2. Assessment of the Pacific cod stock in the Gulf of Alaska

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EXECUTIVE SUMMARY

Due to the government shut-down in October 2013, stock assessments for an abbreviated suite of model runs are required only for Steller sea lion prey species (walleye pollock, Pacific cod, Bering Sea/Aleutian Islands Atka mackerel), and species where a conservation concern has been noted.

Summary of Changes in Assessment Inputs

Relative to the November 2012 assessment, the following changes have been made in the current assessment:

Changes in the Input Data

1. Fishery: preliminary 2013 and updated 2003-2012 total Pacific cod catch
2. Fishery: preliminary 2013 and updated 1997-2012 fishery observer data for Pacific cod catch-at-length
3. Survey: Pacific cod biomass and abundance estimates and length composition data from the 2013 NMFS GOA bottom trawl survey

Changes in Assessment Methodology

The model configuration run for 2013 was the 2012 final model configuration. The 2013 alternate model configuration is identical to the 2013 base model configuration, with the difference that it estimated age-0 recruits for 1977 – 2009 instead of for 1977 – 2011. The recommended ABC and OFL are based on the estimates from the 2013 alternate model, and the summary table below lists the results from the alternate model; the results for the alternate model are presented in the Addendum.

Summary of Results

Quantity	As estimated or *specified last* year:		As estimated or *specified this* year by the alternate model:	
	2013	2014	2014	2015
M (natural mortality rate)	0.38	0.38	0.38	0.38
Tier	3a	3a	3a	3a
Projected total (age 0+) biomass (t)	449,300	440,300	422,000	397,000
Female spawning biomass (t)				
Projected	111,000	112,900	120,100	111,500
Upper 95% confidence interval			142,800	132,500
Lower 95% confidence interval			97,500	90,500
$B_{100\%}$	234,800	234,800	227,800	227,800
$B_{40\%}$	93,900	93,900	91,100	91,100
$B_{35\%}$	82,100	82,100	79,700	79,700
F_{OFL}	0.61	0.61	0.69	0.69
$maxF_{ABC}$	0.49	0.49	0.54	0.54
F_{ABC}	0.49	0.49	0.54	0.54
OFL (t)	97,200	101,100	107,300	101,800
maxABC (t)	80,800	84,200	88,500	84,100
ABC (t)	80,800	84,200	88,500	84,100
Status	As determined *last* year for:			
	2011	2012	2012	2013
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. The SSC concurred with this method in December 2012. However, in this year's 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. 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
2014 ABC	33,306	52,758	2,436	88,500
2015 ABC	31,651	50,135	2,314	84,100

INTRODUCTION

General

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 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," without a numeric modifier, 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 allocation follows the average biomass distribution estimated by the three most recent trawl surveys, and the TAC allocation is within one percent of this distribution on an area-by-area basis. 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 proposed 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 tonnes	1977 – 2013
Federal fishery catch-at-length, by gear type and month	AKFIN / FMA	number, by cm bin	1977 – 2013
State fishery catch-at-length, by gear type and month	ADF&G	number, by cm bin	1997 – 2013
GOA NMFS bottom trawl survey biomass and abundance estimates	AFSC	metric tonnes, 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

Commercial Catch Data

Catch Biomass

Catches for the period 1991-2013 are shown for the three main gear types in Table 2.7. 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 preliminary 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 – 2012 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 2013. 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. The fishery length composition data are available at http://www.afsc.noaa.gov/REFM/Docs/2013/GOA_Pacific_cod.2013.fishery_length_data.xlsx.

Survey Data

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

***Note**: This section contains a description of the analytic approach for the 2013 base model and the 2013 alternate model. The Addendum contains the specific description of the alternate model and how it differs from the base model.*

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

The author's preferred model configuration from 2012, Model 2, was the sole model configuration used in this analysis. This model configuration is identical in structure to the 2011 author's preferred model, with the omission of all sub-27 data.

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

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, 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 survey.

The same functional form (pattern 24 for length-based selectivity, pattern 20 for age-based selectivity) used to define the selectivity schedules in last year's assessment was used again this year. 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 this assessment.

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, 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.

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.

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

RESULTS

***Note**: This section contains the evaluation of and results from the 2013 base model. The characteristics described for the base model are very similar to those for the 2013 alternate model, except as noted in the Addendum, which contains the results for the alternate model.*

Model evaluation

The results from the 2013 model configuration with updated 2013 data are described below. These results were compared with the results from the 2011 and 2012 author's preferred models with data updated through 2012, as discussed in the September 2013 document presented to the Plan Team, "An exploration of GOA Pacific cod stock assessment models for 2013" (http://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2013/Sept/GOApcod.pdf).

Comparing and Contrasting the Models

The model configurations evaluated are very similar in structure. The 2012 and 2013 model configurations are identical in structure, and omit the sub-27 survey data that were used in the 2011 model configuration. All three model configurations have very similar patterns in spawning biomass, in that the maximum occurs in 1982-1983 and the minimum occurs in 2008-2009 (Fig. 2.21). However, the model configurations differ in their estimates of age-0 recruitment and fit to the 27-plus survey abundance estimates (Figs. 2.22 and 2.23, respectively).

As a continuation of the work presented in September 2013 with respect to the "guided jitter", the 2013 model differs from the 2012 model in the initial values of some estimated parameters (primarily for fishery and survey selectivity), the bounds on some estimated parameters (R_0), and the estimation of some parameters that were not estimated in the 2012 model (selectivity). The 2013 model estimated 12 27-plus survey selectivity-at-age curves instead of the 11 estimated in the 2012 model due to the inclusion of the 2013 GOA NMFS bottom trawl survey data in the 2013 model.

Evaluation Criteria

There is only one model configuration for 2013, which is the 2012 model configuration with fishery and survey data updates and changes to the initial values of some estimated parameters.

Selection of the Final Model

There is only one model configuration for 2013, which is the 2012 model configuration with fishery and survey data updates and changes to the initial values of some estimated parameters.

Final Parameter Estimates and Associated Schedules

Table 2.14 lists the number of parameters, the values of the objective function components, and the "effective q" for the 2011, 2012, and 2013 model configurations. The "effective q" is for comparison with 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).

Estimated growth and median recruitment parameters, and "effective q"

	2011 model	2012 model	2013 model
Length at A_{min}	20.64	26.71	27.80
L_∞	99.73	100.88	101.35
k	0.185	0.171	0.166
$Ln(R_0)$	12.43	12.45	12.40
"Effective q"	0.893	0.885	0.899

A_{min} is age 1.33333 (age-1 fish at the time of the NMFS GOA bottom trawl survey, when the data were collected)

Table 2.15 lists the fixed and estimated parameter values for the 2013 model configuration, as well as for the 2011 and 2012 model configurations with data updated through 2012. Table 2.16 lists the estimated length- and weight-at-age for the 5 fishing seasons. Table 2.17 and Fig. 2.17 show the estimated 27-plus survey selectivity-at-age curves for each survey year for 1984 – 2011; the values for 2011 were used for the 2013 survey. The summary of overall fits to the fishery and survey length composition data are shown in Fig. 2.19, by gear type and season. The estimated fishery selectivity curves, by year block, gear type, and season, are shown in Fig. 2.18 and are available at http://www.afsc.noaa.gov/REFM/Docs/2013/GOA_Pacific_cod.2013.estimated_fishery_selectivity.xlsx. Fits to the fishery catch-at-length data by gear type and season are shown in Fig. 2.20.

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. 2.8 and 2.9.

Recruitment and Numbers at Age

Table 2.19 shows the time series of GOA Pacific cod age-0 recruits for the years 1977-2011 as estimated last year and this year. The estimated recruitment time series are accompanied by their respective standard deviations (Fig. 2.10). Table 2.20 shows the numbers-at-age for 1977-2013. The age-0 recruits for 2012 were not estimated as there is no information on age-1 fish in the 2013 27-plus survey data.

Survey Data

Fig. 2.11 shows the fit to the 27-plus survey abundance estimates. Fig. 2.12 shows the fit to the 27-plus survey age composition data, Fig. 2.13 shows the fit to the 27-plus survey length composition data, and Fig. 2.14 shows the fit to the 27-plus mean size-at-age data.

Fishing Mortality

Table 2.21 shows the "effective" annual fishing mortality by age and year for ages 1-19 and years 1977-2012.

Harvest Recommendations

***Note**: This section contains harvest specifications based on the estimates from the 2013 base model, which **differ** from the harvest recommendations listed in the summary table. The authors' recommended harvest recommendations are based on the estimates from the 2013 alternate model, which is described in the Addendum.*

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 (with the exception of the current year, when the stock is being managed under Tier 5). 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:

Reference point:	$B_{35\%}$	$B_{40\%}$	$B_{100\%}$
Spawning biomass:	81,400 t	93,000 t	232,700 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 (2008-2012). 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 25%, longline 23%, and pot 52%. This apportionment results in estimates of $F_{35\%}$ and $F_{40\%}$ equal to 0.689 and 0.544, respectively.

Specification of OFL and Maximum Permissible ABC

Spawning biomass for 2014 is estimated by this year's model at a value of 147,000 t. This is well above the $B_{40\%}$ value of 93,000 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 2014 and 2015 as follows (2015 values are predicated on the assumption that 2014 catch will equal 2014 maximum permissible ABC):

Units	Year	Overfishing Level	Maximum Permissible ABC
Harvest amount	2014	132,200 t	109,000 t
Harvest amount	2015	122,800 t	101,500 t
Fishing mortality rate	2014	0.689	0.544
Fishing mortality rate	2015	0.689	0.544

The age 0+ biomass projections for 2013 and 2014 from this year's model are 510,400 t and 470,000 t, respectively.

ABC Recommendation

In 2005, the SSC used a two-year stair-step approach to recommend the 2006 ABC. In 2006, the GOA Plan Team and SSC recommended keeping ABC at the 2006 level for 2007. In 2007, the GOA Plan Team and SSC adopted a Tier 5 approach for setting the 2008 ABC. In 2008-2010, the GOA Plan Team and SSC recommended setting 2009 ABC at the maximum permissible level under Tier 3.

Following recent practice, this year's ABC recommendations for 2014 and 2015 are at their respective maximum permissible levels of 109,000 t and 101,500 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 of 35% Western, 62% Central, and 3% Eastern were based on the average (across years) of the area-specific biomass estimates from the 2005-2009 surveys. If the same methodology were applied to the 2009-2013 surveys, the proportions would be 33% Western, 64% Central, and 3% Eastern.

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 an estimated vector of 2013 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 2014 and 2015, 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 2014 recommended in the assessment to the *max* F_{ABC} for 2014. (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 2008-2012 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 2013, or 2) above 1/2 of its MSY level in 2013 and expected to be above its MSY level in 2023 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2014 and 2015, 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 2024 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 2014, it does not provide the best estimate of OFL for 2015, because the mean 2015 catch under Scenario 6 is predicated on the 2014 catch being equal to the 2014 OFL, whereas the actual 2014 catch will likely be less than the 2014 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 (2012) is 78,000 t. This is less than the 2012 OFL of 104,000 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 2013 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.

b. If spawning biomass for 2013 is estimated to be above $B_{35\%}$ the stock is above its MSST.

c. If spawning biomass for 2013 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 2023 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 2015 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2015 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2015 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2025. If the mean spawning biomass for 2026 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 – 2013 are listed in Table 2.23.

ECOSYSTEM CONSIDERATIONS

This topic is described in detail in the 2012 stock assessment (A'mar et al., 2012).

DATA GAPS AND RESEARCH PRIORITIES

This topic is described in detail in the 2012 stock assessment (A'mar et al., 2012).

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REFERENCES

A'mar, T., Thompson, G., Martin, M., and W. Palsson. 2012. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 183-322. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501

Bakkala, R. G., and V. G. Wespestad. 1985. Pacific cod. *In* R. G. Bakkala and L. L. Low (editors), Condition of groundfish resources of the eastern Bering Sea and Aleutian Islands region in 1984, p. 37-49. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-83.

Fournier, D. 1983. An analysis of the Hecate Strait Pacific cod fishery using an age-structured model incorporating density-dependent effects. Can. J. Fish. Aquat. Sci. 40:1233-1243.

Fournier, D., and C. P. Archibald. 1982. A general theory for analyzing catch at age data. Can. J. Fish. Aquat. Sci. 38:1195-1207.

Fournier, D.A., H. J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M. N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optim. Methods Softw. 27:233-249.

Greer-Walker, M. 1970. Growth and development of the skeletal muscle fibres of the cod (*Gadus morhua L.*). Journal du Conseil 33:228-244.

Gregory, R. S., C. Morris, and B. Newton. In review. Relative strength of the 2007 and 2008 year-classes, from nearshore surveys of demersal age 0 Atlantic cod in Newman Sound, Bonavista Bay. Can. Sci. Advis. Sec. Res. Doc. series./xxx.

Jung, S., I. Choi, H. Jin, D.-w. Lee, H.-k. Cha, Y. Kim, and J.-y. Lee. 2009. Size-dependent mortality formulation for isochronal fish species based on their fecundity: an example of Pacific cod (*Gadus macrocephalus*) in the eastern coastal areas of Korea. Fisheries Research 97:77-85.

Ketchen, K.S. 1964. Preliminary results of studies on a growth and mortality of Pacific cod (*Gadus macrocephalus*) in Hecate Strait, British Columbia. J. Fish. Res. Bd. Canada 21:1051-1067.

Low, L. L. 1974. A study of four major groundfish fisheries of the Bering Sea. Ph.D. Thesis, Univ. Washington, Seattle, WA 240 p.

Methot, R. D. 1986. Synthetic estimates of historical abundance and mortality for northern anchovy, *Engraulis mordax*. NMFS, Southwest Fish. Cent., Admin. Rep. LJ 86-29, La Jolla, CA.

Methot, R. D. 1990. Synthesis model: An adaptable framework for analysis of diverse stock assessment data. Int. N. Pac. Fish. Comm. Bull. 50:259-277.

Methot, R. D. 1998. Application of stock synthesis to NRC test data sets. *In* V. R. Restrepo (editor), Analyses of simulated data sets in support of the NRC study on stock assessment methods, p. 59-80. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-30.

Methot, R. D. 2000. Technical description of the stock synthesis assessment program. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-NWFSC-43, 46 p.

Methot, R. D. 2005a. Technical description of the Stock Synthesis II Assessment Program. Unpubl. manuscr. National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Blvd. East, Seattle, WA 98112-2097. 54 p.

Methot, R. D. 2005b. User manual for the assessment program Strock Synthesis 2 (SS2), Model Version 1.19. National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Blvd. East, Seattle, WA 98112-2097. 47 p.

Methot, R. D. 2007. User manual for the integrated analysis program Stock Synthesis 2 (SS2), Model Version 2.00c. National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Blvd. East, Seattle, WA 98112-2097. 47 p.

Methot, R. D. 2013. User Manual for Stock Synthesis, Model Version 3.24q. Unpublished manuscript. 150 p.

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

Nichol, D. G., T. Honkalehto, and G. G. Thompson. 2007. Proximity of Pacific cod to the sea floor: Using archival tags to estimate fish availability to research bottom trawls. *Fisheries Research* 86:129-135.

Ona, E., and O. R. Godø. 1990. Fish reaction to trawling noise: the significance for trawl sampling. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer 189: 159–166.

Savin, A. B. 2008. Seasonal distribution and Migrations of Pacific cod *Gadus macrocephalus* (Gadidae) in Anadyr Bay and adjacent waters. Journal of Ichythyology 48:610-621.

Shimada, A. M., and D. K. Kimura. 1994. Seasonal movements of Pacific cod (*Gadus macrocephalus*) in the eastern Bering Sea and adjacent waters based on tag-recapture data. U.S. Natl. Mar. Fish. Serv., Fish. Bull. 92:800-816.

Spies I. 2012. Landscape genetics reveals population subdivision in Bering Sea and Aleutian Islands Pacific cod. *Transactions of the American Fisheries Society* 141:1557-1573.

Stark, J. W. 2007. Geographic and seasonal variations in maturation and growth of female Pacific cod (*Gadus macrocephalus*) in the Gulf of Alaska and Bering Sea. Fish. Bull. 105:396–407.

Thompson, G., T. A'mar, and W. Palsson. 2011. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 161-306. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501

Thompson, G. G., and M. E. Conners. 2007. Report of the Pacific cod technical workshop held at the Alaska Fisheries Science Center, April 24-25, 2007. Unpubl. manuscr., Alaska Fisheries Science Center, Resource Ecology and Fisheries Management Division, 7600 Sand Point Way NE., Seattle, WA 98115-6349. 56 p.

Thompson, G. G., and M. W. Dorn. 2005. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 155-244. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., M. Dorn, and D. Nichol. 2006. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 147-220. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., J. Ianelli, M. Dorn, D. Nichol, S. Gaichas, and K. Aydin. 2007a. Assessment of the Pacific cod stock in the Eastern Bering Sea and Aleutian Islands Area. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 209-327. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., J. Ianelli, M. Dorn, and M. Wilkins. 2007b. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 169-194. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., J. Ianelli, M. Dorn, and M. Wilkins. 2009. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and

fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 165-352. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., J. Ianelli, M. Dorn, and M. Wilkins. 2010. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 157-328. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and R. D. Methot. 1993. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands region as projected for 1994, chapter 2. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and A. M. Shimada. 1990. Pacific cod. *In* L. L. Low and R. E. Narita (editors), Condition of groundfish resources of the eastern Bering Sea-Aleutian Islands region as assessed in 1988, p. 44-66. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-178.

Thompson, G. G, and H. H. Zenger. 1993. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1994, chapter 2. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G, and H. H. Zenger. 1994. Pacific cod. *In* Plan Team for Groundfish Fisheries of the Gulf of Alaska (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1995, chapter 2. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and H. H. Zenger. 1995. Pacific cod. *In* Plan Team for the Groundfish Fisheries of the Gulf of Alaska (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1996, chapter 2. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., H. H. Zenger, and M. K. Dorn. 2002. Assessment of the Pacific cod stock in the Gulf of Alaska. *In* Plan Team for the Groundfish Fisheries of the Gulf of Alaska (compiler), Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska p. 89-167. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Ueda, Y., Y. Narimatsu, T. Hattori, M. Ito, D. Kitagawa, N. Tomikawa, and T. Matsuishi. 2006. Fishing efficiency estimated based on the abundance from virtual population analysis and bottom-trawl surveys of Pacific cod (Gadus macrocephalus) in the waters off the Pacific coast of northern Honshu, Japan. Nippon Suisan Gakkaishi 72:201-209.

Wespestad, V., R. Bakkala, and J. June. 1982. Current abundance of Pacific cod (*Gadus macrocephalus*) in the eastern Bering Sea and expected abundance in 1982-1986. NOAA Tech. Memo. NMFS F/NWC-25, 26 p.

Tables

Table 2.1. Catch (t) for 1991 through 2013 by jurisdiction and gear type (as of 22 October 2013)

	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	20,184	14,514	21,248	723	56,668	797	15,915	4,608	21,319	77,987
2013	19,544	10,526	13,246	472	43,789	773	14,296	1,216	16,284	60,073

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 2013 is current through 22 October. 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 1988-2009. 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	136,000	-
1986	25,012	75,000	125,000	-
1987	32,939	50,000	185,000*	-
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	77,987	65,700	87,600	104,000
2013	60,073	60,600	80,800	97,200

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	33	64	3

Table 2.4 Estimated retained-and discarded GOA Pacific cod from federal waters (source: NMFS/NOAA/AKFIN; as of 1 November 2013)

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	3,316	55,633	58,949
2009	3,869	49,062	52,931
2010	2,857	75,170	78,027
2011	1,816	83,025	84,841
2012	1,016	76,972	77,987
2013	2,725	58,233	60,958

Table 2.5 – Groundfish bycatch, discarded and retained, for GOA Pacific cod as target species (AKFIN; as of 17 October 2013)

	2008		2009		2010		2011		2012		2013	
	D	R	D	R	D	R	D	R	D	R	D	R
Arrowtooth Flounder	2,227.0	904.7	644.9	109.0	391.4	66.6	309.0	269.8	348.0	500.4	719.7	459.3
Atka Mackerel	333.4	1.0	46.5	0.9	56.9	0.1	16.6	0.2	11.8	1.9	19.4	0.1
Flathead Sole	70.9	312.9	25.3	95.0	40.8	33.2	18.8	149.7	51.7	157.5	244.0	163.2
GOA Deep Water Flatfish	16.2	4.6	1.5	0.4	12.5	1.3	7.9	3.8	0.2	3.1	18.3	2.6
GOA Demersal Shelf Rockfish		6.1		2.0		0.8		1.6		0.5		0.4
GOA Dusky Rockfish									25.0	9.4	17.3	5.9
GOA Pelagic Shelf Rockfish	27.7	31.4	32.7	11.2	12.7	14.8	9.8	7.5				
GOA Rex Sole	35.4	113.9	0.0	66.3	8.9	6.8	8.6	31.6	27.8	109.9	26.9	82.2
GOA Rougheye Rockfish	7.3	4.2	4.0	3.3	6.5	1.8	0.9	4.5	0.6	4.3	0.8	2.3
GOA Shallow Water Flatfish	794.3	878.6	43.5	204.9	161.4	517.3	127.6	816.3	124.5	686.3	175.2	698.9
GOA Shortraker Rockfish	3.6	1.8	3.5	4.0	4.7	3.4	3.8	4.0	2.3	3.9	1.3	4.1
GOA Skate, Big	189.4	396.9	211.0	339.2	330.3	609.6	256.4	662.5	83.3	671.6	127.5	419.9
GOA Skate, Longnose	203.5	157.0	115.9	208.8	170.8	253.9	115.7	230.1	12.3	317.1	98.0	257.8
GOA Skate, Other	857.5	100.2	623.6	65.8	900.5	158.1	471.5	195.0	648.9	119.2	674.9	10.9
GOA Thornyhead Rockfish	1.0	6.5	0.4	7.4	0.6	5.4	0.4	7.0	0.3	2.7	4.9	3.3
Halibut											127.8	18.2
Northern Rockfish	91.6	47.0	10.8	13.9	13.9	4.7	7.7	8.2	26.8	24.0	46.2	61.9
Octopus							480.3	379.4	140.8	273.1	30.1	129.8
Other Rockfish	19.3	12.9	23.7	11.8	19.5	8.7	18.5	32.2	9.0	38.3	29.4	34.4
Other Species	950.5	281.4	498.1	264.1	581.9	233.4						
Pacific Ocean Perch	4.4	12.8	4.4	38.2	0.2	8.5	1.3	18.5	7.5	45.8	7.2	4.8
Pollock	2,126.1	866.9	123.2	353.2	203.9	423.7	46.1	503.7	709.8	970.5	62.0	667.4
Sablefish	297.3	63.7	25.5	19.1	43.1	70.4	33.5	60.3	0.6	23.1	48.6	15.4
Sculpin							322.3	10.3	493.4	42.2	419.4	4.4
Shark							76.0	0.7	18.7	0.6	39.0	0.0
Squid											0.2	
Total	8,256.4	4,204.4	2,438.5	1,818.4	2,960.5	2,422.5	2,332.6	3,396.8	2,743.5	4,005.5	2,938.0	3,047.2

Table 2.6 - Incidental catch (t) of non-target species groups by GOA Pacific cod fisheries, 2004-2013 (as of 17 October 2013)

Species/group	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Benthic urochordata	0.0	0.0	0.0	0.0	0.6	3.0	0.0	0.2	0.0	0.0
Birds	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Bivalves	0.3	1.3	2.1	1.2	1.7	4.2	2.7	6.1	1.7	1.9
Brittle star unidentified	0.1	0.2	0.1	0.3	0.1	0.0	0.1	2.1	0.0	0.1
Capelin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corals Bryozoans	0.1	0.0	0.1	0.2	0.0	1.7	0.0	0.7	4.0	0.1
Dark Rockfish	0.0	0.0	0.0	0.0	0.3	2.7	12.3	2.4	1.5	1.0
Eelpouts	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.3	0.1
Eulachon	0.0	0.0	2.4	0.0	0.1	0.0	0.6	0.0	0.0	0.0
Giant Grenadier	0.0	0.0	21.9	81.5	31.0	51.3	140.9	60.4	171.3	126.4
Greenlings	6.2	1.5	3.7	0.8	7.1	1.3	0.8	0.8	1.9	1.0
Grenadier	0.4	0.0	0.6	0.0	66.0	6.6	0.0	8.2	0.0	21.3
Gunnels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hermit crab unidentified	0.1	0.4	0.5	1.7	2.9	3.9	2.1	0.8	0.8	1.9
Invertebrate unidentified	3.7	0.0	12.6	1.6	1.3	0.1	1.1	8.9	4.5	0.4
Misc crabs	0.3	1.7	0.7	6.6	2.4	1.5	3.4	2.5	2.2	3.0
Misc crustaceans	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
Misc fish	136.5	152.5	176.0	539.4	210.5	99.0	87.6	133.7	224.7	72.8
Misc inverts (worms etc)	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other osmerids	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0
Pacific Sand lance	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Pandalid shrimp	0.0	0.0	0.0	0.0	0.0	0.0	0.2	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	1.5	1.1	4.6	0.1	0.4	0.2	10.8	0.8	0.6	1.1
Sea anemone unidentified	1.5	0.7	0.3	5.1	6.0	6.6	7.3	8.8	6.1	5.6
Sea pens whips	0.0	0.0	3.2	1.0	0.0	3.3	3.1	1.4	0.8	1.6
Sea star	1,009.3	937.7	703.5	299.0	316.5	471.9	869.4	717.2	463.6	555.7
Snails	0.6	4.8	2.9	0.8	0.9	2.5	0.7	1.3	3.7	2.4
Sponge unidentified	0.6	1.0	1.2	0.0	1.1	1.6	0.4	0.5	0.4	0.4
Stichaeidae	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0
Surf smelt	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
urchins dollars cucumbers	0.5	1.1	1.0	3.2	0.5	1.3	0.5	2.2	3.6	1.1

Table 2.7 Catch (t) of Pacific cod by year, gear, and season for the years 1991-2013 as configured in the stock assessment models (as of 22 October 2013); values for 2013 season 5 were estimated given the average fraction of catch in season 5 for 2000 – 2012 (0.0324) and the average fraction of each gear type in season 5 for 2000 – 2012 (0.1064, 0.3234, 0.5702, 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	17,131	2,733	2,789	22,653	12,180	570	3,304	16,054	30,068	0	9,212	39,280
2013	14,768	2,558	3,206	20,532	9,645	1,907	955	12,508	25,094	0	3,950	29,044

Table 2.8 – Noncommercial fishery catch (in mt); total source amounts less than 1 mt were omitted (AFSC for GOA bottom trawl survey values; AKFIN for other values, as of 6 November 2013)

Source	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Annual Longline Survey	27.97	13.88	18.10	17.33	16.71	30.99	33.22	27.07	30.50	-
Golden King Crab Pot Survey	1.26	0.15	0.43	0.00	0.00	0.00	0.00	0.00	0.01	-
Gulf of Alaska Bottom Trawl Survey	0.00	20.73	0.00	18.35	0.00	53.11	0.00	29.37	0.00	25.87
IPHC Annual Longline Survey	0.00	0.00	0.00	0.00	0.00	0.00	142.30	124.36	85.60	-
Large-Mesh Trawl Survey	1.67	1.13	0.64	1.03	0.21	0.96	11.70	17.01	20.50	-
Sablefish Longline Survey	1.07	0.63	0.01	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	0.00	1.03	0.00	0.00	-
Small-Mesh Trawl Survey	0.45	0.25	0.27	0.11	0.00	0.00	1.89	1.65	2.66	-
Sport Fishery	0.00	0.00	0.00	0.00	0.00	0.00	113.66	155.53	143.76	-

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 "effective q" for all model configurations (smaller indicates better fit to data; shaded areas indicate comparable categories).

	2011 model	2012 model	2013 model
Number of parameters	253	239	255
Likelihood components (-ln)			
Survey indices	3	1	5
Length compositions	3,075	2,894	3,352
Age compositions	118	94	78
Size-at-age	623	460	461
Recruitment	-22	-22	-22
27-plus survey indices	13	1	5
Sub-27 survey indices	-10	-	-
Total	3,797	3,427	3,874
Length composition likelihoods (-ln)			
Jan-Apr Trawl	714	682	779
Jan-Apr LL	184	177	205
Jan-Apr Pot	285	277	374
May-Aug Trawl	598	578	635
May-Aug LL	112	109	148
May-Aug Pot	279	261	322
Sep-Dec Trawl	465	464	540
Sep-Dec LL	72	70	75
Sep-Dec Pot	180	180	213
27-plus survey	109	96	61
Sub-27 survey	77	-	-
Age compositions likelihoods (-ln)			
Age 27-plus	101	94	78
Age sub-27	17	-	-
Size-at-age likelihoods (-ln)			
Size-at-age 27-plus	552	460	461
Size-at-age sub-27	71	-	-
"Effective q"	0.893	0.885	0.899

Table 2.15 – Parameter values, estimates, and standard deviations

Parameter	Estimate	Std dev
NatM	0.38	_
L_at_Amin	27.798	0.268118
L_at_Amax	101.353	0.726133
VonBert_K	0.166	0.002834
CV_young	3.13	_
CV_old	6.55	_
Wtlen_1	8.84E-06	_
Wtlen_2	3.072	_
Mat50%_Fem	4.35	_
Mat_slope_Fem	-1.963	_
Eggs/kg_inter_Fem	1	_
Eggs/kg_slope_wt_Fem	0	_
RecrDist_GP_1	0	_
RecrDist_Area_1	0	_
RecrDist_Seas_1	0	_
RecrDist_Seas_2	0	_
RecrDist_Seas_3	0	_
RecrDist_Seas_4	0	_
RecrDist_Seas_5	0	_
CohortGrowDev	1	_
AgeKeyParm1	1	_
AgeKeyParm2	0.621	0.0095988
AgeKeyParm3	9.50E-09	_
AgeKeyParm4	0	_
AgeKeyParm5	0.096	_
AgeKeyParm6	1.471	_
AgeKeyParm7	0	_
F-WL1_seas_1	-0.0043	_
F-WL1_seas_2	-0.0978	_
F-WL1_seas_3	0.2608	_
F-WL1_seas_4	0.7063	_
F-WL1_seas_5	-0.2053	_
F-WL2_seas_1	0.0041	_
F-WL2_seas_2	0.0053	_
F-WL2_seas_3	-0.0268	_
F-WL2_seas_4	-0.0600	_
F-WL2_seas_5	0.0156	_
SR_LN(R0)	12.399	0.030354
SR_BH_steep	1	_

SR_sigmaR	0.41	_
SR_envlink	0	_
SR_R1_offset	-0.309	0.126444
SR_autocorr	0	_
Early_InitAge_13	-0.241	0.369111
Early_InitAge_12	-0.301	0.360793
Early_InitAge_11	-0.357	0.353522
Early_InitAge_10	-0.398	0.34803
Early_InitAge_9	-0.398	0.345994
Early_InitAge_8	-0.319	0.349517
Early_InitAge_7	-0.118	0.359715
Early_InitAge_6	0.163	0.358031
Early_InitAge_5	0.243	0.355857
Early_InitAge_4	1.159	0.195699
Early_InitAge_3	0.179	0.221712
Early_InitAge_2	0.248	0.167883
Early_InitAge_1	-0.229	0.185324
Main_RecrDev_1977	1.221	0.0640706
Main_RecrDev_1978	0.068	0.102951
Main_RecrDev_1979	-0.249	0.080041
Main_RecrDev_1980	-0.064	0.0578084
Main_RecrDev_1981	-0.087	0.0602202
Main_RecrDev_1982	0.141	0.0657357
Main_RecrDev_1983	-0.199	0.0881519
Main_RecrDev_1984	-0.170	0.0910641
Main_RecrDev_1985	0.361	0.056292
Main_RecrDev_1986	-0.239	0.070998
Main_RecrDev_1987	0.025	0.0534068
Main_RecrDev_1988	0.074	0.0497591
Main_RecrDev_1989	0.032	0.0537601
Main_RecrDev_1990	0.273	0.045935
Main_RecrDev_1991	0.082	0.0480301
Main_RecrDev_1992	-0.087	0.0528247
Main_RecrDev_1993	0.001	0.0470781
Main_RecrDev_1994	-0.034	0.0455065
Main_RecrDev_1995	0.018	0.0418116
Main_RecrDev_1996	-0.096	0.041667
Main_RecrDev_1997	-0.357	0.0462532
Main_RecrDev_1998	-0.558	0.0508551
Main_RecrDev_1999	-0.276	0.0433951
Main_RecrDev_2000	-0.086	0.039784

Main_RecrDev_2001	-0.354	0.0440533
Main_RecrDev_2002	-0.611	0.0500228
Main_RecrDev_2003	-0.408	0.042554
Main_RecrDev_2004	-0.442	0.0470678
Main_RecrDev_2005	-0.078	0.0448479
Main_RecrDev_2006	0.277	0.0488548
Main_RecrDev_2007	0.292	0.0623721
Main_RecrDev_2008	0.569	0.0802274
Main_RecrDev_2009	0.582	0.100617
Main_RecrDev_2010	0.102	0.130273
Main_RecrDev_2011	0.276	0.198786
InitF_1Jan-Apr_Trawl	0.065	0.0091036
Q_envlink_10_27plus_Trawl_Survey	0.505	0.115065
LnQ_base_10_27plus_Trawl_Survey	0	_
Sel_1_Jan-Apr_Trawl	0	_
Sel_2_Jan-Apr_Trawl	0	_
Sel_3_Jan-Apr_Trawl	0	_
Sel_4_Jan-Apr_Trawl	0	_
Sel_5_Jan-Apr_Trawl	-10	_
Sel_6_Jan-Apr_Trawl	10	_
Sel_1_May-Aug_Trawl	0	_
Sel_2_May-Aug_Trawl	-9.636	9.87395
Sel_3_May-Aug_Trawl	0	_
Sel_4_May-Aug_Trawl	4.543	0.417926
Sel_5_May-Aug_Trawl	-10	_
Sel_6_May-Aug_Trawl	0	_
Sel_1_Sep-Dec_Trawl	0	_
Sel_2_Sep-Dec_Trawl	0	_
Sel_3_Sep-Dec_Trawl	0	_
Sel_4_Sep-Dec_Trawl	4.027	0.445363
Sel_5_Sep-Dec_Trawl	-10	_
Sel_6_Sep-Dec_Trawl	-1.159	0.274682
Sel_1_Jan-Apr_Longline	0	_
Sel_2_Jan-Apr_Longline	0	_
Sel_3_Jan-Apr_Longline	0	_
Sel_4_Jan-Apr_Longline	3.668	0.371396
Sel_5_Jan-Apr_Longline	-10	_
Sel_6_Jan-Apr_Longline	0	_
Sel_1_May-Aug_Longline	0	_
Sel_2_May-Aug_Longline	-9.078	21.2508
Sel_3_May-Aug_Longline	0	_

