Chapter 2: Assessment of the Pacific cod (*Gadus macrocephalus*) stock in the Gulf of Alaska for 2013

Teresa A'mar, Grant Thompson, Michael Martin, and Wayne Palsson

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center
7600 Sand Point Way NE., Seattle, WA 98115-6349

EXECUTIVE SUMMARY

Summary of Changes in Assessment Inputs

Relative to the November 2011 assessment, the following changes have been made in the current assessment:

Changes in the Input Data

1. Fishery: 2011 and preliminary 2012 total Pacific cod catch;
2. Fishery: 2011 observer data for Pacific cod catch-at-length;
3. Fishery: seasonal- and gear-specific catch for 1991 through 2011 were updated;
4. Survey: 2011 Pacific cod age composition and mean size-at-age from the NMFS GOA bottom trawl survey

Changes in Assessment Methodology

Several alternative model configurations were considered in this assessment. The full set of model configurations is shown below (Model A is last year's model):

Model	A	B	1	1Q	2	2Q	3	3Q	4	5
Catchability value	1.04	1.04	1.00	1.04	1.00	1.04	1.00	1.04	1.00	1.00
Tail compression off?	no	yes	yes	yes	yes	yes	yes	yes	yes	yes
Sub-27 abundance/sizecomp data omitted?	no	no	no	no	yes	yes	no	no	yes	no
Sub-27 mean size at age data omitted?	no	no	no	no	yes	yes	yes	yes	yes	yes
27-plus mean size at age data omitted?	no	no	no	no	no	no	yes	yes	yes	no

The stock assessment model configurations were run with Stock Synthesis version 3.24i.

Summary of Results

Quantity	As estimated or *specified last* year for: 2012	2013	As estimated or *recommended this* year for: **2013**	2014
M (natural mortality rate)	0.38	0.38	**0.38**	0.38
Tier	3a	3a	**3a**	3a
Projected total biomass (t)	521,000	530,000	**449,300**	440,300
Female spawning biomass (t)				
Projected	121,000	127,000	**111,000**	112,900
$B_{100\%}$	261,000	261,000	**234,800**	**234,8**00
$B_{40\%}$	104,000	104,000	**93,900**	93,900
$B_{35\%}$	91,400	91,400	**82,100**	82,100
F_{OFL}	0.53	0.53	**0.61**	**0.61**
$maxF_{ABC}$	0.44	0.44	**0.49**	**0.49**
F_{ABC}	0.44	0.44	**0.49**	**0.49**
OFL (t)	104,000	108,000	**97,200**	101,100
maxABC (t)	87,600	91,000	**80,800**	84,200
ABC (t)	87,600	91,000	**80,800**	84,200
Status	As determined *last* year for: 2010	2011	As determined *this* year for: 2011	2012
Overfishing	no	n/a	no	n/a
Overfished	n/a	no	n/a	No
Approaching overfished	n/a	no	n/a	No

Responses to SSC and Plan Team Comments on Assessments in General

<u>*Retrospective analysis*</u>

From the December 2011 SSC minutes: The SSC is pleased to see that many assessment authors have examined retrospective bias in the assessment and encourages the authors and Plan Teams to determine guidelines for how to best evaluate and present retrospective patterns associated with estimates of biomass and recruitment. We recommend that all assessment authors (Tier 3 and higher) bring retrospective analyses forward in next year's assessments.

From the September 2012 Plan Team minutes: The Teams recommend that authors conduct a retrospective analysis back 10 years (thus, back to 2002 for the 2012 assessments), and show the patterns for spawning biomass (both the time series of estimates and the time series of proportional changes relative to the 2012 run). This is consistent with a December 2011 NPFMC SSC request for stock assessment authors to conduct a retrospective analysis. The base model used for the retrospective analysis should be the author's recommended model, even if it differs from the accepted model from previous year.

Due to technical difficulties in model implementation, this request will be addressed next year.

<u>*Total catch accounting*</u>

From the September 2012 Plan Team minutes: The Teams recommend that authors continue to include other removals in an appendix for 2012. Authors may apply those removals in estimating ABC and OFL; however, if this is done, results based on the approach used in the previous assessment much also be presented.

Other catch removals for GOA Pacific cod are minimal and were not applied in the estimation of 2013 and 2014 ABC and OFL.

Responses to SSC and Plan Team Comments Specific to this Assessment

From the May 2012 Plan Team minutes: *"For both the EBS and GOA, the Teams recommend that the authors attempt to explore the divergent ageing bias trends in the two regions and the impacts thereof."*

This issue will be addressed in a future SAFE document.

From the May 2012 Plan Team minutes: *"For both the EBS and GOA, the Teams recommend that the authors attempt to evaluate the biological basis for estimated patterns of seasonal weight at length."*

This issue will be addressed in a future SAFE document.

From the September 2012 Plan Team minutes: *"The Team recommended that discrepancy in likelihoods (Table 1 in assessment) be examined more closely. It appears Model C had a worse fit to the indices compared to Model A (as expected since fewer catchability parameters are involved) whereas the length and age composition data had a far better fit for Model C compared to Model A.*

The Team recommended that the GOA Pacific cod author explore models with the following specifications:

1) Fix q=1
2) Drop sub-27 data
3) Drop mean length-at-age
4) Author's own explorations

From the October 2012 SSC minutes: *"The Plan Team reviewed a suite of GOA Pacific cod models that centered on SSC, Plan Team and public comments and recommendations. The Plan Team recommended that the base model used last year be brought forward for consideration in November and that the authors explore models that consider fixed Q, drop the sub 27 size category, drop the mean length-at-age data and authors' preferred model. The SSC agrees with Plan Team recommendations and looks forward to future model developments and a more thorough documentation of the recent model improvements."*

These model configurations were pursued and are presented below.

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.

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 4.42% per day, with a 95% confidence interval ranging from about 3.31% to 5.03% (Gregory et al. in review); 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. 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 2012, 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 2005), 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 (effective January 1, 2012):

> "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.

Commercial Catch Data

Catch Biomass

Catches for the period 1977-2012 are shown for the three main gear types in Table 2.6. 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. Catches for the years 1977-1980 may or may not include discards.

Catch Per Unit Effort

Fishery catch per unit effort data are available by gear and season for the years 1991-2011. These are included in the models for purposes of comparison only and are not used in parameter estimation. Catch Size Composition

Fishery size compositions are presently available, by gear, for at least one gear type in every year from 1977 through the first part of 2011. Beginning with the 2010 assessment (Thompson et al. 2010), size composition data are based on 1-cm bins ranging from 4 to 120 cm. Because displaying these data would add a large number of pages to the present document, they are not shown here but are available at: http://www.afsc.noaa.gov/REFM/Docs/2011/GOA_Pcod_fishery_sizecomp_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 2.7.

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 1984-2011 are shown for the sub-27 and the 27-plus survey in Table 2.8, 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.

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 2.9; the sample sizes are shown in Table 2.10.

Abundance Estimates

Estimates of total abundance (both in biomass and numbers of fish) obtained from the trawl surveys are shown in Table 2.11, together with their respective coefficients of variation.

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.

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 down 39% from 2009, but still 81% above the 2007 estimate.

ANALYTIC APPROACH

Model Structure

History of Previous Model Structures Developed Under Stock Synthesis

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

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

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

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

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

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

A major change took place in the 2005 assessment (Thompson and Dorn 2005), as the model was migrated to the newly developed Stock Synthesis 2 (SS2) program, which made use of the ADMB modeling architecture (Fournier 2005) 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 (2005, 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 0.92 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 earlier in the year 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 2011, Model 3, was carried over for this assessment. There are two variants of this model configuration:

- 2011 model with 2012 data
- 2011 model with 2012 data and tail compression turned off

These model configurations will be referred to as the "2011 models" in subsequent text.

The following new model configurations were developed for consideration from the September 2012 Plan Team minutes and discussion:

Model	Description
1	Fix q at 1.0 as most of the tuned runs were close to 1.0; request that the mean catchability for 60-81 cm be presented to contrast with experimental value of 0.916
2	Drop sub-27 data to evaluate effect on recruitment estimates and potential interaction with other data sources
3	Drop mean length-at-age, as the lack of fit was quite high as indicated by the large contribution to the total likelihood.
4	as in 2) but drop 27-plus mean length-at-age
5	as in 1) but drop sub-27 mean length-at-age

The following two model configurations were in response to request 1 in the table above; Model 1 has the same structure as Model C from the September 2012 document (Appendix attached):

- Model 1: q set to 1.0, 2 periods of catchability and selectivity for the sub-27 survey
- Model 1Q: Model 1 with q set to 1.04 (the value used in 2011)

The following two model configurations were in response to request 2 in the table above:

- Model 2: q set to 1.0, all sub-27 survey data is omitted
- Model 2Q: Model 2 with q set to 1.04 (the value used in 2011)

The following two model configurations were in response to request 3 in the table above:

- Model 3: q set to 1.0, 2 periods of catchability and selectivity for the sub-27 survey, all sub-27 and 27-plus survey mean length-at-age omitted
- Model 3Q: Model 3 with q set to 1.04 (the value used in 2011)

The following two model configurations were run to determine the impact of subsets of the mean length-at-age data:

- Model 4: Model 2 with the 27-plus mean length-at-age data omitted
- Model 5: Model 1 with the sub-27 mean length-at-age data omitted

The new model configurations have the “tail compression” turned off. This option is part of the assessment program and had been interacting with recruitment estimates in un-anticipated ways (as presented at the September meeting [Appendix attached]). The full set of models is shown below:

Model	2011	2011tc	1	1Q	2	2Q	3	3Q	4	5
Catchability value	1.04	1.04	1.00	1.04	1.00	1.04	1.00	1.04	1.00	1.00
Tail compression off?	no	yes	yes	yes	yes	yes	yes	yes	yes	yes
Sub-27 abundance/sizecomp data omitted?	no	no	no	no	yes	yes	no	no	yes	no
Sub-27 mean size at age data omitted?	no	no	no	no	yes	yes	yes	yes	yes	yes
27-plus mean size at age data omitted?	no	no	no	no	no	no	yes	yes	yes	no

Version 3.24i of SS was used to run all the models in this assessment.

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

All of the models in this assessment set *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 0.92 obtained by Nichol et al. (2007). The resulting value of 1.04 was retained for several of the models in the present assessment; others set catchability equal to 1.00, 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 used for all models 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 used for all models 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 for all models 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 for all models 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 all models 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. In addition, the 2011 models and Models 1, 1Q, 3, 3Q, and 5 estimate annual deviations for catchability in the sub-27 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 assessments was used again this year. This functional form 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 all models considered 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 all models in the present 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

All models included 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), and initial (equilibrium) catch. In addition, all models except 3, 3Q, and 4 included a likelihood component for 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.

Use of Fishery CPUE and Survey Relative Abundance Data in Parameter Estimation

Fishery CPUE data are included in the models for comparative purposes only. Their respective catchabilities are estimated analytically, not statistically.

For the trawl surveys, each year's survey abundance datum is assumed to be drawn from a lognormal distribution specific to that year. The model's estimate of survey abundance in a given year serves as the geometric mean for that year's lognormal distribution, and the ratio of the survey abundance datum's standard error to the survey abundance datum itself serves as the distribution's coefficient of variation, which is then transformed into the "sigma" parameter for the lognormal distribution.

Use of Recruitment Deviation "Data" in Parameter Estimation

The recruitment deviations likelihood component is different from traditional likelihoods because it does not involve "data" in the same sense that traditional likelihoods do. Instead, the log-scale recruitment deviation plays the role of the datum with mean zero and specified (or estimated) standard deviation; but, of course,the *dev*s are parameters, not data.

RESULTS

Model evaluation

The 2011 model configurations and eight new model configurations were evaluated, differentiated by the data used in model fitting. The model evaluation criteria included the relative sizes of the likelihood components, and how well the model estimates fit to the 27-plus and sub-27 survey indices, the survey age composition data, reasonable curves for fishery sand survey selectivity, and that the model estimated the variance-covariance matrix.

Comparing and Contrasting the Models

The model configurations evaluated focused on exploring the impact of different combinations of 27-plus and sub-27 survey data on model fit. The trends in spawning biomass (Fig. 2.2) and recruitment (Fig. 2.3) were similar for all model configurations, although Models 3, 3Q, and 4, which omitted survey mean size-at-age data, estimated consistently higher biomass than the other models. The patterns in fit to the 27-plus survey were similar for most years across all model configurations, although less so for the three most recent survey years (Fig. 2.4). The 2011 model configurations had virtually identical fits to the sub-27 survey, as these model configurations estimate separate q values for each survey year (Fig. 2.5); the other model configurations which included sub-27 data had virtually identical fits when estimating q and selectivity for two periods.

Evaluation Criteria

Table 2.12 lists the number of parameters, the values of the objective function components, and the “effective q” for all 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); all model configurations had a value for “effective q” less than 0.916. The 2011 models fit the sub-27 survey indices well due to time-varying q; the other model configurations did not fit the sub-27 survey indices as well. None of the models fit the 27-plus survey indices well, although Model 4 fit the best of all model configurations. Model 4 fit the 27-plus survey age composition the best of all model configurations; Model 2 has the second best fit. All model configurations had reasonable fishery selectivity curves. All model configurations converged and produced variance-covariance matrices.

Selection of Final Model

Model 2 was selected as the preferred model, as the biomass estimates were similar to estimates from other model configuration which included fitting to survey mean size-at-age data, and it had fewer parameters due to excluding the sub-27 survey data. The sub-27 survey indices are highly variable (Fig. 2.5), and there is considerable uncertainty associated with the probability and consistency of capture of sub-27cm fish in the trawl survey.

Although Model 4 had lower objective function component values than Model 2 for several categories, Model 4 estimated the mean length for age-1 fish to be 27 cm, which is significantly higher than the expected value of 20.5 cm, and higher than the value estimated by Model 2, 24.9 cm (see table below). Therefore, Model 2 is recommended as the base model for this year’s assessment.

	2011 model	2011 model no tc	Model 1	Model 1Q	Model 2	Model 2Q	Model 3	Model 3Q	Model 4	Model 5
Length at A_{min}	20.64	20.55	20.59	20.59	24.86	24.86	25.11	25.10	27.07	22.12
L_∞	99.74	100.16	100.07	100.16	100.51	100.57	98.64	98.68	99.79	102.01
k	0.18	0.18	0.18	0.18	0.18	0.18	0.17	0.17	0.16	0.17
$Ln(R_0)$	12.43	12.43	12.46	12.44	12.41	12.39	12.59	12.58	12.54	12.44
"Effective q"	0.893	0.890	0.860	0.897	0.877	0.906	0.829	0.857	0.794	0.865

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

Final Parameter Estimates and Associated Schedules

Table 2.13 lists the fixed and estimated parameter values for Model 2. Spawning biomass has decreased from a peak in 1980 to a low in 2008 and is increasing (Fig. 2.6). Age-0 recruits had the highest value at the beginning of the time series and has had moderate variability around 230 million since then (Fig. 2.7). The estimates of the 27-plus survey indices do not fit the data well (Fig. 2.8). There does not appear to be a strong relationship between spawning biomass and recruitment (Fig. 2.9). Fishery selectivity for all seasons and gear types varies across fisheries, seasons, and gear types (Fig. 2.10). Survey selectivity for the 27-plus survey is variable (Fig. 2.11). The fits to the fishery catch-at-length data were reasonable in most years, with poor fits to some years in the 1980s for the Jan-Apr trawl fishery (Fig. 2.12). The fits to the 27-plus survey length composition data captured the general patterns (Fig. 2.13). The fits to the 27-plus survey age composition data captured much of the variability between survey years (Fig. 2.14). The fits to the 27-plus survey mean size-at-age data were reasonable (Fig. 2.15). Estimated length-at-age curve is shown in Fig. 2.16.

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 January of 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 2.14 shows the time series of GOA Pacific cod female spawning biomass for the years 1977-2012 as estimated last year and this year under Model 2. The estimated spawning biomass time series are accompanied by their respective standard deviations.

Recruitment and Numbers at Age

Table 2.15 shows the time series of GOA Pacific cod age-0 recruits for the years 1977-2012 as estimated last year and this year under Model 2. The estimated recruitment time series are accompanied by their respective standard deviations. Table 2.5 shows the numbers-at-age for 1977-2012.

Fishing Mortality

Table 2.6 shows the "effective" annual fishing mortality by age and year for ages 1-19 and years 1977-2011.

Harvest Recommendations

Amendment 56 Reference Points

Amendment 56 to the GOA Groundfish Fishery Management Plan (FMP) defines the "overfishing level" (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater. Because reliable estimates of reference points related to maximum sustainable yield (MSY) are currently not available but reliable estimates of reference points related to spawning per recruit are available, Pacific cod in the GOA have generally been managed under Tier 3 of Amendment 56 (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 Model 2:

Reference point:	$B_{35\%}$	$B_{40\%}$	$B_{100\%}$
Spawning biomass:	82,100 t	93,900 t	234,800 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 Model 2's estimates of fishing mortality by gear for the five most recent complete years of data (2007-2011). 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 27%, longline 25%, and pot 48%. This apportionment results in estimates of $F_{35\%}$ and $F_{40\%}$ equal to **0.61** and **0.49**, respectively.

Specification of OFL and Maximum Permissible ABC

Spawning biomass for 2013 is estimated by Model 2 at a value of 111,000 t. This is well above the $B_{40\%}$ value of 93,900 t, thereby placing Pacific cod in sub-tier "a" of Tier 3. Given this, Model 2 estimates OFL, maximum permissible ABC, and the associated fishing mortality rates for 2013 and 2014 as follows (2014 values are predicated on the assumption that 2013 catch will equal 2013 maximum permissible ABC):

Units	Year	Overfishing Level	Maximum Permissible ABC
Harvest amount	2013	**97,2**00 t	**80,800**00T
Harvest amount	2014	101,100t	84,200 t
Fishing mortality rate	2013	0.61	0.49
Fishing mortality rate	2014	0.61	0.49

The age 0+ biomass projections for 2013 and 2014 from Model 2 are 449,300 t and 440,300 t.

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 2013 and 2014 are at their respective maximum permissible levels of **80,800**00 t and 84,200 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 2007-2011 surveys, the proportions would be 32% Western, 65% Central, and 3% Eastern. The SSC and GOA Plan Team have requested that the simple Kalman filter approach that has been used to estimate the proportions of Pacific cod biomass in the EBS and AI since 2004 be applied to the GOA as well. Using this approach, the proportions would be 35% Western, 61% Central, and 4% 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 2013 and 2014, 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 2013 recommended in the assessment to the $max\ F_{ABC}$ for 2013. (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 2006-2010 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 2011 or 2) above 1/2 of its MSY level in 2011 and expected to be above its MSY level in 2021 under this scenario, then the stock is not overfished.)

Scenario 7: In 2013 and 2014, 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 Model 2 in Table 2.18 (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 2013, it does not provide the best estimate of OFL for 2014, because the mean 2014 catch under Scenario 6 is predicated on the 2013 catch being equal to the 2013 OFL, whereas the actual 2013 catch will likely be less than the 2013 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 (2011) is 84,800 t. This is less than the 2011 OFL of 102,600 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 2013:

a. If spawning biomass for 2012 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.

b. If spawning biomass for 2012 is estimated to be above $B_{35\%}$ the stock is above its MSST.

c. If spawning biomass for 2012 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 2.18). If the mean spawning biomass for 2025 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 2.18):

a. If the mean spawning biomass for 2014 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2014 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2014 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 2025 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 2.18, 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 – 2011 are listed in Table 2.19.

ECOSYSTEM CONSIDERATIONS

This section is largely unchanged from last year's assessment, except for the subsection on "Incidental Catch of Nontarget Species."

Ecosystem Effects on the Stock

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

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

Fishery Effects on the Ecosystem

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

Incidental Catch of Nontarget Species

Incidental catches of nontarget species in each year 2003-2012 are shown Table 2.5. In terms of average catch over the time series, only sea stars account for more than 200 t per year.

Steller Sea Lions

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

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

Seabirds

The following is a summary of information provided by Livingston (ed., 2002): In both the BSAI and GOA, the northern fulmar (*Fulmarus glacialis*) comprises the majority of seabird bycatch, which occurs primarily in the longline fisheries, including the hook and line fishery for Pacific cod (Tables 2.30b and 2.30b). Shearwater (*Puffinus* spp.) distribution overlaps with the Pacific cod longline fishery in the Bering Sea, and with trawl fisheries in general in both the Bering Sea and GOA. Black-footed albatross (*Phoebastria nigripes*) is taken in much greater numbers in the GOA longline fisheries than the Bering

Sea longline fisheries, but is not taken in the trawl fisheries. The distribution of Laysan albatross (*Phoebastria immutabilis*) appears to overlap with the longline fisheries in the central and western Aleutians. The distribution of short-tailed albatross (*Phoebastria albatrus*) also overlaps with the Pacific cod longline fishery along the Aleutian chain, although the majority of the bycatch has taken place along the northern portion of the Bering Sea shelf edge (in contrast, only two takes have been recorded in the GOA). Some success has been obtained in devising measures to mitigate fishery-seabird interactions. For example, on vessels larger than 60 ft. LOA, paired streamer lines of specified performance and material standards have been found to reduce seabird incidental take significantly.

Fishery Usage of Habitat

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

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

In the BS, both longline and trawl effort was concentrated north of False Pass (Unimak Island) and along the shelf edge represented by the boundary of areas 513, 517 (in addition, longline effort was concentrated along the shelf edge represented by the boundary of areas 521-533). In the AI, both longline and trawl effort were dispersed over a wide area along the shelf edge. The catcher vessel longline fishery in the AI occurred primarily over mud bottoms. Longline catcher-processors in the AI tended to fish more over rocky bottoms. In the GOA, fishing effort was also dispersed over a wide area along the shelf, though pockets of trawl effort were located near Chirikof, Cape Barnabus, Cape Chiniak and Marmot Flats. The GOA longline fishery for Pacific cod generally took place over gravel, cobble, mud, sand, and rocky bottoms, in depths of 25 fathoms to 140 fathoms.

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

DATA GAPS AND RESEARCH PRIORITIES

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

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Tables

Table 2.1. Catch (t) for 1991 through 2012 by jurisdiction and gear type (as of 3 November 2012)

	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	9,585	12,740	161	41,371	0	7,966	3,242	11,207	52,579
2004	17,513	10,380	14,965	400	43,258	0	10,602	2,765	13,367	56,625
2005	14,549	5,758	14,749	203	35,260	0	9,653	2,673	12,326	47,585
2006	13,131	10,274	14,795	118	38,319	0	8,890	646	9,536	47,854
2007	14,774	11,677	13,515	40	40,006	0	10,885	574	11,459	51,465
2008	20,293	12,358	11,230	62	43,943	0	13,438	1,568	15,006	58,949
2009	13,981	14,050	11,576	194	39,801	325	10,293	2,497	13,116	52,917
2010	21,791	16,674	20,114	423	59,003	375	14,604	4,090	19,069	78,072
2011	16,364	16,508	29,228	721	62,821	725	16,669	4,625	22,018	84,839
2012	19,704	13,017	19,023	722	52,467	628	15,912	4,594	21,134	73,601

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 2012 is current through 3 November. 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	51,462	52,264	68,859	97,600
2008	58,964	50,269	64,493	88,660
2009	52,920	41,807	55,300	66,000
2010	78,071	59,563	79,100	94,100
2011	84,839	65,100	86,800	102,600
2012	73,601	65,700	87,600	104,000

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

	Regulatory area		
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 (ABC)	28.03	56.94	2.63
2012 (TAC)	21.02	42.71	1.97

Table 2.4 Estimated retained-and discarded GOA Pacific cod from federal waters (source: NMFS/NOAA/AKFIN)

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	1,901	39,632	41,533
2002	3,713	38,594	42,307
2003	2,413	50,046	52,459
2004	1,266	55,305	56,571
2005	1,040	46,499	47,539
2006	1,831	45,960	47,791
2007	1,449	49,805	51,253
2008	3,310	55,375	58,685
2009	3,842	48,709	52,551
2010	2,831	74,789	77,620
2011	1,806	82,317	84,124
2012	964	72,111	73,075

Table 2.5 - Incidental catch (t) of non-target species groups by GOA Pacific cod fisheries, 2003-2012 (as of 28 September 2012)

Species/group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Benthic urochordata	0.0	0.0	0.0	0.0	0.0	0.6	3.0	0.0	0.2	0.0
Birds	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bivalves	1.3	0.3	1.3	2.1	1.2	1.7	4.2	2.7	6.1	2.8
Brittle star unidentified	0.0	0.1	0.2	0.1	0.3	0.1	0.0	0.1	2.1	0.0
Capelin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corals Bryozoans	0.0	0.1	0.0	0.1	0.2	0.0	1.7	0.0	0.7	1.9
Dark Rockfish	0.0	0.0	0.0	0.0	0.0	0.3	2.7	12.3	2.4	0.9
Eelpouts	0.3	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1
Eulachon	0.0	0.0	0.0	2.4	0.0	0.1	0.0	0.6	0.0	0.0
Giant Grenadier	0.0	0.0	0.0	21.9	81.5	31.0	51.3	140.9	60.4	8.6
Greenlings	3.1	6.2	1.5	3.7	0.8	7.1	1.3	0.8	0.8	1.6
Grenadier	5.2	0.4	0.0	0.6	0.0	66.0	6.6	0.0	8.2	0.0
Gunnels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hermit crab unidentified	1.0	0.1	0.4	0.5	1.7	2.9	3.9	2.1	0.8	0.4
Invertebrate unidentified	0.5	3.7	0.0	12.6	1.6	1.3	0.1	1.1	8.9	4.0
Misc crabs	1.0	0.3	1.7	0.7	6.6	2.4	1.5	3.4	2.4	2.7
Misc crustaceans	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Misc fish	85.6	136.5	152.5	176.0	539.4	210.5	99.0	87.6	134.0	96.5
Misc inverts (worms etc)	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Other osmerids	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Pacific Sand lance	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Pandalid shrimp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Scypho jellies	8.7	1.5	1.1	4.6	0.1	0.4	0.2	10.8	0.8	0.4
Sea anemone unidentified	0.9	1.5	0.7	0.3	5.1	6.0	6.6	7.3	8.8	4.3
Sea pens whips	0.1	0.0	0.0	3.2	1.0	0.0	3.3	3.1	1.4	0.7
Sea star	468.4	1009.3	937.7	703.5	299.0	316.5	471.9	869.4	717.0	390.1
Snails	5.0	0.6	4.8	2.9	0.8	0.9	2.5	0.7	1.3	1.9
Sponge unidentified	0.2	0.6	1.0	1.2	0.0	1.1	1.6	0.4	0.5	0.0
Stichaeidae	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0
Surf smelt	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
urchins dollars cucumbers	0.8	0.5	1.1	1.0	3.2	0.5	1.3	0.5	2.2	3.0

Table 2.6 Catch (t) of Pacific cod by year, gear, and season for the years 1991-2012 as configured in the stock assessment models (as of 3 November 2012); values for 2012 season 5 were estimated given the average fraction of catch in season 5 for 2000 – 2011 (0.030931) and the average fraction of each gear type in season 5 for 2000 – 2011 (0.110294, 0.315936, 0.57377, 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	26,750
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	2,356	3,127	15,096	7,094	401	4,262	11,757	20,066	546	3,998	24,610
2008	11,156	4,107	6,118	21,381	9,312	641	2,618	12,571	20,394	0	4,600	24,994
2009	6,876	4,613	3,880	15,369	9,598	1,374	3,954	14,926	19,026	0	3,596	22,622
2010	11,009	5,110	7,728	23,847	11,672	776	5,130	17,578	31,009	1	5,638	36,648
2011	9,571	1,939	5,734	17,244	10,248	1,229	6,301	17,778	36,953	102	12,764	49,819
2012	17,131	2,685	2,566	22,382	12,178	560	2,378	15,116	30,068	138	8,247	38,453

Table 2.7 Age compositions observed by the sub-27 and 27-plus GOA bottom trawl survey, 1987-2011. Nact = actual sample size (these get rescaled so that the average across the combined sub-27 and 27-plus age compositions equals 300). 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 2.8 – Relative sub-27 and 27-plus size composition from the 1984 – 2011 bottom trawl surveys (in bins of 4 to 120+ cm)

Year	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007	2009	2011
N	53	39	22	78	89	58	68	22	37	125	103	34
4	0	0	0	0	0	0	1	0	0	0	0	0
5	0	0	0	0	0	0	0	0	8	0	0	0
6	7	0	9	26	0	0	0	1	0	0	0	0
7	65	0	27	14	0	0	0	0	0	0	0	2
8	144	14	27	3	2	0	0	0	1	0	4	0
9	168	30	61	0	0	0	1	0	0	0	0	0
10	94	56	28	0	0	0	0	0	0	0	0	0
11	39	30	0	0	0	2	5	0	0	2	12	1
12	6	20	1	1	1	5	9	0	1	2	46	1
13	3	2	0	7	4	3	15	0	2	4	179	6
14	1	1	0	11	10	21	39	5	6	23	420	4
15	0	4	0	28	17	22	42	3	24	80	391	7
16	7	11	2	95	31	37	35	14	30	159	221	29
17	2	22	4	159	49	58	39	11	40	228	70	38
18	6	36	4	149	86	72	67	12	47	282	30	42
19	10	39	12	121	98	86	78	32	62	292	22	38
20	12	59	21	71	176	104	68	32	53	219	22	50
21	15	38	25	60	135	89	87	51	67	173	20	57
22	24	51	21	74	161	106	69	46	65	115	22	34
23	20	48	34	79	184	89	103	39	41	83	23	47
24	45	58	28	103	173	60	122	25	43	70	14	61
25	42	37	19	95	113	51	112	33	27	57	12	55
26	66	15	7	62	77	55	120	28	31	65	7	24
Year	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007	2009	2011
N	1126	1287	752	1083	736	528	390	596	426	490	1090	771
27	100	28	45	74	138	26	73	27	36	110	37	22
28	138	37	19	65	106	23	85	19	23	83	48	19
29	186	64	14	53	48	21	68	20	11	89	82	17
30	141	130	23	60	11	38	72	16	25	87	101	21
31	149	184	52	88	39	36	63	21	28	66	126	35
32	172	222	45	115	60	61	48	28	50	82	124	95
33	199	230	64	135	87	87	63	38	52	83	173	78
34	171	373	78	143	78	105	52	53	70	93	215	139
35	229	524	91	170	69	103	65	69	68	107	324	233
36	164	507	71	155	106	110	80	84	88	135	357	240
37	176	543	84	169	137	113	98	83	72	166	429	276
38	219	600	133	192	138	110	128	129	84	197	359	183
39	212	601	137	219	174	123	165	147	61	210	403	281
40	375	637	138	259	180	112	119	185	64	265	386	206
41	403	582	157	328	204	146	163	164	80	257	358	391
42	339	409	207	393	208	159	149	216	79	295	349	429
43	413	388	142	396	178	201	141	243	76	315	362	539
44	393	455	224	495	170	191	139	294	64	245	364	512
45	423	249	224	435	191	203	152	281	78	252	370	562
46	475	272	232	410	168	211	125	258	86	235	375	487

Table 2.8 – Relative sub-27 and 27-plus size composition from the 1984 – 2011 bottom trawl surveys (in bins of 4 to 120+ cm)

Year	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007	2009	2011
N	53	39	22	78	89	58	68	22	37	125	103	34
47	448	301	325	474	172	197	138	236	74	163	343	436
48	491	442	442	335	150	230	143	262	98	203	413	395
49	629	453	495	357	207	196	178	244	90	169	384	384
50	719	547	396	434	222	233	128	261	118	174	417	358
51	829	694	366	411	201	176	170	226	116	131	491	308
52	704	694	370	447	279	217	140	273	162	130	523	283
53	689	709	345	590	297	217	129	265	185	104	503	327
54	702	661	417	672	258	238	173	294	275	136	637	369
55	691	706	324	696	339	245	145	336	248	144	529	373
56	550	611	505	587	301	244	144	282	311	133	734	349
57	609	521	390	631	349	296	135	328	308	179	587	368
58	556	588	391	663	369	297	150	314	357	189	671	328
59	473	517	405	523	314	288	141	365	318	190	605	320
60	454	536	390	563	386	261	148	301	359	164	556	273
61	376	426	433	484	443	260	143	300	252	178	438	250
62	270	413	312	396	458	232	130	271	252	160	406	254
63	339	391	281	351	383	197	185	236	214	163	372	216
64	222	428	289	325	340	191	146	201	195	143	410	217
65	213	343	275	319	439	183	153	161	120	116	238	143
66	167	274	240	362	387	163	106	181	120	127	272	129
67	141	275	181	312	327	142	112	134	87	109	231	110
68	134	207	147	278	262	130	88	121	94	83	161	91
69	133	198	133	216	271	130	66	103	69	93	123	59
70	82	142	173	193	236	107	94	96	62	79	131	54
71	55	140	119	137	160	81	59	74	52	59	98	44
72	74	126	122	150	112	82	61	83	40	60	75	45
73	81	85	91	123	93	69	35	69	34	42	72	27
74	42	102	79	96	131	54	49	51	29	44	44	14
75	64	73	51	64	59	36	36	46	27	51	65	17
76	66	65	50	72	65	35	35	32	33	21	45	17
77	60	34	42	59	47	34	30	36	20	31	36	11
78	31	53	37	56	50	32	17	36	16	20	23	9
79	84	47	36	46	52	22	13	39	9	10	18	6
80	95	26	32	28	25	10	20	30	17	11	15	13
81	41	20	29	27	27	10	12	28	12	10	11	4
82	46	14	29	25	23	18	5	25	10	6	18	4
83	25	22	23	14	15	12	4	14	11	7	6	2
84	30	14	30	16	14	5	10	16	23	3	5	5
85	27	23	15	15	12	11	2	12	11	2	5	1
86	20	13	14	12	15	3	5	9	4	2	4	2
87	22	7	10	10	9	3	4	8	11	4	4	2
88	17	6	14	8	7	2	3	4	11	1	2	2
89	11	8	21	15	7	8	4	3	9	3	2	1
90	14	2	11	4	8	1	2	4	26	2	1	1
91	6	2	10	4	13	2	2	6	17	1	0	1

Table 2.8 – Relative sub-27 and 27-plus size composition from the 1984 – 2011 bottom trawl surveys (in bins of 4 to 120+ cm)

Year	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007	2009	2011
N	53	39	22	78	89	58	68	22	37	125	103	34
92	9	4	4	4	8	0	2	4	17	1	2	0
93	3	2	3	6	6	4	7	1	19	3	1	0
94	2	4	8	4	1	0	2	0	10	1	24	0
95	7	2	2	5	7	1	2	1	22	3	1	0
96	1	4	5	4	3	0	2	1	20	1	1	1
97	1	0	3	3	5	2	2	1	19	1	1	0
98	2	1	3	3	2	2	0	1	20	1	0	0
99	0	2	1	2	1	4	0	0	18	0	1	0
100	1	1	1	4	4	3	2	0	10	1	1	0
101	1	2	3	3	1	0	2	0	13	1	1	0
102	0	1	2	2	7	1	1	0	4	1	1	0
103	0	0	1	1	2	0	0	0	8	2	0	0
104	0	0	0	1	1	0	0	0	11	1	0	0
105	0	1	1	1	2	0	0	0	5	0	1	0
106	0	0	0	0	0	0	0	0	2	1	0	0
107	0	0	0	1	1	0	0	0	0	1	0	0
108	0	0	0	0	0	0	0	0	0	0	0	1
109	0	0	0	0	0	0	0	0	0	1	0	0
110	0	0	0	0	0	0	0	0	0	1	0	0
111	0	0	0	0	0	0	0	0	0	0	0	0
112	0	0	0	0	0	0	0	0	0	0	0	0
113	0	0	0	0	0	0	0	0	0	0	0	0
114	0	0	0	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0	0
116	0	0	0	0	0	0	0	0	0	0	0	0
117	0	0	0	0	0	0	0	0	0	0	0	0
118	0	0	0	0	0	0	0	0	0	0	0	0
119	0	0	0	0	0	0	0	0	0	0	0	0
120+	1	0	0	0	0	0	0	0	0	0	0	0

Table 2.9 – 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 2.10 – 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 2.11 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	0.146	320,525	0.156	296,057	0.175	19,526	0.596
1987	394,987	0.130	247,020	0.185	238,165	0.234	6,772	0.374
1990	416,788	0.153	212,132	0.208	193,577	0.243	14,739	0.412
1993	409,848	0.179	231,963	0.190	214,244	0.210	17,021	0.372
1996	538,154	0.200	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	0.204	158,424	0.180	137,041	0.203	21,384	0.270
2003	297,402	0.150	159,749	0.129	153,895	0.134	5,854	0.231
2005	308,091	0.262	139,852	0.208	127,282	0.221	12,570	0.388
2007	233,310	0.139	192,025	0.175	134,261	0.163	57,764	0.425
2009	752,651	0.303	573,509	0.286	422,370	0.239	151,139	0.867
2011	500,975	0.136	348,060	0.177	339,410	0.178	8,650	0.347

Table 2.12. 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	2011 model no tc	Model 1	Model 2	Model 3	Model 4	Model 5
Number of parameters	253	253	245	239	245	239	245
Likelihood components (-ln)							
Survey indices	3	4	15	5	4	-7	15
Length compositions	3,075	3,187	3,147	2,895	3,089	2,862	3,124
Age compositions	118	162	151	82	129	42	157
Size-at-age	623	637	642	501	0	0	557
Recruitment	-22	-22	-23	-24	-22	-21	-23
27-plus survey indices	13	14	12	5	2	-7	12
Sub-27 survey indices	-10	-10	4	-	2	2	3
Total	3,797	3,967	3,931	3,459	3,199	2,875	3,831
Length composition likelihoods (-ln)							
Jan-Apr Trawl	713	710	712	698	709	671	707
Jan-Apr LL	184	187	185	180	183	176	187
Jan-Apr Pot	285	288	286	281	287	277	288
May-Aug Trawl	598	609	612	571	593	586	616
May-Aug LL	112	117	117	107	114	111	117
May-Aug Pot	279	284	286	260	271	260	283
Sep-Dec Trawl	465	470	470	461	476	457	469
Sep-Dec LL	72	73	72	70	71	69	71
Sep-Dec Pot	180	184	184	179	184	179	184
27-plus survey	109	130	127	89	100	78	116
Sub-27 survey	77	137	96	-	99	-	86
Age compositions likelihoods (-ln)							
Age 27-plus	101	110	112	82	88	42	113
Age sub-27	17	52	39	-	41	-	44
Size-at-age likelihoods (-ln)							
Size-at-age 27-plus	552	568	572	501	0	0	557
Size-at-age sub-27	71	68	69	-	0	-	0
"Effective q"	0.893	0.890	0.860	0.877	0.829	0.794	0.865

Table 2.13 – Fixed and estimated parameters and their asymptotic standard deviations for Model 2

Label	Value	SD
NatM_p_1_Fem_GP_1	0.38	_
L_at_Amin_Fem_GP_1	24.8646	0.293326
L_at_Amax_Fem_GP_1	100.506	0.700256
VonBert_K_Fem_GP_1	0.175614	0.002925
CV_young_Fem_GP_1	3.13	_
CV_old_Fem_GP_1	6.55	_
Wtlen_1_Fem	8.84E-06	_
Wtlen_2_Fem	3.07181	_
Mat50%_Fem	4.35	_
Mat_slope_Fem	-1.9632	_
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	0.540713	0.010072
AgeKeyParm3	9.50E-09	_
AgeKeyParm4	0	_
AgeKeyParm5	0.096	_
AgeKeyParm6	1.471	_
AgeKeyParm7	0	_
F-WL1_seas_1	-0.00427	_
F-WL1_seas_2	-0.09781	_
F-WL1_seas_3	0.260771	_
F-WL1_seas_4	0.706346	_
F-WL1_seas_5	-0.20535	_
F-WL2_seas_1	0.004059	_
F-WL2_seas_2	0.005264	_
F-WL2_seas_3	-0.02684	_
F-WL2_seas_4	-0.05997	_
F-WL2_seas_5	0.015615	_
SR_LN(R0)	12.406	0.039547
SR_BH_steep	1	_
SR_sigmaR	0.41	_
SR_envlink	0	_
SR_R1_offset	-0.37431	0.126796
SR_autocorr	0	_
Early_InitAge_13	-0.24235	0.368934
Early_InitAge_12	-0.30545	0.360363
Early_InitAge_11	-0.36531	0.352674
Early_InitAge_10	-0.4119	0.346565
Early_InitAge_9	-0.41976	0.343688

Label	Value	SD
Early_InitAge_8	-0.35184	0.34594
Early_InitAge_7	-0.16307	0.354432
Early_InitAge_6	0.122132	0.357053
Early_InitAge_5	0.284351	0.342494
Early_InitAge_4	1.11813	0.194055
Early_InitAge_3	0.099255	0.21617
Early_InitAge_2	0.093799	0.17006
Early_InitAge_1	-0.08392	0.177035
Main_RecrDev_1977	1.1857	0.066999
Main_RecrDev_1978	-0.14115	0.107732
Main_RecrDev_1979	-0.25471	0.07766
Main_RecrDev_1980	-0.06752	0.061145
Main_RecrDev_1981	-0.06344	0.062944
Main_RecrDev_1982	0.244591	0.065403
Main_RecrDev_1983	-0.05146	0.080939
Main_RecrDev_1984	-0.38361	0.093914
Main_RecrDev_1985	0.401006	0.061908
Main_RecrDev_1986	-0.32373	0.077128
Main_RecrDev_1987	0.099437	0.055324
Main_RecrDev_1988	0.004479	0.056561
Main_RecrDev_1989	0.141577	0.056315
Main_RecrDev_1990	0.230005	0.052957
Main_RecrDev_1991	0.089331	0.053531
Main_RecrDev_1992	-0.0721	0.059286
Main_RecrDev_1993	0.035635	0.053221
Main_RecrDev_1994	0.03759	0.050538
Main_RecrDev_1995	0.037504	0.047647
Main_RecrDev_1996	-0.06485	0.048132
Main_RecrDev_1997	-0.35573	0.051844
Main_RecrDev_1998	-0.47488	0.054299
Main_RecrDev_1999	-0.19136	0.047833
Main_RecrDev_2000	-0.02899	0.044986
Main_RecrDev_2001	-0.35634	0.050699
Main_RecrDev_2002	-0.52407	0.054972
Main_RecrDev_2003	-0.31544	0.051633
Main_RecrDev_2004	-0.35593	0.058906
Main_RecrDev_2005	0.099029	0.067964
Main_RecrDev_2006	0.353826	0.082012
Main_RecrDev_2007	0.300238	0.108483
Main_RecrDev_2008	0.46615	0.122938
Main_RecrDev_2009	0.392219	0.199382
Main_RecrDev_2010	-0.04233	0.392489
Main_RecrDev_2011	-0.05067	0.40328
InitF_1Jan-Apr_Trawl_Fishery	0.075524	0.010688
InitF_2May-Aug_Trawl_Fishery	0	_
InitF_3Sep-Dec_Trawl_Fishery	0	_
InitF_4Jan-Apr_Longline_Fishery	0	_
InitF_5May-Aug_Longline_Fishery	0	_
InitF_6Sep-Dec_Longline_Fishery	0	_
InitF_7Jan-Apr_Pot_Fishery	0	_

Label	Value	SD
InitF_8May-Aug_Pot_Fishery	0	_
InitF_9Sep-Dec_Pot_Fishery	0	_
Q_envlink_10_27plus_Trawl_Survey	0.545013	0.113976
Q_base_10_27plus_Trawl_Survey	0	_
SizeSel_1P_1_Jan-Apr_Trawl_Fishery	0	_
SizeSel_1P_2_Jan-Apr_Trawl_Fishery	0	_
SizeSel_1P_3_Jan-Apr_Trawl_Fishery	5.86635	0.028721
SizeSel_1P_4_Jan-Apr_Trawl_Fishery	0	_
SizeSel_1P_5_Jan-Apr_Trawl_Fishery	-10	_
SizeSel_1P_6_Jan-Apr_Trawl_Fishery	10	_
SizeSel_2P_1_May-Aug_Trawl_Fishery	0	_
SizeSel_2P_2_May-Aug_Trawl_Fishery	-9.67559	8.93329
SizeSel_2P_3_May-Aug_Trawl_Fishery	0	_
SizeSel_2P_4_May-Aug_Trawl_Fishery	4.42432	0.445711
SizeSel_2P_5_May-Aug_Trawl_Fishery	-10	_
SizeSel_2P_6_May-Aug_Trawl_Fishery	0	_
SizeSel_3P_1_Sep-Dec_Trawl_Fishery	0	_
SizeSel_3P_2_Sep-Dec_Trawl_Fishery	0	_
SizeSel_3P_3_Sep-Dec_Trawl_Fishery	0	_
SizeSel_3P_4_Sep-Dec_Trawl_Fishery	3.82519	0.580275
SizeSel_3P_5_Sep-Dec_Trawl_Fishery	-10	_
SizeSel_3P_6_Sep-Dec_Trawl_Fishery	-1.01729	0.266201
SizeSel_4P_1_Jan-Apr_Longline_Fishery	0	_
SizeSel_4P_2_Jan-Apr_Longline_Fishery	0	_
SizeSel_4P_3_Jan-Apr_Longline_Fishery	0	_
SizeSel_4P_4_Jan-Apr_Longline_Fishery	3.98158	0.354505
SizeSel_4P_5_Jan-Apr_Longline_Fishery	-10	_
SizeSel_4P_6_Jan-Apr_Longline_Fishery	0	_
SizeSel_5P_1_May-Aug_Longline_Fishery	0	_
SizeSel_5P_2_May-Aug_Longline_Fishery	-9.15336	19.8785
SizeSel_5P_3_May-Aug_Longline_Fishery	0	_
SizeSel_5P_4_May-Aug_Longline_Fishery	4.50634	0.499382
SizeSel_5P_5_May-Aug_Longline_Fishery	-10	_
SizeSel_5P_6_May-Aug_Longline_Fishery	0	_
SizeSel_6P_1_Sep-Dec_Longline_Fishery	0	_
SizeSel_6P_2_Sep-Dec_Longline_Fishery	-13.6793	_
SizeSel_6P_3_Sep-Dec_Longline_Fishery	0	_
SizeSel_6P_4_Sep-Dec_Longline_Fishery	0	_
SizeSel_6P_5_Sep-Dec_Longline_Fishery	-10	_
SizeSel_6P_6_Sep-Dec_Longline_Fishery	0	_
SizeSel_7P_1_Jan-Apr_Pot_Fishery	0	_
SizeSel_7P_2_Jan-Apr_Pot_Fishery	-14.3135	_
SizeSel_7P_3_Jan-Apr_Pot_Fishery	0	_
SizeSel_7P_4_Jan-Apr_Pot_Fishery	0	_
SizeSel_7P_5_Jan-Apr_Pot_Fishery	-10	_
SizeSel_7P_6_Jan-Apr_Pot_Fishery	0	_
SizeSel_8P_1_May-Aug_Pot_Fishery	0	_
SizeSel_8P_2_May-Aug_Pot_Fishery	-9.05637	21.6445
SizeSel_8P_3_May-Aug_Pot_Fishery	0	_
SizeSel_8P_4_May-Aug_Pot_Fishery	5.08762	0.495773

Label	Value	SD
SizeSel_8P_5_May-Aug_Pot_Fishery	-10	_
SizeSel_8P_6_May-Aug_Pot_Fishery	-1.15075	0.598842
SizeSel_9P_1_Sep-Dec_Pot_Fishery	0	_
SizeSel_9P_2_Sep-Dec_Pot_Fishery	-5.45394	9.91802
SizeSel_9P_3_Sep-Dec_Pot_Fishery	0	_
SizeSel_9P_4_Sep-Dec_Pot_Fishery	4.62388	0.523816
SizeSel_9P_5_Sep-Dec_Pot_Fishery	-10	_
SizeSel_9P_6_Sep-Dec_Pot_Fishery	0	_
AgeSel_10P_1_27plus_Trawl_Survey	0	_
AgeSel_10P_2_27plus_Trawl_Survey	0	_
AgeSel_10P_3_27plus_Trawl_Survey	0	_
AgeSel_10P_4_27plus_Trawl_Survey	0	_
AgeSel_10P_5_27plus_Trawl_Survey	-10	_
AgeSel_10P_6_27plus_Trawl_Survey	0	_
SizeSel_1P_1_Jan-Apr_Trawl_Fishery_BLK1repl_1977	62.6855	1.3002
SizeSel_1P_1_Jan-Apr_Trawl_Fishery_BLK1repl_1990	74.319	0.616703
SizeSel_1P_1_Jan-Apr_Trawl_Fishery_BLK1repl_1995	75.8209	0.60921
SizeSel_1P_1_Jan-Apr_Trawl_Fishery_BLK1repl_2000	70.2658	0.661814
SizeSel_1P_1_Jan-Apr_Trawl_Fishery_BLK1repl_2005	71.2341	0.801381
SizeSel_2P_1_May-Aug_Trawl_Fishery_BLK2repl_1977	55.3117	1.49943
SizeSel_2P_1_May-Aug_Trawl_Fishery_BLK2repl_1985	62.6872	1.28172
SizeSel_2P_1_May-Aug_Trawl_Fishery_BLK2repl_1990	67.23	1.14915
SizeSel_2P_1_May-Aug_Trawl_Fishery_BLK2repl_2000	68.7701	1.66131
SizeSel_2P_1_May-Aug_Trawl_Fishery_BLK2repl_2005	72.773	1.82712
SizeSel_2P_3_May-Aug_Trawl_Fishery_BLK2repl_1977	4.54026	0.220047
SizeSel_2P_3_May-Aug_Trawl_Fishery_BLK2repl_1985	5.15545	0.157182
SizeSel_2P_3_May-Aug_Trawl_Fishery_BLK2repl_1990	5.17156	0.120258
SizeSel_2P_3_May-Aug_Trawl_Fishery_BLK2repl_2000	5.7978	0.132544
SizeSel_2P_3_May-Aug_Trawl_Fishery_BLK2repl_2005	5.93216	0.113571
SizeSel_2P_6_May-Aug_Trawl_Fishery_BLK2repl_1977	0.135011	0.40069
SizeSel_2P_6_May-Aug_Trawl_Fishery_BLK2repl_1985	-0.98921	0.375539
SizeSel_2P_6_May-Aug_Trawl_Fishery_BLK2repl_1990	-2.48035	0.736248
SizeSel_2P_6_May-Aug_Trawl_Fishery_BLK2repl_2000	-1.10311	0.760783
SizeSel_2P_6_May-Aug_Trawl_Fishery_BLK2repl_2005	-1.38551	1.02363
SizeSel_3P_1_Sep-Dec_Trawl_Fishery_BLK3repl_1977	45.5521	4.3318
SizeSel_3P_1_Sep-Dec_Trawl_Fishery_BLK3repl_1980	56.972	3.6502
SizeSel_3P_1_Sep-Dec_Trawl_Fishery_BLK3repl_1985	61.9336	1.77117
SizeSel_3P_1_Sep-Dec_Trawl_Fishery_BLK3repl_1990	63.6057	3.05231
SizeSel_3P_1_Sep-Dec_Trawl_Fishery_BLK3repl_1995	75.3712	1.70177
SizeSel_3P_1_Sep-Dec_Trawl_Fishery_BLK3repl_2000	71.3116	2.4504
SizeSel_3P_1_Sep-Dec_Trawl_Fishery_BLK3repl_2005	74.5874	1.52915
SizeSel_3P_2_Sep-Dec_Trawl_Fishery_BLK3repl_1977	-2.36684	1.66575
SizeSel_3P_2_Sep-Dec_Trawl_Fishery_BLK3repl_1980	-3.90494	5.18596
SizeSel_3P_2_Sep-Dec_Trawl_Fishery_BLK3repl_1985	-9.16494	19.6762
SizeSel_3P_2_Sep-Dec_Trawl_Fishery_BLK3repl_1990	-0.58724	0.273523
SizeSel_3P_2_Sep-Dec_Trawl_Fishery_BLK3repl_1995	-9.27226	17.6423
SizeSel_3P_2_Sep-Dec_Trawl_Fishery_BLK3repl_2000	-4.79988	9.87583
SizeSel_3P_2_Sep-Dec_Trawl_Fishery_BLK3repl_2005	-9.01982	22.2955
SizeSel_3P_3_Sep-Dec_Trawl_Fishery_BLK3repl_1977	3.74845	0.840923
SizeSel_3P_3_Sep-Dec_Trawl_Fishery_BLK3repl_1980	5.05386	0.360485

