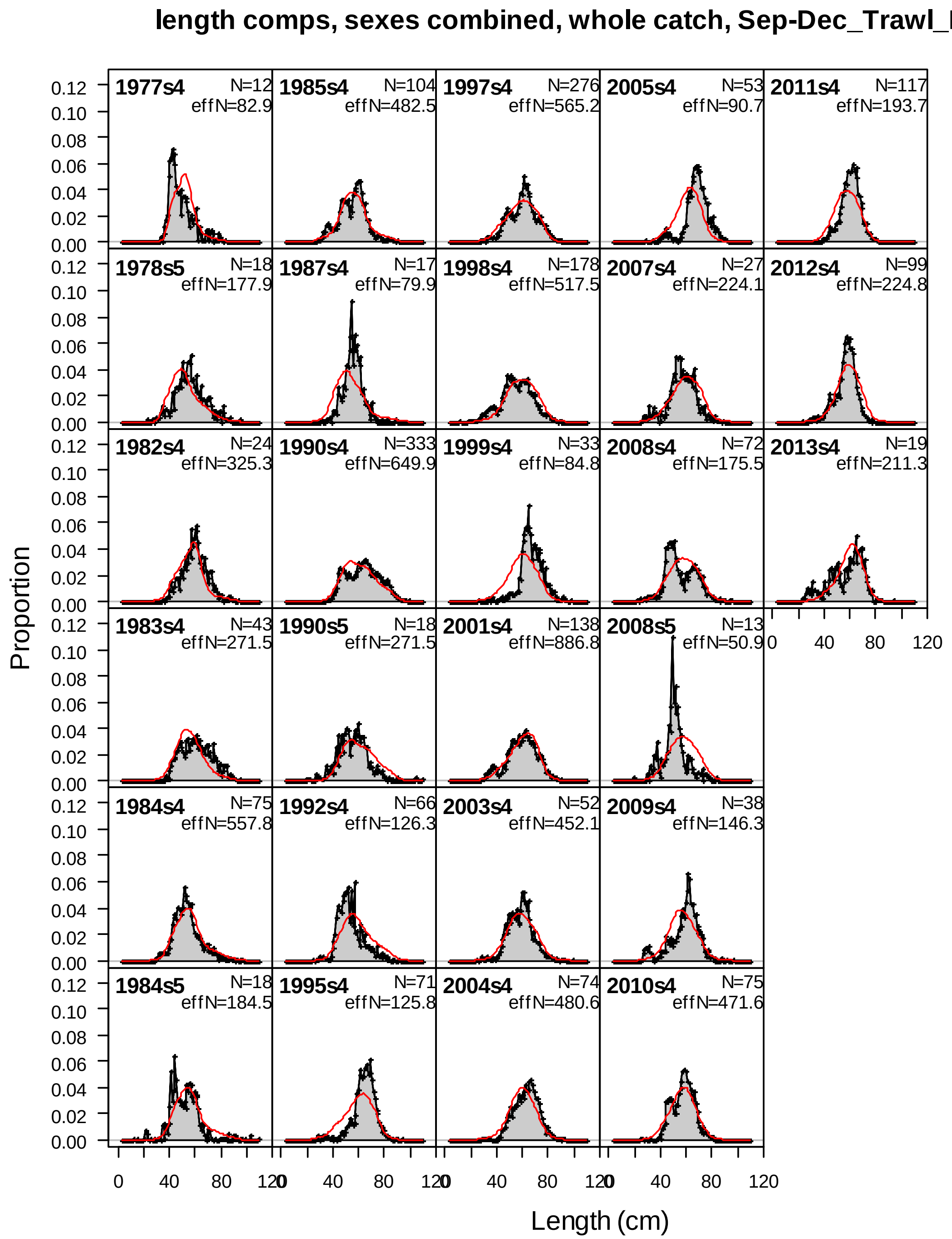
Fig. 2.23 – Fits (solid lines) to fishery length composition data, by season and gear type, from Model S1a