Sel_4_May-Aug_Longline	4.515	0.512609
Sel_5_May-Aug_Longline	-10	_
Sel_6_May-Aug_Longline	0	_
Sel_1_Sep-Dec_Longline	0	_
Sel_2_Sep-Dec_Longline	-13.386	86.7722
Sel_3_Sep-Dec_Longline	0	_
Sel_4_Sep-Dec_Longline	0	_
Sel_5_Sep-Dec_Longline	-10	_
Sel_6_Sep-Dec_Longline	0	_
Sel_1_Jan-Apr_Pot	0	_
Sel_2_Jan-Apr_Pot	-14.148	78.962
Sel_3_Jan-Apr_Pot	0	_
Sel_4_Jan-Apr_Pot	0	_
Sel_5_Jan-Apr_Pot	-10	_
Sel_6_Jan-Apr_Pot	0	_
Sel_1_May-Aug_Pot	0	_
Sel_2_May-Aug_Pot	-9.059	21.5992
Sel_3_May-Aug_Pot	0	_
Sel_4_May-Aug_Pot	5.129	0.481026
Sel_5_May-Aug_Pot	-10	_
Sel_6_May-Aug_Pot	-1.126	0.595198
Sel_1_Sep-Dec_Pot	0	_
Sel_2_Sep-Dec_Pot	-8.686	27.6855
Sel_3_Sep-Dec_Pot	0	_
Sel_4_Sep-Dec_Pot	4.417	0.317326
Sel_5_Sep-Dec_Pot	-10	_
Sel_6_Sep-Dec_Pot	0	_
Sel_1_27plus_Trawl_Survey	0	_
Sel_2_27plus_Trawl_Survey	0	_
Sel_3_27plus_Trawl_Survey	0	_
Sel_4_27plus_Trawl_Survey	0	_
Sel_5_27plus_Trawl_Survey	-10	_
Sel_6_27plus_Trawl_Survey	0	_
Sel_1_Jan-Apr_Trawl_1977	52.053	2.08495
Sel_1_Jan-Apr_Trawl_1990	74.652	0.844435
Sel_1_Jan-Apr_Trawl_1995	77.651	0.800879
Sel_1_Jan-Apr_Trawl_2000	69.482	1.03562
Sel_1_Jan-Apr_Trawl_2005	74.207	1.29948
Sel_3_Jan-Apr_Trawl_1977	4.432	0.349018
Sel_3_Jan-Apr_Trawl_1990	5.866	0.0476663
Sel_3_Jan-Apr_Trawl_1995	5.941	0.0406484

Sel_3_Jan-Apr_Trawl_2000	5.770	0.0708878
Sel_3_Jan-Apr_Trawl_2005	5.951	0.0707631
Sel_1_May-Aug_Trawl_1977	55.272	1.47881
Sel_1_May-Aug_Trawl_1985	62.594	1.27238
Sel_1_May-Aug_Trawl_1990	67.368	1.1118
Sel_1_May-Aug_Trawl_2000	69.410	1.71819
Sel_1_May-Aug_Trawl_2005	72.557	1.57373
Sel_3_May-Aug_Trawl_1977	4.554	0.221697
Sel_3_May-Aug_Trawl_1985	5.188	0.154244
Sel_3_May-Aug_Trawl_1990	5.181	0.11516
Sel_3_May-Aug_Trawl_2000	5.807	0.131884
Sel_3_May-Aug_Trawl_2005	5.887	0.0976895
Sel_6_May-Aug_Trawl_1977	0.054	0.380756
Sel_6_May-Aug_Trawl_1985	-1.073	0.38089
Sel_6_May-Aug_Trawl_1990	-2.628	0.859652
Sel_6_May-Aug_Trawl_2000	-1.146	0.818156
Sel_6_May-Aug_Trawl_2005	-1.330	0.942232
Sel_1_Sep-Dec_Trawl_1977	44.050	3.22025
Sel_1_Sep-Dec_Trawl_1980	57.036	4.1239
Sel_1_Sep-Dec_Trawl_1985	61.248	1.68921
Sel_1_Sep-Dec_Trawl_1990	65.051	3.12901
Sel_1_Sep-Dec_Trawl_1995	74.725	1.41908
Sel_1_Sep-Dec_Trawl_2000	71.572	1.17995
Sel_1_Sep-Dec_Trawl_2005	72.424	1.03086
Sel_2_Sep-Dec_Trawl_1977	0.078	0.62146
Sel_2_Sep-Dec_Trawl_1980	-4.128	9.00636
Sel_2_Sep-Dec_Trawl_1985	-9.109	20.7095
Sel_2_Sep-Dec_Trawl_1990	-0.360	0.314167
Sel_2_Sep-Dec_Trawl_1995	-8.967	23.2193
Sel_2_Sep-Dec_Trawl_2000	-8.286	33.7476
Sel_2_Sep-Dec_Trawl_2005	-9.351	16.075
Sel_3_Sep-Dec_Trawl_1977	3.499	0.823412
Sel_3_Sep-Dec_Trawl_1980	5.081	0.395308
Sel_3_Sep-Dec_Trawl_1985	5.661	0.196594
Sel_3_Sep-Dec_Trawl_1990	5.586	0.24097
Sel_3_Sep-Dec_Trawl_1995	6.219	0.0893658
Sel_3_Sep-Dec_Trawl_2000	5.935	0.0854329
Sel_3_Sep-Dec_Trawl_2005	5.810	0.0662737
Sel_1_Jan-Apr_Longline_1977	57.656	0.873524
Sel_1_Jan-Apr_Longline_1985	72.076	1.41777
Sel_1_Jan-Apr_Longline_1990	70.312	0.817544

Sel_1_Jan-Apr_Longline_1995	74.513	0.796319
Sel_1_Jan-Apr_Longline_2000	69.418	0.681803
Sel_1_Jan-Apr_Longline_2005	69.956	0.434895
Sel_2_Jan-Apr_Longline_1977	-0.108	0.119079
Sel_2_Jan-Apr_Longline_1985	-2.450	0.820722
Sel_2_Jan-Apr_Longline_1990	-0.766	0.466622
Sel_2_Jan-Apr_Longline_1995	-8.888	24.554
Sel_2_Jan-Apr_Longline_2000	-3.061	1.06791
Sel_2_Jan-Apr_Longline_2005	-9.771	6.55083
Sel_3_Jan-Apr_Longline_1977	4.690	0.101704
Sel_3_Jan-Apr_Longline_1985	5.725	0.0844614
Sel_3_Jan-Apr_Longline_1990	5.273	0.0699358
Sel_3_Jan-Apr_Longline_1995	5.465	0.0598706
Sel_3_Jan-Apr_Longline_2000	5.124	0.0612158
Sel_3_Jan-Apr_Longline_2005	5.088	0.0377495
Sel_6_Jan-Apr_Longline_1977	-0.661	0.363604
Sel_6_Jan-Apr_Longline_1985	0.862	0.269082
Sel_6_Jan-Apr_Longline_1990	0.730	0.517576
Sel_6_Jan-Apr_Longline_1995	1.333	0.488818
Sel_6_Jan-Apr_Longline_2000	-0.017	0.222303
Sel_6_Jan-Apr_Longline_2005	0.248	0.201574
Sel_1_May-Aug_Longline_1977	57.086	2.49223
Sel_1_May-Aug_Longline_1980	56.532	0.885677
Sel_1_May-Aug_Longline_1990	71.360	2.23669
Sel_1_May-Aug_Longline_2000	72.490	1.31067
Sel_3_May-Aug_Longline_1977	4.521	0.339348
Sel_3_May-Aug_Longline_1980	4.377	0.136554
Sel_3_May-Aug_Longline_1990	5.093	0.25
Sel_3_May-Aug_Longline_2000	5.088	0.118237
Sel_6_May-Aug_Longline_1977	0.519	0.704762
Sel_6_May-Aug_Longline_1980	-0.516	0.207953
Sel_6_May-Aug_Longline_1990	-1.622	1.21824
Sel_6_May-Aug_Longline_2000	1.489	1.22517
Sel_1_Sep-Dec_Longline_1977	60.385	2.02068
Sel_1_Sep-Dec_Longline_1980	56.867	0.386037
Sel_1_Sep-Dec_Longline_1990	68.659	0.472193
Sel_3_Sep-Dec_Longline_1977	4.774	0.220419
Sel_3_Sep-Dec_Longline_1980	4.324	0.0615482
Sel_3_Sep-Dec_Longline_1990	4.967	0.045564
Sel_4_Sep-Dec_Longline_1977	8.351	2.52665
Sel_4_Sep-Dec_Longline_1980	4.178	0.147006

Sel_4_Sep-Dec_Longline_1990	3.907	0.424088
Sel_6_Sep-Dec_Longline_1977	-8.548	29.9844
Sel_6_Sep-Dec_Longline_1980	-1.392	0.102474
Sel_6_Sep-Dec_Longline_1990	0.006	0.215229
Sel_1_Jan-Apr_Pot_1977	69.069	0.377968
Sel_1_Jan-Apr_Pot_1995	71.818	0.351499
Sel_1_Jan-Apr_Pot_2000	68.206	0.35933
Sel_1_Jan-Apr_Pot_2005	68.644	0.338563
Sel_3_Jan-Apr_Pot_1977	4.781	0.0443654
Sel_3_Jan-Apr_Pot_1995	4.941	0.0354206
Sel_3_Jan-Apr_Pot_2000	4.881	0.0378955
Sel_3_Jan-Apr_Pot_2005	4.748	0.0343199
Sel_4_Jan-Apr_Pot_1977	4.659	0.164737
Sel_4_Jan-Apr_Pot_1995	4.161	0.261562
Sel_4_Jan-Apr_Pot_2000	4.255	0.220823
Sel_4_Jan-Apr_Pot_2005	3.991	0.296513
Sel_6_Jan-Apr_Pot_1977	-2.198	0.275393
Sel_6_Jan-Apr_Pot_1995	-0.535	0.183597
Sel_6_Jan-Apr_Pot_2000	-0.430	0.150766
Sel_6_Jan-Apr_Pot_2005	0.566	0.207636
Sel_1_May-Aug_Pot_1977	64.785	1.5498
Sel_1_May-Aug_Pot_1995	70.981	1.05065
Sel_1_May-Aug_Pot_2000	65.636	0.870028
Sel_3_May-Aug_Pot_1977	4.422	0.253642
Sel_3_May-Aug_Pot_1995	4.863	0.124295
Sel_3_May-Aug_Pot_2000	4.297	0.154226
Sel_1_Sep-Dec_Pot_1977	72.856	1.06864
Sel_1_Sep-Dec_Pot_1995	71.110	1.12982
Sel_1_Sep-Dec_Pot_2000	66.465	0.772324
Sel_1_Sep-Dec_Pot_2005	66.673	0.49659
Sel_3_Sep-Dec_Pot_1977	5.341	0.0996336
Sel_3_Sep-Dec_Pot_1995	4.979	0.127107
Sel_3_Sep-Dec_Pot_2000	4.837	0.0906815
Sel_3_Sep-Dec_Pot_2005	4.730	0.0578001
Sel_6_Sep-Dec_Pot_1977	-1.459	0.530735
Sel_6_Sep-Dec_Pot_1995	0.338	0.56304
Sel_6_Sep-Dec_Pot_2000	-0.279	0.28053
Sel_6_Sep-Dec_Pot_2005	-0.109	0.248909
Sel_1_27plus_Trawl_Survey_1977	4.014	0.0150304
Sel_1_27plus_Trawl_Survey_1987	3.609	0.299877
Sel_1_27plus_Trawl_Survey_1990	3.973	0.287243

Sel_1_27plus_Trawl_Survey_1993	4.533	0.333076
Sel_1_27plus_Trawl_Survey_1996	4.898	0.283652
Sel_1_27plus_Trawl_Survey_1999	4.549	0.57027
Sel_1_27plus_Trawl_Survey_2001	3.648	0.308888
Sel_1_27plus_Trawl_Survey_2003	4.281	0.257564
Sel_1_27plus_Trawl_Survey_2005	4.677	0.362759
Sel_1_27plus_Trawl_Survey_2007	4.208	0.577263
Sel_1_27plus_Trawl_Survey_2009	4.196	0.234571
Sel_1_27plus_Trawl_Survey_2011	3.689	0.244577
Sel_2_27plus_Trawl_Survey_1977	-12.127	99.9973
Sel_2_27plus_Trawl_Survey_1987	-9.362	15.8594
Sel_2_27plus_Trawl_Survey_1990	-8.091	38.8675
Sel_2_27plus_Trawl_Survey_1993	-6.972	39.5115
Sel_2_27plus_Trawl_Survey_1996	-9.601	10.6929
Sel_2_27plus_Trawl_Survey_1999	-2.197	0.568184
Sel_2_27plus_Trawl_Survey_2001	-6.447	47.0216
Sel_2_27plus_Trawl_Survey_2003	-3.387	2.4168
Sel_2_27plus_Trawl_Survey_2005	-7.882	39.5856
Sel_2_27plus_Trawl_Survey_2007	2.488	93.6658
Sel_2_27plus_Trawl_Survey_2009	-9.075	21.3245
Sel_2_27plus_Trawl_Survey_2011	-3.863	0.816588
Sel_3_27plus_Trawl_Survey_1977	1.067	0.0859204
Sel_3_27plus_Trawl_Survey_1987	0.843	0.299353
Sel_3_27plus_Trawl_Survey_1990	0.917	0.247396
Sel_3_27plus_Trawl_Survey_1993	1.580	0.23347
Sel_3_27plus_Trawl_Survey_1996	1.728	0.192109
Sel_3_27plus_Trawl_Survey_1999	1.668	0.426371
Sel_3_27plus_Trawl_Survey_2001	1.099	0.276287
Sel_3_27plus_Trawl_Survey_2003	1.186	0.207709
Sel_3_27plus_Trawl_Survey_2005	1.551	0.245248
Sel_3_27plus_Trawl_Survey_2007	1.817	0.462871
Sel_3_27plus_Trawl_Survey_2009	1.138	0.17981
Sel_3_27plus_Trawl_Survey_2011	0.964	0.218961
Sel_4_27plus_Trawl_Survey_1977	-10	_
Sel_4_27plus_Trawl_Survey_1987	0.565	0.882252
Sel_4_27plus_Trawl_Survey_1990	1.173	0.839589
Sel_4_27plus_Trawl_Survey_1993	0.187	0.659935
Sel_4_27plus_Trawl_Survey_1996	1.998	0.451801
Sel_4_27plus_Trawl_Survey_1999	-0.183	1.68366
Sel_4_27plus_Trawl_Survey_2001	3.107	0.653533
Sel_4_27plus_Trawl_Survey_2003	1.912	0.824127

Sel_4_27plus_Trawl_Survey_2005	4.810	2.40425
Sel_4_27plus_Trawl_Survey_2007	0.235	223.168
Sel_4_27plus_Trawl_Survey_2009	1.000	0.863679
Sel_4_27plus_Trawl_Survey_2011	-2.649	35.9966
Sel_6_27plus_Trawl_Survey_1977	-2.059	0.256591
Sel_6_27plus_Trawl_Survey_1987	-2.633	0.624791
Sel_6_27plus_Trawl_Survey_1990	-1.463	0.568319
Sel_6_27plus_Trawl_Survey_1993	-1.574	0.508154
Sel_6_27plus_Trawl_Survey_1996	-10	_
Sel_6_27plus_Trawl_Survey_1999	-2.511	1.85439
Sel_6_27plus_Trawl_Survey_2001	-8.339	33.1186
Sel_6_27plus_Trawl_Survey_2003	-10	_
Sel_6_27plus_Trawl_Survey_2005	-6.559	56.0798
Sel_6_27plus_Trawl_Survey_2007	4.919	80.9295
Sel_6_27plus_Trawl_Survey_2009	-1.158	1.04971
Sel_6_27plus_Trawl_Survey_2011	-0.698	0.521222

Table 2.16 – Schedules of estimated population length (cm) and weight (kg) by season and age. 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	0.500	2.206	7.325	12.443	15.855	0.000	0.001	0.007	0.031	0.045
1	19.268	22.680	27.798	30.795	32.724	0.088	0.131	0.248	0.374	0.397
2	34.601	36.427	39.072	41.609	43.243	0.507	0.548	0.678	0.886	0.939
3	44.833	46.378	48.618	50.766	52.150	1.120	1.148	1.298	1.569	1.678
4	53.496	54.804	56.701	58.520	59.691	1.925	1.916	2.050	2.362	2.552
5	60.831	61.939	63.545	65.085	66.077	2.855	2.790	2.878	3.208	3.499
6	67.042	67.980	69.340	70.644	71.484	3.848	3.715	3.732	4.063	4.468
7	72.301	73.095	74.247	75.351	76.062	4.852	4.644	4.576	4.893	5.419
8	76.754	77.426	78.401	79.336	79.938	5.830	5.543	5.382	5.678	6.325
9	80.524	81.094	81.919	82.711	83.221	6.757	6.392	6.134	6.402	7.168
10	83.717	84.199	84.898	85.568	86.000	7.614	7.176	6.823	7.061	7.939
11	86.420	86.828	87.420	87.988	88.353	8.396	7.888	7.446	7.653	8.635
12	88.709	89.054	89.555	90.036	90.346	9.099	8.528	8.001	8.178	9.255
13	90.647	90.939	91.364	91.771	92.033	9.724	9.095	8.492	8.640	9.802
14	92.288	92.536	92.895	93.239	93.461	10.274	9.595	8.922	9.044	10.281
15	93.677	93.887	94.191	94.483	94.671	10.755	10.031	9.297	9.394	10.698
16	94.854	95.031	95.289	95.536	95.695	11.173	10.408	9.620	9.696	11.057
17	95.850	96.000	96.218	96.428	96.562	11.532	10.733	9.898	9.954	11.366
18	96.693	96.821	97.005	97.183	97.297	11.840	11.012	10.136	10.175	11.629
19	97.408	97.515	97.672	97.822	97.918	12.104	11.250	10.338	10.363	11.853
20	98.713	98.786	98.890	98.990	99.055	12.588	11.688	10.710	10.707	12.266

Table 2.17 – Schedule of estimated 27-plus survey selectivity-at-age

Age	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007	2009	2011
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.040	0.050	0.028	0.063	0.054	0.074	0.086	0.034	0.048	0.139	0.035	0.058
2	0.245	0.326	0.210	0.256	0.214	0.279	0.398	0.201	0.211	0.420	0.211	0.333
3	0.701	0.852	0.684	0.611	0.520	0.628	0.868	0.604	0.546	0.776	0.631	0.833
4	1.000	1.000	1.000	0.943	0.865	0.944	1.000	0.976	0.906	0.993	0.988	1.000
5	0.622	0.923	1.000	1.000	1.000	1.000	0.995	1.000	1.000	1.000	1.000	1.000
6	0.113	0.378	0.776	0.870	0.999	1.000	0.924	0.991	0.999	1.000	0.839	0.332
7	0.113	0.103	0.417	0.315	0.848	1.000	0.785	0.795	0.983	1.000	0.469	0.332
8	0.113	0.068	0.236	0.177	0.550	0.337	0.609	0.475	0.947	1.000	0.281	0.332
9	0.113	0.067	0.193	0.172	0.272	0.082	0.433	0.211	0.895	1.000	0.243	0.332
10	0.113	0.067	0.188	0.172	0.102	0.075	0.281	0.070	0.827	1.000	0.239	0.332
11	0.113	0.067	0.188	0.172	0.029	0.075	0.167	0.017	0.747	1.000	0.239	0.332
12	0.113	0.067	0.188	0.172	0.006	0.075	0.091	0.003	0.659	1.000	0.239	0.332
13	0.113	0.067	0.188	0.172	0.001	0.075	0.045	0.000	0.565	1.000	0.239	0.332
14	0.113	0.067	0.188	0.172	0.000	0.075	0.021	0.000	0.470	1.000	0.239	0.332
15	0.113	0.067	0.188	0.172	0.000	0.075	0.009	0.000	0.376	1.000	0.239	0.332
16	0.113	0.067	0.188	0.172	0.000	0.075	0.003	0.000	0.287	1.000	0.239	0.332
17	0.113	0.067	0.188	0.172	0.000	0.075	0.001	0.000	0.203	1.000	0.239	0.332
18	0.113	0.067	0.188	0.172	0.000	0.075	0.001	0.000	0.127	1.000	0.239	0.332
19	0.113	0.067	0.188	0.172	0.000	0.075	0.000	0.000	0.060	0.999	0.239	0.332
20	0.113	0.067	0.188	0.172	0.000	0.075	0.000	0.000	0.001	0.993	0.239	0.332

Table 2.18 – Estimated female spawning biomass (t) from the 2012 assessment and this year's assessment

	Last year		**This year**	
Year	Spawning Biomass	Standard Deviation	Spawning Biomass	Standard Deviation
1977	169,031	19,911	186,808	22,033
1978	204,602	21,738	227,088	24,465
1979	213,924	21,714	239,480	24,638
1980	211,323	20,347	238,081	23,167
1981	225,610	19,888	252,175	22,457
1982	257,987	20,899	285,659	23,310
1983	257,838	20,006	285,396	22,223
1984	238,070	17,937	262,246	19,764
1985	225,556	15,822	244,848	17,150
1986	221,341	13,901	234,405	14,690
1987	220,298	12,205	226,094	12,560
1988	208,697	10,634	211,026	10,710
1989	198,776	9,396	202,045	9,314
1990	188,967	8,496	192,004	8,352
1991	169,701	7,650	172,390	7,469
1992	149,600	7,046	151,710	6,845
1993	142,250	6,736	144,063	6,517
1994	145,558	6,645	146,202	6,376
1995	154,545	6,561	155,479	6,310
1996	149,391	6,318	150,300	6,055
1997	141,330	6,042	141,547	5,699
1998	129,266	5,923	128,100	5,432
1999	124,857	6,027	122,142	5,347
2000	113,669	6,172	110,458	5,322
2001	113,039	6,211	109,422	5,207
2002	106,423	6,064	102,436	4,930
2003	95,779	5,968	90,860	4,669
2004	93,901	6,183	87,923	4,641
2005	94,115	6,540	87,611	4,751
2006	89,918	6,685	83,399	4,696
2007	86,436	6,830	79,240	4,581
2008	81,890	7,319	73,601	4,632
2009	83,523	8,598	73,230	5,096
2010	94,670	11,440	81,752	6,434
2011	108,491	15,806	95,863	8,938
2012	123,986	21,106	116,606	12,808
2013	*111,000*		146,930	18,109
2014	*112,900*		*147,000*	

Table 2.19 – Estimated age-0 recruits (000's) from the 2012 assessment and this year's assessment

	Last year		This year	
Year	Age-0	Std. Dev	Age-0	Std. Dev
1977	735,007	51,726	756,157	53,618
1978	195,006	21,277	238,560	25,328
1979	174,073	13,739	173,783	14,582
1980	209,907	13,148	209,123	13,140
1981	210,763	13,353	204,331	12,984
1982	286,796	18,383	256,862	17,289
1983	213,303	16,679	182,726	16,137
1984	153,020	14,258	188,096	17,224
1985	335,354	18,680	319,968	17,552
1986	162,463	12,040	175,593	12,358
1987	248,047	12,296	228,726	12,044
1988	225,576	11,881	240,174	11,897
1989	258,723	13,611	230,335	12,418
1990	282,643	13,593	293,018	13,264
1991	245,553	11,902	241,917	11,354
1992	208,946	11,678	204,391	10,644
1993	232,715	11,611	223,157	10,273
1994	233,170	11,544	215,464	9,911
1995	233,150	11,048	227,150	9,706
1996	210,467	10,416	202,627	8,640
1997	157,347	8,344	156,086	7,279
1998	139,673	7,974	127,597	6,645
1999	185,457	9,988	169,207	7,825
2000	218,151	11,685	205,053	9,113
2001	157,251	9,270	156,483	7,441
2002	132,968	8,680	121,066	6,571
2003	163,815	11,010	148,323	7,457
2004	157,315	11,918	143,264	8,123
2005	247,945	22,268	206,195	12,227
2006	319,899	33,409	294,212	19,619
2007	303,208	39,836	298,706	23,992
2008	357,927	51,699	393,735	39,315
2009	332,420	72,508	399,022	47,592
2010	215,261	87,437	246,927	35,982
2011	213,472	88,978	293,917	62,757
Average	238,765		239,199	

Table 2.20 – Estimated numbers-at-age (millions) at the time of spawning

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	732587	86250	95111	60636	109720	29723	18562	9481	5243	3279	2218	1563	1118	804	752	509	344	233	158	107	223
1978	231124	500988	58971	64870	41185	74374	20145	12583	6429	3557	2226	1507	1062	760	547	512	346	234	159	107	224
1979	168366	158057	342483	40107	43687	27560	49751	13490	8435	4315	2391	1498	1015	717	513	369	346	234	159	107	224
1980	202605	115139	108021	232140	26764	28895	18218	32928	8940	5600	2871	1595	1001	680	480	344	248	232	157	107	223
1981	197962	138554	78694	73136	152327	17274	18824	11996	21795	5932	3722	1912	1063	668	454	321	230	166	156	105	221
1982	248855	135378	94682	53173	47689	97607	11204	12371	7932	14451	3940	2476	1273	709	446	303	214	154	111	104	218
1983	177030	170182	92513	63965	34682	30602	63382	7365	8178	5257	9595	2620	1648	848	473	297	202	143	103	74	215
1984	182233	121064	116275	62255	40981	21702	19472	41040	4808	5358	3452	6313	1726	1088	560	312	197	134	95	68	191
1985	309994	124621	82733	78827	41209	26732	14219	12847	27183	3191	3561	2297	4203	1150	725	373	208	131	89	63	173
1986	170119	211991	85147	56196	52814	27252	17600	9373	8491	18013	2119	2367	1528	2798	766	483	249	139	87	59	157
1987	221596	116338	144806	57700	37377	34629	17865	11595	6201	5633	11970	1410	1576	1018	1863	510	322	166	92	58	144
1988	232688	151541	79319	96773	37136	23393	21678	11351	7466	4025	3672	7819	922	1031	666	1220	334	211	108	61	133
1989	223156	159126	103347	52990	62539	23418	14693	13746	7273	4817	2606	2382	5078	599	670	433	793	217	137	71	126
1990	283884	152603	108680	69742	34167	38146	13918	8758	8291	4429	2950	1602	1467	3130	369	414	267	490	134	85	121
1991	234376	194125	104102	72927	44295	19812	20568	7341	4680	4532	2469	1669	915	843	1807	214	240	155	285	78	120
1992	198020	160270	132457	69960	46642	26084	10827	10833	3844	2469	2413	1326	901	496	459	985	117	131	85	156	108
1993	216201	135412	109431	89432	45374	28127	14695	5909	5905	2118	1375	1357	750	512	283	262	564	67	75	49	152
1994	208747	147846	92477	74018	58453	27879	16328	8319	3348	3381	1226	803	796	442	303	167	155	334	40	45	119
1995	220069	142748	100975	62589	48464	35955	16117	9142	4640	1882	1918	700	460	458	255	175	97	90	193	23	95
1996	196311	150490	97463	68227	40787	29489	20331	8708	4874	2483	1015	1042	382	252	251	140	96	53	49	106	65
1997	151220	134243	102749	65821	44286	24548	16416	10821	4588	2585	1330	548	565	208	137	137	76	52	29	27	93
1998	123620	103409	91618	69219	42297	25943	13050	8261	5394	2316	1326	691	287	297	110	73	73	40	28	15	64
1999	163933	84536	70600	61806	44505	24676	13702	6552	4139	2753	1206	701	369	154	160	59	39	39	22	15	43
2000	198662	112100	57645	47235	38578	24658	12390	6654	3228	2101	1435	641	377	200	84	87	32	21	22	12	32
2001	151605	135851	76527	38856	30427	23035	13918	6926	3784	1875	1239	854	383	226	120	50	53	19	13	13	26
2002	117293	103672	92686	51354	24630	17611	12506	7494	3820	2147	1086	726	504	227	134	71	30	31	12	8	23
2003	143700	80209	70770	62274	32253	13751	9049	6371	3940	2079	1197	614	414	289	130	77	41	17	18	7	18
2004	138799	98268	54743	47484	38973	17982	7085	4629	3370	2163	1172	685	354	240	168	76	45	24	10	11	14
2005	199767	94916	67081	36874	30194	22244	9440	3655	2443	1830	1199	658	387	201	136	96	43	26	14	6	14
2006	285041	136608	64817	45281	23545	17287	11679	4856	1915	1311	999	662	365	216	112	76	53	24	14	8	11
2007	289395	194921	93296	43774	28974	13558	9149	6055	2561	1033	718	553	368	204	120	63	43	30	14	8	11
2008	381462	197897	133065	62763	27473	15874	6652	4367	2956	1289	531	375	291	194	108	64	33	23	16	7	10
2009	386585	260859	135138	89612	39432	15016	7726	3140	2113	1483	665	279	199	155	104	58	34	18	12	9	9
2010	239230	264358	178095	90843	55658	20942	7042	3517	1468	1023	737	335	142	102	79	53	30	18	9	6	9
2011	284755	163594	180522	119872	56607	29636	9819	3203	1646	714	512	375	173	73	53	41	28	15	9	5	8
2012	234985	194723	111700	121662	75613	31188	14635	4727	1580	838	371	270	199	92	39	28	22	15	8	5	7
2013	234985	160691	133018	75631	78924	44963	17231	7917	2589	881	474	212	155	114	53	23	16	13	9	5	7

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

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1977	0.000	0.001	0.002	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002
1978	0.000	0.003	0.012	0.020	0.021	0.020	0.019	0.018	0.017	0.016	0.014	0.013	0.013	0.012	0.011	0.011	0.011	0.011	0.010
1979	0.000	0.003	0.013	0.023	0.024	0.023	0.022	0.021	0.020	0.018	0.017	0.016	0.015	0.014	0.013	0.013	0.013	0.012	0.012
1980	0.000	0.008	0.039	0.062	0.055	0.045	0.040	0.038	0.036	0.034	0.032	0.030	0.029	0.028	0.027	0.027	0.026	0.026	0.026
1981	0.000	0.009	0.043	0.063	0.053	0.040	0.034	0.031	0.030	0.028	0.027	0.026	0.025	0.024	0.024	0.024	0.023	0.023	0.023
1982	0.000	0.008	0.040	0.059	0.049	0.037	0.031	0.029	0.028	0.026	0.025	0.024	0.023	0.022	0.022	0.022	0.021	0.021	0.021
1983	0.000	0.011	0.057	0.084	0.069	0.052	0.044	0.041	0.039	0.038	0.036	0.035	0.034	0.033	0.033	0.032	0.032	0.032	0.031
1984	0.000	0.007	0.032	0.050	0.045	0.038	0.034	0.033	0.031	0.029	0.028	0.026	0.025	0.024	0.024	0.023	0.023	0.023	0.022
1985	0.000	0.003	0.013	0.023	0.026	0.026	0.025	0.023	0.022	0.021	0.020	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019
1986	0.001	0.006	0.024	0.042	0.047	0.046	0.044	0.041	0.038	0.036	0.035	0.034	0.034	0.034	0.034	0.034	0.033	0.033	0.033
1987	0.002	0.013	0.047	0.076	0.077	0.063	0.051	0.043	0.039	0.037	0.036	0.035	0.035	0.035	0.034	0.034	0.034	0.034	0.034
1988	0.001	0.009	0.040	0.070	0.076	0.068	0.058	0.051	0.047	0.044	0.043	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.041
1989	0.000	0.008	0.049	0.091	0.101	0.091	0.077	0.068	0.063	0.060	0.059	0.058	0.058	0.057	0.057	0.057	0.057	0.057	0.057
1990	0.001	0.007	0.037	0.101	0.166	0.195	0.191	0.174	0.158	0.145	0.137	0.131	0.127	0.124	0.122	0.120	0.119	0.119	0.118
1991	0.000	0.004	0.027	0.085	0.164	0.219	0.236	0.233	0.224	0.217	0.211	0.206	0.204	0.202	0.200	0.199	0.199	0.198	0.198
1992	0.000	0.005	0.030	0.101	0.194	0.257	0.275	0.270	0.258	0.248	0.240	0.234	0.230	0.227	0.226	0.224	0.223	0.223	0.222
1993	0.000	0.003	0.022	0.074	0.144	0.190	0.201	0.193	0.182	0.173	0.166	0.161	0.158	0.156	0.154	0.153	0.152	0.152	0.151
1994	0.000	0.002	0.016	0.056	0.112	0.151	0.161	0.157	0.148	0.141	0.136	0.132	0.129	0.128	0.126	0.126	0.125	0.125	0.124
1995	0.000	0.003	0.020	0.068	0.145	0.213	0.243	0.245	0.236	0.227	0.220	0.216	0.214	0.212	0.211	0.211	0.210	0.210	0.210
1996	0.000	0.003	0.021	0.072	0.148	0.212	0.241	0.243	0.235	0.226	0.221	0.217	0.215	0.214	0.213	0.213	0.212	0.212	0.212
1997	0.001	0.006	0.028	0.089	0.180	0.256	0.287	0.286	0.273	0.261	0.252	0.247	0.243	0.241	0.240	0.239	0.238	0.238	0.237
1998	0.000	0.004	0.024	0.086	0.181	0.260	0.291	0.286	0.269	0.254	0.244	0.237	0.233	0.231	0.229	0.228	0.228	0.227	0.226
1999	0.001	0.005	0.029	0.103	0.224	0.325	0.361	0.350	0.324	0.301	0.285	0.275	0.268	0.264	0.262	0.260	0.259	0.258	0.257
2000	0.000	0.005	0.031	0.112	0.221	0.277	0.271	0.240	0.213	0.196	0.186	0.181	0.178	0.176	0.175	0.174	0.174	0.174	0.173
2001	0.001	0.007	0.036	0.106	0.188	0.226	0.216	0.189	0.165	0.150	0.142	0.137	0.134	0.133	0.132	0.131	0.131	0.130	0.130
2002	0.000	0.006	0.038	0.124	0.222	0.264	0.252	0.221	0.196	0.179	0.170	0.165	0.162	0.161	0.160	0.159	0.159	0.159	0.158
2003	0.001	0.007	0.038	0.122	0.227	0.278	0.265	0.229	0.198	0.178	0.167	0.161	0.158	0.156	0.155	0.155	0.154	0.154	0.154
2004	0.001	0.007	0.041	0.136	0.254	0.309	0.292	0.250	0.214	0.192	0.180	0.173	0.169	0.167	0.166	0.165	0.165	0.165	0.164