Label	Value	SD
SizeSel_3P_3_Sep-Dec_Trawl_Fishery_BLK3repl_1985	5.70268	0.199345
SizeSel_3P_3_Sep-Dec_Trawl_Fishery_BLK3repl_1990	5.49662	0.246313
SizeSel_3P_3_Sep-Dec_Trawl_Fishery_BLK3repl_1995	6.26033	0.104742
SizeSel_3P_3_Sep-Dec_Trawl_Fishery_BLK3repl_2000	5.93847	0.141185
SizeSel_3P_3_Sep-Dec_Trawl_Fishery_BLK3repl_2005	6.00674	0.089111
SizeSel_4P_1_Jan-Apr_Longline_Fishery_BLK4repl_1977	57.6245	0.872187
SizeSel_4P_1_Jan-Apr_Longline_Fishery_BLK4repl_1985	73.4914	1.31381
SizeSel_4P_1_Jan-Apr_Longline_Fishery_BLK4repl_1990	70.6922	1.11366
SizeSel_4P_1_Jan-Apr_Longline_Fishery_BLK4repl_1995	74.2486	0.804566
SizeSel_4P_1_Jan-Apr_Longline_Fishery_BLK4repl_2000	69.3501	0.794999
SizeSel_4P_1_Jan-Apr_Longline_Fishery_BLK4repl_2005	69.1428	0.500477
SizeSel_4P_2_Jan-Apr_Longline_Fishery_BLK4repl_1977	-0.45882	0.104061
SizeSel_4P_2_Jan-Apr_Longline_Fishery_BLK4repl_1985	-4.53878	4.74788
SizeSel_4P_2_Jan-Apr_Longline_Fishery_BLK4repl_1990	-5.10085	23.4596
SizeSel_4P_2_Jan-Apr_Longline_Fishery_BLK4repl_1995	-9.08594	21.1225
SizeSel_4P_2_Jan-Apr_Longline_Fishery_BLK4repl_2000	-4.50675	4.69456
SizeSel_4P_2_Jan-Apr_Longline_Fishery_BLK4repl_2005	-9.76238	6.76407
SizeSel_4P_3_Jan-Apr_Longline_Fishery_BLK4repl_1977	4.67492	0.102688
SizeSel_4P_3_Jan-Apr_Longline_Fishery_BLK4repl_1985	5.77666	0.076999
SizeSel_4P_3_Jan-Apr_Longline_Fishery_BLK4repl_1990	5.30472	0.084134
SizeSel_4P_3_Jan-Apr_Longline_Fishery_BLK4repl_1995	5.45472	0.061573
SizeSel_4P_3_Jan-Apr_Longline_Fishery_BLK4repl_2000	5.12967	0.068966
SizeSel_4P_3_Jan-Apr_Longline_Fishery_BLK4repl_2005	5.05858	0.045808
SizeSel_4P_6_Jan-Apr_Longline_Fishery_BLK4repl_1977	-0.83026	0.412807
SizeSel_4P_6_Jan-Apr_Longline_Fishery_BLK4repl_1985	0.808976	0.27459
SizeSel_4P_6_Jan-Apr_Longline_Fishery_BLK4repl_1990	1.19642	0.418355
SizeSel_4P_6_Jan-Apr_Longline_Fishery_BLK4repl_1995	1.17252	0.477003
SizeSel_4P_6_Jan-Apr_Longline_Fishery_BLK4repl_2000	-0.11576	0.225128
SizeSel_4P_6_Jan-Apr_Longline_Fishery_BLK4repl_2005	0.068151	0.216705
SizeSel_5P_1_May-Aug_Longline_Fishery_BLK5repl_1977	56.3137	2.33386
SizeSel_5P_1_May-Aug_Longline_Fishery_BLK5repl_1980	56.6541	0.849127
SizeSel_5P_1_May-Aug_Longline_Fishery_BLK5repl_1990	71.0133	2.23473
SizeSel_5P_1_May-Aug_Longline_Fishery_BLK5repl_2000	72.2856	1.49444
SizeSel_5P_3_May-Aug_Longline_Fishery_BLK5repl_1977	4.45164	0.333884
SizeSel_5P_3_May-Aug_Longline_Fishery_BLK5repl_1980	4.37157	0.132142
SizeSel_5P_3_May-Aug_Longline_Fishery_BLK5repl_1990	5.07006	0.257167
SizeSel_5P_3_May-Aug_Longline_Fishery_BLK5repl_2000	4.99889	0.145532
SizeSel_5P_6_May-Aug_Longline_Fishery_BLK5repl_1977	0.423222	0.664
SizeSel_5P_6_May-Aug_Longline_Fishery_BLK5repl_1980	-0.52565	0.208549
SizeSel_5P_6_May-Aug_Longline_Fishery_BLK5repl_1990	-1.57636	1.18917
SizeSel_5P_6_May-Aug_Longline_Fishery_BLK5repl_2000	1.05756	0.988512
SizeSel_6P_1_Sep-Dec_Longline_Fishery_BLK6repl_1977	58.9952	1.958
SizeSel_6P_1_Sep-Dec_Longline_Fishery_BLK6repl_1980	56.9678	0.387529
SizeSel_6P_1_Sep-Dec_Longline_Fishery_BLK6repl_1990	68.8194	0.522085
SizeSel_6P_3_Sep-Dec_Longline_Fishery_BLK6repl_1977	4.63818	0.232946
SizeSel_6P_3_Sep-Dec_Longline_Fishery_BLK6repl_1980	4.32809	0.061538
SizeSel_6P_3_Sep-Dec_Longline_Fishery_BLK6repl_1990	4.96458	0.052051
SizeSel_6P_4_Sep-Dec_Longline_Fishery_BLK6repl_1977	7.56207	0.847303
SizeSel_6P_4_Sep-Dec_Longline_Fishery_BLK6repl_1980	4.16839	0.149849
SizeSel_6P_4_Sep-Dec_Longline_Fishery_BLK6repl_1990	3.86187	0.411326

Label	Value	SD
SizeSel_6P_6_Sep-Dec_Longline_Fishery_BLK6repl_1977	-8.45229	31.434
SizeSel_6P_6_Sep-Dec_Longline_Fishery_BLK6repl_1980	-1.37793	0.103302
SizeSel_6P_6_Sep-Dec_Longline_Fishery_BLK6repl_1990	-0.19865	0.211466
SizeSel_7P_1_Jan-Apr_Pot_Fishery_BLK7repl_1977	69.0369	0.384451
SizeSel_7P_1_Jan-Apr_Pot_Fishery_BLK7repl_1995	71.7177	0.362686
SizeSel_7P_1_Jan-Apr_Pot_Fishery_BLK7repl_2000	67.999	0.377593
SizeSel_7P_1_Jan-Apr_Pot_Fishery_BLK7repl_2005	68.2901	0.387619
SizeSel_7P_3_Jan-Apr_Pot_Fishery_BLK7repl_1977	4.78708	0.045146
SizeSel_7P_3_Jan-Apr_Pot_Fishery_BLK7repl_1995	4.93938	0.036873
SizeSel_7P_3_Jan-Apr_Pot_Fishery_BLK7repl_2000	4.87376	0.040327
SizeSel_7P_3_Jan-Apr_Pot_Fishery_BLK7repl_2005	4.72843	0.040613
SizeSel_7P_4_Jan-Apr_Pot_Fishery_BLK7repl_1977	4.57339	0.16544
SizeSel_7P_4_Jan-Apr_Pot_Fishery_BLK7repl_1995	4.17395	0.25953
SizeSel_7P_4_Jan-Apr_Pot_Fishery_BLK7repl_2000	4.28071	0.222842
SizeSel_7P_4_Jan-Apr_Pot_Fishery_BLK7repl_2005	4.06327	0.28019
SizeSel_7P_6_Jan-Apr_Pot_Fishery_BLK7repl_1977	-2.13677	0.254541
SizeSel_7P_6_Jan-Apr_Pot_Fishery_BLK7repl_1995	-0.58293	0.187561
SizeSel_7P_6_Jan-Apr_Pot_Fishery_BLK7repl_2000	-0.48199	0.154792
SizeSel_7P_6_Jan-Apr_Pot_Fishery_BLK7repl_2005	0.32856	0.200347
SizeSel_8P_1_May-Aug_Pot_Fishery_BLK8repl_1977	64.6714	1.59067
SizeSel_8P_1_May-Aug_Pot_Fishery_BLK8repl_1995	70.9111	1.10659
SizeSel_8P_1_May-Aug_Pot_Fishery_BLK8repl_2000	65.5352	0.909074
SizeSel_8P_3_May-Aug_Pot_Fishery_BLK8repl_1977	4.41747	0.260896
SizeSel_8P_3_May-Aug_Pot_Fishery_BLK8repl_1995	4.86677	0.131258
SizeSel_8P_3_May-Aug_Pot_Fishery_BLK8repl_2000	4.29032	0.162799
SizeSel_9P_1_Sep-Dec_Pot_Fishery_BLK9repl_1977	72.0713	1.10771
SizeSel_9P_1_Sep-Dec_Pot_Fishery_BLK9repl_1995	70.8309	1.21201
SizeSel_9P_1_Sep-Dec_Pot_Fishery_BLK9repl_2000	65.9386	0.896044
SizeSel_9P_1_Sep-Dec_Pot_Fishery_BLK9repl_2005	66.2771	0.714483
SizeSel_9P_3_Sep-Dec_Pot_Fishery_BLK9repl_1977	5.29516	0.104601
SizeSel_9P_3_Sep-Dec_Pot_Fishery_BLK9repl_1995	4.96429	0.137396
SizeSel_9P_3_Sep-Dec_Pot_Fishery_BLK9repl_2000	4.79775	0.104363
SizeSel_9P_3_Sep-Dec_Pot_Fishery_BLK9repl_2005	4.71262	0.082984
SizeSel_9P_6_Sep-Dec_Pot_Fishery_BLK9repl_1977	-1.58771	0.658867
SizeSel_9P_6_Sep-Dec_Pot_Fishery_BLK9repl_1995	0.241672	0.606992
SizeSel_9P_6_Sep-Dec_Pot_Fishery_BLK9repl_2000	-0.41798	0.320675
SizeSel_9P_6_Sep-Dec_Pot_Fishery_BLK9repl_2005	-0.14559	0.31358
AgeSel_10P_1_27plus_Trawl_Survey_BLK10repl_1977	4.01359	0.008048
AgeSel_10P_1_27plus_Trawl_Survey_BLK10repl_1987	2.03644	0.009261
AgeSel_10P_1_27plus_Trawl_Survey_BLK10repl_1990	3.9154	0.240387
AgeSel_10P_1_27plus_Trawl_Survey_BLK10repl_1993	4.22328	0.329188
AgeSel_10P_1_27plus_Trawl_Survey_BLK10repl_1996	5.17891	0.278601
AgeSel_10P_1_27plus_Trawl_Survey_BLK10repl_1999	4.23629	0.615017
AgeSel_10P_1_27plus_Trawl_Survey_BLK10repl_2001	3.70345	0.254191
AgeSel_10P_1_27plus_Trawl_Survey_BLK10repl_2003	4.25218	0.252552
AgeSel_10P_1_27plus_Trawl_Survey_BLK10repl_2005	4.85767	0.205615
AgeSel_10P_1_27plus_Trawl_Survey_BLK10repl_2007	2.81342	0.223011
AgeSel_10P_1_27plus_Trawl_Survey_BLK10repl_2009	2.02855	0.014569
AgeSel_10P_2_27plus_Trawl_Survey_BLK10repl_1977	-13.6558	_
AgeSel_10P_2_27plus_Trawl_Survey_BLK10repl_1987	-2.85092	0.330704

Label	Value	SD
AgeSel_10P_2_27plus_Trawl_Survey_BLK10repl_1990	-1.84823	0.130366
AgeSel_10P_2_27plus_Trawl_Survey_BLK10repl_1993	-2.21592	1.32797
AgeSel_10P_2_27plus_Trawl_Survey_BLK10repl_1996	-2.72899	0.333879
AgeSel_10P_2_27plus_Trawl_Survey_BLK10repl_1999	-1.08488	0.172209
AgeSel_10P_2_27plus_Trawl_Survey_BLK10repl_2001	-7.9805	37.9686
AgeSel_10P_2_27plus_Trawl_Survey_BLK10repl_2003	-3.20447	1.74529
AgeSel_10P_2_27plus_Trawl_Survey_BLK10repl_2005	-9.14005	20.1009
AgeSel_10P_2_27plus_Trawl_Survey_BLK10repl_2007	0.159078	31.0306
AgeSel_10P_2_27plus_Trawl_Survey_BLK10repl_2009	-2.01586	0.034035
AgeSel_10P_3_27plus_Trawl_Survey_BLK10repl_1977	0.764168	0.057775
AgeSel_10P_3_27plus_Trawl_Survey_BLK10repl_1987	-10	_
AgeSel_10P_3_27plus_Trawl_Survey_BLK10repl_1990	0.694854	0.225812
AgeSel_10P_3_27plus_Trawl_Survey_BLK10repl_1993	1.20944	0.254599
AgeSel_10P_3_27plus_Trawl_Survey_BLK10repl_1996	1.7215	0.173851
AgeSel_10P_3_27plus_Trawl_Survey_BLK10repl_1999	1.29626	0.498248
AgeSel_10P_3_27plus_Trawl_Survey_BLK10repl_2001	0.962207	0.229782
AgeSel_10P_3_27plus_Trawl_Survey_BLK10repl_2003	1.02672	0.211819
AgeSel_10P_3_27plus_Trawl_Survey_BLK10repl_2005	1.47998	0.148214
AgeSel_10P_3_27plus_Trawl_Survey_BLK10repl_2007	0.165322	0.327994
AgeSel_10P_3_27plus_Trawl_Survey_BLK10repl_2009	-9.11184	11.53
AgeSel_10P_4_27plus_Trawl_Survey_BLK10repl_1977	-9.99501	0.160709
AgeSel_10P_4_27plus_Trawl_Survey_BLK10repl_1987	1.56168	0.380914
AgeSel_10P_4_27plus_Trawl_Survey_BLK10repl_1990	-9.97652	_
AgeSel_10P_4_27plus_Trawl_Survey_BLK10repl_1993	-1.90333	9.90276
AgeSel_10P_4_27plus_Trawl_Survey_BLK10repl_1996	-9.96742	_
AgeSel_10P_4_27plus_Trawl_Survey_BLK10repl_1999	-10	_
AgeSel_10P_4_27plus_Trawl_Survey_BLK10repl_2001	3.04285	0.455076
AgeSel_10P_4_27plus_Trawl_Survey_BLK10repl_2003	1.85703	0.735973
AgeSel_10P_4_27plus_Trawl_Survey_BLK10repl_2005	-18.0675	_
AgeSel_10P_4_27plus_Trawl_Survey_BLK10repl_2007	-9.88607	_
AgeSel_10P_4_27plus_Trawl_Survey_BLK10repl_2009	-2.6374	36.3413
AgeSel_10P_6_27plus_Trawl_Survey_BLK10repl_1977	-2.08124	0.180157
AgeSel_10P_6_27plus_Trawl_Survey_BLK10repl_1987	-2.82415	0.512803
AgeSel_10P_6_27plus_Trawl_Survey_BLK10repl_1990	-1.41489	0.469559
AgeSel_10P_6_27plus_Trawl_Survey_BLK10repl_1993	-1.61748	0.501258
AgeSel_10P_6_27plus_Trawl_Survey_BLK10repl_1996	-1.59947	0.548923
AgeSel_10P_6_27plus_Trawl_Survey_BLK10repl_1999	-10	_
AgeSel_10P_6_27plus_Trawl_Survey_BLK10repl_2001	-8.36912	32.689
AgeSel_10P_6_27plus_Trawl_Survey_BLK10repl_2003	-9.74544	7.19514
AgeSel_10P_6_27plus_Trawl_Survey_BLK10repl_2005	0.415027	0.578541
AgeSel_10P_6_27plus_Trawl_Survey_BLK10repl_2007	7.70421	41.8543
AgeSel_10P_6_27plus_Trawl_Survey_BLK10repl_2009	-0.41167	0.429973

Table 2.14 – Estimated female spawning biomass (t) from the 2011 assessment and Model 2

	Last year		This year	
Year	Spawning Biomass	Standard Deviation	Spawning Biomass	Standard Deviation
1977	167,351	19,894	169,031	19,911
1978	195,614	21,366	204,602	21,738
1979	202,005	21,089	213,924	21,714
1980	202,656	19,838	211,323	20,347
1981	221,969	19,786	225,610	19,888
1982	248,968	20,576	257,987	20,899
1983	245,648	19,490	257,838	20,006
1984	227,027	17,444	238,070	17,937
1985	216,277	15,268	225,556	15,822
1986	213,715	13,230	221,341	13,901
1987	214,332	11,480	220,298	12,205
1988	205,381	9,968	208,697	10,634
1989	198,367	8,835	198,776	9,396
1990	187,980	7,930	188,967	8,496
1991	169,558	7,152	169,701	7,650
1992	150,833	6,655	149,600	7,046
1993	143,790	6,413	142,250	6,736
1994	148,362	6,339	145,558	6,645
1995	156,445	6,121	154,545	6,561
1996	150,276	5,816	149,391	6,318
1997	141,684	5,508	141,330	6,042
1998	129,846	5,389	129,266	5,923
1999	125,501	5,464	124,857	6,027
2000	112,891	5,501	113,669	6,172
2001	111,225	5,410	113,039	6,211
2002	104,223	5,211	106,423	6,064
2003	94,330	5,128	95,779	5,968
2004	92,875	5,338	93,901	6,183
2005	92,640	5,657	94,115	6,540
2006	87,802	5,788	89,918	6,685
2007	84,669	5,987	86,436	6,830
2008	80,278	6,552	81,890	7,319
2009	83,448	8,031	83,523	8,598
2010	95,784	11,105	94,670	11,440
2011	108,953	15,548	108,491	15,806
2012	121,180	18,284	123,986	21,106

Table 2.15 – Estimated age-0 recruits (000's) from the 2011 assessment and Model 2

	Last year		Model 2	
Year	Age-0	SD	Age-0	SD
1977	671,545	51,305	735,007	51,726
1978	158,776	17,249	195,006	21,277
1979	194,972	14,217	174,073	13,739
1980	215,021	13,158	209,907	13,148
1981	220,450	14,577	210,763	13,353
1982	304,994	18,701	286,796	18,383
1983	211,702	15,936	213,303	16,679
1984	211,084	14,512	153,020	14,258
1985	319,579	16,570	335,354	18,680
1986	171,859	11,039	162,463	12,040
1987	288,696	12,634	248,047	12,296
1988	213,873	11,618	225,576	11,881
1989	311,488	14,659	258,723	13,611
1990	275,951	13,772	282,643	13,593
1991	258,427	12,177	245,553	11,902
1992	212,641	11,492	208,946	11,678
1993	252,984	11,668	232,715	11,611
1994	251,854	11,581	233,170	11,544
1995	236,085	10,438	233,150	11,048
1996	212,948	9,303	210,467	10,416
1997	152,037	7,726	157,347	8,344
1998	158,598	8,120	139,673	7,974
1999	200,927	9,842	185,457	9,988
2000	228,817	11,275	218,151	11,685
2001	145,779	8,515	157,251	9,270
2002	151,163	9,182	132,968	8,680
2003	163,610	10,797	163,815	11,010
2004	177,435	12,943	157,315	11,918
2005	291,254	25,963	247,945	22,268
2006	324,737	34,283	319,899	33,409
2007	332,116	44,918	303,208	39,836
2008	372,360	53,770	357,927	51,699
2009	255,623	61,794	332,420	72,508
2010	361,467	95,517	215,261	87,437
2011			213,472	88,978
Average	250,319		238,765	

Table 2.16 – Estimated numbers-at-age (millions) at the time of spawning for Model 2

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	735.0	97.1	79.3	54.5	102.7	30.2	17.4	8.8	4.9	3.1	2.1	1.5	1.1	0.8	0.7	0.5	0.3	0.2	0.2	0.1	0.2
1978	195.0	502.6	66.4	54.2	37.0	69.6	20.5	11.8	6.0	3.3	2.1	1.4	1.0	0.7	0.5	0.5	0.3	0.2	0.2	0.1	0.2
1979	174.1	133.4	343.7	45.2	36.4	24.7	46.5	13.7	7.9	4.0	2.2	1.4	1.0	0.7	0.5	0.4	0.3	0.2	0.2	0.1	0.2
1980	209.9	119.0	91.2	233.4	30.2	24.0	16.3	30.8	9.1	5.2	2.7	1.5	0.9	0.6	0.5	0.3	0.2	0.2	0.2	0.1	0.2
1981	210.8	143.5	81.4	61.9	153.2	19.2	15.5	10.6	20.2	6.0	3.4	1.8	1.0	0.6	0.4	0.3	0.2	0.2	0.1	0.1	0.2
1982	286.8	144.1	98.1	55.2	40.5	97.5	12.4	10.1	7.0	13.3	3.9	2.3	1.2	0.7	0.4	0.3	0.2	0.1	0.1	0.1	0.2
1983	213.3	196.1	98.5	66.6	36.2	25.8	62.9	8.1	6.6	4.6	8.8	2.6	1.5	0.8	0.4	0.3	0.2	0.1	0.1	0.1	0.2
1984	153.0	145.9	134.1	66.7	42.9	22.5	16.3	40.5	5.3	4.3	3.0	5.8	1.7	1.0	0.5	0.3	0.2	0.1	0.1	0.1	0.2
1985	335.4	104.6	99.7	91.2	44.3	27.9	14.6	10.7	26.7	3.5	2.9	2.0	3.8	1.1	0.7	0.3	0.2	0.1	0.1	0.1	0.2
1986	162.5	229.3	71.5	67.9	61.4	29.4	18.4	9.7	7.1	17.7	2.3	1.9	1.3	2.5	0.8	0.4	0.2	0.1	0.1	0.1	0.1
1987	248.0	111.1	156.7	48.6	45.4	40.3	19.2	12.0	6.3	4.7	11.7	1.5	1.3	0.9	1.7	0.5	0.3	0.2	0.1	0.1	0.1
1988	225.6	169.6	75.8	105.7	31.7	28.6	25.2	12.2	7.8	4.1	3.0	7.6	1.0	0.8	0.6	1.1	0.3	0.2	0.1	0.1	0.1
1989	258.7	154.3	115.7	51.1	69.2	20.1	17.9	16.0	7.8	5.0	2.7	2.0	4.9	0.6	0.5	0.4	0.7	0.2	0.1	0.1	0.1
1990	282.6	176.9	105.4	78.5	33.4	42.7	12.0	10.8	9.7	4.8	3.1	1.7	1.2	3.1	0.4	0.3	0.2	0.4	0.1	0.1	0.1
1991	245.6	193.3	120.9	71.5	51.5	20.4	24.4	6.7	6.1	5.6	2.8	1.8	1.0	0.7	1.9	0.2	0.2	0.1	0.3	0.1	0.1
1992	208.9	167.9	132.1	82.0	46.9	31.2	11.3	12.8	3.5	3.2	3.0	1.5	1.0	0.5	0.4	1.0	0.1	0.1	0.1	0.1	0.1
1993	232.7	142.9	114.8	89.8	54.2	28.8	17.5	6.0	6.7	1.9	1.7	1.6	0.8	0.5	0.3	0.2	0.6	0.1	0.1	0.0	0.1
1994	233.2	159.1	97.7	78.1	59.5	33.6	16.6	9.7	3.3	3.8	1.1	1.0	0.9	0.5	0.3	0.2	0.1	0.3	0.0	0.0	0.1
1995	233.2	159.5	108.8	66.6	52.2	37.8	20.1	9.6	5.6	1.9	2.2	0.6	0.6	0.6	0.3	0.2	0.1	0.1	0.2	0.0	0.1
1996	210.5	159.4	109.0	74.0	44.1	32.4	21.6	10.9	5.1	3.0	1.0	1.2	0.3	0.3	0.3	0.2	0.1	0.1	0.0	0.1	0.1
1997	157.3	143.9	109.0	74.1	48.9	27.2	18.3	11.6	5.7	2.7	1.6	0.6	0.6	0.2	0.2	0.2	0.1	0.1	0.0	0.0	0.1
1998	139.7	107.6	98.3	73.8	48.3	29.1	14.5	9.1	5.6	2.8	1.3	0.8	0.3	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.1
1999	185.5	95.5	73.5	66.8	48.4	29.0	15.8	7.4	4.6	2.9	1.5	0.7	0.4	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0
2000	218.2	126.8	65.2	49.6	42.6	27.4	14.6	7.5	3.5	2.3	1.5	0.8	0.4	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0
2001	157.3	149.2	86.7	44.2	32.4	25.7	15.5	8.1	4.2	2.0	1.3	0.9	0.5	0.2	0.1	0.0	0.1	0.0	0.0	0.0	0.0
2002	133.0	107.5	101.9	58.6	28.6	19.3	14.3	8.5	4.5	2.4	1.2	0.8	0.5	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0
2003	163.8	90.9	73.5	68.9	37.5	16.3	10.0	7.2	4.4	2.4	1.3	0.7	0.4	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0
2004	157.3	112.0	62.1	49.6	44.0	21.5	8.6	5.1	3.8	2.4	1.4	0.8	0.4	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0
2005	247.9	107.6	76.5	42.0	32.0	25.7	11.5	4.5	2.7	2.1	1.4	0.8	0.4	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0
2006	319.9	169.6	73.5	51.9	27.3	18.9	13.8	6.0	2.4	1.5	1.2	0.8	0.5	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0
2007	303.2	218.8	115.9	49.9	33.9	16.3	10.3	7.4	3.2	1.3	0.8	0.7	0.4	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0
2008	357.9	207.3	149.4	78.4	32.1	19.4	8.3	5.1	3.7	1.7	0.7	0.5	0.4	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0
2009	332.4	244.8	141.7	101.1	50.3	18.2	9.7	4.0	2.5	1.9	0.9	0.4	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0
2010	215.3	227.3	167.2	95.8	64.6	28.1	9.0	4.6	1.9	1.3	1.0	0.5	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
2011	213.5	147.2	155.3	113.2	61.3	36.0	13.8	4.2	2.2	1.0	0.7	0.5	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
2012	244.3	146.0	100.6	105.3	73.2	35.2	18.4	6.8	2.1	1.2	0.5	0.4	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0

Table 2.17 – Estimates of "effective" fishing mortality (= -ln($N_{a+1,y+1}/N_{a,y}$)-M) at age and year for Model 2

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	0.003	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
1978	0.000	0.005	0.015	0.023	0.023	0.022	0.021	0.020	0.019	0.018	0.017	0.016	0.015	0.014	0.014	0.014	0.013	0.013	0.013
1979	0.000	0.004	0.016	0.026	0.027	0.025	0.024	0.023	0.022	0.021	0.019	0.018	0.017	0.017	0.016	0.016	0.015	0.015	0.015
1980	0.000	0.006	0.039	0.072	0.067	0.054	0.048	0.045	0.043	0.041	0.039	0.036	0.035	0.034	0.033	0.032	0.032	0.031	0.031
1981	0.000	0.007	0.041	0.070	0.061	0.046	0.039	0.036	0.035	0.033	0.031	0.030	0.029	0.028	0.028	0.027	0.027	0.027	0.026
1982	0.000	0.006	0.038	0.065	0.056	0.042	0.035	0.033	0.031	0.030	0.029	0.027	0.026	0.026	0.025	0.025	0.024	0.024	0.024
1983	0.000	0.008	0.054	0.092	0.079	0.059	0.050	0.047	0.045	0.043	0.041	0.040	0.038	0.038	0.037	0.037	0.036	0.036	0.036
1984	0.000	0.005	0.029	0.053	0.050	0.042	0.038	0.037	0.035	0.033	0.031	0.030	0.028	0.027	0.027	0.026	0.026	0.025	0.025
1985	0.000	0.002	0.011	0.022	0.028	0.028	0.027	0.026	0.024	0.023	0.022	0.022	0.022	0.021	0.021	0.021	0.021	0.021	0.021
1986	0.000	0.004	0.020	0.040	0.048	0.049	0.047	0.044	0.042	0.040	0.038	0.038	0.037	0.037	0.037	0.036	0.036	0.036	0.036
1987	0.001	0.010	0.040	0.074	0.079	0.066	0.054	0.046	0.042	0.040	0.039	0.038	0.038	0.037	0.037	0.037	0.037	0.037	0.037
1988	0.001	0.008	0.033	0.067	0.080	0.073	0.062	0.055	0.051	0.049	0.048	0.047	0.046	0.046	0.046	0.046	0.046	0.046	0.046
1989	0.000	0.007	0.039	0.087	0.106	0.098	0.083	0.074	0.068	0.066	0.065	0.064	0.064	0.063	0.063	0.063	0.063	0.063	0.063
1990	0.000	0.005	0.033	0.099	0.170	0.202	0.197	0.178	0.160	0.148	0.140	0.135	0.131	0.129	0.127	0.126	0.125	0.124	0.124
1991	0.000	0.003	0.023	0.082	0.166	0.226	0.245	0.239	0.230	0.222	0.216	0.213	0.211	0.209	0.209	0.208	0.208	0.207	0.207
1992	0.000	0.003	0.026	0.096	0.198	0.268	0.286	0.277	0.263	0.253	0.246	0.242	0.239	0.237	0.236	0.236	0.235	0.235	0.235
1993	0.000	0.002	0.019	0.070	0.146	0.197	0.208	0.198	0.186	0.176	0.170	0.166	0.164	0.163	0.162	0.161	0.161	0.160	0.160
1994	0.000	0.002	0.014	0.053	0.113	0.156	0.166	0.160	0.150	0.143	0.138	0.135	0.133	0.132	0.132	0.131	0.131	0.131	0.130
1995	0.000	0.002	0.017	0.066	0.147	0.218	0.248	0.248	0.237	0.226	0.219	0.215	0.212	0.211	0.210	0.209	0.209	0.208	0.208
1996	0.000	0.002	0.018	0.069	0.151	0.218	0.246	0.244	0.234	0.225	0.219	0.215	0.213	0.212	0.211	0.210	0.210	0.210	0.209
1997	0.000	0.004	0.024	0.085	0.182	0.262	0.293	0.289	0.274	0.260	0.251	0.245	0.241	0.239	0.237	0.236	0.236	0.235	0.235
1998	0.000	0.003	0.020	0.081	0.181	0.264	0.294	0.286	0.267	0.251	0.240	0.233	0.229	0.227	0.225	0.224	0.224	0.223	0.222
1999	0.000	0.004	0.024	0.095	0.220	0.325	0.361	0.347	0.319	0.295	0.279	0.268	0.261	0.257	0.255	0.253	0.252	0.251	0.250
2000	0.000	0.003	0.025	0.101	0.215	0.276	0.270	0.239	0.211	0.194	0.184	0.179	0.176	0.174	0.173	0.173	0.172	0.172	0.172
2001	0.000	0.006	0.030	0.098	0.183	0.224	0.214	0.186	0.163	0.148	0.140	0.135	0.133	0.131	0.130	0.130	0.129	0.129	0.129
2002	0.000	0.004	0.031	0.113	0.215	0.261	0.248	0.216	0.190	0.174	0.165	0.160	0.158	0.156	0.155	0.155	0.154	0.154	0.154
2003	0.000	0.005	0.031	0.110	0.218	0.272	0.259	0.222	0.191	0.172	0.162	0.156	0.153	0.151	0.150	0.150	0.149	0.149	0.149
2004	0.000	0.005	0.033	0.121	0.241	0.299	0.283	0.240	0.205	0.183	0.172	0.165	0.162	0.160	0.159	0.158	0.158	0.157	0.157
2005	0.000	0.003	0.022	0.090	0.192	0.249	0.246	0.222	0.200	0.186	0.178	0.174	0.171	0.170	0.169	0.168	0.168	0.168	0.168
2006	0.000	0.002	0.021	0.090	0.198	0.260	0.257	0.232	0.210	0.196	0.189	0.185	0.182	0.181	0.180	0.180	0.179	0.179	0.179
2007	0.000	0.003	0.027	0.111	0.233	0.299	0.294	0.263	0.236	0.220	0.210	0.205	0.202	0.200	0.199	0.199	0.198	0.198	0.198
2008	0.000	0.005	0.035	0.132	0.275	0.355	0.351	0.314	0.281	0.259	0.246	0.239	0.235	0.233	0.231	0.230	0.230	0.229	0.229
2009	0.000	0.004	0.026	0.107	0.232	0.305	0.301	0.269	0.239	0.220	0.209	0.203	0.199	0.197	0.196	0.195	0.195	0.194	0.194
2010	0.000	0.005	0.033	0.135	0.294	0.386	0.382	0.341	0.303	0.279	0.265	0.258	0.254	0.251	0.249	0.249	0.248	0.247	0.247
2011	0.000	0.003	0.029	0.130	0.282	0.366	0.358	0.319	0.285	0.264	0.253	0.247	0.243	0.241	0.240	0.239	0.239	0.239	0.238

Table 2.18 – Results for the projection scenarios for Model 2

Year	ABC	OFL	Catch	F	SSB	Total Bio
Scenarios 1 and 2, Maximum Tier 3 ABC harvest permissible						
2013	80,830	97,251	80,830	0.489	111,042	449,342
2014	84,284	101,181	84,284	0.489	112,955	440,370
2015	78,932	94,605	78,932	0.489	104,180	417,649
2016	72,033	86,364	72,033	0.489	96,676	400,856
2017	68,497	81,490	68,497	0.482	94,575	395,340
2018	67,177	80,065	67,177	0.470	94,516	395,040
2019	67,445	80,442	67,445	0.467	95,099	396,375
2020	67,759	80,842	67,759	0.466	95,492	397,395
2021	67,856	80,976	67,856	0.466	95,494	397,987
2022	67,995	81,125	67,995	0.467	95,684	398,687
2023	68,163	81,333	68,163	0.468	95,799	399,181
2024	68,270	81,464	68,270	0.468	95,973	399,308
2025	68,438	81,676	68,438	0.468	96,180	399,472
Scenario 3, F_{ABC} at average F over the past 5 years						
Year	ABC	OFL	Catch	F	SSB	Total Bio
2013	80,830	97,251	56,149	0.323	114,485	449,342
2014	91,344	109,592	63,703	0.323	125,880	463,899
2015	91,096	109,078	63,712	0.323	123,522	457,316
2016	86,422	103,556	60,383	0.323	118,853	448,253
2017	84,117	100,909	58,674	0.323	117,473	445,176
2018	83,803	100,532	58,444	0.323	117,250	444,900
2019	83,827	100,469	58,552	0.323	117,378	445,097
2020	83,872	100,492	58,660	0.323	117,446	445,267
2021	83,741	100,330	58,610	0.323	117,251	445,339
2022	83,716	100,291	58,603	0.323	117,329	445,746
2023	83,815	100,405	58,665	0.323	117,421	446,150
2024	83,950	100,570	58,750	0.323	117,608	446,313
2025	84,117	100,774	58,878	0.323	117,847	446,536
Scenario 4, ½ Maximum ABC harvest possible						
Year	ABC	OFL	Catch	F	SSB	Total Bio
2013	80,830	97,251	39,180	0.218	116,727	449,342
2014	96,245	115,431	46,994	0.218	135,094	480,181
2015	100,275	119,998	49,220	0.218	138,509	487,187
2016	98,122	117,480	48,110	0.218	137,361	486,807
2017	96,813	116,038	47,342	0.218	137,783	488,213
2018	96,946	116,225	47,381	0.218	138,563	490,341
2019	97,412	116,783	47,609	0.218	139,313	492,010
2020	97,783	117,219	47,798	0.218	139,785	493,122
2021	97,857	117,300	47,841	0.218	139,846	493,802
2022	97,938	117,402	47,874	0.218	140,068	494,555
2023	98,070	117,560	47,939	0.218	140,252	495,171
2024	98,232	117,755	48,017	0.218	140,504	495,484
2025	98,439	118,002	48,121	0.218	140,798	495,824

Table 2.18 – (continued) Results for the projection scenarios for Model 2

Scenario 5, No fishing (F_{ABC} = 0)						
Year	ABC	OFL	Catch	F	SSB	Total Bio
2013	80,830	97,251	0	0	121,561	449,342
2014	107,692	129,064	0	0	157,343	518,061
2015	124,144	148,390	0	0	178,855	564,717
2016	131,798	157,556	0	0	192,561	597,961
2017	136,586	163,446	0	0	203,707	623,920
2018	140,610	168,337	0	0	212,154	643,473
2019	143,941	172,351	0	0	218,488	657,779
2020	146,476	175,393	0	0	223,071	668,151
2021	148,165	177,419	0	0	226,132	675,607
2022	149,380	178,887	0	0	228,486	681,193
2023	150,304	180,000	0	0	230,194	685,246
2024	151,044	180,892	0	0	231,542	688,032
2025	151,682	181,658	0	0	232,648	690,185
Scenario 6, Whether Pacific cod are overfished – $SB_{35\%}$ = 82,100						
Year	ABC	OFL	Catch	F	SSB	Total Bio
2013	80,830	97,251	97,251	0.610	108,617	449,342
2014	79,637	95,643	95,643	0.610	104,680	424,824
2015	71,585	85,097	85,097	0.603	92,941	393,625
2016	60,175	71,249	71,249	0.554	85,753	375,009
2017	59,088	70,131	70,131	0.552	85,529	374,773
2018	59,574	70,907	70,907	0.550	86,134	376,715
2019	60,007	71,488	71,488	0.549	86,613	377,877
2020	60,207	71,740	71,740	0.549	86,800	378,393
2021	60,146	71,634	71,634	0.548	86,665	378,602
2022	60,224	71,733	71,733	0.549	86,812	379,181
2023	60,328	71,855	71,855	0.549	86,906	379,616
2024	60,486	72,074	72,074	0.550	87,063	379,740
2025	60,619	72,240	72,240	0.550	87,225	379,797
Scenario 7, Whether Pacific cod are approaching an overfished condition						
Year	ABC	OFL	Catch	F	SSB	Total Bio
2013	80,830	97,251	80,830	0.489	111,042	449,342
2014	84,284	101,181	84,284	0.489	112,955	440,370
2015	78,932	94,605	94,605	0.610	101,626	417,649
2016	65,919	77,847	77,847	0.580	89,529	386,097
2017	60,388	71,659	71,659	0.559	86,526	377,481
2018	59,750	71,121	71,121	0.551	86,357	377,245
2019	60,002	71,486	71,486	0.549	86,665	377,977
2020	60,195	71,727	71,727	0.549	86,815	378,421
2021	60,141	71,629	71,629	0.548	86,671	378,614
2022	60,222	71,731	71,731	0.549	86,814	379,186
2023	60,327	71,854	71,854	0.549	86,906	379,617
2024	60,485	72,074	72,074	0.550	87,063	379,740
2025	60,619	72,240	72,240	0.550	87,225	379,797

Table 2.19 – Biological reference points from GOA Pacific cod SAFE documents for years 2001 – 2011

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*

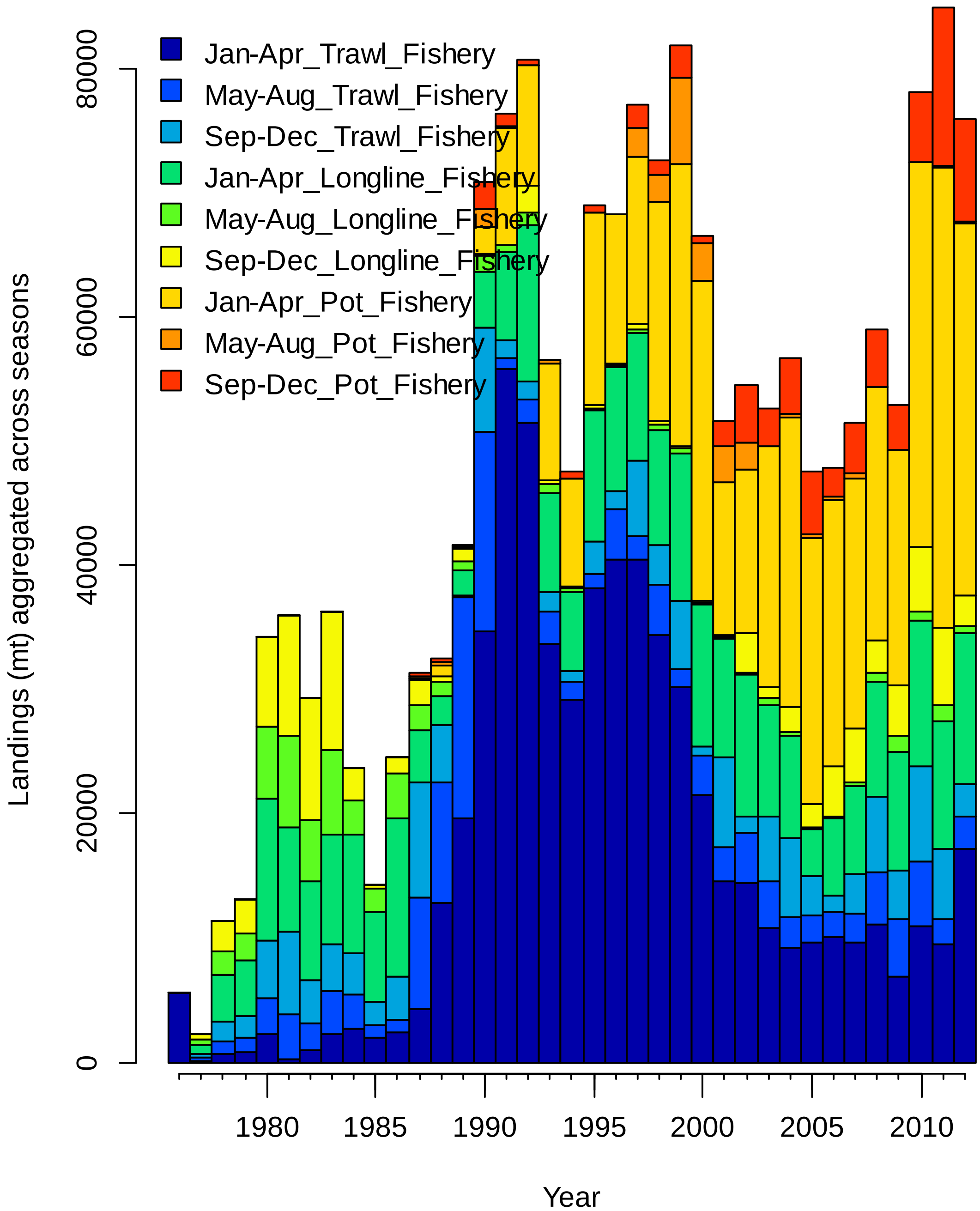

Figure 2.1 – Total catch, by season and gear type

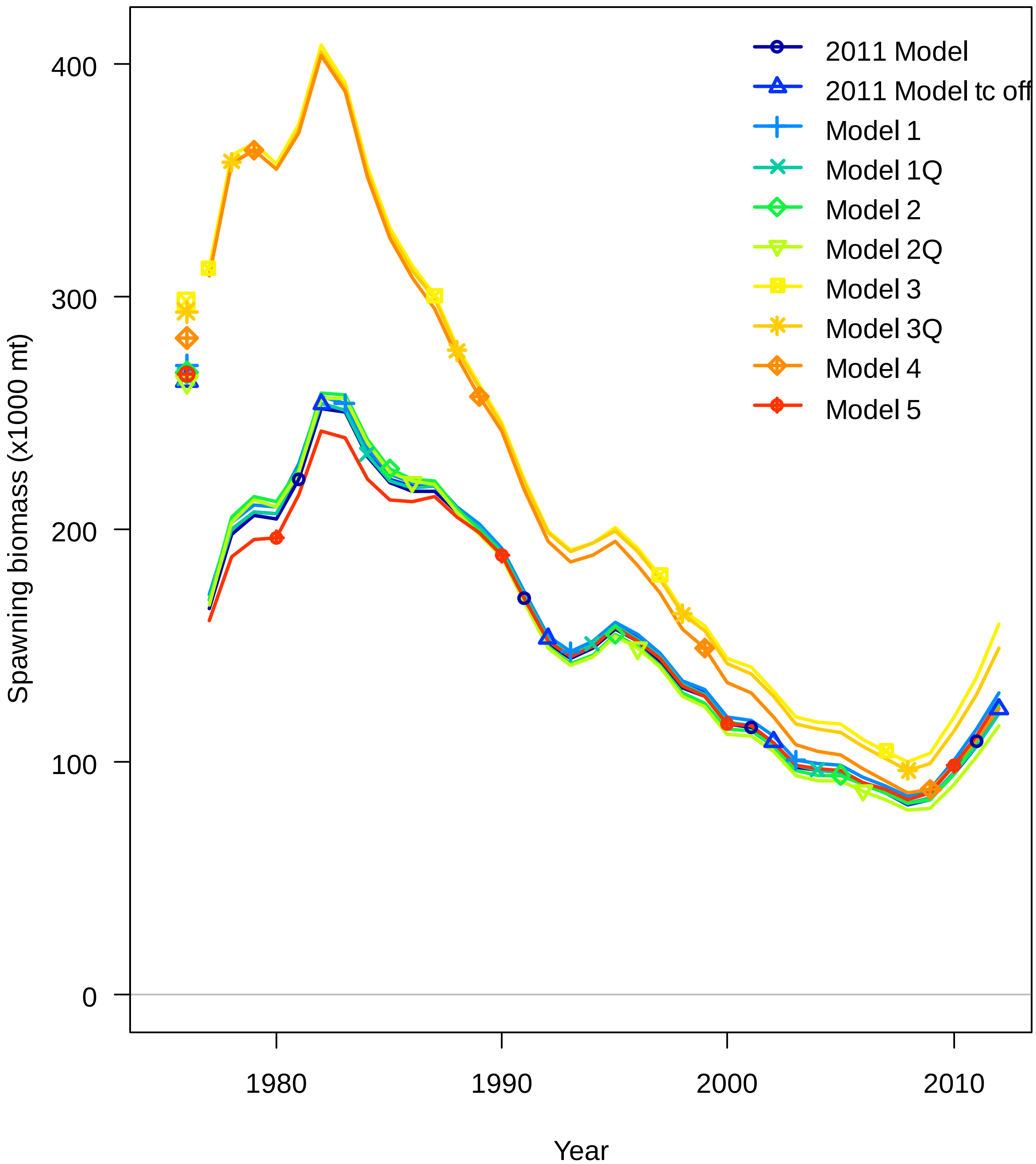

Figure 2.2 – Estimated spawning biomass for all model configurations

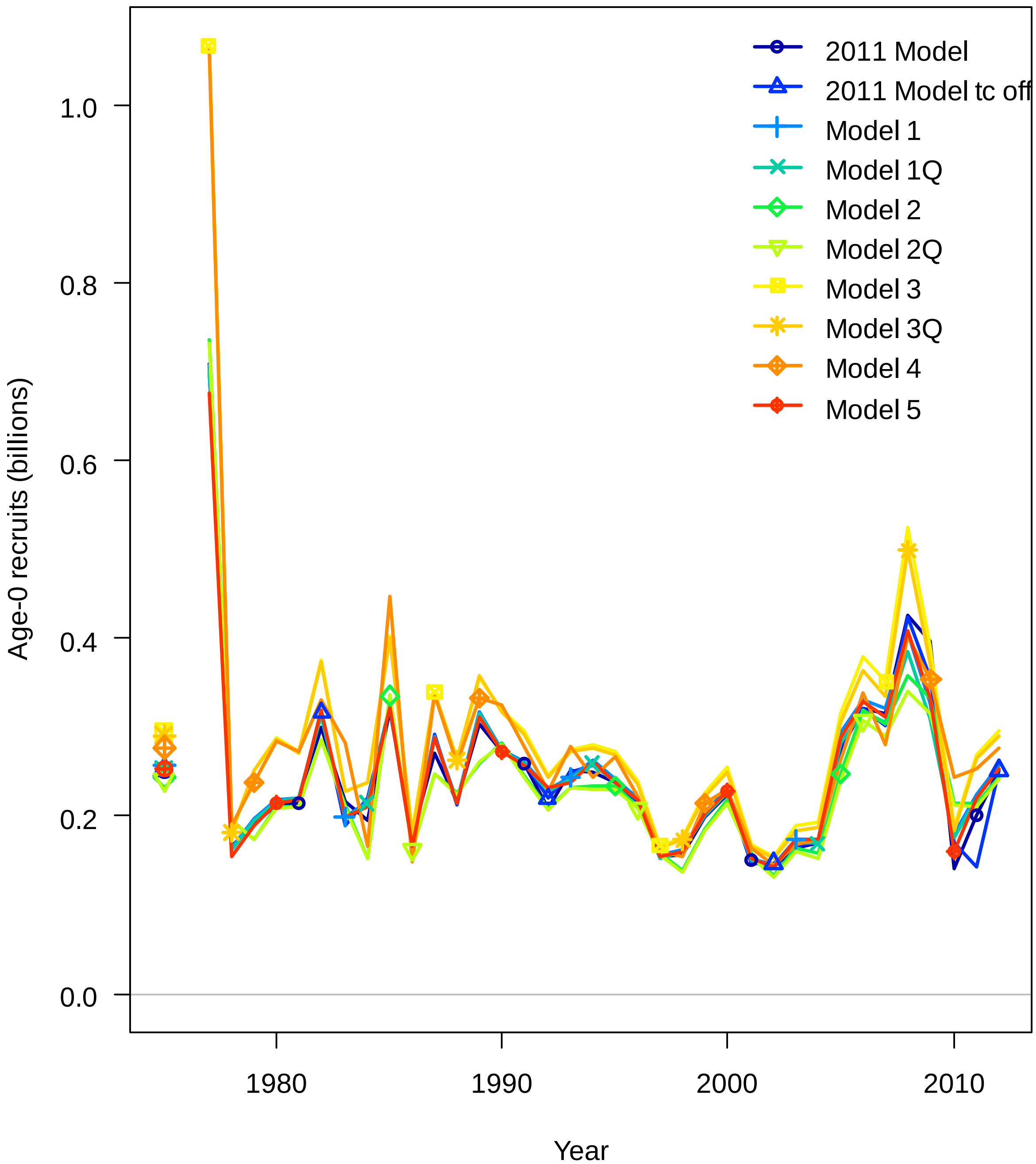

Figure 2.3 – Estimated age-0 recruits for all model configurations

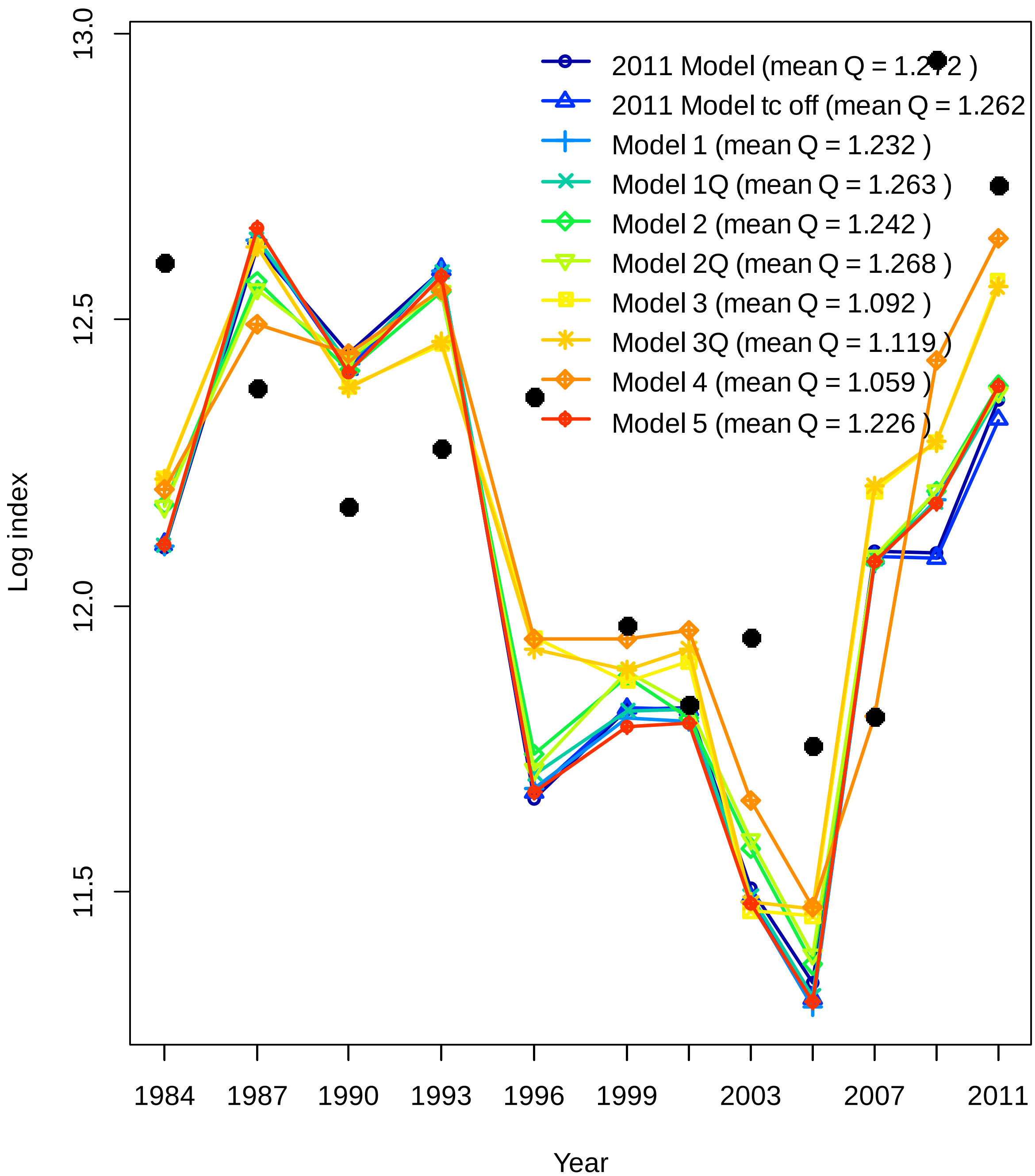

Figure 2.4 – Estimated 27-plus survey indices for all model configurations (log scale)