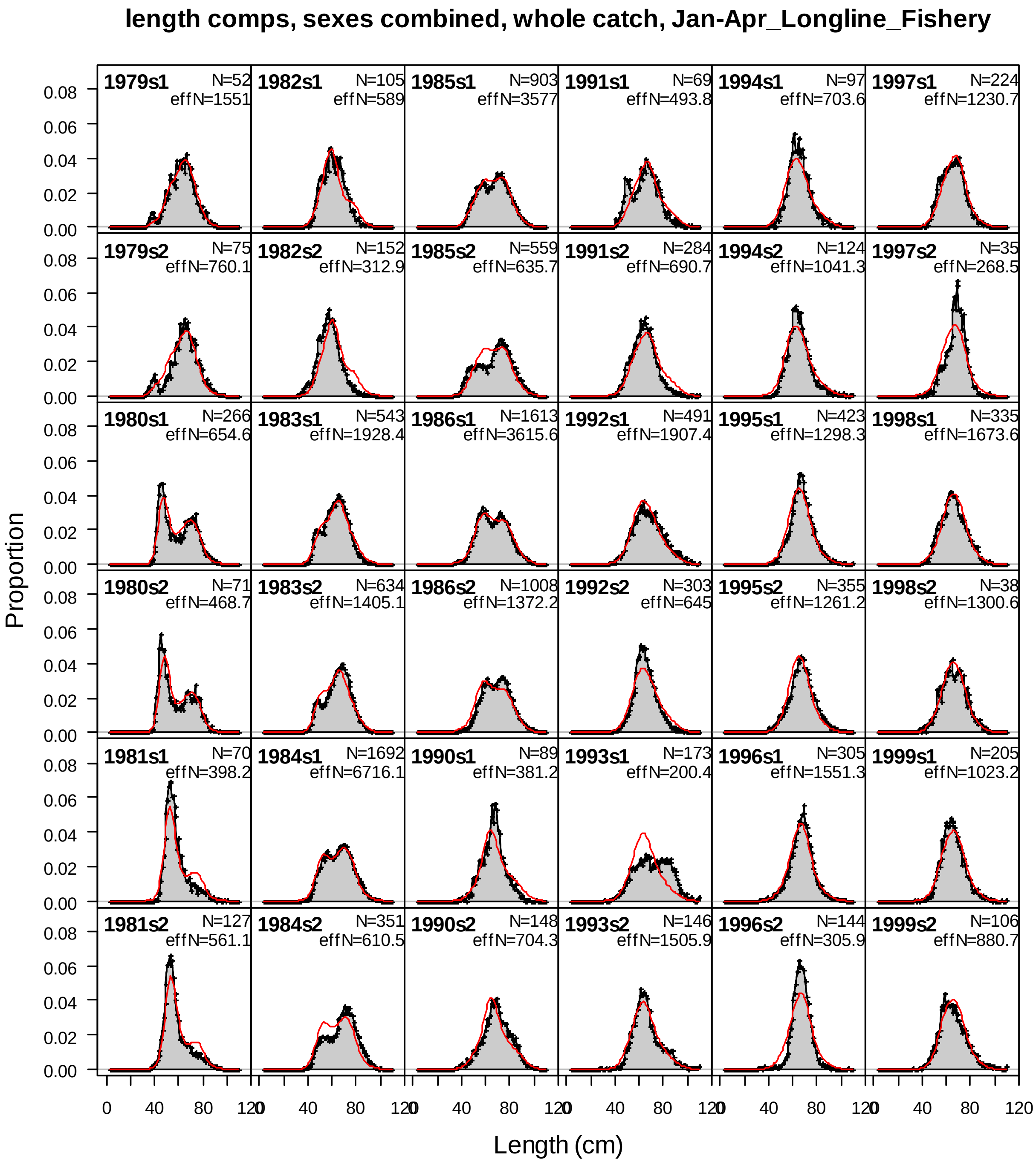



length comps, sexes combined, whole catch, Jan-Apr_Trawl_Fishery
Proportion
Length (cm)
1984s1 N=14 effN=45.8
1990s1 N=36 effN=268.9
1993s1 N=90 effN=574.4
1996s1 N=112 effN=1459.5
1999s1 N=121 effN=748.3
2002s1 N=64 effN=702.9
1984s2 N=12 effN=71.2
1990s2 N=269 effN=1302.2
1993s2 N=262 effN=705.3
1996s2 N=137 effN=542.1
1999s2 N=66 effN=734.9
2002s2 N=33 effN=218.6
1985s2 N=5 effN=26.4
1991s1 N=202 effN=717
1994s1 N=73 effN=1963.7
1997s1 N=490 effN=1960
2000s1 N=99 effN=820.3
2003s1 N=67 effN=292.6
1988s1 N=26 effN=111.5
1991s2 N=317 effN=1445.9
1994s2 N=103 effN=376.5
1997s2 N=283 effN=593.5
2000s2 N=16 effN=452.5
2004s1 N=42 effN=396.9
1988s2 N=26 effN=189.9
1992s1 N=323 effN=1219.4
1995s1 N=171 effN=403.8
1998s1 N=531 effN=1577.2
2001s1 N=83 effN=1075.4
2005s1 N=30 effN=202.9
1989s2 N=7 effN=34.3
1992s2 N=264 effN=1108.9
1995s2 N=197 effN=2042
1998s2 N=272 effN=503.4
2001s2 N=22 effN=263
2006s1 N=37 effN=640.9


length comps, sexes combined, whole catch, Jan-Apr_Trawl_Fishery
2007s1 N=57 effN=303
2011s2 N=5 effN=131.1
2008s1 N=37 effN=257.3
2012s1 N=23 effN=522.6
2008s2 N=6 effN=71.4
2012s2 N=30 effN=584
2009s1 N=24 effN=105.5
2013s1 N=8 effN=126.4
2010s1 N=37 effN=286.7
2013s2 N=16 effN=224.9
2011s1 N=33 effN=152.6
2014s1 N=12 effN=341.8
Proportion
Length (cm)


length comps, sexes combined, whole catch, May-Aug_Trawl_Fishery
Proportion
Length (cm)
1980s3 N=23 effN=56.1
1990s3 N=382 effN=3297.7
2003s3 N=42 effN=548.3
2010s3 N=33 effN=132.3
1982s3 N=22 effN=226.9
1997s3 N=15 effN=97.9
2004s3 N=20 effN=208.8
2011s3 N=22 effN=96.4
1983s3 N=43 effN=606.1
1998s3 N=121 effN=2173.4
2005s3 N=18 effN=113.7
2012s3 N=15 effN=132.9
1984s3 N=328 effN=1122.6
2000s3 N=16 effN=278.2
2007s3 N=24 effN=259.7
2013s3 N=24 effN=388
1985s3 N=196 effN=394.9
2001s3 N=29 effN=313.7
2008s3 N=42 effN=128.4
2014s3 N=65 effN=165.4
1988s3 N=69 effN=262.5
2002s3 N=35 effN=290.1
2009s3 N=28 effN=181.1
0.00 0.02 0.04 0.06 0.08
0 40 80 120


length comps, sexes combined, whole catch, Sep-Dec_Trawl_Fishery
1977s4 N=12 effN=82.9
1985s4 N=104 effN=482.5
1997s4 N=276 effN=565.2
2005s4 N=53 effN=90.7
2011s4 N=117 effN=193.7
1978s5 N=18 effN=177.9
1987s4 N=17 effN=79.9
1998s4 N=178 effN=517.5
2007s4 N=27 effN=224.1
2012s4 N=99 effN=224.8
1982s4 N=24 effN=325.3
1990s4 N=333 effN=649.9
1999s4 N=33 effN=84.8
2008s4 N=72 effN=175.5
2013s4 N=19 effN=211.3
1983s4 N=43 effN=271.5
1990s5 N=18 effN=271.5
2001s4 N=138 effN=886.8
2008s5 N=13 effN=50.9
1984s4 N=75 effN=557.8
1992s4 N=66 effN=126.3
2003s4 N=52 effN=452.1
2009s4 N=38 effN=146.3
1984s5 N=18 effN=184.5
1995s4 N=71 effN=125.8
2004s4 N=74 effN=480.6
2010s4 N=75 effN=471.6
Proportion
Length (cm)


