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

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Executive Summary

Summary of Changes in Assessment Inputs

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

Changes in the input data

1. Federal and state catch data for 2014 were updated and preliminary federal and state catch data for 2015 were included;
2. Commercial federal and state fishery size composition data for 2014 were updated, and preliminary commercial federal and state fishery size composition data for 2015 were included; and
3. Estimates of biomass and abundance and population length composition data from the 2015 GOA NMFS bottom trawl data were included

Changes in the methodology

One of the models in this year's assessment is the 2014 final model, which is provided for reference.

Two additional models which differ significantly from the 2014 final model are also presented. These differences include:

- Using the 27-plus part of the GOA NMFS bottom trawl survey for the abundance estimates, the length and age composition data, and the conditional age-at-length data;
- Using 4 blocks of non-parametric survey selectivity-at-age;
- Changing A_{min} from 1 to 3;
- Capping the sample sizes for the fishery catch-at-length data at 400; and
- Lowering the weights on the likelihood components for the fishery catch-at-length data

Summary of Results

Quantity	As estimated or *specified last* year for: 2015	2016	As estimated or *specified this* year for: 2016	2017
M (natural mortality rate)	0.38	0.38	0.38	0.38
Tier	3a	3a	3a	3a
Projected total (age 0+) biomass (t)	583,800	558,200	518,800	472,800
Female spawning biomass (t)				
Projected	155,400	150,400	165,600	141,800
$B_{100\%}$	316,500	316,500	325,200	325,200
$B_{40\%}$	126,600	126,600	130,000	130,000
$B_{35\%}$	110,700	110,700	113,800	113,800
F_{OFL}	0.626	0.626	0.495	0.495
$maxF_{ABC}$	0.502	0.502	0.407	0.407
F_{ABC}	0.502	0.502	0.407	0.407
OFL (t)	140,300	133,100	116,700	100,800
maxABC (t)	117,200	110,700	98,600	85,200
ABC (t)	117,200	110,700	98,600	85,200
Status	As determined *last* year for: 2013	2014	As determined *this* year for: 2014	2015
Overfishing	no	n/a	no	n/a
Overfished	n/a	no	n/a	no
Approaching overfished	n/a	no	n/a	no

Area apportionment

In 2012 the ABC for GOA Pacific cod was apportioned among regulatory areas using a Kalman filter approach based on trawl survey biomass estimates. In the 2013 assessment, the random effects model (which is similar to the Kalman filter approach, and was recommended in the Survey Average working group report which was presented to the Plan Team in September 2013) was used; this method was used for the ABC apportionment for 2014. The SSC concurred with this method in December 2013. Using this method with the trawl survey biomass estimates through 2015, the area-apportioned ABCs are:

	Western	Central	Eastern	Total
Random effects area apportionment (percent)	41.08	50.01	8.91	100.00
2016 ABC	40,503	49,312	8,785	98,600
2017 ABC	34,998	42,610	7,592	85,200

Responses to SSC and Plan Team Comments Specific to this Assessment

Plan Team, September 2015: "*The Team discussed how new survey data (not presented at the meeting) might affect management advice. The Team's preference was for only a few models to be advanced to November in recognition that a new assessment author would be taking over. There was discussion about the historical 1987 ages and whether or not that data should be included. Age 1 data appears to warrant removal but the Team did not have a firm recommendation on this topic.* ***The Plan team recommends that Model 0 (the 2014 accepted model with new data) and the author's preferred model (model 4 with non-parametric selectivity and four blocks of survey selectivity) be advanced to November.***"
Response: The models labeled "Model 0" and "Model 4" in September are included in this analysis as Model 1 and Model 2, respectively.

SSC, October 2015: "*Preliminary models for Pacific Cod in the Gulf of Alaska included four alternative model structures, including last year's model (model 0) and the final model from 2011 (model 2). Two variants on last year's model were developed to address the treatment of age-1 fish in the model and the use of 1984 and 1987 survey data (models 3, 4).* ***The SSC concurs with the Plan Team recommendation to bring forward models 0 and 4 in December.***"
Response: The models labeled "Model 0" and "Model 4" in September are included in this analysis as Model 1 and Model 2, respectively.

SSC, October 2015: "*In addition, the SSC encourages a step-by-step exploration of the impact of the 1984 and 1987 data on model performance. If there is not enough time to complete these analyses by December, and considering the upcoming change in assessment authors, this issue could be addressed in the next assessment cycle. Uncertainties or potential biases in the 1987 age data could also be explored by working with the aging group, or through a review of previous work on this issue.*"
Response: The exploration of the impact of the 1984 and 1987 GOA NMFS bottom trawl survey data on model performance was not done in this analysis. Age samples for 1984 are not available, and the age samples for 1987 are incomplete as approximately half of the samples collected have not been located.

Introduction

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

Review of Life History

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

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

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

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

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

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

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

Fishery

During the two decades prior to passage of the Magnuson Fishery Conservation and Management Act (MFCMA) in 1976, the fishery for Pacific cod in the GOA was small, averaging around 3,000 t per year. Most of the catch during this period was taken by the foreign fleet, whose catches of Pacific cod were usually incidental to directed fisheries for other species. By 1976, catches had increased to 6,800 t. Catches of Pacific cod since 1991 are shown in Table 2.1; catches prior to that are listed in Thompson et al. (2011). Presently, the Pacific cod stock is exploited by a multiple-gear fishery, including trawl, longline, pot, and jig components. Trawl gear took the largest share of the catch in every year but one from 1991-2002, although pot gear has taken the largest single-gear share of the catch in each year since 2003 (not counting 2015, for which data are not yet complete). Figure 2.1 shows landings by gear and season since 1977. Table 2.1 shows the catch by jurisdiction and gear type.

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

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

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

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

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

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

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

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

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

Data

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

Data	Source	Type	Years included
Federal and state fishery catch, by gear type and month	AKFIN	metric tons	1977 – 2015
Federal fishery catch-at-length, by gear type and month	AKFIN / FMA	number, by cm bin	1977 – 2015
State fishery catch-at-length, by gear type and month	ADF&G	number, by cm bin	1997 – 2015
GOA NMFS bottom trawl survey biomass and abundance estimates	AFSC	metric tons, numbers	1984 – 2015
GOA NMFS bottom trawl survey length composition	AFSC	number, by cm bin	1984 – 2015
GOA NMFS bottom trawl survey age composition	AFSC	number, by age	1987 – 2013
GOA NMFS bottom trawl survey mean length-at-age and conditional age-at-length	AFSC	mean value and number	1987 – 2013

Fishery

Catch Biomass

Catches for the period 1991-2015 are shown for the three main gear types in Table 2.7, with the catches for 2015 seasons 4 and 5 (Sep – Oct and Nov – Dec) estimated given the average fraction of annual catch in each month for 2010 – 2014 and the average fraction of each gear type in seasons 4 and 5 for 2010 – 2014. This table also shows gear-specific catches by “selectivity seasons,” which are obtained from combinations of “catch seasons.” The catch seasons are defined as January-February, March-April, May-August, September-October, and November-December. Three selectivity seasons are defined by combining catch seasons 1 and 2 into selectivity season 1, equating catch season 3 with selectivity season 2, and combining catch seasons 4 and 5 into selectivity season 3. The catch seasons used were the result of a statistical analysis described in the 2010 assessment (Thompson et al. 2010), and the selectivity seasons were chosen to correspond as closely as possible to the traditional seasons used in previous assessments (given the revised catch seasons). In years for which estimates of the distribution by gear or period were unavailable, proxies based on other years’ distributions were used. Non-commercial catches for 2006 – 2014 are shown in Table 2.8.

Catch Size Composition

Fishery size compositions are presently available, by gear and season, for at least one gear type in every year from 1977 through the first half of 2015. Beginning with the 2010 assessment (Thompson et al. 2010), size composition data are based on 1-cm bins ranging from 4 to 120 cm. As the maximum percent of fish larger than 110 cm over each year-gear type-season is less than 0.5%, the upper limit of the length bins has been decreased to 110 cm, with the 110-cm bin accounting for all fish 110 cm and larger.

Survey

Survey Age Composition

Age compositions from each trawl survey except 1984 and 2015 are available (note that the sample size for the 1987 was very small, however). The age compositions and actual sample sizes are shown in Table 2.9 and Fig. 2.7.

Survey Size Composition

For the last few assessments, the size composition data from the trawl surveys of the GOA conducted by the Alaska Fisheries Science Center have been partitioned into two length categories: fish smaller than 27 cm (the “sub-27” survey) and fish 27 cm and larger (the “27-plus” survey). The relative size compositions from 1984-2015 are shown for the sub-27 and the 27-plus survey in Table 2.10, using the same 1-cm length bins defined above for the fishery catch size compositions. Columns in this table sum to the actual number of fish measured in each year. The full size compositions are shown in Fig. 2.6.

Mean Size at Age

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

Abundance Estimates

Estimates of total abundance (both in biomass and numbers of fish) obtained from the trawl surveys are shown in Table 2.12 and Fig. 2.3, together with their respective coefficients of variation. The abundance estimates by area are shown in Fig. 2.5.

The highest biomass ever observed by the survey was the 2009 estimate of 752,651 t, and the low point was the preceding (2007) estimate of 233,310 t. The 2009 biomass estimate represented a 223% increase over the 2007 estimate. The 2011 biomass estimate was down 33% from 2009, but still 115% above the 2007 estimate. The 2015 biomass estimate is a significant decrease (50%) from the 2013 estimate (Fig. 2.2). The biomass estimates by area are shown in Fig. 2.4.

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

The 2015 total abundance estimate is a significant decrease (42%) from the 2013 estimate. The 2015 abundance estimate for fish 27 cm and larger is also a significant decrease of (29%) from the 2013 estimate; the 27-plus abundance estimates have been decreasing by at least 19% between survey years since 2009 (Fig. 2.3). The 2015 abundance estimate for fish less than 27 cm is a large decrease (84%) from the 2013 estimate. The total, 27-plus, and sub-27 abundance estimates for 2015 are a decrease of at least 56% from the 2009 estimates.

Analytic Approach

Model Structure

History of Previous Model Structures Developed Under Stock Synthesis

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

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

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

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

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

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

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

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

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

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

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

The 2009 assessment (Thompson et al. 2009) featured a total of ten models reflecting a great many alternative assumptions and use or non-use of certain data, particularly age composition data. Relative to the 2008 assessment, the main changes in the model accepted by the Plan Team and SSC were as follow: 1) input standard deviations of all "dev" vectors were set iteratively by matching the standard deviations of the set of estimated "devs;" 2) the standard deviation of length at age was estimated outside the model as a linear function of mean length at age; 3) catchability for the pre-1996 trawl survey was estimated freely while catchability for the post-1993 trawl survey was fixed at the value that sets the average (weighted by numbers at length) of the product of catchability and selectivity for the 60-81 cm size range equal to the point estimate of 0.916 obtained by Nichol et al. (2007); 4) potential ageing bias was accounted for in the ageing error matrix by examining alternative bias values in increments of 0.1 for ages 2 and above, resulting in a positive bias of 0.4 years for these ages (age-specific bias values were also examined, but did not improve the fit significantly); 5) weighting of the age composition data was returned to its traditional level; 6) except for the parameter governing selectivity at age 0, all parameters of the selectivity function for the post-1993 years of the 27-plus trawl survey were allowed to vary in each survey year except for the most recent; and 7) cohort-specific growth devs were estimated for all years through 2008.

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

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

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

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

Model Structures Considered in This Year's Assessment

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

One of the models in this year's assessment are based on the 2014 final model. This model (labeled "Model 0") is characterized by:

- Three gear types (trawl, longline, and pot), 5 seasons (Jan-Feb, Mar-Apr, May-Aug, Sept-Oct, and Nov-Dec), and three fishery selectivity "seasons" (Jan-Apr, May-Aug, and Sept-Dec);
- Time-varying fishery selectivity-at-length for all gears and seasons (3 – 7 blocks);
- Using the GOA NMFS bottom trawl survey as one source of data instead of being split into sub-27 and 27-plus, for the abundance estimates and the length and age composition data;
- Using 3 blocks of non-parametric survey selectivity-at-age;
- Including the survey conditional age-at-length data; and
- Using the recruitment variability multiplier (sigmaR multiplier, value 4.0) for age-0 recruits for 2012, 2013, and 2014.

The model labeled "Model 1" is the 2014 final model with 2015 data, which includes data for the full 2015 GOA NMFS bottom trawl survey.

The additional two models (labeled "Model 2" and "Model 3") differ significantly from the 2014 final model by:

- Using the 27-plus part of the GOA NMFS bottom trawl survey for the abundance estimates, the length and age composition data, and the conditional age-at-length data;
- Using 4 blocks of non-parametric survey selectivity-at-age;
- Increasing A_{min} from 1 to 3, as data for fish smaller than 27 cm aged 1 and 2 have been omitted;
- Capping the sample sizes for the fishery catch-at-length data at 400; and
- Evaluating lower weights on the likelihood components for the fishery catch-at-age data

Model 3 differs from Model 2 by including an additional period for fishery selectivity-at-length for 2013 – 2015 for all gear-season combinations except for pot gear season 3, as there were few data for this gear type and season. This selectivity change was made to account for possible changes in the characteristics of the fishery observer length data since the fishery observer program was restructured in 2013.

The author's preferred model configuration is Model 3, with the weight on the likelihood components for the fishery catch-at-length data decreased from 1 to 0.25.

Parameters Estimated Outside the Assessment Model

Natural Mortality

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

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

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

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

Catchability

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

Variability in Estimated Age

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

Variability in Length at Age

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

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

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

Weight at Length

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

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

The above parameters were retained in the present assessment.

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

Parameters Estimated Inside the Assessment Model

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

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

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

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

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

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

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

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

Likelihood Components

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

In SS, emphasis factors are specified to determine which likelihood components receive the greatest attention during the parameter estimation process. As in previous assessments, all likelihood components were given an emphasis of 1.0 in the present assessment. An evaluation of weights on the fishery catch-at-length likelihood components was performed with Models 2 and 3, as the sum of the fishery catch-at-length likelihood components is over 4 times that of all other likelihood components combined.

Use of Size Composition Data in Parameter Estimation

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

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

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

For the models in this analysis, the number of hauls or trips was used as the sample size instead of the adjusted sample size as calculated above. The sample sizes for the survey length composition data are the number of hauls in that survey year in which cod length frequencies were measured.

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

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

The sample sizes for the fishery catch-at-length data were capped at 400, which affected 29 out of the 324 sample sizes. The average of the sample sizes for the fishery catch-at-length data with the cap is 149.

Use of Age Composition Data in Parameter Estimation

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

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

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

The average of the sample sizes for the survey population length composition data is 80, and 81 for the survey population age composition data.

Results

Model Evaluation

The 2014 final model, without and with data from 2015, and two additional models are presented. The two new models differed in which and how the survey data were used and the number of periods for time-varying survey selectivity-at-age. The model evaluation criteria included the relative sizes of the likelihood components, and how well the model estimates fit to the survey indices, the survey age composition and conditional age-at-length data, reasonable curves for fishery and survey selectivity, the retrospective pattern, and that the model estimated the variance-covariance matrix.

The 2014 final model, without and with data from 2015, labeled “Model 0” and “Model 1”, respectively, were fit to the same catch, fishery catch-at-length, and full GOA NMFS bottom trawl survey abundance, length and age composition data, and conditional age-at-length data excepting the 2015 data. The 2015 models, labeled “Model 2” and “Model 3”, were fit to survey data from the 27-plus part of the GOA NMFS bottom trawl survey. Both sets of models estimated non-parametric survey selectivity-at-age, with the 2014 models estimating 3 periods (1984 – 1993, 1996 – 2005, and 2007 – 2015) and the 2015 models estimating 4 periods (1984 – 1987, 1990 – 1993, 1996 – 2005, and 2007 – 2015) of survey selectivity.

Comparing and Contrasting the Models

The four models estimated similar patterns for spawning biomass, although the estimates from Model 0 were lower than those from the other models (Fig. 2.8); over the recent period, Models 1 and 2 estimate flat or decreasing spawning biomass, and Models 0 and 3 estimate increasing spawning biomass. The estimates of age-0 recruits differed between the two sets of models for most of the historical period (Fig. 2.9); the differences between Models 0 and 1 were primarily in the recent estimates, as were the estimates for Models 2 and 3. All models fit the survey indices reasonably well in the middle of the time series, and had mediocre fits early and later in the time series, with Models 2 and 3 fitting slightly better to the early abundance estimates than the 2014 models due to the additional early period of survey selectivity (Fig. 2.10); none of the models were able to account well for the large increase in survey abundance between 2007 and 2009, and the significant decreases since 2009.

The two sets of models differed in their fits to their respective sets of survey data with respect to likelihood components (Table 2.13). All models had similar fits to the fishery catch-at-length data. The growth parameter estimates also differed between the two sets of models. The 2015 models, which did not include any survey data for fish less than 27 cm, estimated a higher length-at-Amin and length-at-A∞ than Models 0 and 1; A_{min} is 1.33333 for Models 0 and 1 and 3.33333 for Models 2 and 3.