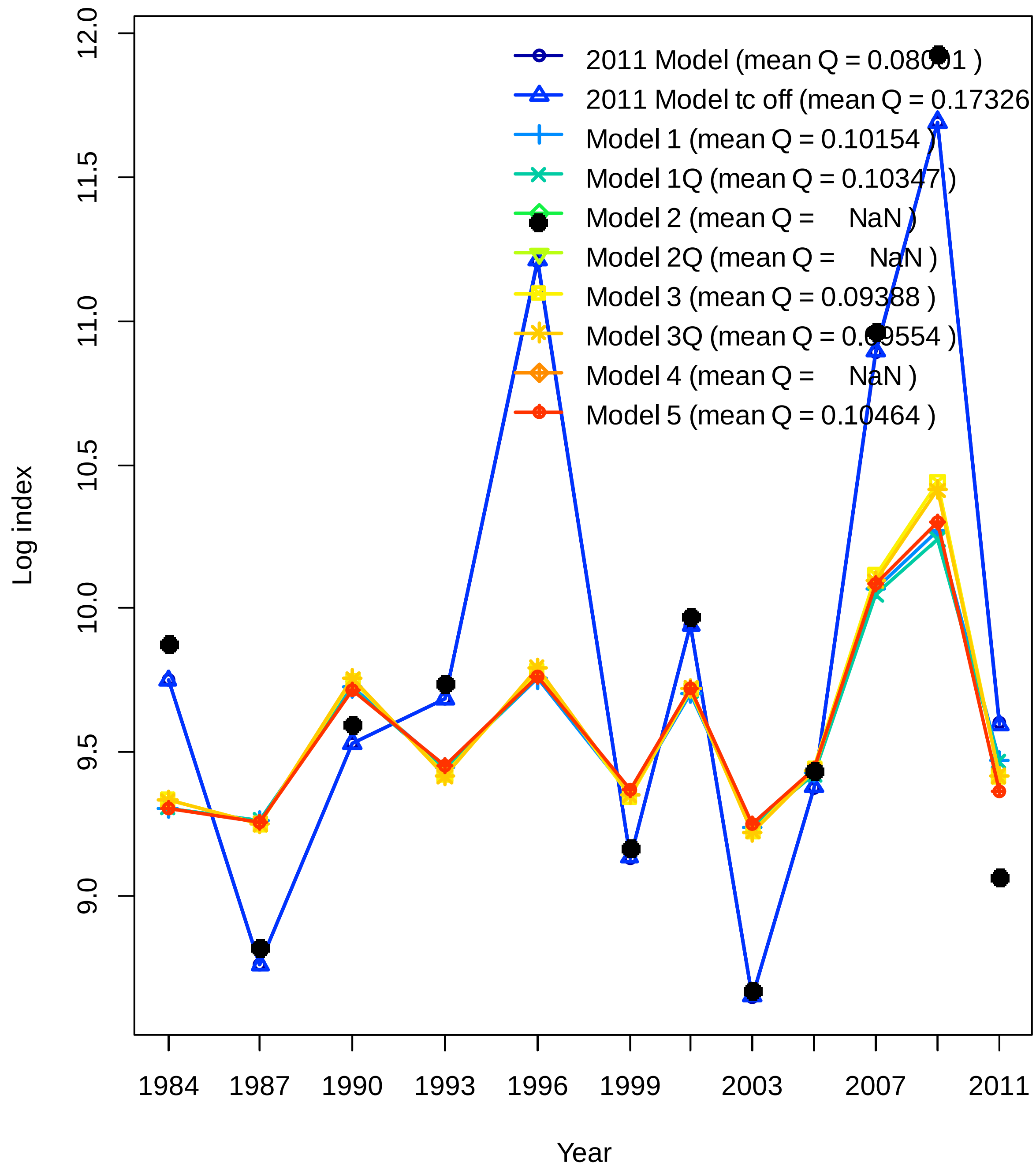

Figure 2.5 – Estimated sub-27 survey indices for all model configurations (log scale)

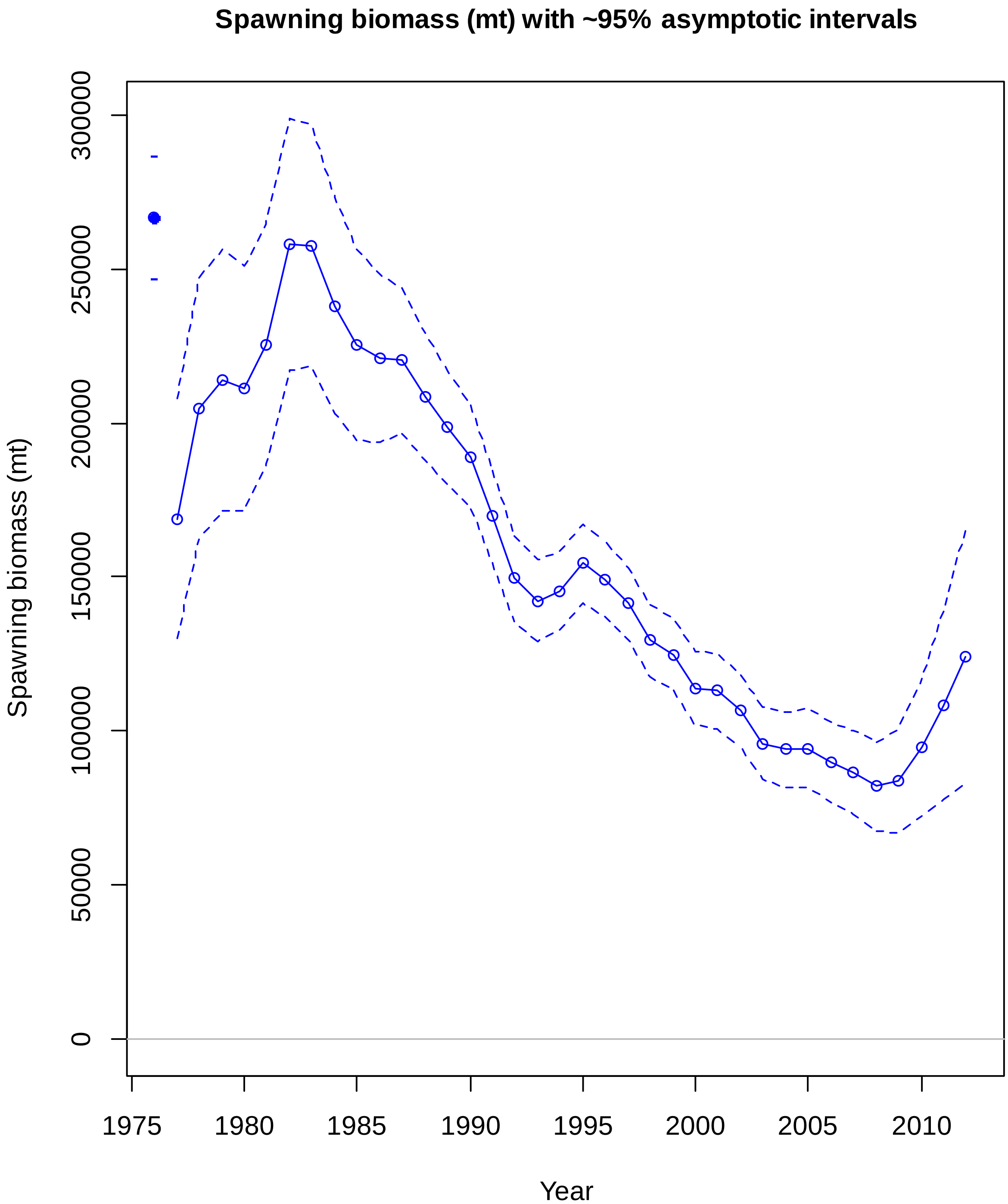

Figure 2.6 – Estimated spawning biomass for Model 2

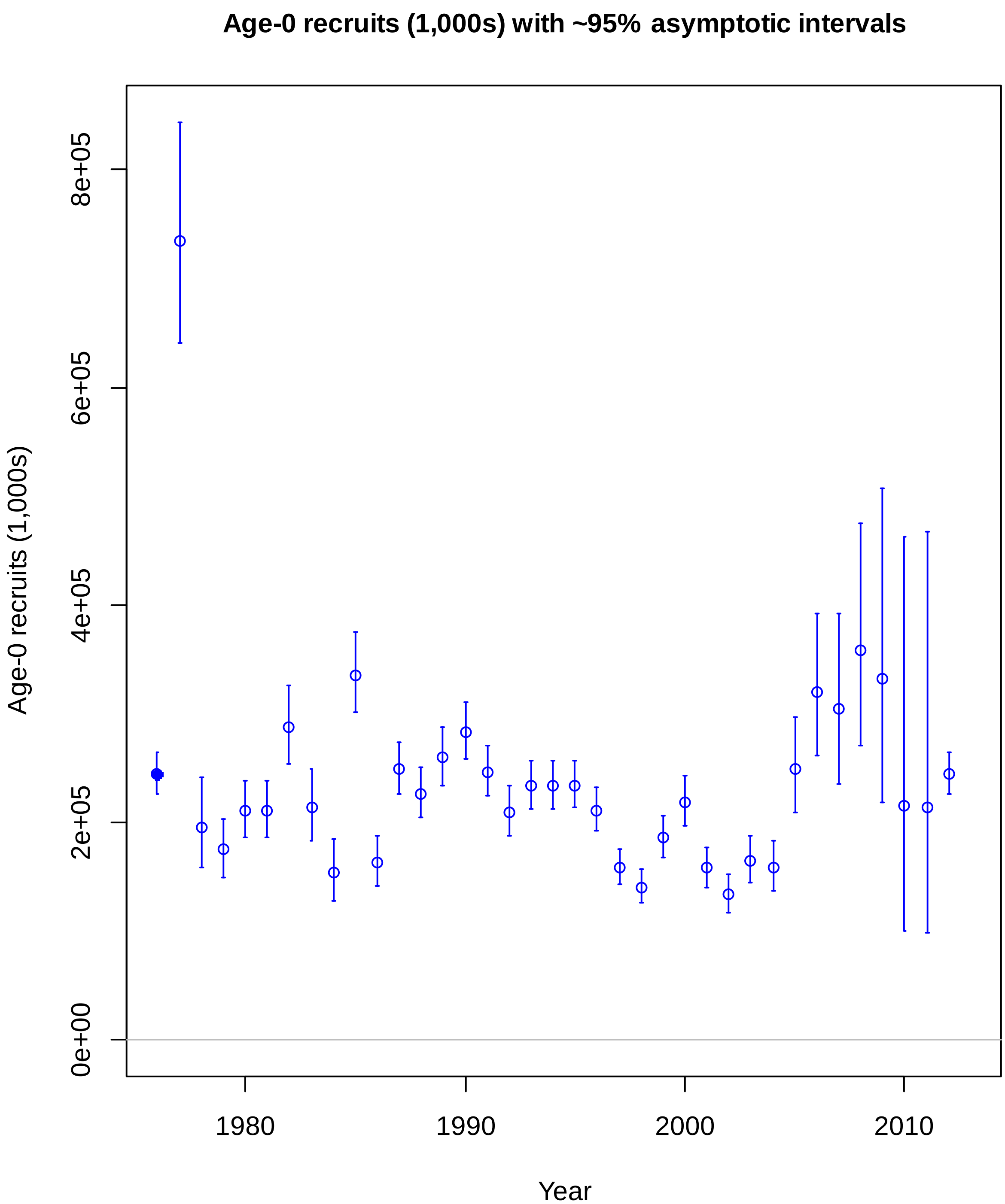

Figure 2.7 – Estimated age-0 recruits for Model 2

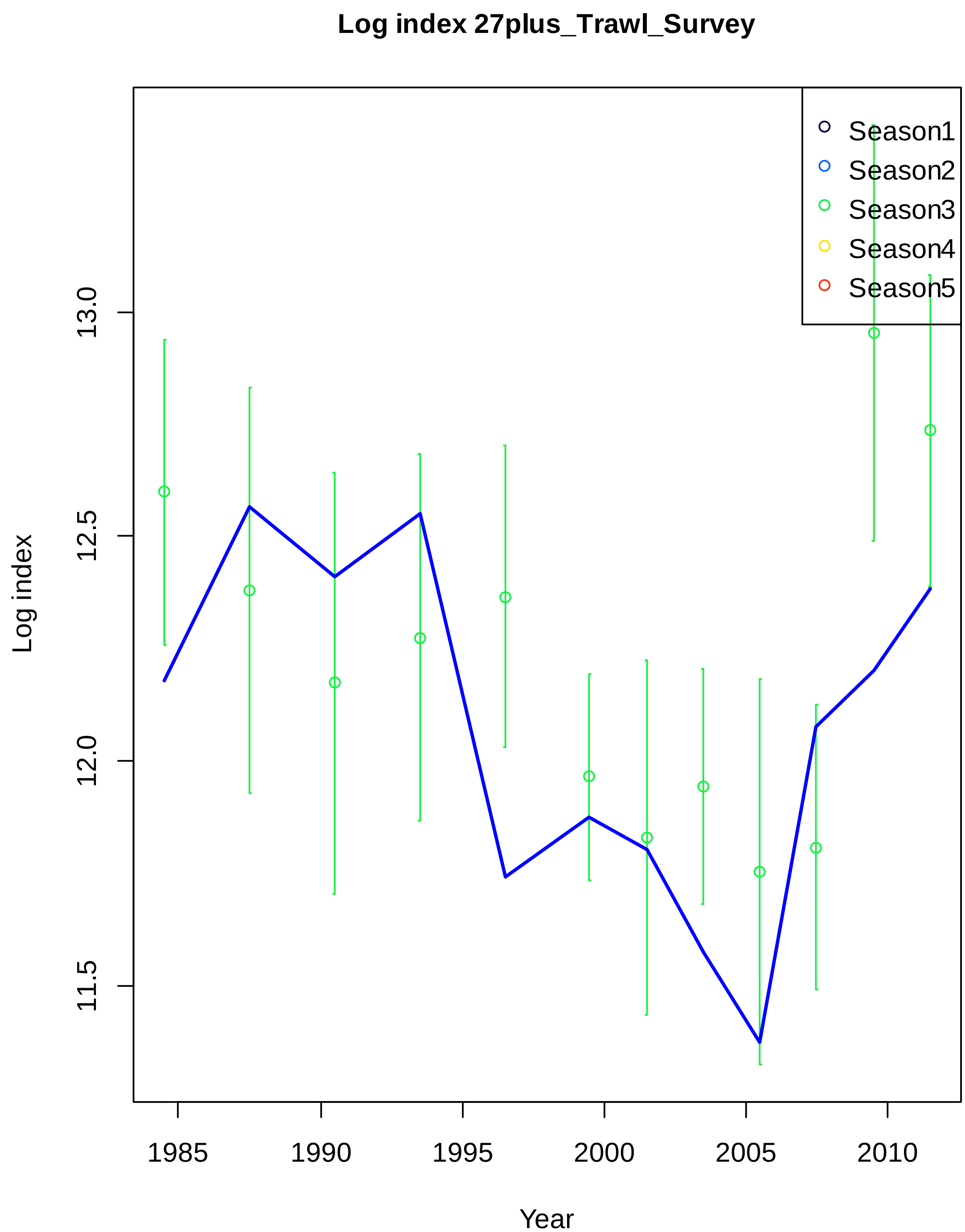

Figure 2.8 – Estimated 27-plus survey indices for Model 2

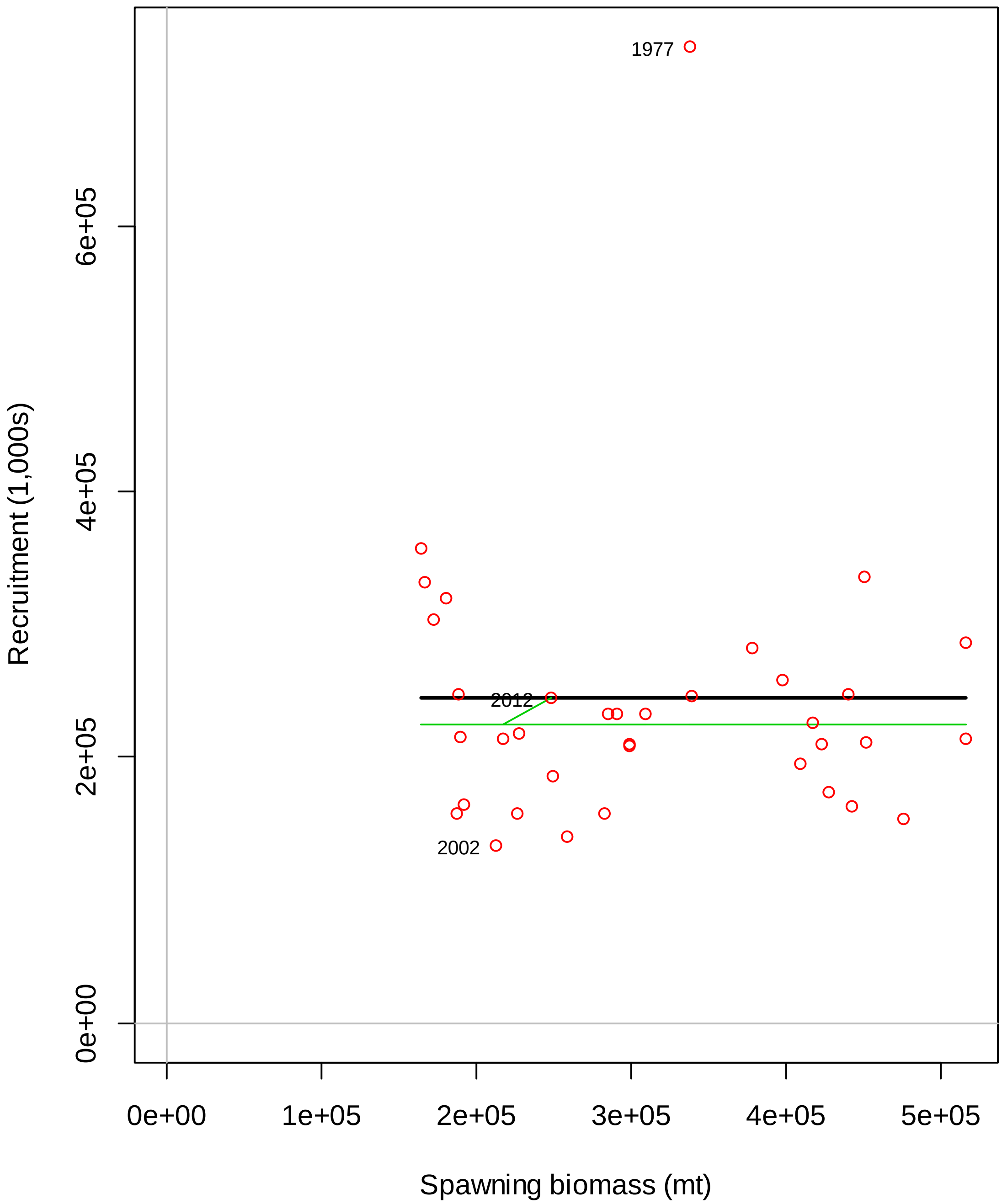

Figure 2.9 – Spawning biomass-recruitment for Model 2

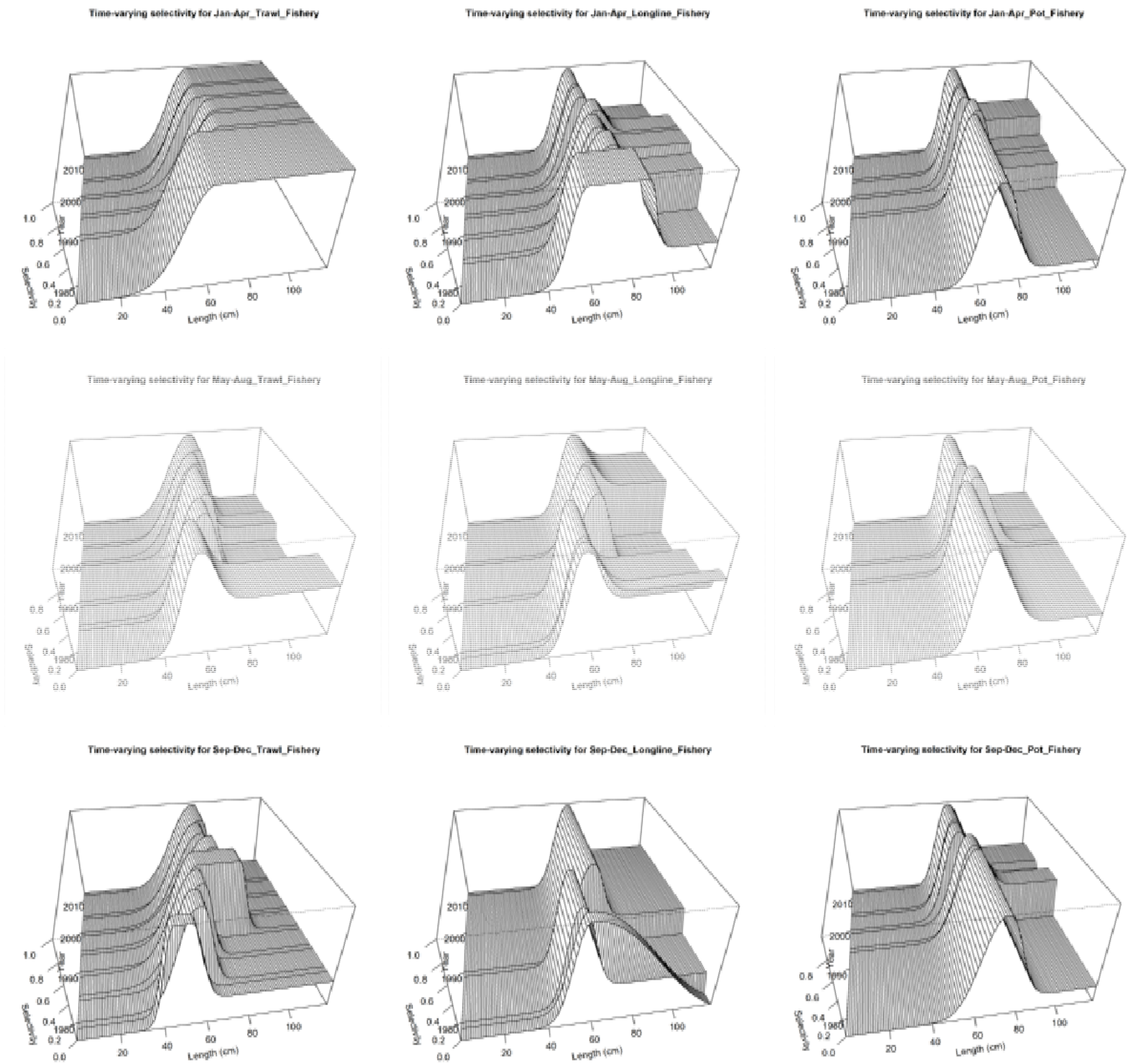

Figure 2.10 – Fishery selectivity-at-length, by seasons (rows) and gear type (columns), for Model 2

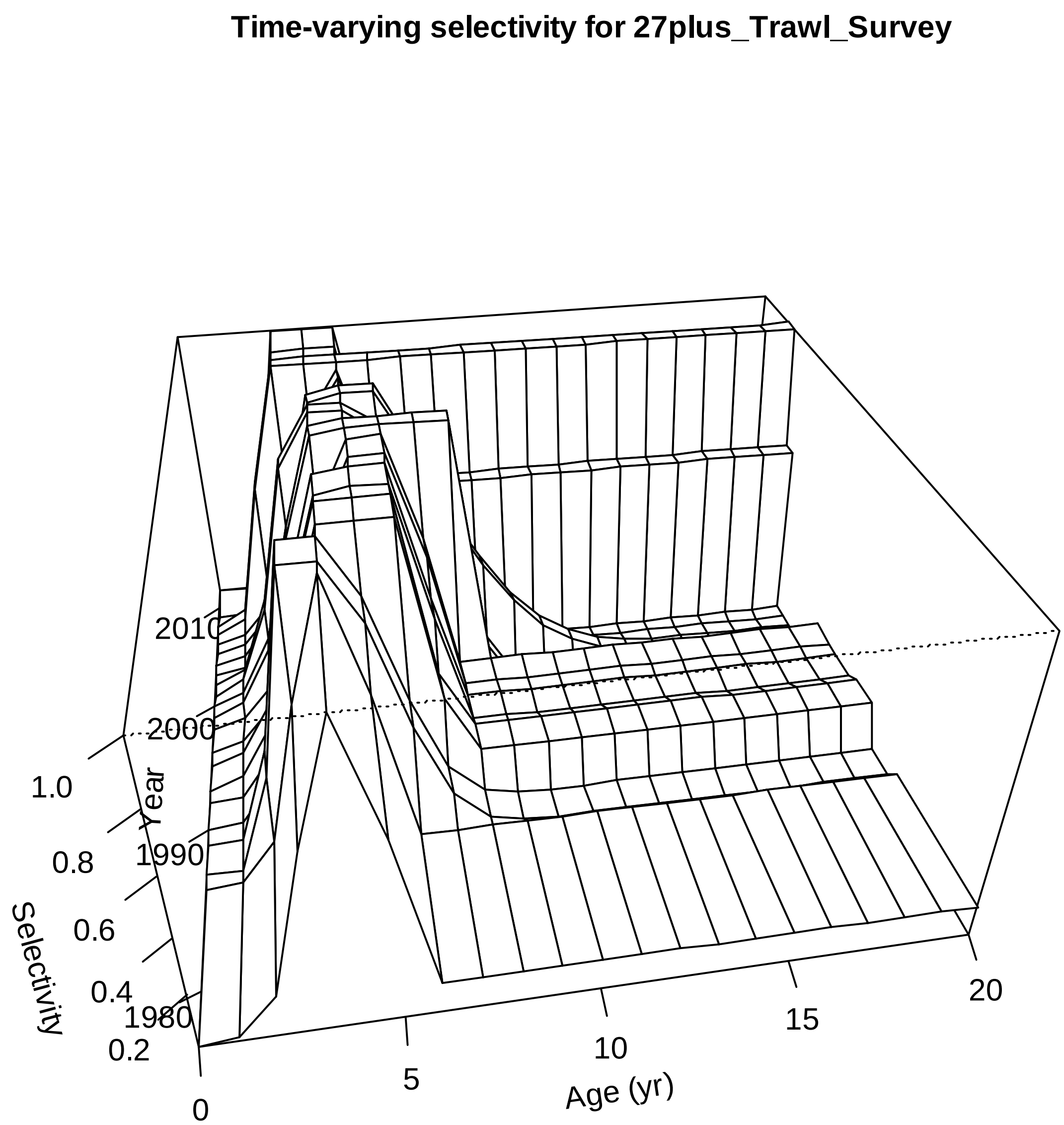

Figure 2.11 – 27-plus survey selectivity-at-age for Model 2

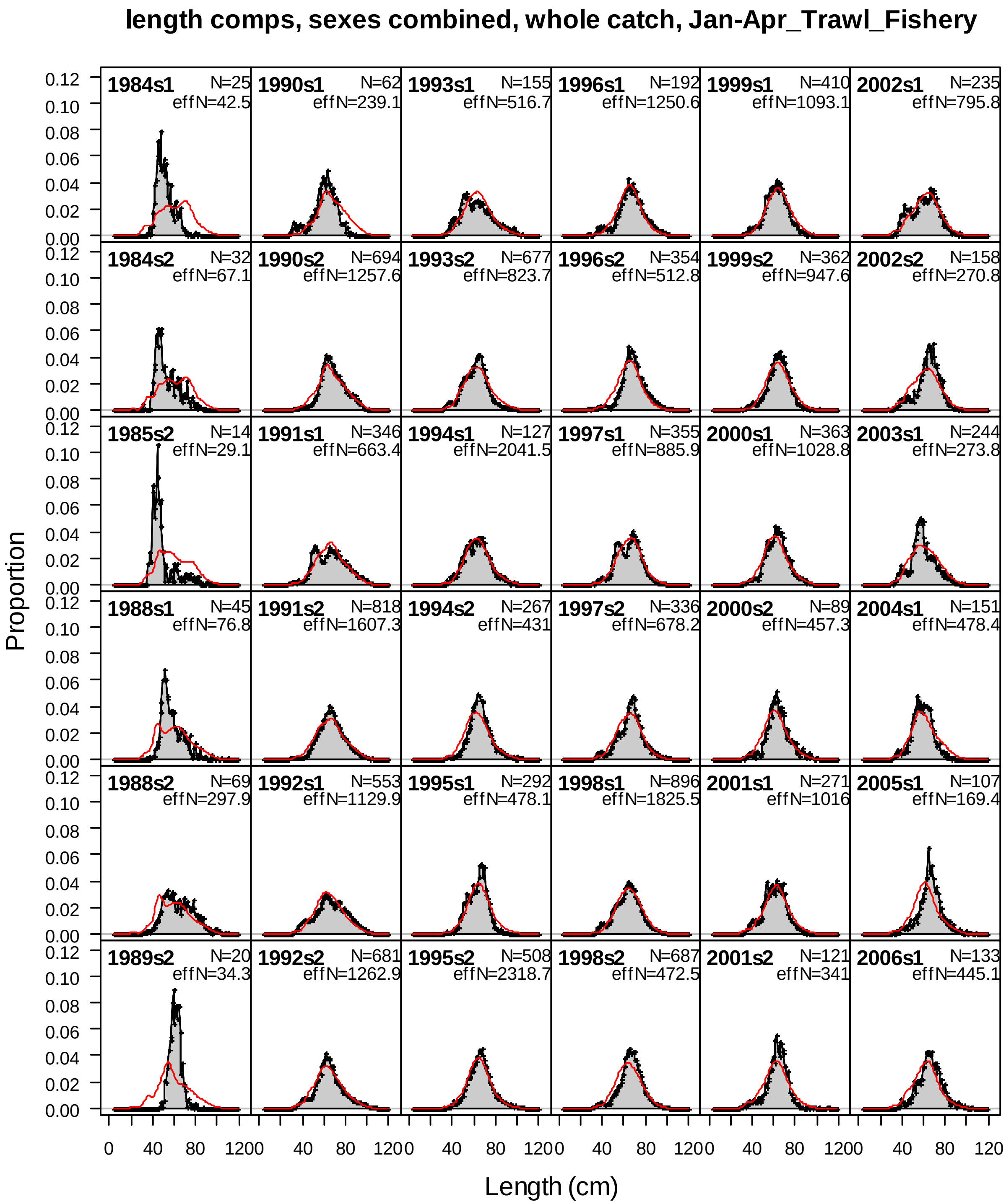

Figure 2.12 – Fits to fishery catch-at-length for Model 2

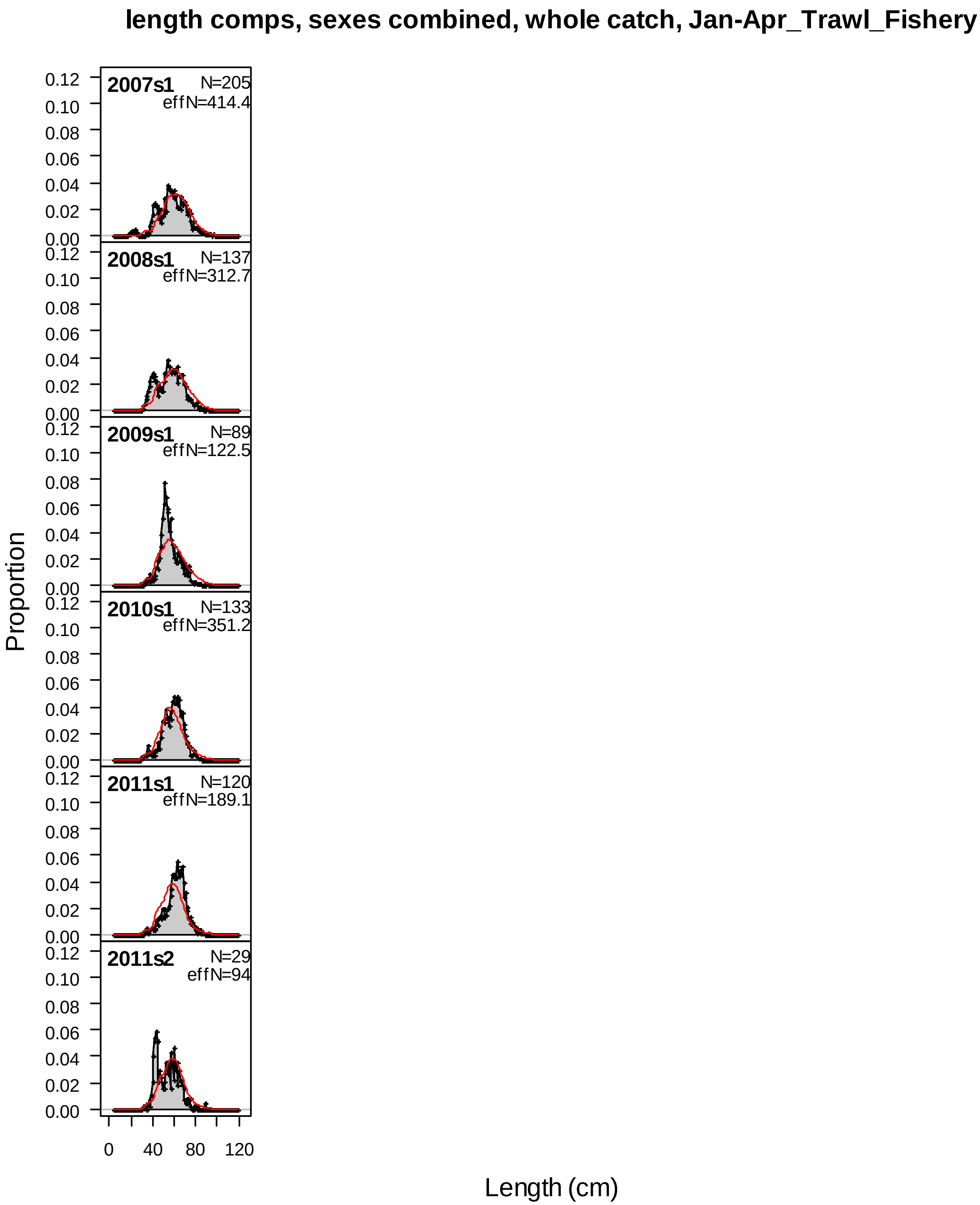

Figure 2.12 – Fits to fishery catch-at-length for Model 2 (continued)

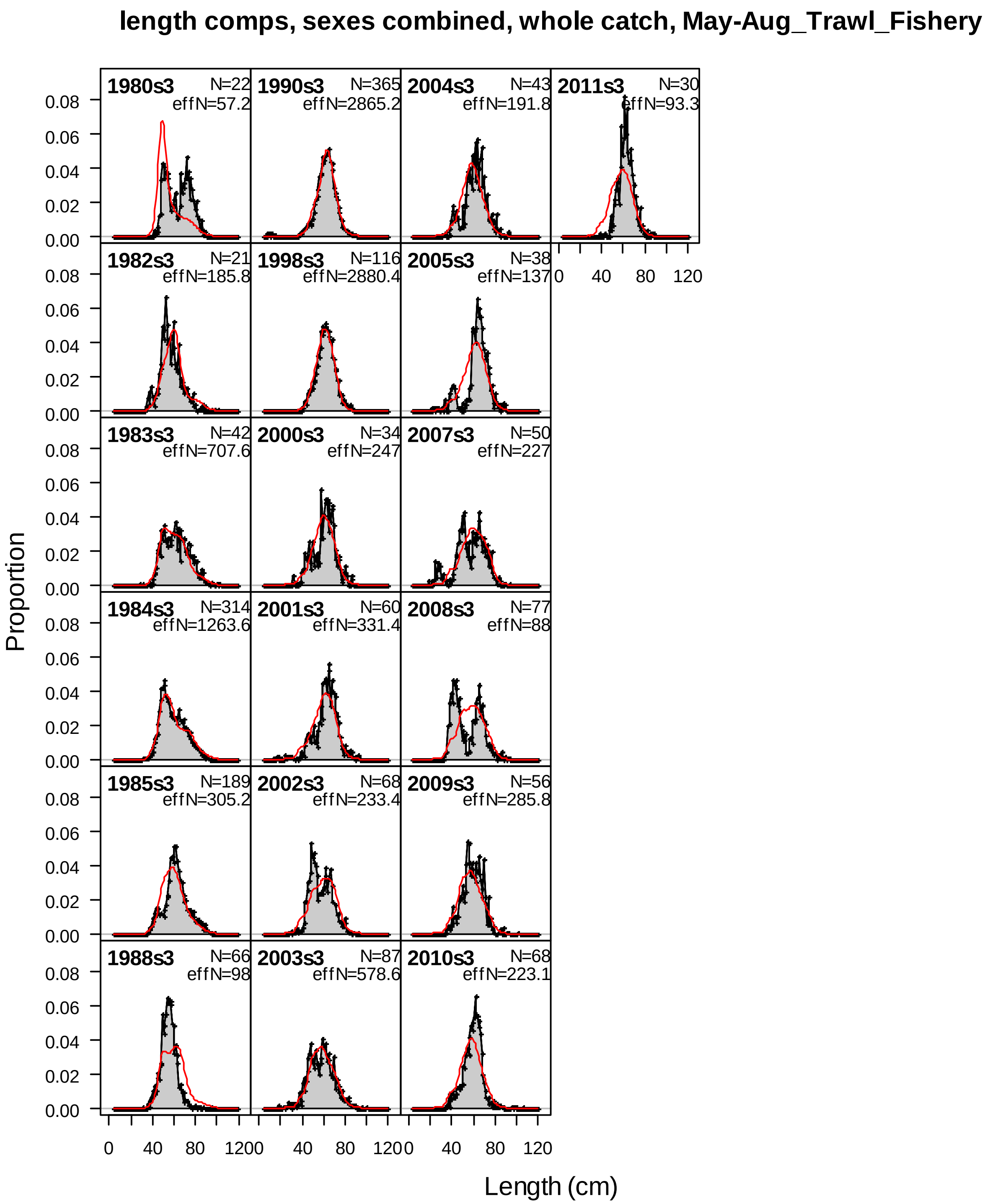

Figure 2.12 – Fits to fishery catch-at-length for Model 2 (continued)

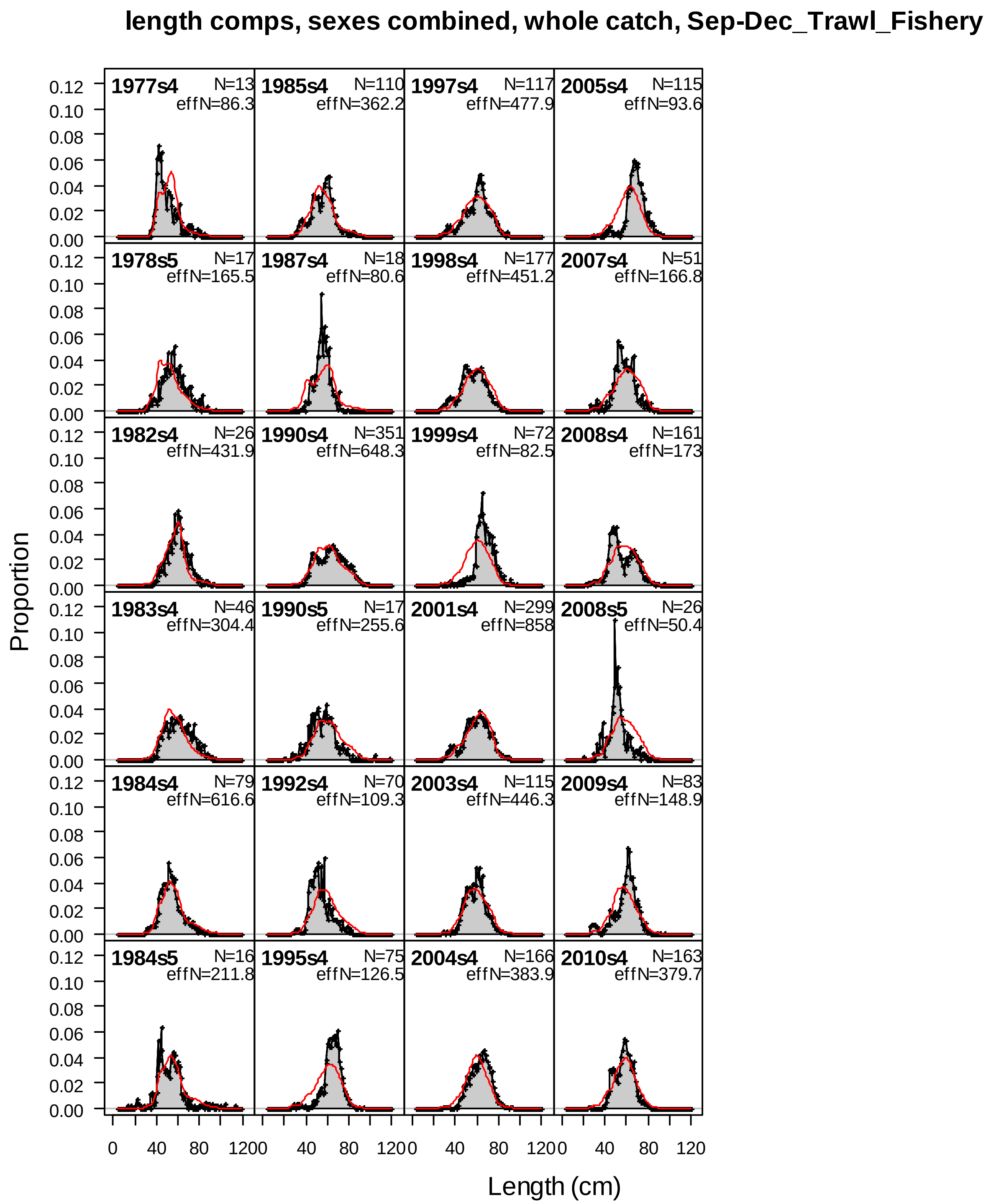

Figure 2.12 – Fits to fishery catch-at-length for Model 2 (continued)

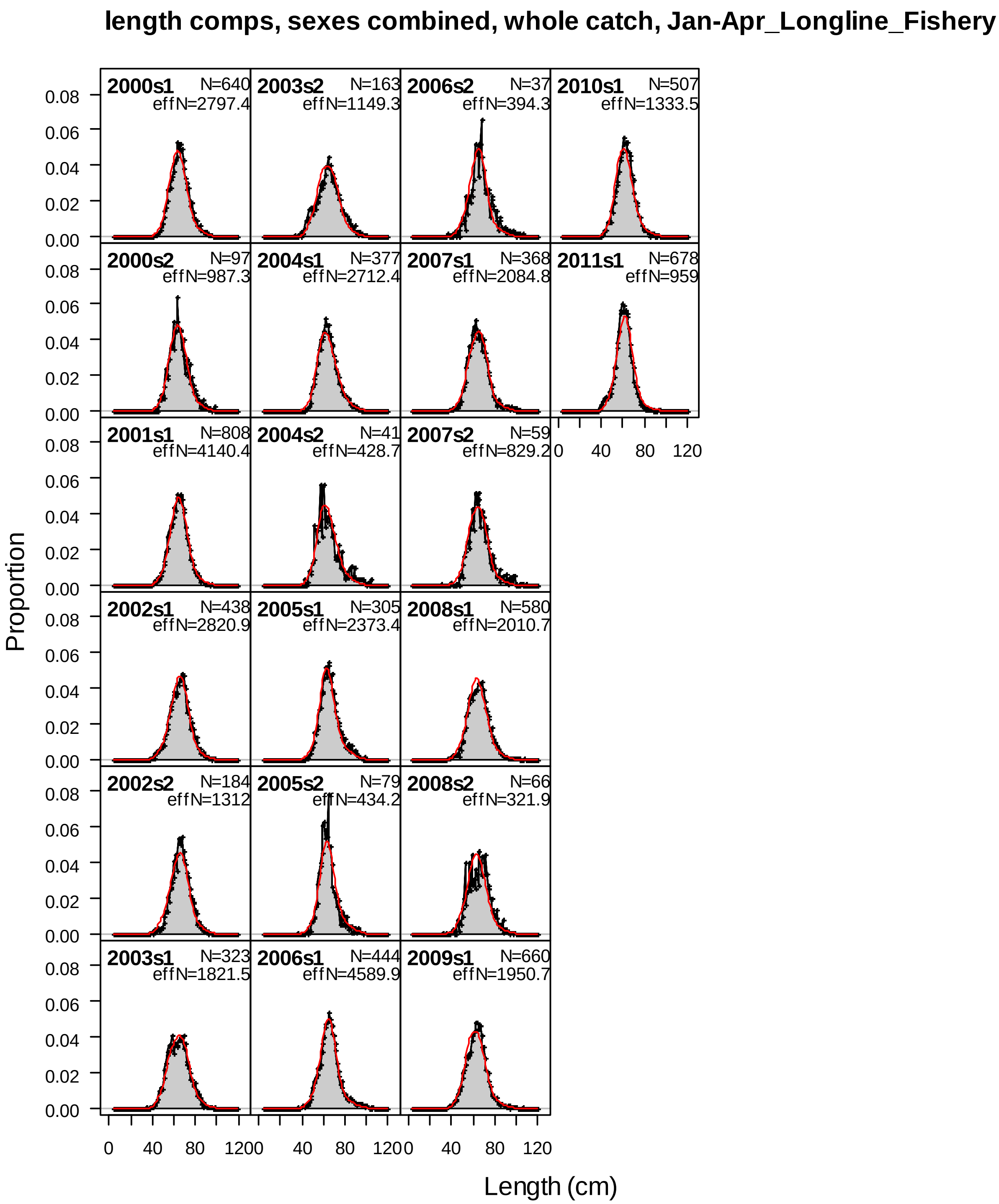

Figure 2.12 – Fits to fishery catch-at-length for Model 2 (continued)