length comps, sexes combined, whole catch, Jan-Apr_Longline_Fishery
1979s1 N=52 effN=1551
1982s1 N=105 effN=589
1985s1 N=903 effN=3577
1991s1 N=69 effN=493.8
1994s1 N=97 effN=703.6
1997s1 N=224 effN=1230.7
1979s2 N=75 effN=760.1
1982s2 N=152 effN=312.9
1985s2 N=559 effN=635.7
1991s2 N=284 effN=690.7
1994s2 N=124 effN=1041.3
1997s2 N=35 effN=268.5
1980s1 N=266 effN=654.6
1983s1 N=543 effN=1928.4
1986s1 N=1613 effN=3615.6
1992s1 N=491 effN=1907.4
1995s1 N=423 effN=1298.3
1998s1 N=335 effN=1673.6
1980s2 N=71 effN=468.7
1983s2 N=634 effN=1405.1
1986s2 N=1008 effN=1372.2
1992s2 N=303 effN=645
1995s2 N=355 effN=1261.2
1998s2 N=38 effN=1300.6
1981s1 N=70 effN=398.2
1984s1 N=1692 effN=6716.1
1990s1 N=89 effN=381.2
1993s1 N=173 effN=200.4
1996s1 N=305 effN=1551.3
1999s1 N=205 effN=1023.2
1981s2 N=127 effN=561.1
1984s2 N=351 effN=610.5
1990s2 N=148 effN=704.3
1993s2 N=146 effN=1505.9
1996s2 N=144 effN=305.9
1999s2 N=106 effN=880.7
Proportion
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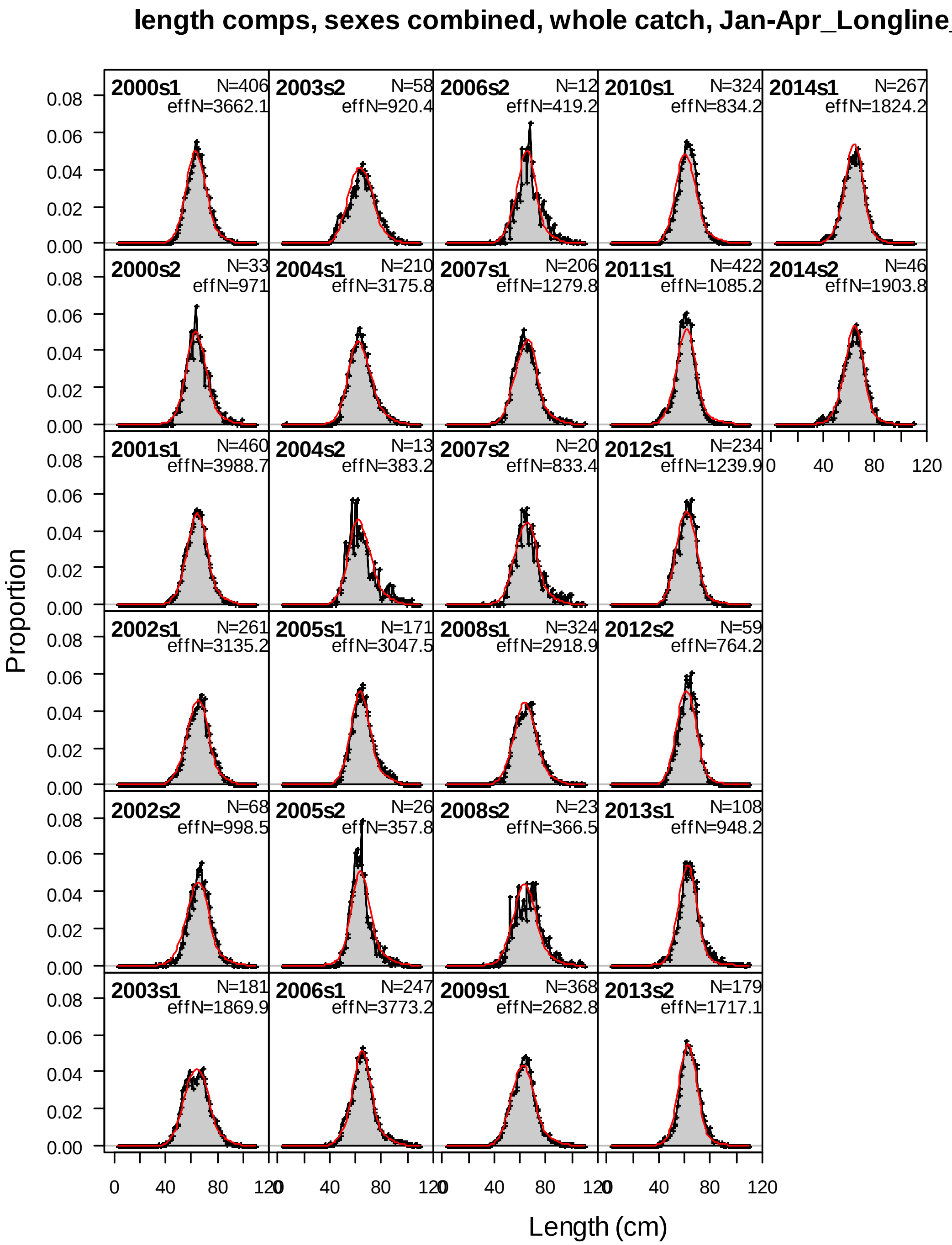
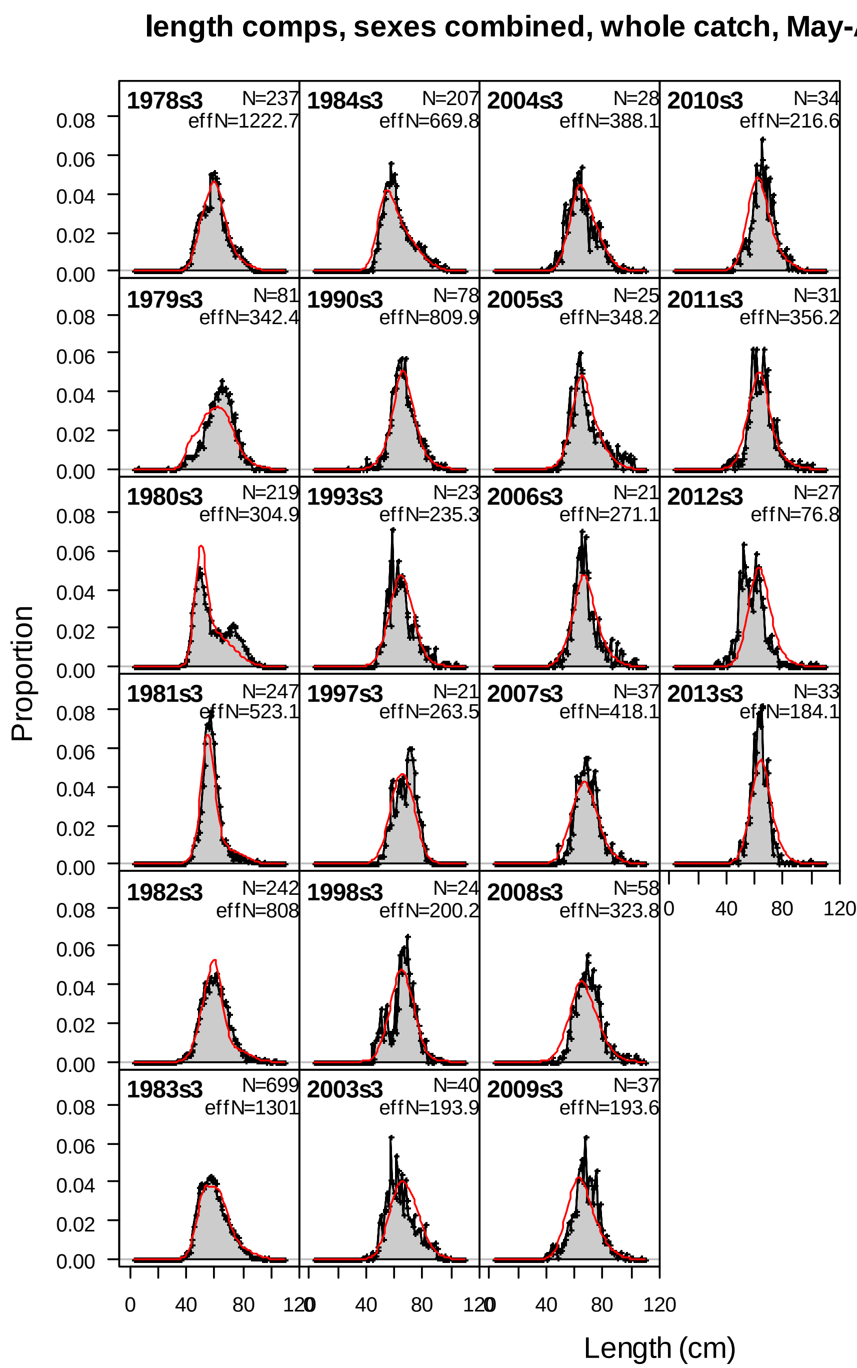
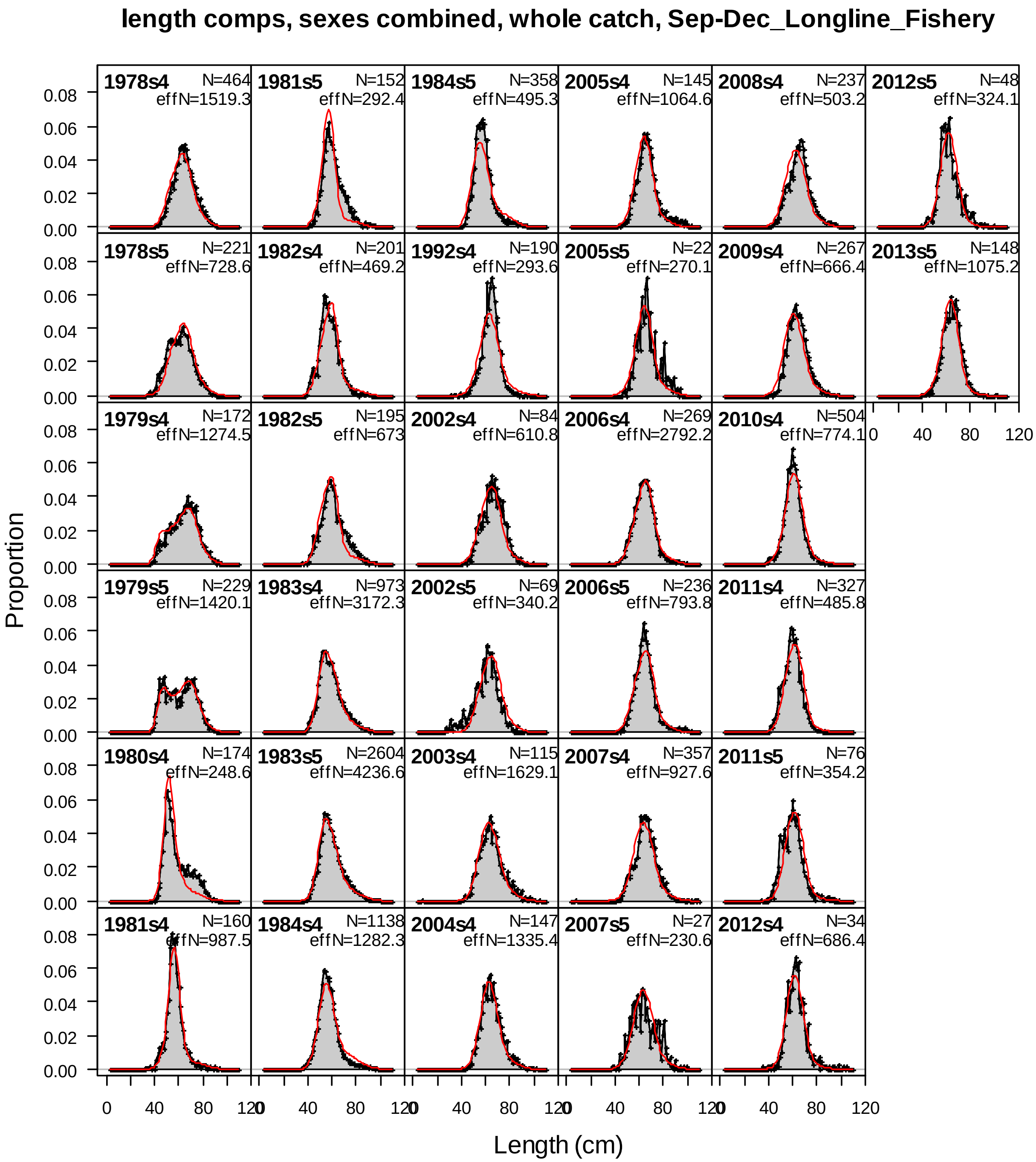
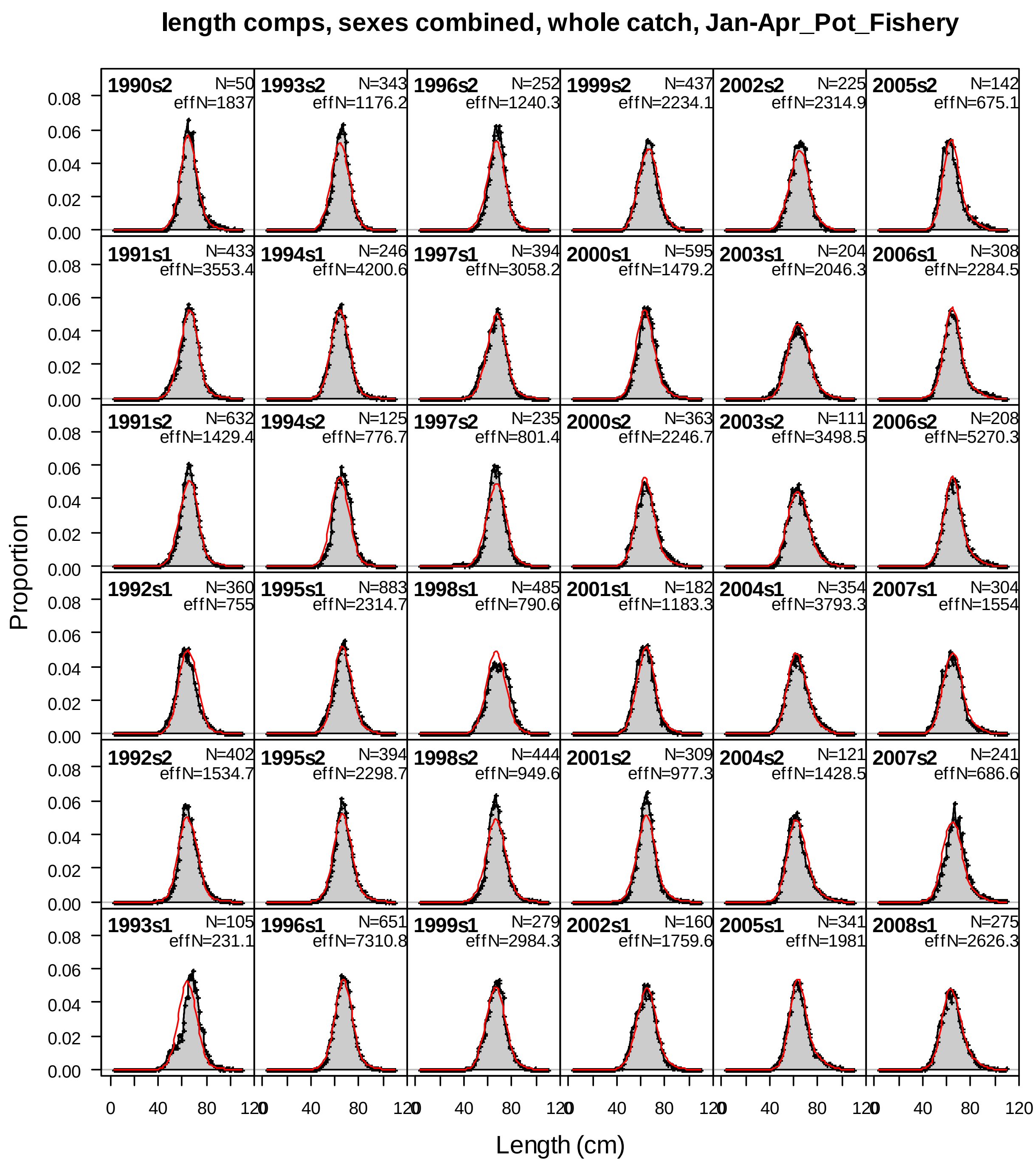
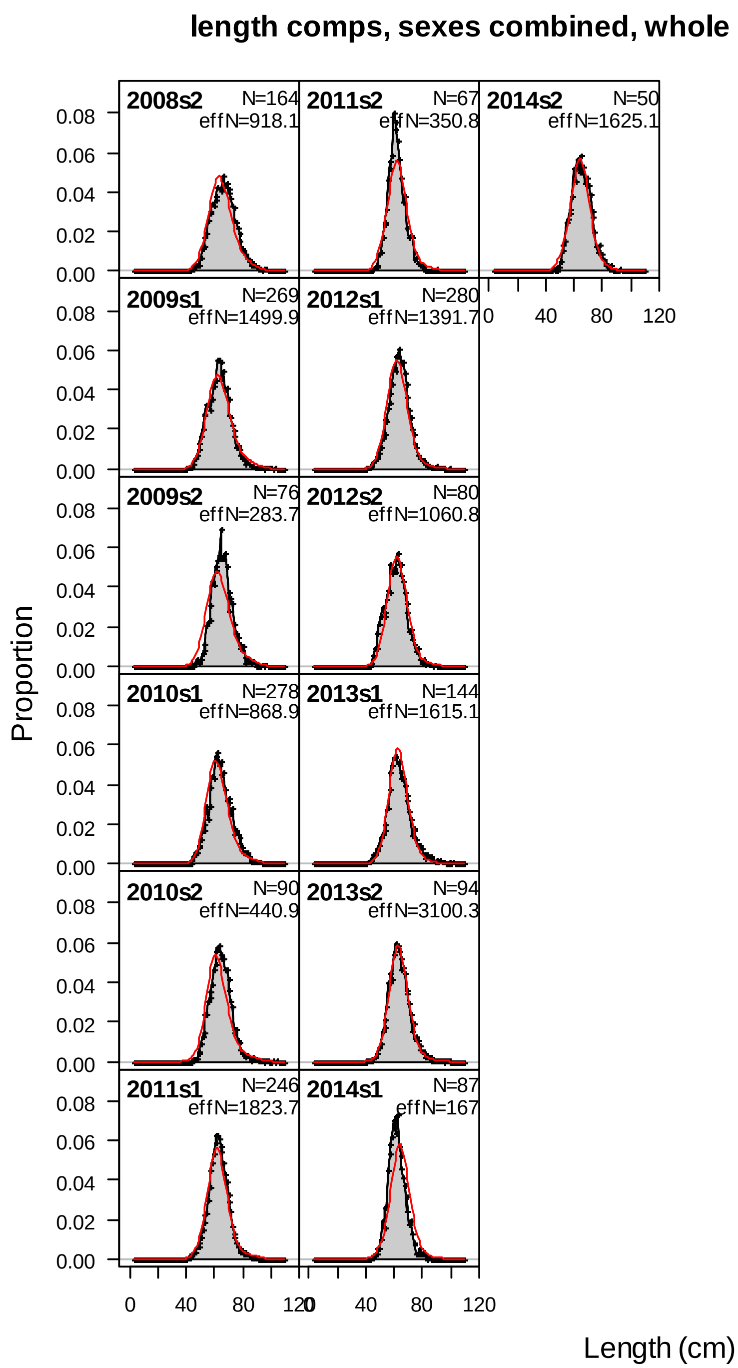
0.02
0.04
0.06
0.08
0
40
80
120
Length (cm)