The sum of the likelihood components for the fishery catch-at-length data was over 4 times that of the other likelihood components combined. Different versions of Models 2 and 3 were run with lower weights of ¾, ½, and ¼ applied to the 9 likelihood components for the fishery catch-at-length data to evaluate the impact of the weights on the model fits. These models had the additional designation of "¾ fsh", "½ fsh", or "¼ fsh". All 8 models have similar patterns for spawning biomass (Fig. 2.11), with most of the differences in the recent period, where Model 2 estimated nearly flat values and Model 3 estimated an increase then a decrease. The models with lower weights had lower values for the previously large estimate of 2011 age-0 recruits and higher values for the values from the latter 2000s (Fig. 2.12). The models with lower weights fit to the survey abundance index better than those with higher weights, with Model 3 fitting better than Model 2 (Fig. 2.13).

Evaluation Criteria

Model 3 fit the 27-plus survey data better than Model 2, and fit the fishery catch-at-length data better as well, excepting pot gear seasons 1, 2, and 3. All model configurations had reasonable fishery selectivity-at-length curves. All model configurations converged and produced variance-covariance matrices.

Selection of final model

Models 2 and 3 are preferred over the 2014 models, as the new models omit most of the more variable part of the survey data, the age-1 data. Models 2 and 3 with the weights on the fishery catch-at-length data of ¼ fit the survey data better than the models with higher weights. Model 3, the model with a new period of fishery selectivity for 2013 – 2015, fit the data better than Model 2. The preferred model is Model 3 – ¼ fsh, as this model was best able to estimate the survey abundance index from 2007 through 2015. Model 2 – ¼ fsh could be the alternate preferred model if there does not appear to be enough evidence for a change in the fishery catch-at-length data characteristics since 2013.

Final parameter estimates and associated schedules

The fixed and estimated parameters for Model 3 – ¼ fsh are listed in Table 2.14. Total biomass has decreased from a peak in 1980 to a low in 2008 and is increasing (Fig. 2.14); spawning biomass has a similar pattern with more uncertainty for the recent years (Fig. 2.15). Age-0 recruits had the highest value at the beginning of the time series and had moderate variability since then (Fig. 2.16). The estimates of the 27-plus survey abundance estimates fit the data reasonably well, and less well in for 2007 and 2009, due to the large difference and the high estimate for 2009 (Fig. 2.17). There does not appear to be a strong relationship between spawning biomass and recruitment (Fig. 2.18). The estimates of the survey population length composition data are reasonable in most years, with an overestimate of 40-cm fish in 2009 (Fig. 2.19). The fits to the survey population age composition data are reasonable (Fig. 2.20), as are the fits to the survey population length composition data (Fig. 2.21). The fits to the survey conditional age-at-length data are good, with moderate variability where there are abundant data (Fig. 2.22). The estimated length-at-age relationship is shown in Fig. 2.13.

Survey selectivity-at-age for the latter period had a peak at a lower age than the previous period (Fig. 2.24). Fishery selectivity-at-length was more variable, both within and between seasons and gear types, with the new period for 2013 – 2015 estimated to have a lower peak for all seasons and gear types with the new period (Fig. 2.25). The fits to the fishery catch-at-length data were reasonable in most years (Figs. 2.26 and 2.27).

The seasonal length-at-age and weight-at-age schedules are in Table 2.15. Survey selectivity-at-age by time period is in Table 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 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 2.17 shows the time series of GOA Pacific cod female spawning biomass for the years 1977-2015 as estimated last year and this year. The estimated spawning biomass time series are accompanied by their respective standard deviations. Total and spawning biomass are shown in Figs. 2.14 and 2.15.

Recruitment and Numbers at Age
Table 2.18 shows the time series of GOA Pacific cod age-0 recruits for the years 1977-2014 as estimated last year and this year. The estimated recruitment time series are accompanied by their respective standard deviations (Fig. 2.16). Table 2.19 shows the numbers-at-age for 1977-2015.

Survey Data
Fig. 2.17 shows the fit to the 27-plus survey abundance estimates. Fig. 2.19 shows the 1990 – 2013 survey length composition data, which were not used in model fitting, and the estimated survey length composition. Fig. 2.20 shows the fit to the survey age composition data and Fig. 2.21 shows the fit to the survey length composition data for 1984, 1987, and 2015. Figure 2.22 shows the fit to the survey conditional age-at-length data.

Fishing Mortality
Table 2.20 shows the “effective” annual fishing mortality by age and year for ages 1-19 and years 1977-2014. The “effective” annual fishing mortality is $-\ln(N_{a+1,y+1}/N_{a,y})-M$.

Retrospective analysis
Estimates of spawning biomass for Model 3 – ¼ fsh with an ending year of 2006 through 2015 are very similar for 1984 through 2000, and have a consistent downward adjustment for the recent years as more data are included (Fig. 2.28). Relative differences in estimates of spawning biomass show the same pattern for the more recent years (Fig. 2.29). The fits to the survey abundance index were similar for all years, with more difference for the recent estimates for 2015 and the earlier years (Fig. 2.30).

Harvest Recommendations

Amendment 56 Reference Points

Amendment 56 to the GOA Groundfish Fishery Management Plan (FMP) defines the "overfishing level" (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater. Because reliable estimates of reference points related to maximum sustainable yield (MSY) are currently not available but reliable estimates of reference points related to spawning per recruit are available, Pacific cod in the GOA have generally been managed under Tier 3 of Amendment 56. Tier 3 uses the following reference points: $B_{40\%}$, equal to 40% of the equilibrium spawning biomass that would be obtained in the absence of fishing; $F_{35\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 35% of the level that would be obtained in the absence of fishing; and $F_{40\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 40% of the level that would be obtained in the absence of fishing. The following formulae apply under Tier 3:

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

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

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

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

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

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

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

$F_{OFL} = 0$

$F_{ABC} = 0$

Other useful biomass reference points which can be calculated using this assumption are $B_{100\%}$ and $B_{35\%}$, defined analogously to $B_{40\%}$. These reference points are estimated as follows, based on this year's model, Model 3 – ¼ fsh:

Reference point:	$B_{35\%}$	$B_{40\%}$	$B_{100\%}$
Spawning biomass:	113,800 t	130,000 t	325,200 t

For a stock exploited by multiple gear types, estimation of $F_{35\%}$ and $F_{40\%}$ requires an assumption regarding the apportionment of fishing mortality among those gear types. For this assessment, the apportionment was based on this year's model's estimates of fishing mortality by gear for the five most recent complete years of data (2010-2014). 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 20.5%, longline 22.4%, and pot 57.1%. This apportionment results in estimates of $F_{35\%}$ and $F_{40\%}$ equal to 0.495 and 0.407, respectively.

Specification of OFL and Maximum Permissible ABC

Spawning biomass for 2016 is estimated by this year's model to be 165,600 t. This is above the $B_{40\%}$ value of 130,000 t, thereby placing Pacific cod in sub-tier "a" of Tier 3. Given this, the model estimates OFL, maximum permissible ABC, and the associated fishing mortality rates for 2016 and 2017 as follows (2017 values are predicated on the assumption that 2016 catch will equal 2016 maximum permissible ABC):

Units	Year	Overfishing Level (OFL)	Maximum Permissible ABC
Harvest amount	2016	116,700 t	98,600 t
Harvest amount	2017	100,800 t	85,200 t
Fishing mortality rate	2016	0.495	0.407
Fishing mortality rate	2017	0.495	0.407

The age 0+ biomass projections for 2016 and 2017 from this year's model are 518,800 t and 472,800 t, respectively.

ABC Recommendation

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

Following this practice, this year's ABC recommendations for 2016 and 2017 are at their respective maximum permissible levels of 98,600 t and 85,200 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 based on the 2009-2013 surveys were 33% Western, 64% Central, and 3% Eastern. In the 2013 assessment, the random effects model was used for the 2014 ABC apportionment. Using this method with the trawl survey biomass estimates through 2015, the area-apportioned ABCs are:

	Western	Central	Eastern	Total
Random effects area apportionment (percent)	41.08	50.01	8.91	100.00
2016 ABC	40,503	49,312	8,785	98,600
2017 ABC	34,998	42,610	7,592	85,200

Standard Harvest and Recruitment Scenarios and Projection Methodology

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with a vector of 2015 estimated numbers at age. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TACs for 2016 and 2017, 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 2016 recommended in the assessment to the *max* F_{ABC} for 2016. (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 2010-2014 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 2015, or 2) above 1/2 of its MSY level in 2015 and expected to be above its MSY level in 2025 under this scenario, then the stock is not overfished.)

Scenario 7: In 2016 and 2017, 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 2028 under this scenario, then the stock is not approaching an overfished condition.)

Projections and Status Determination

Projections corresponding to the standard scenarios are shown for this year's model in Table 2.21 (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 2016, it does not provide the best estimate of OFL for 2017, because the mean 2017 catch under Scenario 6 is predicated on the 2016 catch being equal to the 2016 OFL, whereas the actual 2016 catch will likely be less than the 2016 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 (2014) is 84,840 t. This is less than the 2014 OFL of 140,300 t. Therefore, the stock is not being subjected to overfishing.

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

Is the stock currently overfished? This depends on the stock's estimated spawning biomass in 2015:

a. If spawning biomass for 2015 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.

b. If spawning biomass for 2015 is estimated to be above $B_{35\%}$ the stock is above its MSST.

c. If spawning biomass for 2015 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 2.21). 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 2.21):

a. If the mean spawning biomass for 2018 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2018 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2018 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2028. If the mean spawning biomass for 2028 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 2.21, 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 – 2015 are listed in Table 2.22.

Ecosystem Considerations

Ecosystem Effects on the Stock

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

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

Fishery Effects on the Ecosystem

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

Incidental Catch of Nontarget Species

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

Steller Sea Lions

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

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

Seabirds

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

Fishery Usage of Habitat

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

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

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

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

Data Gaps and Research Priorities

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

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Tables

Table 2.1. Catch (t) for 1991 through 2015 by jurisdiction and gear type (as of 2015-10-19)

	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	18,884	9,525	12,765	161.42	41,335	62	7,943	3,242	11,247	52,582
2004	17,513	10,326	14,966	400.11	43,205	51	10,602	2,765	13,419	56,624
2005	14,549	5,732	14,749	203.39	35,233	26	9,653	2,673	12,351	47,584
2006	13,132	10,244	14,540	117.99	38,034	55	9,146	662	9,863	47,897
2007	14,775	11,539	13,573	44.30	39,932	270	11,378	682	12,329	52,261
2008	20,293	12,106	11,229	62.67	43,691	317	13,438	1,568	15,323	59,014
2009	13,976	13,968	11,951	205.69	40,101	676	9,919	2,500	13,096	53,196
2010	21,755	16,537	20,114	428.99	58,836	826	14,604	4,045	19,475	78,310
2011	16,449	16,547	29,231	721.78	62,949	995	16,675	4,627	22,297	85,246
2012	20,181	14,466	21,237	722.23	56,607	862	15,939	4,613	21,414	78,021
2013	21,700	12,869	17,008	475.57	52,053	1,087	14,154	1,303	16,544	68,597
2014	26,801	14,747	19,956	1,047.50	62,552	1,006	18,445	2,837	22,288	84,840
2015	21,252	10,197	15,990	407.52	47,846	207	19,714	2,778	22,699	70,545

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 2015 is current through 2015-10-19. The values in the column labeled "TAC" correspond to "optimum yield" for the years 1980-1986, "target quota" for the year 1987, and true TAC for the years 1988-present. The ABC value listed for 1987 is the upper bound of the range. Source: NPFMC staff.

Year	Catch	TAC	ABC	OFL
1980	35,345	60,000	-	-
1981	36,131	70,000	-	-
1982	29,465	60,000	-	-
1983	36,540	60,000	-	-
1984	23,898	60,000	-	-
1985	14,428	60,000		-
1986	25,012	75,000	136,000	-
1987	32,939	50,000	125,000	-
1988	33,802	80,000	99,000	-
1989	43,293	71,200	71,200	-
1990	72,517	90,000	90,000	-
1991	76,328	77,900	77,900	-
1992	80,747	63,500	63,500	87,600
1993	56,488	56,700	56,700	78,100
1994	47,485	50,400	50,400	71,100
1995	68,985	69,200	69,200	126,000
1996	68,280	65,000	65,000	88,000
1997	77,018	69,115	81,500	180,000
1998	72,525	66,060	77,900	141,000
1999	81,785	67,835	84,400	134,000
2000	66,560	59,800	76,400	102,000
2001	51,542	52,110	67,800	91,200
2002	54,483	44,230	57,600	77,100
2003	52,582	40,540	52,800	70,100
2004	56,624	48,033	62,810	102,000
2005	47,584	44,433	58,100	86,200
2006	47,897	52,264	68,859	95,500
2007	52,261	52,264	68,859	97,600
2008	59,014	50,269	64,493	88,660
2009	53,196	41,807	55,300	66,000
2010	78,310	59,563	79,100	94,100
2011	85,246	65,100	86,800	102,600
2012	78,021	65,700	87,600	104,000
2013	68,597	60,600	88,500	107,300
2014	84,840	75,202	102,850	140,300
2015	70,545	-		

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

Year(s)	Western	Central	Eastern
1977-1985	28	56	16
1986	40	44	16
1987	27	56	17
1988-1989	19	73	8
1990	33	66	1
1991	33	62	5
1992	37	61	2
1993-1994	33	62	5
1995-1996	29	66	5
1997-1999	35	63	2
2000-2001	36	57	7
2002	39	55	6
2002	38	56	6
2003	39	55	6
2003	38	56	6
2004	36	57	7
2004	35.3	56.5	8.2
2005	36	57	7
2005	35.3	56.5	8.2
2006	39	55	6
2006	38.54	54.35	7.11
2007	39	55	6
2007	38.54	54.35	7.11
2008	39	57	4
2008	38.69	56.55	4.76
2009	39	57	4
2009	38.69	56.55	4.76
2010	35	62	3
2010	34.86	61.75	3.39
2011	35	62	3
2011	35	62	3
2012	35	62	3
2012	32	65	3
2013	38	60	3
2014	37	60	3
2015	38	60	3

Table 2.4 Estimated retained-and discarded GOA Pacific cod from federal waters (source: AKFIN; as of 2015-09-29)

Year	Discarded	Retained	Grand Total
1991	1,429	74,899	76,328
1992	3,873	76,199	80,073
1993	5,844	49,865	55,709
1994	3,109	43,540	46,649
1995	3,525	64,560	68,085
1996	7,534	60,530	68,064
1997	4,783	63,057	67,840
1998	1,709	59,811	61,520
1999	1,617	66,311	67,928
2000	1,362	52,904	54,266
2001	1,904	39,715	41,619
2002	3,715	38,631	42,345
2003	2,483	50,096	52,579
2004	1,269	55,355	56,625
2005	1,044	46,541	47,585
2006	1,840	46,014	47,854
2007	1,441	49,988	51,428
2008	3,308	55,720	59,027
2009	3,944	49,252	53,196
2010	2,870	75,440	78,310
2011	2,076	83,169	85,246
2012	973	77,048	78,021
2013	4,629	63,968	68,597
2014	5,224	79,616	84,840
2015	1,581	65,838	67,418

Table 2.5 – Groundfish bycatch, discarded and retained, for 2011 – 2015 for GOA Pacific cod as target species (AKFIN; as of 2015-10-19)