2005	0.000	0.004	0.027	0.101	0.202	0.259	0.258	0.236	0.216	0.203	0.196	0.192	0.190	0.189	0.188	0.188	0.187	0.187	0.187
2006	0.000	0.003	0.026	0.101	0.209	0.271	0.272	0.250	0.230	0.218	0.211	0.207	0.205	0.203	0.203	0.202	0.202	0.202	0.202
2007	0.000	0.005	0.034	0.125	0.248	0.315	0.312	0.284	0.259	0.244	0.235	0.230	0.227	0.226	0.225	0.224	0.224	0.223	0.223
2008	0.001	0.007	0.044	0.152	0.298	0.380	0.378	0.343	0.311	0.291	0.279	0.272	0.268	0.266	0.265	0.264	0.263	0.263	0.262
2009	0.000	0.005	0.034	0.126	0.257	0.332	0.331	0.300	0.271	0.252	0.242	0.236	0.232	0.230	0.229	0.229	0.228	0.228	0.227
2010	0.001	0.007	0.043	0.160	0.328	0.424	0.423	0.383	0.346	0.323	0.310	0.303	0.299	0.296	0.295	0.294	0.293	0.293	0.293
2011	0.000	0.005	0.037	0.149	0.307	0.392	0.388	0.351	0.319	0.300	0.289	0.284	0.281	0.279	0.278	0.277	0.277	0.277	0.276
2012	0.000	0.004	0.029	0.112	0.230	0.298	0.300	0.277	0.255	0.242	0.235	0.231	0.229	0.228	0.227	0.227	0.226	0.226	0.226

Table 2.22 – Results for the projection scenarios

Scenarios 1 and 2, Maximum tier 3 ABC harvest permissible						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2013	93,748	113,955	62,084	133,139	0.339	486,275
2014	109,088	132,201	109,088	147,003	0.544	510,407
2015	101,509	122,817	101,509	134,229	0.544	470,099
2016	92,170	111,592	92,170	123,111	0.544	434,245
2017	84,793	102,689	84,793	113,552	0.544	405,665
2018	78,894	95,577	78,894	106,089	0.544	384,521
2019	74,037	89,508	74,037	100,457	0.540	370,241
2020	70,126	84,698	70,126	96,999	0.529	362,125
2021	68,541	82,794	68,541	95,625	0.525	358,944
2022	68,301	82,517	68,301	95,509	0.525	358,388
2023	68,411	82,638	68,411	95,518	0.525	358,045
2024	68,205	82,377	68,205	95,216	0.525	357,287
2025	68,072	82,203	68,072	95,121	0.524	357,140
2026	67,956	82,061	67,956	94,988	0.524	356,852
Scenario 3, F_{ABC} at average F over the past 5 years						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2013	66,400	113,955	62,084	133,139	0.339	486,275
2014	77,557	132,201	77,557	149,988	0.366	510,407
2015	79,595	134,919	79,595	149,490	0.366	500,108
2016	76,955	130,428	76,955	144,953	0.366	480,410
2017	73,234	124,128	73,234	138,083	0.366	458,515
2018	69,328	117,557	69,328	131,190	0.366	439,026
2019	65,889	111,786	65,889	125,077	0.366	423,970
2020	63,248	107,371	63,248	120,548	0.366	413,751
2021	61,603	104,603	61,603	117,850	0.366	407,607
2022	60,867	103,329	60,867	116,711	0.366	404,681
2023	60,594	102,838	60,594	116,121	0.366	402,920
2024	60,341	102,391	60,341	115,490	0.366	401,418
2025	60,137	102,019	60,137	115,160	0.366	400,739
2026	60,004	101,812	60,004	114,877	0.366	400,110
Scenario 4, $F_{ABC} = F_{60\%}$						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2013	43,942	113,955	62,084	133,139	0.339	486,275
2014	51,472	132,201	51,472	152,264	0.232	510,407
2015	57,035	145,041	57,035	162,481	0.232	525,108
2016	58,263	147,891	58,263	165,500	0.232	522,980
2017	57,420	145,674	57,420	163,070	0.232	511,419
2018	55,559	140,990	55,559	158,347	0.232	497,098
2019	53,460	135,755	53,460	152,952	0.232	483,876

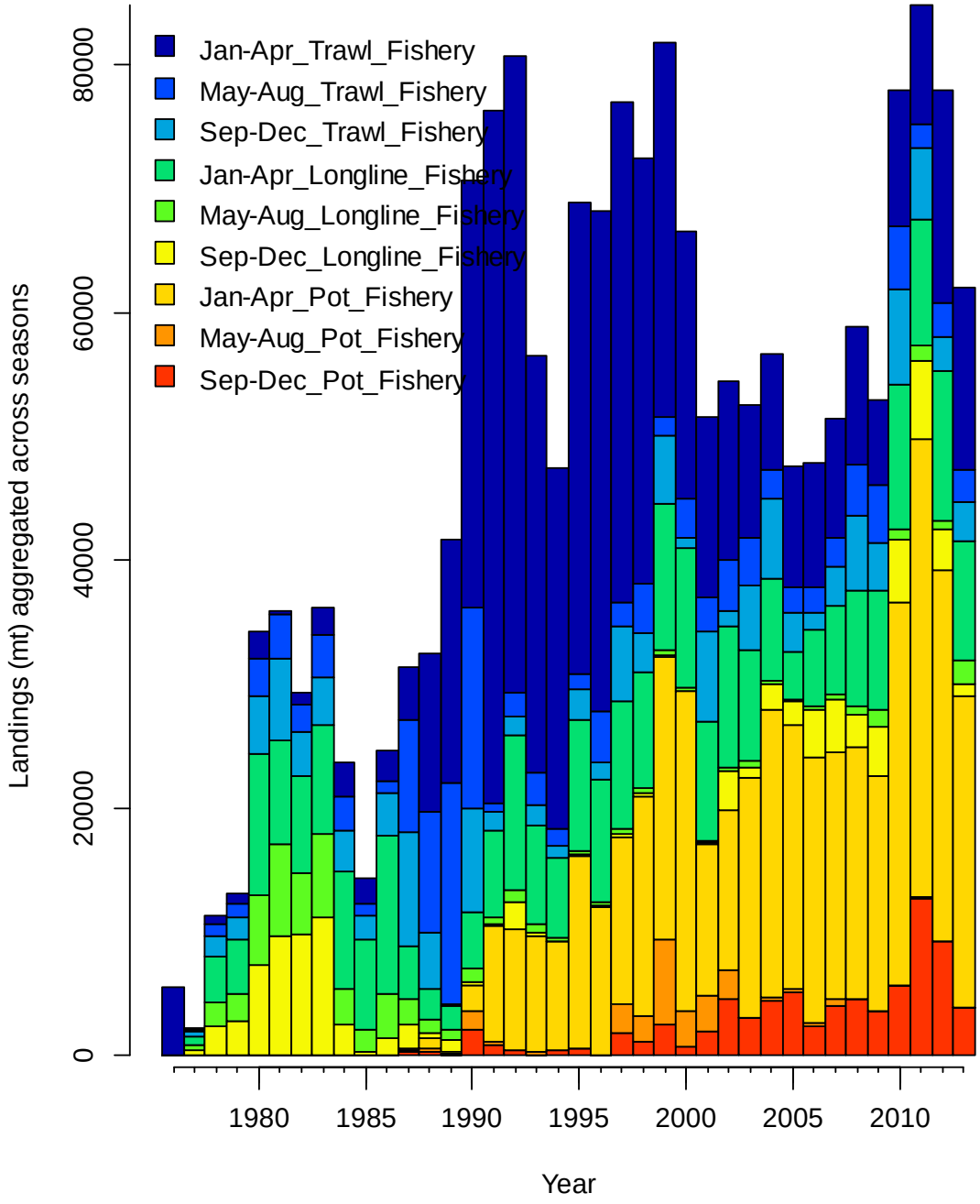
2020	51,605	131,174	51,605	148,314	0.232	473,579
2021	50,297	127,982	50,297	145,139	0.232	466,470
2022	49,591	126,279	49,591	143,466	0.232	462,393
2023	49,259	125,433	49,259	142,456	0.232	459,693
2024	49,001	124,749	49,001	141,528	0.232	457,529
2025	48,794	124,235	48,794	140,971	0.232	456,349
2026	48,652	123,870	48,652	140,522	0.232	455,349
Scenario 5, No fishing (F_{ABC} = 0)						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2013	0	113,955	62,084	133,139	0.339	486,275
2014	0	132,201	0	156,329	0.000	510,407
2015	0	165,259	0	189,003	0.000	574,831
2016	0	187,640	0	213,207	0.000	619,368
2017	0	200,536	0	227,962	0.000	645,745
2018	0	206,349	0	235,805	0.000	659,393
2019	0	207,711	0	238,773	0.000	664,960
2020	0	206,833	0	239,130	0.000	666,038
2021	0	205,400	0	238,557	0.000	664,959
2022	0	204,340	0	238,014	0.000	663,562
2023	0	203,649	0	237,391	0.000	661,799
2024	0	202,962	0	236,504	0.000	659,777
2025	0	202,330	0	235,794	0.000	658,310
2026	0	201,771	0	235,113	0.000	656,823
Scenario 6, Whether Pacific cod are overfished – $SB_{35\%}$ = 81,400						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2013	113,955	113,955	62,084	133,139	0.339	486,275
2014	132,201	132,201	132,201	144,624	0.689	510,407
2015	114,050	114,050	114,050	123,371	0.689	448,265
2016	99,285	99,285	99,285	109,036	0.689	403,879
2017	89,692	89,692	89,692	98,854	0.689	373,439
2018	81,360	81,360	81,360	91,952	0.673	352,989
2019	74,301	74,301	74,301	87,835	0.638	341,638
2020	71,682	71,682	71,682	86,247	0.625	338,079
2021	71,191	71,191	71,191	85,937	0.624	337,523
2022	71,583	71,583	71,583	86,271	0.626	338,089
2023	71,785	71,785	71,785	86,399	0.626	338,023
2024	71,505	71,505	71,505	86,150	0.625	337,369
2025	71,455	71,455	71,455	86,113	0.625	337,371
2026	71,345	71,345	71,345	85,996	0.625	337,123
Scenario 7, Whether Pacific cod is approaching overfished condition						
Year	ABC	OFL	Catch	SSB	F	Total Bio

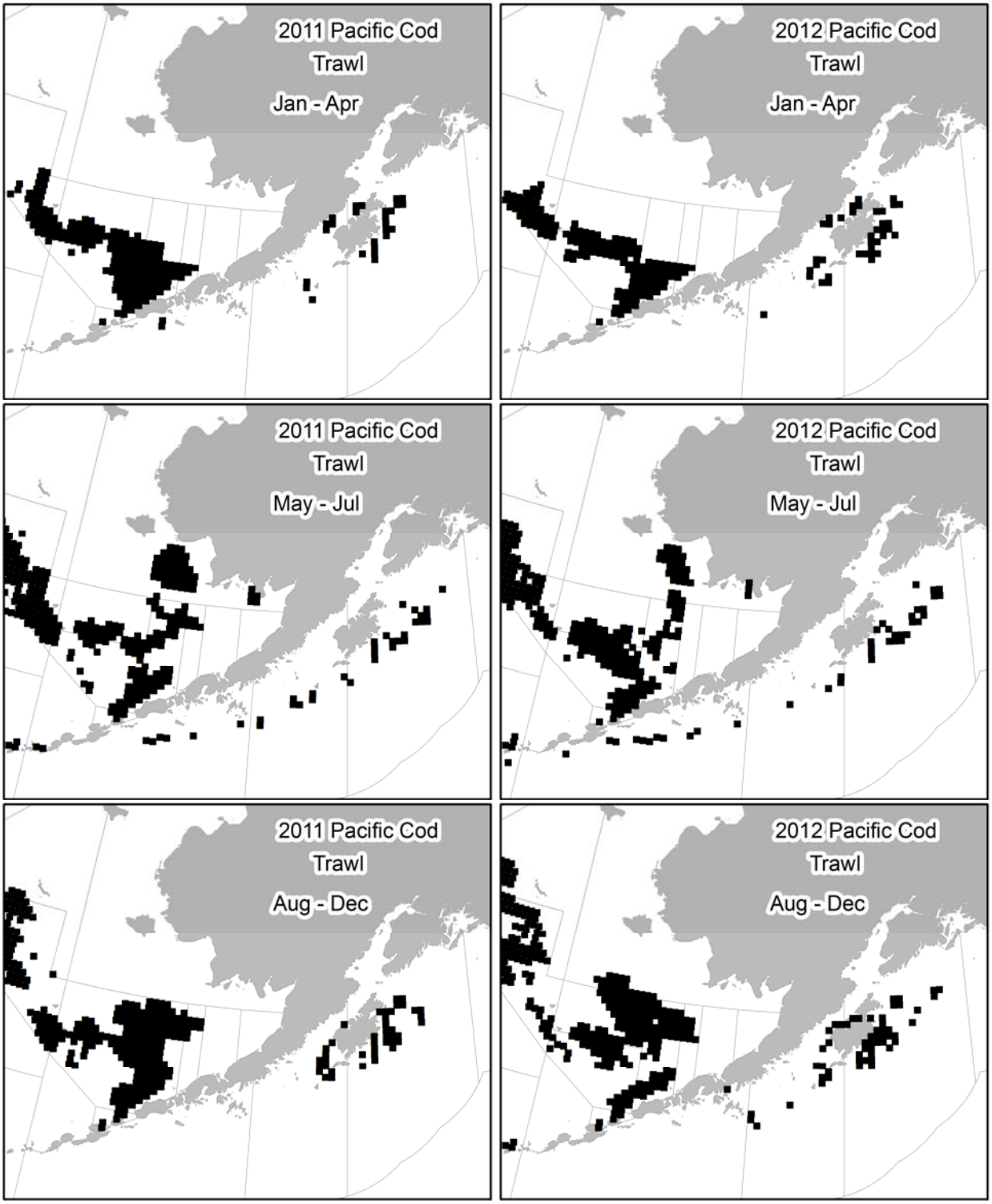
2013	113,955	113,955	62,084	133,139	0.339	486,275
2014	132,201	132,201	109,088	147,003	0.544	510,407
2015	122,817	122,817	101,509	134,229	0.544	470,099
2016	111,592	111,592	111,592	121,081	0.689	434,245
2017	95,436	95,436	95,436	104,502	0.689	387,437
2018	84,727	84,727	84,727	94,320	0.683	359,033
2019	75,234	75,234	75,234	88,510	0.642	343,311
2020	71,865	71,865	71,865	86,407	0.626	338,454
2021	71,210	71,210	71,210	85,971	0.624	337,596
2022	71,582	71,582	71,582	86,279	0.626	338,103
2023	71,783	71,783	71,783	86,400	0.626	338,025
2024	71,504	71,504	71,504	86,150	0.625	337,369
2025	71,454	71,454	71,454	86,113	0.625	337,371
2026	71,345	71,345	71,345	85,996	0.625	337,123

Table 2.23 – Biological reference points from GOA Pacific cod SAFE documents for years 2001 – 2013

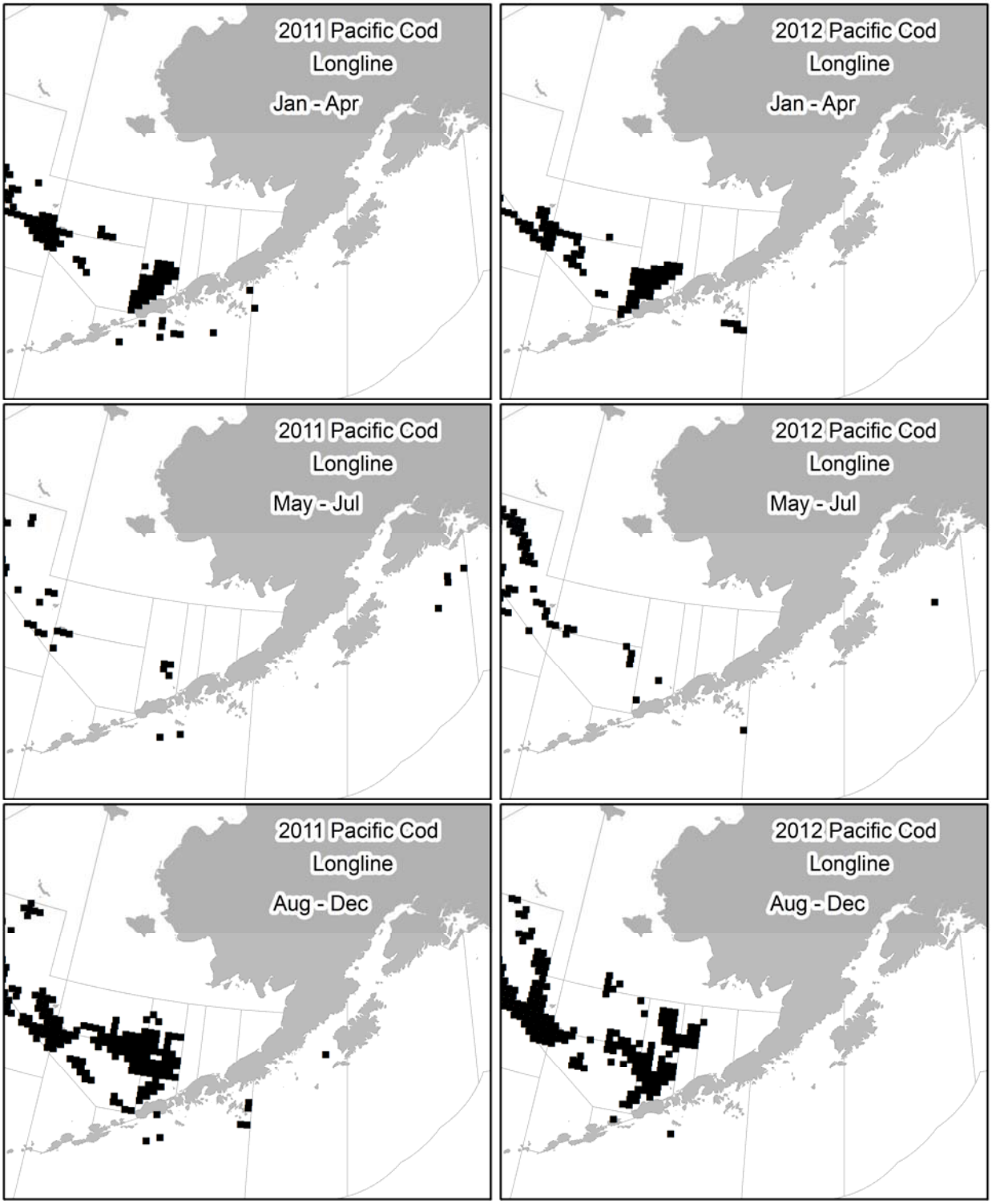
Year	$SB_{100\%}$	$SB_{40\%}$	$F_{40\%}$	SB_{y+1}	ABC_{y+1}
2001	212,000	85,000	0.41	82,000	57,600
2002	226,000	90,300	0.35	88,300	52,800
2003	222,000	88,900	0.34	103,000	62,810
2004	211,000	84,400	0.31	91,700	58,100
2005	329,000	132,000	0.56	165,000	68,859
2006	259,000	103,000	0.46	136,000	68,859
2007	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	*232,700*	*93,000*	*0.54*	*147,000*	*109,000*

Figure 2.1 – Fishery catches by season and gear (AKFIN; as of 17 October 2013)

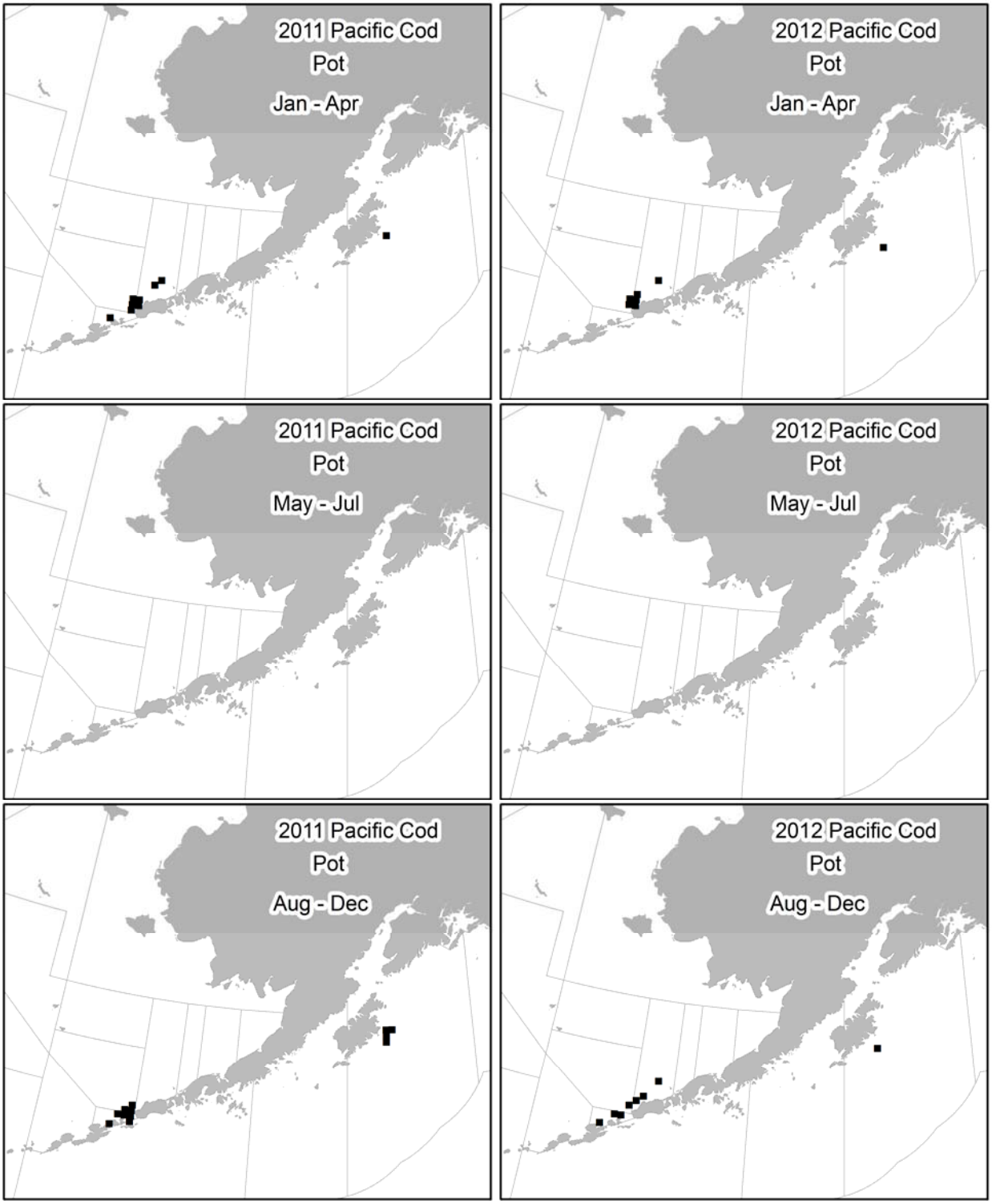




GOA maps showing each 400 square km cell with trawl hauls containing Pacific cod from at least 3 distinct vessels by season in 2011-2012, overlaid against NMFS 3-digit statistical areas



GOA maps showing each 400 square km cell with longling sets containing Pacific cod from at least 3 distinct vessels by season in 2011-2012, overlaid against NMFS 3-digit statistical areas



GOA maps showing each 400 square km cell with pot sets containing Pacific cod from at least 3 distinct vessels by season in 2011-2012, overlaid against NMFS 3-digit statistical areas

Figure 2.2 – GOA NMFS bottom trawl survey biomass estimates for Pacific cod

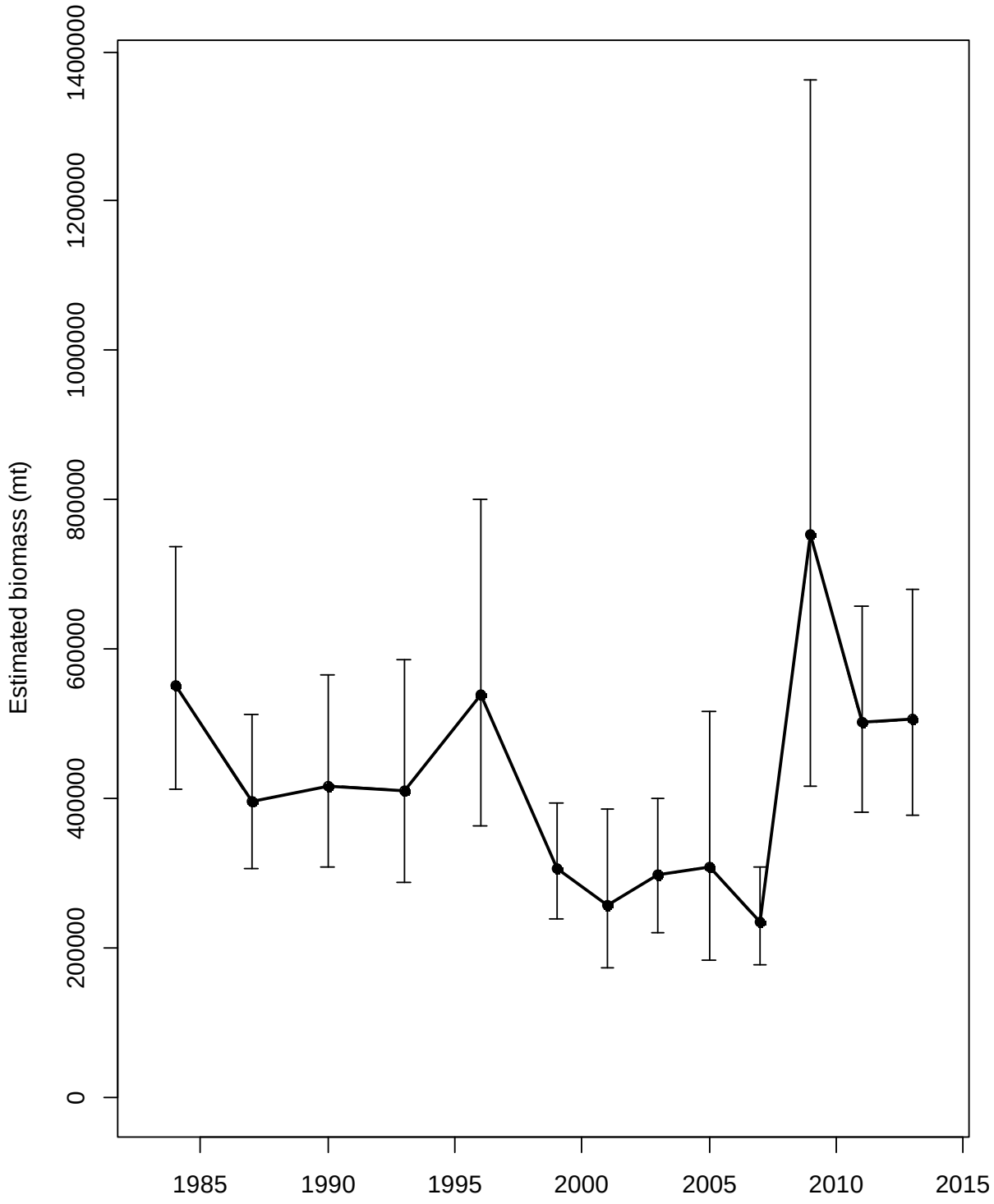


Figure 2.3 – GOA NMFS survey abundance estimates for Pacific cod

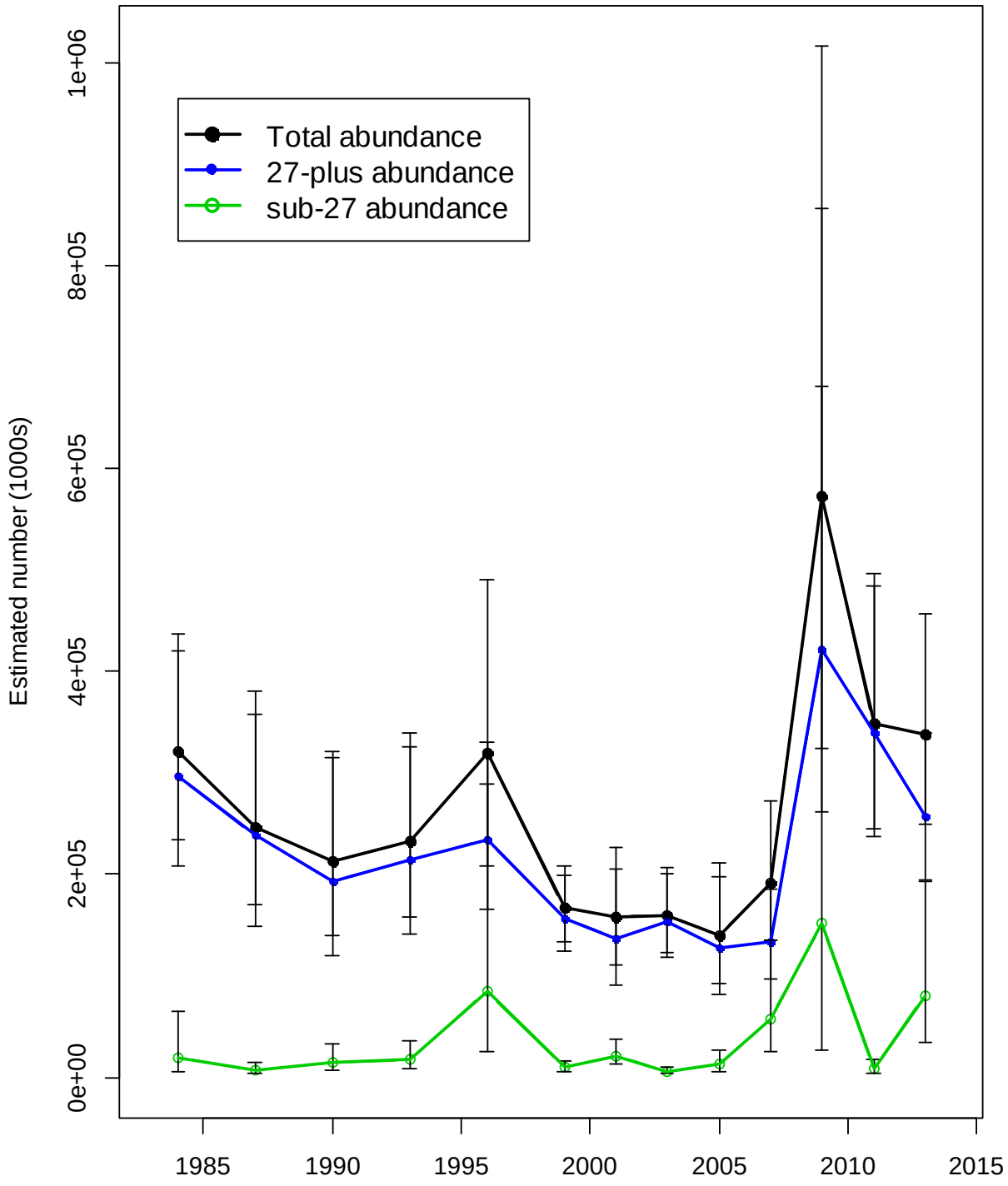


Figure 2.4 – GOA NMFS bottom trawl survey biomass estimates by area (in mt)