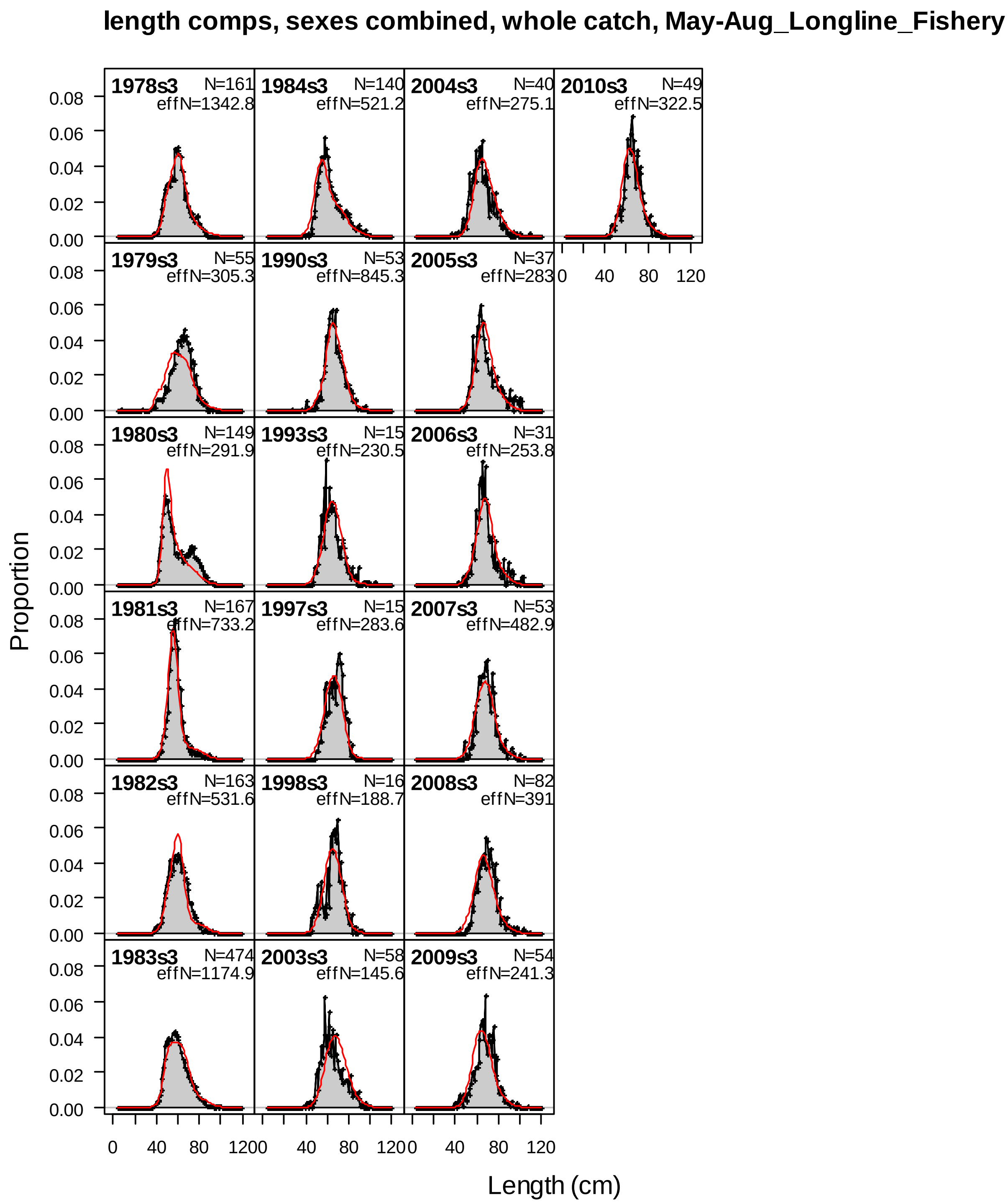

Figure 2.12 – Fits to fishery catch-at-length for Model 2 (continued)

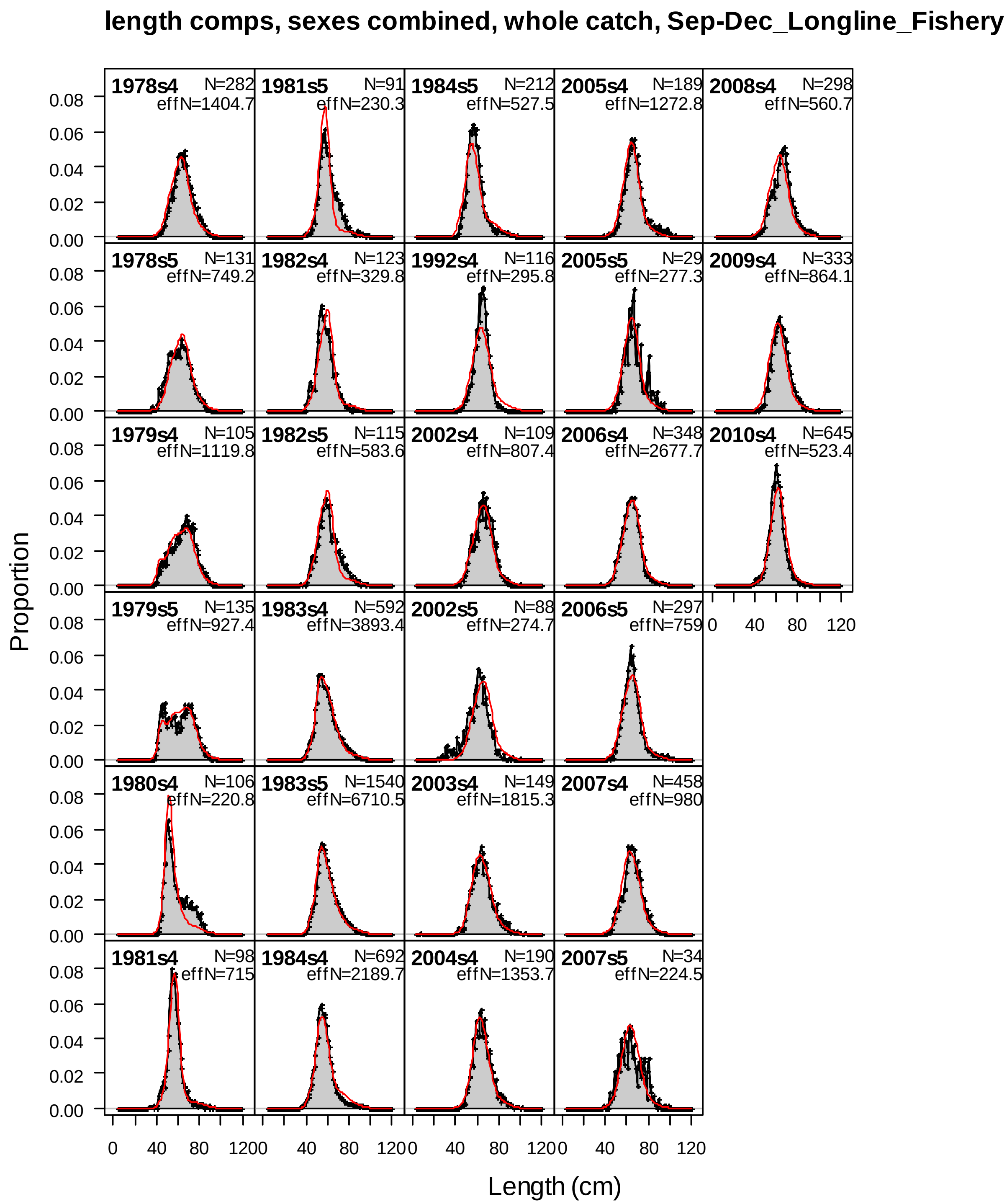

Figure 2.12 – Fits to fishery catch-at-length for Model 2 (continued)

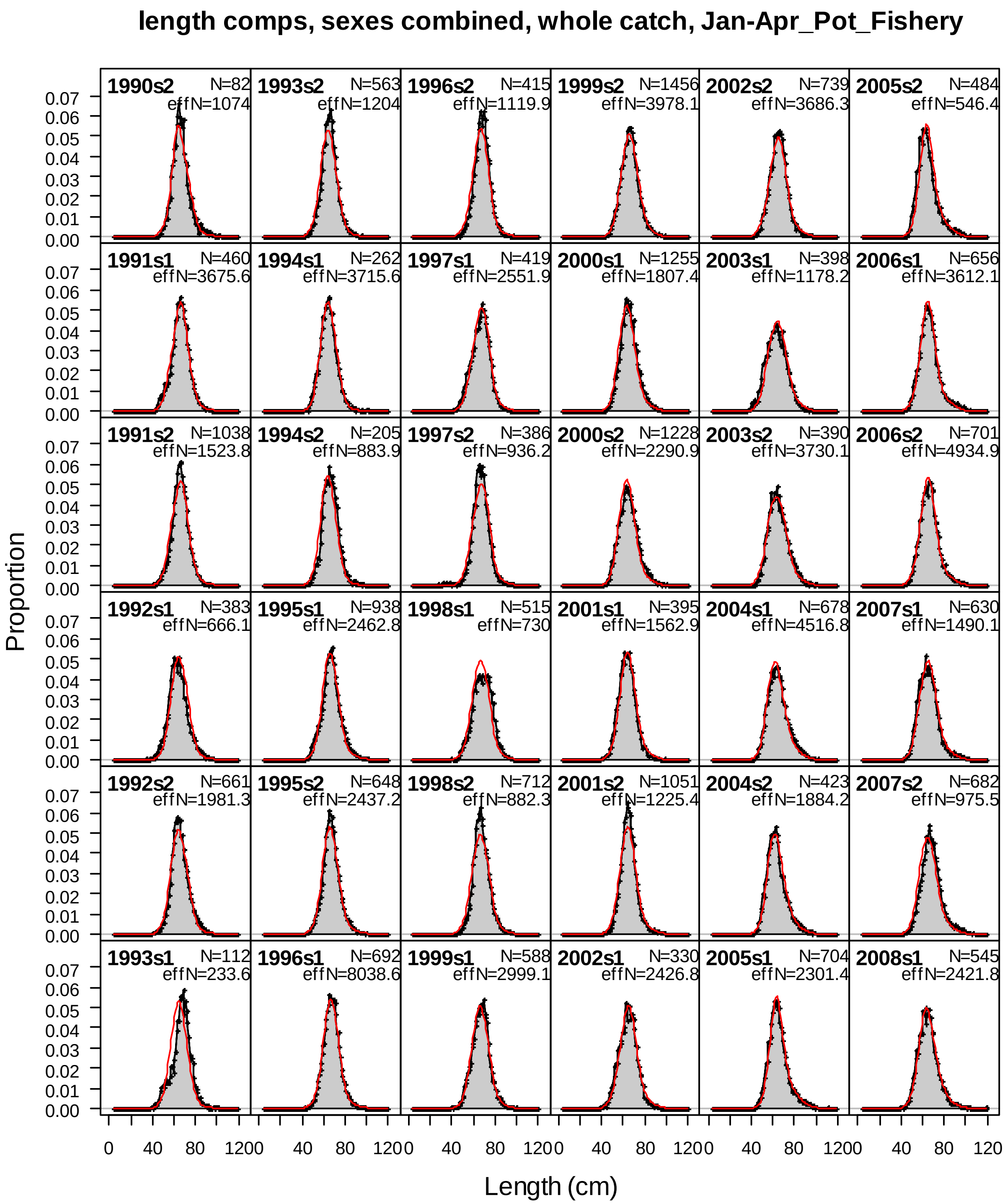

Figure 2.12 – Fits to fishery catch-at-length for Model 2 (continued)

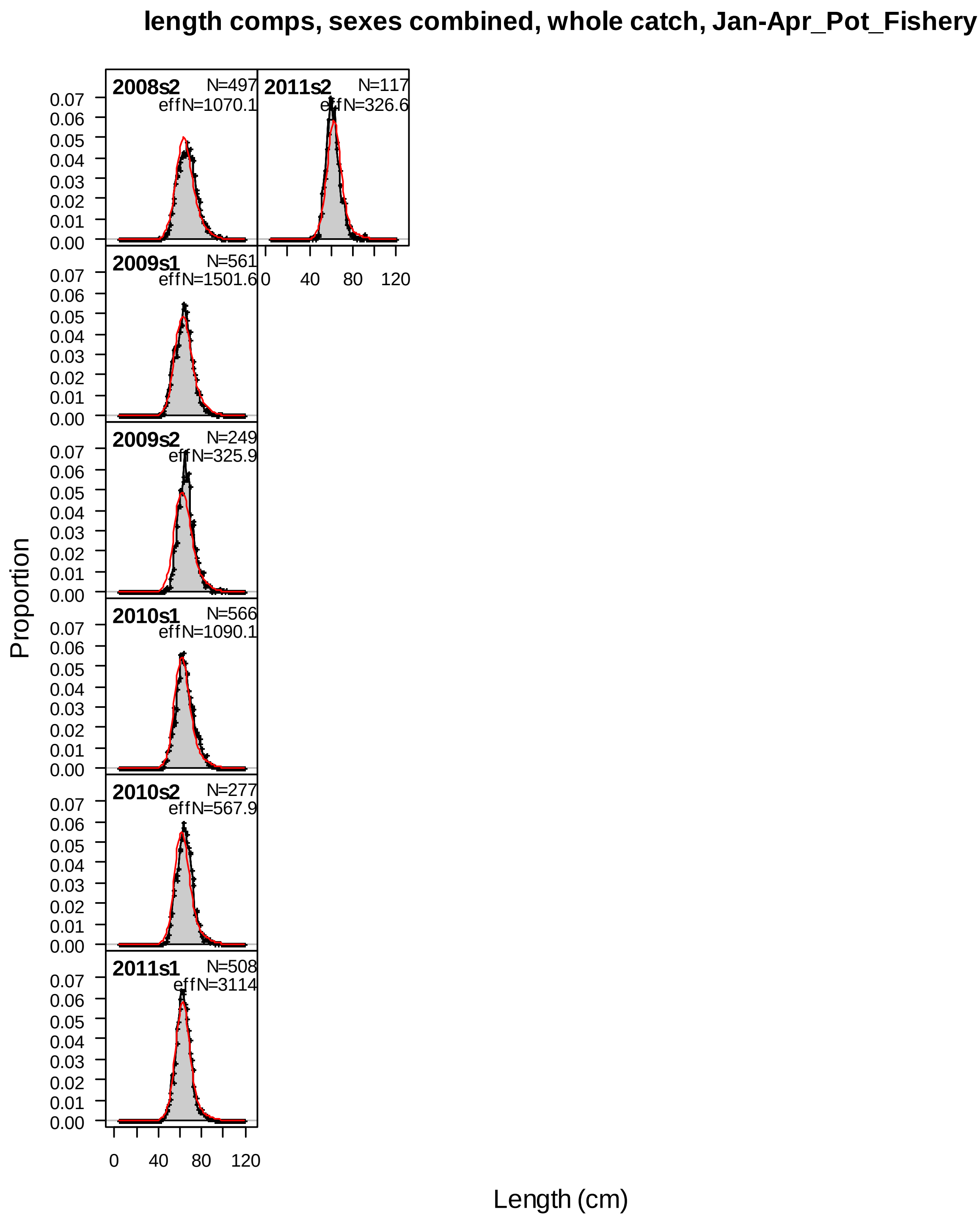

Figure 2.12 – Fits to fishery catch-at-length for Model 2 (continued)

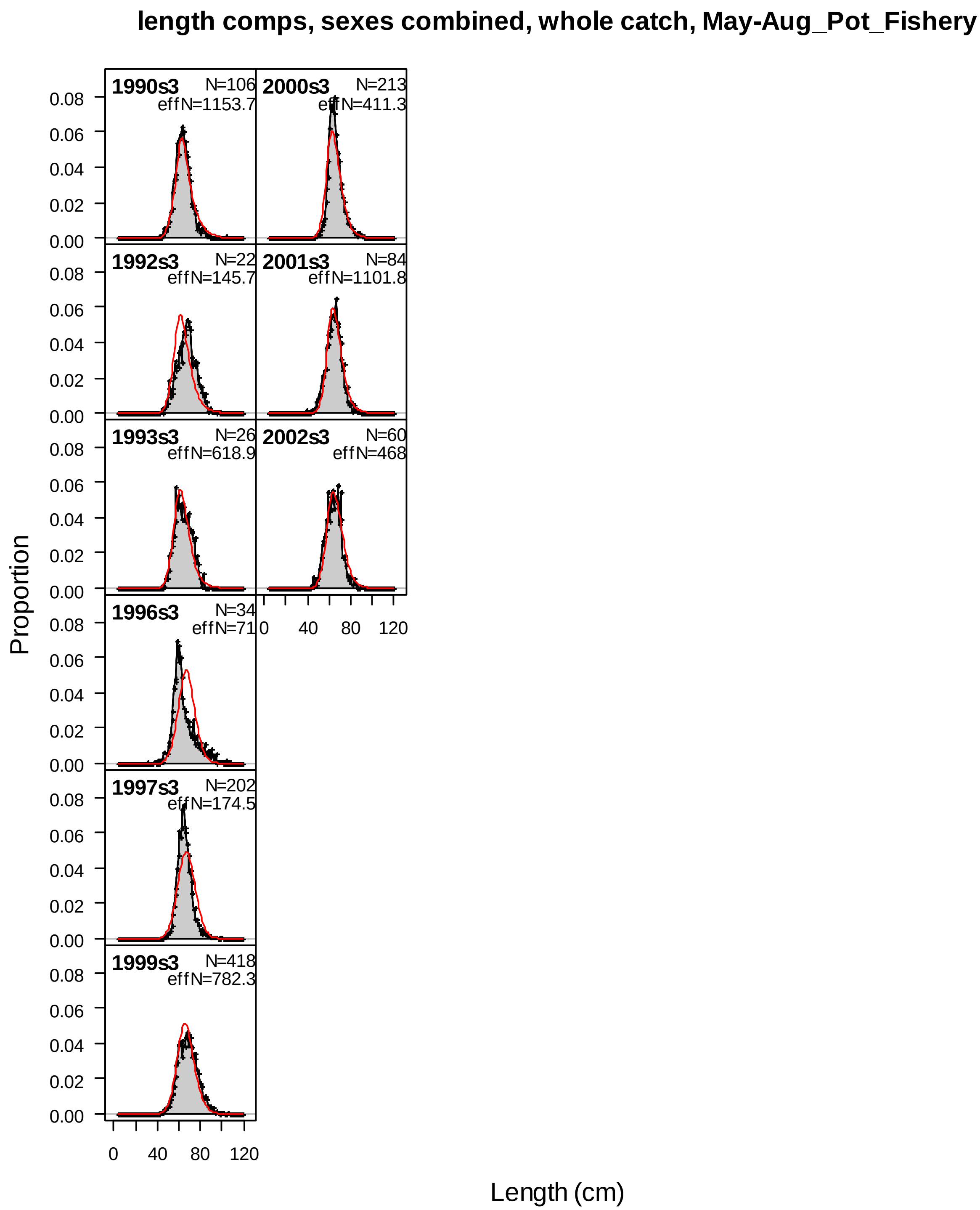

Figure 2.12 – Fits to fishery catch-at-length for Model 2 (continued)

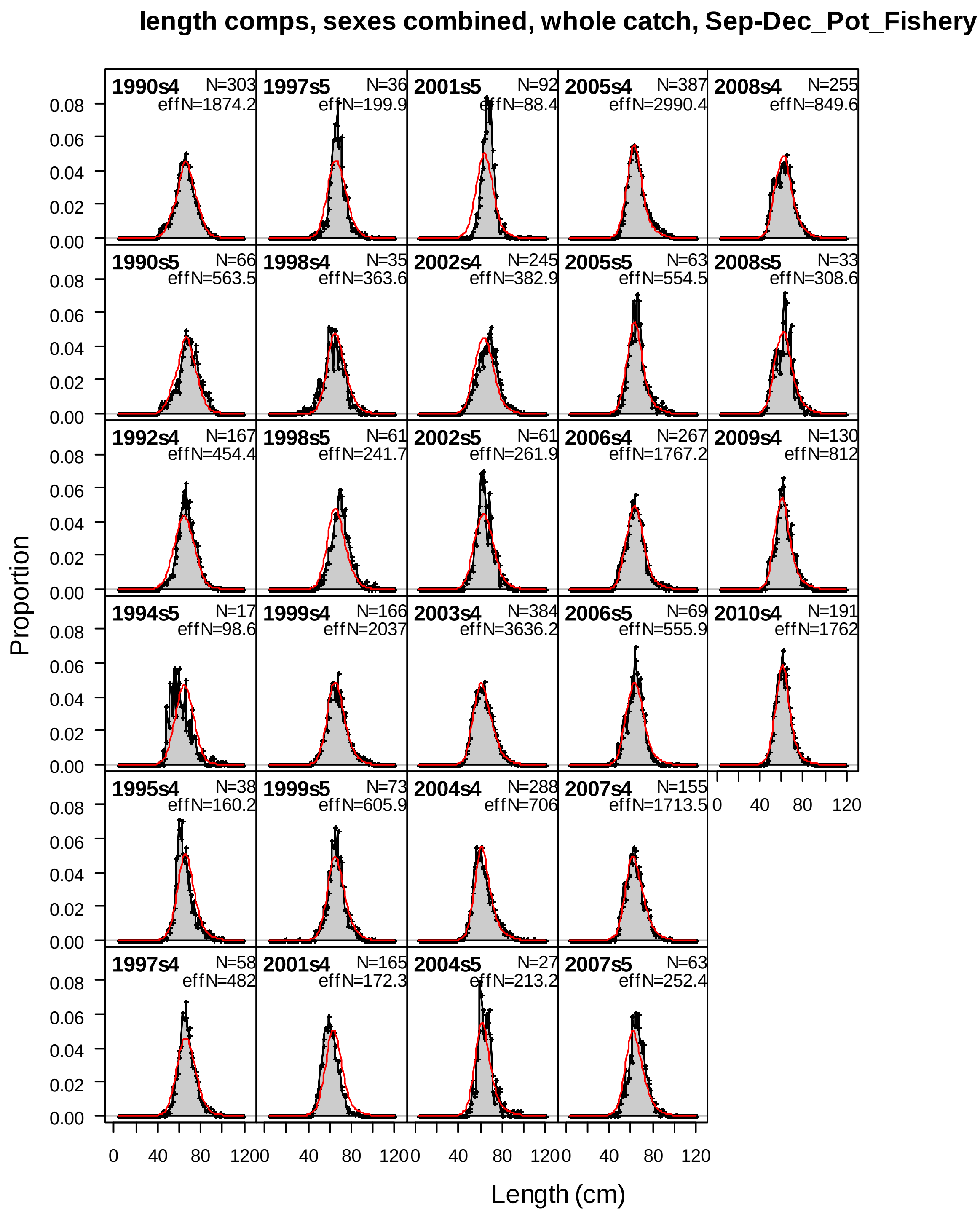

Figure 2.12 – Fits to fishery catch-at-length for Model 2 (continued)

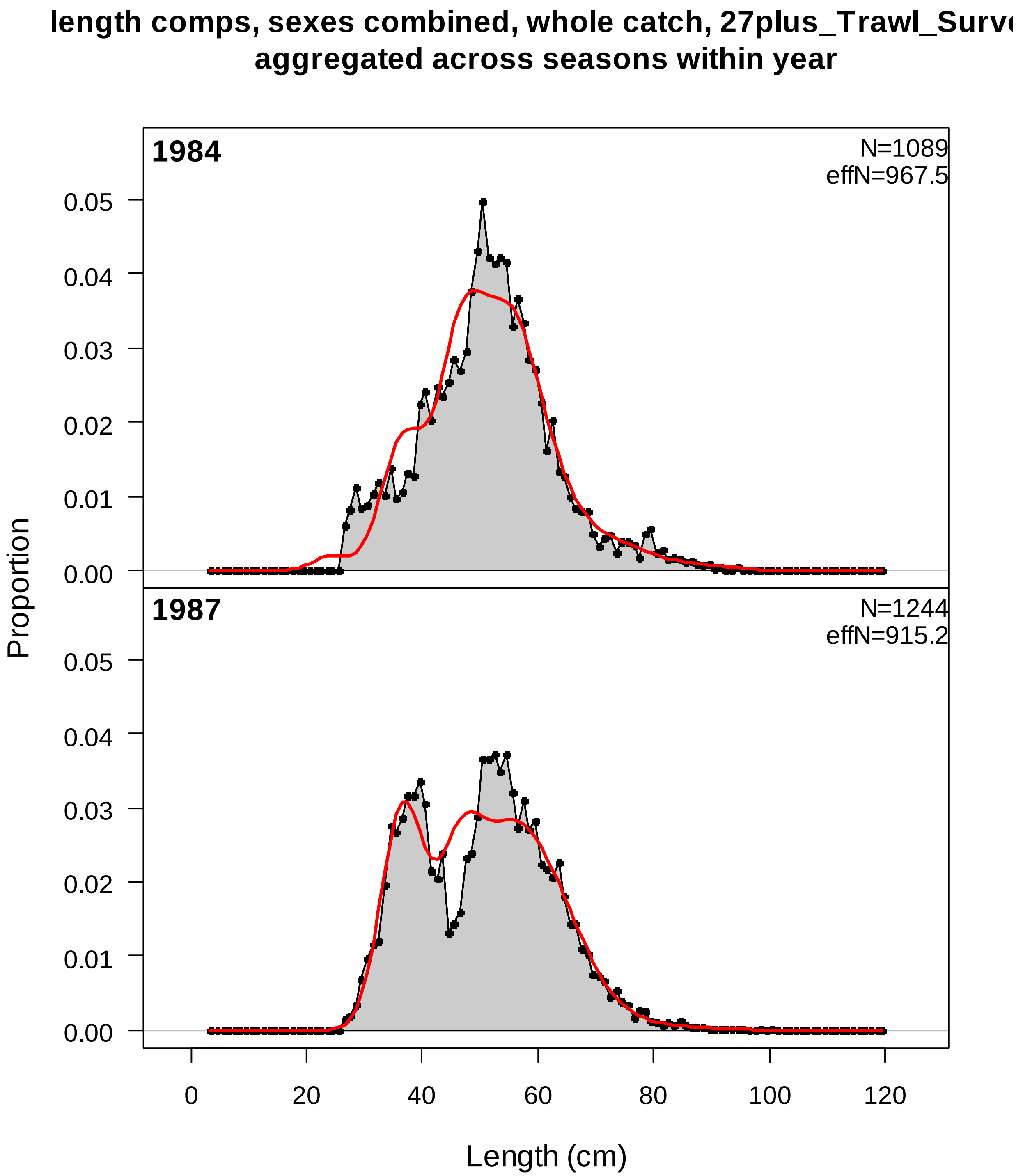

Figure 2.13 – Fits to 27-plus survey length comp data for Model 2

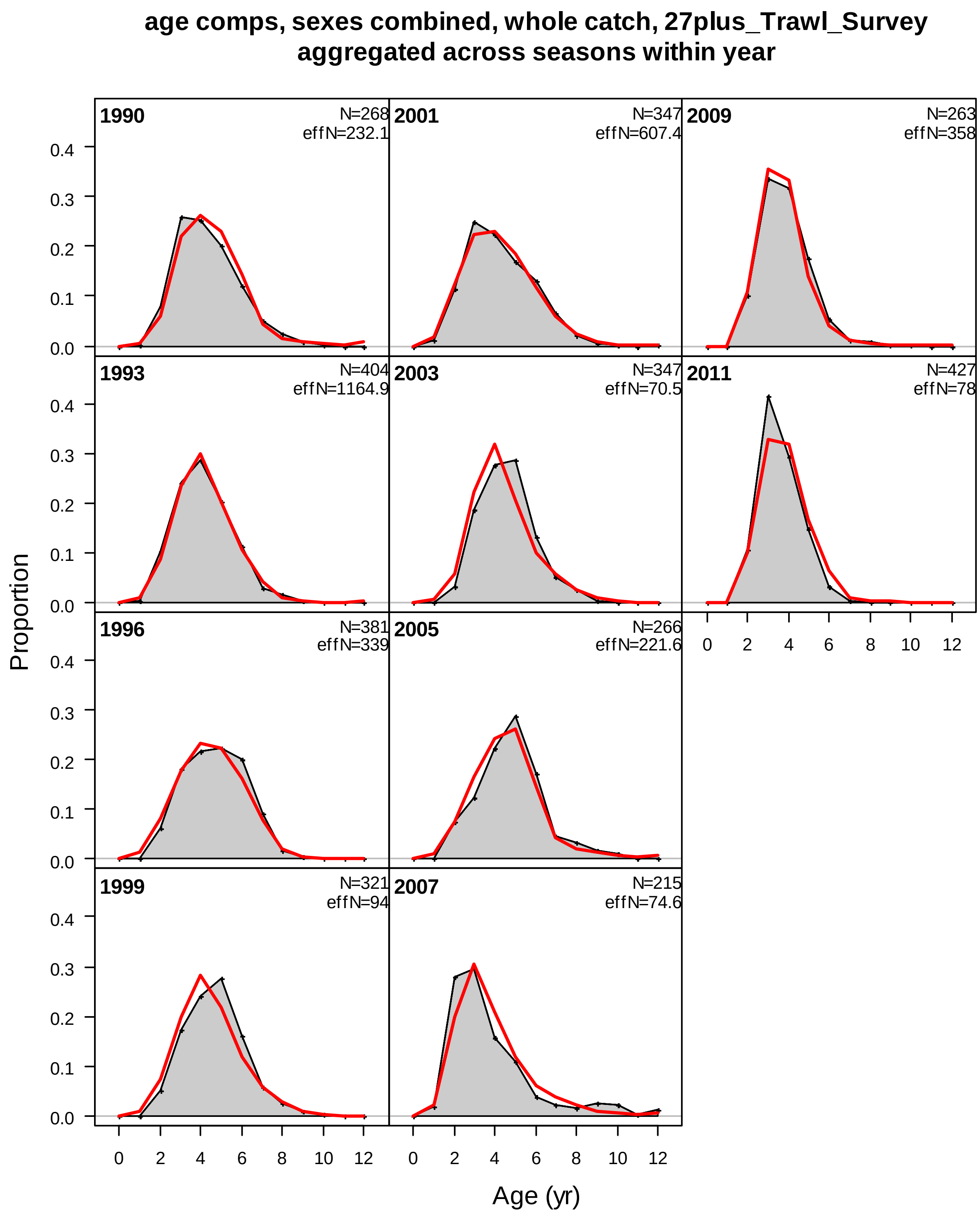

Figure 2.14 – Fits to 27-plus survey age comp data for Model 2

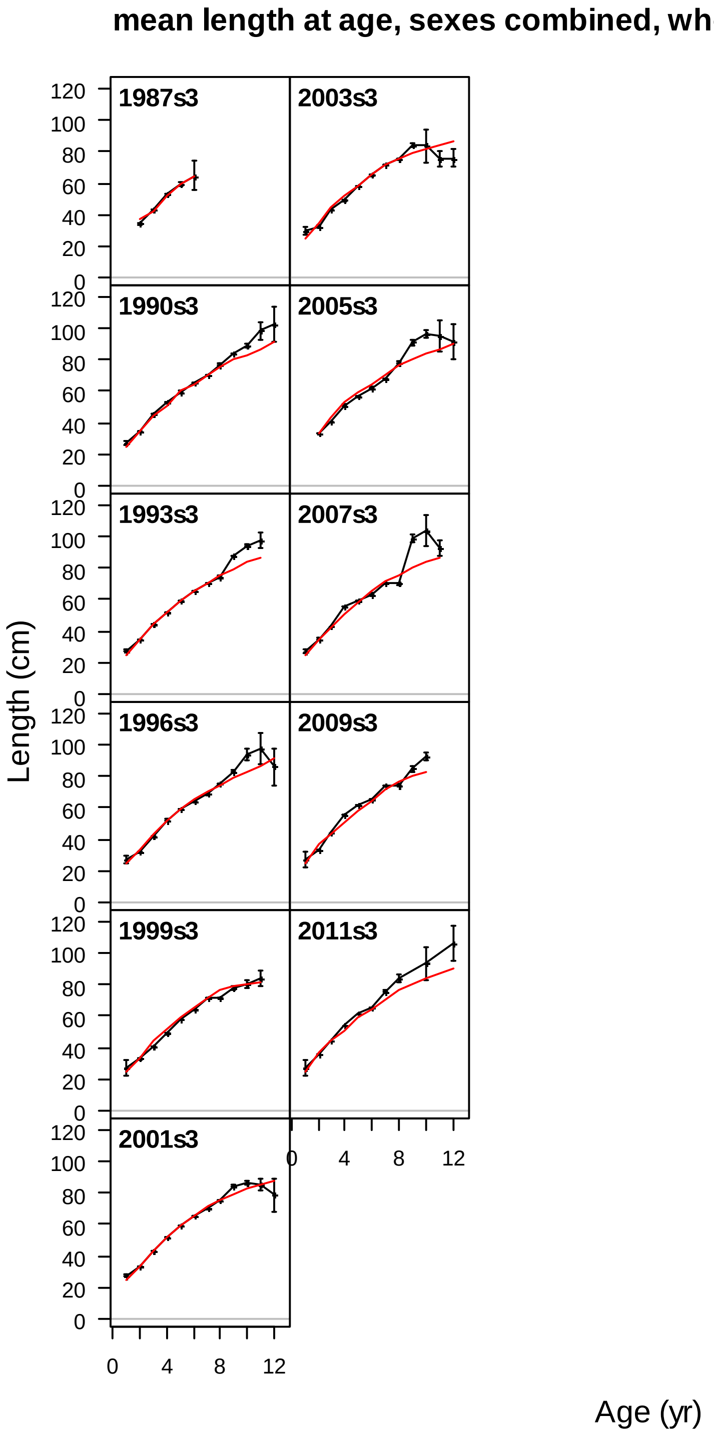

Figure 2.15 – Fits to 27-plus mean size-at-age for Model 2

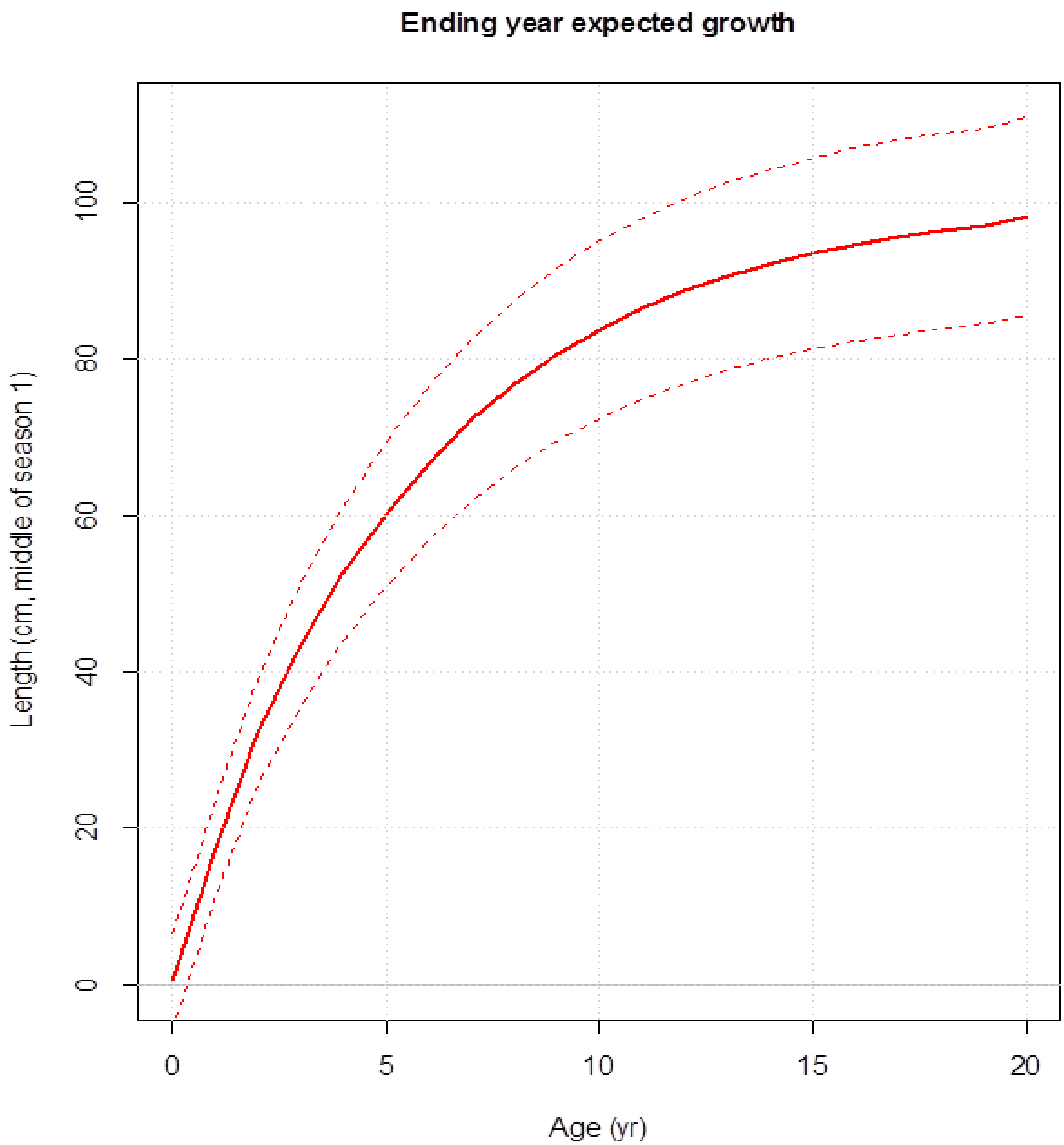

Figure 2.16 – Estimated length-at-age for Model 2

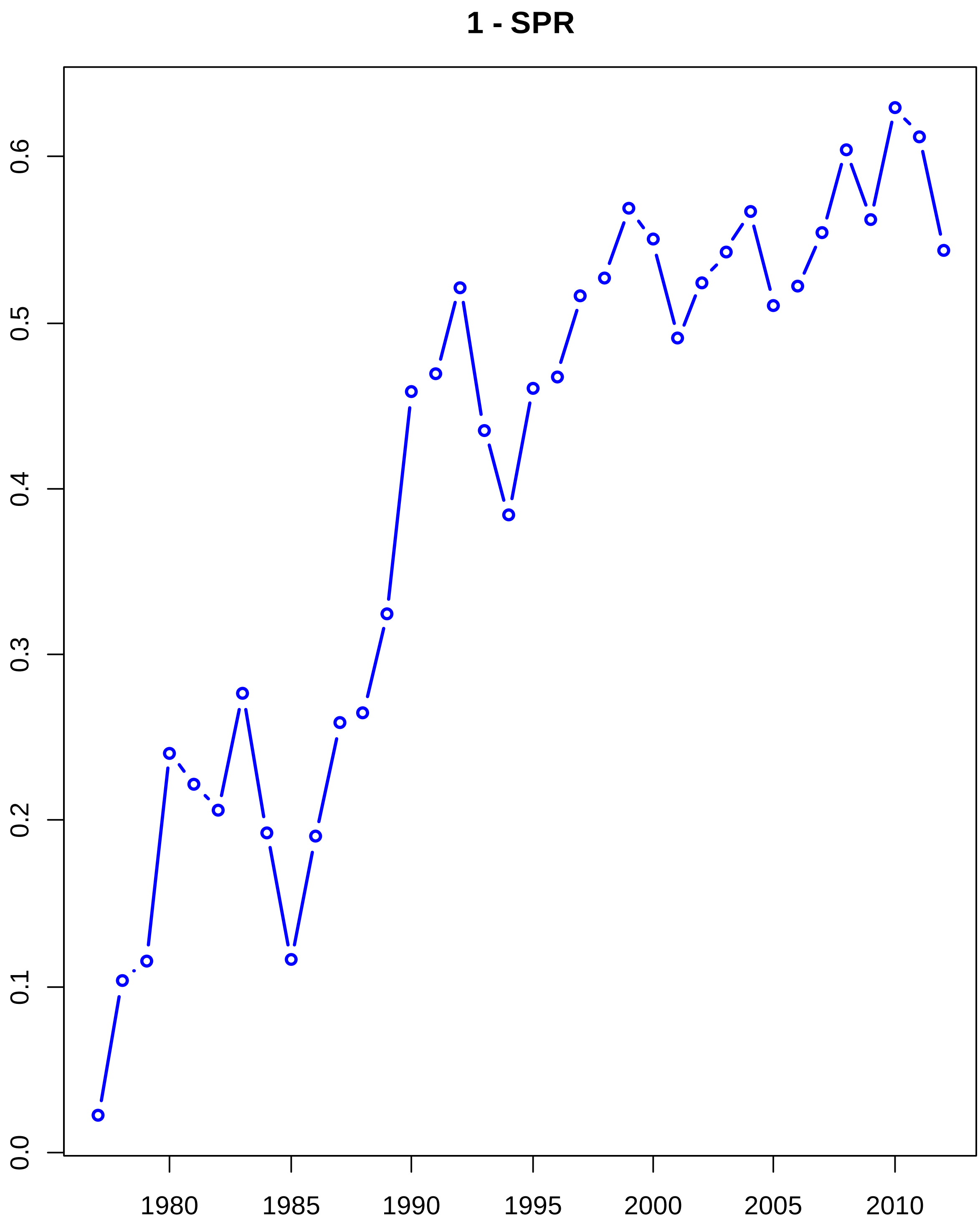

Figure 2.17 – 1 – SPR for Model 2

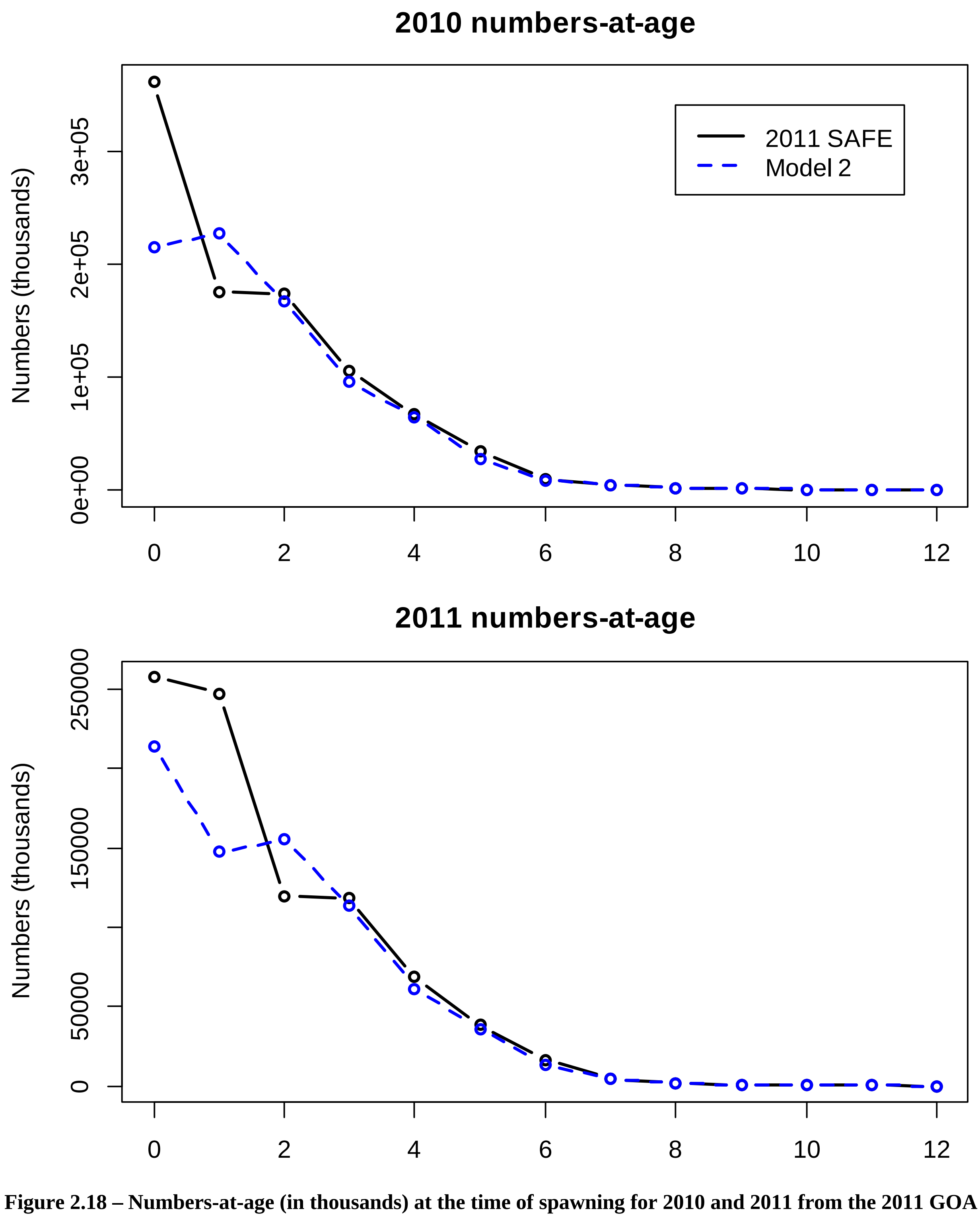

Figure 2.18 – Numbers-at-age (in thousands) at the time of spawning for 2010 and 2011 from the 2011 GOA Pacific cod SAFE document and Model 2

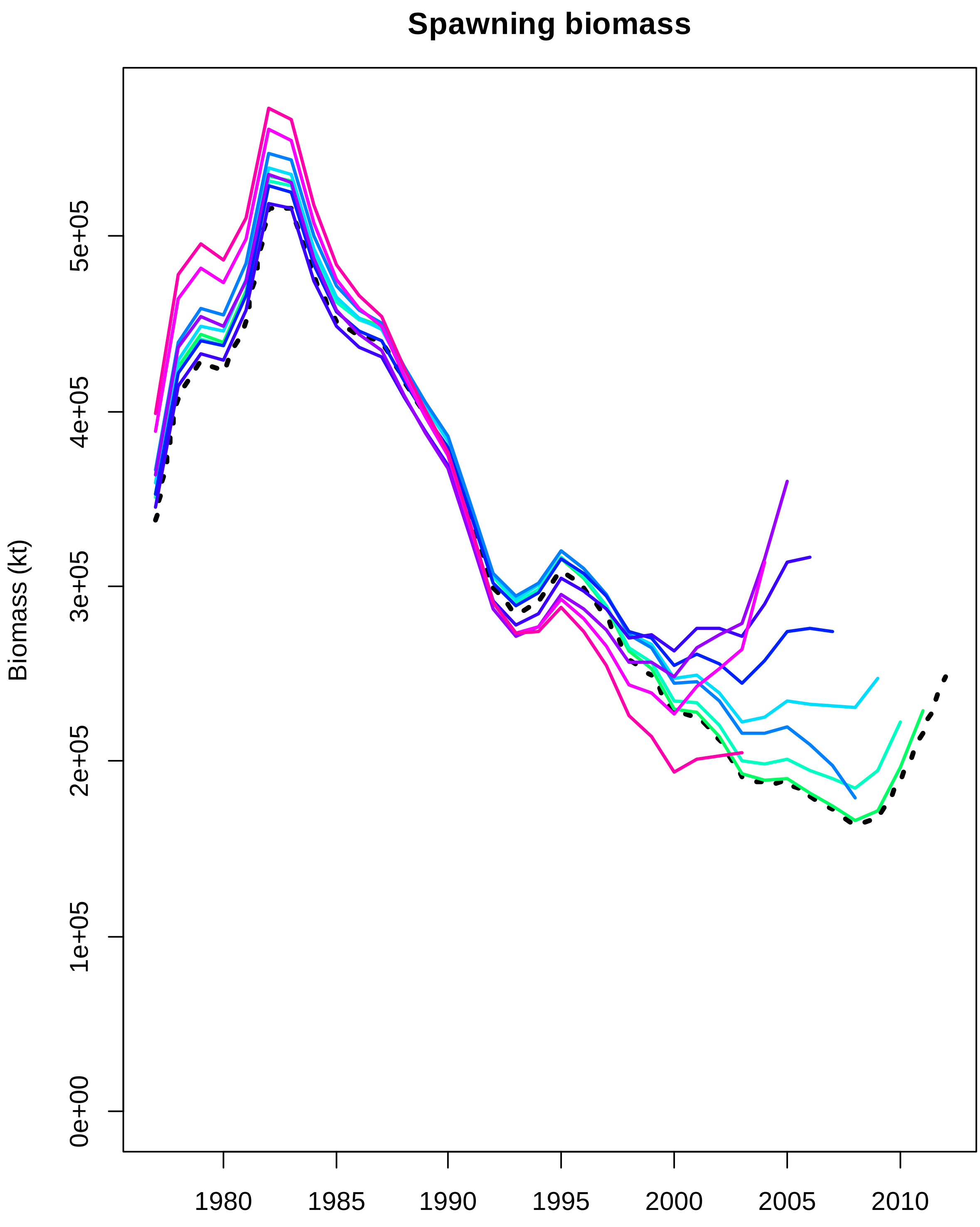

Figure 2.19 – Estimates of spawning biomass for 2003 – 2012 for Model 2

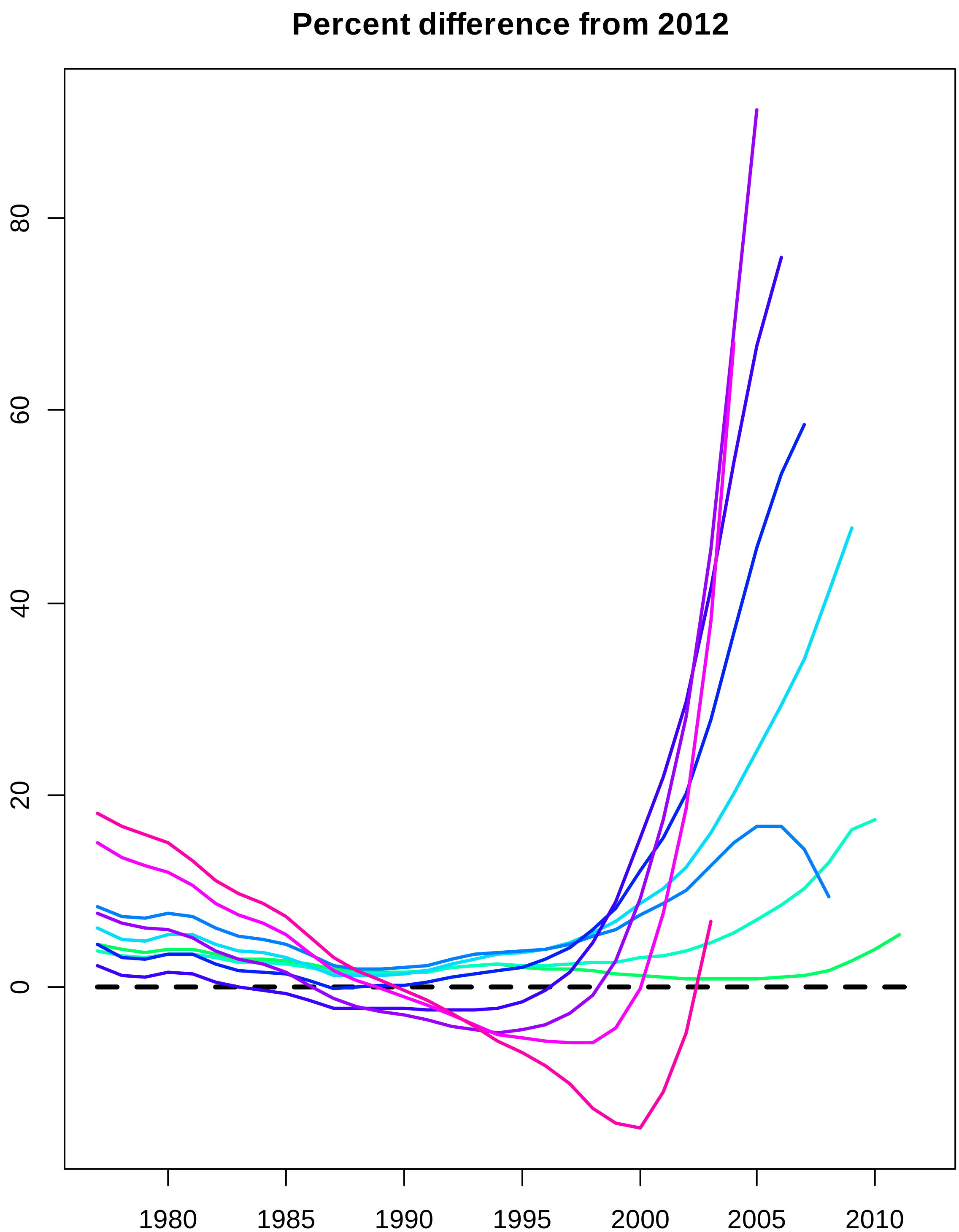

Figure 2.20 – Percent difference between spawning biomass for 2003 – 2011 and 2012 for Model 2

Chapter 2 Appendix: An exploration of GOA Pacific cod stock assessment models for 2012

Teresa A'mar

Resource Ecology and Fisheries Management Division
Alaska Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
7600 Sand Point Way NE., Seattle, WA 98115

Introduction

This document represents an effort to respond to comments made the GOA Plan Team, the joint BSAI and GOA Plan Teams, and the SSC on the 2011 assessments of the Pacific cod (*Gadus macrocephalus*) stocks in the Gulf of Alaska (Thompson et al., 2011). In order to allow for exploration of a wide variety of modeling assumptions, this preliminary overview focuses on model development rather than application of the same model(s) to multiple data sets. Specifically, the Stock Synthesis model configurations presented here are applied to the data used in the 2011 GOA Pacific cod stock assessment.