	2011		2012		2013		2014		2015	
	D	R	D	R	D	R	D	R	D	R
Arrowtooth Flounder	310.4	268.8	332.7	498.9	877.1	575.9	823.2	499.3	372.9	548.2
Atka Mackerel	16.6	0.2	12.4	1.9	21.4	0.1	7.4	0.3	134.6	0.2
Flathead Sole	19.2	149.7	52.3	157.5	249.4	178.5	119.5	180.4	95.2	225.6
GOA Deep Water Flatfish	8.5	3.8	0.2	3.1	18.4	5.6	1.0	9.1	25.1	10.2
GOA Demersal Shelf Rockfish		3.0		0.5		1.7		1.6		1.4
GOA Dusky Rockfish			23.1	9.4	17.4	6.5	2.8	39.1		
GOA Pelagic Shelf Rockfish	10.0	7.5								
GOA Rex Sole	8.6	31.6	27.8	109.9	17.5	95.1	12.0	72.7	9.0	77.1
GOA Rougheye Rockfish	0.9	5.1	0.4	4.3	0.4	5.0	1.5	5.1	0.1	8.4
GOA Shallow Water Flatfish	127.7	816.3	125.1	686.3	173.7	792.0	323.1	595.0	291.3	665.5
GOA Shortraker Rockfish	3.8	4.1	2	4	1.4	4.7	3.0	4.9	0.0	6.2
GOA Skate, Big	299.0	662.5	83.3	671.6	227.1	422.7	463.8	179.0		
GOA Skate, Longnose	144.4	230.1	9.3	317.3	114.8	320.4	68.2	223.7		
GOA Skate, Other	105.7	226.0	584.6	119.3	1,879.8	603.8	1,177.4	635.4	105.7	226.0
GOA Thornyhead Rockfish			0.3	2.7	2.6	16.2	1.0	2.6		
Halibut					1.0	36.6	10.2	41.2	31.0	40.0
Northern Rockfish	8.2	8.2	26.8	24	48.1	61.9	12.8	58.7	10.9	34.8
Octopus	482.1	379.4	135	273.1	108.8	211.7	258.0	313.3		
Other Rockfish	20.1	33.5	6.9	38.6	28.7	38.6	28.5	27.3	15.8	64.8
Other Species					192.7	218.3	1,084.6	550.7	589.1	331.2
Pacific Ocean Perch	1.3	18.5	7.5	45.8	7.0	5.3	0.4	14.4	80.1	55.0
Pollock	47.5	503.7	710.4	970.5	105.1	750.4	91.5	1,422.8	113.9	914.4
Sablefish	49.4	60.3	0.4	23.1	74.4	16.4	12.4	44.8	18.5	26.8
Sculpin	332.9	10.3	414.4	42.2	481.7	4.7	538.7	6.9	518.1	3.3
Shark	90.7	0.7	18.8	0.6	66.1	0.1	66.7	0.2		
Squid					0.1	0.8		0.0	0.2	1.2
Total	2,573.7	4,004.8	3,736.50	3,549.70	3,545.0	3,549.7	4,952.1	4,155.2	3,484.1	3,652.3

Table 2.6 - Incidental catch (t) of non-target species groups by GOA Pacific cod fisheries, 2007-2015 (as of 2015-10-19)

Species/group	2007	2008	2009	2010	2011	2012	2013	2014	2015
Benthic urochordata	0.0	0.6	3.0	0.0	0.2	0.0	0.0	0.1	1.7
Birds	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.1	0.0
Bivalves	1.2	1.7	4.2	2.7	6.2	1.7	2.0	1.5	1.3
Brittle star unidentified	0.3	0.1	0.0	0.1	2.1	0.0	0.1	0.0	0.0
Capelin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corals Bryozoans	0.2	0.0	1.7	0.0	0.7	4.0	0.1	1.0	0.7
Dark Rockfish	0.0	0.3	2.7	12.4	2.5	1.5	1.1	1.9	5.1
Eelpouts	0.0	0.1	0.0	0.1	0.0	0.3	0.2	0.1	0.1
Eulachon	0.0	0.1	0.0	0.6	0.0	0.0	0.0	0.2	0.0
Giant Grenadier	81.5	31.0	51.3	142.7	60.4	175.8	144.5	160.6	73.7
Greenlings	0.8	7.1	1.3	0.8	0.8	1.9	1.2	1.3	1.3
Grenadier	0.0	66.0	6.6	11.3	8.2	0.0	24.1	15.6	0.0
Gunnels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	3.1
Hermit crab unidentified	1.7	2.9	3.9	2.1	0.8	0.8	1.8	0.5	0.2
Invertebrate unidentified	1.6	1.3	0.1	1.6	9.1	4.5	0.4	1.9	5.1
Misc crabs	6.6	2.4	1.5	3.4	2.5	2.2	2.9	3.0	0.9
Misc crustaceans	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.5
Misc fish	539.4	210.5	99.0	89.0	134.2	224.3	91.9	128.8	81.8
Misc inverts (worms etc)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other osmerids	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pacific Sand lance	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Pandalid shrimp	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Polychaete unidentified	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scypho jellies	0.1	0.4	0.2	11.1	0.8	0.6	1.8	1.1	2.6
Sea anemone unidentified	5.1	6.0	6.6	7.2	8.8	6.0	7.7	5.9	4.4
Sea pens whips	1.0	0.0	3.3	3.9	1.4	0.8	2.5	2.8	1.7
Sea star	299.0	316.5	471.9	871.0	718.0	462.5	553.2	867.4	799.4
Snails	0.8	0.9	2.5	0.7	1.3	3.7	2.6	28.2	10.1
Sponge unidentified	0.0	1.1	1.6	0.7	0.5	0.4	0.5	0.4	0.3
Stichaeidae	0.0	0.0	1.8	0.0	0.0	0.0	0.1	0.0	0.0
Surf smelt	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
urchins dollars cucumbers	3.2	0.5	1.3	0.5	2.2	3.6	1.3	1.6	4.1

Table 2.7 Catch (t) of Pacific cod by year, gear, and season for the years 1991-2015 as configured in the stock assessment models; the values for 2015 seasons 4 and 5 (Sep – Oct and Nov – Dec) were estimated given the average fraction of catch in each month for 2010 – 2014 and the average fraction of each gear type in seasons 4 and 5 for 2010 – 2014 (as of 2015-10-02).

	Trawl				Longline				Pot			
Year	Jan-Apr	May-Aug	Sep-Dec	Total	Jan-Apr	May-Aug	Sep-Dec	Total	Jan-Apr	May-Aug	Sep-Dec	Total
1991	55,862	778	1,493	58,133	7,052	540	72	7,664	9,413	183	934	10,530
1992	51,479	1,828	1,500	54,807	12,545	966	2,243	15,754	9,698	19	470	10,187
1993	33,637	2,625	1,551	37,813	7,999	784	181	8,964	9,384	326	0	9,710
1994	29,150	1,433	877	31,460	6,431	299	52	6,782	8,714	33	496	9,243
1995	38,198	1,117	2,597	41,912	10,553	214	227	10,994	15,410	76	592	16,078
1996	40,506	4,023	1,494	46,023	9,885	215	106	10,206	12,025	27	0	12,052
1997	40,407	1,970	6,044	48,421	10,213	390	379	10,982	13,411	2,356	1,848	17,615
1998	34,372	4,014	3,200	41,586	9,307	444	264	10,015	17,652	2,137	1,136	20,925
1999	30,122	1,520	5,550	37,192	11,808	403	158	12,369	22,793	6,859	2,572	32,224
2000	21,579	3,148	750	25,477	11,401	170	107	11,678	25,768	2,938	699	29,405
2001	14,522	2,753	7,228	24,503	9,644	135	142	9,921	12,275	2,885	1,958	17,118
2002	14,466	4,069	1,309	19,844	11,410	161	3,159	14,730	13,049	2,288	4,573	19,910
2003	10,796	3,780	5,271	19,847	8,932	579	765	10,276	19,399	0	3,057	22,456
2004	9,221	2,429	6,400	18,050	8,259	268	2,046	10,573	23,334	276	4,392	28,002
2005	9,658	2,131	3,159	14,948	3,838	174	1,875	5,887	21,361	250	5,139	26,749
2006	10,028	2,081	1,332	13,441	6,156	251	3,948	10,355	21,417	261	2,381	24,059
2007	9,613	2,357	3,127	15,097	7,094	401	4,262	11,757	20,030	546	3,997	24,574
2008	11,157	4,108	6,118	21,382	9,312	642	2,618	12,572	20,394	0	4,600	24,994
2009	6,877	4,616	3,879	15,372	9,609	1,372	3,954	14,935	19,027	0	3,596	22,624
2010	11,574	4,508	7,703	23,785	11,866	885	5,201	17,952	30,915	1	5,639	36,556
2011	9,594	1,996	5,733	17,323	10,384	1,397	6,328	18,109	36,947	3	12,861	49,811
2012	17,146	2,711	2,788	22,645	12,140	594	3,348	16,081	30,070	0	9,226	39,295
2013	14,860	2,428	5,122	22,410	9,732	2,562	2,326	14,621	25,135	0	6,424	31,559
2014	16,508	7,092	5,244	28,844	10,636	1,023	4,650	16,309	29,631	127	9,942	39,700
2015	15,954	2,866	5,151	23,972	9,594	747	2,894	13,235	34,769	0	4,846	39,614

Table 2.8 – Noncommercial fishery catch (in t); total source amounts less than 1 mt were omitted (AFSC for GOA bottom trawl survey values; AKFIN for other values, as of 2015-10-19)

Source	2006	2007	2008	2009	2010	2011	2012	2013	2014
Annual Longline Survey	18.10	17.33	16.71	30.99	33.22	27.07	30.50	22.73	33.37
Bait for Crab Fishery	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.44	7.35
Golden King Crab Pot Survey	0.43	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Gulf of Alaska Bottom Trawl Survey	0.00	0.00	0.00	0.00	0.00	29.39	0.00	26.22	0.00
IPHC Annual Longline Survey	0.00	0.00	0.00	0.00	142.30	124.36	85.60	123.20	138.09
Large-Mesh Trawl Survey	0.64	1.03	0.21	0.96	11.70	17.01	20.50	18.58	13.09
Sablefish Longline Survey	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salmon EFP 13-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.65	8.32
Shumigans Acoustic Survey	0.00	0.00	0.00	0.00	1.03	0.00	0.00	0.00	0.00
Small-Mesh Trawl Survey	0.27	0.11	0.00	0.00	1.89	1.65	2.66	1.68	1.42
Sport Fishery	0.00	0.00	0.00	0.00	113.66	155.53	143.76	131.13	199.26

Table 2.9 Age compositions observed by the sub-27 and 27-plus GOA bottom trawl survey, 1987-2013. N = number of hauls.

Year	N	0	1	2	3	4	5	6	7	8	9	10	11	12+
1987	2	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	3	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	18	0.000	0.979	0.021	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	14	0.000	0.882	0.118	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	16	0.000	0.972	0.028	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2001	36	0.000	0.922	0.078	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	17	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	14	0.000	0.804	0.196	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2007	22	0.000	0.994	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2009	20	0.000	0.991	0.008	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2011	26	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
2013	35	0.000	0.920	0.080	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Year	N	0	1	2	3	4	5	6	7	8	9	10	11	12+
1987	3	0.000	0.000	0.208	0.322	0.295	0.147	0.028	0.000	0.000	0.000	0.000	0.000	0.000
1990	27	0.000	0.005	0.067	0.239	0.251	0.209	0.132	0.057	0.028	0.009	0.002	0.000	0.000
1993	60	0.000	0.005	0.079	0.215	0.270	0.225	0.138	0.041	0.021	0.004	0.001	0.000	0.000
1996	81	0.000	0.004	0.060	0.163	0.188	0.217	0.216	0.121	0.022	0.007	0.001	0.000	0.000
1999	65	0.000	0.001	0.052	0.174	0.240	0.278	0.162	0.058	0.025	0.008	0.001	0.001	0.000
2001	136	0.000	0.013	0.115	0.251	0.223	0.168	0.131	0.066	0.023	0.007	0.002	0.000	0.001
2003	117	0.000	0.001	0.032	0.188	0.275	0.285	0.132	0.052	0.027	0.004	0.001	0.001	0.001
2005	80	0.000	0.000	0.065	0.120	0.183	0.296	0.229	0.061	0.028	0.007	0.007	0.001	0.003
2007	55	0.000	0.023	0.182	0.352	0.164	0.137	0.059	0.050	0.029	0.004	0.000	0.001	0.000
2009	92	0.000	0.000	0.100	0.337	0.316	0.175	0.052	0.011	0.007	0.001	0.000	0.000	0.000
2011	133	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
2013	120	0.000	0.002	0.060	0.269	0.230	0.244	0.136	0.045	0.012	0.002	0.000	0.001	0.000

Table 2.10 – Relative size composition from the 1984 – 2015 bottom trawl surveys (in 1-cm bins from 4 to 110 cm). N = number of hauls.

Year	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007	2009	2011	2013	2015
N	48	33	29	65	87	67	151	129	84	64	98	143	134	70
4	0	0	0	0	0	0	2	0	0	0	0	0	0	3
5	0	0	0	0	0	0	0	0	15	0	1	0	12	0
6	60	0	37	52	0	0	0	2	0	0	1	0	15	2
7	580	0	110	29	0	0	0	0	0	0	0	4	0	0
8	1291	84	111	6	5	0	0	0	1	0	40	0	7	0
9	1498	174	253	0	0	0	1	0	0	0	0	0	0	0
10	841	327	115	0	0	0	0	0	0	0	3	0	3	0
11	345	174	0	0	0	1	7	0	0	5	113	1	4	0
12	53	118	2	1	4	3	13	0	2	6	417	1	44	9
13	27	10	0	14	11	2	22	1	3	11	1628	10	167	14
14	5	5	0	23	30	15	56	9	11	68	3822	8	162	30
15	0	26	0	57	53	15	60	6	44	235	3551	12	465	77
16	62	62	9	193	96	26	50	29	54	469	2012	50	633	157
17	22	132	16	325	149	40	55	23	73	671	636	67	1150	181
18	50	211	17	304	265	50	95	26	85	834	270	73	1432	168
19	92	227	48	247	301	60	111	65	112	862	200	65	1621	251
20	110	345	86	145	540	73	96	65	97	647	198	88	979	239
21	137	221	104	122	414	62	123	105	122	514	185	98	967	184
22	211	301	85	151	495	74	98	96	118	345	198	60	1002	222
23	178	285	139	161	565	62	146	81	74	249	212	81	513	196
24	406	342	117	210	532	42	173	52	78	208	129	106	605	211
25	373	219	78	193	346	36	159	69	48	170	105	96	419	172
26	589	90	31	127	237	38	171	58	56	197	68	41	415	139
27	635	175	72	138	142	33	117	55	58	199	88	65	381	112
28	871	232	30	121	109	29	135	40	37	146	114	58	378	82
29	1173	397	23	99	50	27	108	41	17	157	196	52	281	67
30	893	804	37	112	11	48	115	33	40	155	242	61	212	102
31	939	1138	83	164	41	45	101	43	44	115	301	102	190	82
32	1088	1374	72	213	62	77	76	57	80	138	297	281	166	177
33	1256	1423	103	251	90	110	100	77	83	146	414	231	124	178
34	1080	2314	125	265	80	133	83	108	111	159	514	412	173	349
35	1447	3246	146	317	71	129	104	142	109	191	776	690	227	640
36	1037	3141	113	288	110	139	127	171	141	240	854	710	179	636
37	1111	3363	135	314	142	143	156	171	114	290	1028	818	334	983
38	1385	3721	214	357	142	139	204	264	134	345	859	543	258	1080
39	1337	3727	220	407	180	156	264	302	97	363	965	834	362	1092
40	2369	3951	222	481	185	141	190	379	102	460	924	609	475	1007
41	2544	3605	252	609	210	184	261	335	128	451	857	1159	551	861
42	2140	2537	333	729	215	201	238	442	127	519	836	1271	738	785
43	2608	2403	228	736	183	254	226	498	121	554	868	1596	736	742
44	2484	2823	359	919	175	241	221	603	102	431	871	1517	897	842
45	2669	1544	360	808	197	256	243	576	124	442	886	1667	1236	999
46	3000	1689	373	762	173	267	200	529	138	413	898	1445	1068	1235
47	2829	1867	522	881	177	249	221	483	118	287	822	1294	931	1347
48	3100	2742	709	623	155	290	229	537	157	358	989	1172	1146	1494
49	3969	2810	795	663	214	247	284	499	144	298	919	1138	1091	1650
50	4542	3392	635	807	229	294	204	536	189	308	999	1062	1091	1656
51	5232	4302	587	764	208	222	271	464	186	231	1175	913	823	1652
52	4443	4302	594	831	288	273	223	560	259	230	1253	838	800	1596
53	4353	4393	554	1096	306	274	206	544	295	180	1205	970	763	1289
54	4432	4099	669	1249	267	300	277	602	440	238	1526	1095	859	1232
55	4366	4377	520	1293	350	309	231	689	396	254	1267	1107	1135	1113
56	3476	3786	811	1090	310	308	230	578	497	230	1758	1034	1069	844
57	3845	3232	626	1172	360	373	215	671	491	312	1405	1092	1186	736
58	3508	3643	627	1231	381	375	240	644	569	327	1607	972	1427	599
59	2985	3206	650	971	323	363	225	748	507	330	1448	950	1365	557
60	2868	3323	626	1046	398	330	236	618	573	287	1332	808	1427	448
61	2373	2639	694	899	457	329	228	614	402	305	1048	742	1478	423
62	1705	2560	501	737	472	293	208	555	403	278	972	753	1300	307
63	2140	2423	451	652	395	248	295	484	341	286	891	639	1083	282
64	1404	2650	463	604	351	241	232	412	310	251	981	642	981	253
65	1343	2128	441	592	453	231	244	329	192	203	569	423	897	284

Table 2.10 – Relative size composition from the 1984 – 2015 bottom trawl surveys (in 1-cm bins from 4 to 110 cm). N = number of hauls.