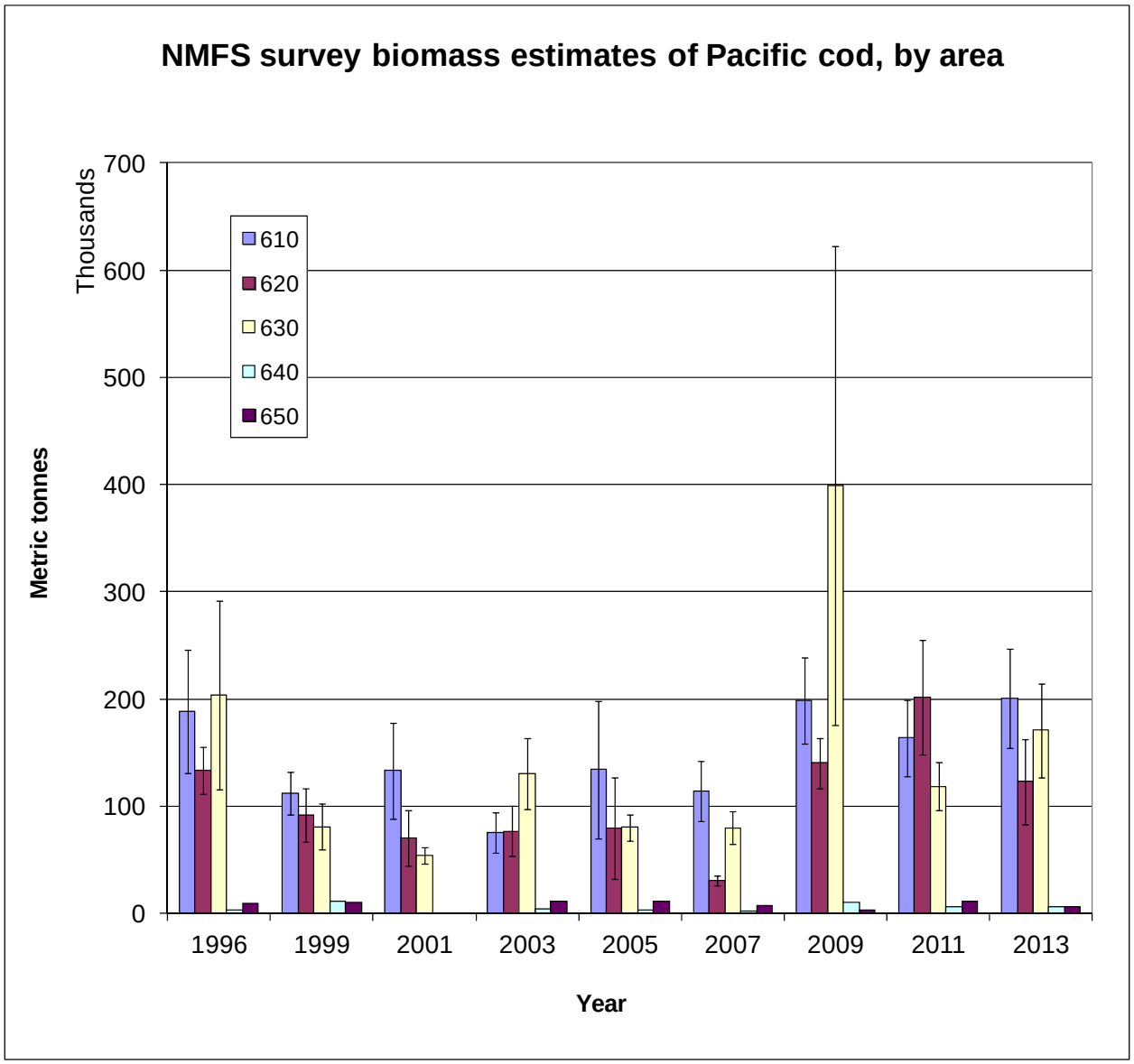


Figure 2.5 – GOA NMFS bottom trawl survey abundance estimates by area (in numbers)

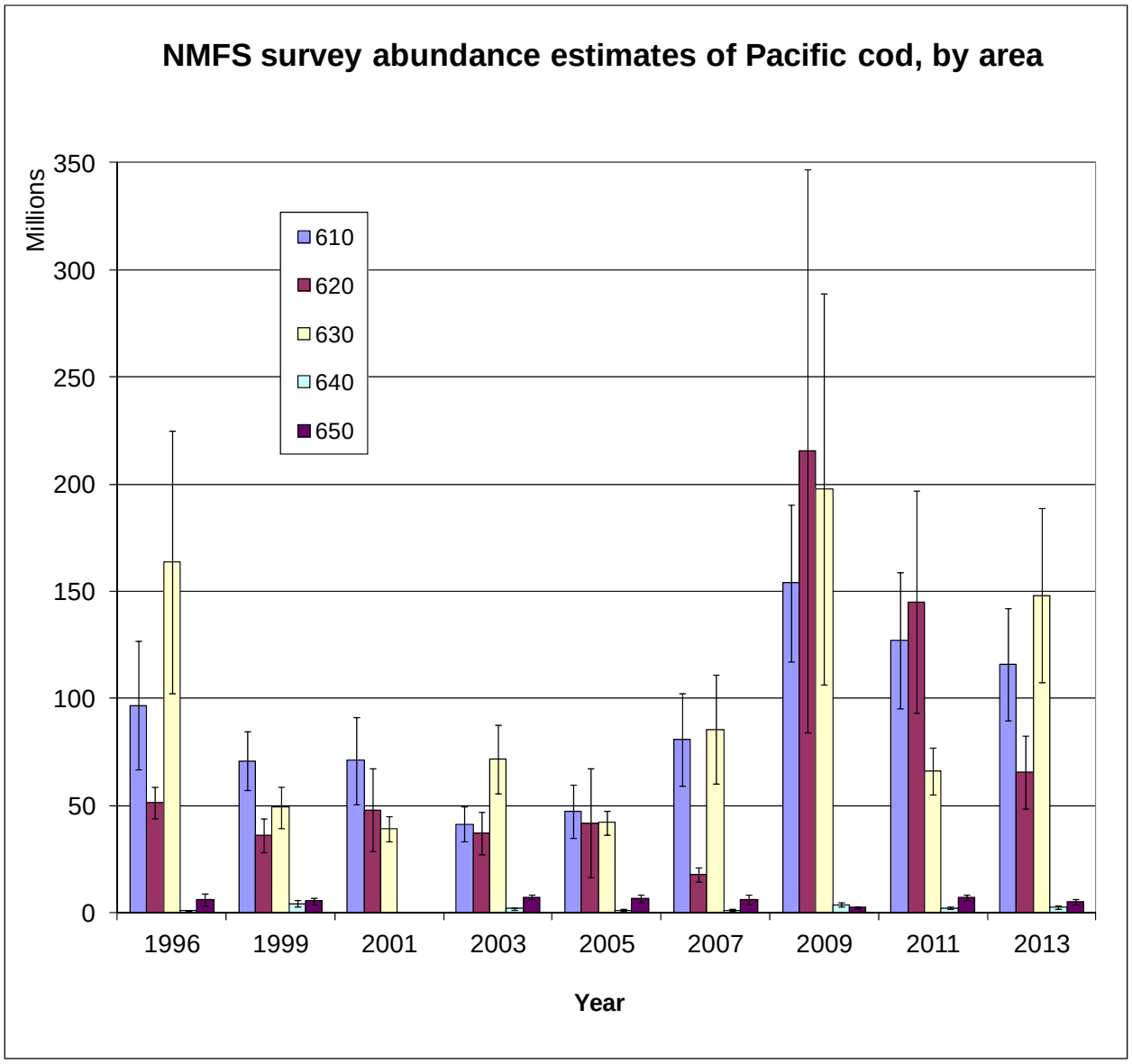


Figure 2.6 – GOA NMFS bottom trawl population length estimates for Pacific cod

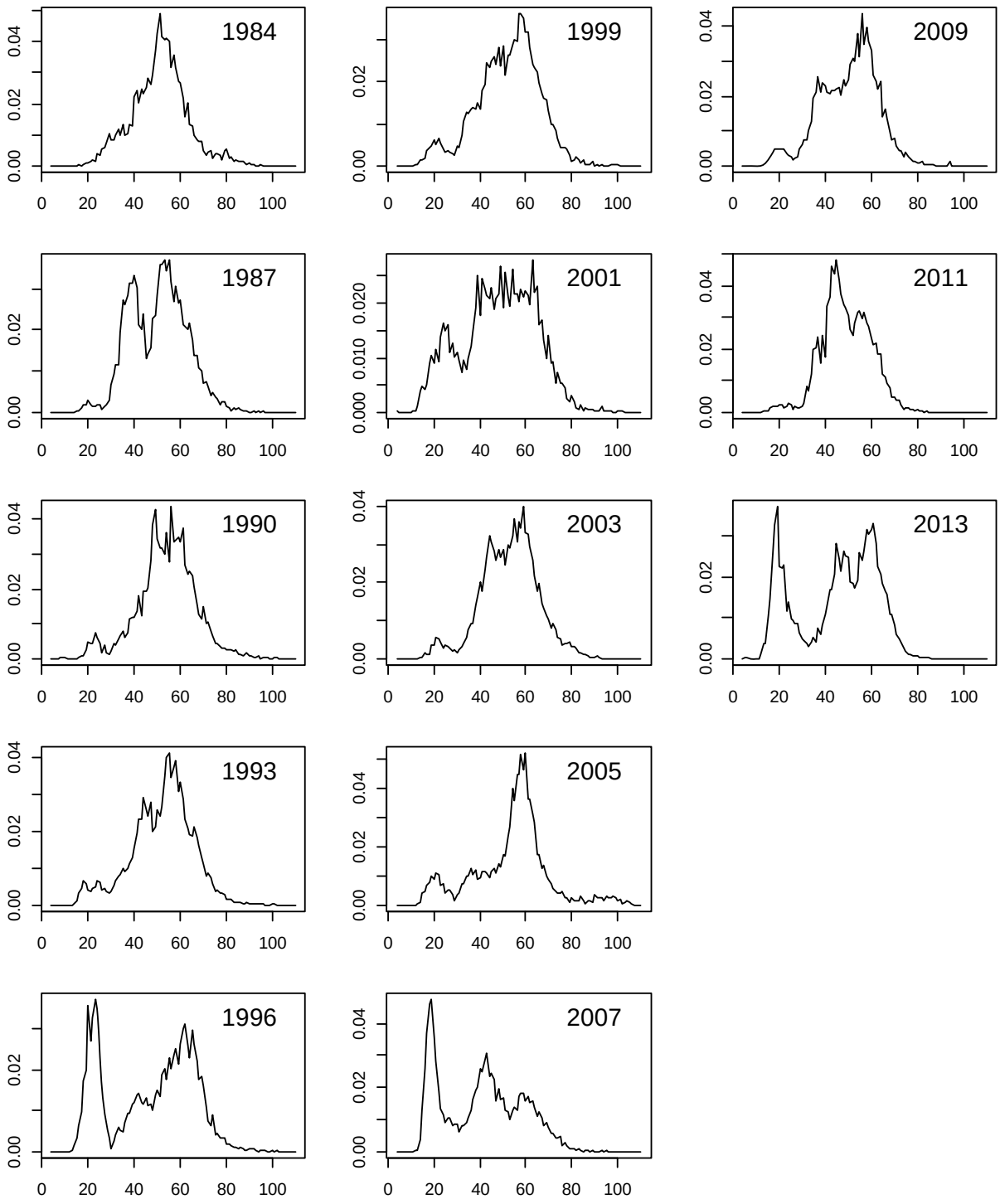


Figure 2.7 – GOA NMFS bottom trawl population age estimates for Pacific cod

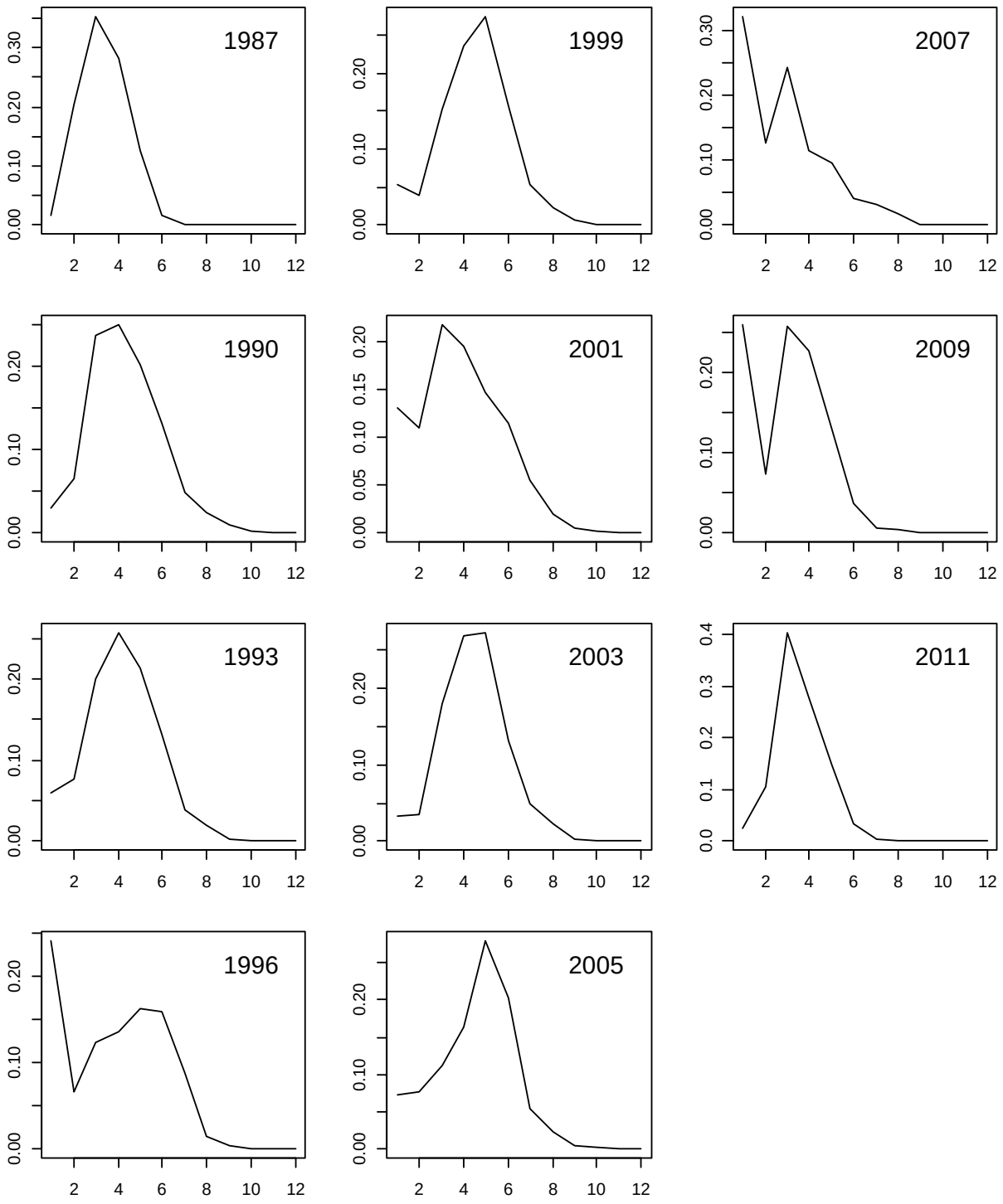


Figure 2.8 – Estimates of total (age 0+) biomass

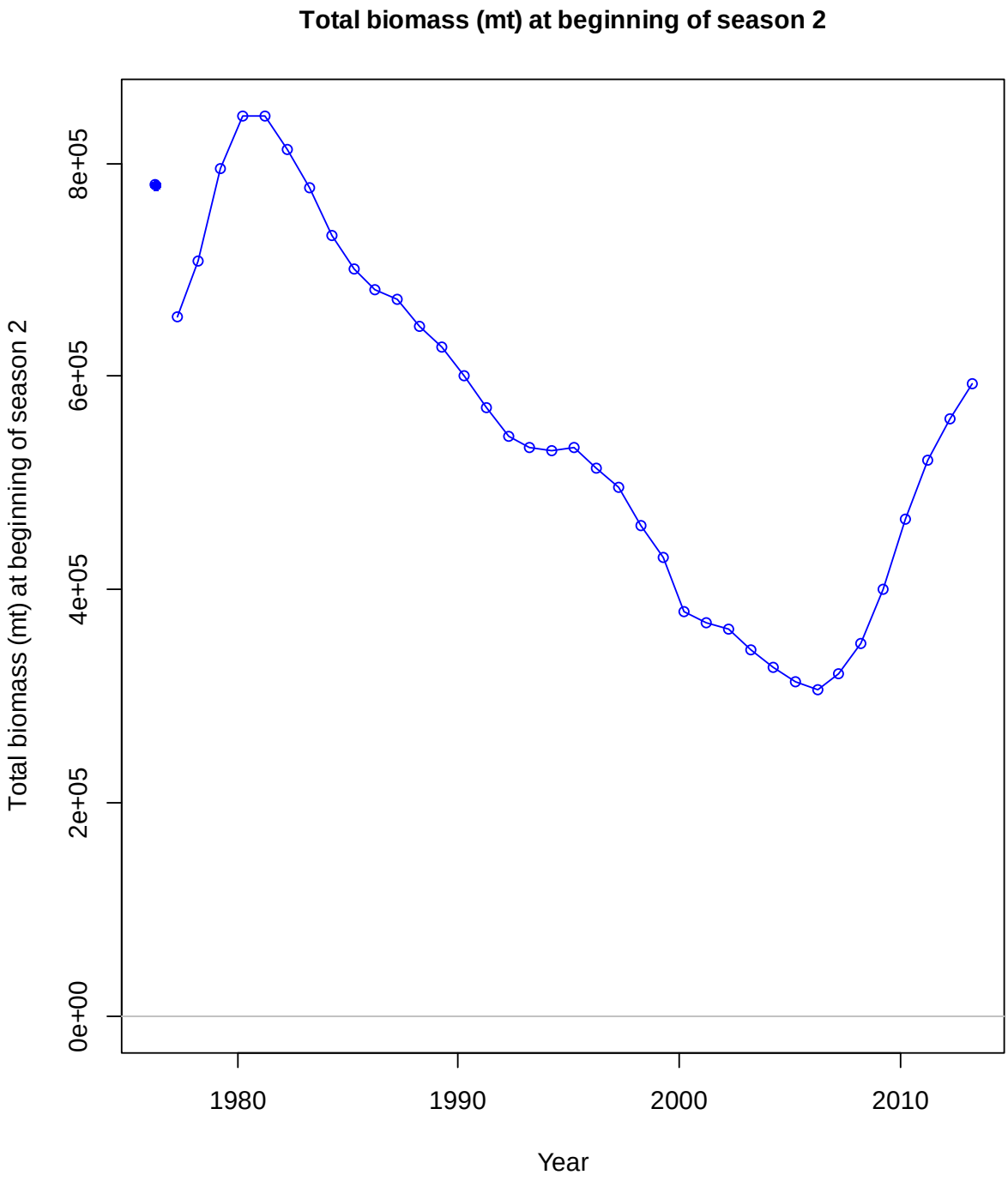


Figure 2.9 – Estimates of female spawning biomass

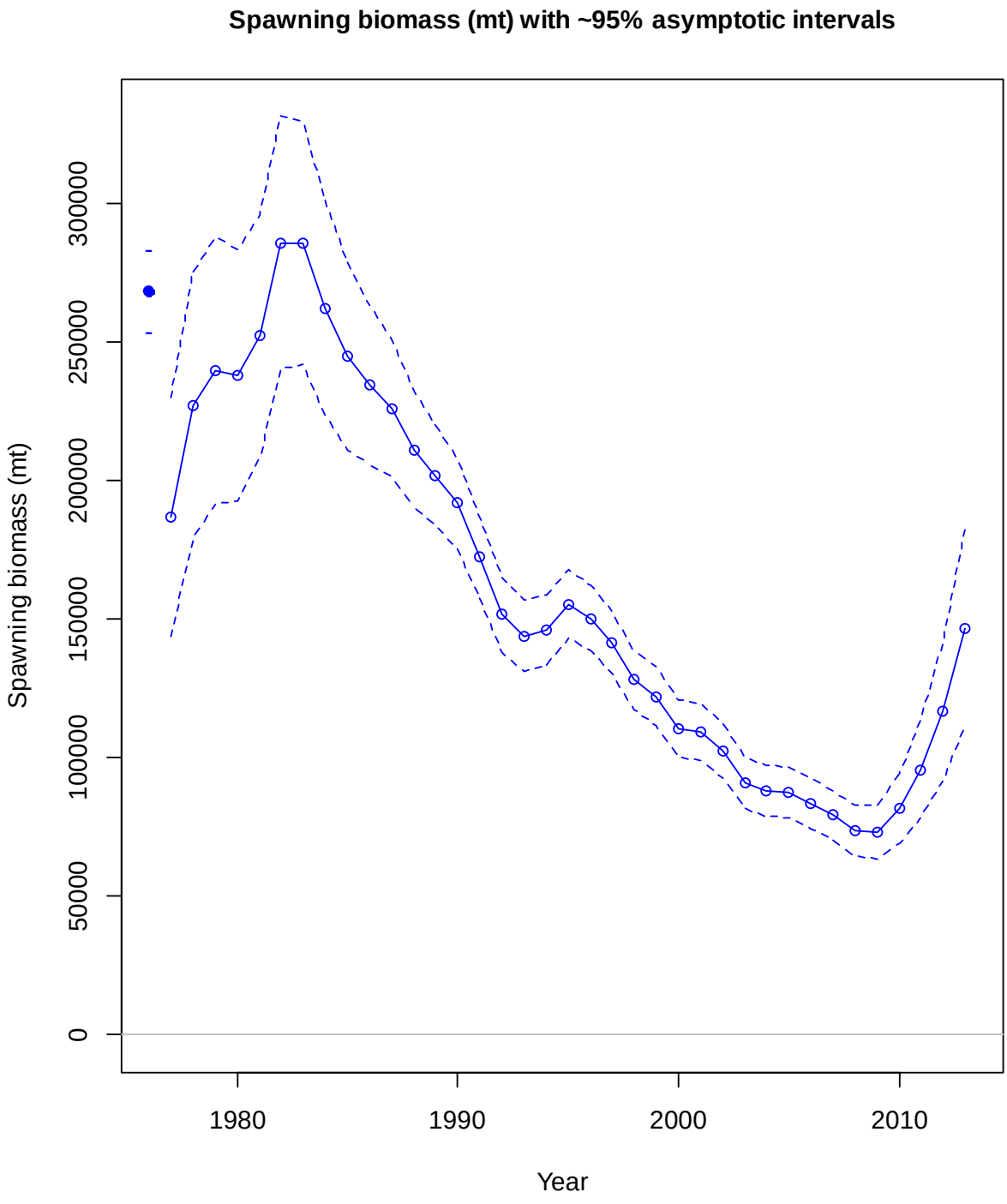


Figure 2.10 – Estimates of age-0 recruits

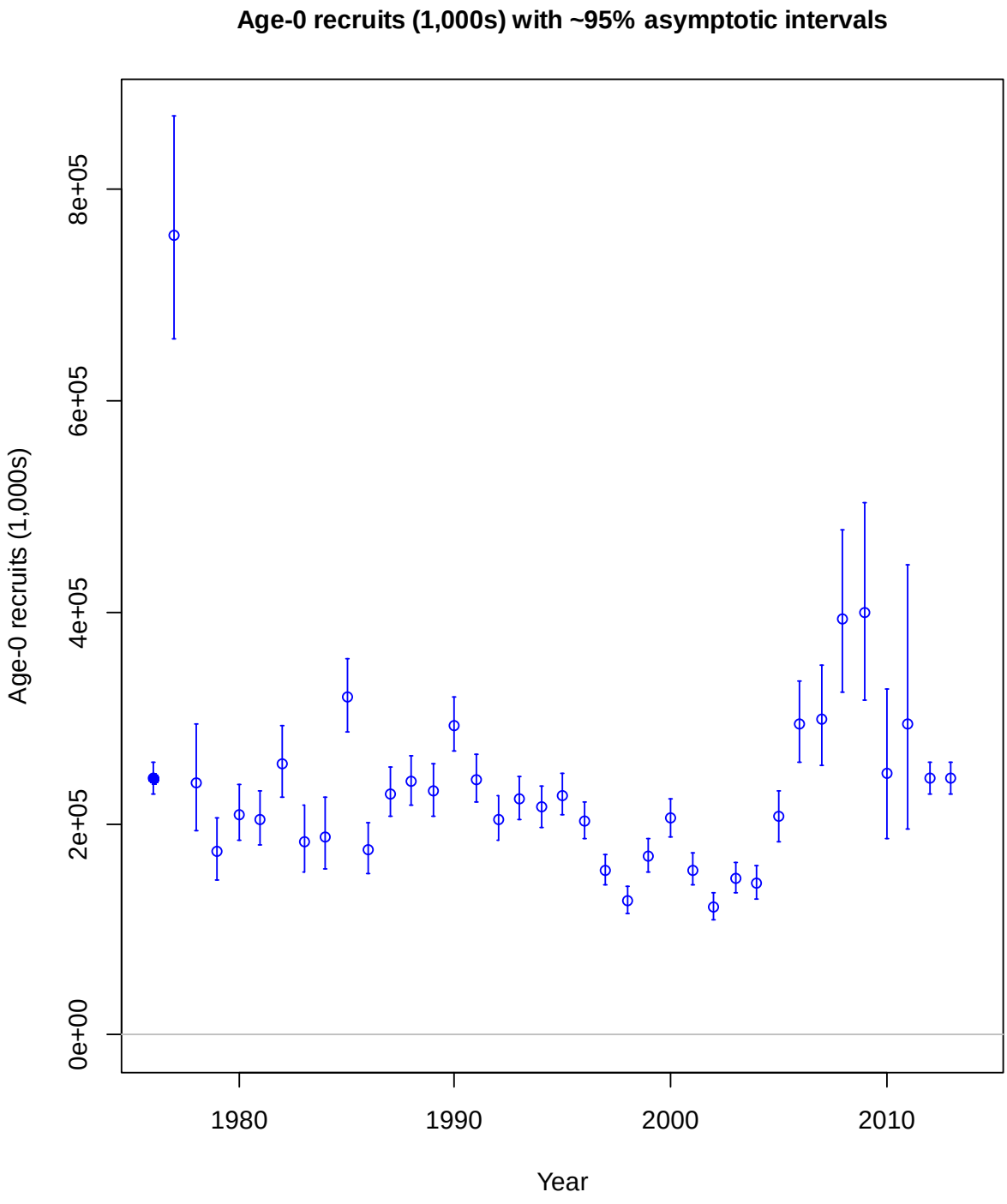


Figure 2.11 – Fit to the abundance estimates from the GOA NMFS bottom trawl survey

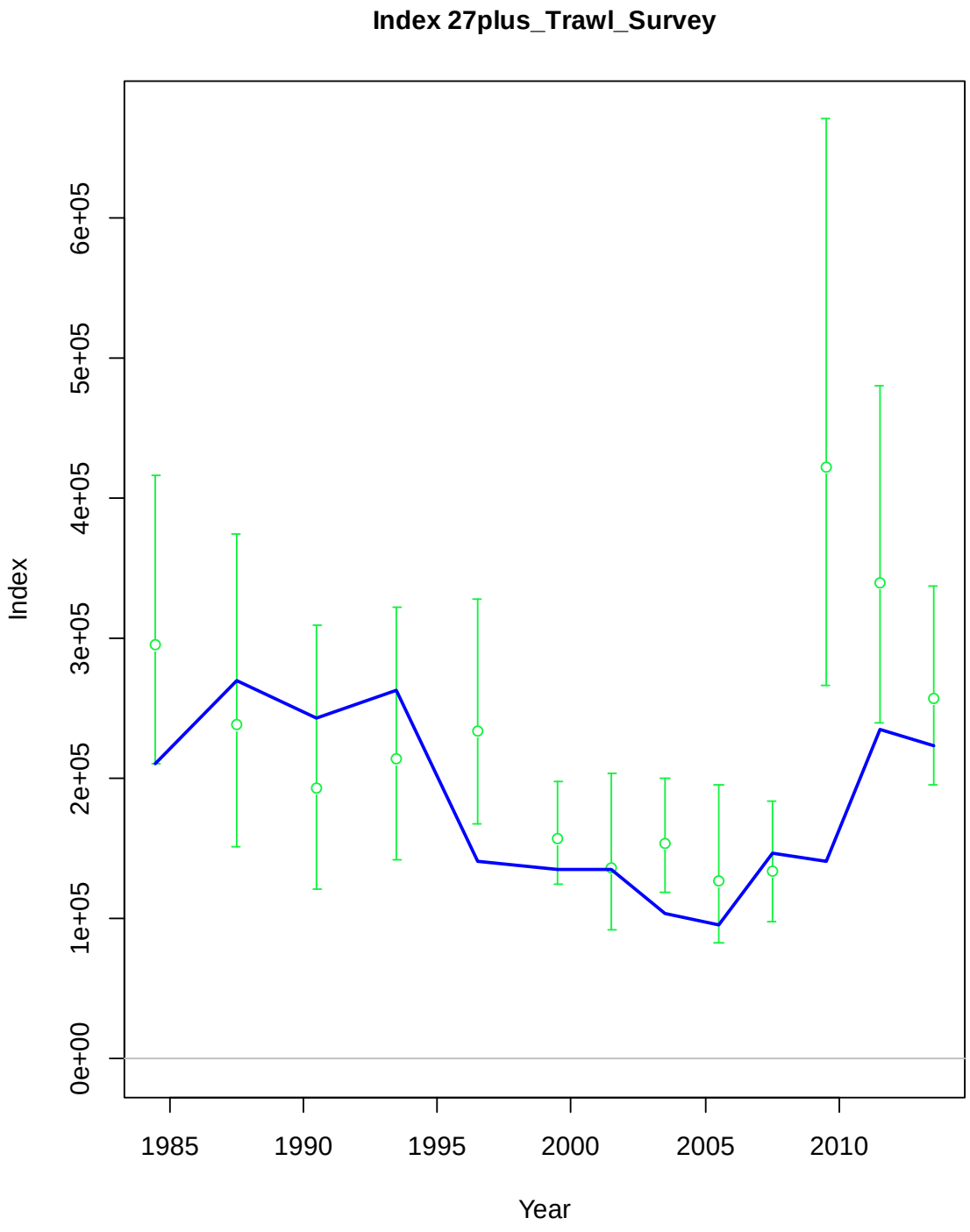


Figure 2.12 – Fit to the age composition data from the GOA NMFS bottom trawl survey

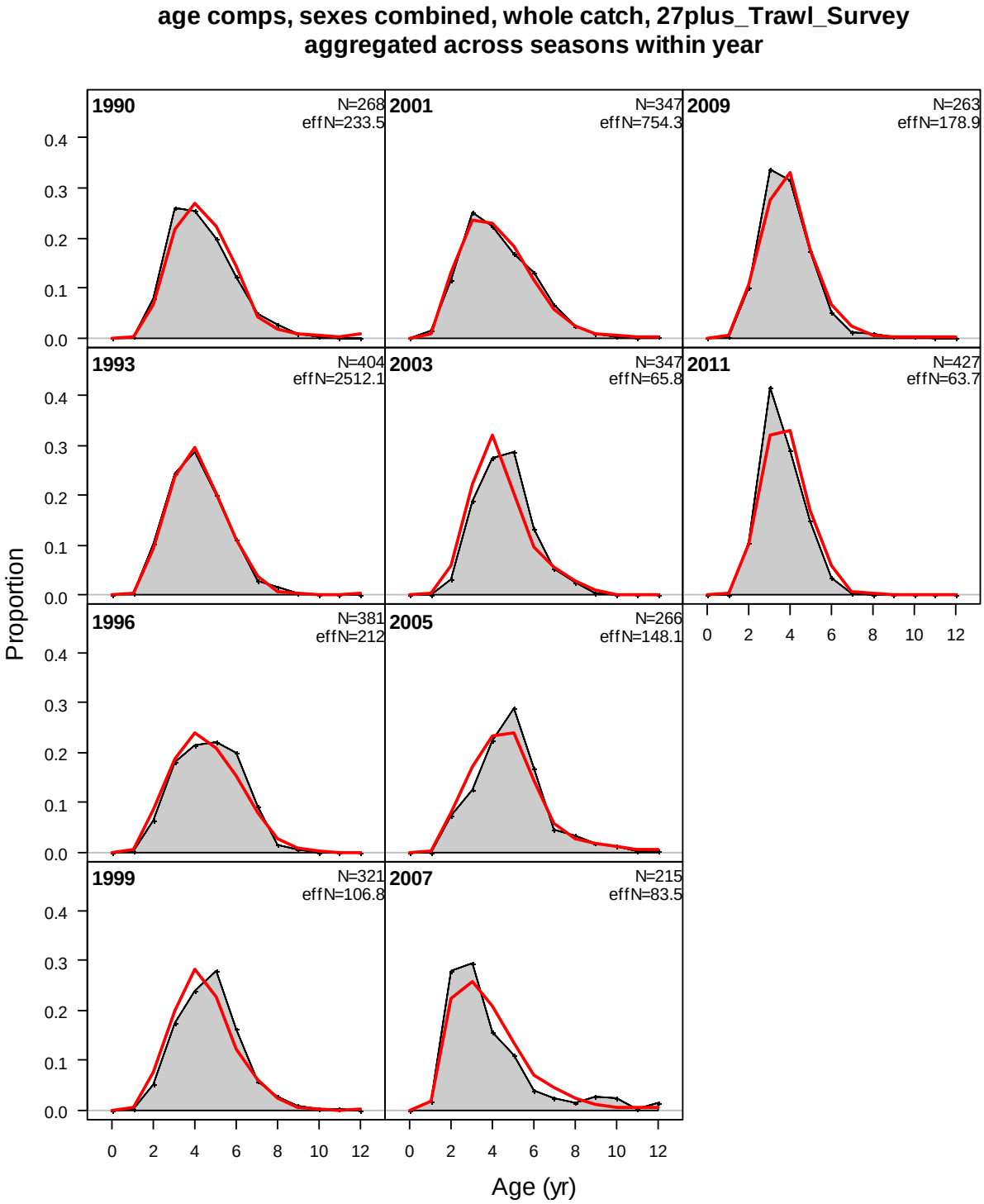


Figure 2.13 – Fit to the length composition data from the GOA NMFS bottom trawl survey