Comments from the Plan Teams and SSC

Joint Plan Team Comments from the May 2012 Minutes

JPT1: "For the GOA, the Teams recommend that the preliminary assessment include the following two models, which are in addition to any models that the authors wish to propose: Model 1 is last year's final model, and Model 2 is last year's final model with re-tuned catchability."
Response: The initial results from these model configurations are included as Models 1 and 1Q ("Q" indicates the model was iteratively tuned so that mean catchability for 60-81 cm was 0.916).

JPT2: "For both the EBS and GOA, the Teams recommend that the authors attempt to explore the divergent ageing bias trends in the two regions and the impacts thereof."
Response: This issue will be addressed in the November SAFE document.

JPT3: "For both the EBS and GOA, the Teams recommend that the authors attempt to evaluate the biological basis for estimated patterns of seasonal weight at length."
Response: This issue will be addressed in the November SAFE document.

JPT4: "For both the EBS and GOA, the Teams recommend that the authors attempt to estimate catchability internally. This can be addressed as an option under Model 1 without developing and presenting a full set of results for an additional model (full results for the base case of Model 1 are requested, however)."
Response: The initial results from this model configuration are included as Model E.

JPT5: "For the GOA only, the Teams recommend that the authors reduce the number of parameters. This can be addressed as an option under Model 1 without developing and presenting a full set of results for an additional model (full results for the base case of Model 1 are requested, however)."
Response: Models B, BQ, C, CQ, and D have fewer estimated parameters than Models 1 and 1Q.

JPT6: "Seven model evaluation criteria were proposed: 1) fitting the age composition data (unanimous CIE recommendation); 2) internal estimation of aging error bias (much more efficient); 3) *correspondence between the model-estimated mean size-at-age and the empirical survey mean size-at-age of the first three modes of the average survey size composition; 4) correspondence of the product of survey catchability and survey selectivity (for the 61 to 80 cm size range) from the model and the value of 0.916 estimated by Nichol et al. (2007); 5) accounting for full variability in the observed length-at-age among individuals and years; 6) low temporal variability in survey selectivity and catchability; and 7) reasonable retrospective behavior. The Plan Team endorsed, and the SSC concurs, with these selection criteria, which are a distillation of past preferences and recommendations from the Plan Teams, CIE reviewers, the public, and the SSC. These criteria will be used when evaluating the results of model configurations."*

Responses correspond to each of the JPT proposed model evaluation criteria listed above:

Criteria 1, The fits to the survey age composition data are presented for all models;

Criteria 2, All model configurations estimate ageing bias;

Criteria 3, Comparison of survey mean size-at-age with model-estimated survey mean size-at-age will be addressed in the November SAFE document;

Criteria 4, Calculated values for mean 27-plus survey catchability for 60 – 81 cm for all model configurations are presented in Table 2;

Criteria 5, This issue will be addressed in the November SAFE document;

Criteria 6, Five model configurations were explored that have two time blocks defined for catchability and selectivity for the sub-27 survey; one model configuration has two time blocks defined for selectivity for the 27-plus survey as well, as the base model configurations have two time blocks defined for catchability of the 27-plus survey (1984 – 1993 and 1996 – present) due to the switch from 30-minute to 15-minute tows in the survey design; and

Criteria 7, This issue will be addressed in the November SAFE document and when the Plan Team working group on retrospective analyses is completed.

SSC Comments from the June 2012 Minutes

SSC1: "As for the EBS, the SSC agrees with the choice of last year's final model (formerly Model 3, new model 1) as the baseline model for the Gulf of Alaska and a second model (model 2) that re-tunes catchability to match the empirical estimates from Nichol et al. (2007)."

Response: The initial results from these model configurations are included as Models 1 and 1Q.

Summary of the base model configuration

The base model configuration for 2012 is the 2011 Model 3 configuration. The software used to run all models was SS v3.24f as compiled on 03 August 2012 with ADMB v.11 (Last year's models used v3.22b, as compiled on 8/3/11).

Model evaluation

Model configurations for 2012

The following details attributes of the requested models:

Model 1:	2011 Model 3 (the base model)
Model 1Q:	Model 1 with mean catchability for the 27-plus survey tuned iteratively to 0.916

These models include:

- Time-varying fishery selectivity-at-length for all gears and seasons;
- Two blocks for catchability for the 27-plus survey, 1984 – 1993 and 1996 – 2011;
- Time-varying catchability for the Sub-27 survey;
- Time-varying survey selectivity-at-age for the 27-plus survey;

- Constant survey selectivity-at-age for the Sub-27 survey; and
- Median recruitment before 1977 restricted to be less than the post-1976 median recruitment, as the pre-1977 recruitment deviation is restricted to be less than 0.0

On evaluation of these models it was suggested by Ian Stewart and Ian Taylor (NWFSC, pers. comm.) to change the Stock Synthesis option "comp_tail_compression" from 0.000001 (used previously) to -1, which turns this feature off and uses all of the age and length composition data. This feature, when implemented as last year, binned the values in the composition "tails" for both the observed and expected values. This change is applied in subsequent models beginning with:

<u>Model A</u>: Model 1 (the base model) with tail compression turned off
<u>Model AQ</u>: Model A with mean catchability for the 27-plus survey tuned iteratively to 0.916

The four base models estimated very similar values for spawning biomass (Fig. 1), although the estimates of recruitment differ in recent years (Fig. 2), which is also seen in the fits to the 27-plus and sub-27 survey indices (Figs. 3 and 4). The fits to the survey length composition data for Models 1 (Figs. 5 and 7) and A (Figs. 6 and 8) also differ substantially, which shows the impact of tail compression and is likely the reason for differences in recent recruitment estimates.

The following considerations for proceeding with alternative models should consider (and for which feedback would be appreciated) include:

- The importance using the ADF&G nearshore trawl survey data as an additional index;
- The use of time-varying catchability coefficients for the sub-27 survey;
- Fitting the age composition for the sub-27 survey; and
- The use of time-varying selectivity for the 27-plus survey.

Alternative model configurations evaluated included:

<u>Model B</u>: Model A with sub-27 survey changed from time-varying Q and constant selectivity to two blocks for both Q and selectivity (split at 1996), and the initial value for the pre-1996 Q deviation for both the 27-plus and sub-27 surveys set to 0.0

<u>Model BQ</u>: Model B with mean catchability for the 27-plus survey tuned iteratively to 0.916

<u>Model C</u>: Model B with the initial value for pre-1977 recruitment deviation changed to 0.0 and the upper bound increased to allow positive values

<u>Model CQ</u>: Model C with mean catchability for the 27-plus survey tuned iteratively to 0.916

<u>Model D</u>: Model C with 27-plus survey changed from 11 to 2 blocks for selectivity (split at 1996)

<u>Model E</u>: Model A with Q for the 27-plus survey estimated, and the initial value for the pre-1996 Q deviation for both the 27-plus and sub-27 surveys set to 0.0 (See JPT4)

<u>Model 1B</u>: Model B with tail compression set to the value used in Model 1

<u>Model 1C</u>: Model C with tail compression set to the value used in Model 1

The changes for Q and selectivity for the sub-27 survey characterizes the assumption that the data are representative of cohort strength, rather than survey variability. For comparison purposes only, the GOA Pacific cod length composition data from the ADF&G crab and groundfish nearshore trawl survey are presented. Small fish, 5 – 15 cm, which are assumed to be age-0, are sampled by the ADF&G survey and are prominently featured in the data in some years. The NMFS GOA bottom trawl survey samples fish less than 27 cm, which are assumed to be primarily age-1 fish. The results of a comparison of the proportions-at-length data from the ADF&G survey and the NMFS survey suggest that the relative numbers of assumed age-0 fish in the ADF&G survey in a given year are similar to the relative numbers of assumed age-1 fish in the NMFS survey the following year (Figs. 9 – 12). The change from time-varying to constant Q is featured in Models B, BQ, C, CQ, and D.

Similarly, the changes to selectivity for the 27-plus survey characterize the assumption that the data are representative of the stock characteristics, rather than survey variability. These assumptions and model configurations will be investigated further. This feature is present in Model D.

To evaluate convergence, Models 1, 1Q, A, AQ, C, and CQ have been tested using the Stock Synthesis "jitter" functionality which generates random initial values based on parameter bounds and other properties. The jitter parameter was set to 0.1 and each model was run 50 times. If the jitter runs produced initial values which led to a lower value for the objection function, then these initial values were used as the starting point for another set of 50 jitter runs. To complement this work, the initial values of some deviation parameters were set to 0.0 to test convergence. Since deviation parameters are applied to other variables, setting the initial value to 0.0 represents the assumption that this deviation has no positive or negative impact on the variable. This was done for variables in Models B, BQ, C, CQ, D, and E.

Model configurations 1B and 1C were included as a comparison to Models 1 and 1Q, as these model configurations have tail compression turned on.

Results

The values for total likelihood for Models 1 and 1Q are lower than those for all new model configurations (Table 1), due to the change in the comp_tail_compression functionality. Model C has the lowest value of all new model configurations for both total likelihood and AIC; Model CQ has the lowest value for total likelihood and AIC of all new model configurations where the mean 27-plus survey catchability has been tuned iteratively to 0.916.

The calculated values for the mean catchability for the 27-plus survey for 60 – 81 cm ranged from values in the neighborhood of 0.916 for tuned model configurations to above 0.94 for the other model configurations (Table 2); the values for the pre-1996 Q deviation for the 27-plus and sub-27 surveys were in the neighborhood of 0.5 and -0.5, respectively, save for Model E, which estimated catchability for the 27-plus survey. The (base) values for catchability for the sub-27 survey ranged from a low of 0.07 to a high of 0.16.

The estimates of spawning biomass are similar across all new model configurations, save for Model E, which has consistently lower estimates due to estimating the catchability for the 27-plus survey to be significantly higher than all other model configurations (Figs. 13 and 14). The estimates of age-0 recruits are similar across the new model configurations, with Model D having higher estimates in recent years and Model E having lower estimates in recent years (Figs. 15 and 16).

The estimates of the (log) survey indices are similar for the 27-plus survey for Models 1, 1Q, A, AQ, B, BQ, C, and CQ, as these model configurations model this survey catchability and selectivity in the same manner (Figs. 17 and 18); Models D and E have different patterns due to estimating fewer selectivity curves and catchability, respectively. The base models, Models 1, 1Q, A, and AQ, estimate catchability for each survey year for the sub-27 survey, so the estimated values are close to the actual values, as these model configurations essentially track the numbers of age-1 fish seen in the survey (Figs. 19 and 20). Models B, BQ, C, CQ, and D estimated constant catchability for the periods 1984 – 1993 and 1996 – 2011, which results in less variability in the estimates.

Models 1, 1Q, 1B, and 1C have tail compression turned on. The estimates of spawning biomass are similar for all models (Fig. 21), although the estimates of age-0 recruitment differ in recent years (Fig. 22). The estimates of the survey indices are similar for the 27-plus survey (Fig. 23), as these model configurations model this survey catchability and selectivity in the same manner. The sub-27 survey estimates differ significantly (Fig. 24), as Models 1B and 1C estimate constant catchability for two periods rather than a separate catchability for each survey year.

The fits to the survey age composition data for all model configurations are shown in Figs. 25 – 48.

Tables

Table 20 – The likelihood components, number of parameters, and AIC values for the SS3 model configurations. Jitter convergence implies that the negative log likelihood total was lower (or as low) as any of the jittered runs.

Model	Total	Survey	Length comps	Age comps 27-plus	Age comps sub-27	Size at age	Recruit	Parameters	AIC	Jitter convergence?
1	3,842	4.34	3,116	80.67	16.61	645.73	-21.16	252	8,189	Yes
1Q	3,847	6.01	3,114	80.63	17.14	651.58	-22.37	252	8,199	Yes
A	3,990	1.73	3,217	89.25	46.69	657.67	-22.92	252	8,484	Yes
AQ	3,992	2.87	3,217	89.95	46.63	658.48	-22.84	252	8,489	Yes
B	3,952	14.12	3,175	91.22	36.59	656.63	-22.43	244	8,391	Yes
BQ	3,954	14.51	3,176	91.06	36.60	657.20	-22.33	244	8,395	Yes
C	3,951	13.14	3,177	91.61	36.65	654.93	-22.51	244	8,389	Yes
CQ	3,953	14.35	3,176	90.80	36.60	657.29	-22.35	244	8,394	Yes
D	4,094	-7.95	3,210	233.86	32.02	643.33	-16.61	207	8,603	Yes
E	3,959	-6.69	3,208	83.65	46.42	649.70	-21.63	253	8,425	Yes
1B	3,844	13.99	3,102	80.76	14.57	655.01	-22.46	244	8,176	Yes
1C	3,843	13.30	3,103	81.26	14.57	653.03	-22.52	244	8,174	Yes

Table 21 – Fixed and estimated catchability parameters for the 27-plus and sub-27 surveys (estimated values are in bold)

Model	Q for 27-plus survey	Mean Q for 60-81 cm for 27-plus survey (calc.)	Dev for Q for 27-plus survey (1984-1993)	Q for sub-27 survey	Min/max devs for Q for sub-27 survey	Dev for Q for sub-27 survey (1984-1993)
1	1.0400	0.9241	**0.5106**	**0.0749**	**-0.97 / 1.34**	-
1Q	1.0107	0.9159	**0.5387**	**0.0760**	**-1.01 / 1.31**	-
A	1.0400	0.9419	**0.4964**	**0.1318**	**-0.86 / 1.37**	-
AQ	1.0118	0.9168	**0.5288**	**0.1304**	**-0.85 / 1.35**	-
B	1.0400	0.9425	**0.5045**	**0.1164**	-	**-0.51**
BQ	1.0120	0.9154	**0.5250**	**0.1145**	-	**-0.49**
C	1.0400	0.9265	**0.4999**	**0.1144**	-	**-0.49**
CQ	1.0136	0.9165	**0.5231**	**0.1145**	-	**-0.49**
D	1.0400	0.9630	**0.5146**	**0.1077**	-	**-0.39**
E	**1.8817**	1.7314	**-0.0037**	**0.1592**	**-1.00 / 1.83**	-
1B	1.0400	0.9432	**0.5118**	**0.1156**	**-**	**-0.93**
1C	1.0400	0.9303	**0.5082**	**0.1140**	**-**	**-0.92**

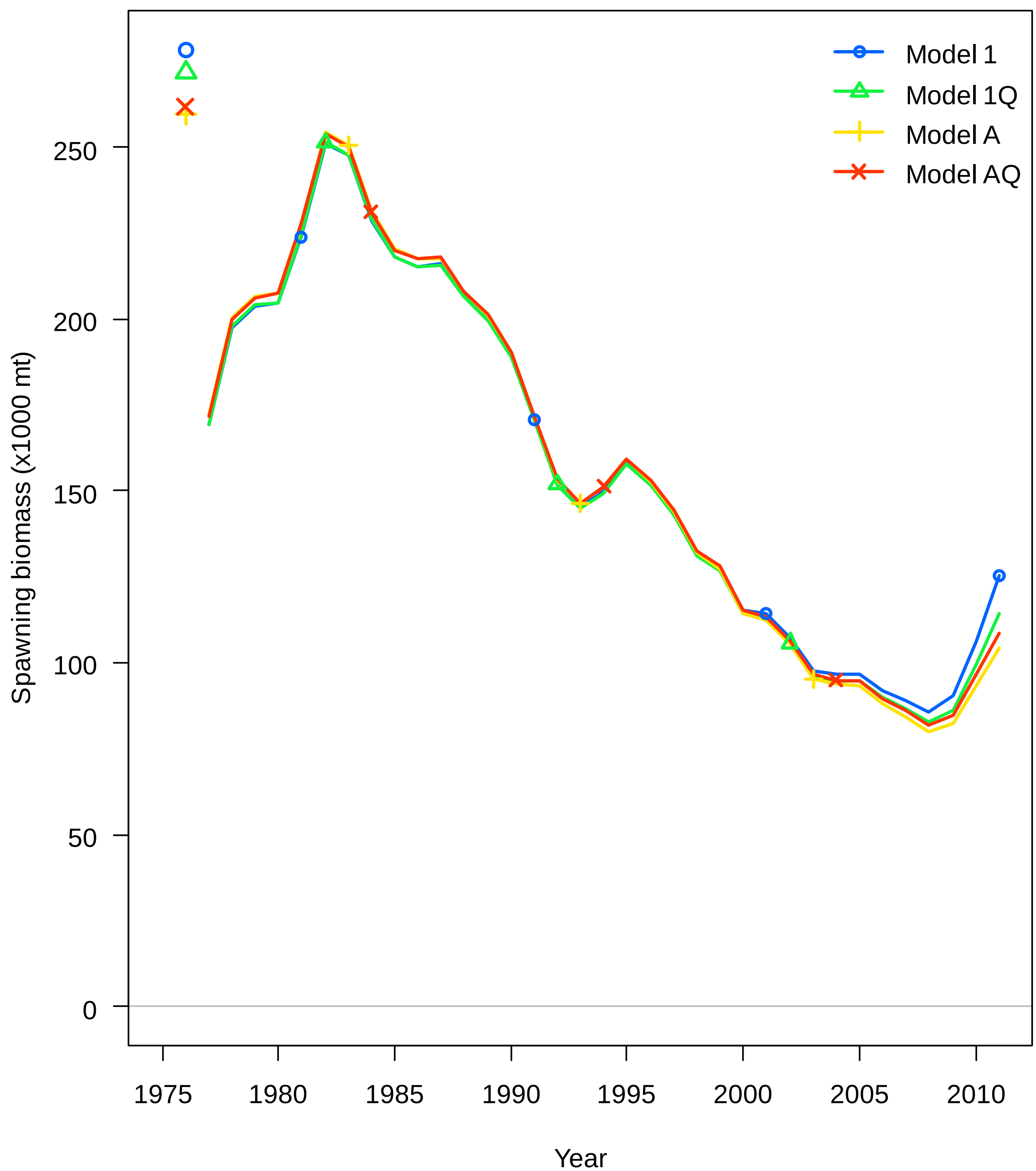

Figure 21 – Estimates of spawning biomass for Models 1, 1Q, A, and AQ

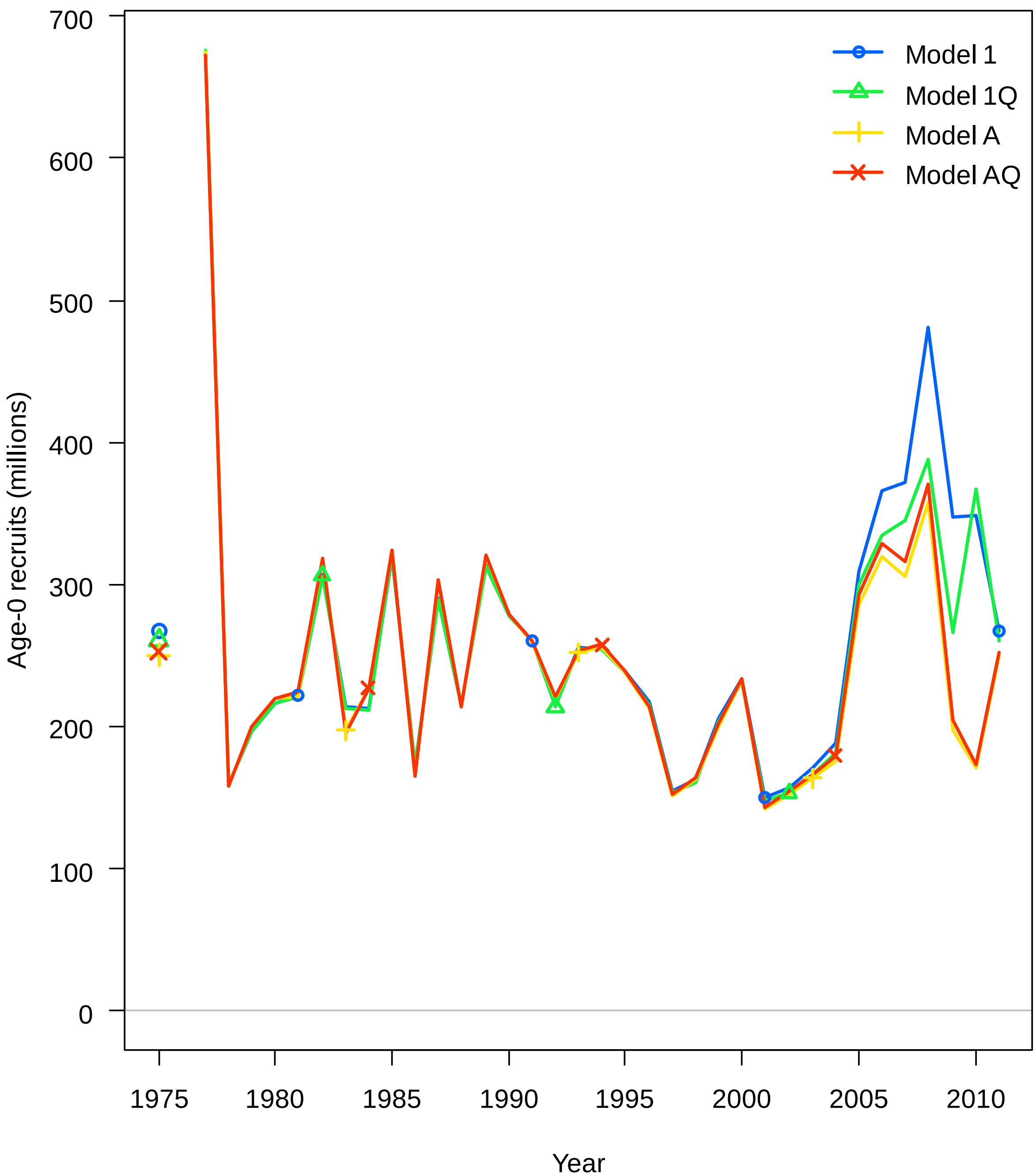

Figure 22 – Estimates of age-0 recruits Models 1, 1Q, A, and AQ

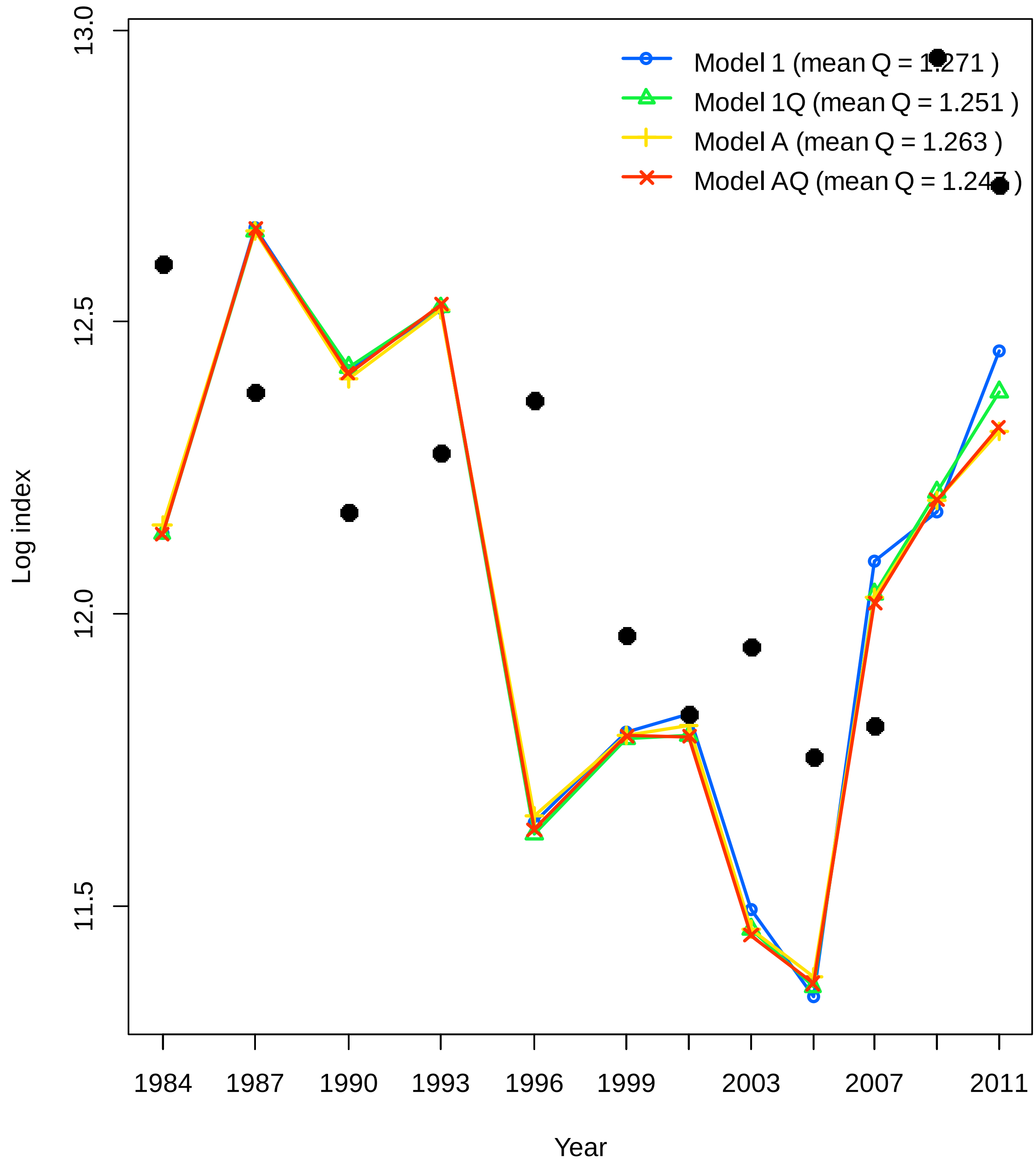

Figure 23 – Log survey estimates and model fits for the 27-plus survey for Models 1, 1Q, A, and AQ

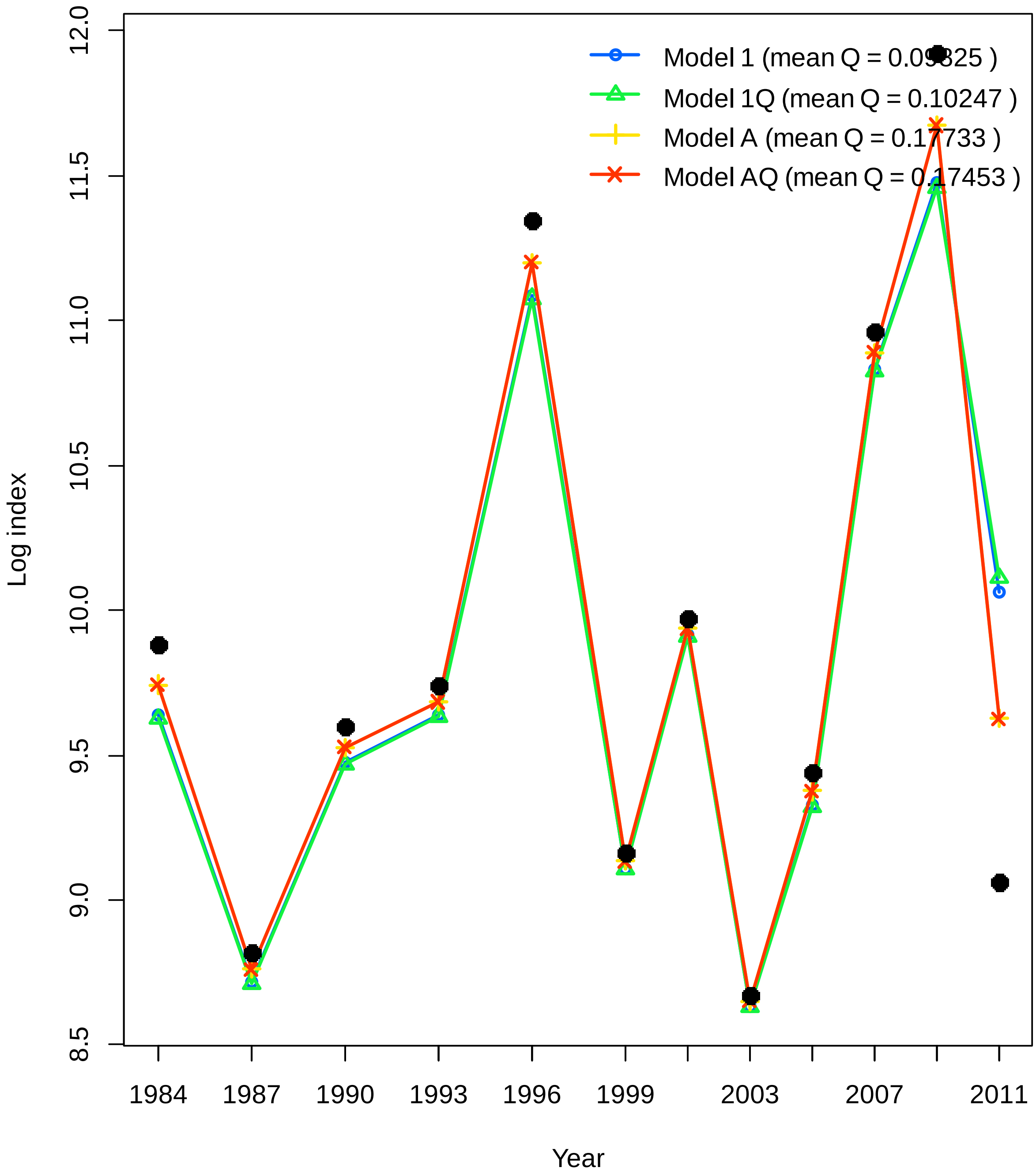

Figure 24 – Log survey estimates and model fits for the sub-27 survey for Models 1, 1Q, A, and AQ

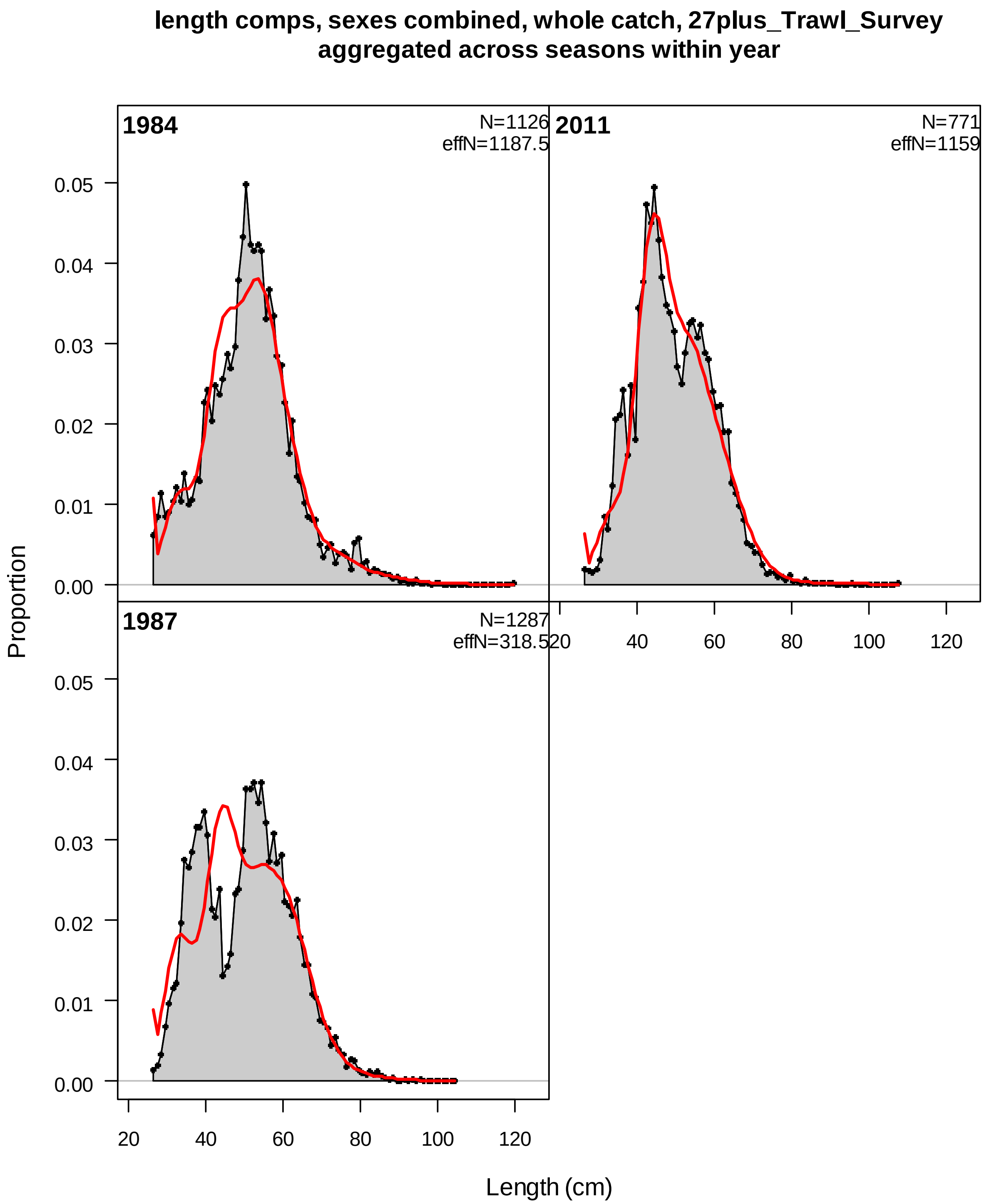

Figure 25 – Proportions-at-length for the 27-plus survey for Model 1 (data in grey, model estimates in red)

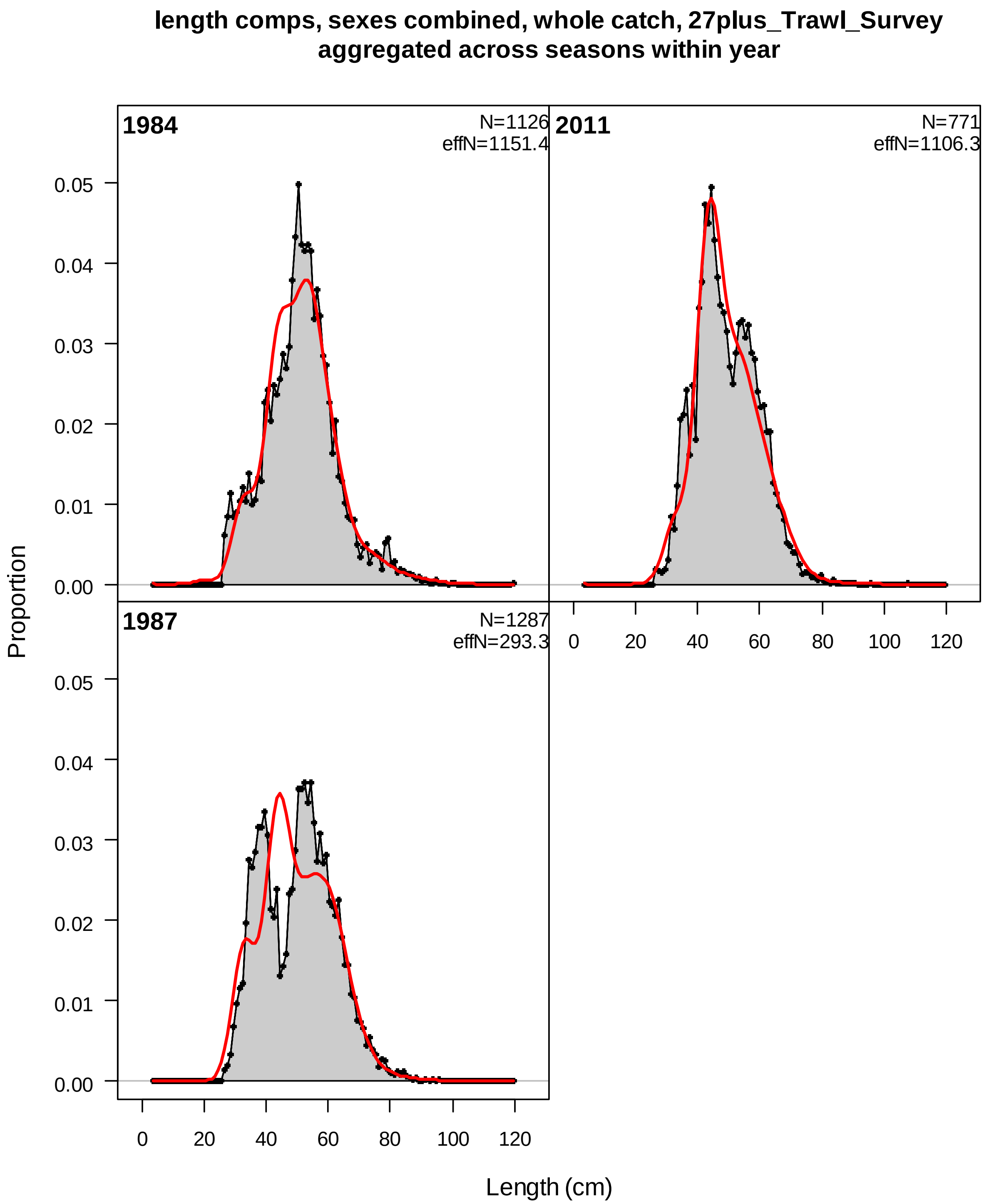

Figure 26 – Proportions-at-length for the 27-plus survey for Model A (data in grey, model estimates in red)

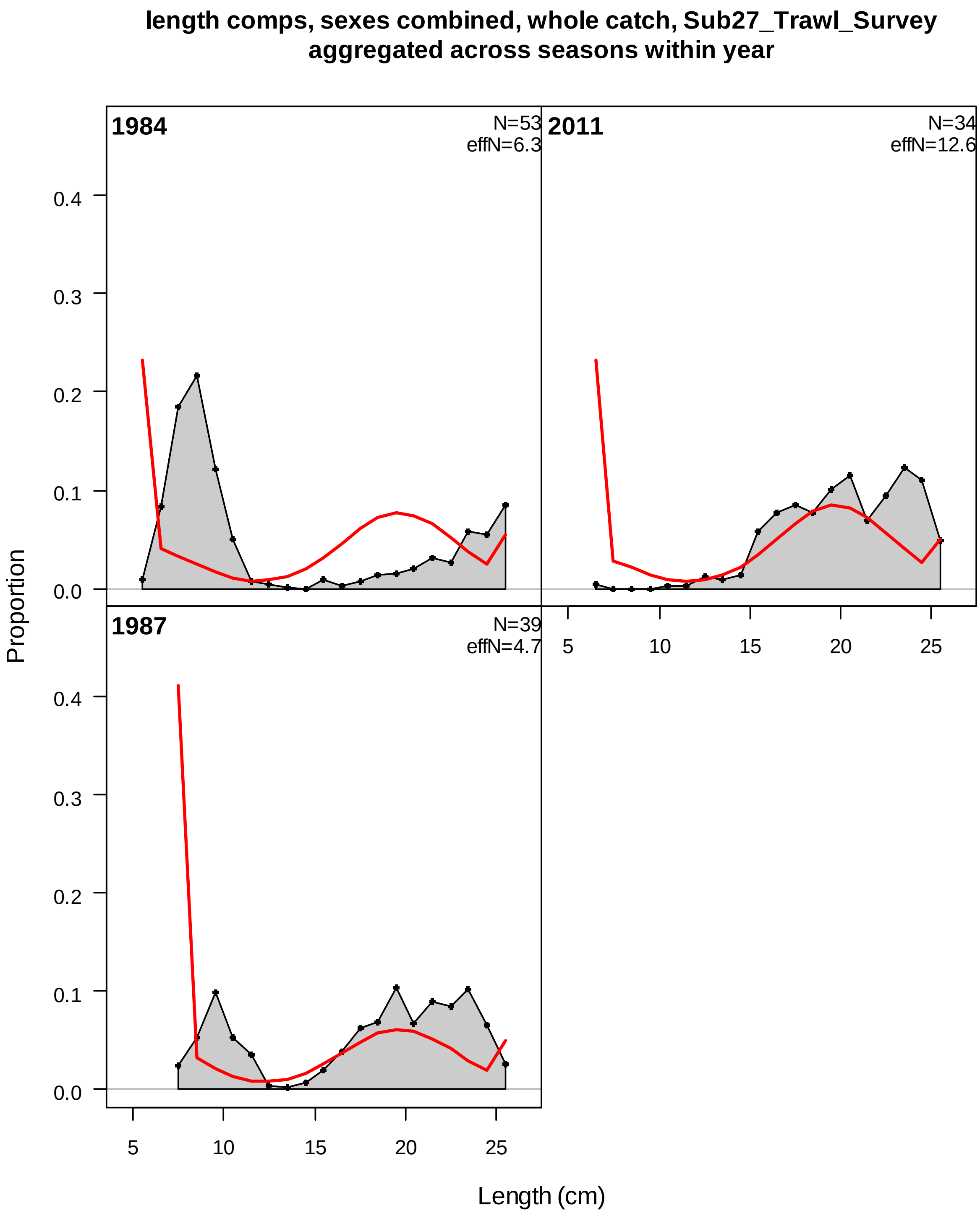

Figure 27 – Proportions-at-length for the sub-27 survey for Model 1 (data in grey, model estimates in red)

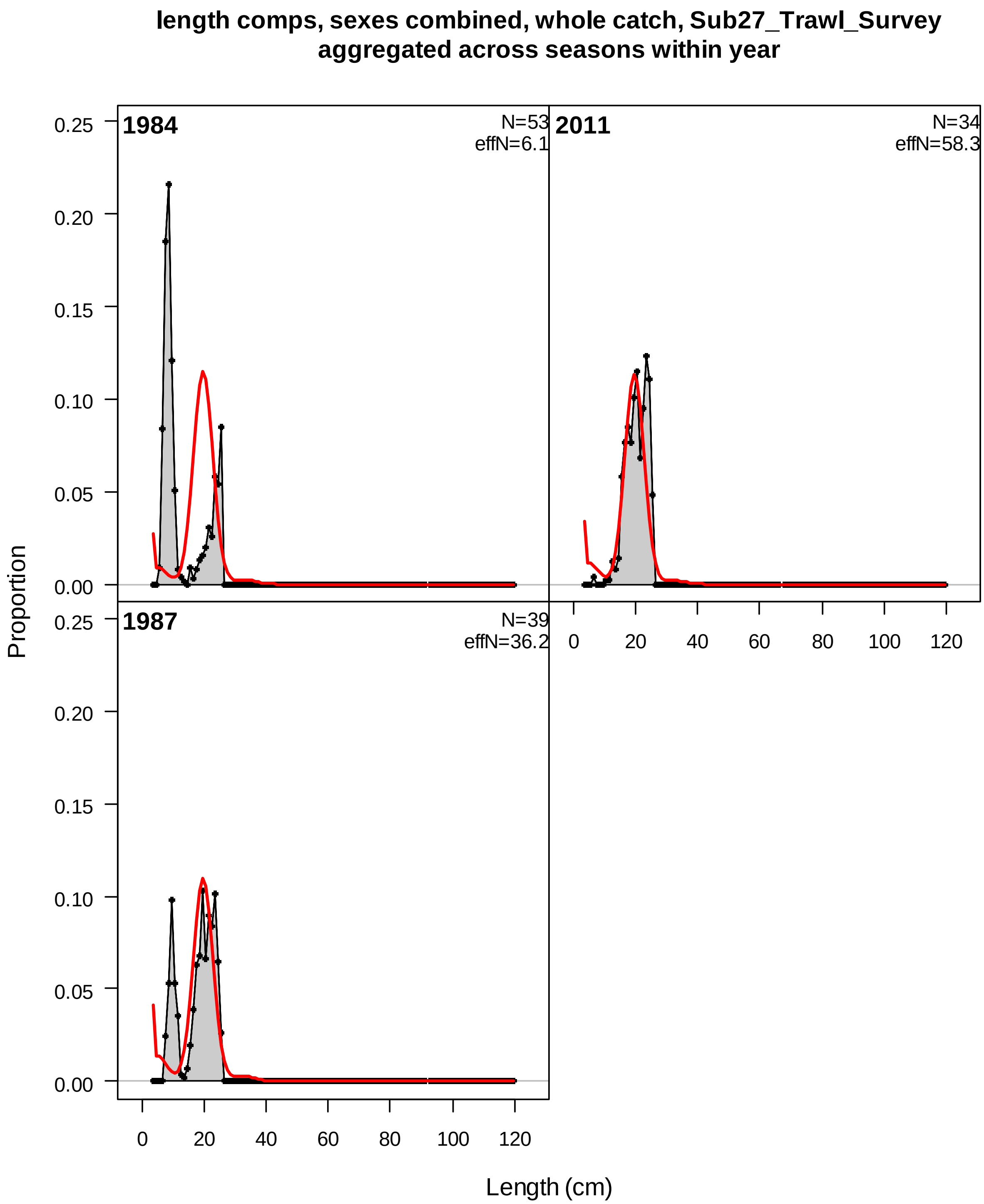

Figure 28 – Proportions-at-length for the sub-27 survey for Model A (data in grey, model estimates in red)