Year	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007	2009	2011	2013	2015
N	48	33	29	65	87	67	151	129	84	64	98	143	134	70
66	1053	1700	385	673	399	206	169	370	192	223	650	383	772	231
67	889	1703	290	579	337	179	179	274	138	192	553	327	719	209
68	845	1285	235	516	270	165	141	248	150	146	385	270	510	141
69	838	1230	214	401	279	164	106	211	111	158	294	175	487	139
70	520	878	277	358	243	135	150	196	100	139	314	161	353	92
71	347	870	191	254	165	102	95	151	82	100	234	132	262	108
72	469	784	196	279	116	103	97	170	64	105	180	134	227	106
73	510	525	147	229	96	87	55	140	54	74	171	80	186	115
74	267	635	126	179	135	68	78	104	46	74	104	41	116	105
75	402	452	82	119	61	45	57	95	43	90	157	51	84	67
76	419	406	81	133	67	44	57	67	52	37	107	50	52	39
77	378	210	68	109	48	43	48	74	31	54	87	31	53	38
78	195	328	59	104	52	40	27	73	26	31	54	26	29	36
79	528	292	58	85	53	27	21	80	14	15	43	19	34	33
80	601	159	52	52	26	13	32	62	28	20	37	39	39	24
81	261	127	47	51	27	13	19	56	19	18	27	13	13	43
82	294	85	46	47	24	23	8	52	15	7	44	10	12	8
83	157	137	37	25	16	15	6	29	18	13	14	6	15	30
84	187	88	48	29	14	6	15	32	36	6	12	15	16	8
85	171	143	24	28	12	14	3	25	17	4	12	3	18	11
86	127	78	22	22	15	4	8	19	6	1	9	7	3	2
87	141	41	16	18	9	4	7	15	17	8	9	6	5	7
88	107	39	22	15	7	3	5	8	18	2	4	5	5	14
89	72	52	33	27	7	10	6	6	14	5	4	4	5	2
90	89	11	18	7	9	1	2	8	41	3	2	3	1	17
91	41	12	16	8	14	3	3	12	27	1	0	3	4	1
92	56	24	6	8	8	0	3	8	28	2	5	1	2	7
93	18	14	5	12	6	5	12	2	30	5	2	0	1	2
94	12	23	12	8	1	0	3	0	16	2	57	0	0	3
95	42	14	3	10	8	1	3	3	35	6	3	1	0	3
96	9	27	8	7	3	0	3	1	31	1	2	4	0	0
97	9	3	5	5	5	2	2	1	31	2	1	0	5	2
98	13	5	5	5	2	2	0	1	32	2	0	0	3	1
99	1	12	1	4	1	5	0	0	29	0	3	0	0	0
100	3	5	1	8	4	3	4	0	16	1	1	0	3	0
101	5	9	5	6	1	0	3	0	21	1	1	0	0	0
102	1	3	4	3	7	1	1	0	6	1	2	0	1	3
103	0	1	2	1	2	0	0	0	13	4	0	0	0	0
104	0	0	0	1	1	0	0	0	18	2	0	0	0	0
105	0	9	1	1	2	0	0	0	9	0	2	0	0	0
106	0	0	0	0	0	0	0	0	3	1	0	0	0	0
107	0	0	0	1	1	0	0	0	0	1	0	0	0	0
108	0	0	0	0	0	0	0	0	0	0	0	2	0	0
109	0	1	0	0	0	0	0	0	0	1	0	0	0	0
110+	4	1	0	0	0	0	0	0	0	1	0	0	2	0

Table 2.11 – Mean size-at-age (in cm) observed by the sub-27 and 27-plus GOA bottom trawl survey, 1987-2013

Year	0	1	2	3	4	5	6	7	8	9	10	11	12+
1987	0.000	19.589	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	22.391	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	20.044	25.542	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	0.000	21.013	25.358	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	0.000	20.491	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	20.838	24.904	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	0.000	21.134	24.960	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2005	0.000	19.550	24.272	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2007	0.000	19.378	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	15.235	24.691	25.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2011	0.000	20.888	25.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2013	0.000	19.154	25.241	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	35.302	42.797	52.594	59.181	63.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.000	27.172	35.189	45.986	53.320	60.008	65.053	70.919	77.335	83.940	87.115	95.906	102.000
1993	0.000	27.486	34.238	44.282	52.310	59.043	65.745	70.818	75.220	85.440	92.024	96.469	0.000
1996	0.000	27.000	31.652	41.745	52.448	59.423	64.509	69.099	76.365	82.946	88.278	100.000	85.000
1999	0.000	27.000	32.531	40.898	48.750	58.109	64.307	71.183	71.236	76.110	78.764	79.013	0.000
2001	0.000	27.455	32.891	42.672	52.146	58.789	65.791	70.278	75.381	83.929	85.393	85.000	79.737
2003	0.000	29.443	32.624	43.779	49.022	57.859	64.836	71.645	75.361	84.488	83.423	77.033	74.398
2005	0.000	0.000	33.305	41.236	51.228	57.485	62.366	67.687	74.311	83.762	95.245	90.000	87.000
2007	0.000	27.306	35.729	43.951	55.827	60.451	64.168	70.657	70.914	73.626	96.000	75.297	0.000
2009	0.000	27.000	33.832	44.429	55.491	61.880	66.069	73.321	72.930	80.523	87.437	0.000	0.000
2011	0.000	27.000	35.648	44.818	53.954	62.005	65.850	75.559	80.946	0.000	0.000	0.000	108.000
2013	0.000	27.498	30.884	44.791	52.688	60.459	63.678	67.224	70.765	77.382	0.000	72.000	0.000

Table 2.12 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	0.096	320,525	0.102	275,167	0.114	19,526	0.596
1987	394,987	0.085	247,020	0.121	197,022	0.152	5,127	0.239
1990	416,788	0.100	212,132	0.135	180,108	0.158	14,049	0.261
1993	409,848	0.117	231,963	0.124	204,101	0.137	16,928	0.237
1996	538,154	0.131	319,068	0.140	233,959	0.113	84,382	0.373
1999	306,413	0.083	166,584	0.074	156,185	0.077	9,548	0.176
2001	257,614	0.133	158,424	0.118	136,970	0.133	21,354	0.175
2003	297,402	0.098	159,749	0.085	154,181	0.088	5,799	0.150
2005	308,175	0.170	139,895	0.135	127,324	0.144	12,571	0.247
2007	232,035	0.091	192,306	0.114	134,035	0.107	58,118	0.267
2009	752,651	0.195	573,469	0.185	422,330	0.153	151,139	0.494
2011	500,975	0.089	348,060	0.116	339,385	0.117	8,650	0.222
2013	506,362	0.097	337,992	0.099	257,315	0.091	80,677	0.288
2015	253,694	0.069	196,334	0.079	183,071	0.083	13,131	0.216

Table 2.13. Number of parameters, negative log-likelihoods, and growth parameters for all model configurations (smaller indicates better fit to data).

	Model 0	Model 1	Model 2	Model 2 – ¼ fsh	Model 3	Model 3 – ¼ fsh
Number of parameters	229	229	244	244	269	269
Length compositions	2213.67	2146.87	2037.96	558.10	2017.88	540.97
Age compositions	440.65	477.60	486.35	441.05	471.59	433.80
Recruitment	-17.84	-7.76	-17.35	-30.87	-20.17	-31.06
Forecast recruitment	3.62	1.03	0.90	0.55	1.00	0.51
27-plus survey indices			11.66	-7.81	-9.86	-17.91
Full survey indices	-14.69	25.48				
Total	2625.49	2643.31	2519.60	961.12	2460.52	926.41
Length composition likelihoods (-ln)						
Jan-Apr Trawl	298.71	299.47	283.85	72.82	283.16	71.79
May-Aug Trawl	141.51	135.79	133.19	37.98	128.50	34.82
Sep-Dec Trawl	220.77	220.29	211.48	55.45	207.07	53.36
Jan-Apr LL	440.17	450.54	429.69	117.95	424.09	117.27
May-Aug LL	133.98	148.80	157.83	42.20	153.16	39.63
Sep-Dec LL	334.87	368.49	330.13	91.56	328.39	86.08
Jan-Apr Pot	271.23	283.37	262.62	71.65	265.28	70.10
May-Aug Pot	45.47	45.67	46.36	11.92	46.49	12.05
Sep-Dec Pot	168.65	174.96	172.83	45.74	171.80	44.48
27-plus survey			9.99	10.85	9.99	11.39
Full survey	158.32	19.50				
Age compositions likelihoods (-ln)						
27-plus survey			486.35	441.05	471.59	433.80
Full survey	440.65	477.60				
Growth parameters						
Length-at-Amin	23.31	26.23	42.41	43.97	42.74	44.24
Length-at-A∞	94.70	93.77	93.67	97.77	93.40	98.22
k	0.200	0.189	0.199	0.174	0.204	0.172
CV for L-at-Amin	4.57	3.49	4.43	4.57	4.52	4.59
CV for L-at-A∞	6.66	7.33	7.34	6.21	7.38	6.12
$\ln(R_0)$	12.57	12.62	12.72	12.81	12.76	12.81

Table 2.14 – Parameter values, estimates, and standard deviations from Model 3 – ¼ fsh

Label	Value	StdDev	Label	Value	StdDev
NatM_p_1_Fem_GP_1	0.380	_	SizeSel_2P_1_May-Aug_Trawl_Fishery_BLK2repl_1990	66.880	2.212
L_at_Amin_Fem_GP_1	44.240	0.360	SizeSel_2P_1_May-Aug_Trawl_Fishery_BLK2repl_2000	68.280	4.628
L_at_Amax_Fem_GP_1	98.220	1.754	SizeSel_2P_1_May-Aug_Trawl_Fishery_BLK2repl_2005	70.000	3.762
VonBert_K_Fem_GP_1	0.172	0.010	SizeSel_2P_1_May-Aug_Trawl_Fishery_BLK2repl_2013	41.990	4.678
CV_young_Fem_GP_1	4.594	0.154	SizeSel_2P_3_May-Aug_Trawl_Fishery_BLK2repl_1977	4.687	0.454
CV_old_Fem_GP_1	6.121	0.447	SizeSel_2P_3_May-Aug_Trawl_Fishery_BLK2repl_1985	5.265	0.326
Wtlen_1_Fem	0.000	_	SizeSel_2P_3_May-Aug_Trawl_Fishery_BLK2repl_1990	5.159	0.241
Wtlen_2_Fem	3.072	_	SizeSel_2P_3_May-Aug_Trawl_Fishery_BLK2repl_2000	5.874	0.387
Mat50%_Fem	4.350	_	SizeSel_2P_3_May-Aug_Trawl_Fishery_BLK2repl_2005	5.847	0.288
Mat_slope_Fem	-1.963	_	SizeSel_2P_3_May-Aug_Trawl_Fishery_BLK2repl_2013	4.117	0.938
Eggs/kg_inter_Fem	1	_	SizeSel_2P_6_May-Aug_Trawl_Fishery_BLK2repl_1977	0.169	0.791
Eggs/kg_slope_wt_Fem	0	_	SizeSel_2P_6_May-Aug_Trawl_Fishery_BLK2repl_1985	-1.023	0.717
RecrDist_GP_1	0	_	SizeSel_2P_6_May-Aug_Trawl_Fishery_BLK2repl_1990	-2.423	1.317
RecrDist_Area_1	0	_	SizeSel_2P_6_May-Aug_Trawl_Fishery_BLK2repl_2000	-0.955	1.730
RecrDist_Seas_1	0	_	SizeSel_2P_6_May-Aug_Trawl_Fishery_BLK2repl_2005	-1.793	2.137
RecrDist_Seas_2	0	_	SizeSel_2P_6_May-Aug_Trawl_Fishery_BLK2repl_2013	3.338	13.908
RecrDist_Seas_3	0	_	SizeSel_3P_1_Sep-Dec_Trawl_Fishery_BLK3repl_1977	47.247	10.945
RecrDist_Seas_4	0	_	SizeSel_3P_1_Sep-Dec_Trawl_Fishery_BLK3repl_1980	56.612	3.700
RecrDist_Seas_5	0	_	SizeSel_3P_1_Sep-Dec_Trawl_Fishery_BLK3repl_1985	59.784	3.407
CohortGrowDev	1	_	SizeSel_3P_1_Sep-Dec_Trawl_Fishery_BLK3repl_1990	64.819	6.138
AgeKeyParm1	1	_	SizeSel_3P_1_Sep-Dec_Trawl_Fishery_BLK3repl_1995	71.942	3.002
AgeKeyParm2	0.120	0.057	SizeSel_3P_1_Sep-Dec_Trawl_Fishery_BLK3repl_2000	69.884	3.400
AgeKeyParm3	9.50E-09	_	SizeSel_3P_1_Sep-Dec_Trawl_Fishery_BLK3repl_2005	69.459	2.672
AgeKeyParm4	0	_	SizeSel_3P_1_Sep-Dec_Trawl_Fishery_BLK3repl_2013	47.653	10.395
AgeKeyParm5	0.096	_	SizeSel_3P_2_Sep-Dec_Trawl_Fishery_BLK3repl_1977	-2.781	6.201
AgeKeyParm6	1.471	_	SizeSel_3P_2_Sep-Dec_Trawl_Fishery_BLK3repl_1980	-6.000	_
AgeKeyParm7	0	_	SizeSel_3P_2_Sep-Dec_Trawl_Fishery_BLK3repl_1985	-7.000	_
F-WL1_seas_1	-0.0043	_	SizeSel_3P_2_Sep-Dec_Trawl_Fishery_BLK3repl_1990	-0.411	0.656
F-WL1_seas_2	-0.0978	_	SizeSel_3P_2_Sep-Dec_Trawl_Fishery_BLK3repl_1995	-7.000	_
F-WL1_seas_3	0.2608	_	SizeSel_3P_2_Sep-Dec_Trawl_Fishery_BLK3repl_2000	-7.000	_
F-WL1_seas_4	0.7063	_	SizeSel_3P_2_Sep-Dec_Trawl_Fishery_BLK3repl_2005	-7.000	_
F-WL1_seas_5	-0.2054	_	SizeSel_3P_2_Sep-Dec_Trawl_Fishery_BLK3repl_2013	-0.658	0.959
F-WL2_seas_1	0.0041	_	SizeSel_3P_3_Sep-Dec_Trawl_Fishery_BLK3repl_1977	4.179	1.809
F-WL2_seas_2	0.0053	_	SizeSel_3P_3_Sep-Dec_Trawl_Fishery_BLK3repl_1980	5.217	0.490
F-WL2_seas_3	-0.0268	_	SizeSel_3P_3_Sep-Dec_Trawl_Fishery_BLK3repl_1985	5.626	0.392
F-WL2_seas_4	-0.0600	_	SizeSel_3P_3_Sep-Dec_Trawl_Fishery_BLK3repl_1990	5.645	0.461
F-WL2_seas_5	0.0156	_	SizeSel_3P_3_Sep-Dec_Trawl_Fishery_BLK3repl_1995	6.225	0.202
SR_LN(R0)	12.808	0.047	SizeSel_3P_3_Sep-Dec_Trawl_Fishery_BLK3repl_2000	5.949	0.275

SR_BH_steep	1	_
SR_sigmaR	0.41	_
SR_envlink	0	_
SR_R1_offset	0.160	0.163
SR_autocorr	0.000	_
Early_InitAge_15	-0.050	0.400
Early_InitAge_14	-0.067	0.397
Early_InitAge_13	-0.089	0.393
Early_InitAge_12	-0.111	0.389
Early_InitAge_11	-0.129	0.386
Early_InitAge_10	-0.136	0.384
Early_InitAge_9	-0.118	0.384
Early_InitAge_8	-0.062	0.388
Early_InitAge_7	0.040	0.395
Early_InitAge_6	0.213	0.423
Early_InitAge_5	0.787	0.370
Early_InitAge_4	0.596	0.320
Early_InitAge_3	-0.087	0.291
Early_InitAge_2	-0.374	0.267
Early_InitAge_1	0.477	0.220
Early_RecrDev_1977	1.106	0.161
Main_RecrDev_1978	-0.371	0.244
Main_RecrDev_1979	0.059	0.157
Main_RecrDev_1980	0.098	0.146
Main_RecrDev_1981	0.055	0.171
Main_RecrDev_1982	0.071	0.190
Main_RecrDev_1983	-0.199	0.241
Main_RecrDev_1984	0.298	0.202
Main_RecrDev_1985	0.108	0.179
Main_RecrDev_1986	-0.236	0.177
Main_RecrDev_1987	0.372	0.111
Main_RecrDev_1988	-0.076	0.143
Main_RecrDev_1989	0.467	0.118
Main_RecrDev_1990	0.275	0.124
Main_RecrDev_1991	0.046	0.128
Main_RecrDev_1992	0.075	0.127
Main_RecrDev_1993	0.097	0.115
Main_RecrDev_1994	0.121	0.111
Main_RecrDev_1995	0.110	0.105
Main_RecrDev_1996	-0.231	0.115