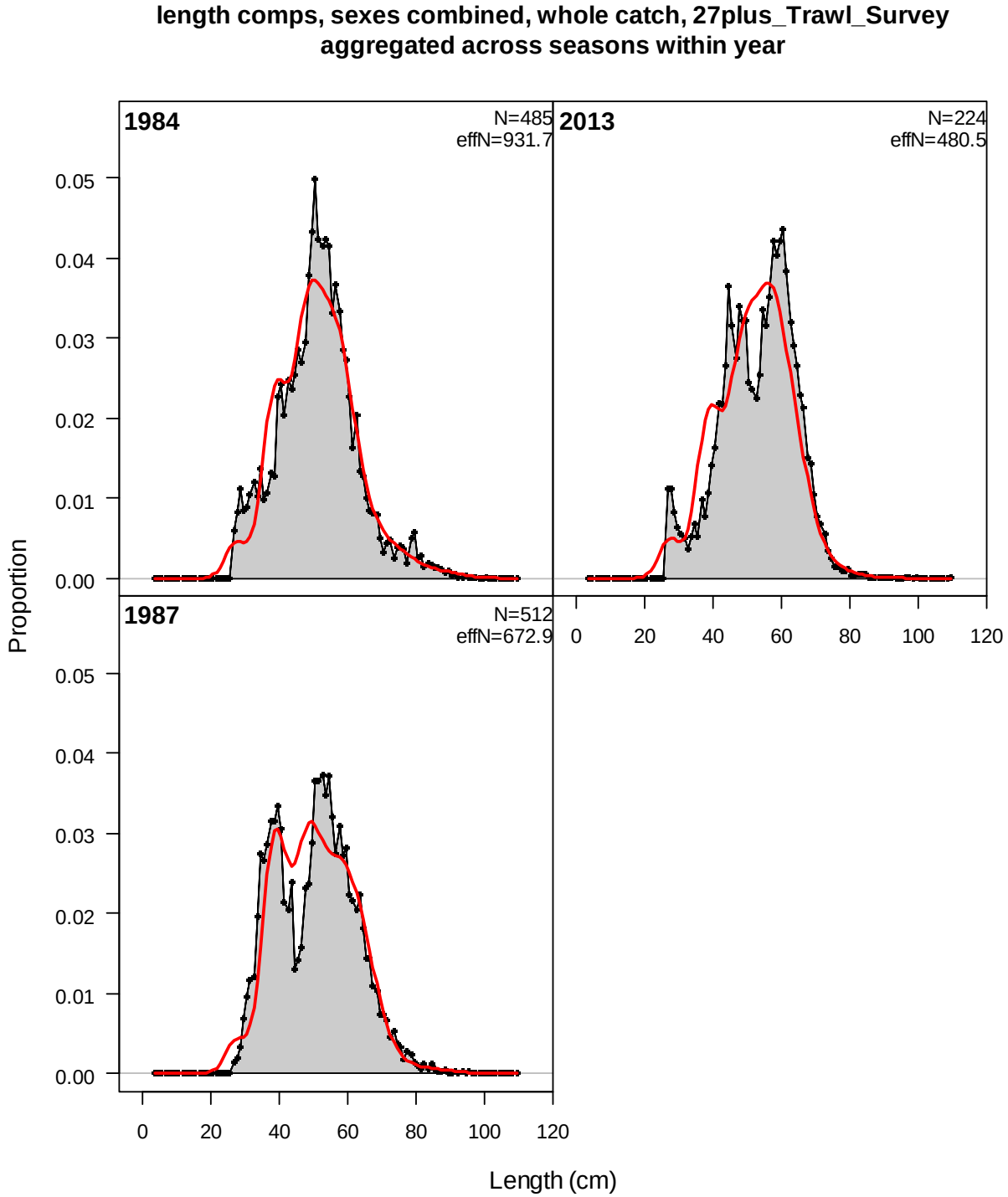


Figure 2.14 – Fit to mean size-at-age data from the GOA NMFS bottom trawl survey

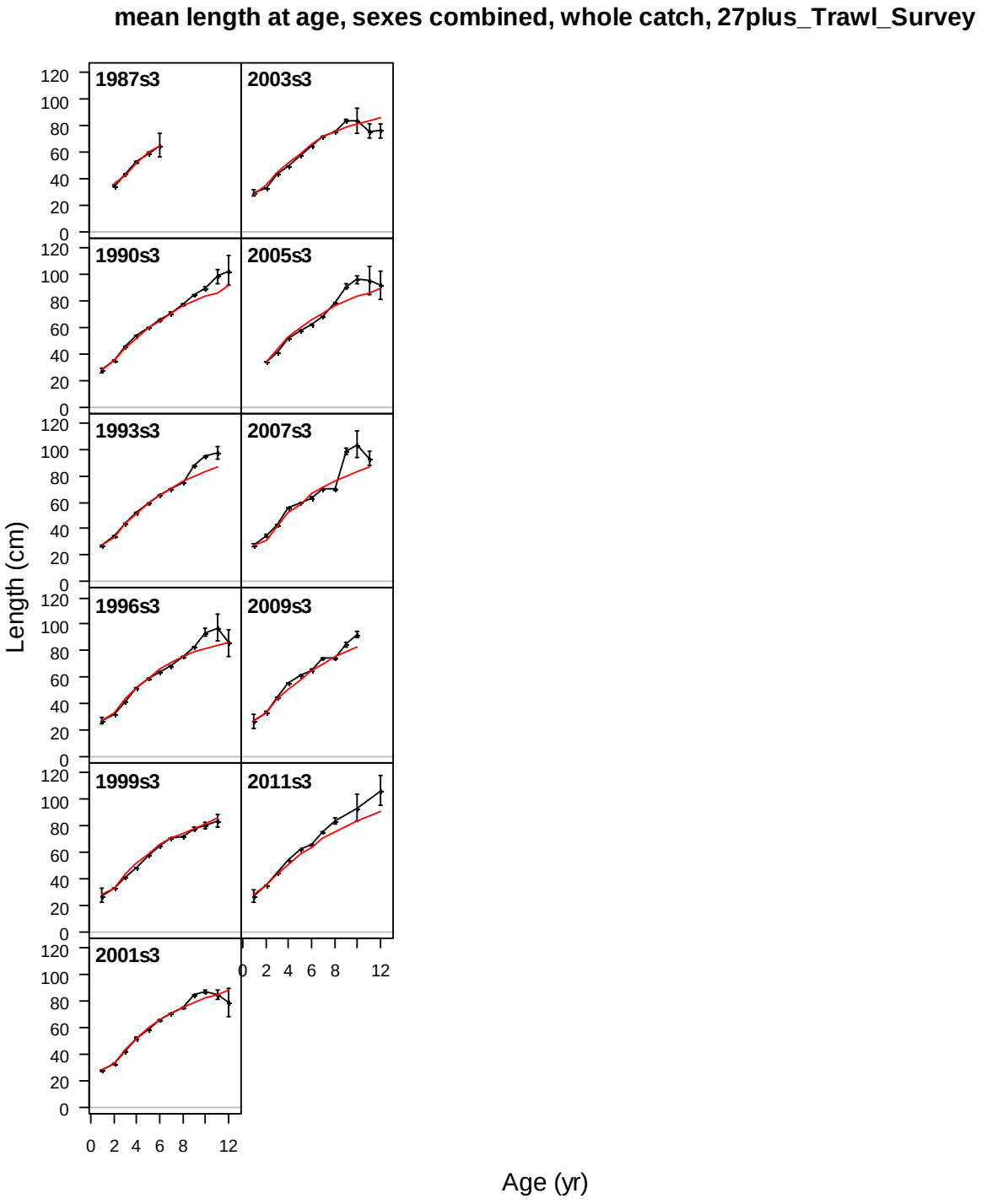


Figure 2.15 – Estimates of spawning biomass and age-0 recruits

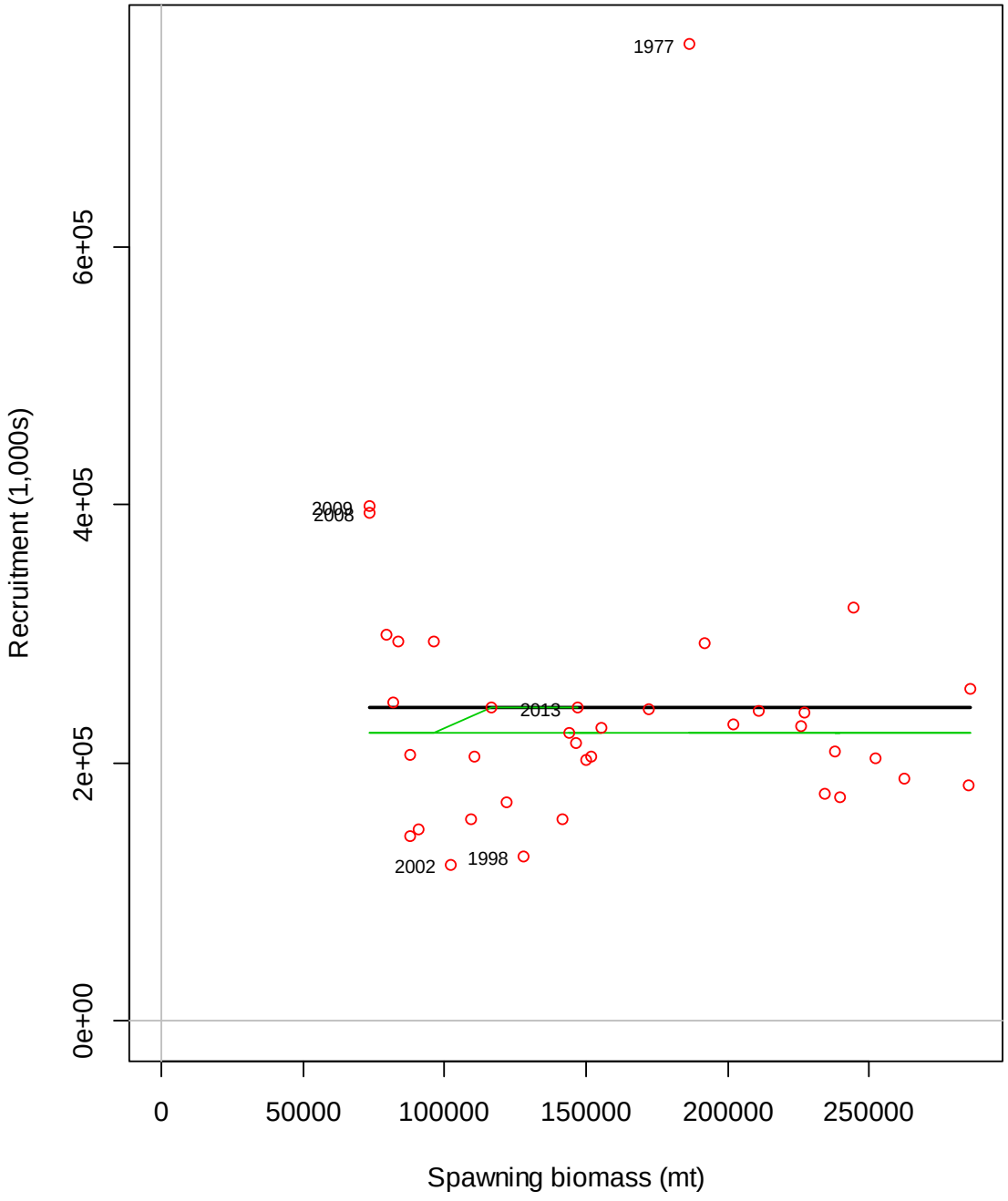


Figure 2.16 – Estimated length-at-age

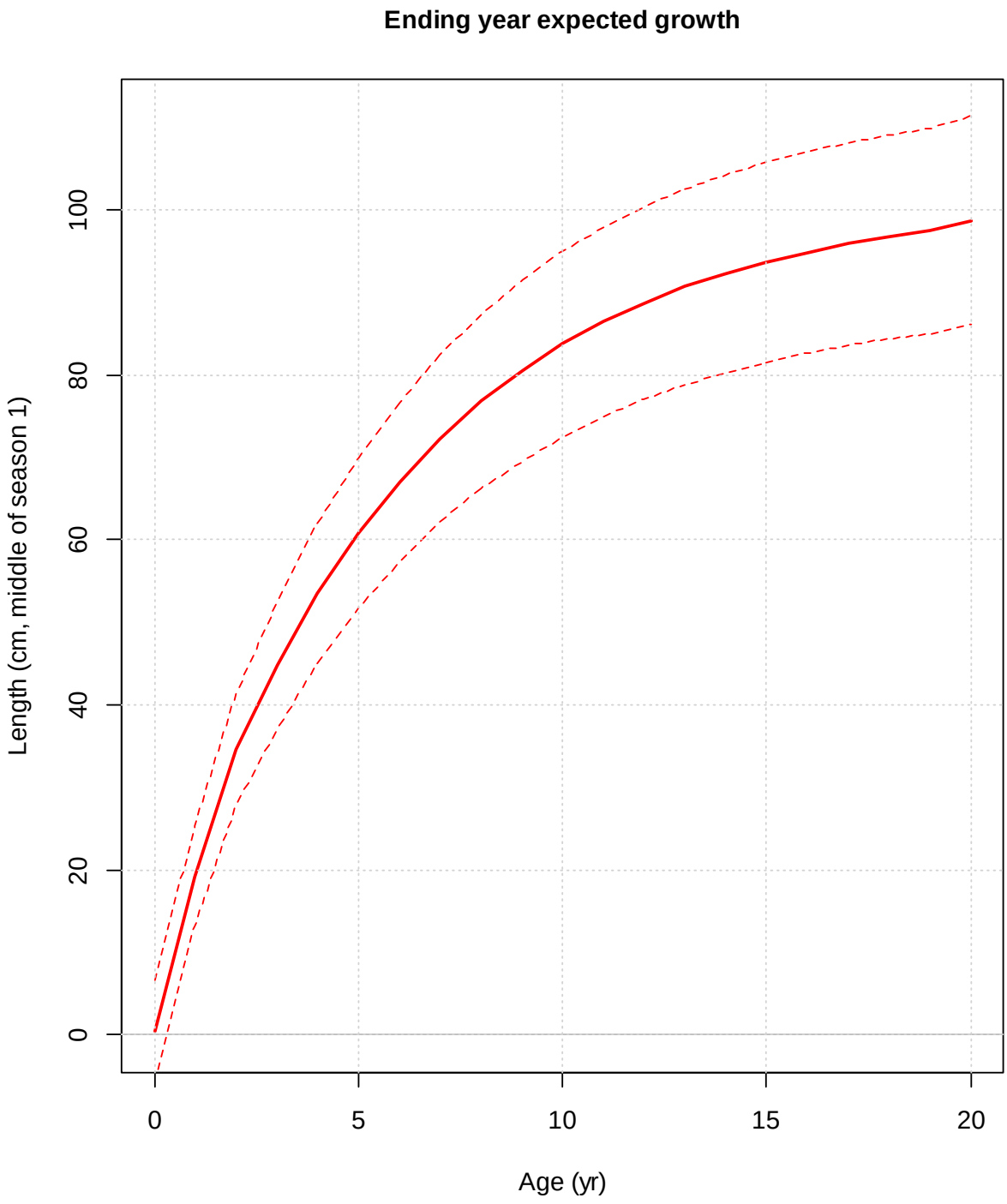


Figure 2.17 – Estimate survey selectivity-at-age

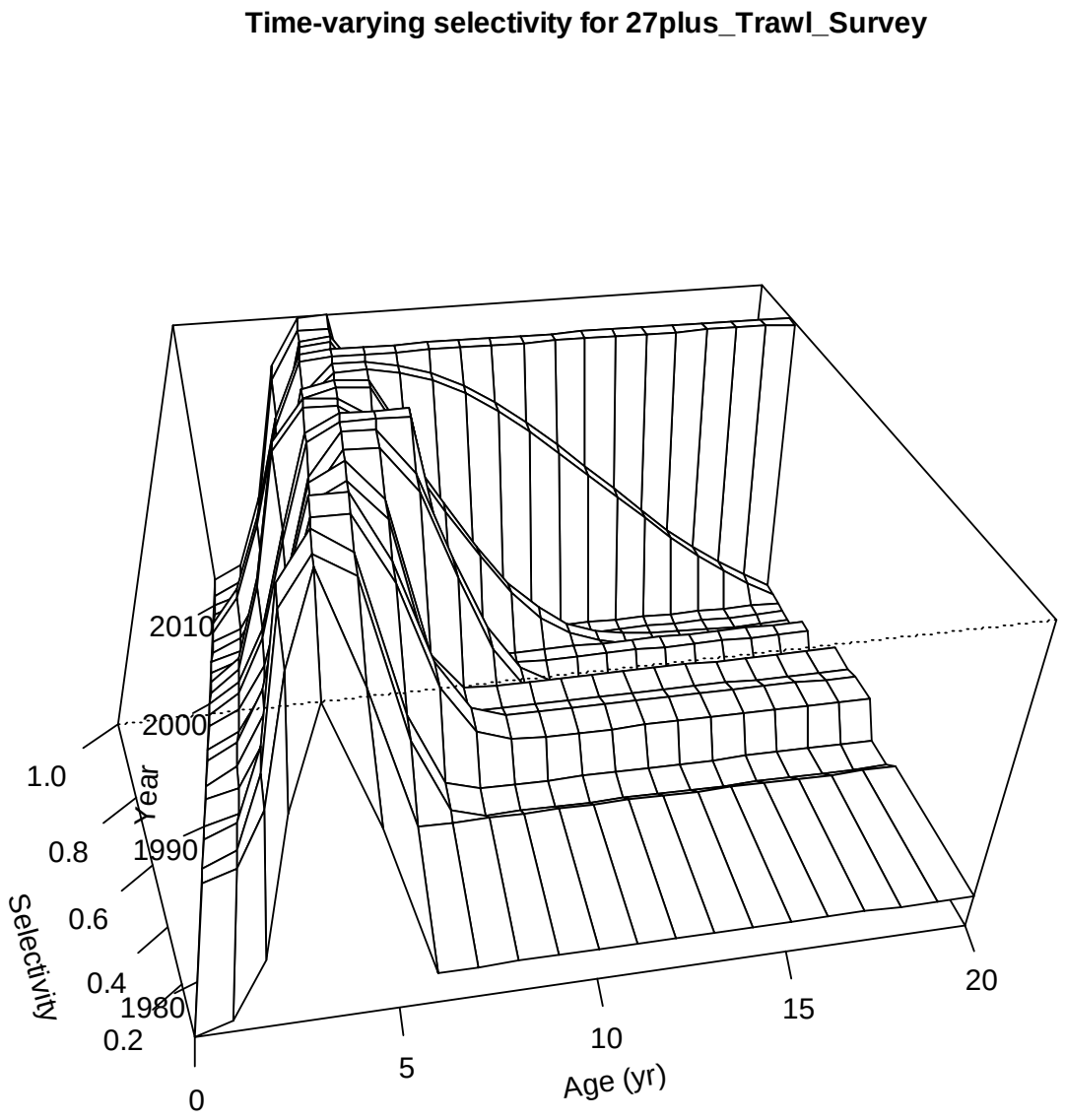


Figure 2.18 – Fishery selectivity-at-length curves by gear (columns) and season (rows)

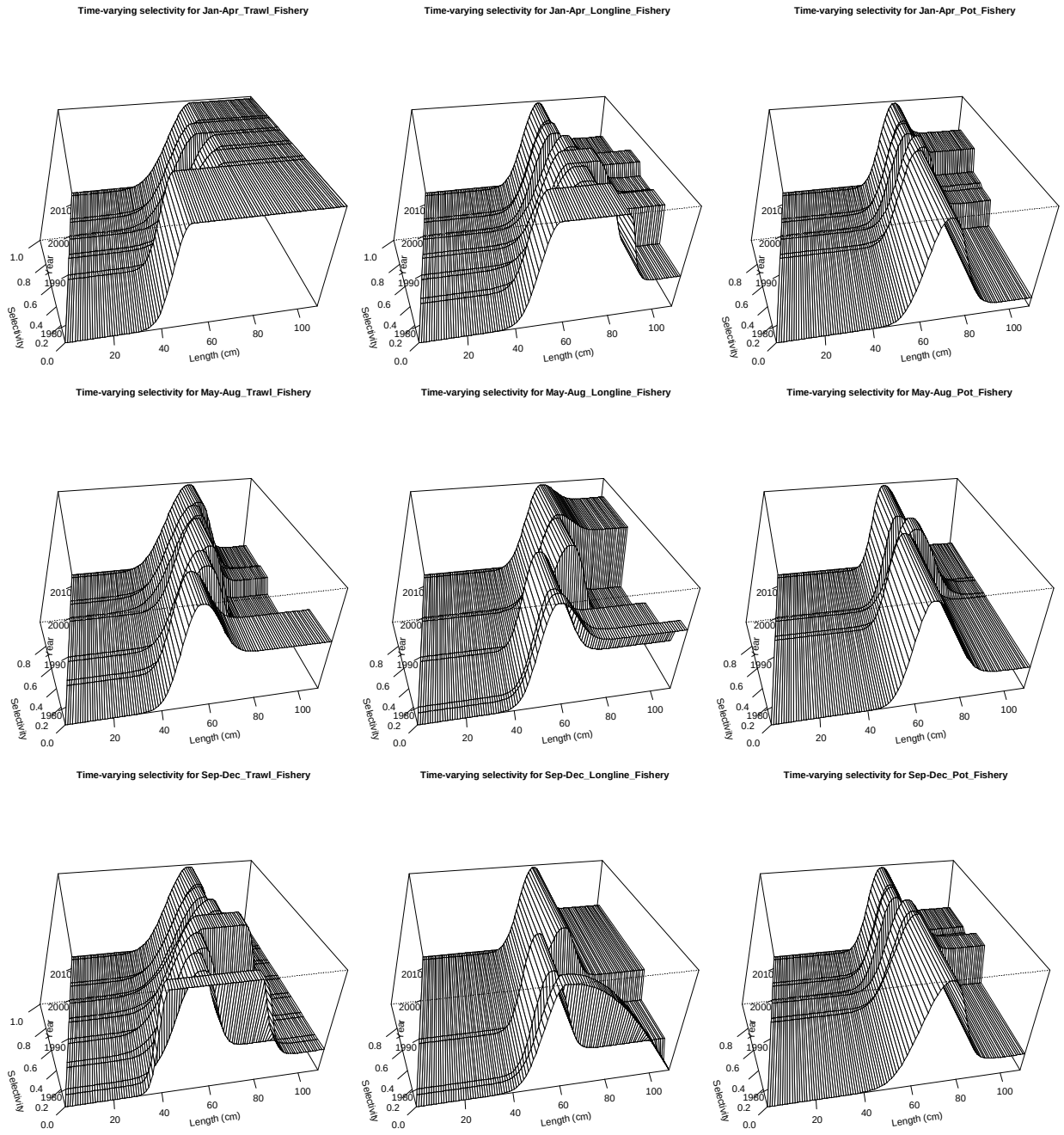


Figure 2.19 – Summary of fits to length composition data, for season-gear groupings

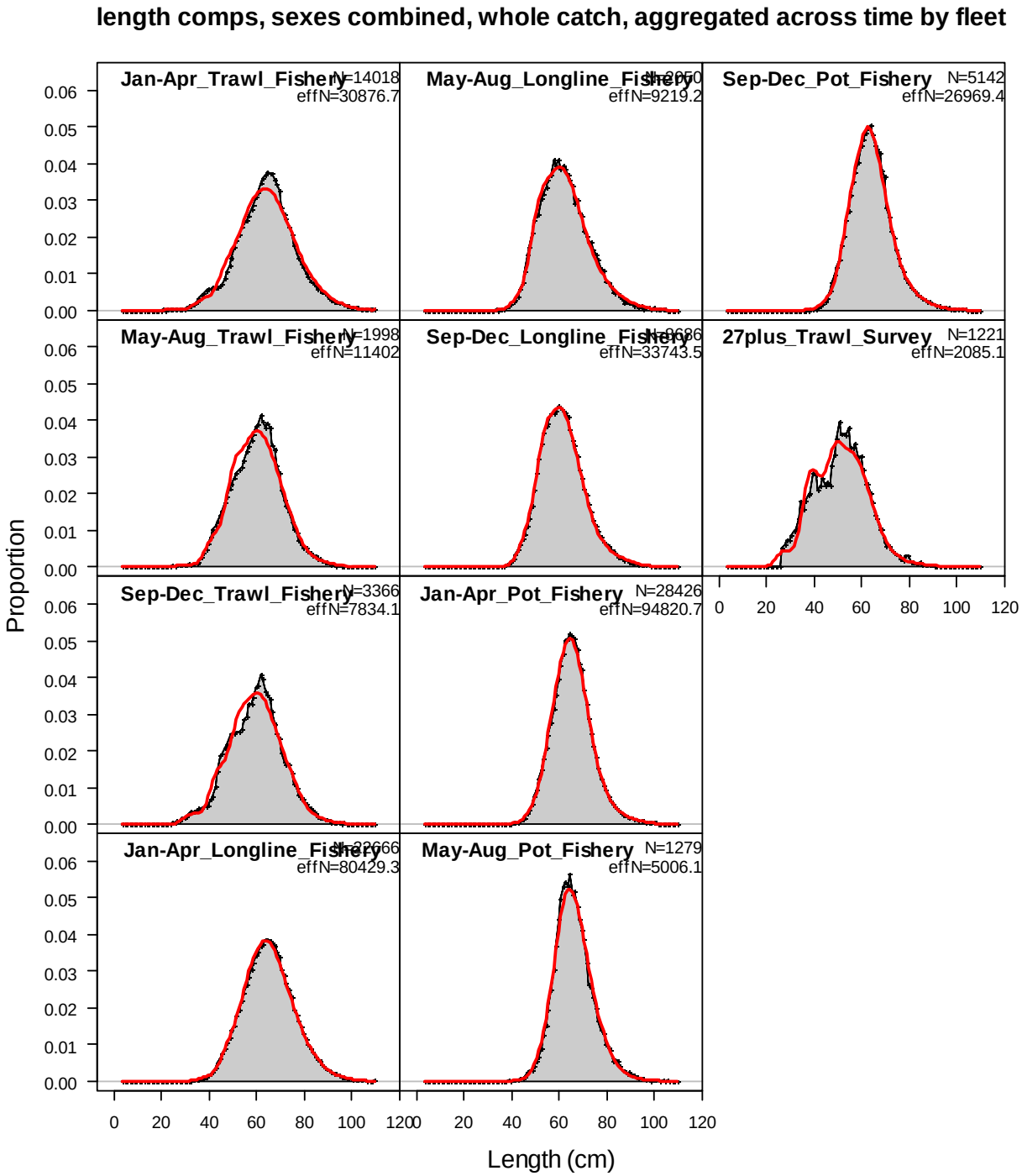
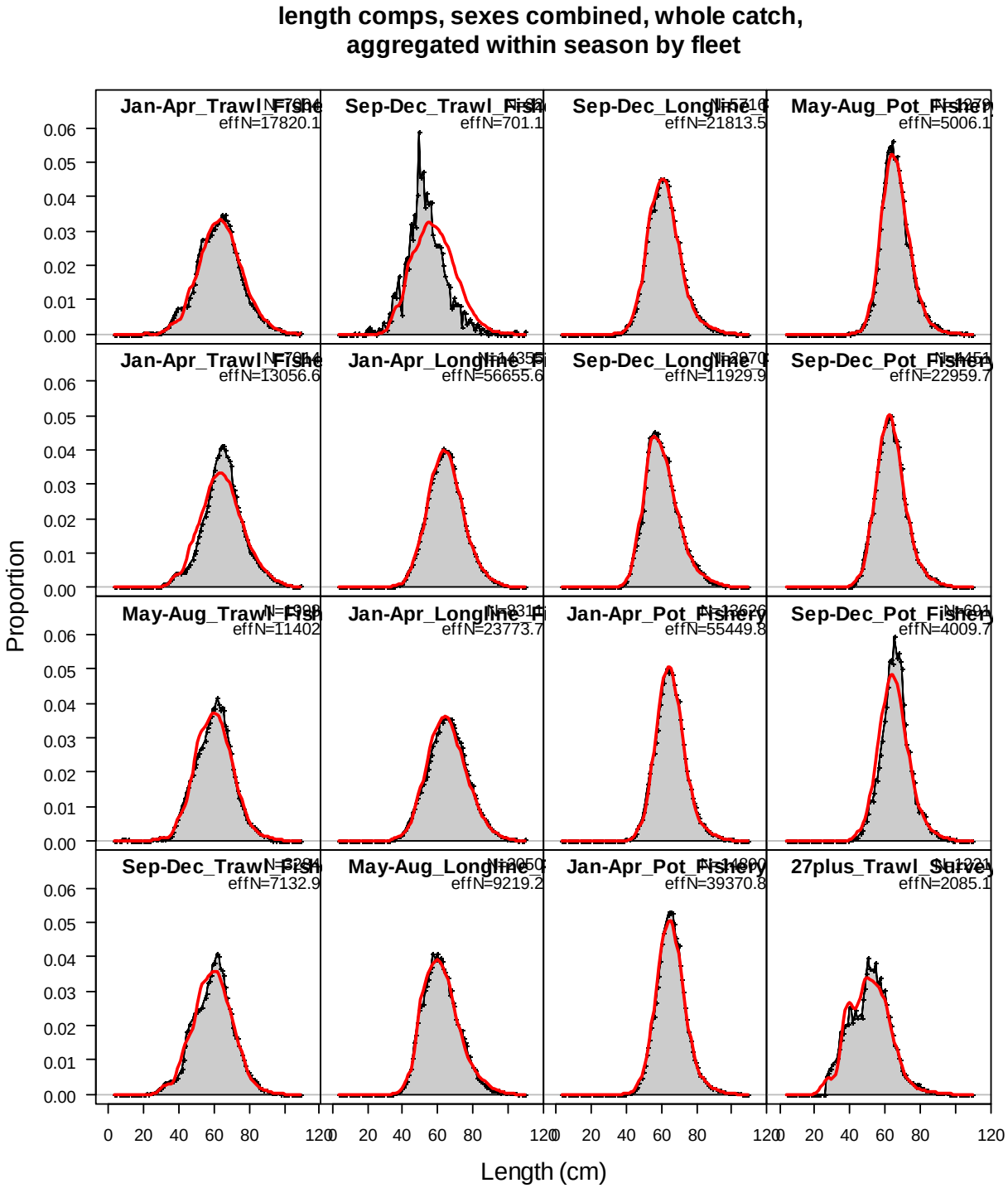
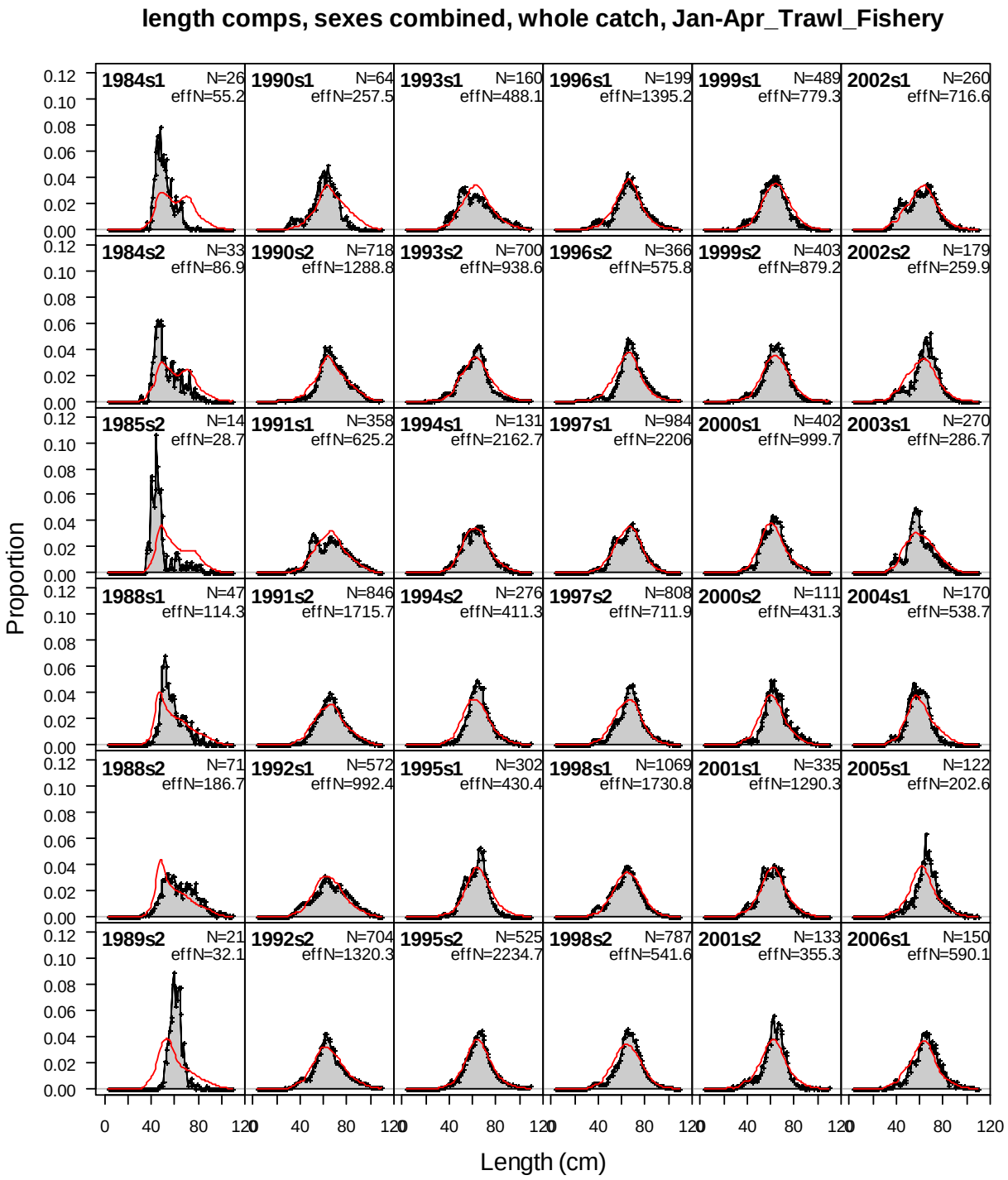
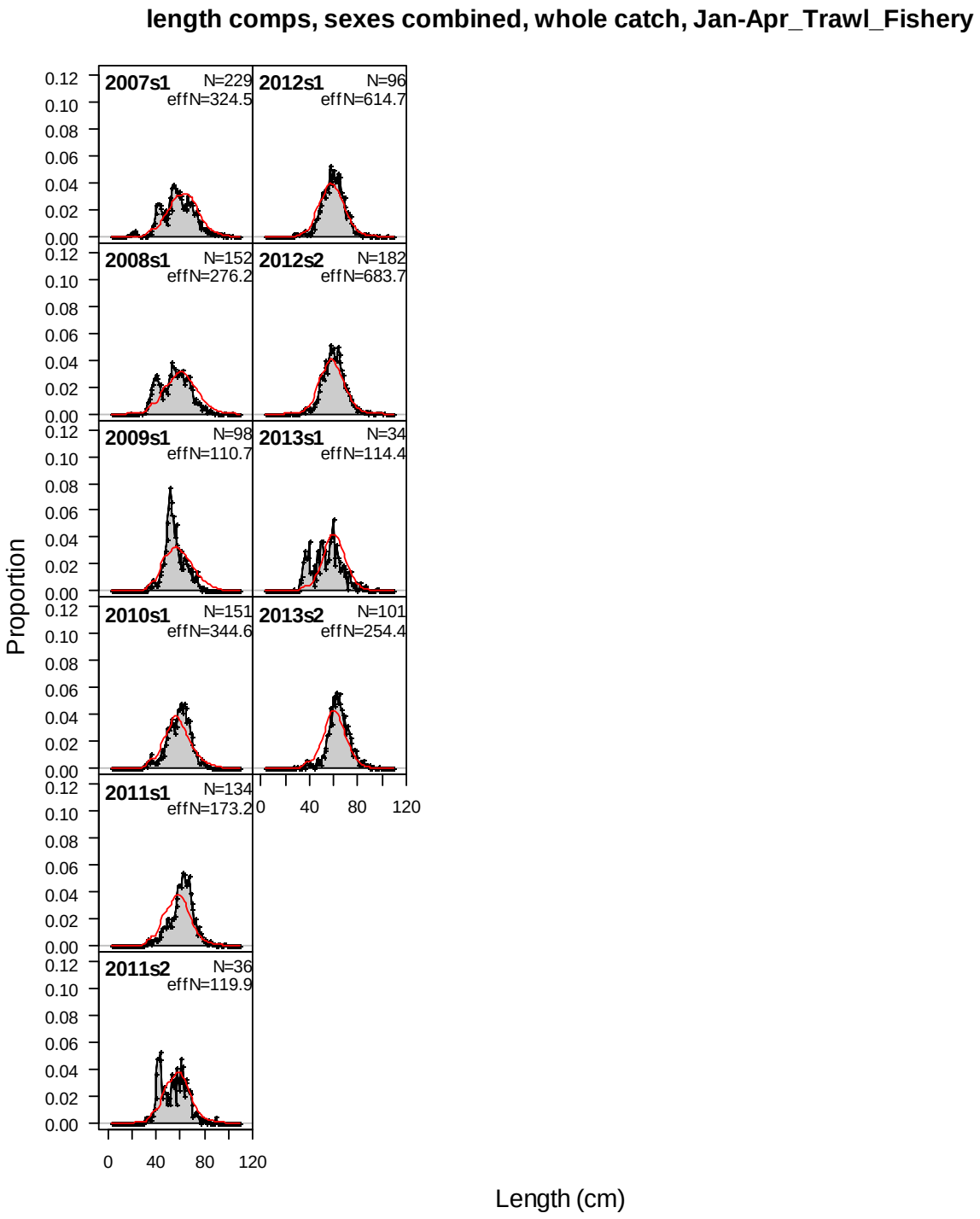
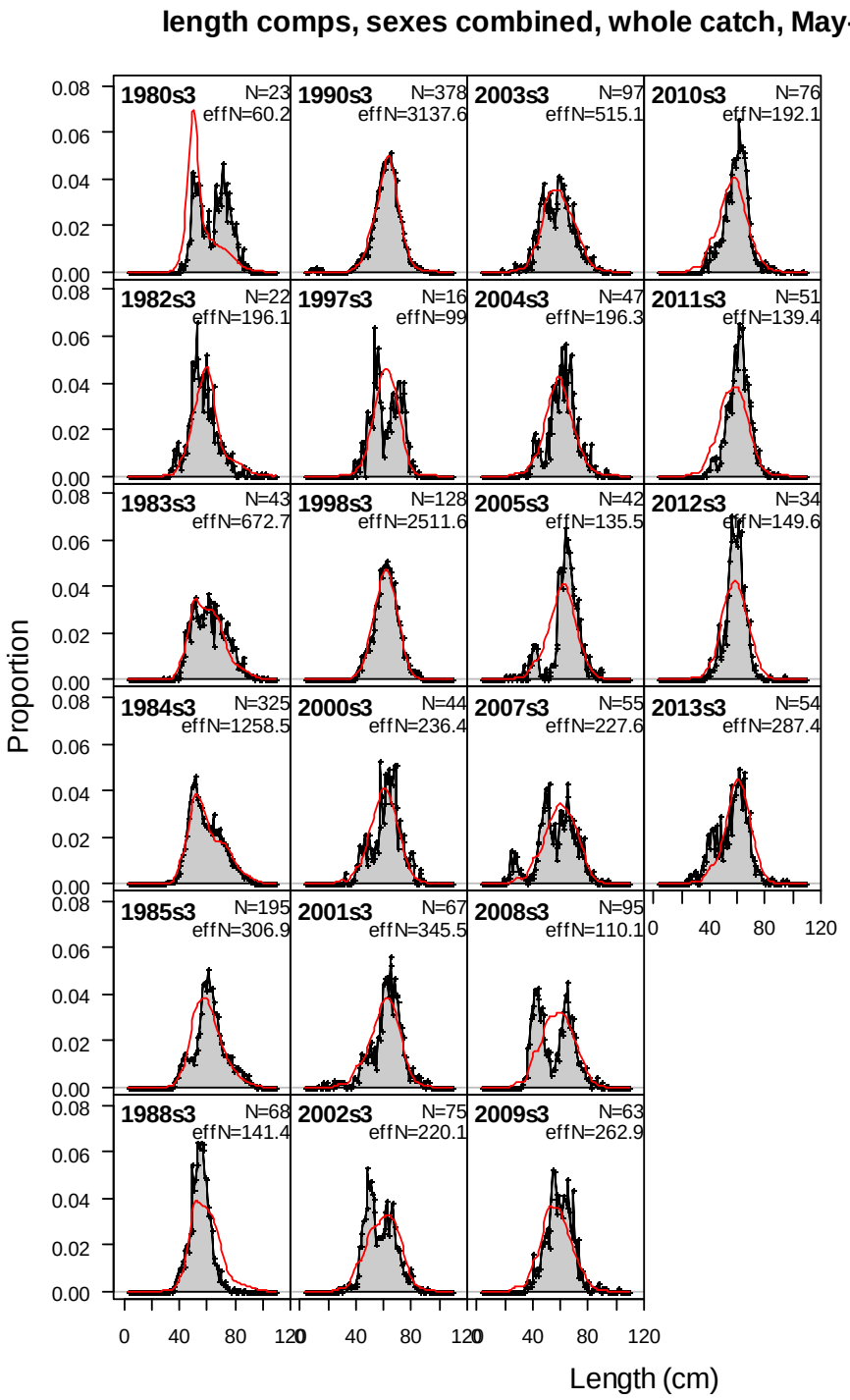