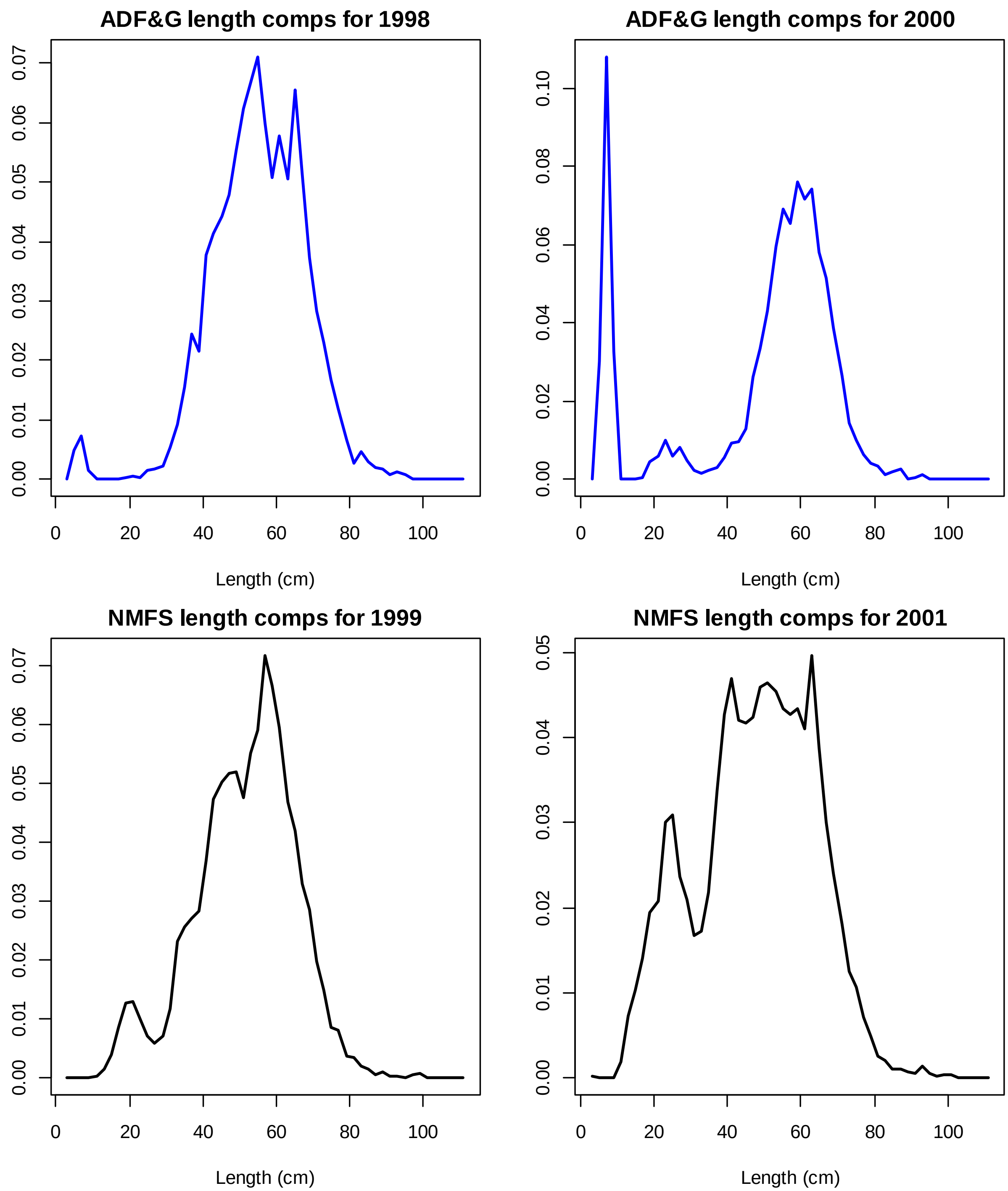

Figure 29 – Length composition data from the ADF&G survey for 1998 and 2000 (top row), length composition data from the NMFS GOA bottom trawl survey for 1999 and 2001 (bottom row)

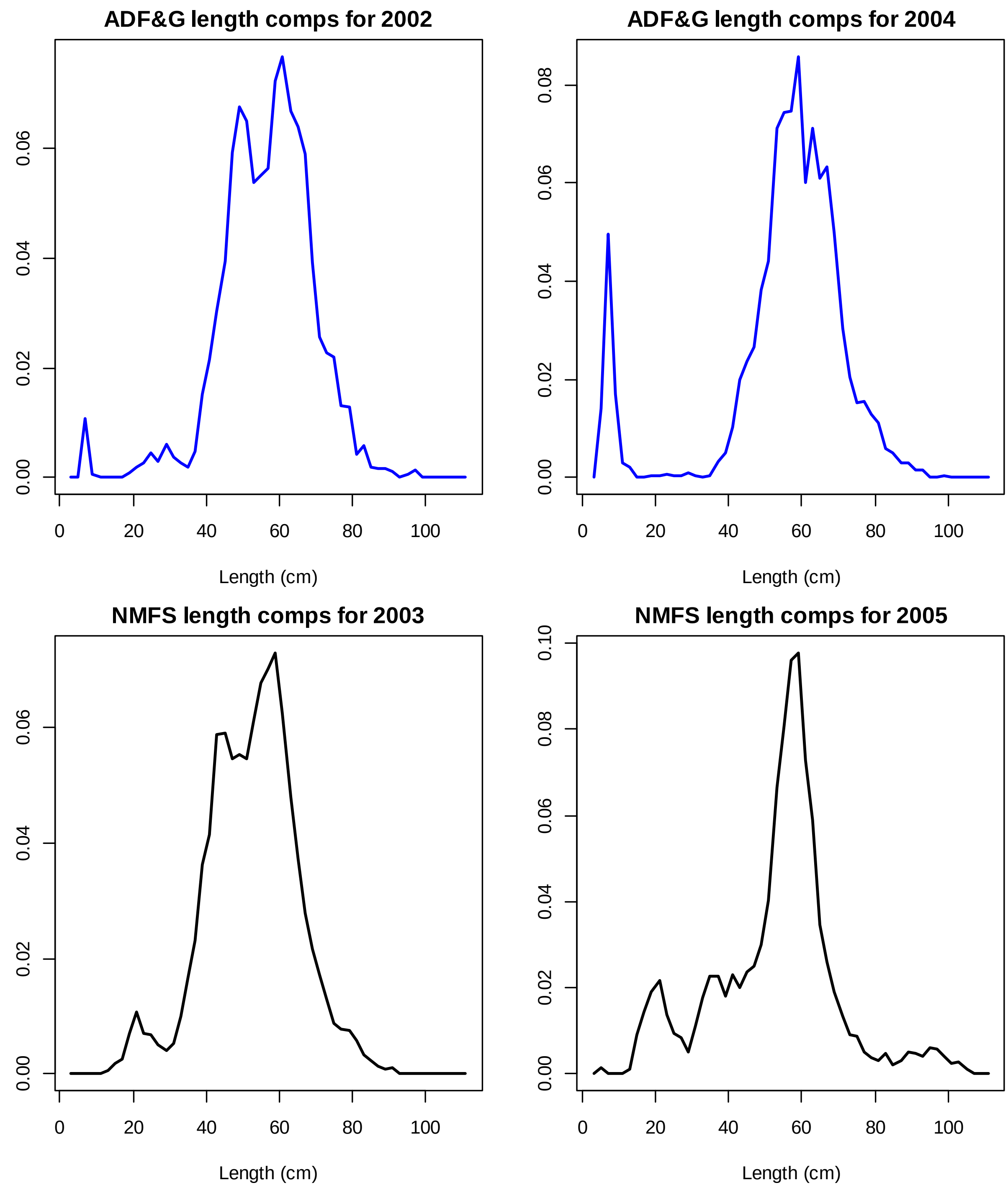

Figure 30 – Length composition data from the ADF&G survey for 2002 and 2004 (top row), length composition data from the NMFS GOA bottom trawl survey for 2003 and 2005 (bottom row)

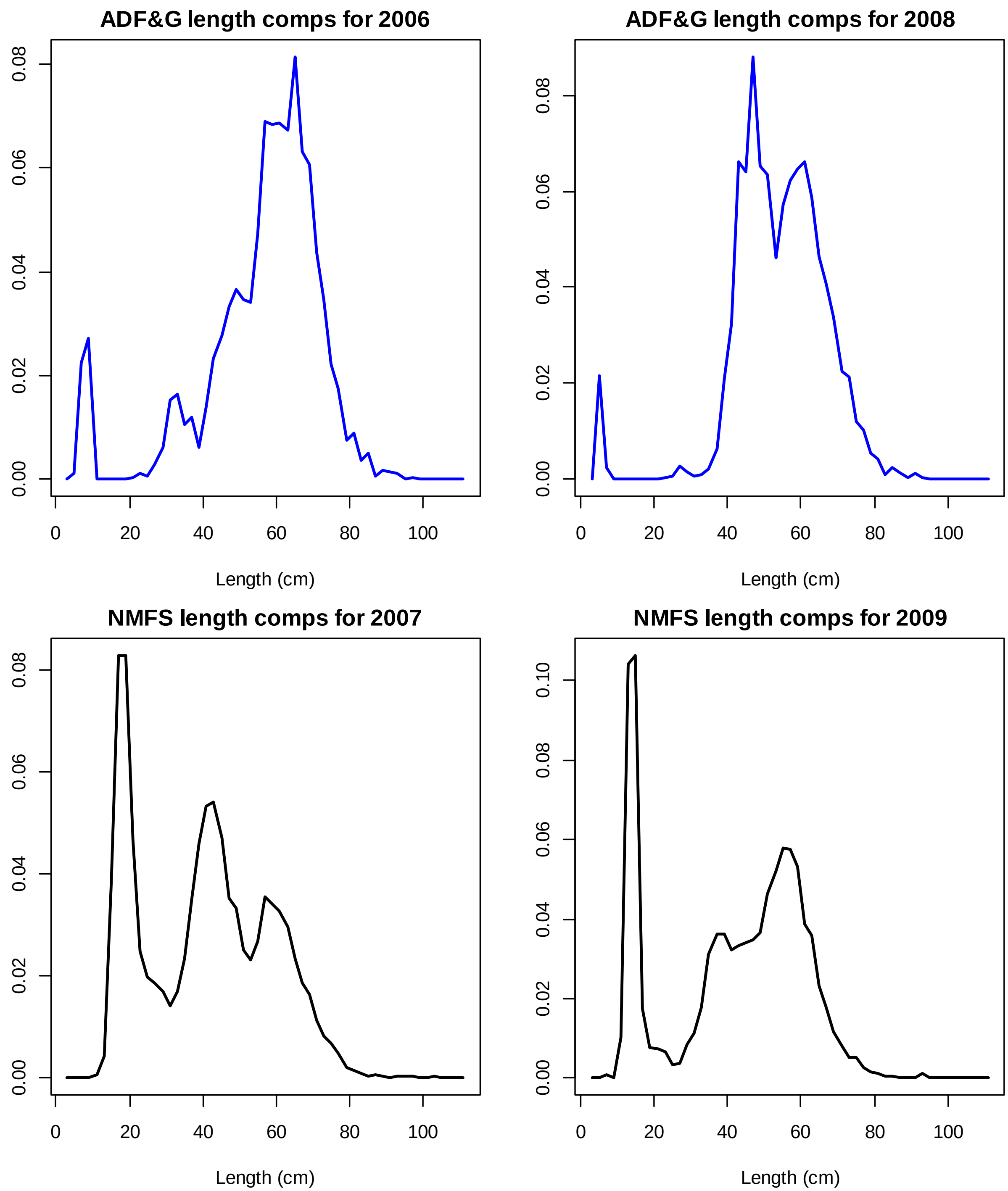

Figure 31 – Length composition data from the ADF&G survey for 2006 and 2008 (top row), length composition data from the NMFS GOA bottom trawl survey for 2007 and 2009 (bottom row)

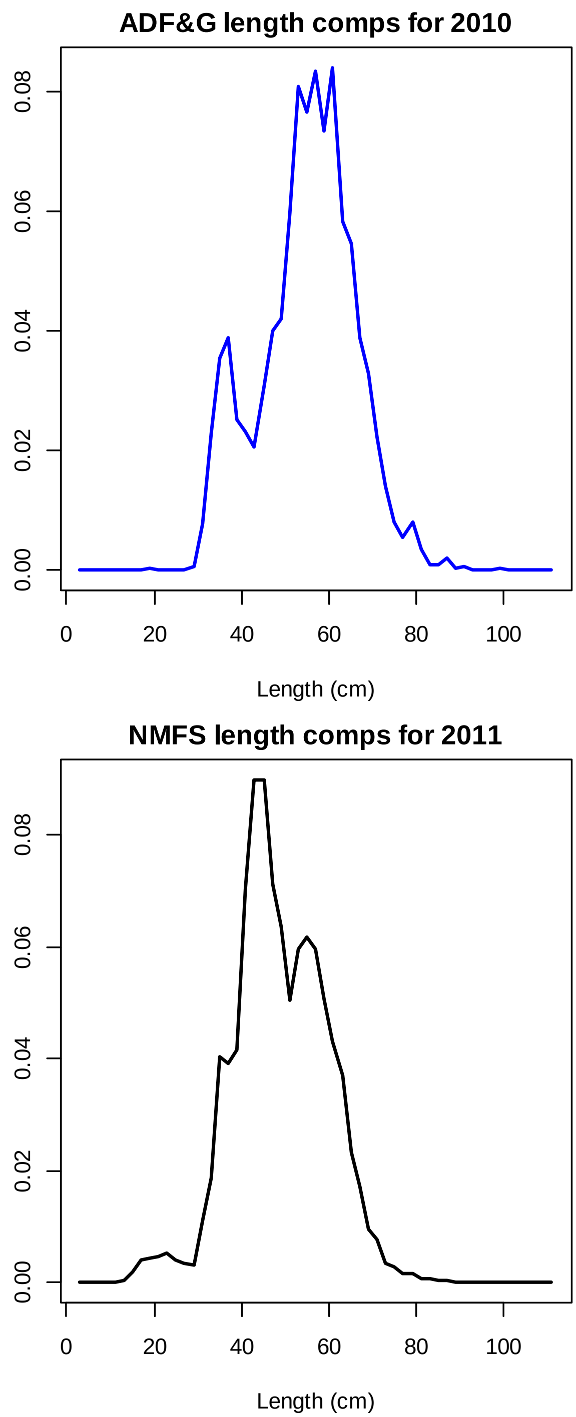

Figure 32 – Length composition data from the ADF&G survey for 2010 (top row), length composition data from the NMFS GOA bottom trawl survey for 2011 (bottom row)

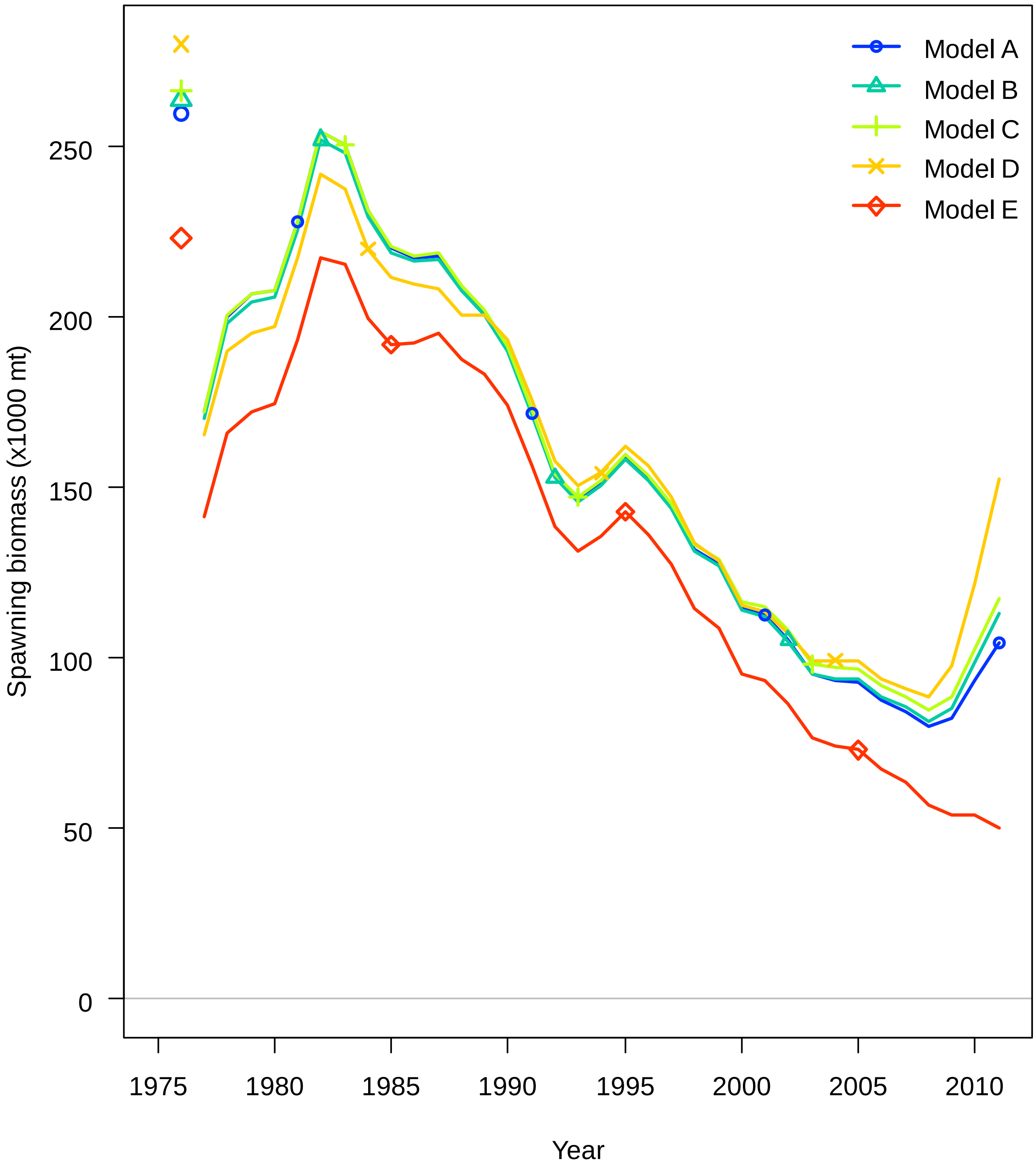

Figure 33 – Estimates of spawning biomass for Models A, B, C, D, and E

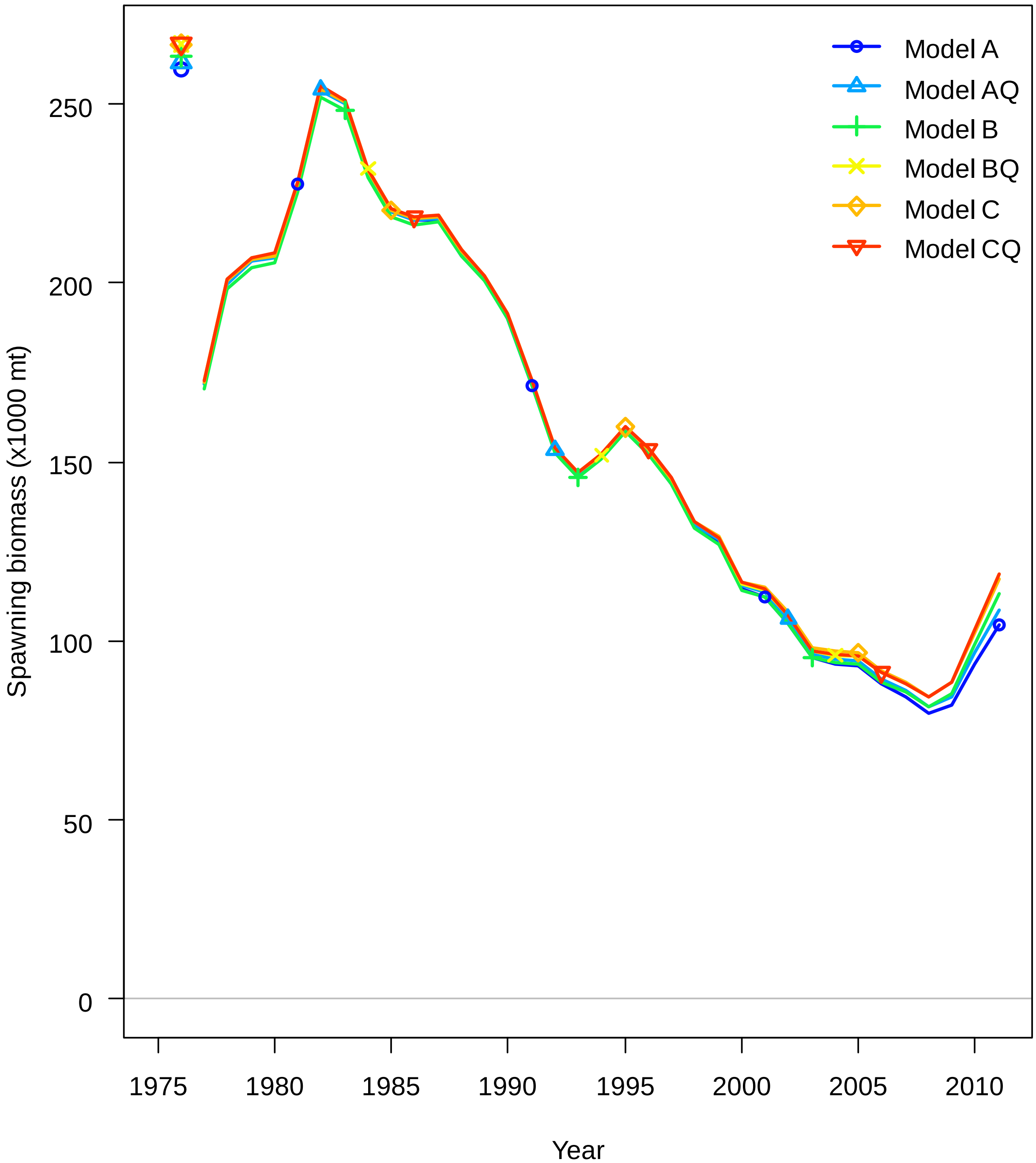

Figure 34 – Estimates of spawning biomass for Models A, AQ, B, BQ, C, and CQ

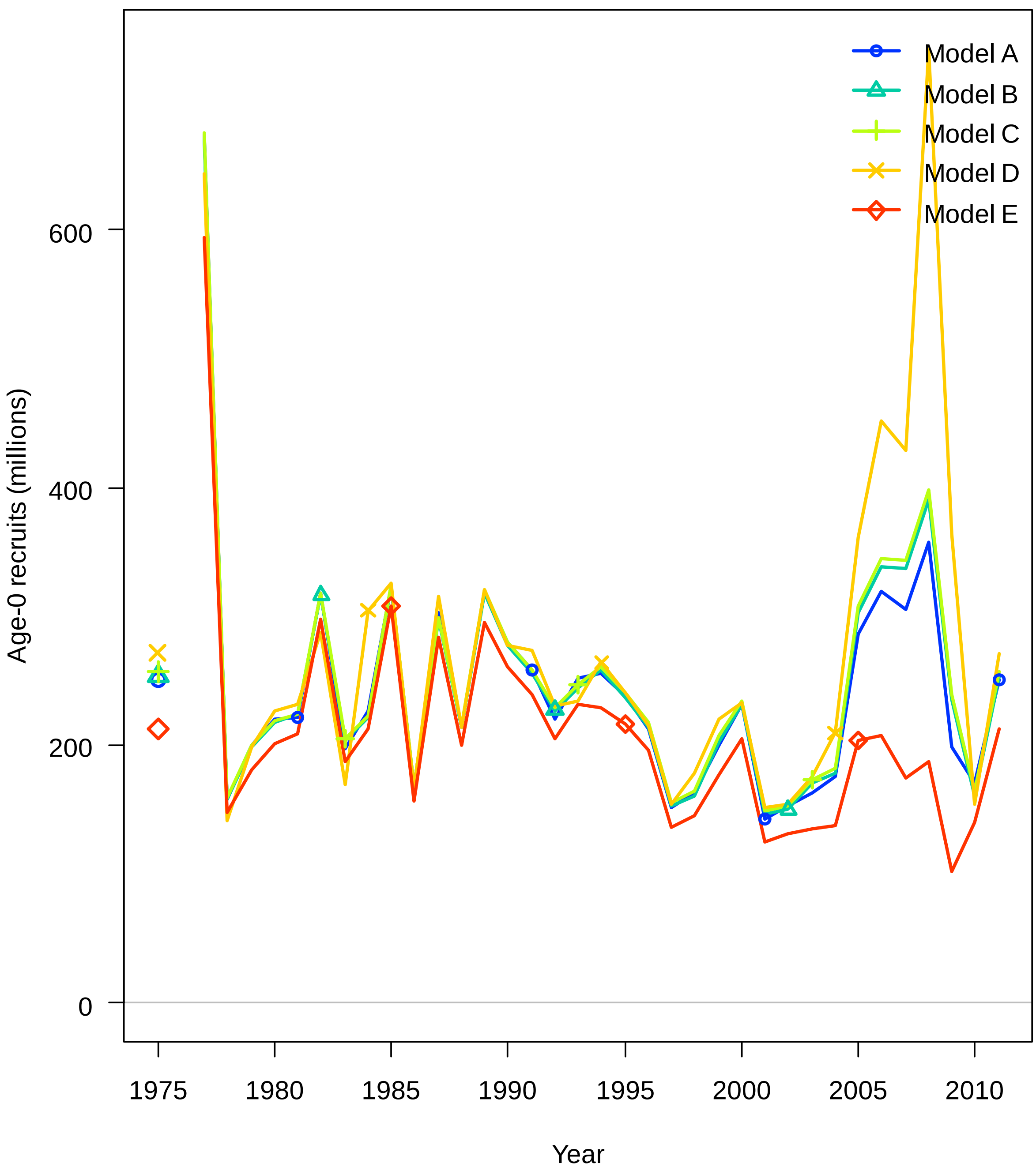

Figure 35 – Estimates of age-0 recruitment for Models A, B, C, D, and E

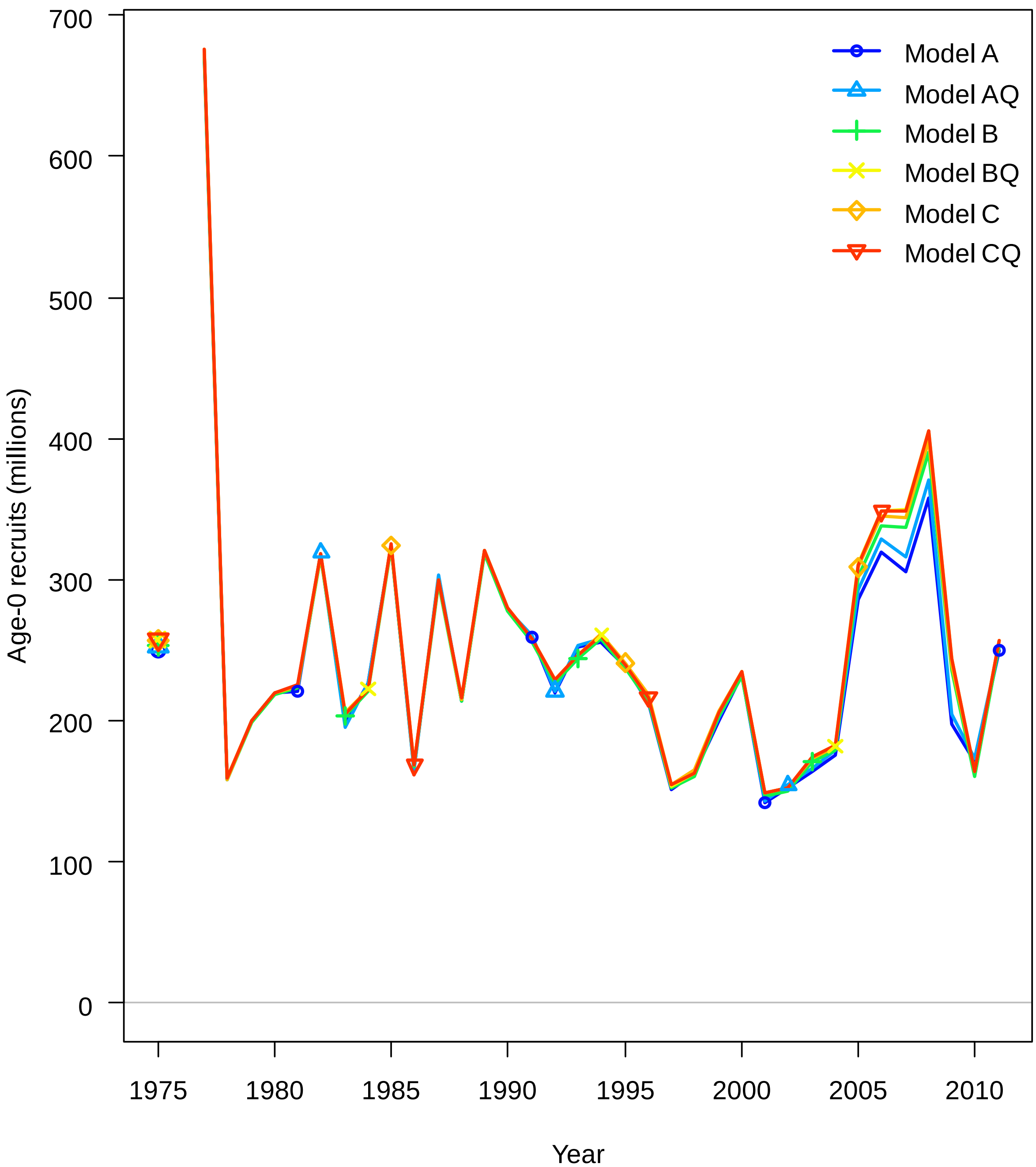

Figure 36 – Estimates of age-0 recruitment for Models A, AQ, B, BQ, C, and CQ

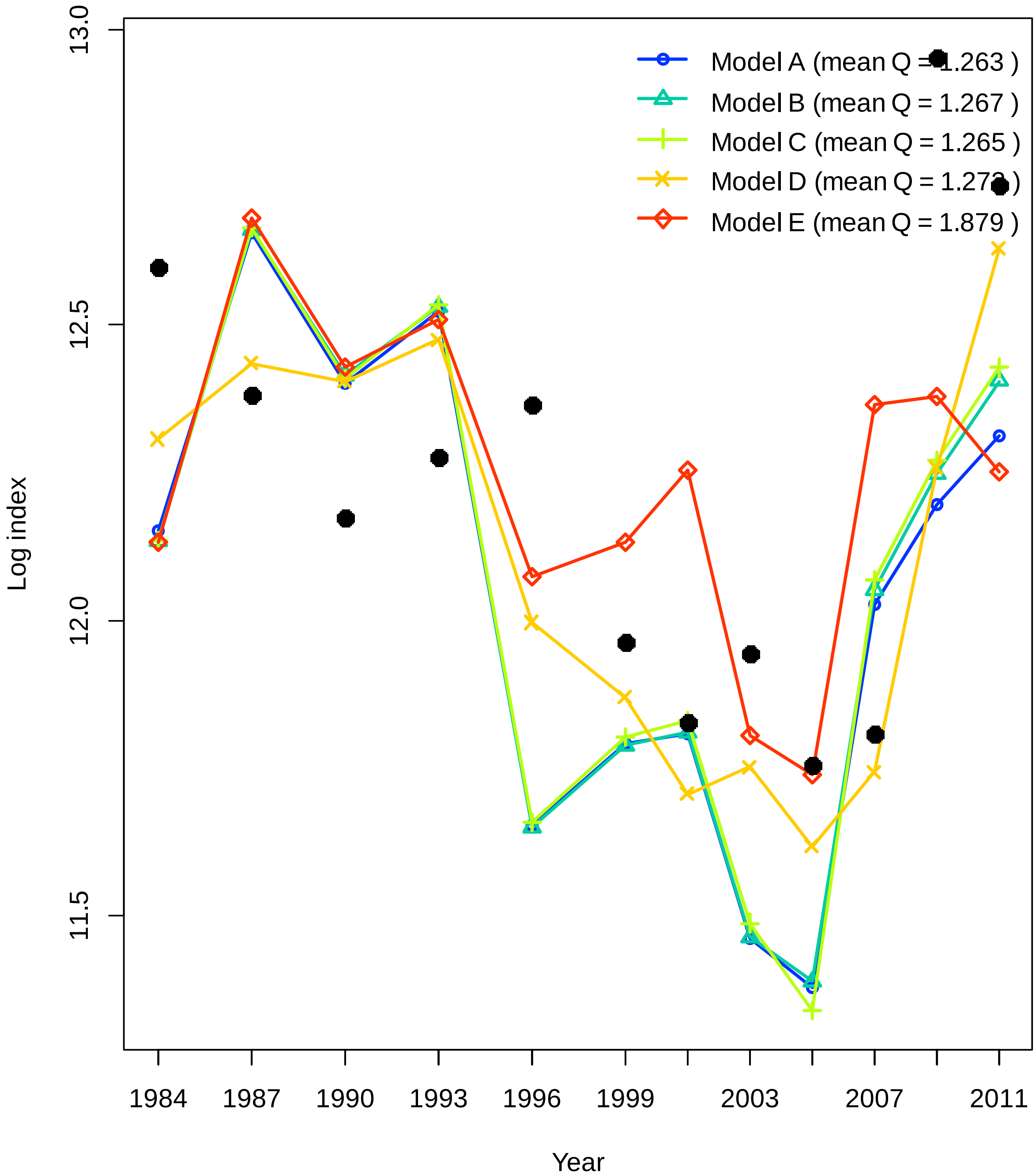

Figure 37 – Log survey estimates and model fits for the 27-plus survey for Models A, B, C, D, and E

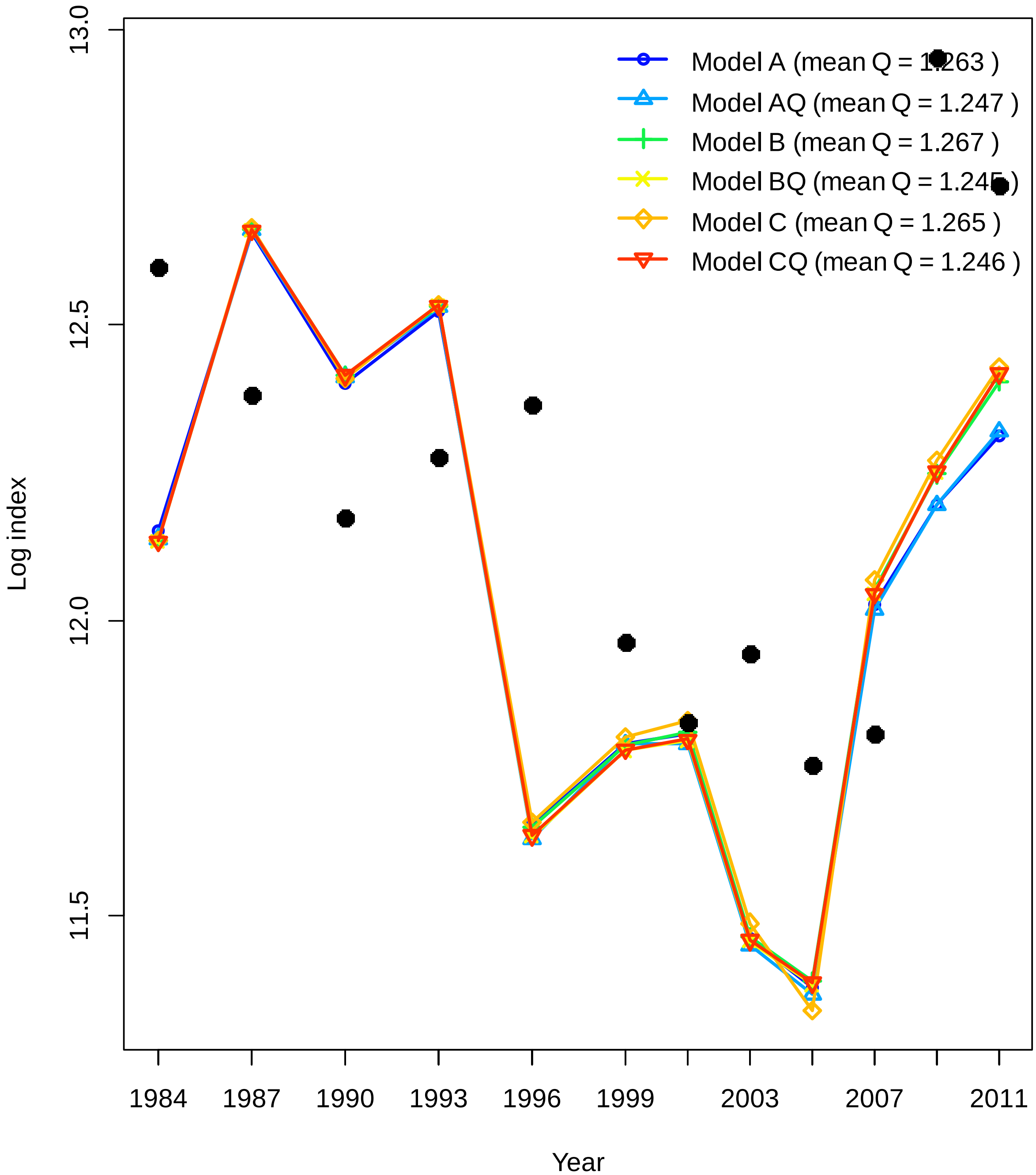

Figure 38 – Log survey estimates and model fits for the 27-plus survey for Models A, AQ, B, BQ, C, and CQ

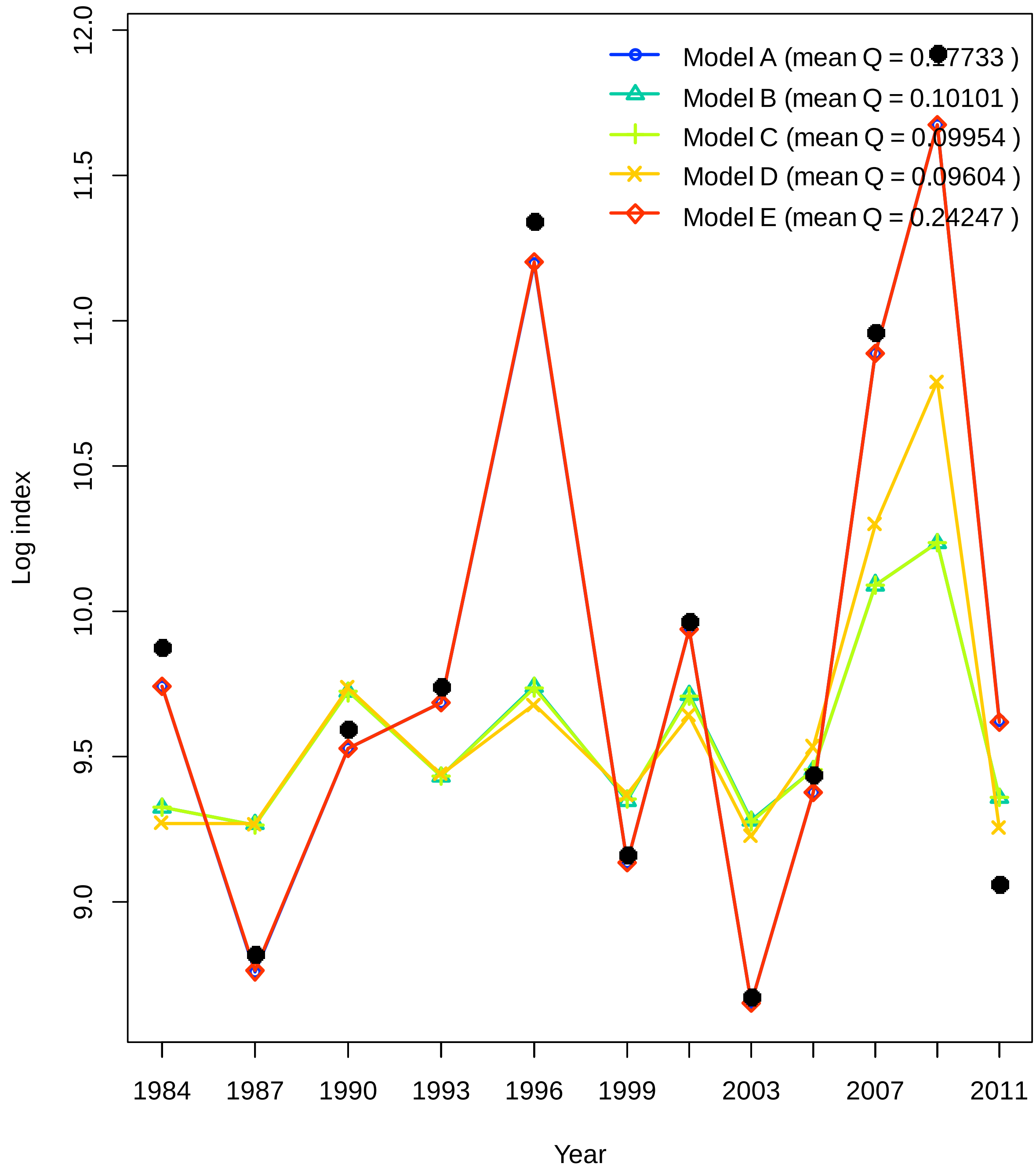

Figure 39 – Log survey estimates and model fits for the sub-27 survey for Models A, B, C, D, and E

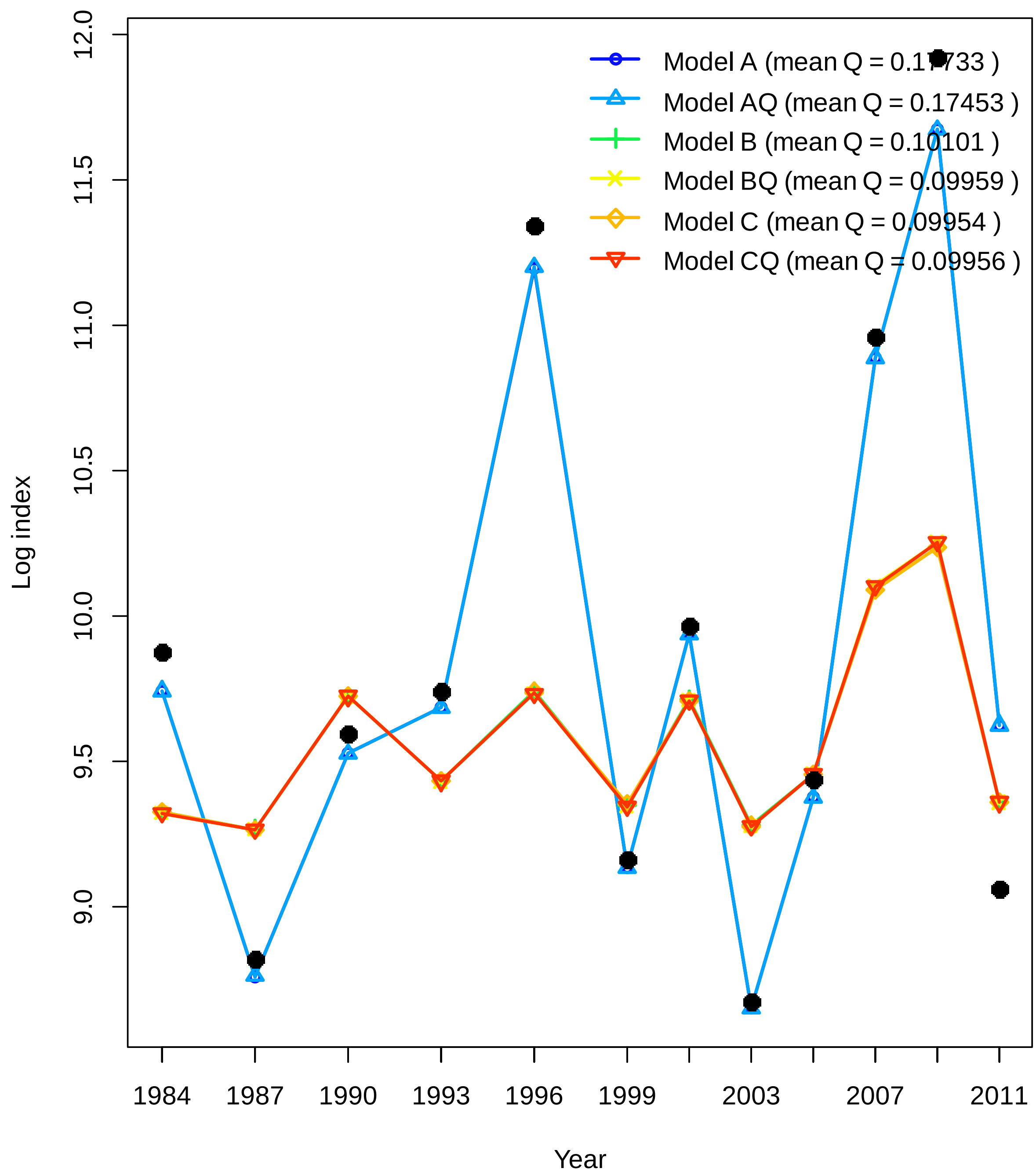

Figure 40 – Log survey estimates and model fits for the sub-27 survey for Models A, AQ, B, BQ, C, and CQ

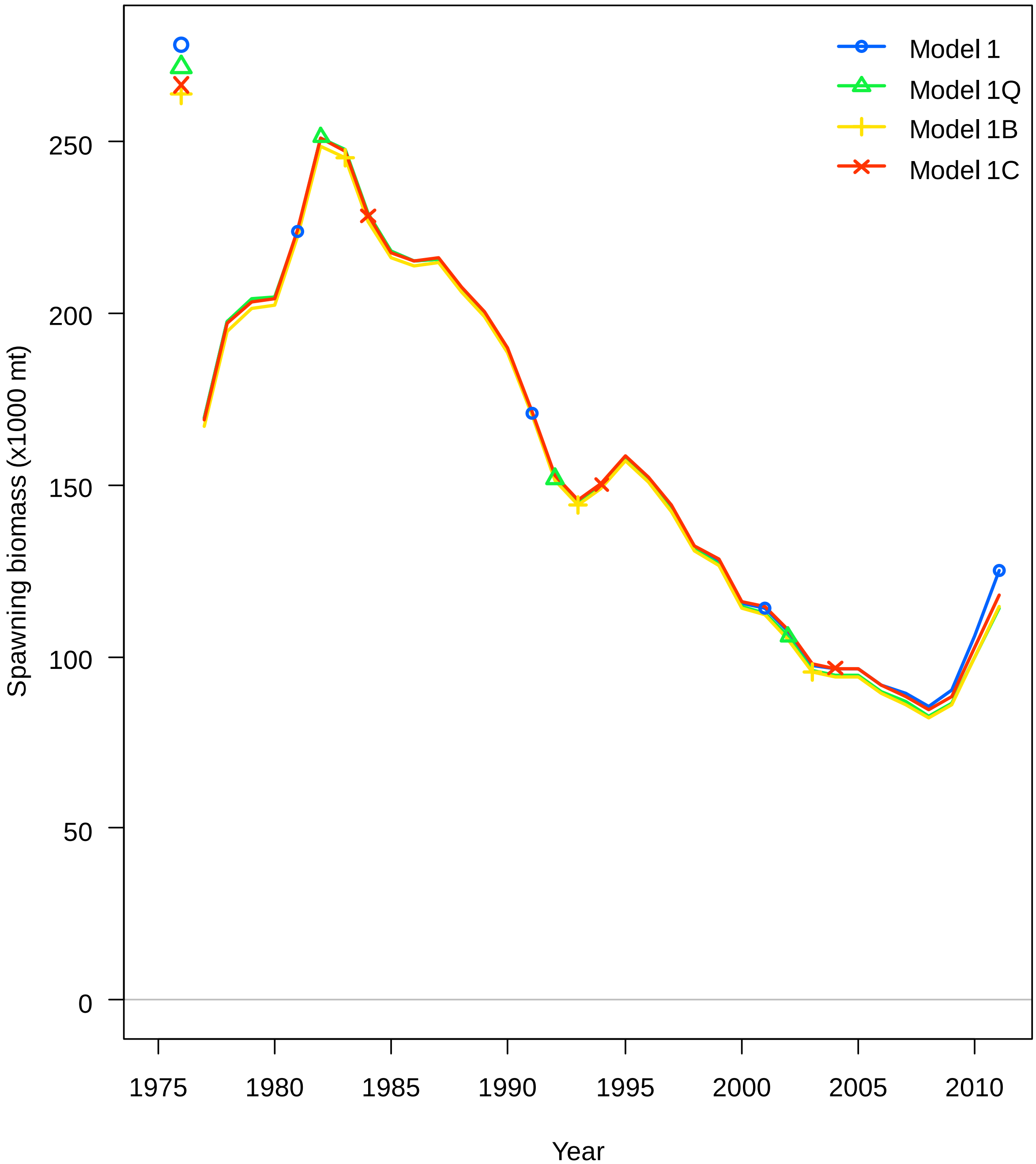

Figure 41 – Estimates of spawning biomass for Models 1, 1Q, 1B, and 1C

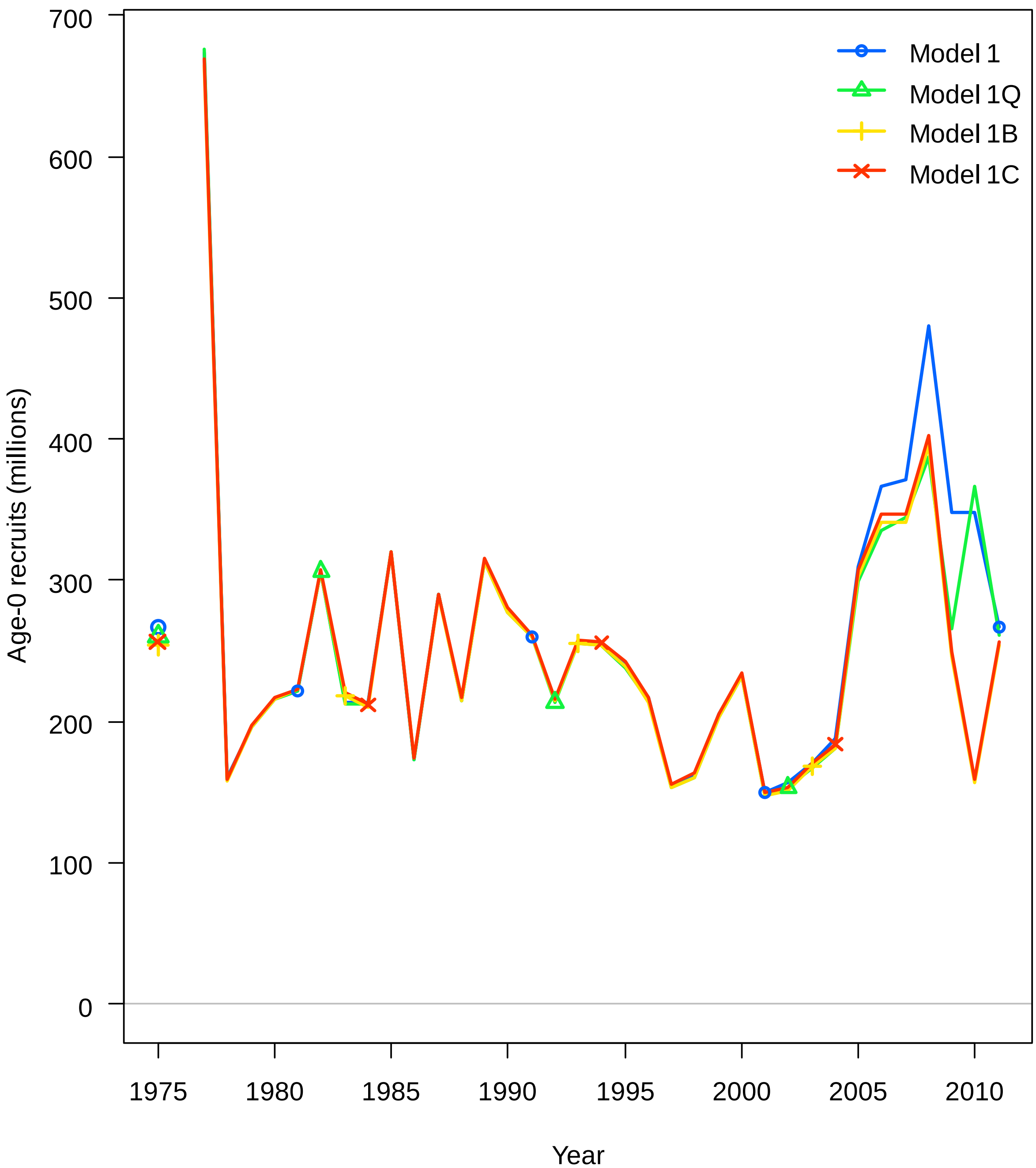

Figure 42 – Estimates of age-0 recruitment for Models 1, 1Q, 1B, and 1C

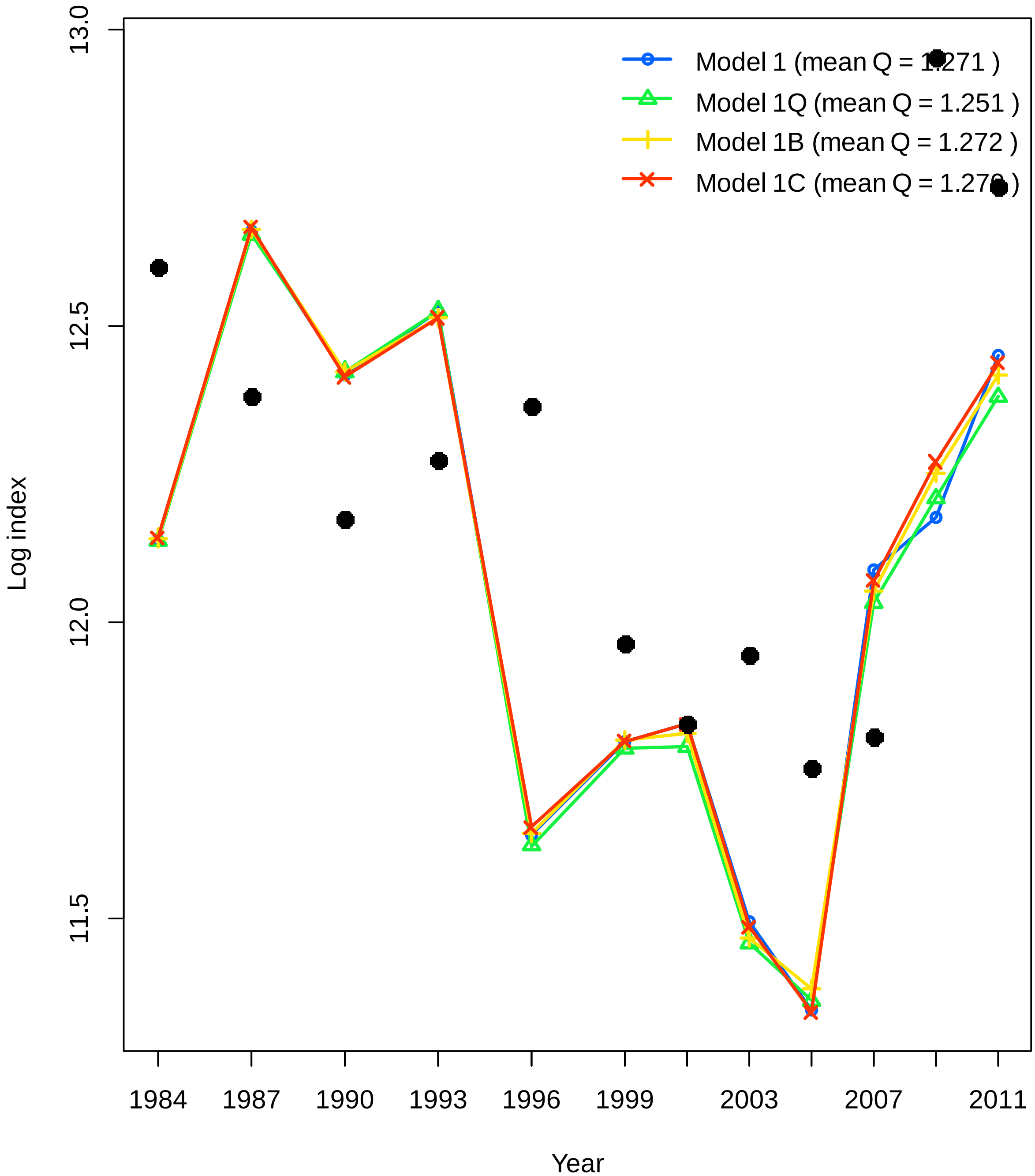

Figure 43 – Log survey estimates and model fits for the sub-27 survey for Models 1, 1Q, 1B, and 1C