SizeSel_3P_3_Sep-Dec_Trawl_Fishery_BLK3repl_2005	5.818	0.204
SizeSel_3P_3_Sep-Dec_Trawl_Fishery_BLK3repl_2013	5.115	1.269
SizeSel_4P_1_Jan-Apr_Longline_Fishery_BLK4repl_1977	55.326	2.687
SizeSel_4P_1_Jan-Apr_Longline_Fishery_BLK4repl_1985	69.579	4.873
SizeSel_4P_1_Jan-Apr_Longline_Fishery_BLK4repl_1990	70.856	1.913
SizeSel_4P_1_Jan-Apr_Longline_Fishery_BLK4repl_1995	73.056	1.584
SizeSel_4P_1_Jan-Apr_Longline_Fishery_BLK4repl_2000	68.602	2.075
SizeSel_4P_1_Jan-Apr_Longline_Fishery_BLK4repl_2005	68.396	1.036
SizeSel_4P_1_Jan-Apr_Longline_Fishery_BLK4repl_2013	67.573	1.715
SizeSel_4P_2_Jan-Apr_Longline_Fishery_BLK4repl_1977	-0.276	0.284
SizeSel_4P_2_Jan-Apr_Longline_Fishery_BLK4repl_1985	-1.372	1.532
SizeSel_4P_2_Jan-Apr_Longline_Fishery_BLK4repl_1990	-7.000	_
SizeSel_4P_2_Jan-Apr_Longline_Fishery_BLK4repl_1995	-7.000	_
SizeSel_4P_2_Jan-Apr_Longline_Fishery_BLK4repl_2000	-3.849	5.663
SizeSel_4P_2_Jan-Apr_Longline_Fishery_BLK4repl_2005	-7.000	_
SizeSel_4P_2_Jan-Apr_Longline_Fishery_BLK4repl_2013	-7.000	_
SizeSel_4P_3_Jan-Apr_Longline_Fishery_BLK4repl_1977	4.556	0.364
SizeSel_4P_3_Jan-Apr_Longline_Fishery_BLK4repl_1985	5.691	0.325
SizeSel_4P_3_Jan-Apr_Longline_Fishery_BLK4repl_1990	5.365	0.156
SizeSel_4P_3_Jan-Apr_Longline_Fishery_BLK4repl_1995	5.435	0.130
SizeSel_4P_3_Jan-Apr_Longline_Fishery_BLK4repl_2000	5.110	0.193
SizeSel_4P_3_Jan-Apr_Longline_Fishery_BLK4repl_2005	5.053	0.106
SizeSel_4P_3_Jan-Apr_Longline_Fishery_BLK4repl_2013	5.354	0.168
SizeSel_4P_6_Jan-Apr_Longline_Fishery_BLK4repl_1977	-0.469	0.777
SizeSel_4P_6_Jan-Apr_Longline_Fishery_BLK4repl_1985	1.404	1.447
SizeSel_4P_6_Jan-Apr_Longline_Fishery_BLK4repl_1990	1.625	1.194
SizeSel_4P_6_Jan-Apr_Longline_Fishery_BLK4repl_1995	0.763	0.733
SizeSel_4P_6_Jan-Apr_Longline_Fishery_BLK4repl_2000	-0.482	0.496
SizeSel_4P_6_Jan-Apr_Longline_Fishery_BLK4repl_2005	-0.664	0.377
SizeSel_4P_6_Jan-Apr_Longline_Fishery_BLK4repl_2013	-0.322	0.631
SizeSel_5P_1_May-Aug_Longline_Fishery_BLK5repl_1977	57.310	4.191
SizeSel_5P_1_May-Aug_Longline_Fishery_BLK5repl_1980	56.308	1.564
SizeSel_5P_1_May-Aug_Longline_Fishery_BLK5repl_1990	69.332	3.741
SizeSel_5P_1_May-Aug_Longline_Fishery_BLK5repl_2000	70.752	2.913
SizeSel_5P_1_May-Aug_Longline_Fishery_BLK5repl_2013	65.084	4.295
SizeSel_5P_3_May-Aug_Longline_Fishery_BLK5repl_1977	4.707	0.559
SizeSel_5P_3_May-Aug_Longline_Fishery_BLK5repl_1980	4.409	0.261
SizeSel_5P_3_May-Aug_Longline_Fishery_BLK5repl_1990	4.942	0.465
SizeSel_5P_3_May-Aug_Longline_Fishery_BLK5repl_2000	5.054	0.305
SizeSel_5P_3_May-Aug_Longline_Fishery_BLK5repl_2013	5.268	0.499

Main_RecrDev_1997	-0.275	0.117
Main_RecrDev_1998	-0.111	0.103
Main_RecrDev_1999	0.070	0.104
Main_RecrDev_2000	-0.034	0.107
Main_RecrDev_2001	-0.480	0.135
Main_RecrDev_2002	-0.514	0.129
Main_RecrDev_2003	-0.433	0.122
Main_RecrDev_2004	-0.391	0.114
Main_RecrDev_2005	0.253	0.100
Main_RecrDev_2006	0.276	0.100
Main_RecrDev_2007	0.458	0.108
Main_RecrDev_2008	0.391	0.101
Main_RecrDev_2009	-0.048	0.121
Main_RecrDev_2010	-0.372	0.129
Main_RecrDev_2011	0.126	0.147
Main_RecrDev_2012	-0.056	0.166
Late_RecrDev_2013	-0.394	0.310
Late_RecrDev_2014	-0.125	0.389
Late_RecrDev_2015	0.000	0.410
InitF_1Jan-Apr_Trawl_Fishery	0.033	0.006
InitF_2May-Aug_Trawl_Fishery	0	_
InitF_3Sep-Dec_Trawl_Fishery	0	_
InitF_4Jan-Apr_Longline_Fishery	0	_
InitF_5May-Aug_Longline_Fishery	0	_
InitF_6Sep-Dec_Longline_Fishery	0	_
InitF_7Jan-Apr_Pot_Fishery	0	_
InitF_8May-Aug_Pot_Fishery	0	_
InitF_9Sep-Dec_Pot_Fishery	0	_
Q_envlink_10_Trawl_Survey	0.156	0.189
LnQ_base_10_Trawl_Survey	0	_
SizeSel_1P_1_Jan-Apr_Trawl_Fishery	0	_
SizeSel_1P_2_Jan-Apr_Trawl_Fishery	0	_
SizeSel_1P_3_Jan-Apr_Trawl_Fishery	0	_
SizeSel_1P_4_Jan-Apr_Trawl_Fishery	0	_
SizeSel_1P_5_Jan-Apr_Trawl_Fishery	-10	_
SizeSel_1P_6_Jan-Apr_Trawl_Fishery	10	_
SizeSel_2P_1_May-Aug_Trawl_Fishery	0	_
SizeSel_2P_2_May-Aug_Trawl_Fishery	-7	_
SizeSel_2P_3_May-Aug_Trawl_Fishery	0	_
SizeSel_2P_4_May-Aug_Trawl_Fishery	4.389	0.837

SizeSel_5P_6_May-Aug_Longline_Fishery_BLK5repl_1977	-0.209	1.121
SizeSel_5P_6_May-Aug_Longline_Fishery_BLK5repl_1980	-0.716	0.524
SizeSel_5P_6_May-Aug_Longline_Fishery_BLK5repl_1990	-1.948	2.686
SizeSel_5P_6_May-Aug_Longline_Fishery_BLK5repl_2000	0.151	1.463
SizeSel_5P_6_May-Aug_Longline_Fishery_BLK5repl_2013	-2.292	3.523
SizeSel_6P_1_Sep-Dec_Longline_Fishery_BLK6repl_1977	58.142	3.221
SizeSel_6P_1_Sep-Dec_Longline_Fishery_BLK6repl_1980	56.434	0.953
SizeSel_6P_1_Sep-Dec_Longline_Fishery_BLK6repl_1990	67.743	1.026
SizeSel_6P_1_Sep-Dec_Longline_Fishery_BLK6repl_2013	62.426	2.249
SizeSel_6P_3_Sep-Dec_Longline_Fishery_BLK6repl_1977	4.713	0.381
SizeSel_6P_3_Sep-Dec_Longline_Fishery_BLK6repl_1980	4.381	0.160
SizeSel_6P_3_Sep-Dec_Longline_Fishery_BLK6repl_1990	4.972	0.110
SizeSel_6P_3_Sep-Dec_Longline_Fishery_BLK6repl_2013	4.982	0.270
SizeSel_6P_4_Sep-Dec_Longline_Fishery_BLK6repl_1977	9.000	_
SizeSel_6P_4_Sep-Dec_Longline_Fishery_BLK6repl_1980	4.420	0.383
SizeSel_6P_4_Sep-Dec_Longline_Fishery_BLK6repl_1990	4.028	0.601
SizeSel_6P_4_Sep-Dec_Longline_Fishery_BLK6repl_2013	4.562	0.879
SizeSel_6P_6_Sep-Dec_Longline_Fishery_BLK6repl_1977	-8.249	34.349
SizeSel_6P_6_Sep-Dec_Longline_Fishery_BLK6repl_1980	-1.362	0.280
SizeSel_6P_6_Sep-Dec_Longline_Fishery_BLK6repl_1990	-0.742	0.363
SizeSel_6P_6_Sep-Dec_Longline_Fishery_BLK6repl_2013	-1.835	1.221
SizeSel_7P_1_Jan-Apr_Pot_Fishery_BLK7repl_1977	69.040	0.968
SizeSel_7P_1_Jan-Apr_Pot_Fishery_BLK7repl_1995	71.309	0.975
SizeSel_7P_1_Jan-Apr_Pot_Fishery_BLK7repl_2000	67.552	1.187
SizeSel_7P_1_Jan-Apr_Pot_Fishery_BLK7repl_2005	67.627	0.968
SizeSel_7P_1_Jan-Apr_Pot_Fishery_BLK7repl_2013	64.285	2.000
SizeSel_7P_3_Jan-Apr_Pot_Fishery_BLK7repl_1977	4.840	0.114
SizeSel_7P_3_Jan-Apr_Pot_Fishery_BLK7repl_1995	4.967	0.104
SizeSel_7P_3_Jan-Apr_Pot_Fishery_BLK7repl_2000	4.942	0.135
SizeSel_7P_3_Jan-Apr_Pot_Fishery_BLK7repl_2005	4.799	0.111
SizeSel_7P_3_Jan-Apr_Pot_Fishery_BLK7repl_2013	4.837	0.251
SizeSel_7P_4_Jan-Apr_Pot_Fishery_BLK7repl_1977	4.472	0.435
SizeSel_7P_4_Jan-Apr_Pot_Fishery_BLK7repl_1995	4.170	0.606
SizeSel_7P_4_Jan-Apr_Pot_Fishery_BLK7repl_2000	4.350	0.597
SizeSel_7P_4_Jan-Apr_Pot_Fishery_BLK7repl_2005	4.121	0.554
SizeSel_7P_4_Jan-Apr_Pot_Fishery_BLK7repl_2013	4.183	1.059
SizeSel_7P_6_Jan-Apr_Pot_Fishery_BLK7repl_1977	-1.904	0.563
SizeSel_7P_6_Jan-Apr_Pot_Fishery_BLK7repl_1995	-0.753	0.461
SizeSel_7P_6_Jan-Apr_Pot_Fishery_BLK7repl_2000	-0.842	0.441
SizeSel_7P_6_Jan-Apr_Pot_Fishery_BLK7repl_2005	-0.434	0.350

SizeSel_2P_5_May-Aug_Trawl_Fishery	-10	_
SizeSel_2P_6_May-Aug_Trawl_Fishery	0	_
SizeSel_3P_1_Sep-Dec_Trawl_Fishery	0	_
SizeSel_3P_2_Sep-Dec_Trawl_Fishery	0	_
SizeSel_3P_3_Sep-Dec_Trawl_Fishery	0	_
SizeSel_3P_4_Sep-Dec_Trawl_Fishery	4.235	0.846
SizeSel_3P_5_Sep-Dec_Trawl_Fishery	-10	_
SizeSel_3P_6_Sep-Dec_Trawl_Fishery	-1.248	0.548
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	3.933	0.552
SizeSel_4P_5_Jan-Apr_Longline_Fishery	-10	_
SizeSel_4P_6_Jan-Apr_Longline_Fishery	0.000	_
SizeSel_5P_1_May-Aug_Longline_Fishery	0.000	_
SizeSel_5P_2_May-Aug_Longline_Fishery	-7.000	_
SizeSel_5P_3_May-Aug_Longline_Fishery	0.000	_
SizeSel_5P_4_May-Aug_Longline_Fishery	5.062	0.812
SizeSel_5P_5_May-Aug_Longline_Fishery	-10.000	_
SizeSel_5P_6_May-Aug_Longline_Fishery	0.000	_
SizeSel_6P_1_Sep-Dec_Longline_Fishery	0.000	_
SizeSel_6P_2_Sep-Dec_Longline_Fishery	-7.000	_
SizeSel_6P_3_Sep-Dec_Longline_Fishery	0.000	_
SizeSel_6P_4_Sep-Dec_Longline_Fishery	0.000	_
SizeSel_6P_5_Sep-Dec_Longline_Fishery	-10.000	_
SizeSel_6P_6_Sep-Dec_Longline_Fishery	0.000	_
SizeSel_7P_1_Jan-Apr_Pot_Fishery	0.000	_
SizeSel_7P_2_Jan-Apr_Pot_Fishery	-7.000	_
SizeSel_7P_3_Jan-Apr_Pot_Fishery	0.000	_
SizeSel_7P_4_Jan-Apr_Pot_Fishery	0.000	_
SizeSel_7P_5_Jan-Apr_Pot_Fishery	-10.000	_
SizeSel_7P_6_Jan-Apr_Pot_Fishery	0.000	_
SizeSel_8P_1_May-Aug_Pot_Fishery	0.000	_
SizeSel_8P_2_May-Aug_Pot_Fishery	-7.000	_
SizeSel_8P_3_May-Aug_Pot_Fishery	0.000	_
SizeSel_8P_4_May-Aug_Pot_Fishery	4.725	0.997
SizeSel_8P_5_May-Aug_Pot_Fishery	-10.000	_
SizeSel_8P_6_May-Aug_Pot_Fishery	-0.988	0.878
SizeSel_9P_1_Sep-Dec_Pot_Fishery	0.000	_
SizeSel_9P_2_Sep-Dec_Pot_Fishery	-7.000	_
SizeSel_7P_6_Jan-Apr_Pot_Fishery_BLK7repl_2013	-0.729	0.723
SizeSel_8P_1_May-Aug_Pot_Fishery_BLK8repl_1977	64.954	3.166
SizeSel_8P_1_May-Aug_Pot_Fishery_BLK8repl_1995	67.718	2.198
SizeSel_8P_1_May-Aug_Pot_Fishery_BLK8repl_2000	65.128	2.482
SizeSel_8P_3_May-Aug_Pot_Fishery_BLK8repl_1977	4.448	0.516
SizeSel_8P_3_May-Aug_Pot_Fishery_BLK8repl_1995	4.545	0.334
SizeSel_8P_3_May-Aug_Pot_Fishery_BLK8repl_2000	4.311	0.463
SizeSel_9P_1_Sep-Dec_Pot_Fishery_BLK9repl_1977	72.158	1.926
SizeSel_9P_1_Sep-Dec_Pot_Fishery_BLK9repl_1995	71.761	2.298
SizeSel_9P_1_Sep-Dec_Pot_Fishery_BLK9repl_2000	66.270	1.903
SizeSel_9P_1_Sep-Dec_Pot_Fishery_BLK9repl_2005	65.720	1.202
SizeSel_9P_1_Sep-Dec_Pot_Fishery_BLK9repl_2013	63.663	3.184
SizeSel_9P_3_Sep-Dec_Pot_Fishery_BLK9repl_1977	5.313	0.187
SizeSel_9P_3_Sep-Dec_Pot_Fishery_BLK9repl_1995	5.388	0.225
SizeSel_9P_3_Sep-Dec_Pot_Fishery_BLK9repl_2000	5.020	0.225
SizeSel_9P_3_Sep-Dec_Pot_Fishery_BLK9repl_2005	4.759	0.155
SizeSel_9P_3_Sep-Dec_Pot_Fishery_BLK9repl_2013	5.073	0.445
SizeSel_9P_6_Sep-Dec_Pot_Fishery_BLK9repl_1977	-1.260	0.835
SizeSel_9P_6_Sep-Dec_Pot_Fishery_BLK9repl_1995	-0.327	0.933
SizeSel_9P_6_Sep-Dec_Pot_Fishery_BLK9repl_2000	-0.572	0.629
SizeSel_9P_6_Sep-Dec_Pot_Fishery_BLK9repl_2005	-0.847	0.473
SizeSel_9P_6_Sep-Dec_Pot_Fishery_BLK9repl_2013	-1.854	1.975
AgeSel_10P_1_Trawl_Survey_BLK10repl_1977	-1000	_
AgeSel_10P_1_Trawl_Survey_BLK10repl_1990	-1000	_
AgeSel_10P_1_Trawl_Survey_BLK10repl_1996	-1000	_
AgeSel_10P_1_Trawl_Survey_BLK10repl_2007	-1000	_
AgeSel_10P_2_Trawl_Survey_BLK10repl_1977	2.782	93.221
AgeSel_10P_2_Trawl_Survey_BLK10repl_1990	8.556	28.928
AgeSel_10P_2_Trawl_Survey_BLK10repl_1996	8.776	24.103
AgeSel_10P_2_Trawl_Survey_BLK10repl_2007	8.793	25.829
AgeSel_10P_3_Trawl_Survey_BLK10repl_1977	9.058	21.738
AgeSel_10P_3_Trawl_Survey_BLK10repl_1990	1.708	0.653
AgeSel_10P_3_Trawl_Survey_BLK10repl_1996	2.107	0.469
AgeSel_10P_3_Trawl_Survey_BLK10repl_2007	2.827	0.520
AgeSel_10P_4_Trawl_Survey_BLK10repl_1977	1.266	0.606
AgeSel_10P_4_Trawl_Survey_BLK10repl_1990	0.814	0.374
AgeSel_10P_4_Trawl_Survey_BLK10repl_1996	1.427	0.213
AgeSel_10P_4_Trawl_Survey_BLK10repl_2007	1.816	0.159
AgeSel_10P_5_Trawl_Survey_BLK10repl_1977	0.655	0.404
AgeSel_10P_5_Trawl_Survey_BLK10repl_1990	0.737	0.318