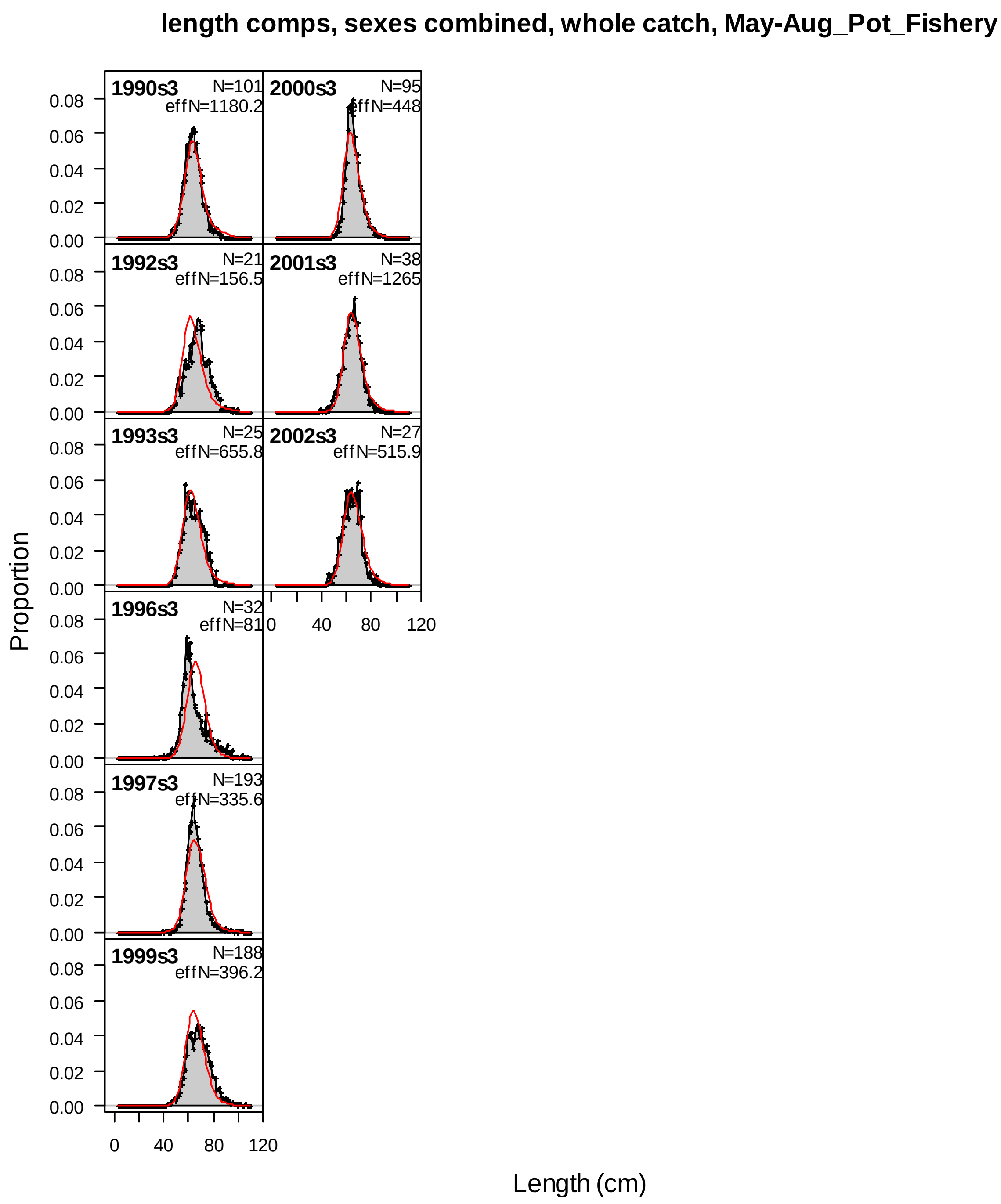

length comps, sexes combined, whole catch, Jan-Apr_Longline_Fishery
2000s1 N=406 effN=3662.1
2003s2 N=58 effN=920.4
2006s2 N=12 effN=419.2
2010s1 N=324 effN=834.2
2014s1 N=267 effN=1824.2
2000s2 N=33 effN=971
2004s1 N=210 effN=3175.8
2007s1 N=206 effN=1279.8
2011s1 N=422 effN=1085.2
2014s2 N=46 effN=1903.8
2001s1 N=460 effN=3988.7
2004s2 N=13 effN=383.2
2007s2 N=20 effN=833.4
2012s1 N=234 effN=1239.9
2002s1 N=261 effN=3135.2
2005s1 N=171 effN=3047.5
2008s1 N=324 effN=2918.9
2012s2 N=59 effN=764.2
2002s2 N=68 effN=998.5
2005s2 N=26 effN=357.8
2008s2 N=23 effN=366.5
2013s1 N=108 effN=948.2
2003s1 N=181 effN=1869.9
2006s1 N=247 effN=3773.2
2009s1 N=368 effN=2682.8
2013s2 N=179 effN=1717.1
Proportion
0.00
0.02
0.04
0.06
0.08
0
40
80
120
Length (cm)