Figure 2.20 – Fits to length composition data, by season and gear type




length comps, sexes combined, whole catch, Jan-Apr_Trawl_Fishery
1984s1 N=26 effN=55.2
1990s1 N=64 effN=257.5
1993s1 N=160 effN=488.1
1996s1 N=199 effN=1395.2
1999s1 N=489 effN=779.3
2002s1 N=260 effN=716.6
1984s2 N=33 effN=86.9
1990s2 N=718 effN=1288.8
1993s2 N=700 effN=938.6
1996s2 N=366 effN=575.8
1999s2 N=403 effN=879.2
2002s2 N=179 effN=259.9
1985s2 N=14 effN=28.7
1991s1 N=358 effN=625.2
1994s1 N=131 effN=2162.7
1997s1 N=984 effN=2206
2000s1 N=402 effN=999.7
2003s1 N=270 effN=286.7
1988s1 N=47 effN=114.3
1991s2 N=846 effN=1715.7
1994s2 N=276 effN=411.3
1997s2 N=808 effN=711.9
2000s2 N=111 effN=431.3
2004s1 N=170 effN=538.7
1988s2 N=71 effN=186.7
1992s1 N=572 effN=992.4
1995s1 N=302 effN=430.4
1998s1 N=1069 effN=1730.8
2001s1 N=335 effN=1290.3
2005s1 N=122 effN=202.6
1989s2 N=21 effN=32.1
1992s2 N=704 effN=1320.3
1995s2 N=525 effN=2234.7
1998s2 N=787 effN=541.6
2001s2 N=133 effN=355.3
2006s1 N=150 effN=590.1
Proportion
Length (cm)


length comps, sexes combined, whole catch, Jan-Apr_Trawl_Fishery
2007s1 N=229 effN=324.5
2012s1 N=96 effN=614.7
2008s1 N=152 effN=276.2
2012s2 N=182 effN=683.7
2009s1 N=98 effN=110.7
2013s1 N=34 effN=114.4
2010s1 N=151 effN=344.6
2013s2 N=101 effN=254.4
2011s1 N=134 effN=173.2
2011s2 N=36 effN=119.9
Proportion
Length (cm)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2005s3 N=42 effN=135.5
2012s3 N=34 effN=149.6
1984s3 N=325 effN=1258.5
2000s3 N=44 effN=236.4
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2013s3 N=54 effN=287.4
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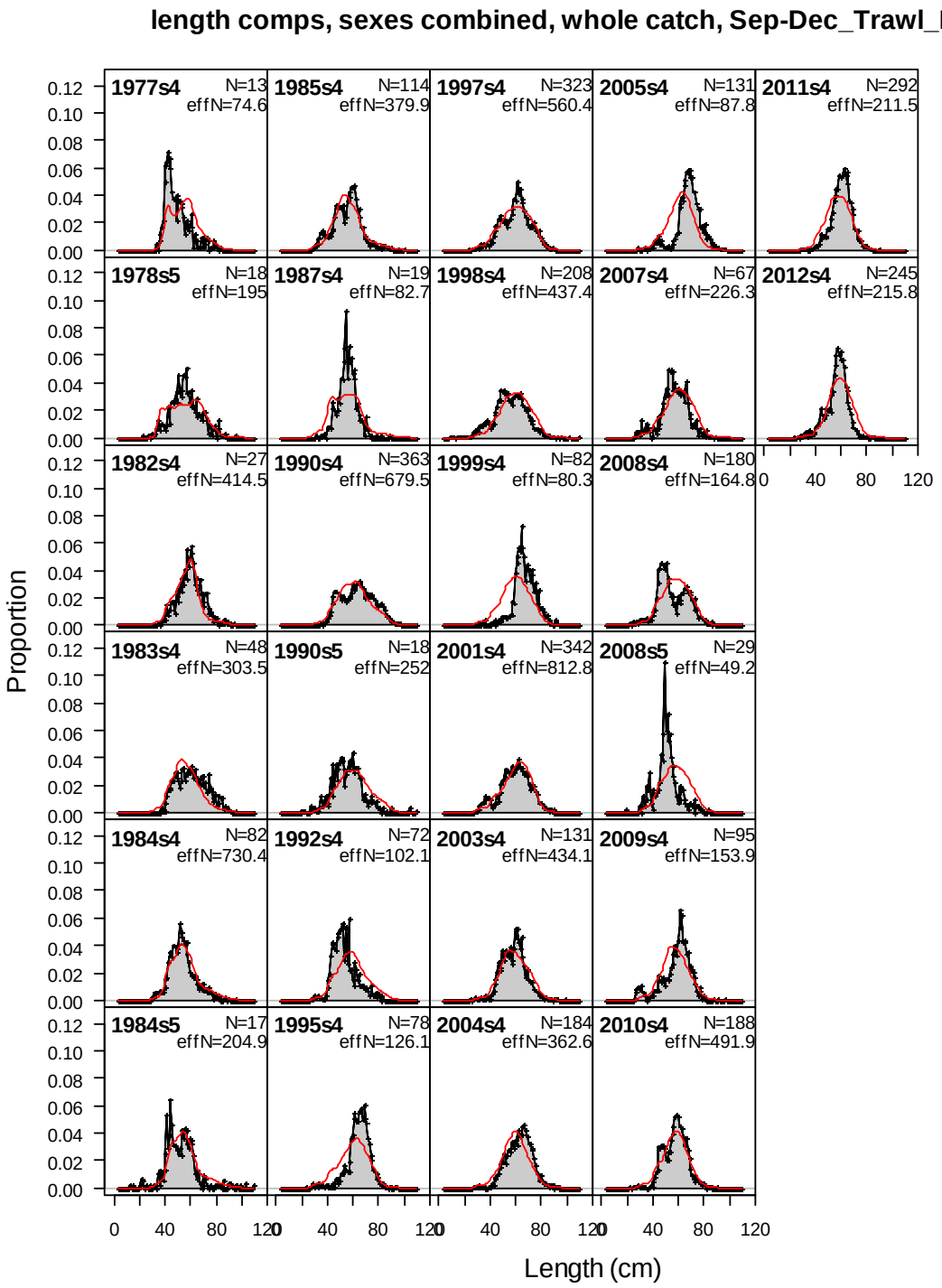
Length (cm)


length comps, sexes combined, whole catch, Sep-Dec_Trawl_Fishery
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1997s4 N=323 effN=560.4
2005s4 N=131 effN=87.8
2011s4 N=292 effN=211.5
1978s5 N=18 effN=195
1987s4 N=19 effN=82.7
1998s4 N=208 effN=437.4
2007s4 N=67 effN=226.3
2012s4 N=245 effN=215.8
1982s4 N=27 effN=414.5
1990s4 N=363 effN=679.5
1999s4 N=82 effN=80.3
2008s4 N=180 effN=164.8
1983s4 N=48 effN=303.5
1990s5 N=18 effN=252
2001s4 N=342 effN=812.8
2008s5 N=29 effN=49.2
1984s4 N=82 effN=730.4
1992s4 N=72 effN=102.1
2003s4 N=131 effN=434.1
2009s4 N=95 effN=153.9
1984s5 N=17 effN=204.9
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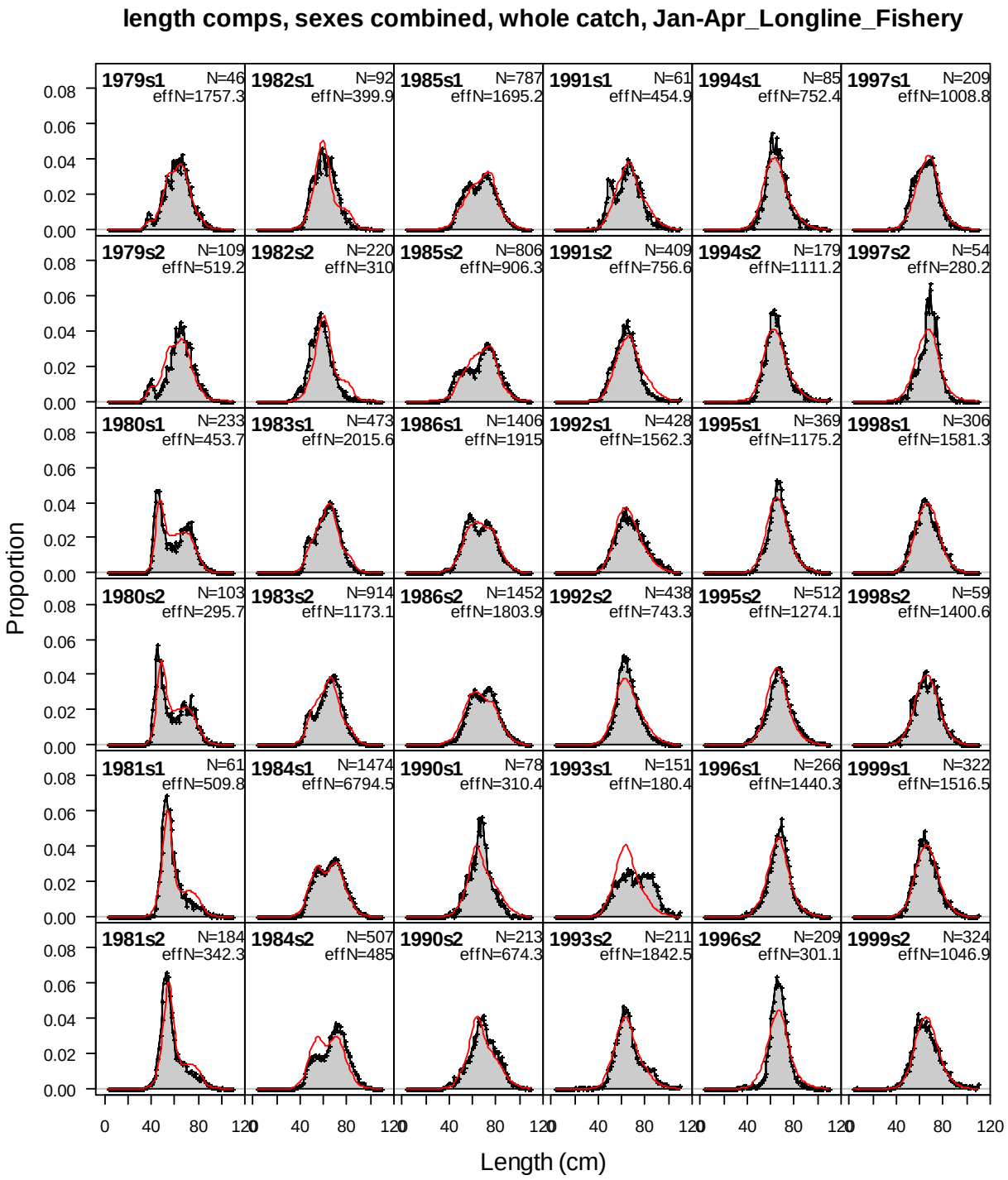
Proportion
Length (cm)


length comps, sexes combined, whole catch, Jan-Apr_Longline_Fishery
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1997s1 N=209 effN=1008.8
1979s2 N=109 effN=519.2
1982s2 N=220 effN=310
1985s2 N=806 effN=906.3
1991s2 N=409 effN=756.6
1994s2 N=179 effN=1111.2
1997s2 N=54 effN=280.2
1980s1 N=233 effN=453.7
1983s1 N=473 effN=2015.6
1986s1 N=1406 effN=1915
1992s1 N=428 effN=1562.3
1995s1 N=369 effN=1175.2
1998s1 N=306 effN=1581.3
1980s2 N=103 effN=295.7
1983s2 N=914 effN=1173.1
1986s2 N=1452 effN=1803.9
1992s2 N=438 effN=743.3
1995s2 N=512 effN=1274.1
1998s2 N=59 effN=1400.6
1981s1 N=61 effN=509.8
1984s1 N=1474 effN=6794.5
1990s1 N=78 effN=310.4
1993s1 N=151 effN=180.4
1996s1 N=266 effN=1440.3
1999s1 N=322 effN=1516.5
1981s2 N=184 effN=342.3
1984s2 N=507 effN=485
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1993s2 N=211 effN=1842.5
1996s2 N=209 effN=301.1
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0.08
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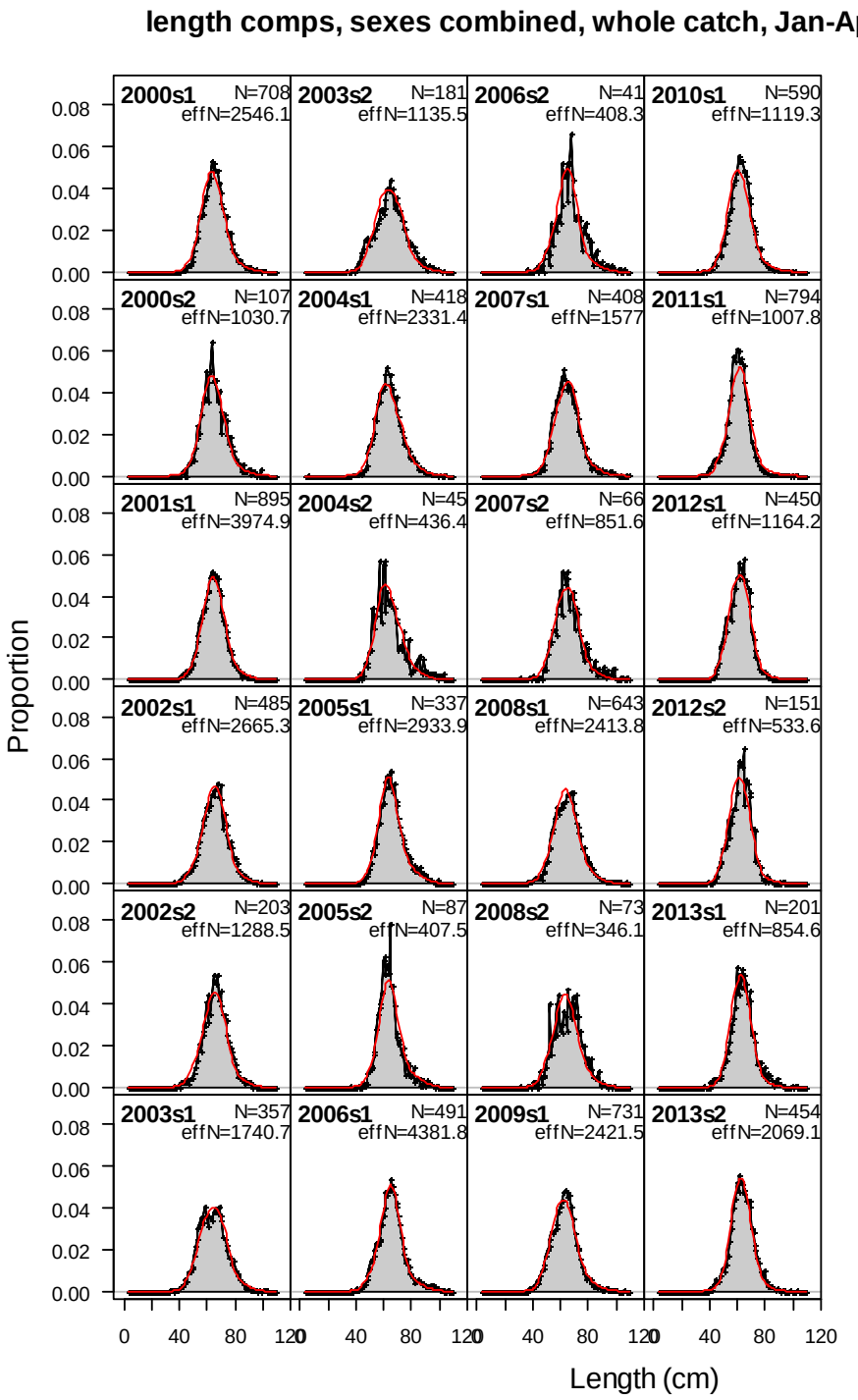
Length (cm)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2004s1 N=418 effN=2331.4
2007s1 N=408 effN=1577
2011s1 N=794 effN=1007.8
2001s1 N=895 effN=3974.9
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2012s1 N=450 effN=1164.2
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2008s1 N=643 effN=2413.8
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2005s2 N=87 effN=407.5
2008s2 N=73 effN=346.1
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2009s1 N=731 effN=2421.5
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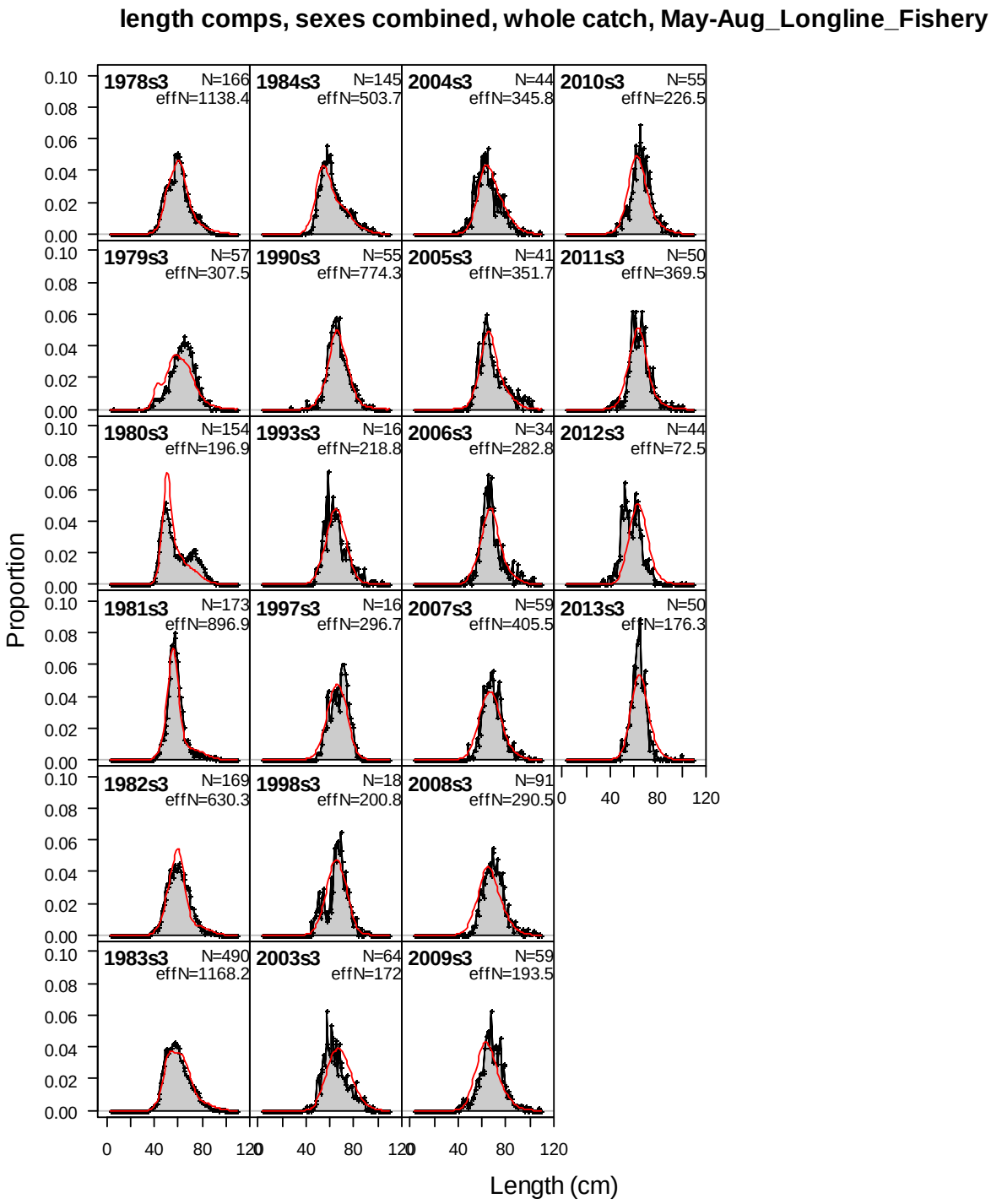
40
80
120
Length (cm)


length comps, sexes combined, whole catch, May-Aug_Longline_Fishery
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2010s3 N=55 effN=226.5
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1990s3 N=55 effN=774.3
2005s3 N=41 effN=351.7
2011s3 N=50 effN=369.5
1980s3 N=154 effN=196.9
1993s3 N=16 effN=218.8
2006s3 N=34 effN=282.8
2012s3 N=44 effN=72.5
1981s3 N=173 effN=896.9
1997s3 N=16 effN=296.7
2007s3 N=59 effN=405.5
2013s3 N=50 effN=176.3
1982s3 N=169 effN=630.3
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2008s3 N=91 effN=290.5
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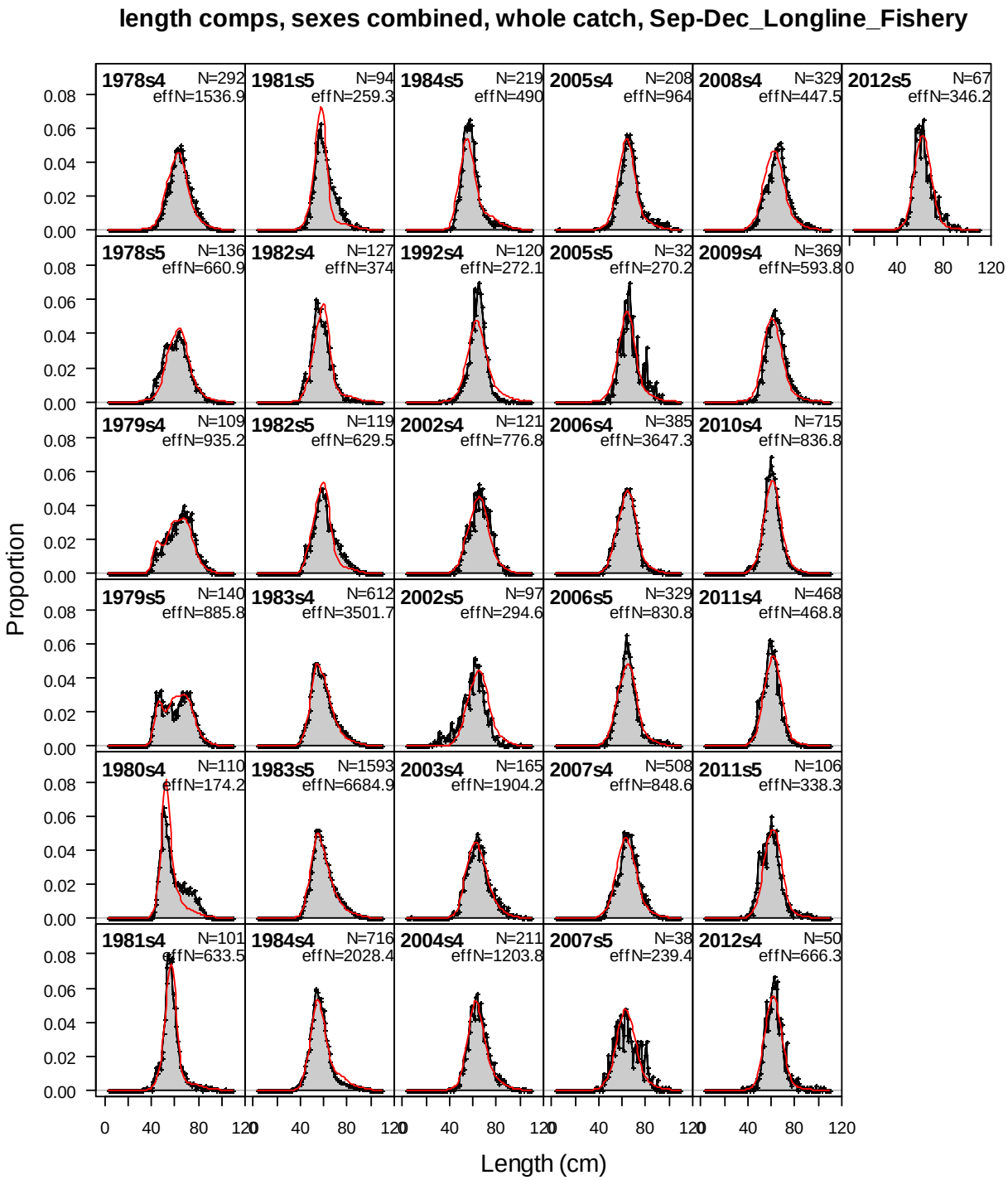
Proportion
Length (cm)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2008s4 N=329 effN=447.5
2012s5 N=67 effN=346.2
1978s5 N=136 effN=660.9
1982s4 N=127 effN=374
1992s4 N=120 effN=272.1
2005s5 N=32 effN=270.2
2009s4 N=369 effN=593.8
1979s4 N=109 effN=935.2
1982s5 N=119 effN=629.5
2002s4 N=121 effN=776.8
2006s4 N=385 effN=3647.3
2010s4 N=715 effN=836.8
1979s5 N=140 effN=885.8
1983s4 N=612 effN=3501.7
2002s5 N=97 effN=294.6
2006s5 N=329 effN=830.8
2011s4 N=468 effN=468.8
1980s4 N=110 effN=174.2
1983s5 N=1593 effN=6684.9
2003s4 N=165 effN=1904.2
2007s4 N=508 effN=848.6
2011s5 N=106 effN=338.3
1981s4 N=101 effN=633.5
1984s4 N=716 effN=2028.4
2004s4 N=211 effN=1203.8
2007s5 N=38 effN=239.4
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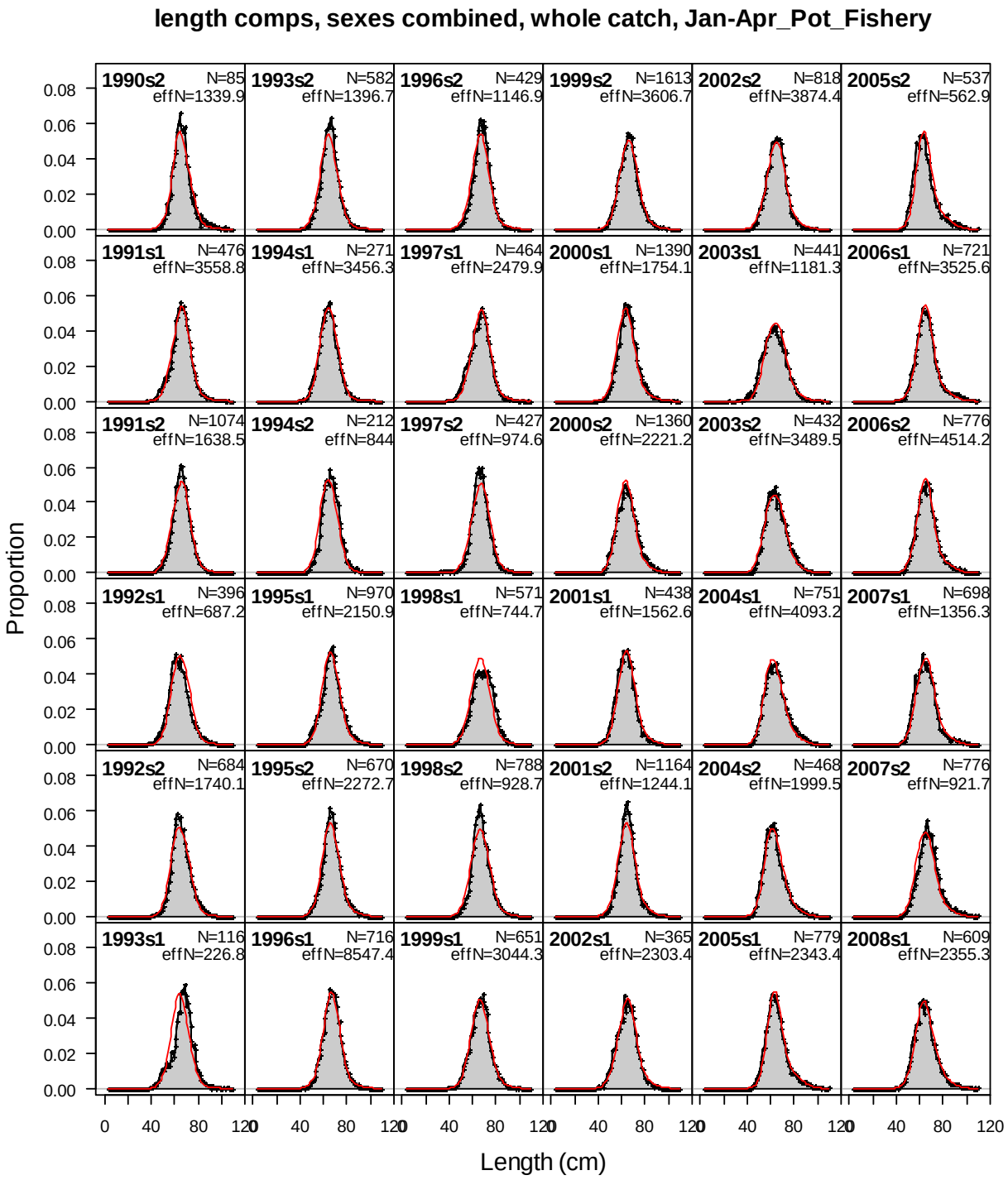
80
120
Length (cm)