SizeSel_9P_3_Sep-Dec_Pot_Fishery	0.000	_
SizeSel_9P_4_Sep-Dec_Pot_Fishery	4.340	0.531
SizeSel_9P_5_Sep-Dec_Pot_Fishery	-10.000	_
SizeSel_9P_6_Sep-Dec_Pot_Fishery	0.000	_
AgeSel_10P_1_Trawl_Survey	-2.000	_
AgeSel_10P_2_Trawl_Survey	3.000	_
AgeSel_10P_3_Trawl_Survey	-1.000	_
AgeSel_10P_4_Trawl_Survey	2.000	_
AgeSel_10P_5_Trawl_Survey	0.000	_
AgeSel_10P_6_Trawl_Survey	0.000	_
AgeSel_10P_7_Trawl_Survey	0.000	_
AgeSel_10P_8_Trawl_Survey	-1.000	_
AgeSel_10P_9_Trawl_Survey	-1.000	_
AgeSel_10P_10_Trawl_Survey	-1.000	_
AgeSel_10P_11_Trawl_Survey	-1.000	_
AgeSel_10P_12_Trawl_Survey	-1.000	_
AgeSel_10P_13_Trawl_Survey	-1.000	_
AgeSel_10P_14_Trawl_Survey	-2.000	_
AgeSel_10P_15_Trawl_Survey	-999	_
AgeSel_10P_16_Trawl_Survey	-999	_
AgeSel_10P_17_Trawl_Survey	-999	_
AgeSel_10P_18_Trawl_Survey	-999	_
AgeSel_10P_19_Trawl_Survey	-999	_
AgeSel_10P_20_Trawl_Survey	-999	_
AgeSel_10P_21_Trawl_Survey	-999	_
SizeSel_1P_1_Jan-Apr_Trawl_Fishery_BLK1repl_1977	49.481	5.865
SizeSel_1P_1_Jan-Apr_Trawl_Fishery_BLK1repl_1990	74.404	2.559
SizeSel_1P_1_Jan-Apr_Trawl_Fishery_BLK1repl_1995	75.609	2.321
SizeSel_1P_1_Jan-Apr_Trawl_Fishery_BLK1repl_2000	66.355	4.089
SizeSel_1P_1_Jan-Apr_Trawl_Fishery_BLK1repl_2005	69.561	4.745
SizeSel_1P_1_Jan-Apr_Trawl_Fishery_BLK1repl_2013	56.979	11.276
SizeSel_1P_3_Jan-Apr_Trawl_Fishery_BLK1repl_1977	4.102	1.222
SizeSel_1P_3_Jan-Apr_Trawl_Fishery_BLK1repl_1990	5.934	0.147
SizeSel_1P_3_Jan-Apr_Trawl_Fishery_BLK1repl_1995	5.947	0.133
SizeSel_1P_3_Jan-Apr_Trawl_Fishery_BLK1repl_2000	5.687	0.319
SizeSel_1P_3_Jan-Apr_Trawl_Fishery_BLK1repl_2005	5.887	0.311
SizeSel_1P_3_Jan-Apr_Trawl_Fishery_BLK1repl_2013	5.589	0.950
SizeSel_2P_1_May-Aug_Trawl_Fishery_BLK2repl_1977	54.969	3.063
SizeSel_2P_1_May-Aug_Trawl_Fishery_BLK2repl_1985	62.137	2.645

AgeSel_10P_5_Trawl_Survey_BLK10repl_1996	0.712	0.167
AgeSel_10P_5_Trawl_Survey_BLK10repl_2007	0.000	_
AgeSel_10P_6_Trawl_Survey_BLK10repl_1977	0.000	_
AgeSel_10P_6_Trawl_Survey_BLK10repl_1990	0.622	0.292
AgeSel_10P_6_Trawl_Survey_BLK10repl_1996	0.420	0.125
AgeSel_10P_6_Trawl_Survey_BLK10repl_2007	0.000	_
AgeSel_10P_7_Trawl_Survey_BLK10repl_1977	-1.691	2.989
AgeSel_10P_7_Trawl_Survey_BLK10repl_1990	-0.375	0.370
AgeSel_10P_7_Trawl_Survey_BLK10repl_1996	0.000	_
AgeSel_10P_7_Trawl_Survey_BLK10repl_2007	-0.748	0.250
AgeSel_10P_8_Trawl_Survey_BLK10repl_1977	0.067	3.528
AgeSel_10P_8_Trawl_Survey_BLK10repl_1990	-0.076	0.620
AgeSel_10P_8_Trawl_Survey_BLK10repl_1996	-0.253	0.219
AgeSel_10P_8_Trawl_Survey_BLK10repl_2007	-0.270	0.356
AgeSel_10P_9_Trawl_Survey_BLK10repl_1977	-0.023	0.733
AgeSel_10P_9_Trawl_Survey_BLK10repl_1990	-0.458	0.736
AgeSel_10P_9_Trawl_Survey_BLK10repl_1996	-0.451	0.371
AgeSel_10P_9_Trawl_Survey_BLK10repl_2007	-1.828	0.610
AgeSel_10P_10_Trawl_Survey_BLK10repl_1977	-0.067	2.132
AgeSel_10P_10_Trawl_Survey_BLK10repl_1990	-1.220	0.739
AgeSel_10P_10_Trawl_Survey_BLK10repl_1996	-1.639	0.711
AgeSel_10P_10_Trawl_Survey_BLK10repl_2007	-2.873	0.749
AgeSel_10P_11_Trawl_Survey_BLK10repl_1977	-0.864	4.211
AgeSel_10P_11_Trawl_Survey_BLK10repl_1990	-1.890	1.153
AgeSel_10P_11_Trawl_Survey_BLK10repl_1996	-0.433	0.794
AgeSel_10P_11_Trawl_Survey_BLK10repl_2007	-0.005	0.147
AgeSel_10P_12_Trawl_Survey_BLK10repl_1977	-0.020	0.629
AgeSel_10P_12_Trawl_Survey_BLK10repl_1990	-5.338	6.290
AgeSel_10P_12_Trawl_Survey_BLK10repl_1996	-8.123	38.551
AgeSel_10P_12_Trawl_Survey_BLK10repl_2007	-4.207	2.681
AgeSel_10P_13_Trawl_Survey_BLK10repl_1977	-0.027	0.872
AgeSel_10P_13_Trawl_Survey_BLK10repl_1990	-0.151	4.523
AgeSel_10P_13_Trawl_Survey_BLK10repl_1996	-5.516	90.484
AgeSel_10P_13_Trawl_Survey_BLK10repl_2007	-0.011	0.345
AgeSel_10P_14_Trawl_Survey_BLK10repl_1977	-0.368	4.916
AgeSel_10P_14_Trawl_Survey_BLK10repl_1990	-0.560	2.743
AgeSel_10P_14_Trawl_Survey_BLK10repl_1996	-5.004	111.567
AgeSel_10P_14_Trawl_Survey_BLK10repl_2007	-2.963	22.214

Table 2.15 – Schedules of estimated population length (cm) and weight (kg) by season and age from Model 3 – ¼ fsh. Season 1=Jan-Feb, Season 2=Mar-Apr, Season 3=May-Aug, Season 4=Sep-Oct, Season 5=Nov-Dec. Lengths and weights correspond to season mid-points.

Age	Length, in cm					Mass, in kg				
	1	2	3	4	5	1	2	3	4	5
0	0.500	1.594	4.874	8.155	10.342	0.001	0.001	0.005	0.014	0.018
1	12.529	14.716	17.996	21.277	23.464	0.031	0.043	0.078	0.140	0.153
2	25.651	27.838	31.118	34.399	36.586	0.216	0.252	0.356	0.524	0.572
3	38.773	40.960	44.240	46.512	47.973	0.730	0.795	0.989	1.228	1.306
4	49.393	50.773	52.769	54.682	55.912	1.517	1.525	1.664	1.951	2.093
5	57.108	58.269	59.951	61.561	62.597	2.362	2.322	2.428	2.740	2.967
6	63.604	64.582	65.997	67.354	68.226	3.282	3.181	3.228	3.547	3.872
7	69.073	69.897	71.089	72.231	72.965	4.224	4.053	4.025	4.336	4.768
8	73.679	74.372	75.376	76.337	76.955	5.147	4.902	4.790	5.083	5.623
9	77.556	78.140	78.985	79.795	80.315	6.023	5.705	5.504	5.774	6.420
10	80.821	81.313	82.024	82.706	83.144	6.835	6.446	6.158	6.401	7.147
11	83.570	83.984	84.583	85.157	85.526	7.573	7.119	6.747	6.963	7.802
12	85.885	86.233	86.738	87.221	87.532	8.235	7.721	7.271	7.460	8.384
13	87.834	88.127	88.552	88.959	89.221	8.822	8.253	7.733	7.896	8.896
14	89.475	89.722	90.080	90.422	90.643	9.337	8.721	8.137	8.275	9.343
15	90.857	91.065	91.366	91.654	91.840	9.787	9.128	8.487	8.604	9.731
16	92.020	92.195	92.449	92.692	92.848	10.176	9.480	8.790	8.887	10.066
17	93.000	93.147	93.361	93.565	93.697	10.511	9.783	9.049	9.129	10.353
18	93.824	93.949	94.128	94.301	94.411	10.799	10.043	9.272	9.336	10.599
19	94.519	94.623	94.775	94.920	95.013	11.044	10.265	9.461	9.513	10.809
20	95.758	95.827	95.928	96.024	96.086	11.490	10.669	9.806	9.833	11.190

Table 2.16 – Schedule of estimated survey selectivity-at-age from Model 3 – ¼ fsh

Age	1984 and 1987	1990 and 1993	1996 – 2005	2007 – 2015
0	0.000	0.000	0.000	0.000
1	0.000	0.021	0.009	0.010
2	0.146	0.114	0.077	0.163
3	0.519	0.257	0.322	1.000
4	1.000	0.537	0.657	1.000
5	1.000	1.000	1.000	1.000
6	0.184	0.687	1.000	0.473
7	0.197	0.637	0.776	0.361
8	0.193	0.403	0.495	0.058
9	0.180	0.119	0.096	0.003
10	0.076	0.018	0.062	0.003
11	0.074	0.000	0.000	0.000
12	0.072	0.000	0.000	0.000
13	0.050	0.000	0.000	0.000
14	0.035	0.000	0.000	0.000
15	0.024	0.000	0.000	0.000
16	0.017	0.000	0.000	0.000
17	0.011	0.000	0.000	0.000
18	0.008	0.000	0.000	0.000
19	0.005	0.000	0.000	0.000
20	0.004	0.000	0.000	0.000

Table 2.17 – Estimated female spawning biomass (t) from the 2014 assessment and this year's assessment from Model 3 – ¼ fsh

	Last year		**This year**	
Year	Spawning Biomass	Standard Deviation	Spawning Biomass	Standard Deviation
1977	417,262	64,250	449,277	91,438
1978	514,875	74,306	483,965	96,177
1979	528,010	73,382	474,895	92,067
1980	502,250	67,096	459,504	85,451
1981	510,750	64,125	475,040	82,750
1982	561,345	65,805	493,067	80,319
1983	539,730	60,570	467,587	72,914
1984	486,303	53,334	428,067	63,905
1985	438,862	46,804	399,136	55,378
1986	396,007	40,714	376,380	48,032
1987	355,515	35,200	354,220	42,404
1988	319,025	30,626	331,807	38,100
1989	306,546	28,269	320,414	35,217
1990	290,091	26,221	300,556	32,543
1991	260,199	23,940	277,791	30,240
1992	235,414	22,712	261,240	29,232
1993	226,204	22,314	257,833	28,811
1994	229,276	22,529	269,945	29,044
1995	239,934	22,819	280,725	28,352
1996	231,890	22,279	271,803	26,591
1997	220,810	21,694	261,124	24,797
1998	207,654	21,495	246,415	23,056
1999	202,477	21,597	239,692	21,664
2000	192,391	21,775	222,655	20,222
2001	186,894	20,940	213,974	18,660
2002	174,210	19,679	204,412	17,460
2003	158,567	18,548	197,263	16,798
2004	153,702	18,120	197,748	16,669
2005	150,557	17,715	193,289	16,271
2006	140,153	16,594	179,638	15,455
2007	127,838	15,217	166,316	14,308
2008	115,273	14,245	152,734	13,268
2009	109,778	14,049	152,479	12,880
2010	115,966	15,256	168,483	13,963
2011	129,024	17,827	189,732	15,923
2012	147,788	21,528	213,863	18,412
2013	173,781	26,328	230,967	19,805
2014	183,784	30,013	223,789	19,519
2015	*175,464*		202,714	18,216
2016			*186,487*	

Table 2.18 – Estimated age-0 recruits (000’s) from the 2014 assessment and this year’s assessment from Model 3 – ¼ fsh

	Last year		This year	
Year	Age-0	Std. Dev	Age-0	Std. Dev
1977	1,508,670	166,531	1,013,700	174,408
1978	202,845	45,570	231,525	59,298
1979	317,978	39,722	356,072	61,556
1980	330,569	36,194	370,251	60,832
1981	262,242	28,787	354,591	66,239
1982	304,565	36,760	360,392	73,302
1983	149,883	27,381	274,935	69,632
1984	403,273	61,991	452,174	95,438
1985	427,420	54,495	373,821	70,263
1986	181,773	31,939	265,017	49,993
1987	337,732	36,908	486,590	61,766
1988	319,716	34,500	310,942	49,159
1989	320,271	37,262	535,463	70,800
1990	418,127	42,785	441,684	59,149
1991	303,450	32,348	351,270	47,057
1992	261,965	31,346	361,603	50,000
1993	339,257	34,955	369,741	44,076
1994	268,213	29,790	378,873	44,407
1995	373,745	38,943	374,486	41,017
1996	238,654	24,452	266,241	30,898
1997	211,612	24,564	254,934	32,064
1998	177,263	20,136	300,444	32,147
1999	249,317	27,191	359,980	40,924
2000	270,200	27,556	324,201	34,812
2001	200,770	20,803	207,727	29,779
2002	128,980	16,534	200,778	26,371
2003	185,809	18,991	217,726	27,577
2004	161,719	18,699	227,012	26,229
2005	243,789	26,509	432,358	46,058
2006	350,814	38,031	442,054	44,014
2007	321,135	37,887	530,396	58,736
2008	453,897	58,116	496,064	47,544
2009	364,342	56,371	319,956	38,768
2010	230,731	42,984	231,420	28,899
2011	352,569	86,650	380,621	55,897
2012	516,742	92,639	317,262	51,187
2013	285,954	61,298	231,207	72,008
2014			308,988	121,074
2015			357,397	147,491
Average	323,675	(1977 – 2013)	360,855	(1977 – 2014)

Table 2.19 – Estimated numbers-at-age (millions) at the time of spawning (middle of season 2) from Model 3 – ¼ fsh