length comps, sexes combined, whole catch, May-Aug_Longline_Fishery
1978s3 N=237 effN=1222.7
1984s3 N=207 effN=669.8
2004s3 N=28 effN=388.1
2010s3 N=34 effN=216.6
1979s3 N=81 effN=342.4
1990s3 N=78 effN=809.9
2005s3 N=25 effN=348.2
2011s3 N=31 effN=356.2
1980s3 N=219 effN=304.9
1993s3 N=23 effN=235.3
2006s3 N=21 effN=271.1
2012s3 N=27 effN=76.8
1981s3 N=247 effN=523.1
1997s3 N=21 effN=263.5
2007s3 N=37 effN=418.1
2013s3 N=33 effN=184.1
1982s3 N=242 effN=808
1998s3 N=24 effN=200.2
2008s3 N=58 effN=323.8
1983s3 N=699 effN=1301
2003s3 N=40 effN=193.9
2009s3 N=37 effN=193.6
Proportion
Length (cm)


length comps, sexes combined, whole catch, Sep-Dec_Longline_Fishery
1978s4 N=464 effN=1519.3
1981s5 N=152 effN=292.4
1984s5 N=358 effN=495.3
2005s4 N=145 effN=1064.6
2008s4 N=237 effN=503.2
2012s5 N=48 effN=324.1
1978s5 N=221 effN=728.6
1982s4 N=201 effN=469.2
1992s4 N=190 effN=293.6
2005s5 N=22 effN=270.1
2009s4 N=267 effN=666.4
2013s5 N=148 effN=1075.2
1979s4 N=172 effN=1274.5
1982s5 N=195 effN=673
2002s4 N=84 effN=610.8
2006s4 N=269 effN=2792.2
2010s4 N=504 effN=774.1
1979s5 N=229 effN=1420.1
1983s4 N=973 effN=3172.3
2002s5 N=69 effN=340.2
2006s5 N=236 effN=793.8
2011s4 N=327 effN=485.8
1980s4 N=174 effN=248.6
1983s5 N=2604 effN=4236.6
2003s4 N=115 effN=1629.1
2007s4 N=357 effN=927.6
2011s5 N=76 effN=354.2
1981s4 N=160 effN=987.5
1984s4 N=1138 effN=1282.3
2004s4 N=147 effN=1335.4
2007s5 N=27 effN=230.6
2012s4 N=34 effN=686.4
Proportion
0.00
0.02
0.04
0.06
0.08
0
40
80
120
Length (cm)


length comps, sexes combined, whole catch, Jan-Apr_Pot_Fishery
1990s2 N=50 effN=1837
1993s2 N=343 effN=1176.2
1996s2 N=252 effN=1240.3
1999s2 N=437 effN=2234.1
2002s2 N=225 effN=2314.9
2005s2 N=142 effN=675.1
1991s1 N=433 effN=3553.4
1994s1 N=246 effN=4200.6
1997s1 N=394 effN=3058.2
2000s1 N=595 effN=1479.2
2003s1 N=204 effN=2046.3
2006s1 N=308 effN=2284.5
1991s2 N=632 effN=1429.4
1994s2 N=125 effN=776.7
1997s2 N=235 effN=801.4
2000s2 N=363 effN=2246.7
2003s2 N=111 effN=3498.5
2006s2 N=208 effN=5270.3
1992s1 N=360 effN=755
1995s1 N=883 effN=2314.7
1998s1 N=485 effN=790.6
2001s1 N=182 effN=1183.3
2004s1 N=354 effN=3793.3
2007s1 N=304 effN=1554
1992s2 N=402 effN=1534.7
1995s2 N=394 effN=2298.7
1998s2 N=444 effN=949.6
2001s2 N=309 effN=977.3
2004s2 N=121 effN=1428.5
2007s2 N=241 effN=686.6
1993s1 N=105 effN=231.1
1996s1 N=651 effN=7310.8
1999s1 N=279 effN=2984.3
2002s1 N=160 effN=1759.6
2005s1 N=341 effN=1981
2008s1 N=275 effN=2626.3
Proportion
0.00
0.02
0.04
0.06
0.08
0
40
80
120
Length (cm)


length comps, sexes combined, whole catch, Jan-Apr_Pot_Fishery
2008s2 N=164 effN=918.1
2011s2 N=67 effN=350.8
2014s2 N=50 effN=1625.1
2009s1 N=269 effN=1499.9
2012s1 N=280 effN=1391.7
2009s2 N=76 effN=283.7
2012s2 N=80 effN=1060.8
2010s1 N=278 effN=868.9
2013s1 N=144 effN=1615.1
2010s2 N=90 effN=440.9
2013s2 N=94 effN=3100.3
2011s1 N=246 effN=1823.7
2014s1 N=87 effN=167
Proportion
Length (cm)


length comps, sexes combined, whole catch, May-Aug_Pot_Fishery
1990s3 N=101 effN=1180.2
2000s3 N=95 effN=448
1992s3 N=21 effN=156.5
2001s3 N=38 effN=1265
1993s3 N=25 effN=655.8
2002s3 N=27 effN=515.9
1996s3 N=32 effN=81
1997s3 N=193 effN=335.6
1999s3 N=188 effN=396.2
Proportion
Length (cm)