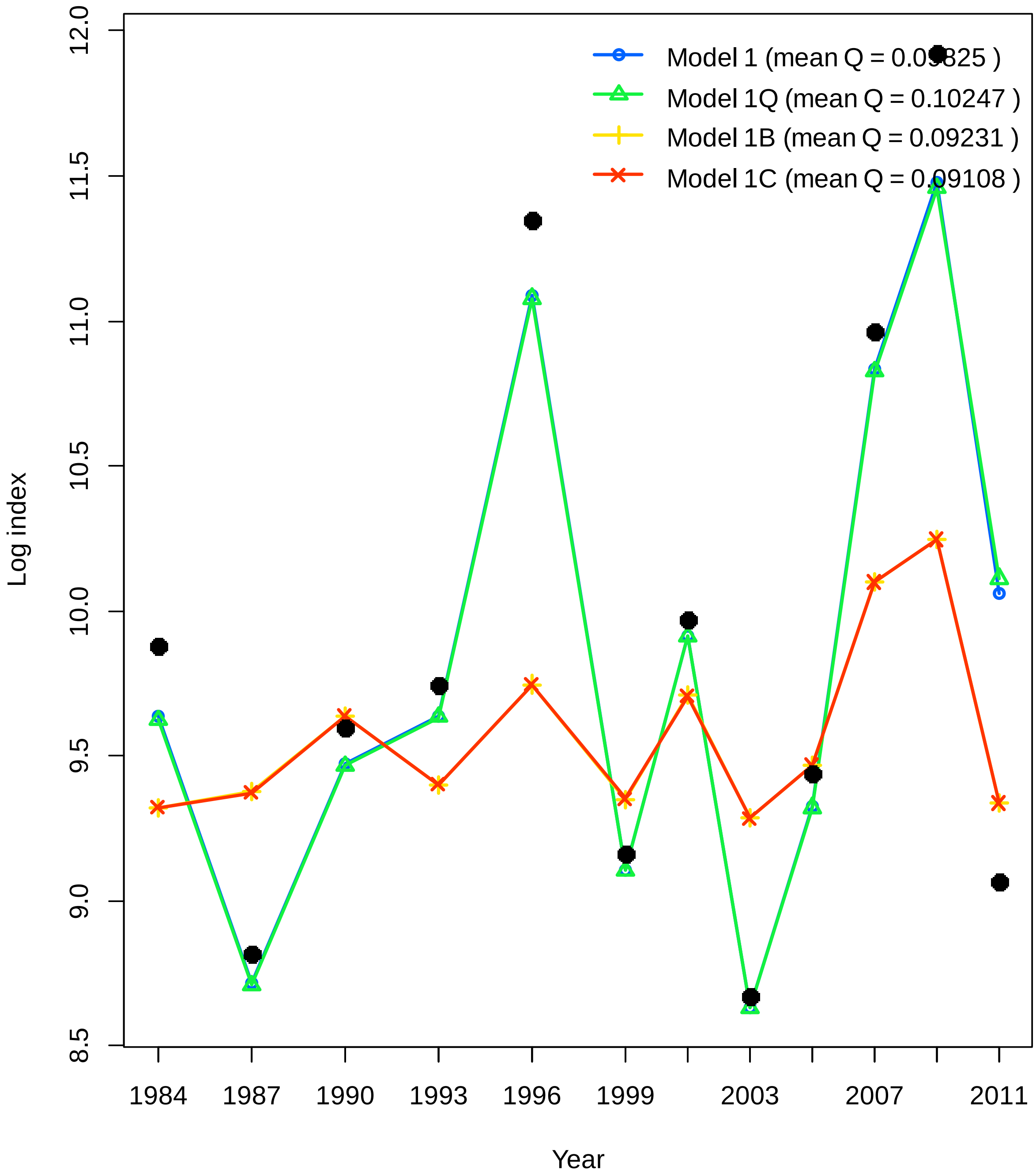

Figure 44 – Log survey estimates and model fits for the sub-27 survey for Models 1, 1Q, 1B, and 1C

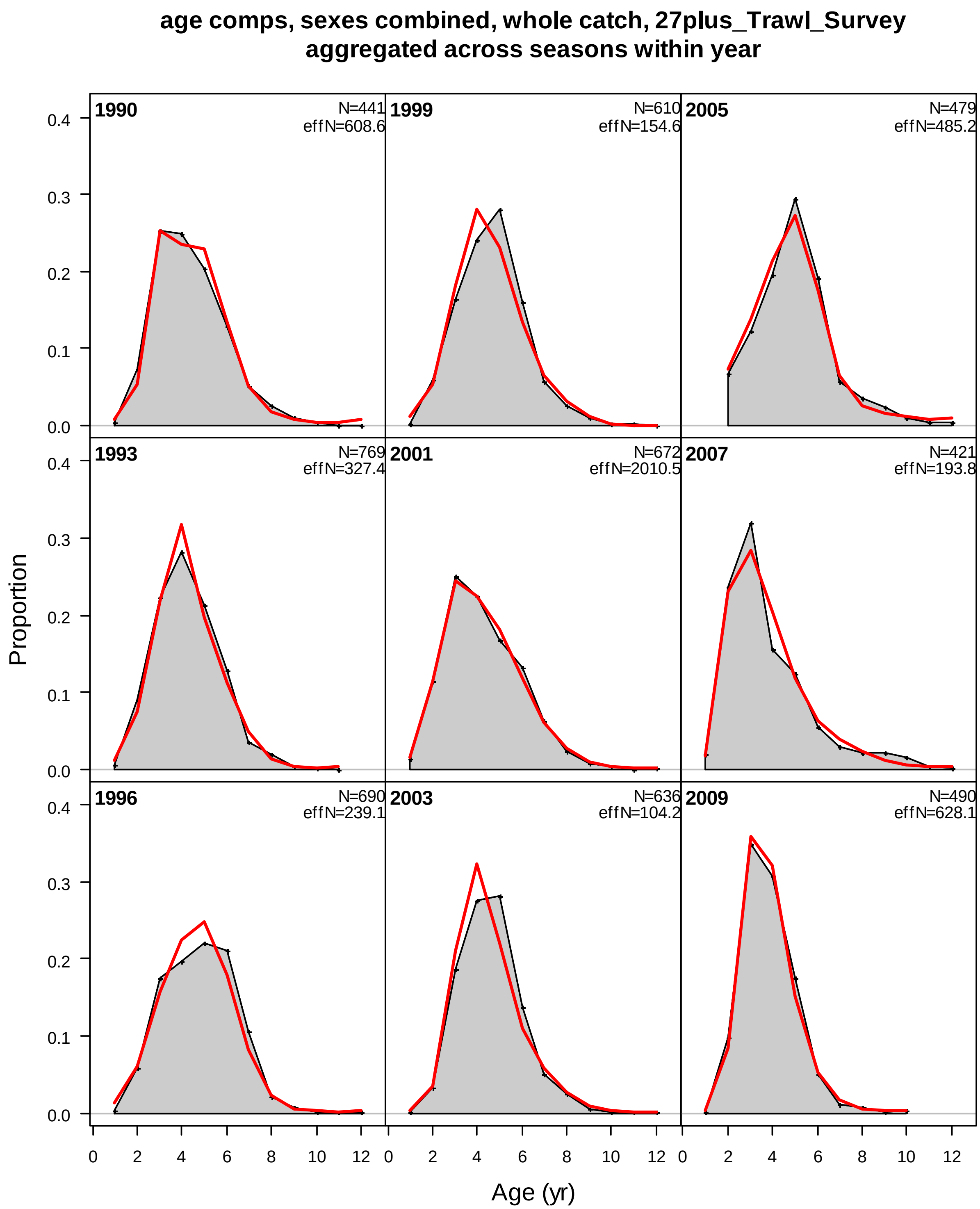

Figure 45 – Age composition data and model estimates for the 27-plus survey for Model 1

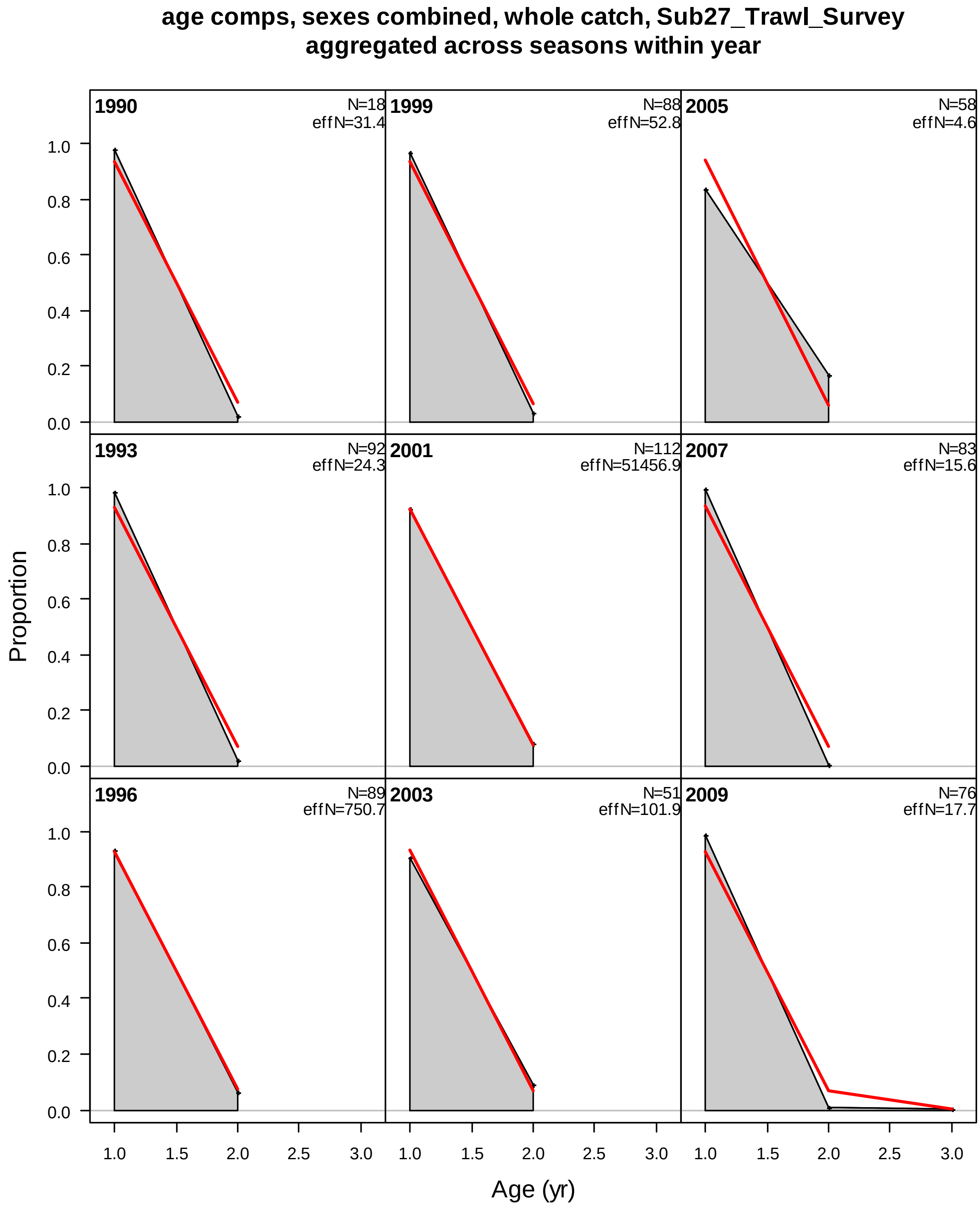

Figure 46 – Age composition data and model estimates for the sub-27 survey for Model 1

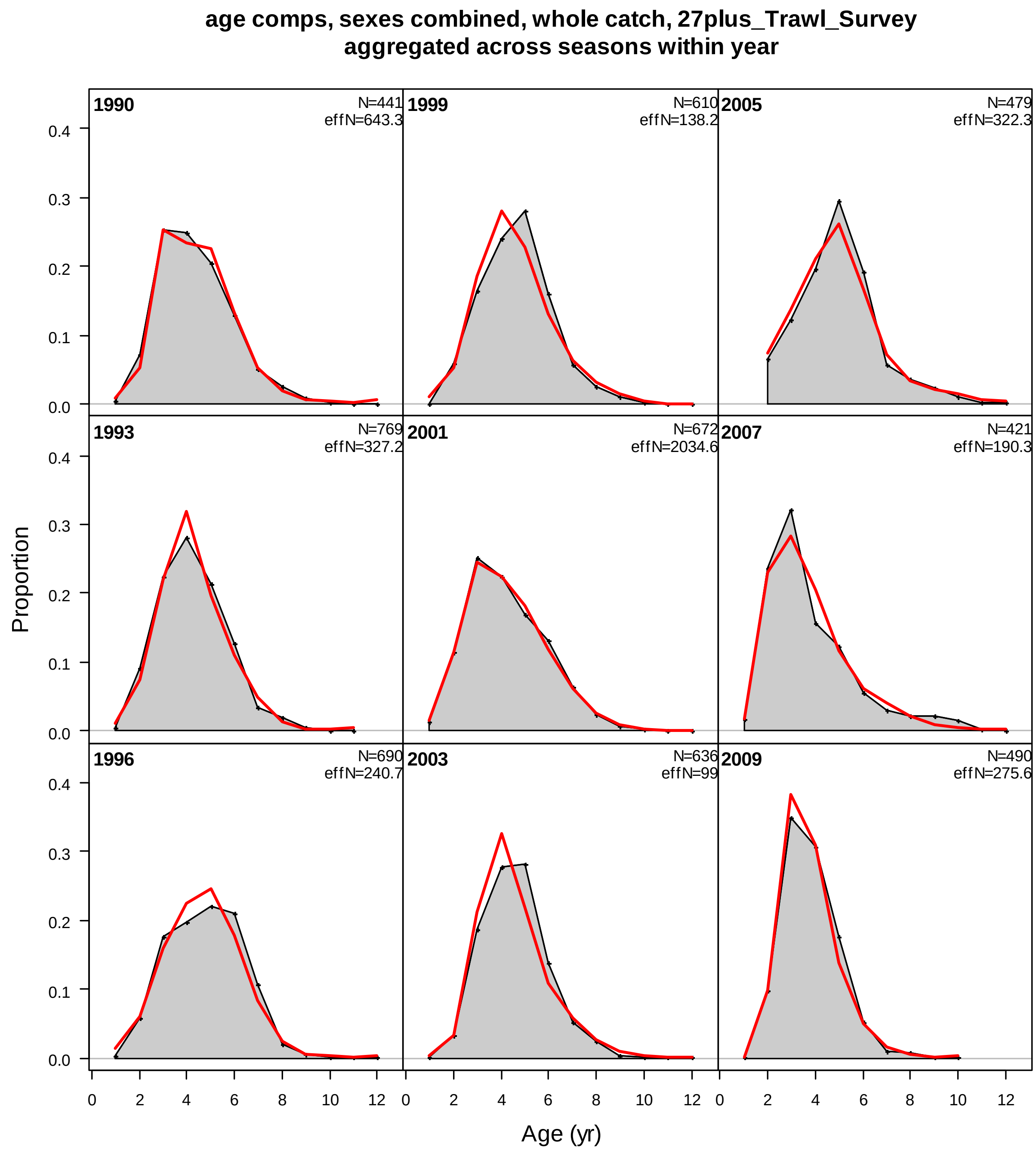

Figure 47 – Age composition data and model estimates for the 27-plus survey for Model 1Q

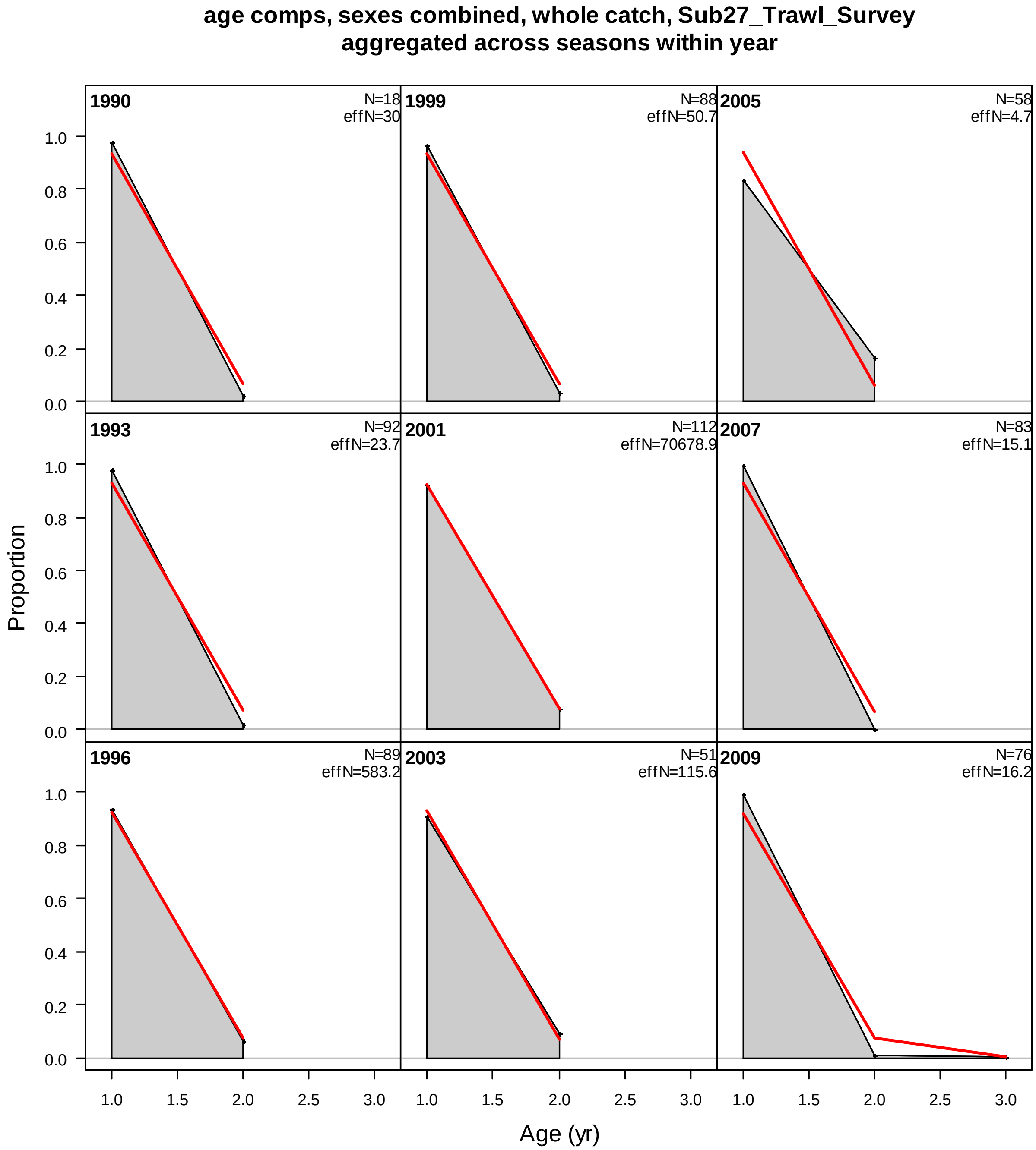

Figure 48 – Age composition data and model estimates for the sub-27 survey for Model 1Q

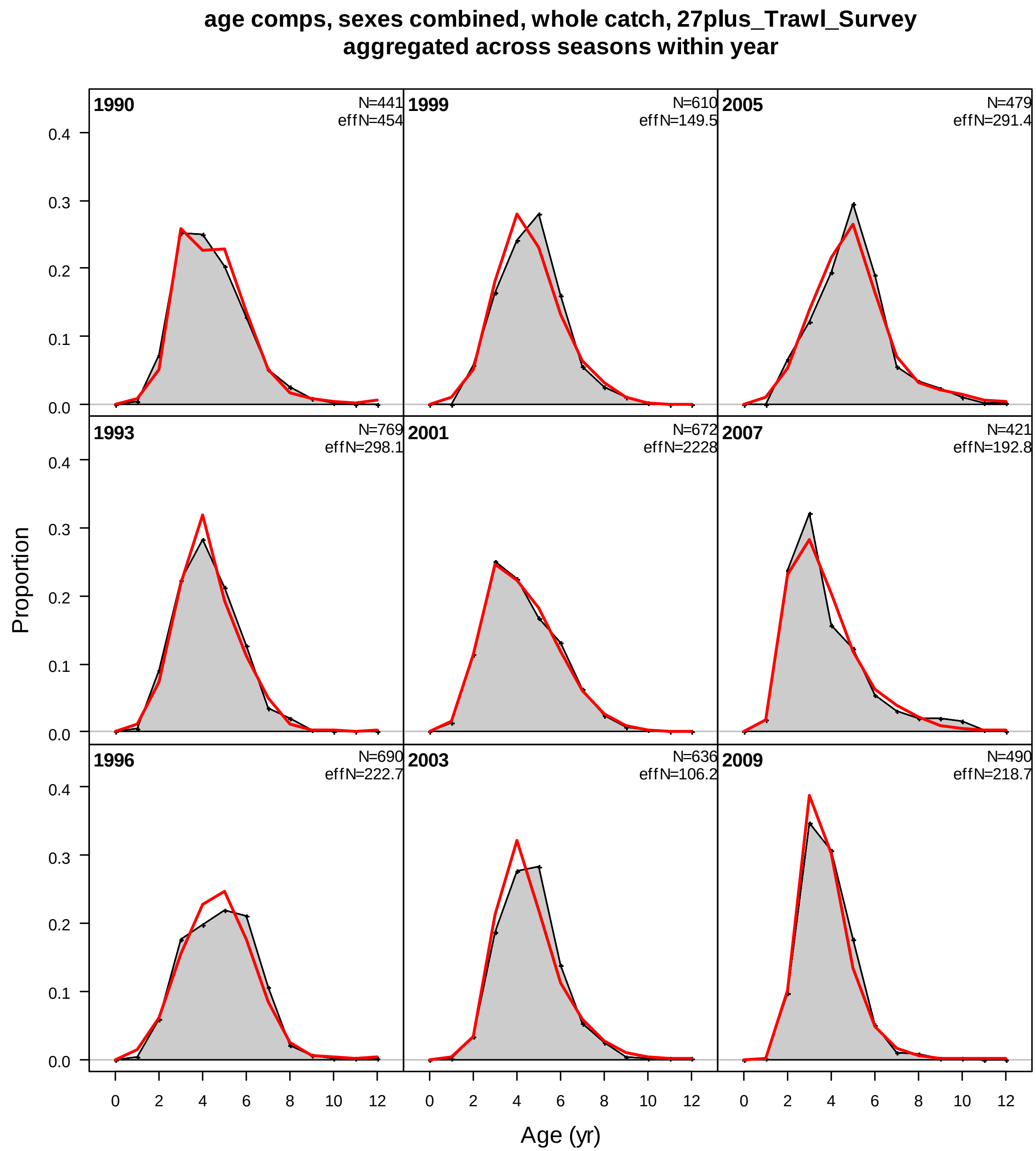

Figure 49 – Age composition data and model estimates for the 27-plus survey for Model A

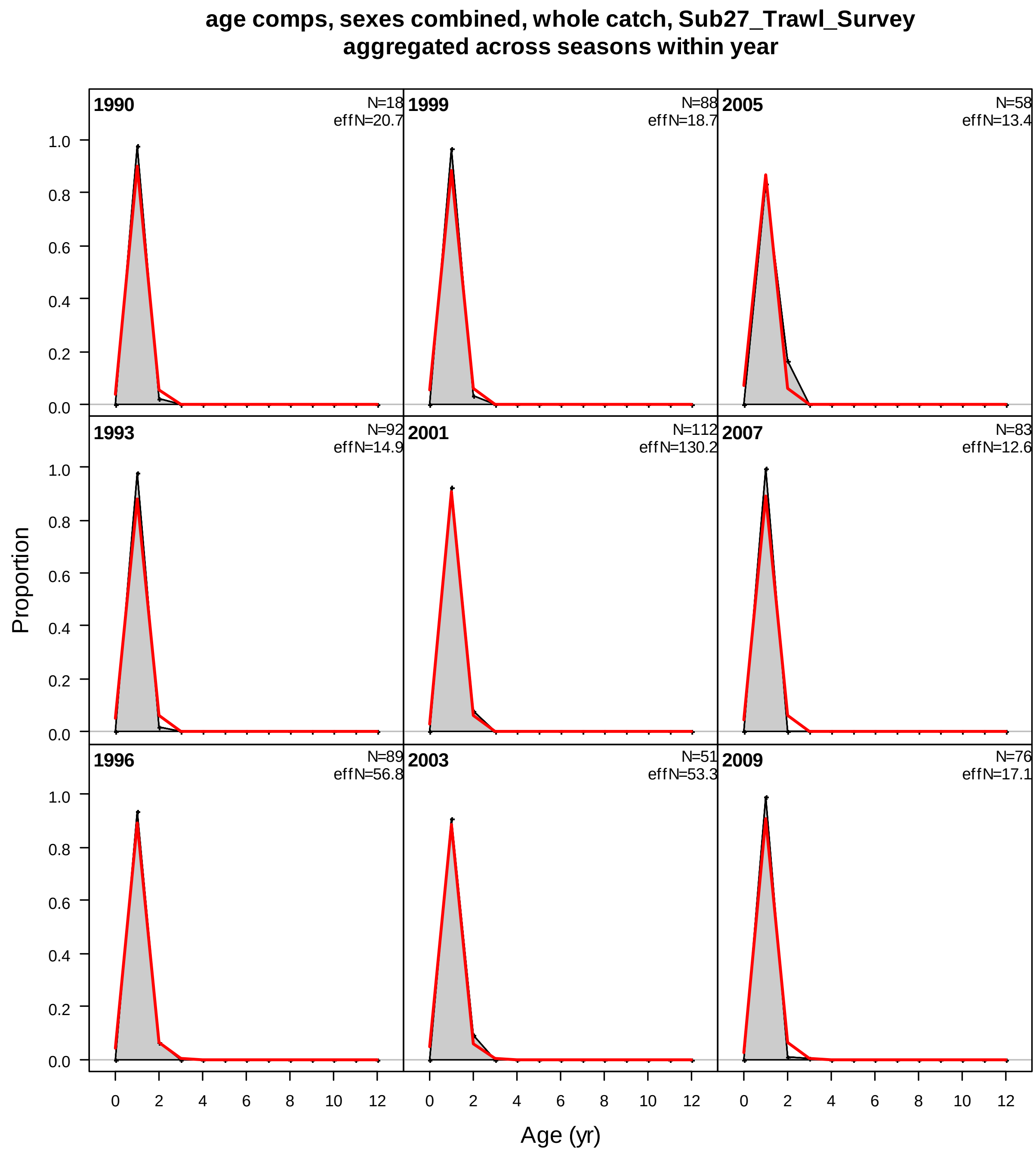

Figure 50 – Age composition data and model estimates for the sub-27 survey for Model A

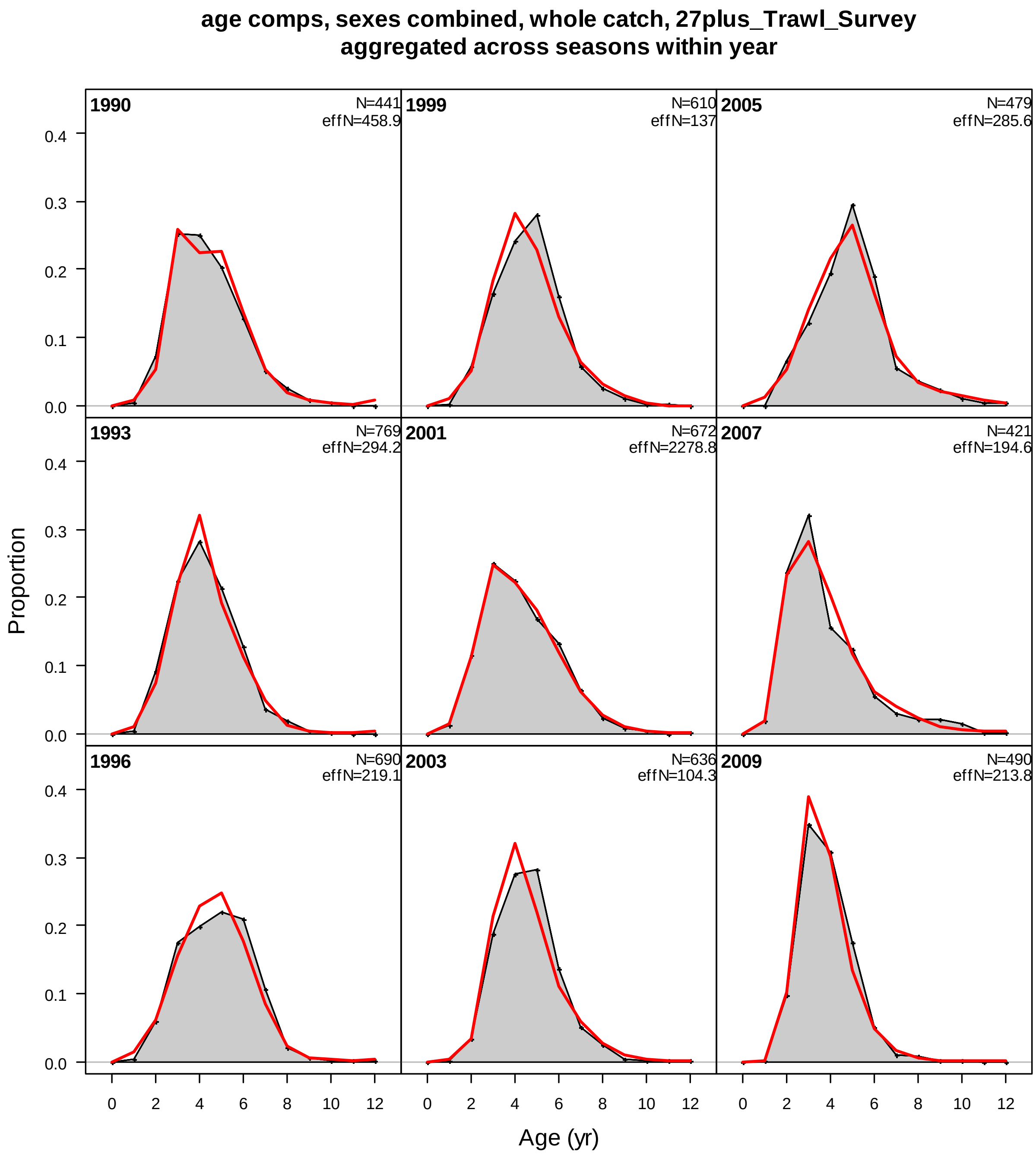

Figure 51 – Age composition data and model estimates for the 27-plus survey for Model AQ

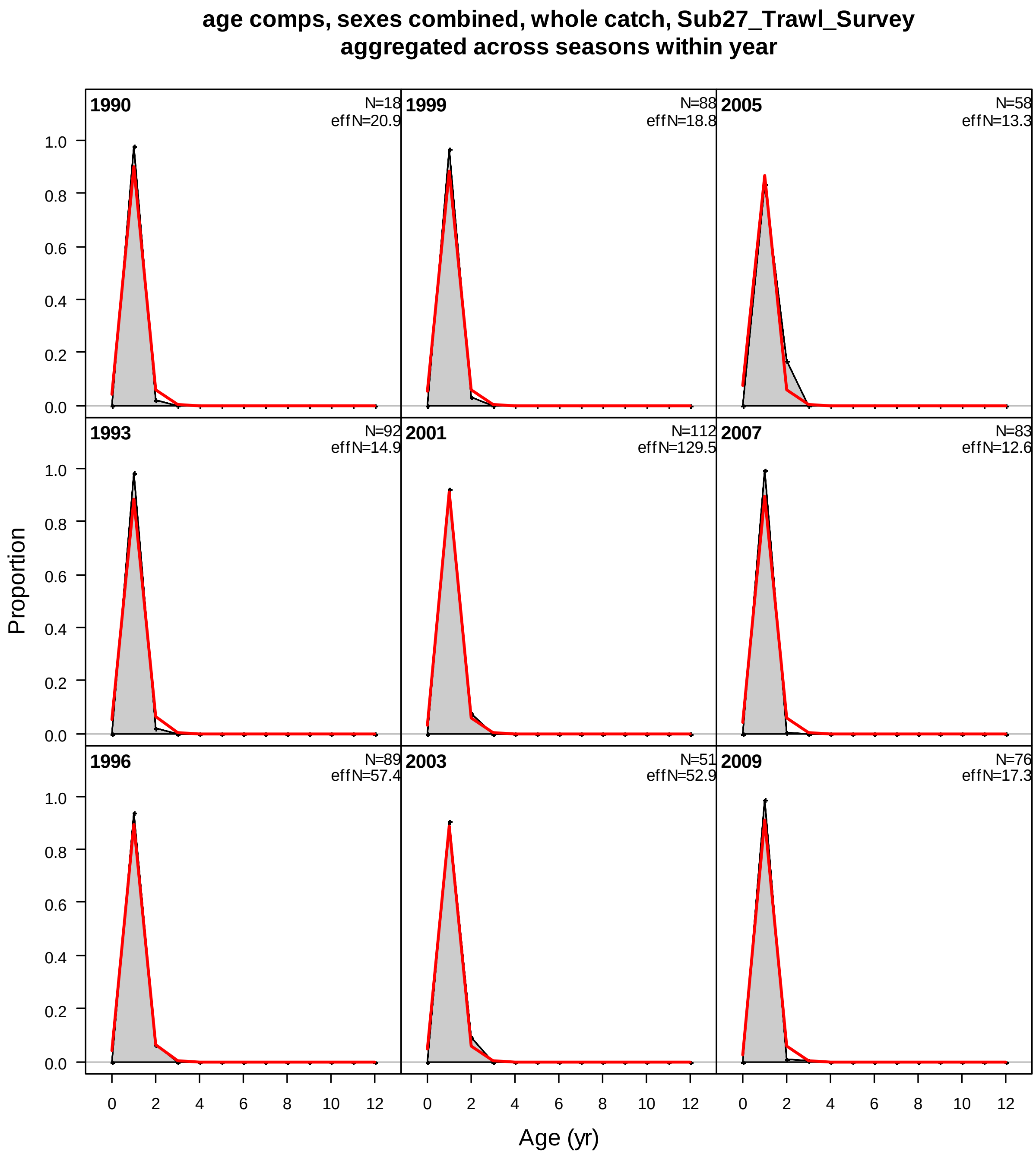

Figure 52 – Age composition data and model estimates for the sub-27 survey for Model AQ

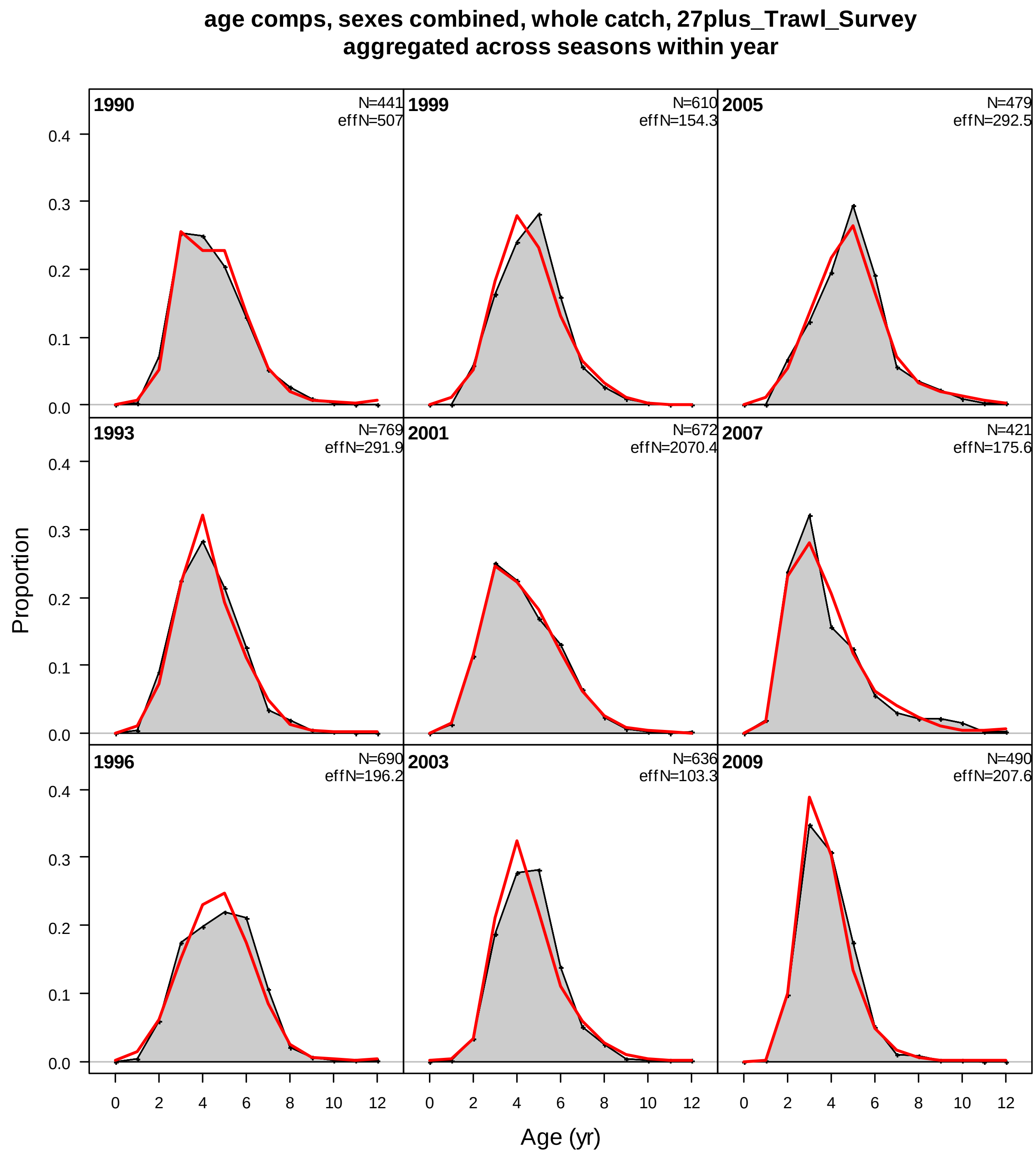

Figure 53 – Age composition data and model estimates for the 27-plus survey for Model B

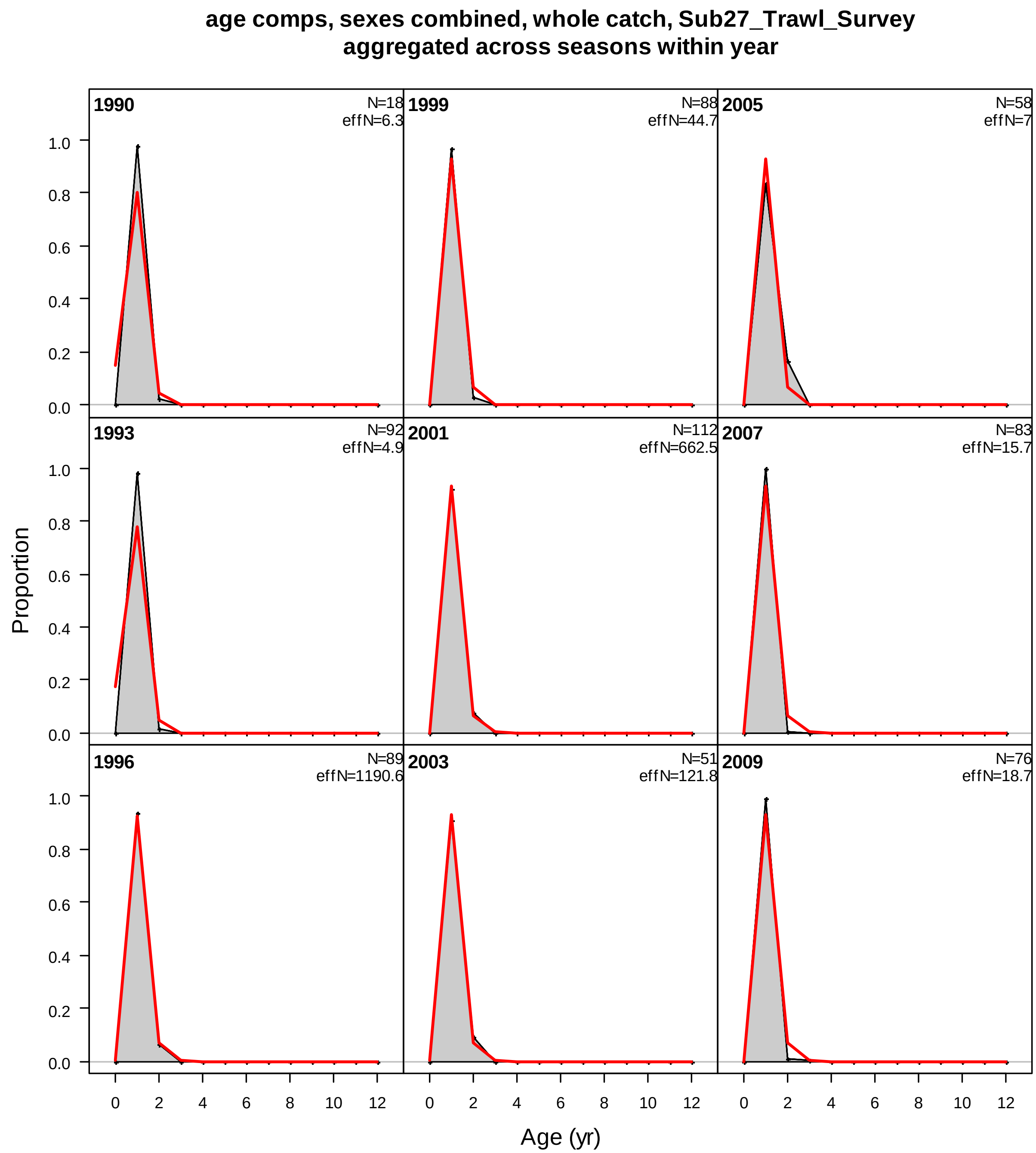

Figure 54 – Age composition data and model estimates for the sub-27 survey for Model B

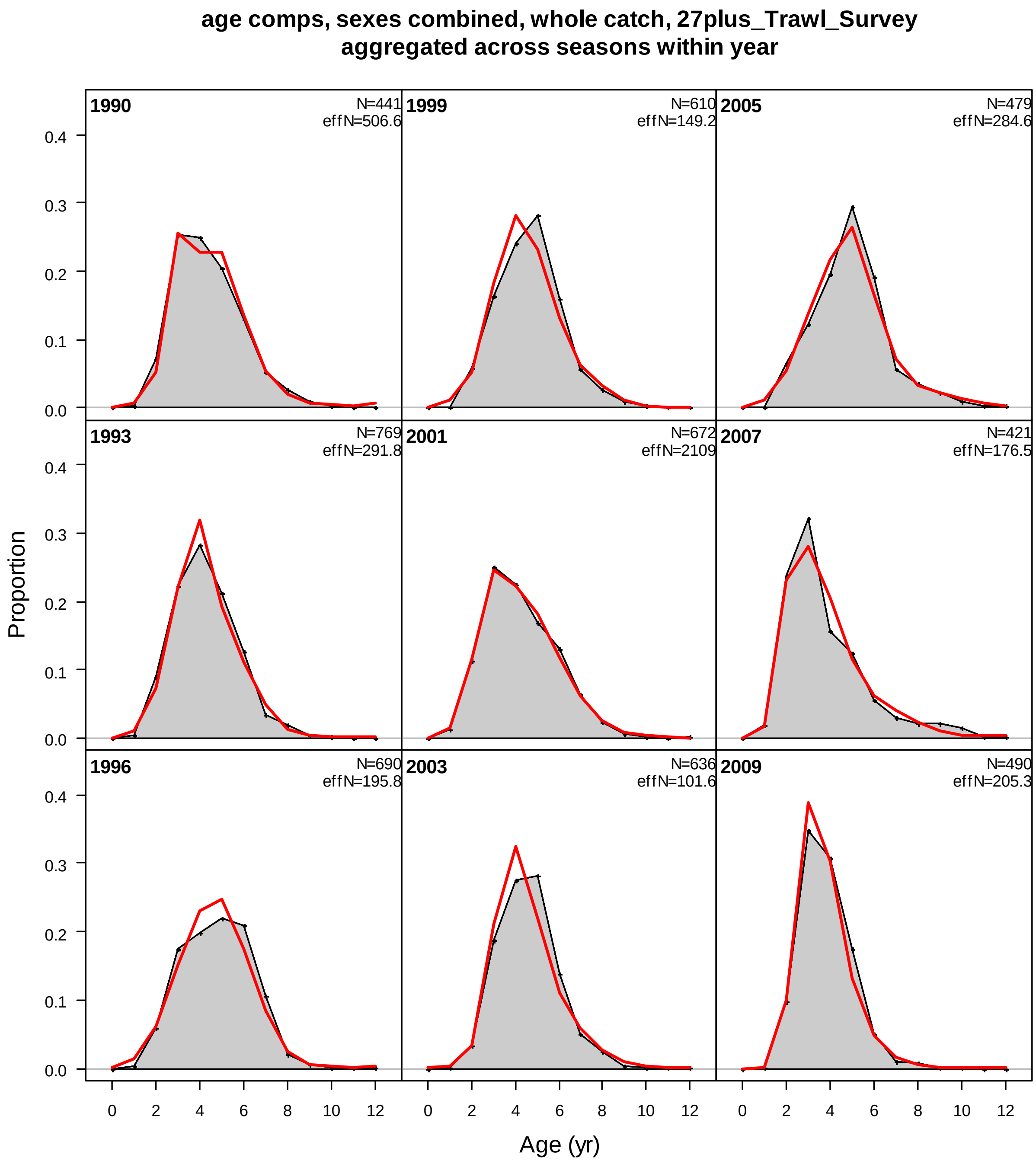

Figure 55 – Age composition data and model estimates for the 27-plus survey for Model BQ