length comps, sexes combined, whole catch, Jan-Apr_Pot_Fishery
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1996s2 N=429 effN=1146.9
1999s2 N=1613 effN=3606.7
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2005s2 N=537 effN=562.9
1991s1 N=476 effN=3558.8
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2000s1 N=1390 effN=1754.1
2003s1 N=441 effN=1181.3
2006s1 N=721 effN=3525.6
1991s2 N=1074 effN=1638.5
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1997s2 N=427 effN=974.6
2000s2 N=1360 effN=2221.2
2003s2 N=432 effN=3489.5
2006s2 N=776 effN=4514.2
1992s1 N=396 effN=687.2
1995s1 N=970 effN=2150.9
1998s1 N=571 effN=744.7
2001s1 N=438 effN=1562.6
2004s1 N=751 effN=4093.2
2007s1 N=698 effN=1356.3
1992s2 N=684 effN=1740.1
1995s2 N=670 effN=2272.7
1998s2 N=788 effN=928.7
2001s2 N=1164 effN=1244.1
2004s2 N=468 effN=1999.5
2007s2 N=776 effN=921.7
1993s1 N=116 effN=226.8
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1999s1 N=651 effN=3044.3
2002s1 N=365 effN=2303.4
2005s1 N=779 effN=2343.4
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0.08
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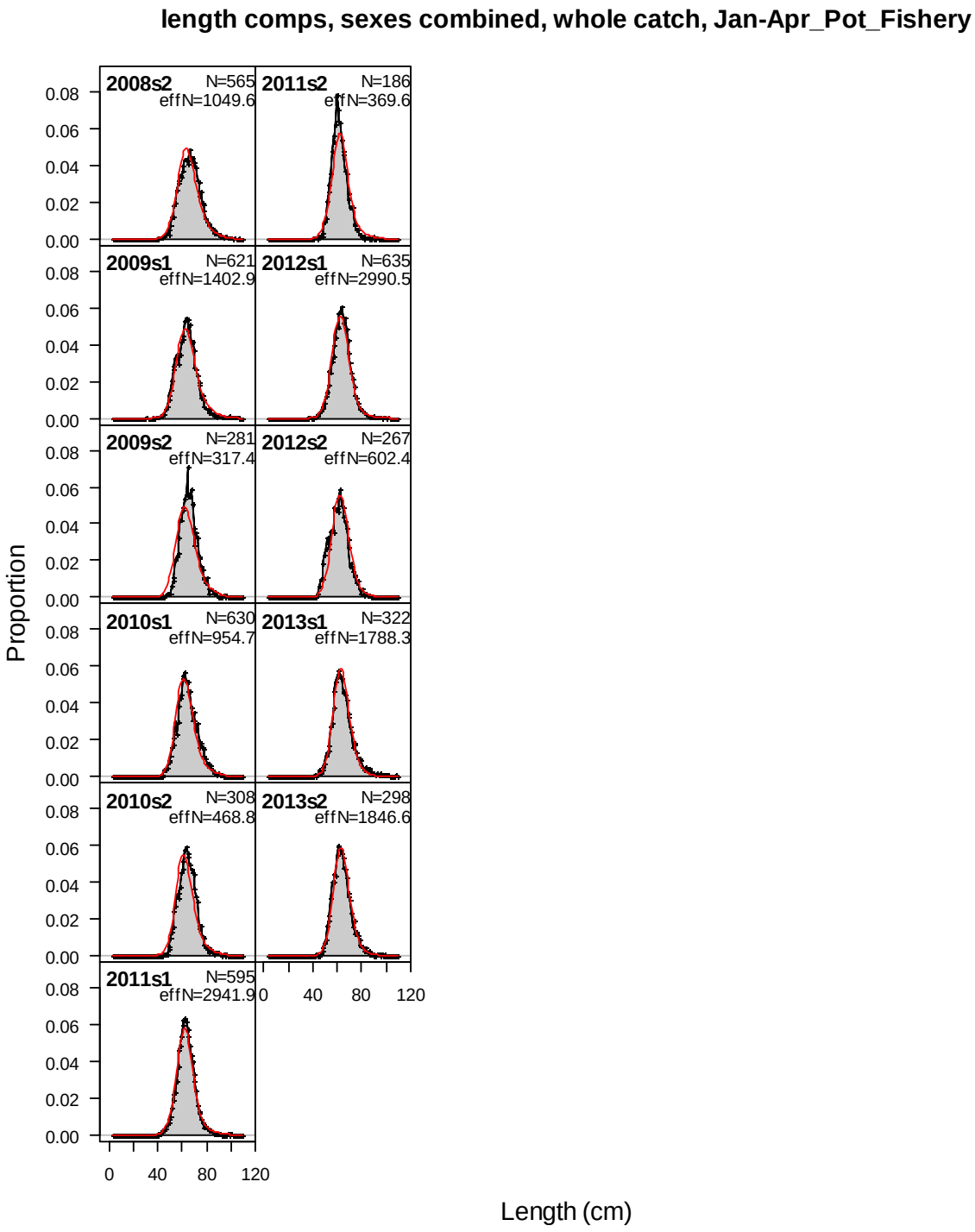
40
80
120
Length (cm)


length comps, sexes combined, whole catch, Jan-Apr_Pot_Fishery
2008s2 N=565 effN=1049.6
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2009s1 N=621 effN=1402.9
2012s1 N=635 effN=2990.5
2009s2 N=281 effN=317.4
2012s2 N=267 effN=602.4
2010s1 N=630 effN=954.7
2013s1 N=322 effN=1788.3
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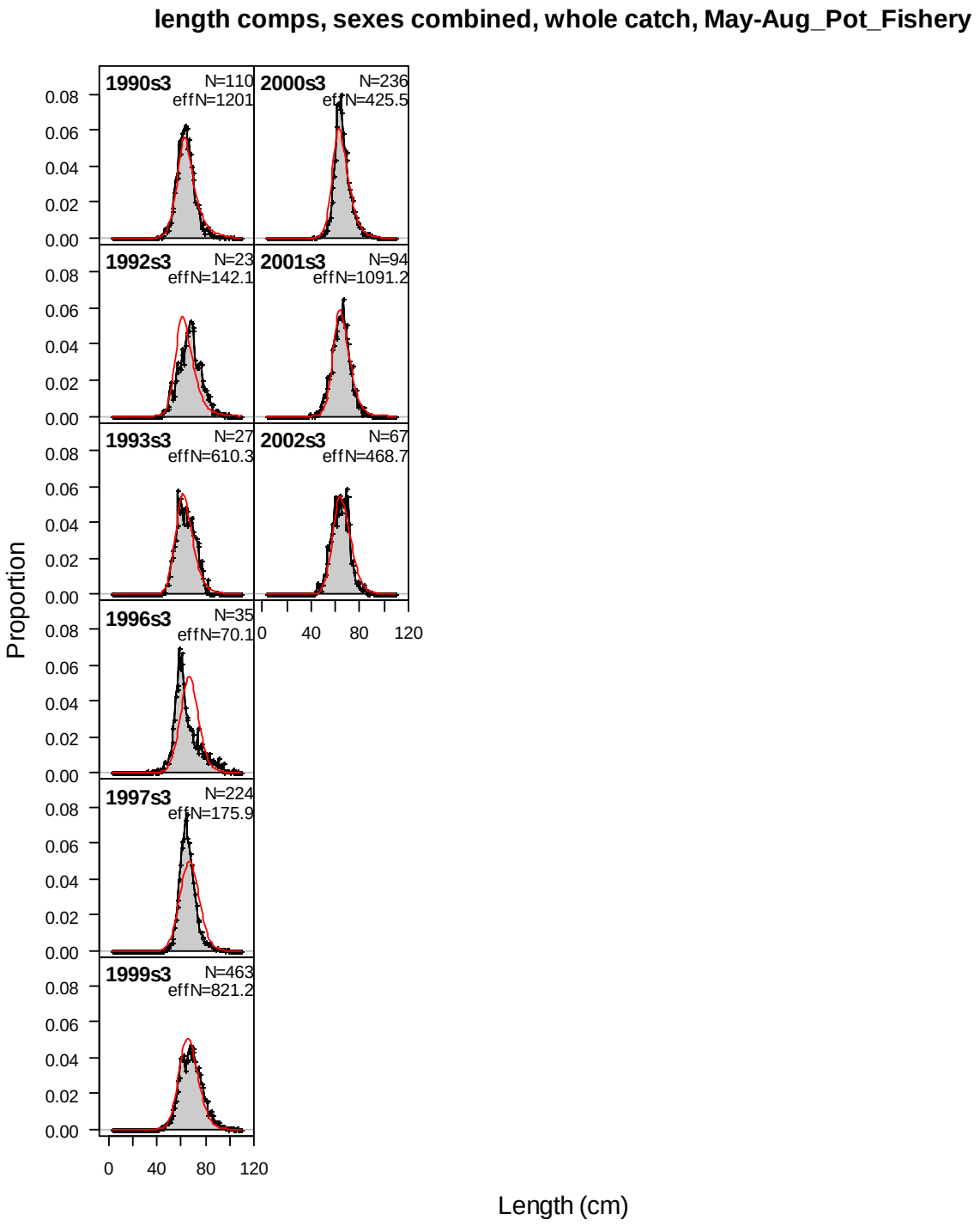
Proportion
Length (cm)


length comps, sexes combined, whole catch, May-Aug_Pot_Fishery
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2001s3 N=94 effN=1091.2
1993s3 N=27 effN=610.3
2002s3 N=67 effN=468.7
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1997s3 N=224 effN=175.9
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Proportion
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0.06
0.08
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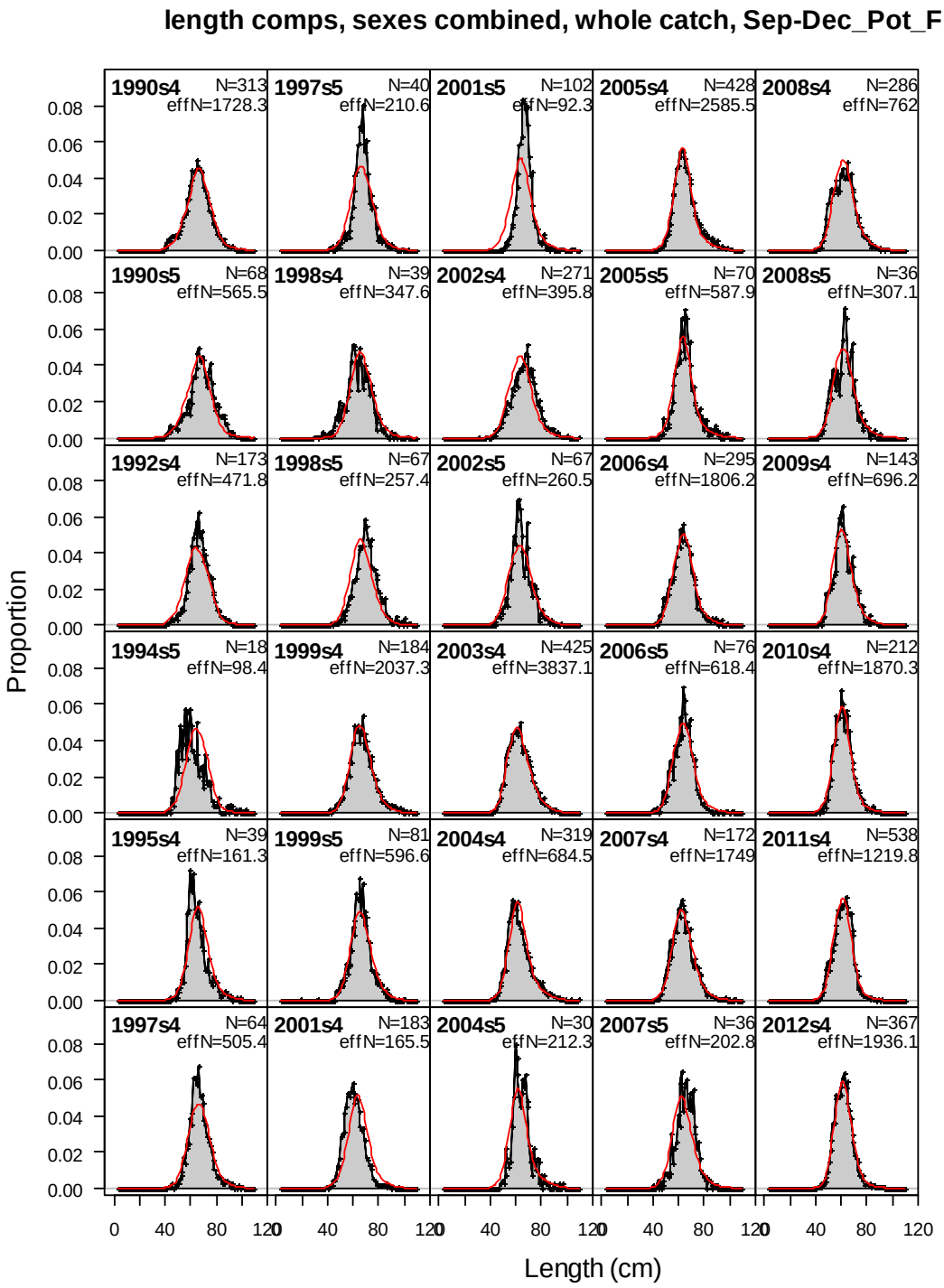
40
80
120
Length (cm)


length comps, sexes combined, whole catch, Sep-Dec_Pot_Fishery
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1997s5 N=40 effN=210.6
2001s5 N=102 effN=92.3
2005s4 N=428 effN=2585.5
2008s4 N=286 effN=762
1990s5 N=68 effN=565.5
1998s4 N=39 effN=347.6
2002s4 N=271 effN=395.8
2005s5 N=70 effN=587.9
2008s5 N=36 effN=307.1
1992s4 N=173 effN=471.8
1998s5 N=67 effN=257.4
2002s5 N=67 effN=260.5
2006s4 N=295 effN=1806.2
2009s4 N=143 effN=696.2
1994s5 N=18 effN=98.4
1999s4 N=184 effN=2037.3
2003s4 N=425 effN=3837.1
2006s5 N=76 effN=618.4
2010s4 N=212 effN=1870.3
1995s4 N=39 effN=161.3
1999s5 N=81 effN=596.6
2004s4 N=319 effN=684.5
2007s4 N=172 effN=1749
2011s4 N=538 effN=1219.8
1997s4 N=64 effN=505.4
2001s4 N=183 effN=165.5
2004s5 N=30 effN=212.3
2007s5 N=36 effN=202.8
2012s4 N=367 effN=1936.1
Proportion
0.00
0.02
0.04
0.06
0.08
0
40
80
120
Length (cm)

Figure 2.21 – Estimates of spawning biomass for the 2011, 2012, and 2013 models

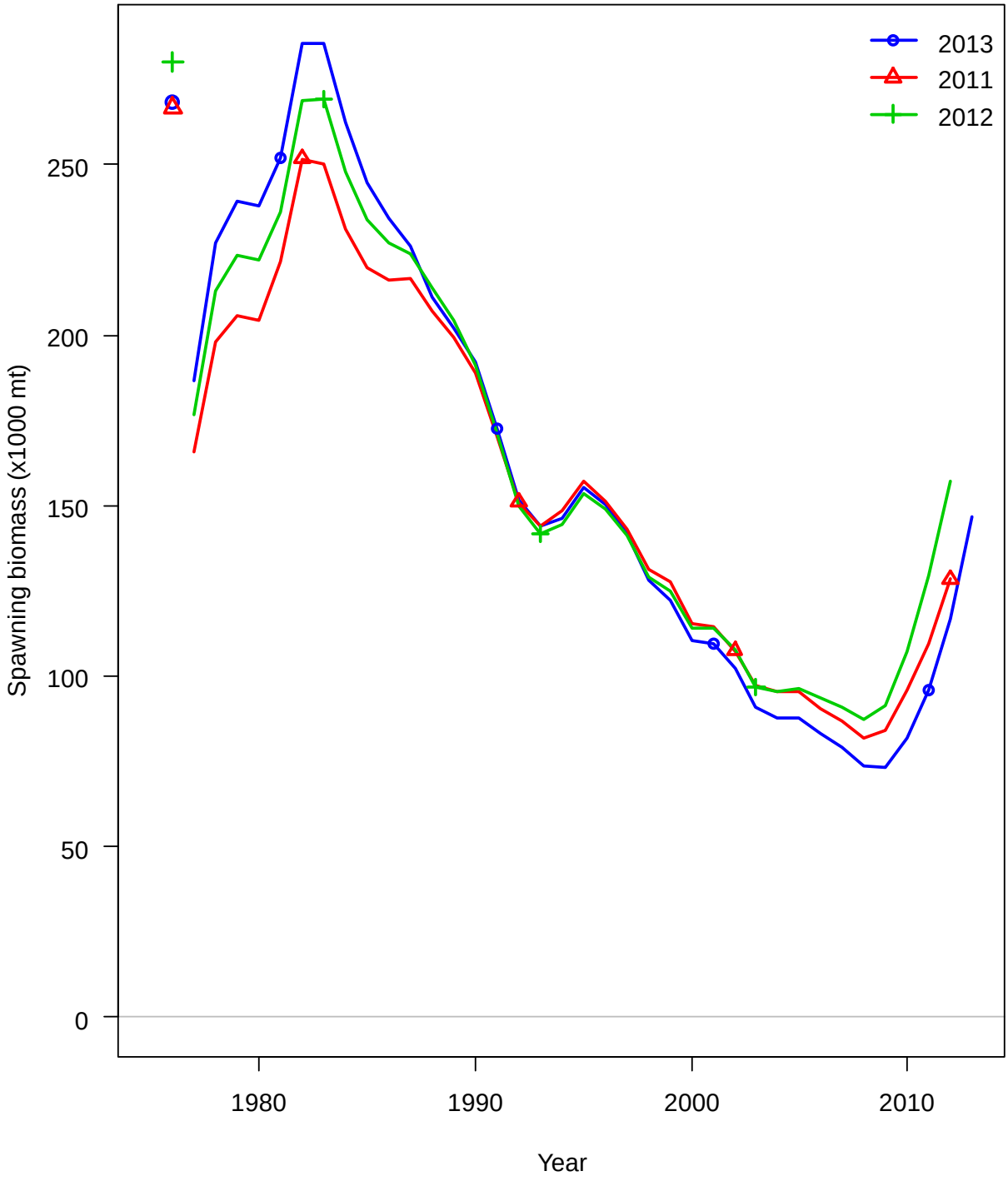


Figure 2.22 – Estimates of age-0 recruits for the 2011, 2012, and 2013 models

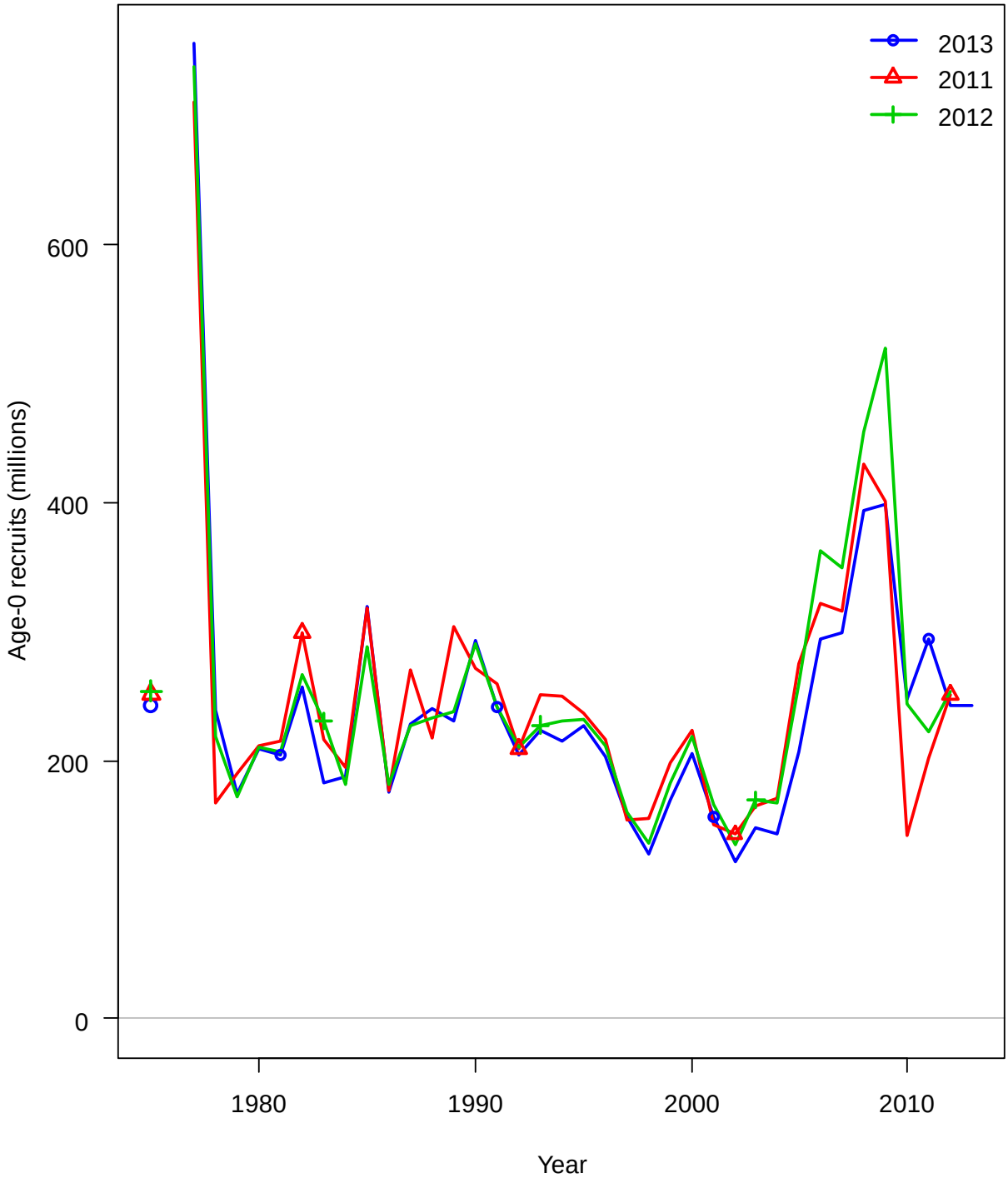


Figure 2.23 – Fits to the 27-plus survey abundance estimates for the 2011, 2012, and 2013 models

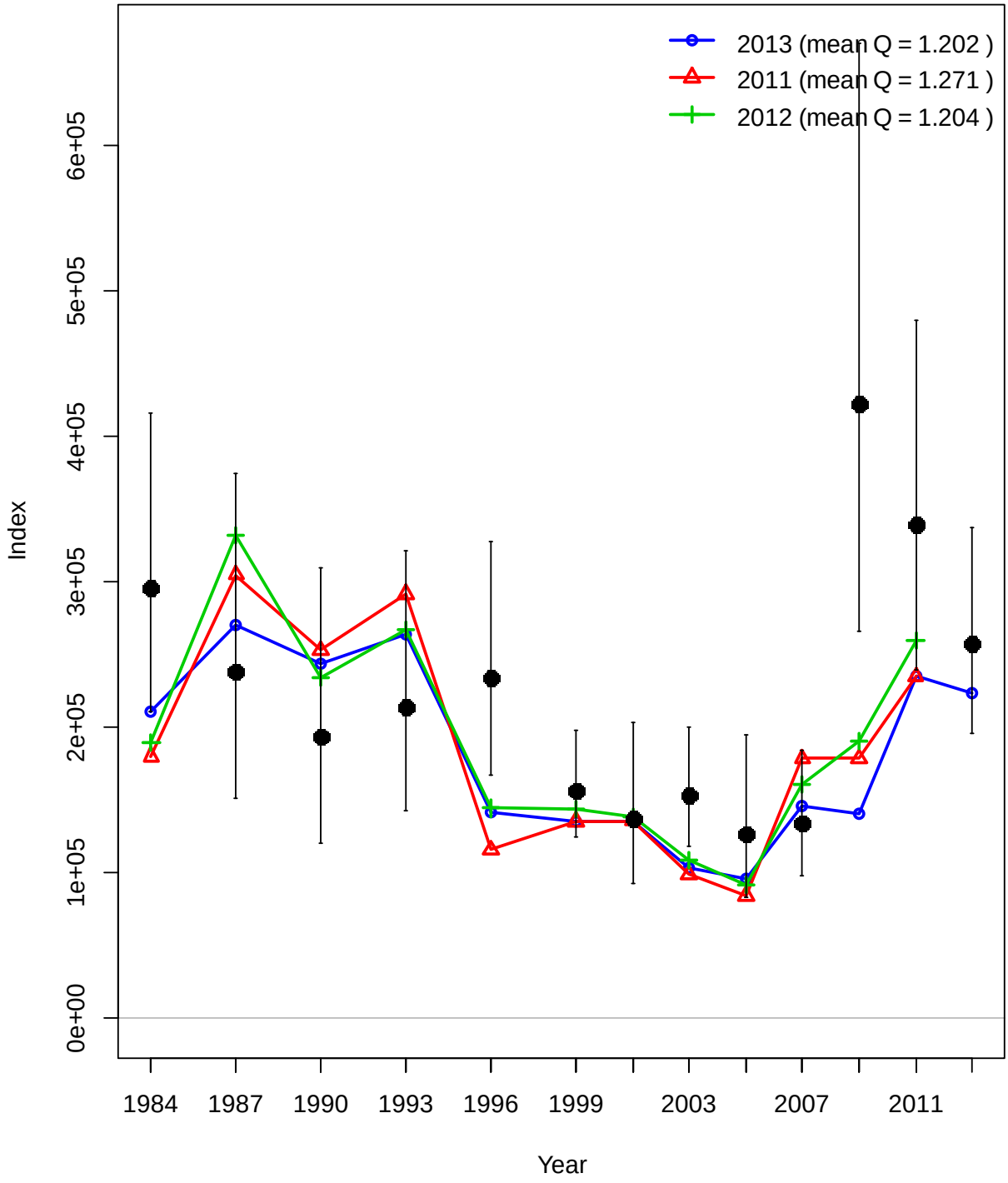


Figure 2.24 – GOA NMFS bottom trawl estimates for population-at-length proportions for 2007, 2009, 2011, and 2013; the vertical lines in 2007, 2009, and 2011 are the survey mean length-at-age values for age 3 (blue), 4 (red), 5 (green), and 6 (grey), and the vertical lines in 2013 are the model-estimated mean length-at-age values at the time of the survey

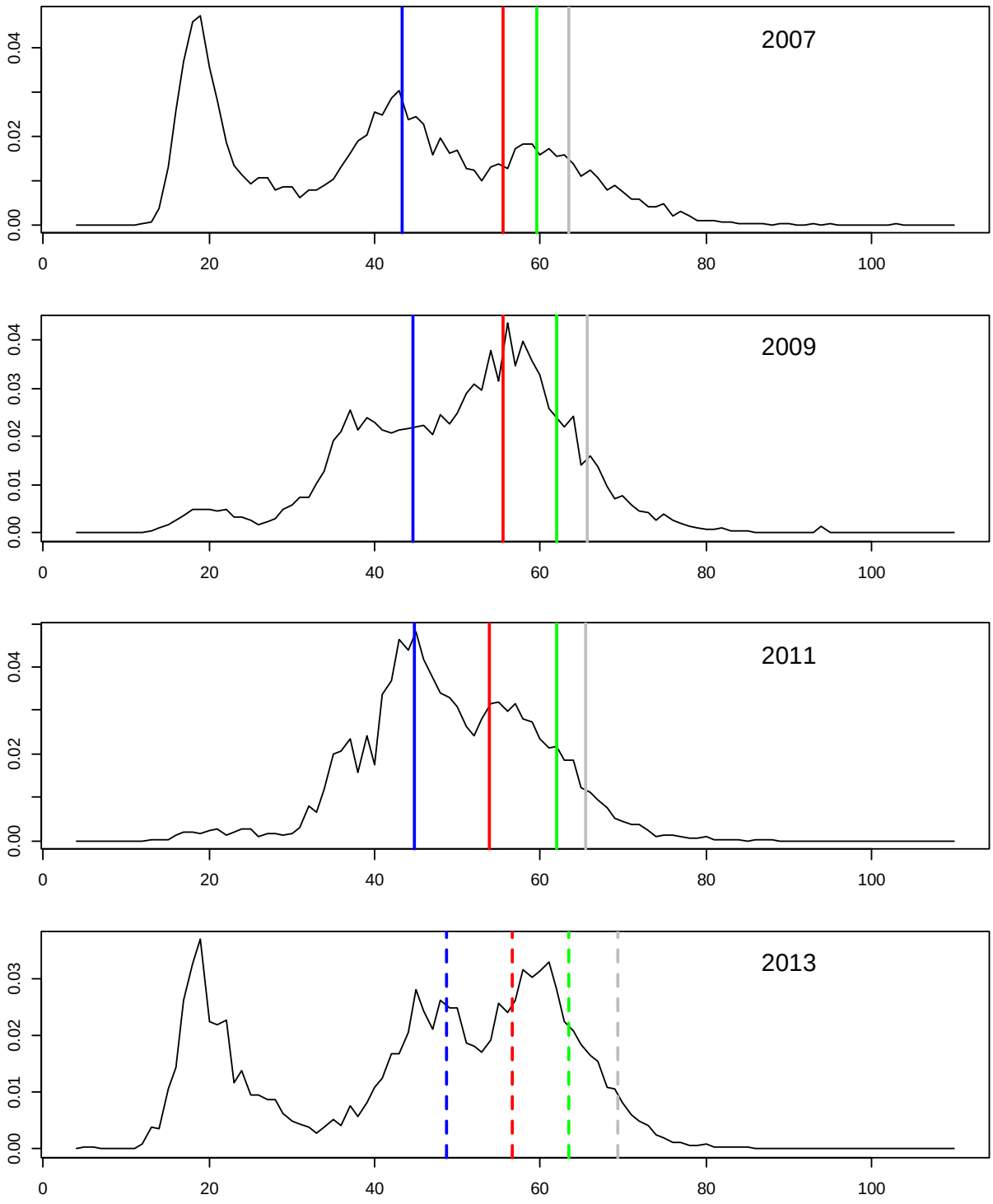
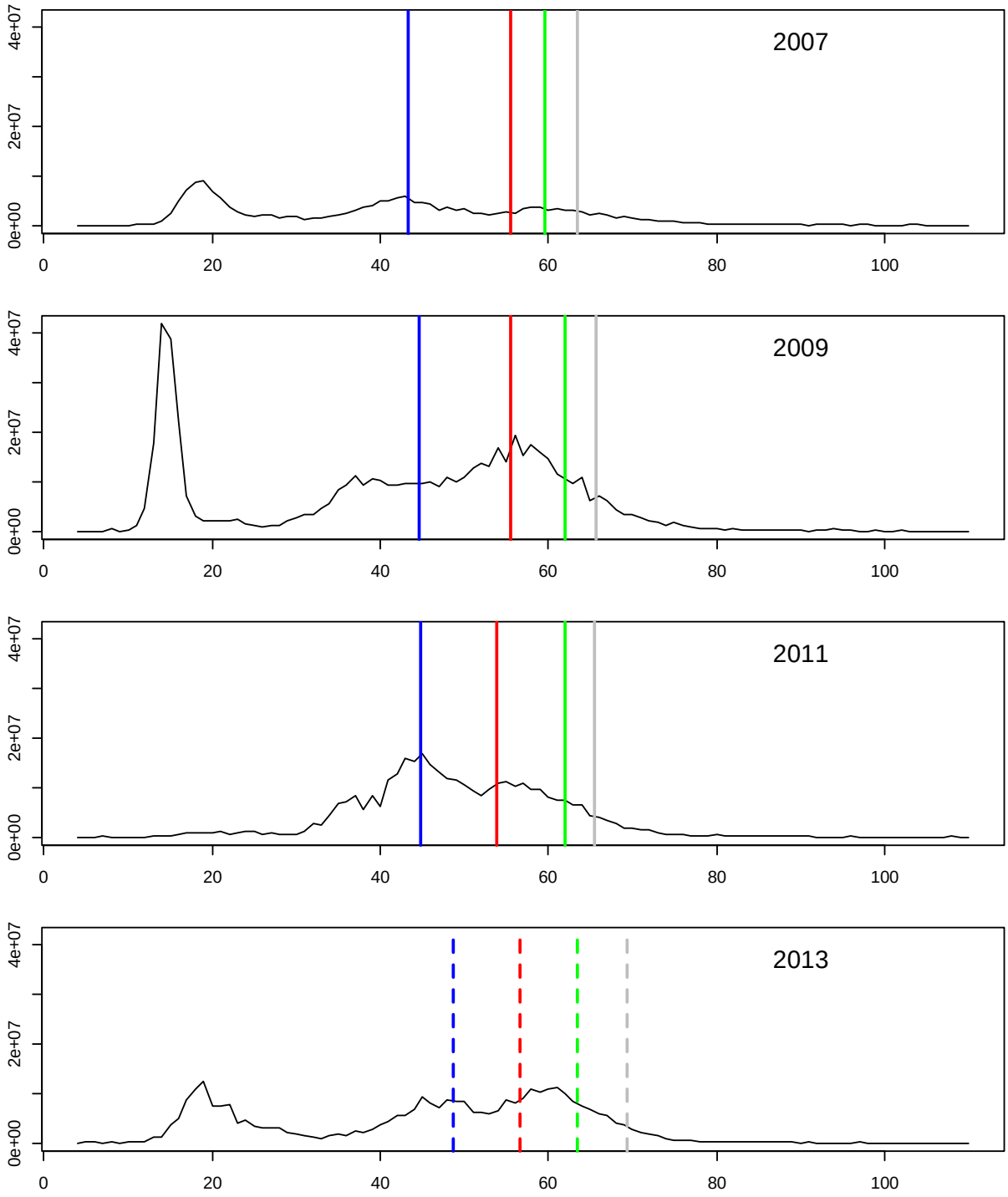


Figure 2.25 – GOA NMFS bottom trawl estimates for population-at-length abundance for 2007, 2009, 2011, and 2013; the vertical lines in 2007, 2009, and 2011 are the survey mean length-at-age values for age 3 (blue), 4 (red), 5 (green), and 6 (grey), and the vertical lines in 2013 are the model-estimated mean length-at-age values at the time of the survey



Addendum: Assessment of the Pacific cod stock in the Gulf of Alaska

Teresa A'mar

***Note**: The authors' recommended ABC and OFL are based on the results from the 2013 alternate model. This model is very similar to the 2013 base model and is described below. The main document contains a description of the analytical approach for and the results from the 2013 base model.*

EXECUTIVE SUMMARY

The stock assessment model used for the 2013 GOA Pacific cod SAFE estimated age-0 recruits for 1977 through 2011 and set the 2012 and 2013 age-0 recruits to the average level of age-0 recruitment. However, the estimate of the 2011 year class from this model was both higher than the average level and highly uncertain, and there is little information on age-2 fish in the data available in 2013.