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	982.1	420.3	122.7	111.8	151.1	124.5	47.7	27.3	16.8	10.8	7.2	4.9	3.4	2.4	1.7	1.1	0.9	0.6	0.4	0.3	0.6
1978	224.3	671.6	287.4	83.8	76.2	102.9	84.8	32.5	18.6	11.4	7.3	4.9	3.4	2.3	1.6	1.1	0.8	0.6	0.4	0.3	0.6
1979	345.0	153.4	459.3	196.3	56.9	51.5	69.5	57.3	22.0	12.6	7.7	5.0	3.3	2.3	1.6	1.1	0.8	0.5	0.4	0.3	0.6
1980	358.7	235.9	104.9	313.3	132.5	38.1	34.5	46.6	38.5	14.8	8.5	5.2	3.4	2.2	1.5	1.1	0.7	0.5	0.4	0.3	0.6
1981	343.5	245.3	161.3	71.6	210.4	87.5	25.2	22.9	31.2	25.8	9.9	5.7	3.5	2.3	1.5	1.0	0.7	0.5	0.3	0.2	0.6
1982	349.2	234.9	167.7	110.0	47.9	138.1	57.5	16.7	15.3	20.8	17.3	6.7	3.8	2.4	1.5	1.0	0.7	0.5	0.3	0.2	0.6
1983	266.4	238.8	160.7	114.4	73.6	31.5	90.8	38.1	11.1	10.2	14.0	11.6	4.5	2.6	1.6	1.0	0.7	0.5	0.3	0.2	0.5
1984	438.1	182.2	163.3	109.5	76.0	47.7	20.4	59.5	25.2	7.4	6.8	9.3	7.8	3.0	1.7	1.1	0.7	0.5	0.3	0.2	0.5
1985	362.2	299.6	124.6	111.4	73.8	50.5	31.7	13.6	39.8	16.9	5.0	4.6	6.3	5.2	2.0	1.2	0.7	0.5	0.3	0.2	0.5
1986	256.8	247.7	204.9	85.0	75.4	49.5	33.7	21.1	9.1	26.6	11.3	3.3	3.1	4.2	3.5	1.4	0.8	0.5	0.3	0.2	0.5
1987	471.4	175.6	169.4	139.7	57.3	50.2	32.8	22.4	14.1	6.1	17.9	7.6	2.2	2.1	2.8	2.3	0.9	0.5	0.3	0.2	0.5
1988	301.3	322.4	120.0	115.0	92.5	37.1	32.3	21.2	14.6	9.3	4.0	11.8	5.0	1.5	1.4	1.9	1.6	0.6	0.3	0.2	0.4
1989	518.8	206.0	220.4	81.5	76.2	60.1	23.9	20.9	13.8	9.6	6.1	2.6	7.8	3.3	1.0	0.9	1.2	1.0	0.4	0.2	0.4
1990	427.9	354.8	140.9	150.2	54.2	48.8	37.5	14.8	13.0	8.7	6.1	3.9	1.7	5.0	2.1	0.6	0.6	0.8	0.7	0.3	0.4
1991	340.3	292.6	242.5	95.8	99.5	34.1	29.0	21.6	8.5	7.6	5.1	3.6	2.3	1.0	3.0	1.3	0.4	0.4	0.5	0.4	0.4
1992	350.3	232.7	200.0	165.0	63.7	63.3	20.6	16.9	12.5	4.9	4.4	3.0	2.1	1.4	0.6	1.8	0.8	0.2	0.2	0.3	0.5
1993	358.2	239.6	159.1	136.3	110.5	41.1	39.1	12.4	10.1	7.4	3.0	2.7	1.8	1.3	0.8	0.4	1.1	0.5	0.1	0.1	0.5
1994	367.1	245.0	163.8	108.5	91.6	72.0	25.8	23.9	7.5	6.1	4.6	1.8	1.7	1.1	0.8	0.5	0.2	0.7	0.3	0.1	0.4
1995	362.8	251.0	167.5	111.7	72.9	59.7	45.2	15.8	14.5	4.6	3.8	2.8	1.1	1.0	0.7	0.5	0.3	0.1	0.4	0.2	0.3
1996	257.9	248.1	171.6	114.1	74.9	47.2	37.0	27.1	9.3	8.6	2.7	2.3	1.7	0.7	0.6	0.4	0.3	0.2	0.1	0.3	0.3
1997	247.0	176.4	169.6	116.9	76.4	48.3	29.1	22.0	16.0	5.5	5.1	1.6	1.4	1.0	0.4	0.4	0.3	0.2	0.1	0.1	0.3
1998	291.1	168.9	120.6	115.5	78.0	48.7	29.1	16.8	12.6	9.2	3.2	3.0	1.0	0.8	0.6	0.2	0.2	0.2	0.1	0.1	0.2
1999	348.8	199.1	115.5	82.2	77.2	49.8	29.4	16.9	9.6	7.3	5.4	1.9	1.8	0.6	0.5	0.4	0.1	0.1	0.1	0.1	0.2
2000	314.1	238.5	136.1	78.5	54.2	47.9	29.0	16.6	9.5	5.6	4.3	3.2	1.1	1.1	0.4	0.3	0.2	0.1	0.1	0.1	0.1
2001	201.3	214.8	163.1	92.7	52.4	34.8	29.6	17.7	10.2	5.9	3.5	2.7	2.0	0.7	0.7	0.2	0.2	0.1	0.1	0.1	0.1
2002	194.5	137.6	146.8	111.0	61.5	33.2	21.0	17.6	10.6	6.2	3.7	2.2	1.7	1.3	0.5	0.4	0.1	0.1	0.1	0.0	0.1
2003	210.9	133.0	94.1	100.0	73.6	38.5	19.7	12.2	10.4	6.4	3.8	2.3	1.4	1.1	0.8	0.3	0.3	0.1	0.1	0.1	0.1
2004	219.9	144.3	90.9	64.1	66.3	46.2	23.0	11.5	7.3	6.3	3.9	2.4	1.4	0.9	0.7	0.5	0.2	0.2	0.1	0.0	0.1
2005	418.9	150.4	98.6	62.0	42.6	42.0	27.8	13.6	6.9	4.4	3.9	2.5	1.5	0.9	0.6	0.4	0.3	0.1	0.1	0.0	0.1
2006	428.3	286.5	102.8	67.2	41.3	26.9	25.1	16.3	8.1	4.2	2.7	2.4	1.5	0.9	0.6	0.3	0.3	0.2	0.1	0.1	0.1
2007	513.9	292.9	195.8	70.1	44.8	26.1	16.1	14.7	9.7	4.9	2.6	1.7	1.5	1.0	0.6	0.4	0.2	0.2	0.1	0.0	0.1
2008	480.6	351.4	200.2	133.3	46.2	27.5	14.9	9.0	8.3	5.6	2.9	1.5	1.0	0.9	0.6	0.4	0.2	0.1	0.1	0.1	0.1
2009	310.0	328.7	240.3	136.4	88.0	28.4	15.6	8.2	5.0	4.8	3.3	1.8	0.9	0.6	0.6	0.4	0.2	0.1	0.1	0.1	0.1
2010	224.2	212.0	224.7	163.5	89.5	53.2	15.7	8.4	4.5	2.8	2.8	2.0	1.0	0.6	0.4	0.3	0.2	0.1	0.1	0.1	0.1
2011	368.8	153.3	144.9	153.0	107.6	54.2	29.5	8.4	4.6	2.5	1.7	1.7	1.2	0.6	0.3	0.2	0.2	0.1	0.1	0.1	0.1
2012	307.4	252.2	104.8	98.6	100.9	65.9	30.7	16.2	4.7	2.6	1.5	1.0	1.0	0.7	0.4	0.2	0.1	0.1	0.1	0.1	0.1
2013	224.0	210.2	172.3	71.0	64.8	63.0	39.3	18.1	9.7	2.9	1.6	0.9	0.6	0.6	0.5	0.2	0.1	0.1	0.1	0.1	0.1
2014	299.4	153.2	143.5	115.9	45.6	39.2	36.8	23.0	10.8	5.9	1.8	1.0	0.6	0.4	0.4	0.3	0.2	0.1	0.1	0.1	0.1
2015	346.3	204.7	104.6	96.2	72.9	26.5	21.7	20.4	13.2	6.4	3.6	1.1	0.6	0.4	0.2	0.2	0.2	0.1	0.1	0.0	0.1

Table 2.20 – Estimates of "effective" fishing mortality (= $-\ln(N_{a+1,y+1}/N_{a,y})-M$) at age (a) and year (y) from Model 3 – ¼ fsh

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1977	0.000	0.000	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1978	0.000	0.001	0.006	0.011	0.012	0.011	0.010	0.009	0.009	0.008	0.008	0.007	0.007	0.007	0.007	0.006	0.006	0.006	0.006
1979	0.000	0.001	0.007	0.013	0.014	0.013	0.012	0.011	0.011	0.010	0.009	0.009	0.008	0.008	0.008	0.008	0.007	0.007	0.007
1980	0.000	0.001	0.016	0.036	0.039	0.032	0.027	0.024	0.022	0.021	0.020	0.019	0.018	0.017	0.017	0.017	0.016	0.016	0.016
1981	0.000	0.002	0.019	0.039	0.040	0.032	0.025	0.022	0.020	0.019	0.018	0.017	0.016	0.016	0.016	0.015	0.015	0.015	0.015
1982	0.000	0.001	0.016	0.036	0.037	0.029	0.023	0.020	0.018	0.017	0.016	0.016	0.015	0.015	0.014	0.014	0.014	0.014	0.014
1983	0.000	0.002	0.023	0.050	0.051	0.041	0.032	0.028	0.026	0.024	0.023	0.022	0.022	0.021	0.021	0.021	0.020	0.020	0.020
1984	0.000	0.001	0.013	0.030	0.032	0.028	0.024	0.022	0.021	0.019	0.018	0.017	0.016	0.016	0.016	0.015	0.015	0.015	0.015
1985	0.000	0.001	0.005	0.013	0.017	0.018	0.017	0.016	0.015	0.014	0.014	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
1986	0.000	0.001	0.011	0.025	0.032	0.032	0.030	0.028	0.027	0.026	0.025	0.024	0.024	0.023	0.023	0.023	0.023	0.023	0.023
1987	0.000	0.004	0.023	0.047	0.055	0.049	0.039	0.032	0.028	0.026	0.025	0.025	0.024	0.024	0.024	0.024	0.024	0.024	0.024
1988	0.000	0.002	0.018	0.043	0.053	0.050	0.043	0.038	0.034	0.032	0.031	0.030	0.030	0.029	0.029	0.029	0.029	0.029	0.029
1989	0.000	0.001	0.020	0.055	0.070	0.068	0.059	0.051	0.046	0.043	0.042	0.042	0.041	0.041	0.041	0.041	0.041	0.041	0.041
1990	0.000	0.001	0.014	0.049	0.096	0.127	0.134	0.126	0.115	0.105	0.099	0.094	0.091	0.089	0.087	0.086	0.085	0.085	0.084
1991	0.000	0.001	0.009	0.039	0.085	0.129	0.151	0.155	0.151	0.146	0.142	0.139	0.137	0.136	0.135	0.135	0.135	0.134	0.134
1992	0.000	0.001	0.010	0.043	0.097	0.146	0.170	0.173	0.167	0.160	0.155	0.151	0.149	0.148	0.147	0.146	0.146	0.146	0.145
1993	0.000	0.001	0.007	0.031	0.069	0.105	0.121	0.122	0.116	0.110	0.105	0.102	0.100	0.099	0.098	0.098	0.097	0.097	0.097
1994	0.000	0.000	0.005	0.023	0.053	0.082	0.096	0.097	0.093	0.088	0.085	0.083	0.081	0.080	0.079	0.079	0.079	0.079	0.078
1995	0.000	0.001	0.007	0.030	0.070	0.113	0.138	0.144	0.140	0.133	0.127	0.123	0.121	0.119	0.118	0.117	0.117	0.117	0.116
1996	0.000	0.001	0.007	0.031	0.072	0.113	0.137	0.142	0.138	0.131	0.126	0.123	0.121	0.119	0.118	0.118	0.118	0.117	0.117
1997	0.000	0.002	0.011	0.039	0.087	0.135	0.161	0.165	0.158	0.149	0.142	0.137	0.134	0.132	0.131	0.130	0.130	0.129	0.129
1998	0.000	0.001	0.008	0.035	0.084	0.134	0.161	0.163	0.154	0.144	0.135	0.130	0.126	0.124	0.122	0.121	0.121	0.120	0.120
1999	0.000	0.001	0.010	0.042	0.102	0.163	0.195	0.196	0.182	0.166	0.154	0.146	0.141	0.138	0.136	0.134	0.133	0.133	0.132
2000	0.000	0.001	0.010	0.046	0.106	0.151	0.159	0.144	0.125	0.110	0.101	0.095	0.092	0.090	0.089	0.089	0.088	0.088	0.088
2001	0.000	0.002	0.013	0.047	0.094	0.126	0.130	0.116	0.099	0.087	0.079	0.074	0.071	0.070	0.069	0.068	0.068	0.068	0.067
2002	0.000	0.001	0.012	0.051	0.107	0.144	0.147	0.130	0.112	0.098	0.090	0.085	0.082	0.080	0.079	0.079	0.078	0.078	0.078
2003	0.000	0.001	0.012	0.048	0.102	0.141	0.146	0.130	0.109	0.094	0.084	0.078	0.075	0.073	0.072	0.071	0.071	0.071	0.070
2004	0.000	0.002	0.013	0.052	0.112	0.154	0.158	0.139	0.116	0.098	0.088	0.081	0.078	0.076	0.074	0.074	0.073	0.073	0.072

2005	0.000	0.001	0.009	0.041	0.094	0.132	0.136	0.120	0.102	0.089	0.081	0.077	0.074	0.073	0.072	0.072	0.072	0.071	0.071
2006	0.000	0.001	0.009	0.041	0.098	0.142	0.148	0.131	0.111	0.097	0.089	0.084	0.082	0.080	0.080	0.079	0.079	0.079	0.078
2007	0.000	0.001	0.013	0.055	0.126	0.176	0.181	0.158	0.134	0.116	0.106	0.100	0.096	0.094	0.093	0.093	0.092	0.092	0.092
2008	0.000	0.002	0.017	0.069	0.153	0.213	0.220	0.193	0.163	0.141	0.127	0.120	0.115	0.113	0.112	0.111	0.110	0.110	0.109
2009	0.000	0.001	0.013	0.057	0.132	0.189	0.197	0.172	0.144	0.123	0.111	0.104	0.099	0.097	0.096	0.095	0.094	0.094	0.094
2010	0.000	0.002	0.017	0.072	0.169	0.243	0.252	0.221	0.186	0.160	0.144	0.135	0.131	0.128	0.126	0.125	0.124	0.124	0.124
2011	0.000	0.001	0.014	0.068	0.162	0.231	0.237	0.207	0.173	0.149	0.135	0.127	0.122	0.120	0.118	0.117	0.117	0.117	0.116
2012	0.000	0.001	0.012	0.056	0.129	0.184	0.191	0.170	0.146	0.128	0.118	0.112	0.109	0.107	0.106	0.106	0.105	0.105	0.105
2013	0.000	0.007	0.033	0.079	0.127	0.144	0.130	0.108	0.091	0.080	0.075	0.072	0.071	0.070	0.069	0.069	0.069	0.069	0.069
2014	0.000	0.010	0.049	0.112	0.174	0.193	0.173	0.142	0.120	0.107	0.100	0.097	0.095	0.094	0.093	0.093	0.093	0.093	0.093

Table 2.21 – Results for the projection scenarios from Model 3 – ¼ fsh. ABC, OFL, Catch, Female Spawning Stock Biomass (SSB), and Total Biomass (Total Bio) in metric tons. Fishing mortality (F) is also presented.