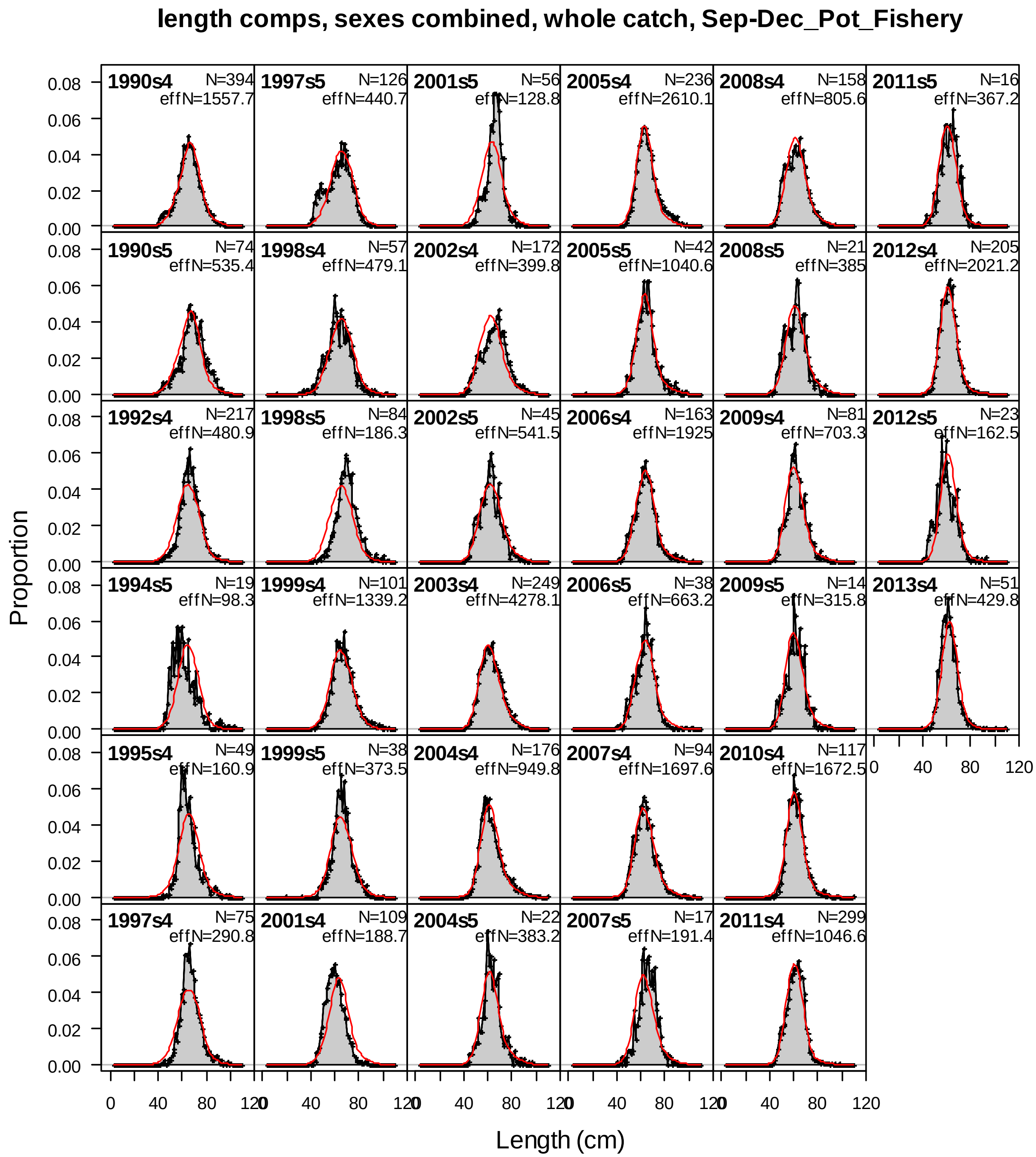

length comps, sexes combined, whole catch, Sep-Dec_Pot_Fishery
Proportion
Length (cm)
1990s4 N=394 effN=1557.7
1997s5 N=126 effN=440.7
2001s5 N=56 effN=128.8
2005s4 N=236 effN=2610.1
2008s4 N=158 effN=805.6
2011s5 N=16 effN=367.2
1990s5 N=74 effN=535.4
1998s4 N=57 effN=479.1
2002s4 N=172 effN=399.8
2005s5 N=42 effN=1040.6
2008s5 N=21 effN=385
2012s4 N=205 effN=2021.2
1992s4 N=217 effN=480.9
1998s5 N=84 effN=186.3
2002s5 N=45 effN=541.5
2006s4 N=163 effN=1925
2009s4 N=81 effN=703.3
2012s5 N=23 effN=162.5
1994s5 N=19 effN=98.3
1999s4 N=101 effN=1339.2
2003s4 N=249 effN=4278.1
2006s5 N=38 effN=663.2
2009s5 N=14 effN=315.8
2013s4 N=51 effN=429.8
1995s4 N=49 effN=160.9
1999s5 N=38 effN=373.5
2004s4 N=176 effN=949.8
2007s4 N=94 effN=1697.6
2010s4 N=117 effN=1672.5
1997s4 N=75 effN=290.8
2001s4 N=109 effN=188.7
2004s5 N=22 effN=383.2
2007s5 N=17 effN=191.4
2011s4 N=299 effN=1046.6

Figure 2.24 – Estimates of spawning biomass with 95% confidence intervals for Model S1a with 2013 survey age data with ending years of 2005 through 2014

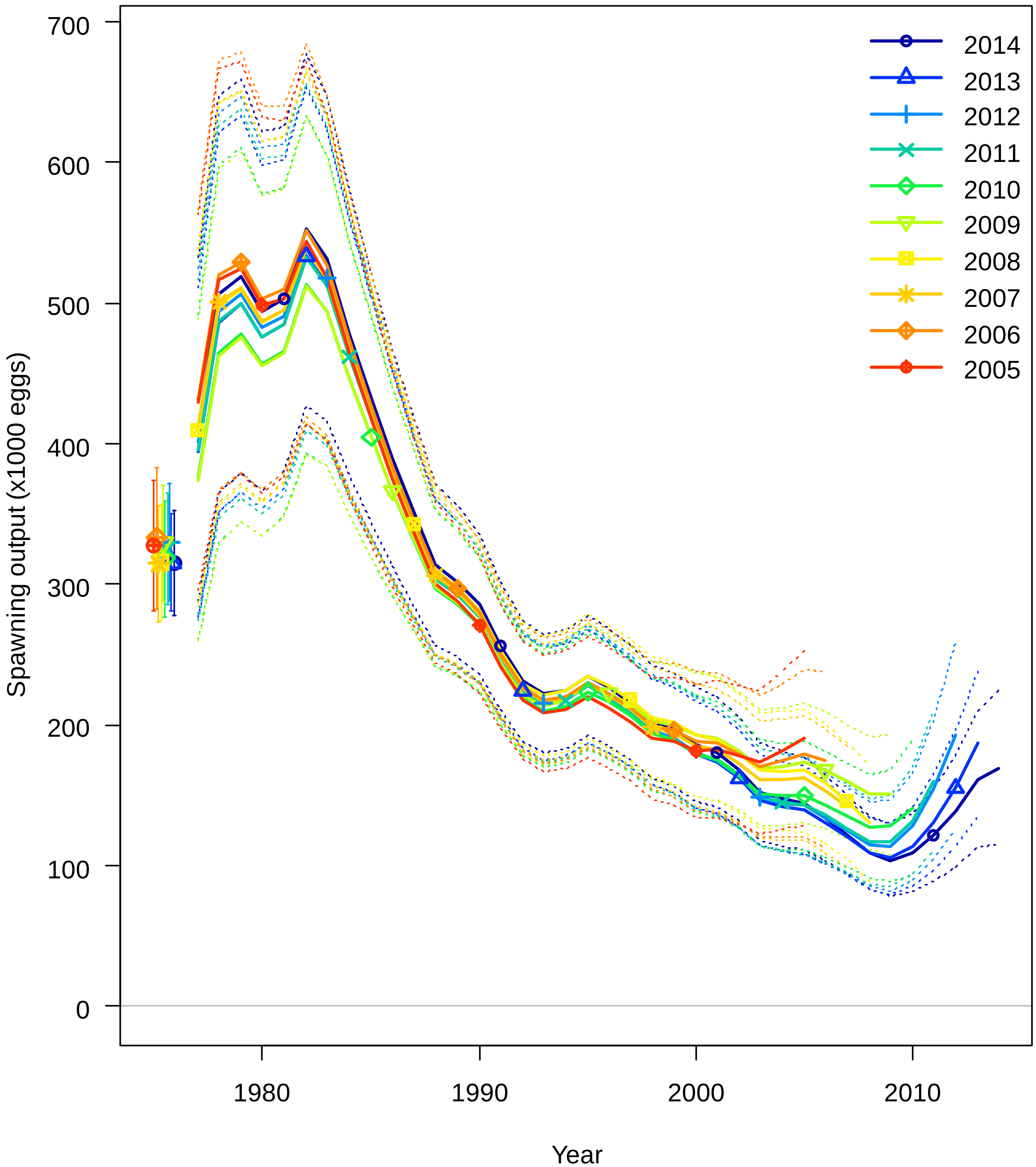


Figure 2.25 – Relative differences in estimates of spawning biomass for Model S1a with 2013 survey age data with ending years of 2005 through 2014