This analysis uses the 2013 stock assessment model with a change to estimate age-0 recruits for 1977 through 2009 only, instead of for 1977 through 2011. This change is based on one of the recommendations from the "Working Group Report on Issues Related to Recruitment" document (http://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2013/Sept/Recruitment%20working%20group%20phase%20III%20report%20draft%202.pdf), which was discussed at the September 2013 Plan Team meeting. This change sets the 2010, 2011, 2012, and 2013 age-0 recruits to the average level, and results in a decrease in the ABC from 109,000 t estimated in the 2013 stock assessment model, to 88,500 t estimated in this alternative model with fixed recent recruitment.

Description of Change

One of the topics discussed in the "Working Group Report on Issues Related to Recruitment" document was B, "Estimation of parameters (average recruitment, stock-recruitment relationships, σ_R)", under which was the subtopic B1, "Establishing criteria for excluding individual within-regime year classes from estimates." The recommendation of the working group was that:

*Alternative B1.5 (**recommendation**): Defining $A_{10\%}$ as the first age with a survey selectivity of at least 10% and X as floor(1/(1-exp(-sqrt(M)))), for any species with a lifespan greater than $A_{10\%}$ + 1 years, exclude all year classes spawned within the last $A_{10\%}$ + X years.*

For the stock assessment model used in the 2013 GOA Pacific cod SAFE, $A_{10\%}$ is age 2 for the 27-plus survey selectivity-at-age in 2013, and X is 2. This adjustment results in excluding the estimation of year classes spawned within the last 4 years, which are the 2010, 2011, 2012, and 2013 year classes.

Results of Change

The alternate model is identical to the 2013 stock assessment model, with the change that age-0 recruits are not estimated for the 2010, 2011, 2012, and 2013 year classes. The age-0 recruits for these year classes are set to the average level of age-0 recruits.

The 2013 stock assessment model and the alternate model have similar fits to the data, with respect to the likelihood (Table 1); the likelihood components differ by approximately 1 for all components. Table 2 shows the results for the projection scenarios described in the 2013 GOA Pacific cod SAFE document for the alternate model. Table 3 shows the summary of results for the 2012 stock assessment model and the 2013 alternate model.

The alternate model estimates a slightly lower spawning biomass for 2008 through 2013, and slightly smaller uncertainty bounds for 2008 through 2013 as well (Fig. 1). The estimates for age-0 recruits from the alternate model are nearly identical to those from the 2013 stock assessment model from the beginning of the time series through 2006, and the alternate model estimates lower values for age-0 recruits for 2007 on (Figs. 2 and 3). The alternate model has a poorer fit to the 2013 27-plus survey abundance estimate than the 2013 model does (Fig. 4); the fits to the survey for both models are nearly identical for all years prior to 2013. Fig. 5 shows the estimated numbers-at-age for 2013 and projected numbers-at-age for 2014 for the 2013 model and the alternate model, with the largest difference between the estimates being the 2011 year class, which are age 2 in 2013 and age 3 in 2014.

GOA NMFS bottom trawl biomass estimates by area (in percent)

					Average of 3 most recent surveys		
Year	Western (610)	Central (620 and 630)	Eastern (640 +)		W	C	E
2007	48.95	47.32	3.73		39.29	56.31	4.40
2009	26.44	71.68	1.88		39.63	56.99	3.38
2011	32.65	63.92	3.43		36.01	60.97	3.02
2013	39.60	57.94	2.46		32.90	64.51	2.59

Table 24 – Negative log likelihood components for the 2013 stock assessment model and the alternate model

	2013 model (2011 recruit cutoff)	2013 alternate model (2009 recruit cutoff)
TOTAL NLL	3,873.63	3,875.82
Survey	4.71	5.51
Fsh length comp	3,290.29	3,291.30
Srv length comp	61.47	60.55
Srv age comp	77.72	76.79
Srv size-at-age	461.38	462.41
Recruitment	-22.07	-20.89
Parameters	255	253

Table 25 - Results for the projection scenarios for the alternate model

Scenarios 1 and 2, Maximum tier 3 ABC harvest permissible						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2013	77,816	94,615	62,084	110,003	0.418	407,626
2014	88,523	107,344	88,523	120,185	0.543	422,039
2015	84,193	101,874	84,193	111,551	0.543	397,050
2016	76,850	93,038	76,850	102,590	0.543	374,441
2017	72,169	87,464	72,169	97,515	0.543	361,183
2018	69,830	84,473	69,830	94,938	0.542	354,129
2019	67,477	81,456	67,477	93,486	0.530	350,375
2020	66,464	80,239	66,464	92,879	0.524	349,323
2021	66,330	80,103	66,330	92,824	0.523	349,358
2022	66,604	80,453	66,604	93,198	0.524	350,012
2023	66,873	80,767	66,873	93,379	0.525	350,121
2024	66,731	80,588	66,731	93,165	0.524	349,576
2025	66,644	80,471	66,644	93,121	0.524	349,545
2026	66,549	80,354	66,549	93,007	0.524	349,318
Scenario 3, F_{ABC} at average F over the past 5 years						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2013	54,718	94,615	62,084	110,003	0.418	486,275
2014	62,459	107,345	62,459	122,618	0.362	510,407
2015	65,536	111,867	65,536	124,223	0.362	500,108
2016	63,829	108,890	63,829	120,956	0.362	480,410
2017	61,767	105,542	61,767	118,196	0.362	458,515
2018	60,441	103,347	60,441	116,163	0.362	439,026
2019	59,473	101,711	59,473	114,421	0.362	423,970
2020	58,845	100,598	58,845	113,448	0.362	413,751
2021	58,536	99,977	58,536	112,896	0.362	407,607
2022	58,285	99,484	58,285	112,341	0.362	404,681
2023	58,127	99,211	58,127	112,127	0.362	402,920
2024	58,087	99,156	58,087	112,052	0.362	401,418
2025	58,116	99,216	58,116	112,132	0.362	400,739
2026	58,201	99,337	58,201	112,292	0.362	400,110
Scenario 4, $F_{ABC} = F_{60\%}$						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2013	36,453	94,615	62,084	110,003	0.418	407,626
2014	41,712	107,344	41,712	124,403	0.232	422,039
2015	47,134	119,907	47,134	134,597	0.232	441,839
2016	48,481	123,022	48,481	137,579	0.232	447,662
2017	48,445	123,104	48,445	138,578	0.232	448,894
2018	48,282	122,809	48,282	138,864	0.232	448,655
2019	48,098	122,370	48,098	138,587	0.232	447,956

2020	47,855	121,762	47,855	138,001	0.232	447,057
2021	47,649	121,276	47,649	137,592	0.232	446,274
2022	47,607	121,214	47,607	137,668	0.232	446,218
2023	47,657	121,327	47,657	137,745	0.232	446,040
2024	47,629	121,225	47,629	137,516	0.232	445,475
2025	47,568	121,081	47,568	137,407	0.232	445,310
2026	47,516	120,945	47,516	137,234	0.232	444,954
Scenario 5, No fishing (F_{ABC} = 0)						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2013	0	94,615	62,084	110,003	0.418	407,626
2014	0	107,344	0	127,662	0.000	422,039
2015	0	136,270	0	156,166	0.000	482,209
2016	0	155,723	0	176,815	0.000	526,886
2017	0	168,508	0	192,253	0.000	559,993
2018	0	177,244	0	203,513	0.000	584,001
2019	0	183,211	0	211,318	0.000	601,171
2020	0	187,134	0	216,532	0.000	613,123
2021	0	189,769	0	220,164	0.000	621,321
2022	0	191,812	0	223,011	0.000	627,424
2023	0	193,395	0	225,032	0.000	631,536
2024	0	194,376	0	226,184	0.000	634,023
2025	0	194,978	0	227,015	0.000	635,952
2026	0	195,321	0	227,470	0.000	636,992
Scenario 6, Whether Pacific cod are overfished – $SB_{35\%}$ = 79,700						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2013	94,615	94,615	62,084	110,003	0.418	407,626
2014	107,344	107,344	107,344	118,277	0.688	422,039
2015	94,743	94,743	94,743	102,668	0.688	379,227
2016	82,686	82,686	82,686	90,953	0.687	349,301
2017	72,858	72,858	72,858	85,749	0.646	334,539
2018	71,005	71,005	71,005	84,720	0.637	331,162
2019	70,143	70,143	70,143	84,326	0.628	330,136
2020	69,606	69,606	69,606	84,061	0.623	329,948
2021	69,656	69,656	69,656	84,099	0.623	330,220
2022	70,088	70,088	70,088	84,464	0.625	330,876
2023	70,263	70,263	70,263	84,580	0.626	330,817
2024	69,994	69,994	69,994	84,348	0.624	330,210
2025	69,977	69,977	69,977	84,330	0.625	330,255
2026	69,871	69,871	69,871	84,216	0.624	330,027
Scenario 7, Whether Pacific cod is approaching overfished condition						
Year	ABC	OFL	Catch	SSB	F	Total Bio

2013	94,615	94,615	62,084	110,003	0.418	407,626
2014	107,344	107,344	88,523	120,185	0.543	422,039
2015	101,874	101,874	84,193	111,551	0.543	397,050
2016	93,038	93,038	93,038	100,905	0.688	374,441
2017	80,614	80,614	80,614	90,063	0.680	345,991
2018	72,404	72,404	72,404	85,559	0.643	333,225
2019	70,210	70,210	70,210	84,409	0.629	330,284
2020	69,546	69,546	69,546	84,050	0.623	329,897
2021	69,628	69,628	69,628	84,092	0.623	330,197
2022	70,080	70,080	70,080	84,463	0.625	330,872
2023	70,261	70,261	70,261	84,580	0.626	330,817
2024	69,994	69,994	69,994	84,348	0.624	330,210
2025	69,977	69,977	69,977	84,330	0.625	330,255
2026	69,871	69,871	69,871	84,216	0.624	330,026

Table 26 – Summary of results for the 2012 model and the alternate model

Quantity	As estimated or *specified last* year:		As estimated or *specified this* year by the alternate model:	
	2013	2014	2014	2015
M (natural mortality rate)	0.38	0.38	0.38	0.38
Tier	3a	3a	3a	3a
Projected total (age 0+) biomass (t)	449,300	440,300	422,000	397,000
Female spawning biomass (t)				
Projected	111,000	112,900	120,100	111,500
Upper 95% confidence interval			142,800	132,500
Lower 95% confidence interval			97,500	90,500
$B_{100\%}$	234,800	234,800	227,800	227,800
$B_{40\%}$	93,900	93,900	91,100	91,100
$B_{35\%}$	82,100	82,100	79,700	79,700
F_{OFL}	0.61	0.61	0.69	0.69
$maxF_{ABC}$	0.49	0.49	0.54	0.54
F_{ABC}	0.49	0.49	0.54	0.54
OFL (t)	97,200	101,100	107,300	101,800
maxABC (t)	80,800	84,200	88,500	84,100
ABC (t)	80,800	84,200	88,500	84,100
Status	As determined *last* year for:			
	2011	2012	2012	2013
Overfishing	no	n/a	no	n/a
Overfished	n/a	no	n/a	no
Approaching overfished	n/a	no	n/a	no

Figure 26 – Estimated spawning biomass for the 2013 model and the alternate model

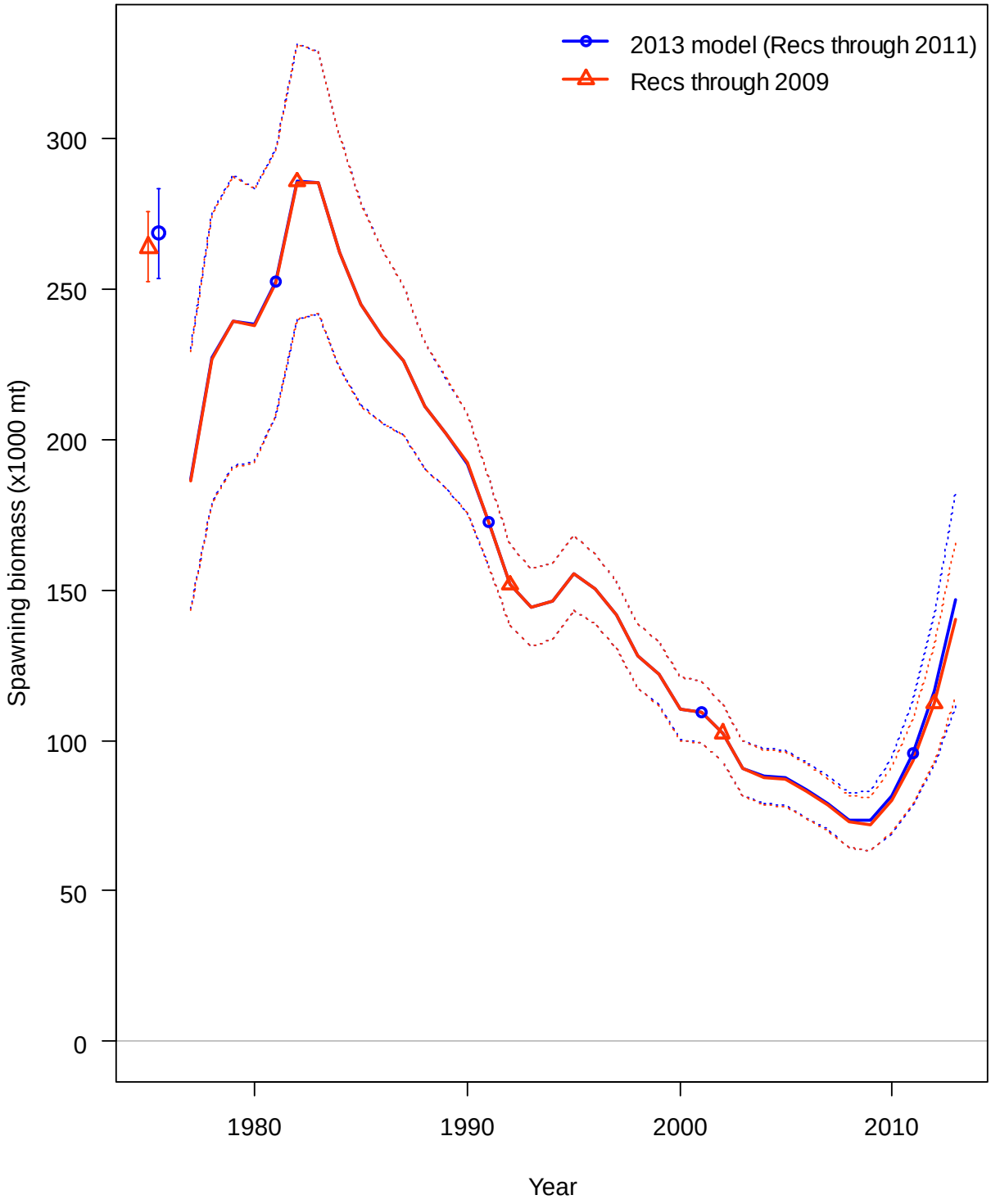


Figure 27 – Estimated age-0 recruits for the 2013 model and the alternate model

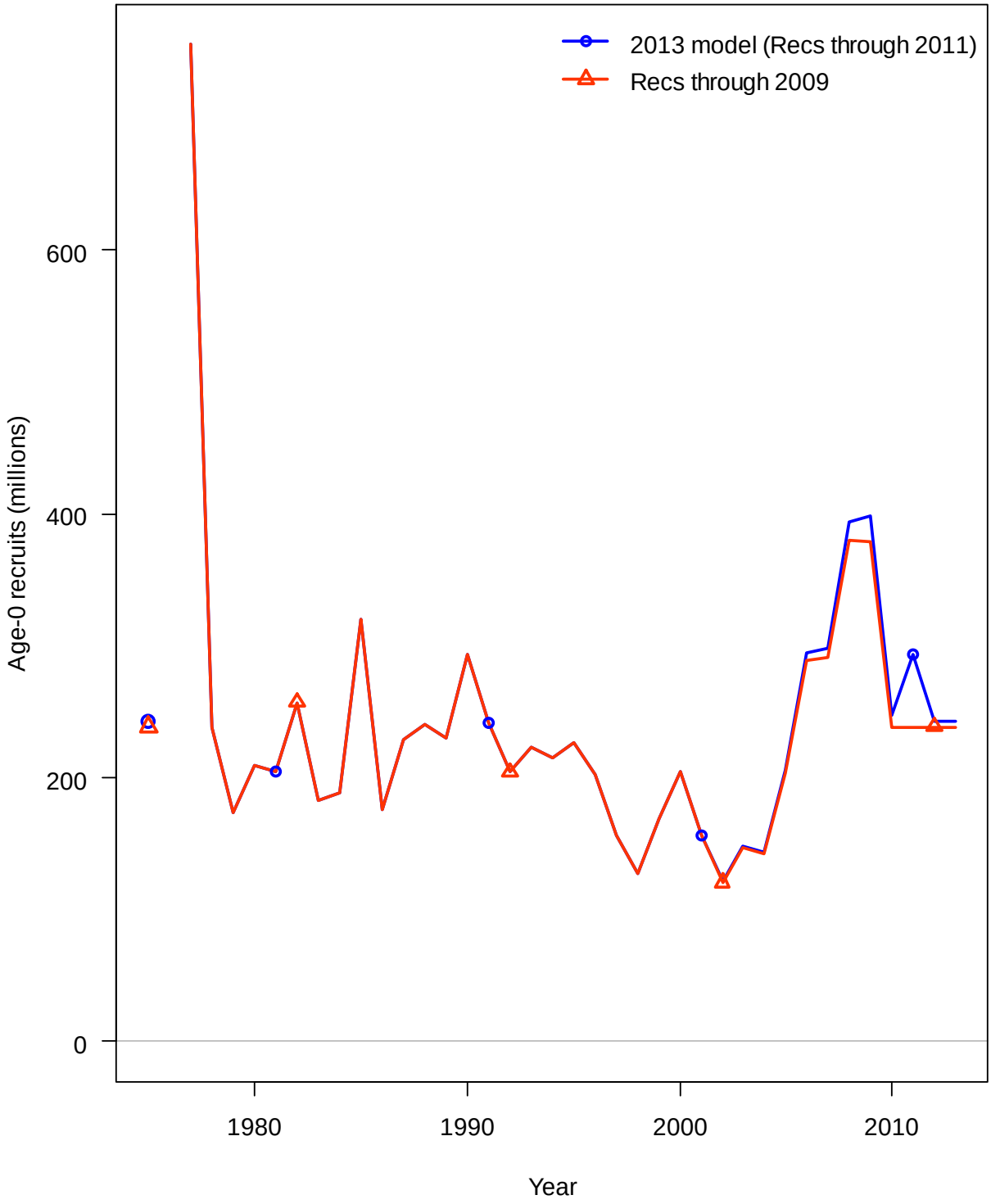


Figure 28 – Estimated recruitment deviations for the 2013 model and the alternate model

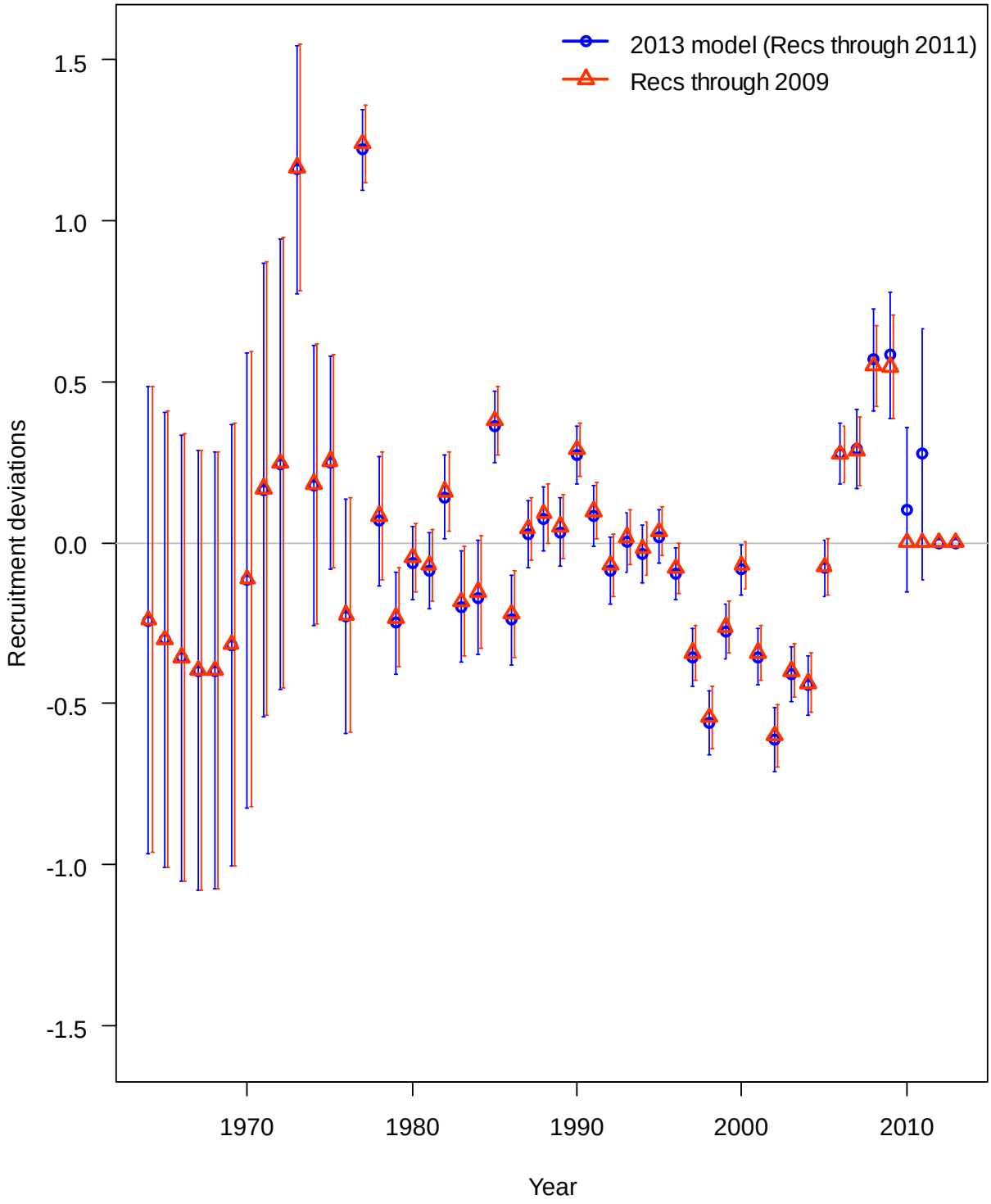


Figure 29 – Fits to the 27-plus survey abundance indices for the 2013 model and the alternate model

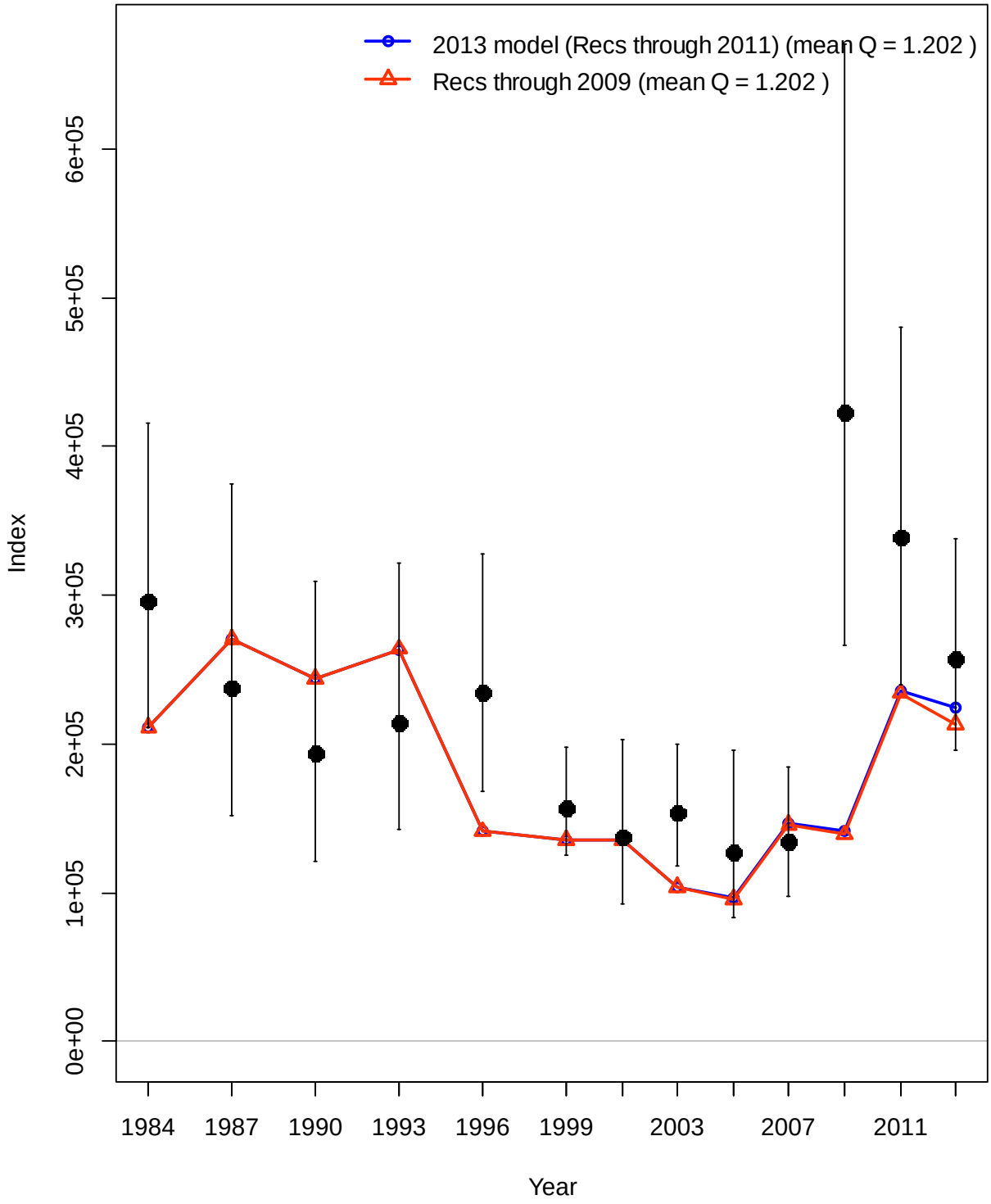
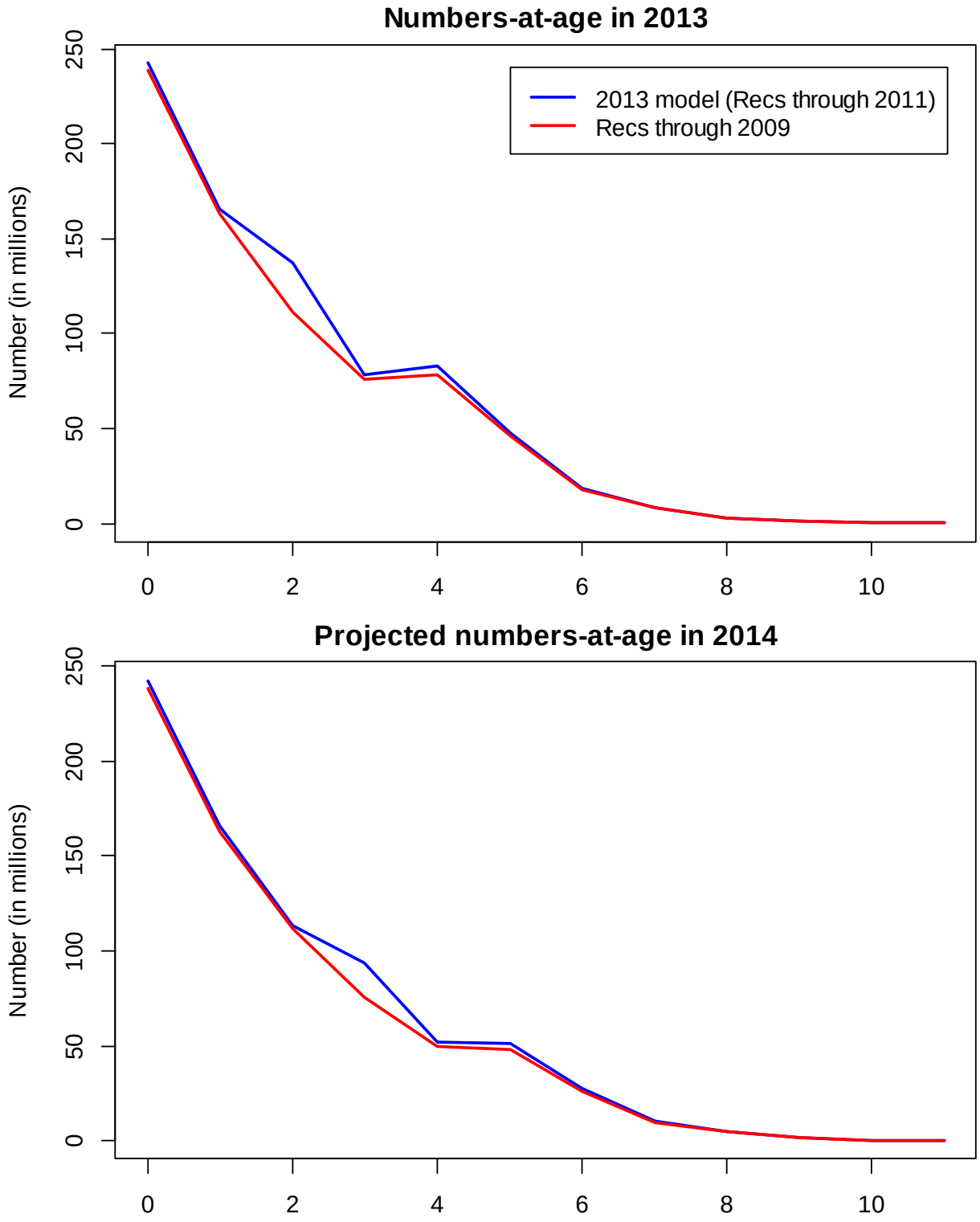



Figure 30 – Estimated and projected numbers-at-age for the 2013 model and the alternate model