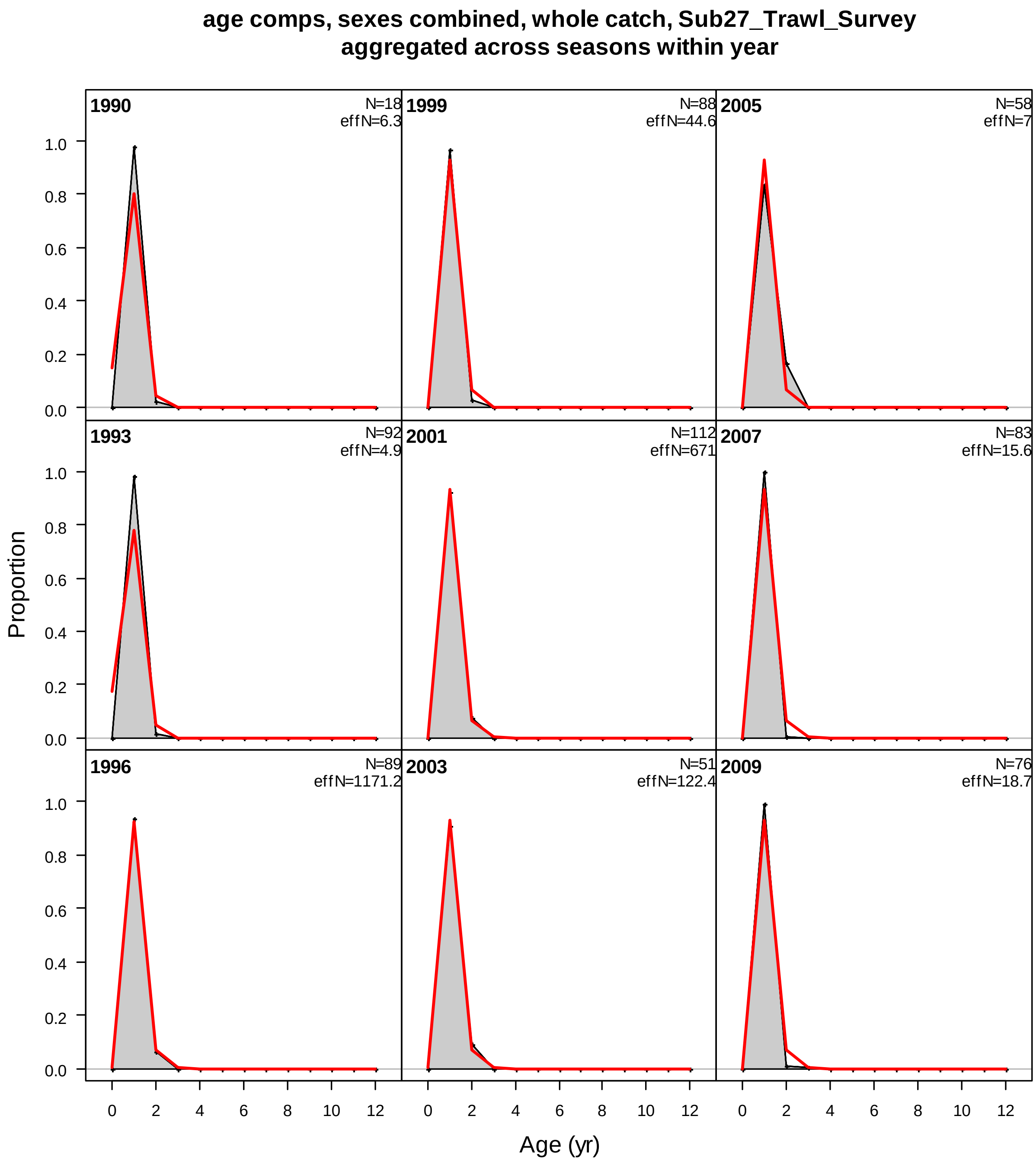

Figure 56 – Age composition data and model estimates for the sub-27 survey for Model BQ

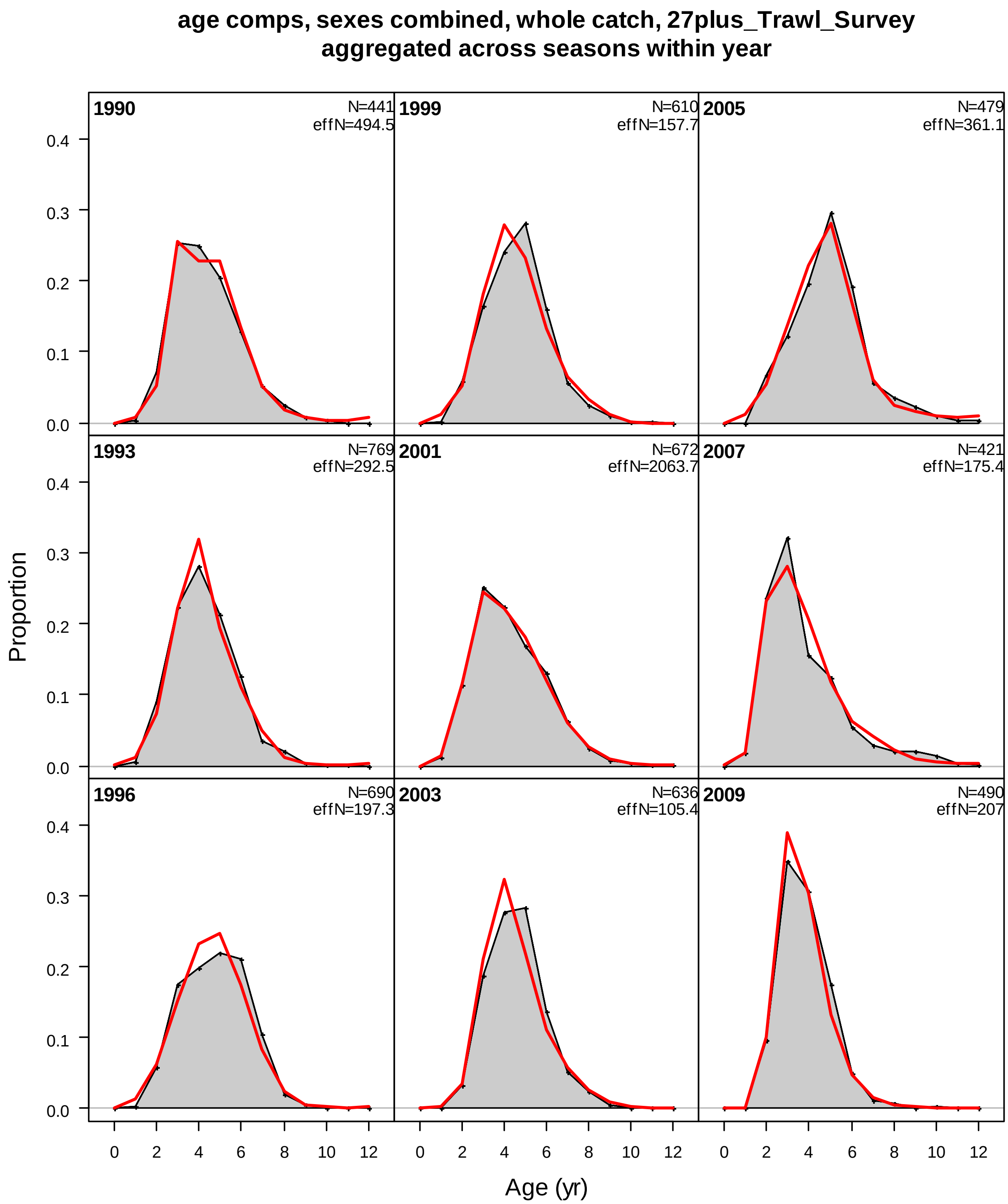

Figure 57 – Age composition data and model estimates for the 27-plus survey for Model C

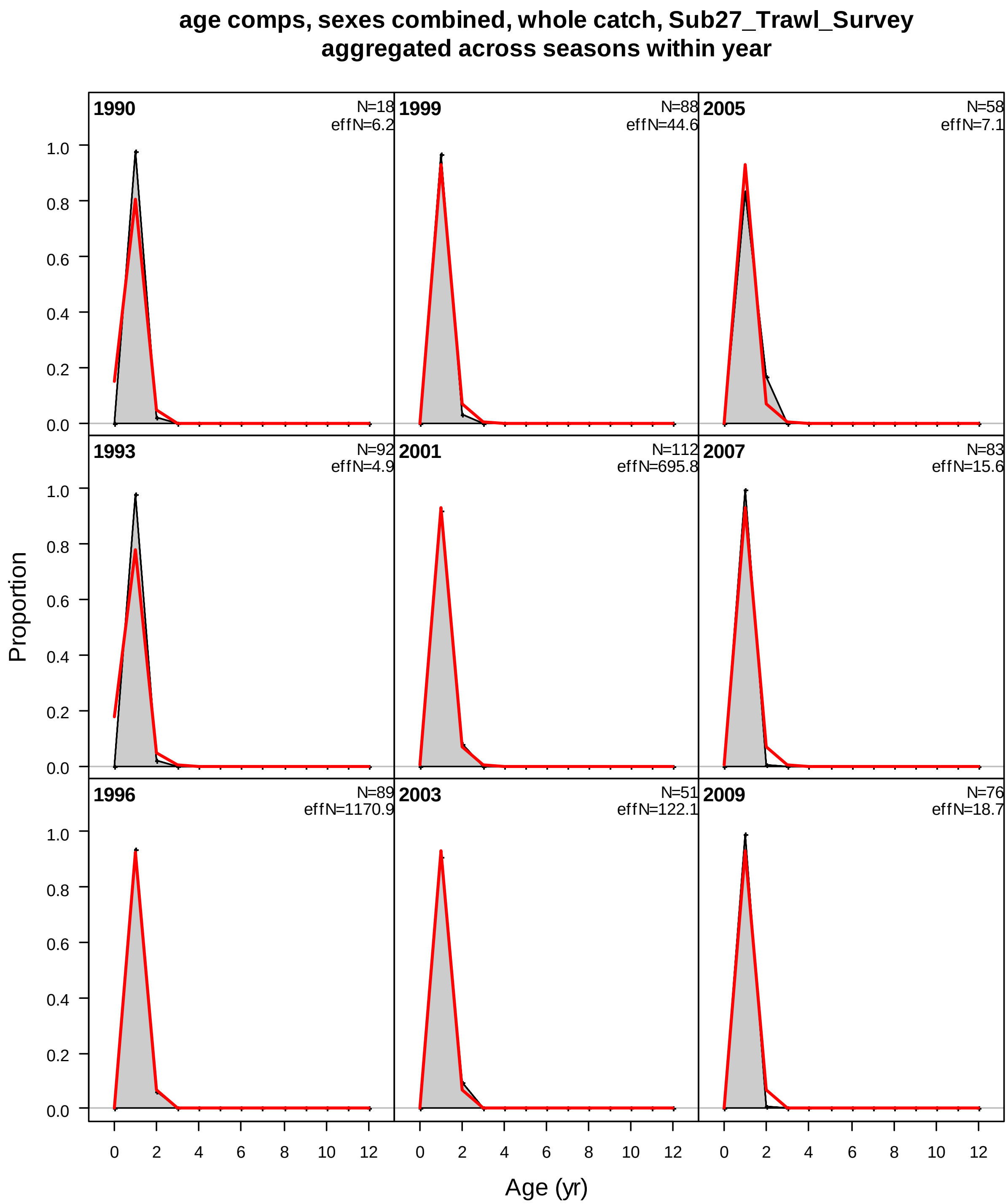

Figure 58 – Age composition data and model estimates for the sub-27 survey for Model C

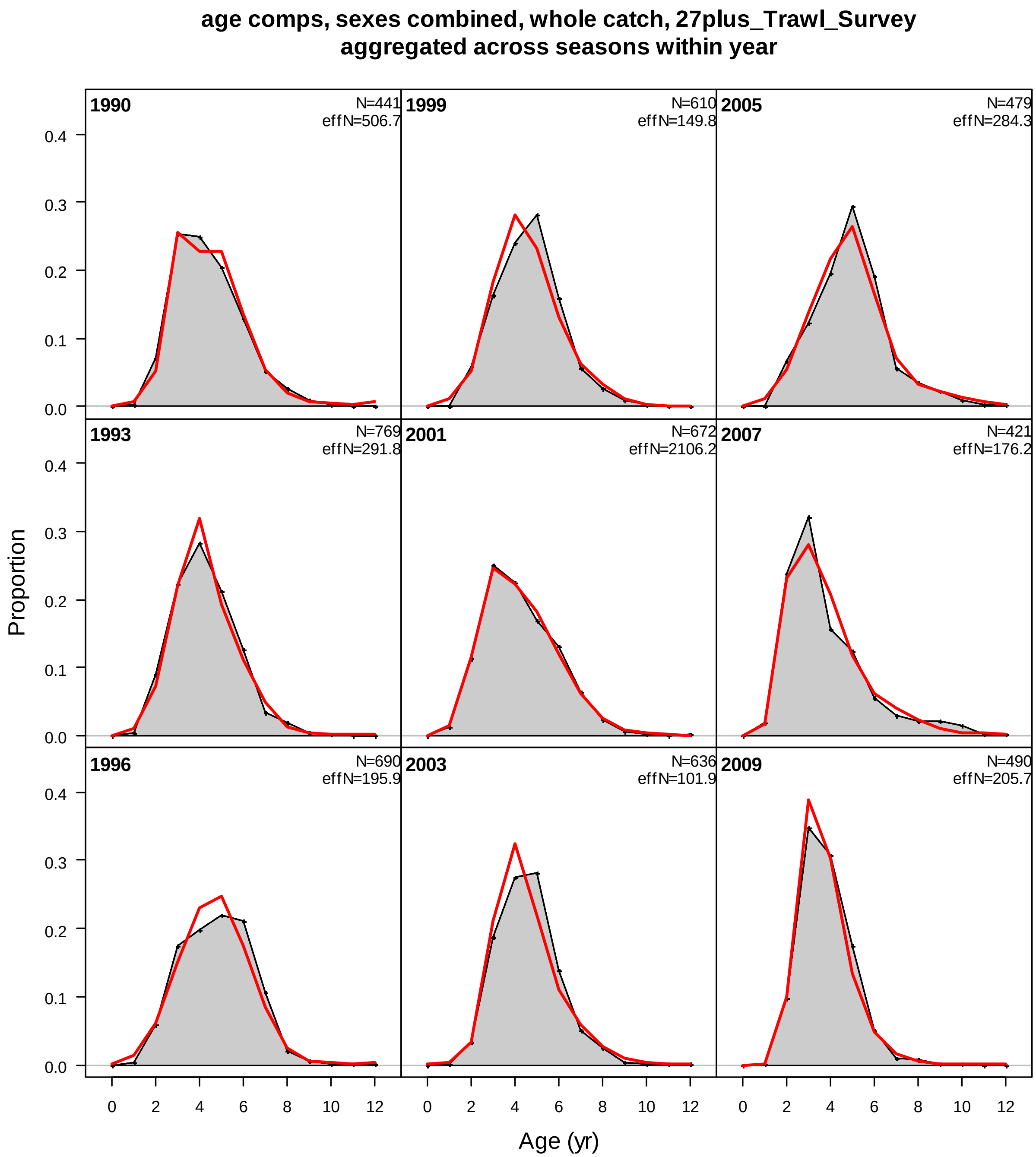

Figure 59 – Age composition data and model estimates for the 27-plus survey for model CQ

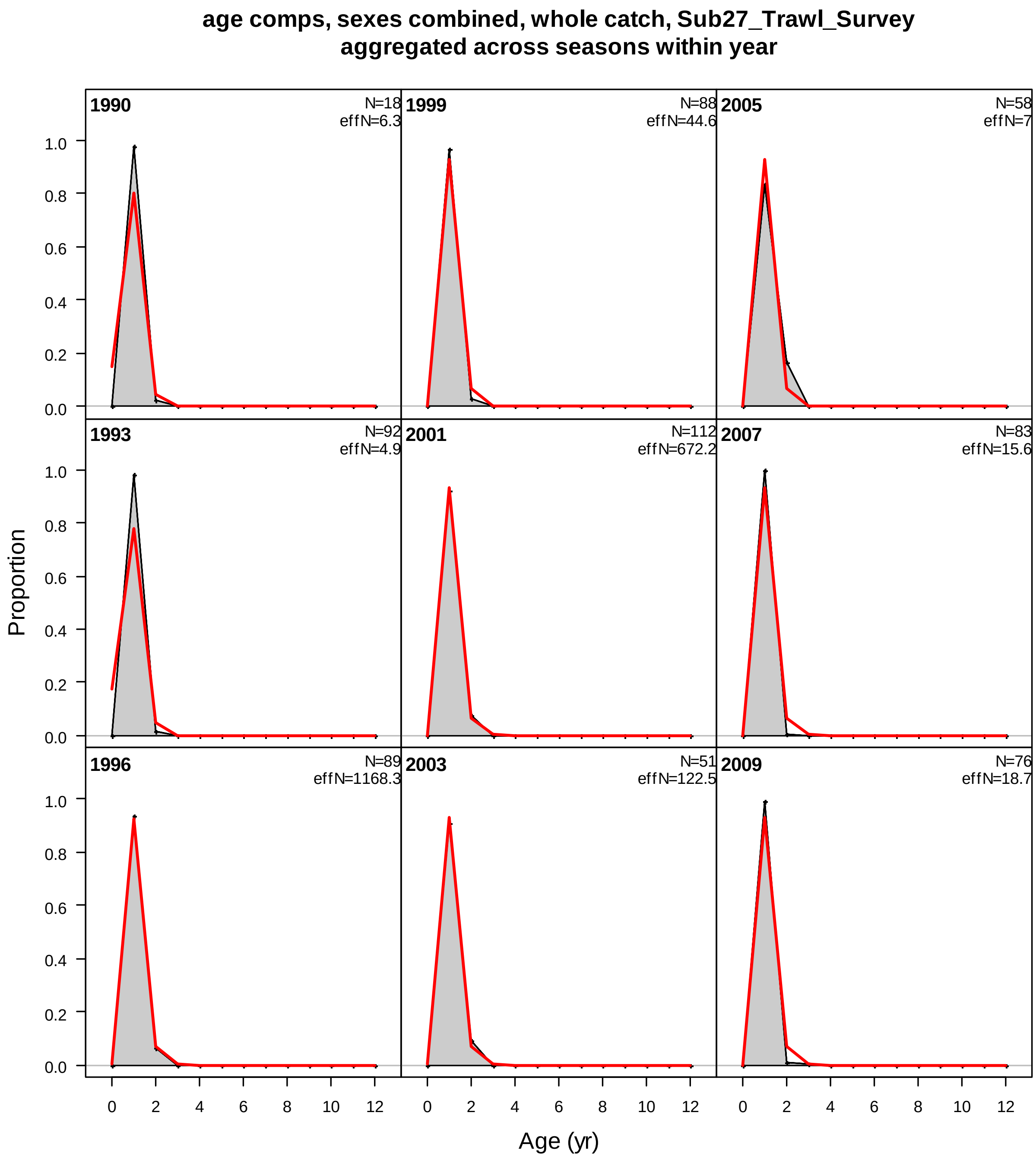

Figure 60 – Age composition data and model estimates for the sub-27 survey for Model CQ

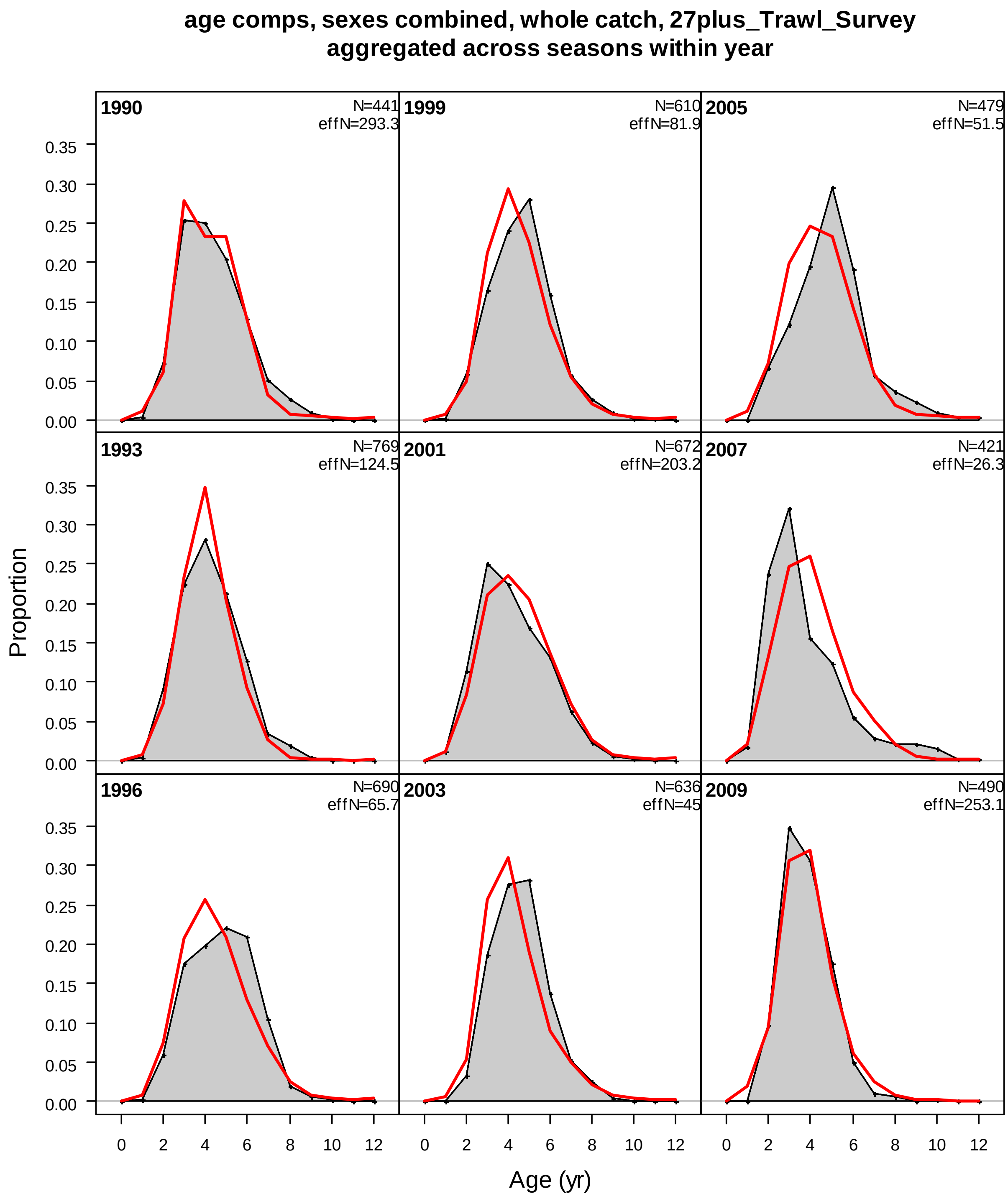

Figure 61 – Age composition data and model estimates for the 27-plus survey for Model D

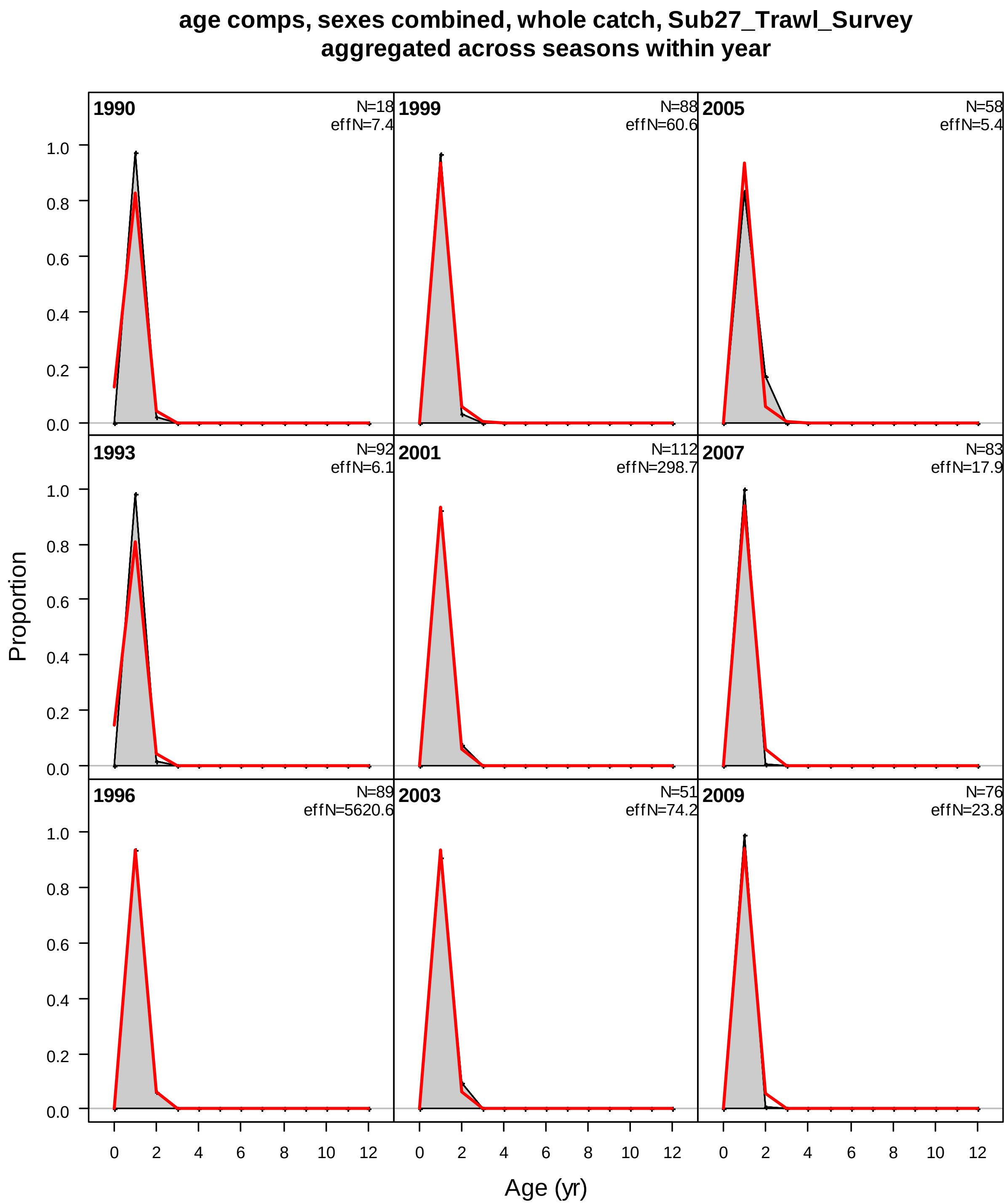

Figure 62 – Age composition data and model estimates for the sub-27 survey for Model D

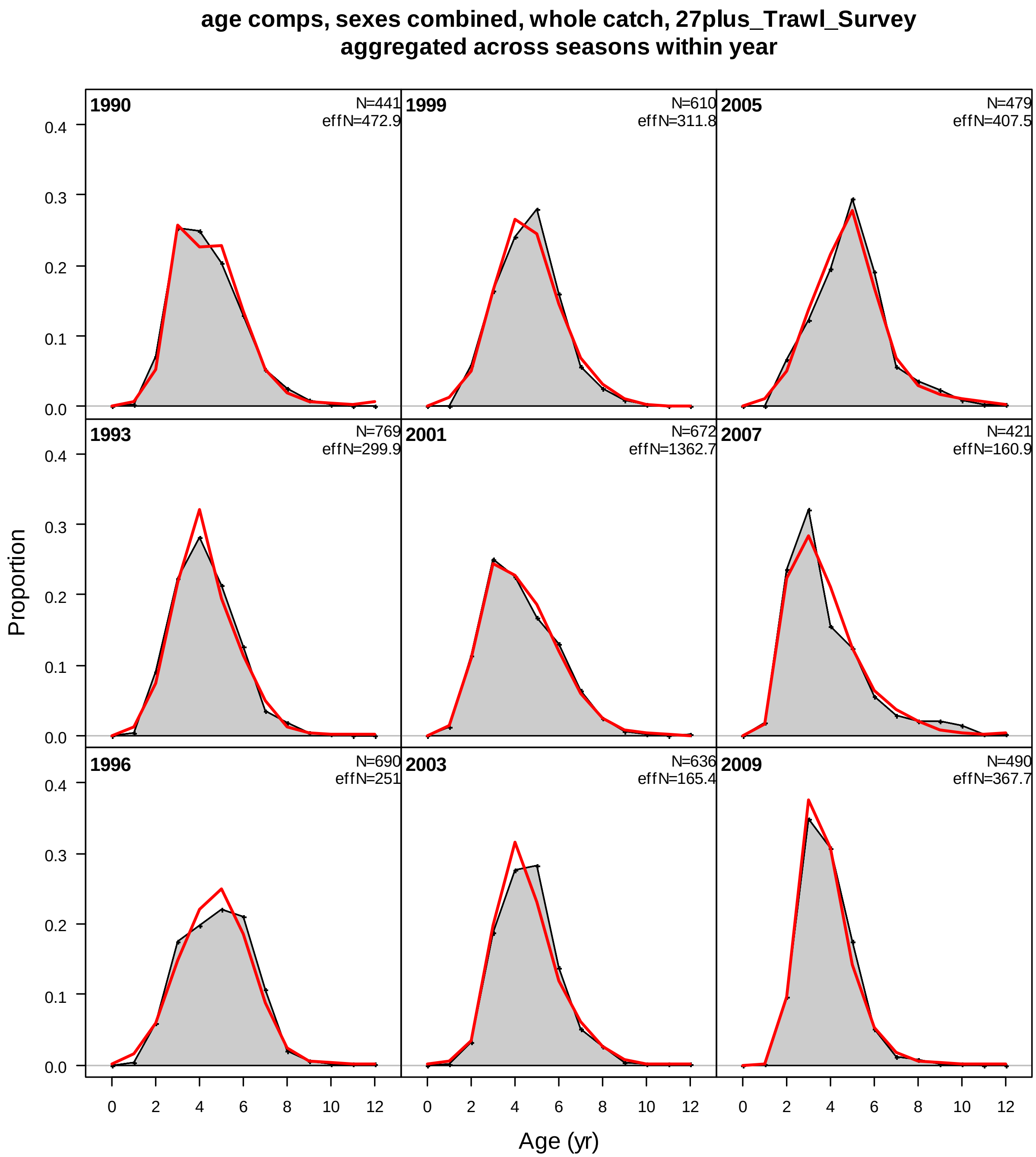

Figure 63 – Age composition data and model estimates for the 27-plus survey for Model E

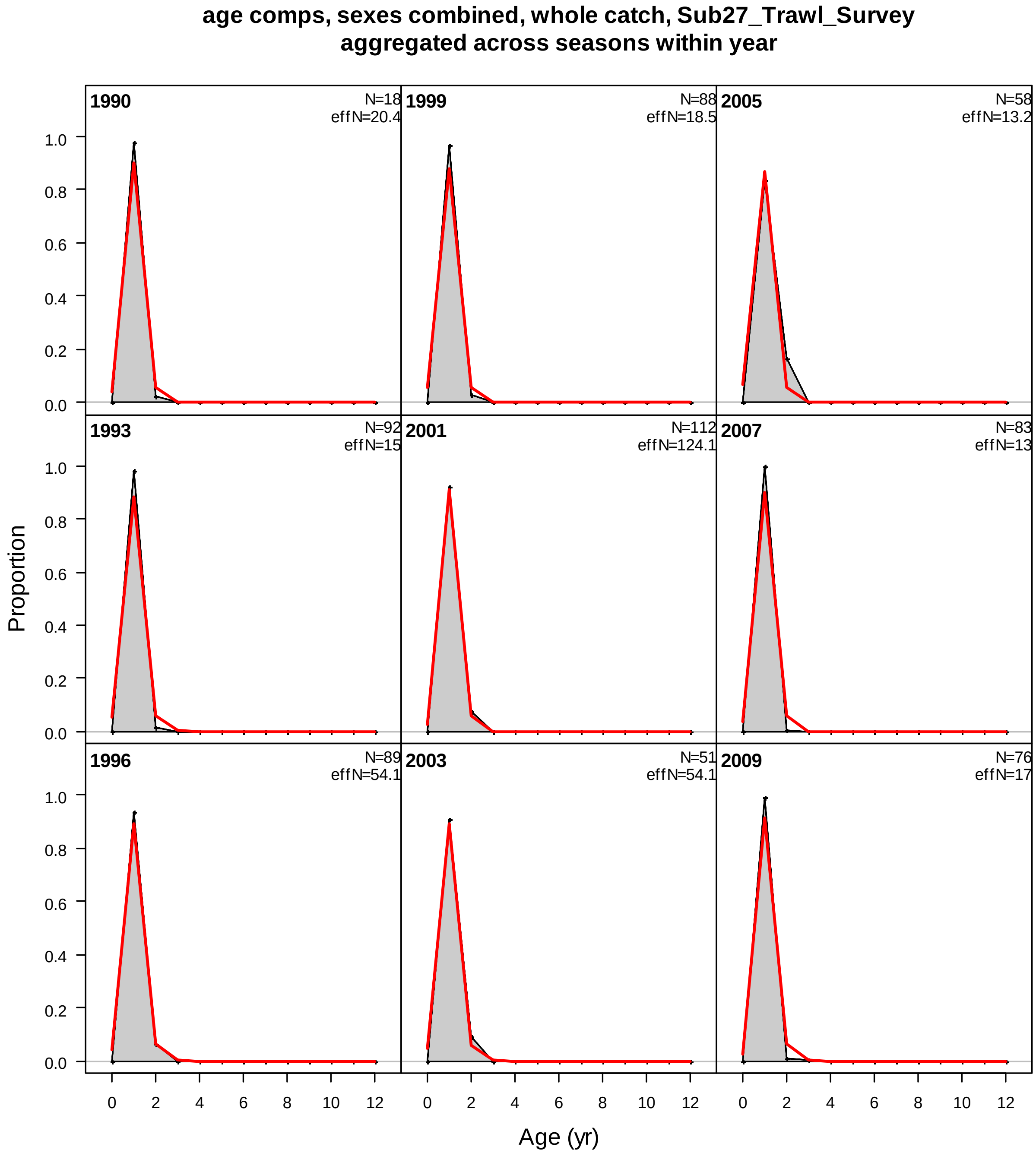

Figure 64 – Age composition data and model estimates for the sub-27 survey for Model E

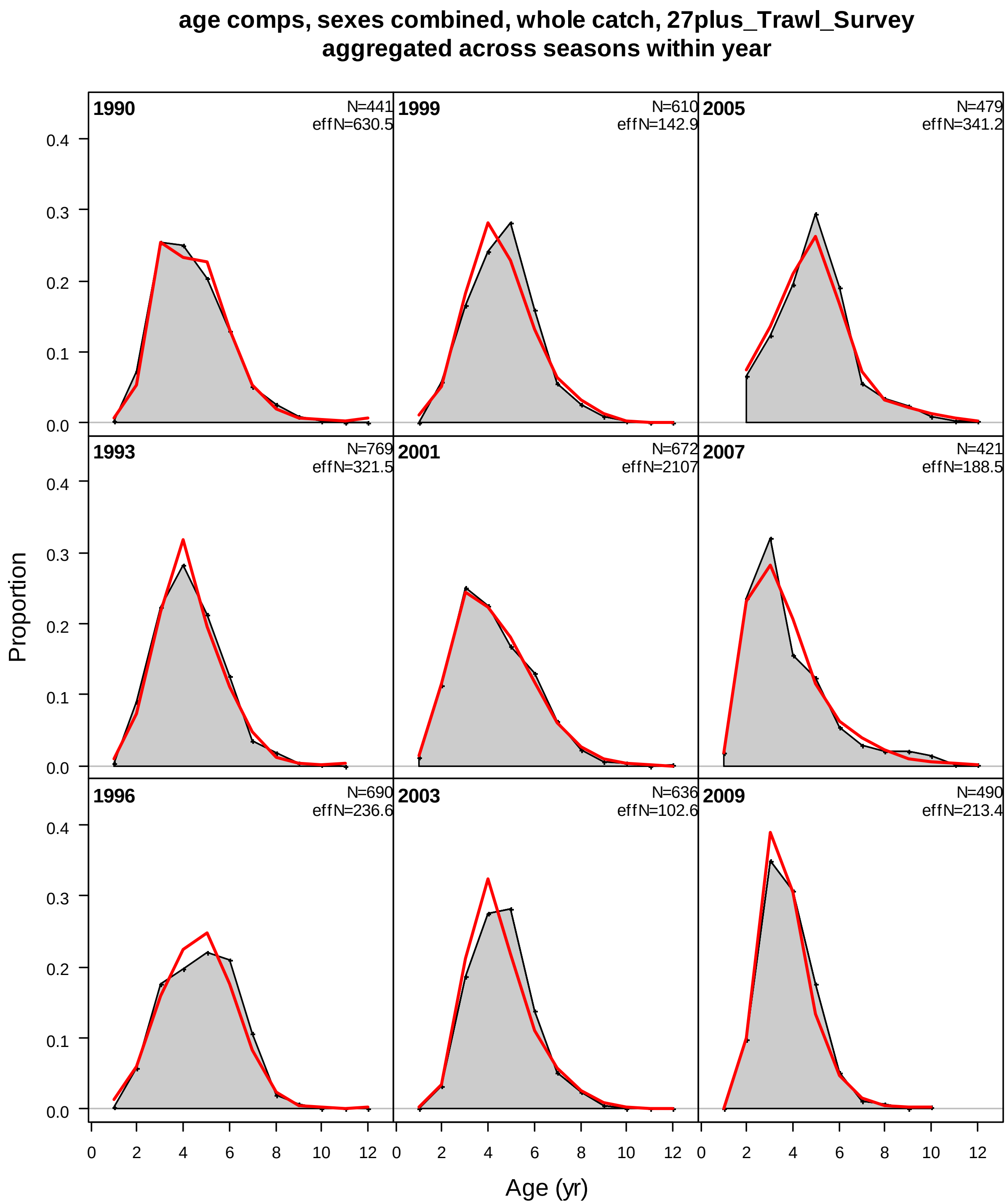

Figure 65 – Age composition data and model estimates for the 27-plus survey for Model 1B

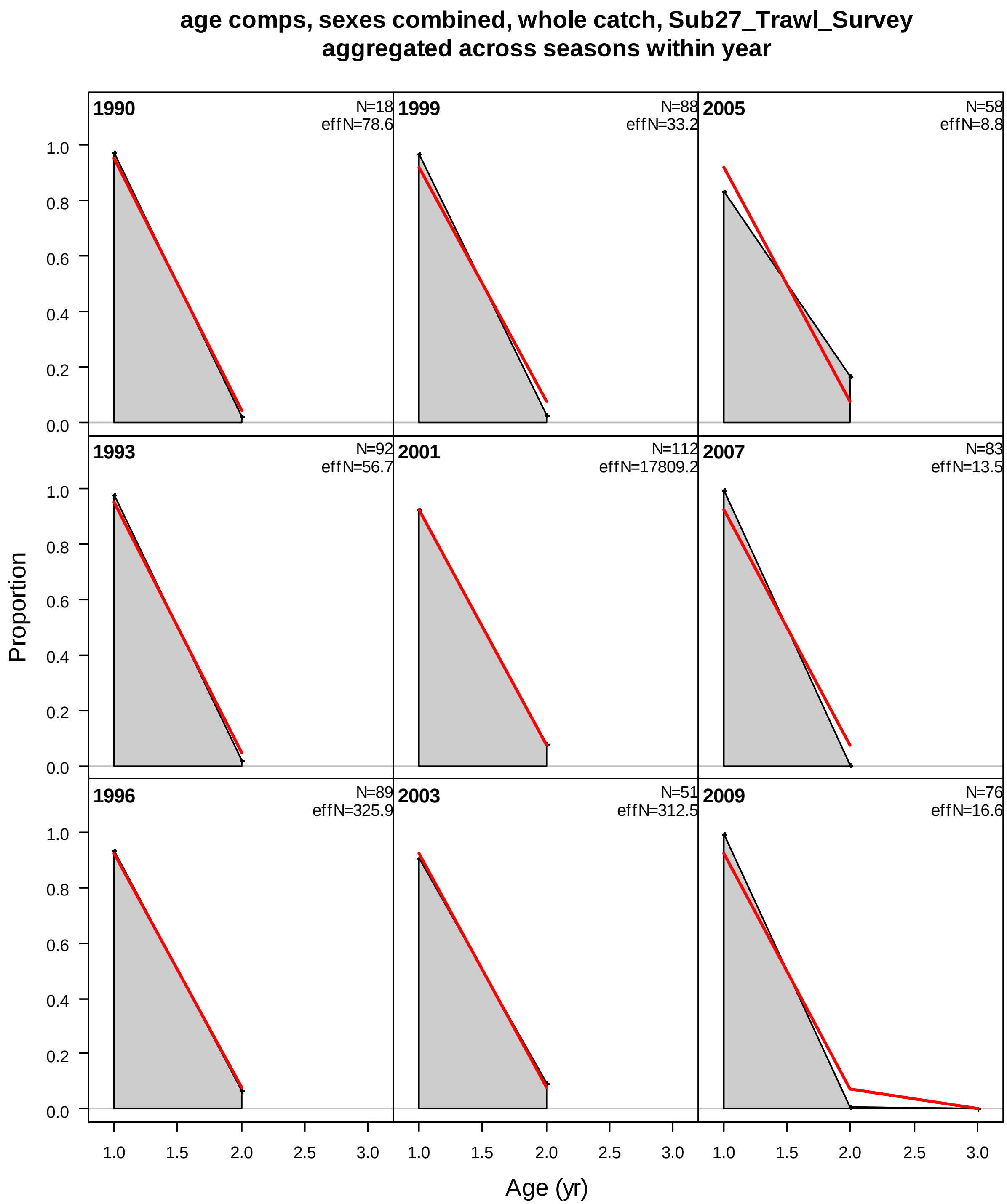

Figure 66 – Age composition data and model estimates for the sub-27 survey for Model 1B

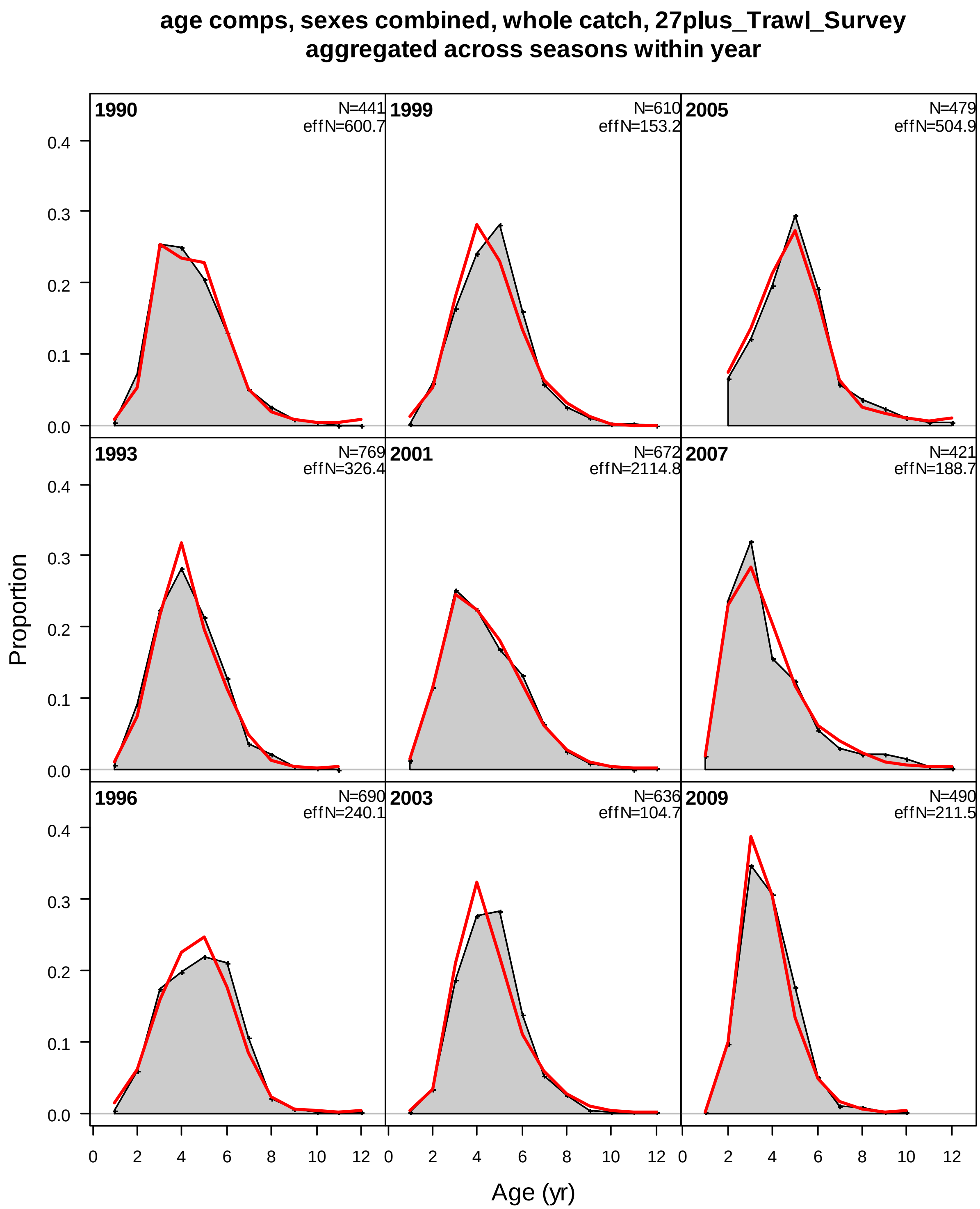

Figure 67 – Age composition data and model estimates for the 27-plus survey for Model 1C

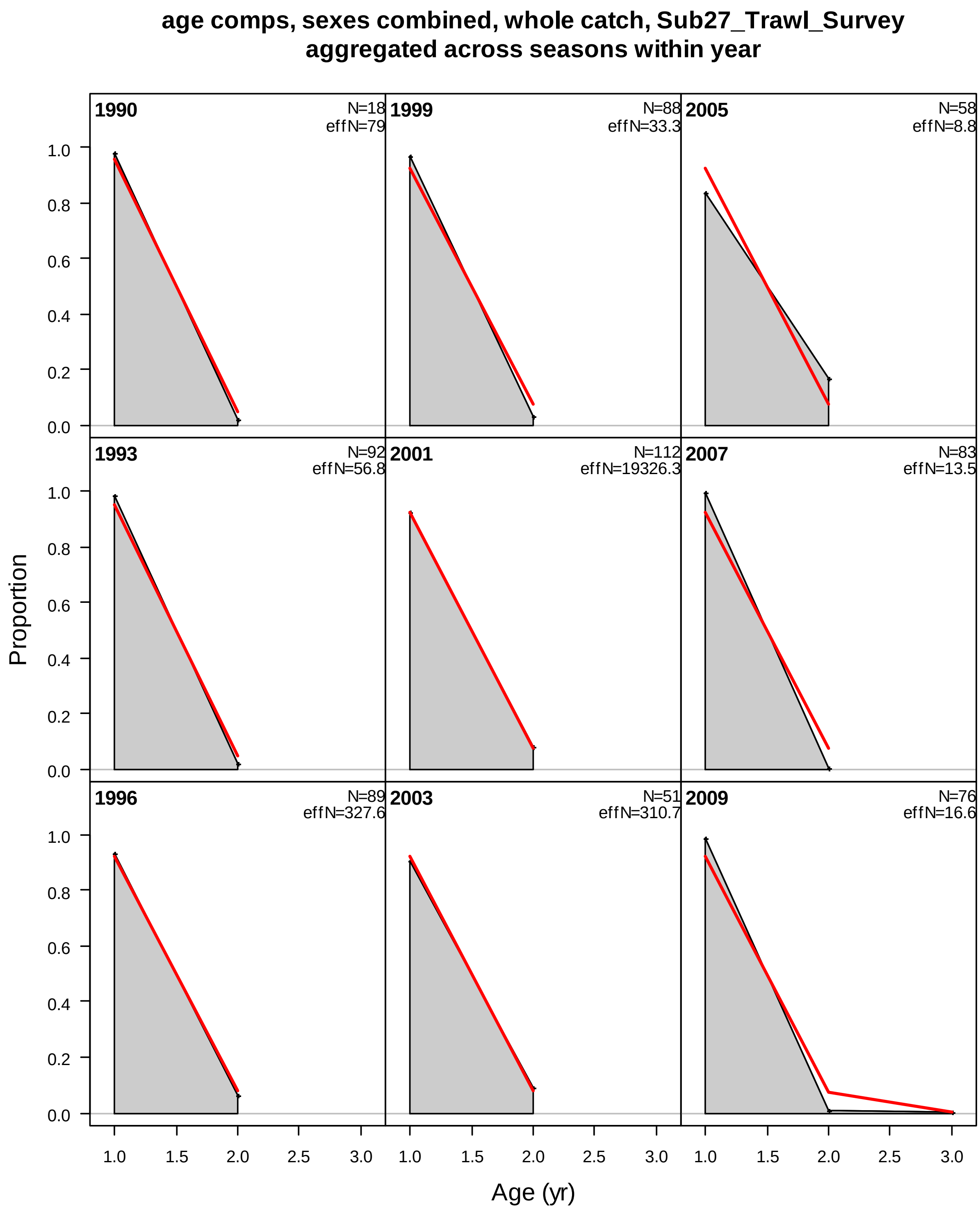

Figure 68 – Age composition data and model estimates for the sub-27 survey for Model 1C