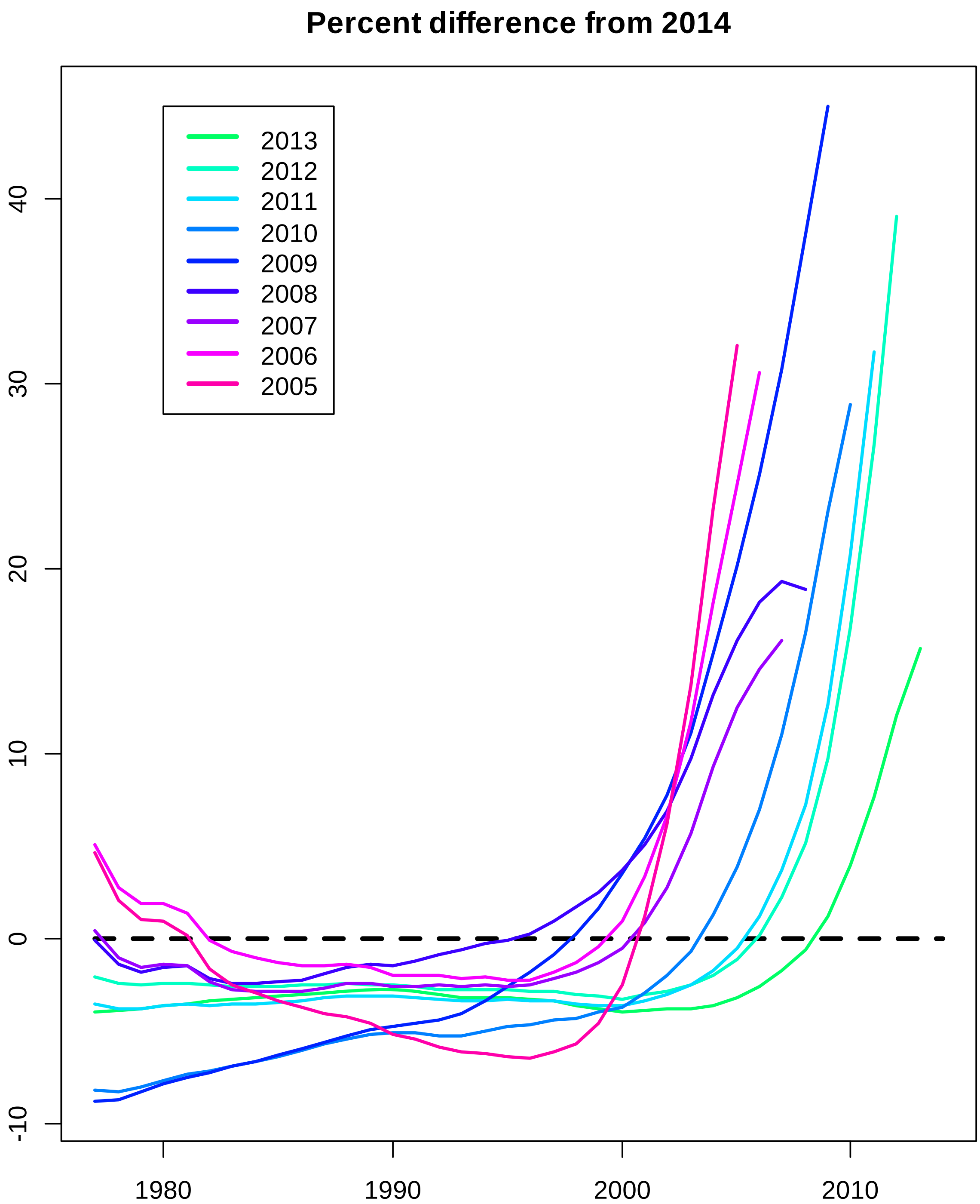


Figure 2.26 - Trajectory of Pacific cod fishing mortality and female spawning biomass as estimated by Model S1a, 1977-2016. Because Pacific cod is a key prey of Steller sea lions, harvests of Pacific cod would be restricted to incidental catch in the event that spawning biomass fell below B20%.

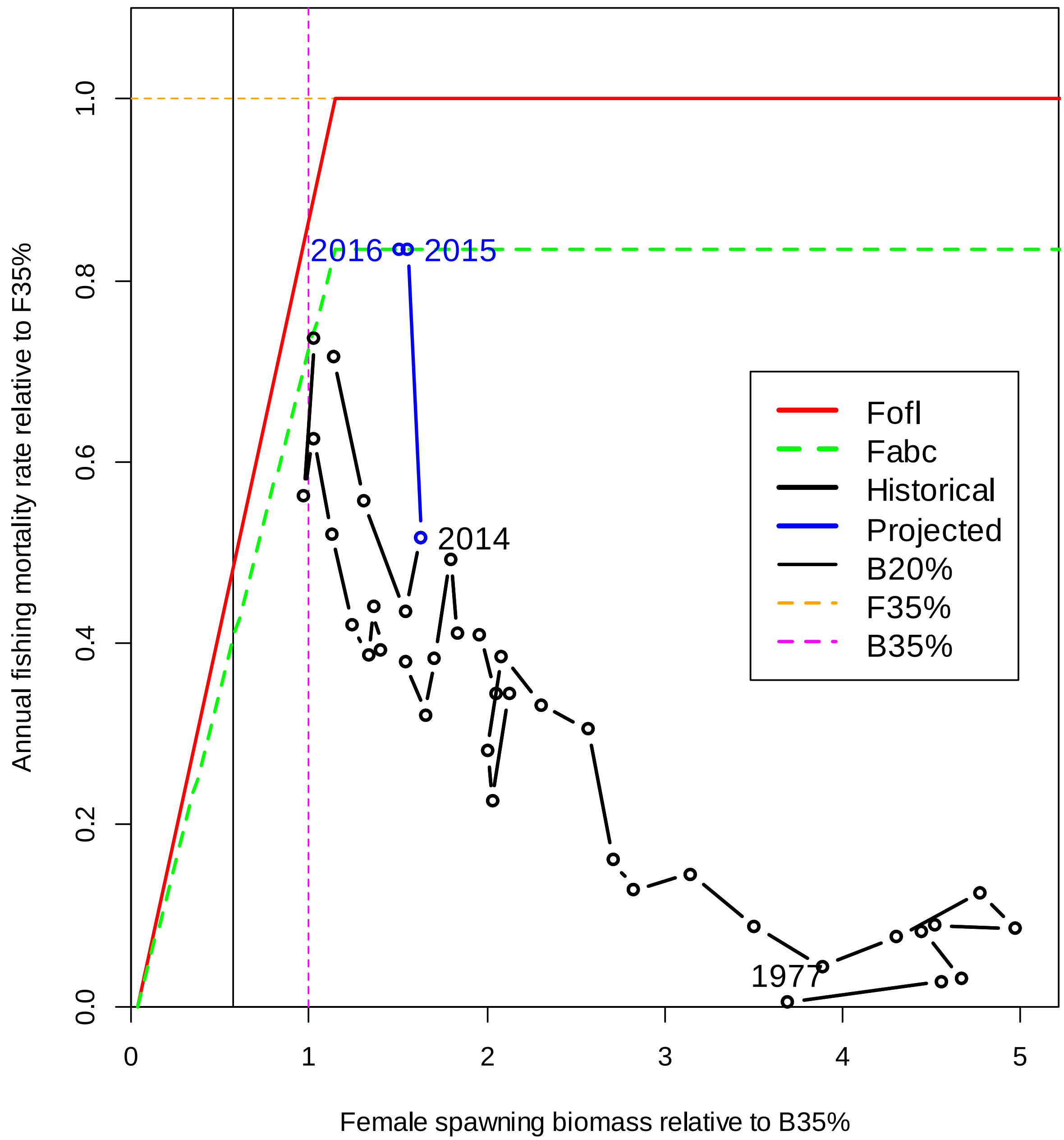


Fig. 2.27 – Comparison of the GOA NMFS bottom trawl survey biomass estimates and the annual longline survey relative population number (RPN) estimates (Dana Hanselman, pers.comm.)