Scenarios 1 and 2, Maximum tier 3 ABC harvest permissible						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2015	109,053	128,891	76,821	183,623	0.274	556,467
2016	98,630	116,728	98,630	165,676	0.407	518,868
2017	85,255	100,878	85,255	141,837	0.407	472,817
2018	74,502	87,543	74,502	124,778	0.389	451,733
2019	72,362	85,200	72,362	121,199	0.378	455,676
2020	78,788	92,795	78,788	125,617	0.389	471,153
2021	82,959	97,808	82,959	129,947	0.391	480,467
2022	84,892	100,160	84,892	132,604	0.390	483,447
2023	85,209	100,538	85,209	133,716	0.388	482,359
2024	84,673	99,940	84,673	133,023	0.389	478,908
2025	83,760	98,785	83,760	131,686	0.390	476,346
2026	82,734	97,636	82,734	130,559	0.388	475,237
2027	82,733	97,650	82,733	130,335	0.388	476,309
2028	83,150	98,153	83,150	130,917	0.388	478,888
Scenario 3, F_{ABC} at average F over the past 5 years						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2015	67,953	128,891	76,821	183,623	0.274	556,467
2016	61,293	116,728	61,293	169,117	0.240	518,868
2017	58,385	110,997	58,385	160,605	0.240	508,786
2018	56,431	107,365	56,431	152,084	0.240	507,808
2019	57,127	108,974	57,127	151,703	0.240	519,299
2020	60,231	114,864	60,231	157,827	0.240	537,944
2021	63,535	120,948	63,535	164,843	0.240	552,978
2022	65,797	125,059	65,797	170,155	0.240	561,620
2023	66,770	126,848	66,770	173,325	0.240	564,859
2024	66,747	126,739	66,747	174,006	0.240	564,233
2025	66,230	125,772	66,230	173,440	0.240	563,309
2026	65,749	124,925	65,749	172,626	0.240	562,983
2027	65,645	124,748	65,645	172,384	0.240	564,053
2028	65,872	125,095	65,872	172,965	0.240	566,651
Scenario 4, $F_{ABC} = F_{60\%}$						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2015	55,746	128,891	76,821	183,623	0.274	556,467
2016	50,243	116,728	50,243	170,079	0.193	518,868
2017	49,193	114,013	49,193	166,278	0.193	519,496
2018	48,461	112,378	48,461	161,022	0.193	525,709
2019	49,490	115,103	49,490	162,717	0.193	541,750
2020	52,358	121,748	52,358	170,373	0.193	563,680
2021	55,403	128,569	55,403	178,756	0.193	581,585
2022	57,569	133,408	57,569	185,296	0.193	592,775

2023	58,605	135,706	58,605	189,485	0.193	598,128
2024	58,743	135,992	58,743	190,931	0.193	599,097
2025	58,399	135,236	58,399	190,859	0.193	599,225
2026	58,030	134,444	58,030	190,319	0.193	599,499
2027	57,945	134,314	57,945	190,210	0.193	600,874
2028	58,133	134,737	58,133	190,867	0.193	603,651
Scenario 5, No fishing (F_{ABC} = 0)						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2015	0	128,891	76,821	183,623	0.274	556,467
2016	0	116,728	0	174,175	0.000	518,868
2017	0	127,835	0	192,711	0.000	568,523
2018	0	137,357	0	206,381	0.000	614,908
2019	0	147,893	0	222,944	0.000	662,334
2020	0	160,392	0	242,912	0.000	710,020
2021	0	172,659	0	262,432	0.000	750,978
2022	0	182,598	0	279,155	0.000	783,135
2023	0	189,173	0	292,256	0.000	806,833
2024	0	192,698	0	300,978	0.000	822,870
2025	0	194,125	0	306,348	0.000	834,419
2026	0	194,639	0	309,560	0.000	842,694
2027	0	195,255	0	311,894	0.000	849,370
2028	0	196,209	0	314,188	0.000	855,714
Scenario 6, Whether Pacific cod are overfished – $SB_{35\%}$ = 113,800						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2015	128,891	128,891	76,821	183,623	0.274	556,467
2016	116,728	116,728	116,728	163,891	0.495	518,868
2017	96,016	96,016	96,016	132,973	0.495	455,512
2018	74,841	74,841	74,841	113,462	0.429	426,936
2019	74,606	74,606	74,606	111,443	0.421	434,838
2020	83,277	83,277	83,277	116,500	0.441	452,031
2021	88,868	88,868	88,868	120,399	0.449	460,560
2022	90,938	90,938	90,938	122,069	0.451	461,374
2023	90,642	90,642	90,642	122,283	0.449	458,263
2024	89,414	89,414	89,414	121,096	0.448	453,693
2025	87,988	87,988	87,988	119,688	0.447	450,926
2026	86,903	86,903	86,903	118,735	0.445	450,199
2027	86,955	86,955	86,955	118,708	0.444	451,687
2028	87,810	87,810	87,810	119,400	0.446	454,565
Scenario 7, Whether Pacific cod is approaching overfished condition						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2015	128,891	128,891	76,821	183,623	0.274	556,467
2016	116,728	116,728	98,630	165,676	0.407	518,868
2017	100,878	100,878	85,255	141,837	0.407	472,817
2018	87,543	87,543	87,543	123,572	0.469	451,733

2019	78,817	78,817	78,817	115,175	0.436	443,264
2020	84,301	84,301	84,301	117,642	0.445	454,378
2021	88,899	88,899	88,899	120,684	0.450	461,065
2022	90,867	90,867	90,867	122,155	0.451	461,525
2023	90,608	90,608	90,608	122,323	0.449	458,345
2024	89,404	89,404	89,404	121,117	0.448	453,740
2025	87,985	87,985	87,985	119,697	0.447	450,947
2026	86,901	86,901	86,901	118,738	0.445	450,206
2027	86,954	86,954	86,954	118,708	0.444	451,688
2028	87,809	87,809	87,809	119,400	0.446	454,564

Table 2.22 – Biological reference points from GOA Pacific cod SAFE documents for years 2001 – 2015

Year	$SB_{100\%}$	$SB_{40\%}$	$F_{40\%}$	SB_{y+1}	ABC_{y+1}
2001	212,000	85,000	0.41	82,000	57,600
2002	226,000	90,300	0.35	88,300	52,800
2003	222,000	88,900	0.34	103,000	62,810
2004	211,000	84,400	0.31	91,700	58,100
2005	329,000	132,000	0.56	165,000	68,859
2006	259,000	103,000	0.46	136,000	68,859
2007	302,000	121,000	0.49	108,000	66,493
2008	255,500	102,200	0.52	88,000	55,300
2009	291,500	116,600	0.49	117,600	79,100
2010	256,300	102,500	0.42	124,100	86,800
2011	261,000	104,000	0.44	121,000	87,600
2012	234,800	93,900	0.49	111,000	80,800
2013	227,800	91,100	0.54	120,100	88,500
2014	316,500	126,600	0.50	155,400	102,850
2015	*325,200*	*130,000*	*0.41*	*165,600*	*98,600*

Figures

Fig. 2.1 – Fishery catches by season and gear (AKFIN; as of 2015-10-02)

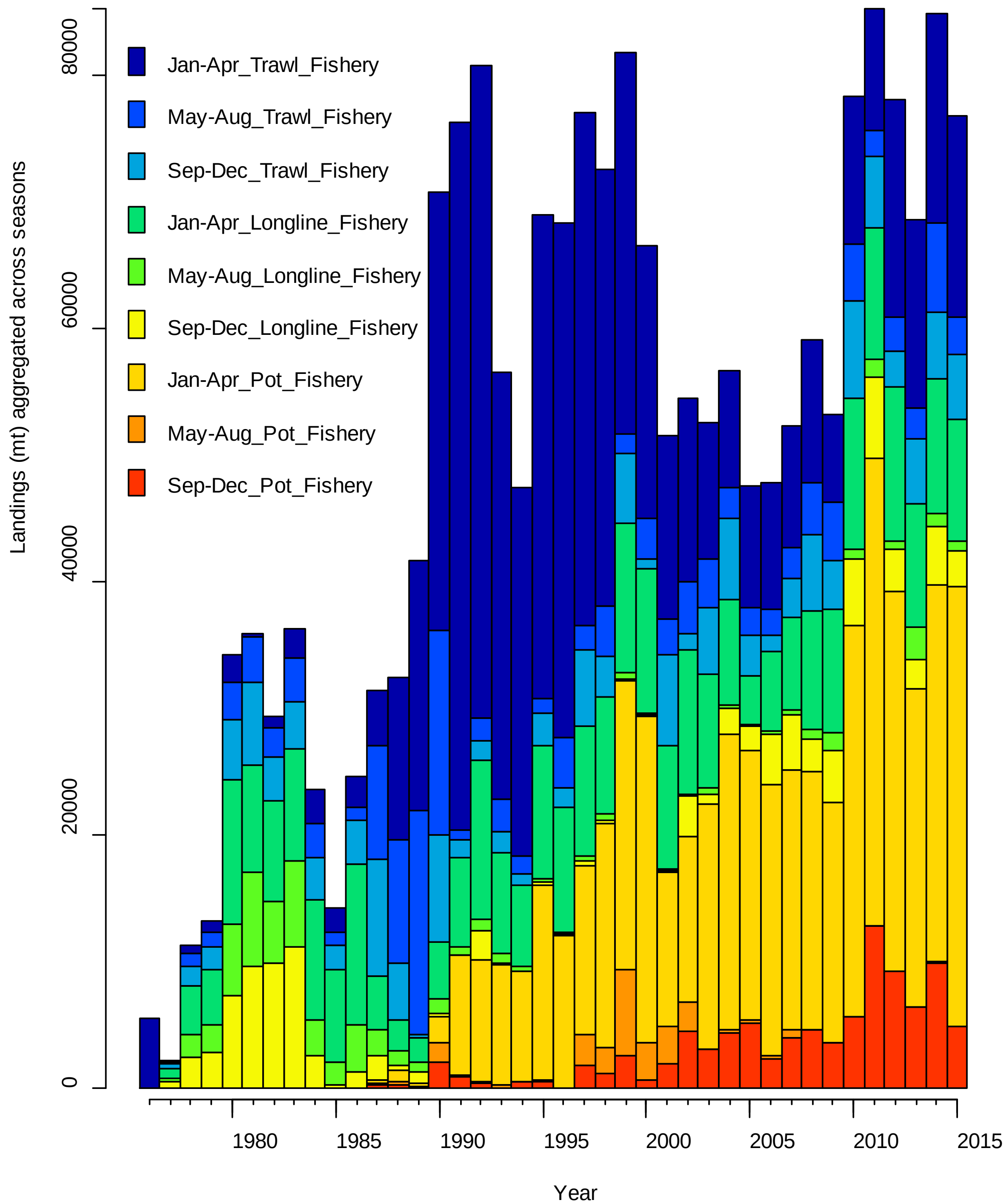


Fig. 2.2 – GOA NMFS bottom trawl survey biomass estimates for Pacific cod, with 95% confidence interval

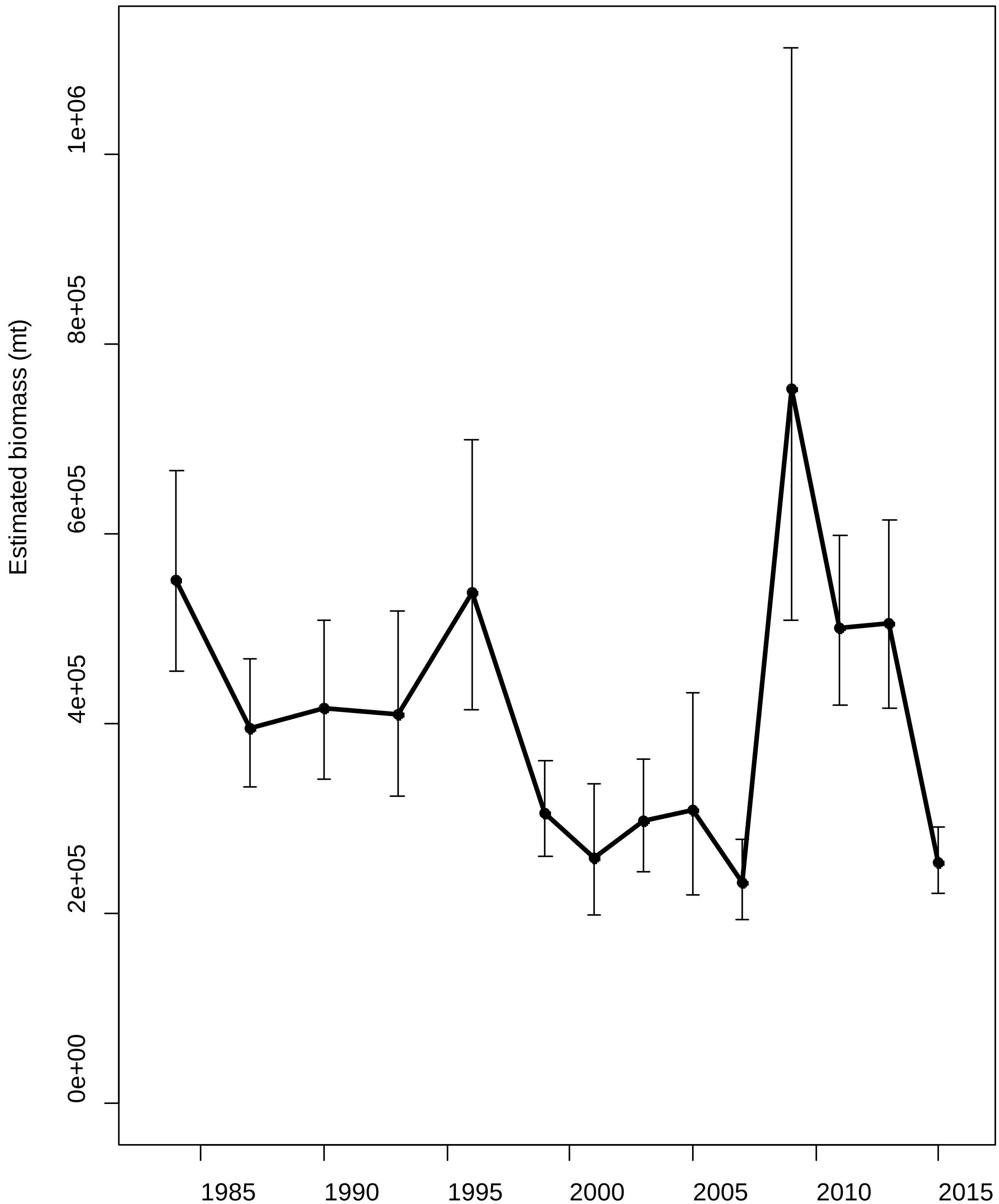


Fig. 2.3 – GOA NMFS survey abundance estimates for Pacific cod, with 95% confidence interval

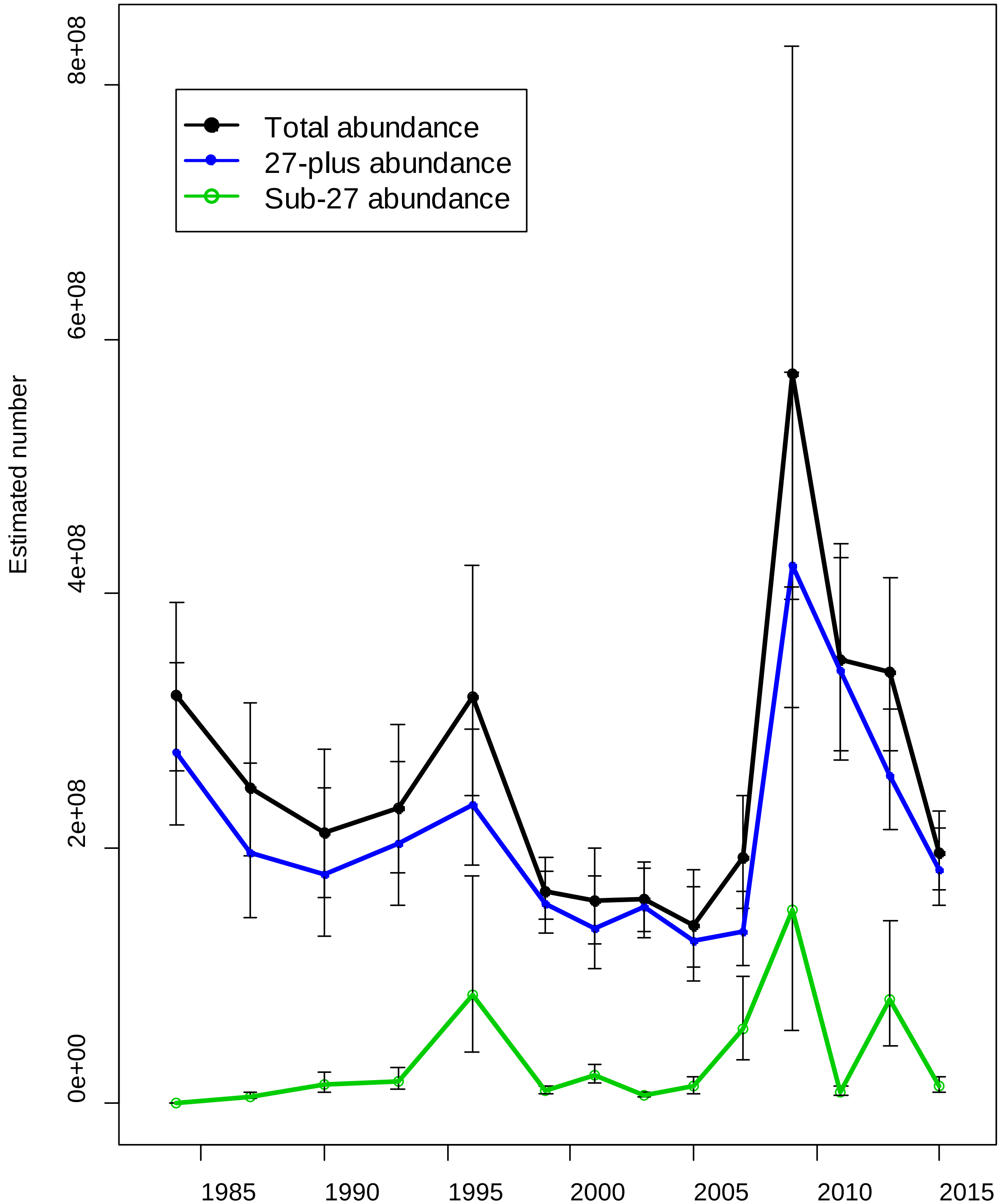


Fig. 2.4 – GOA NMFS bottom trawl survey biomass estimates by area (in t)

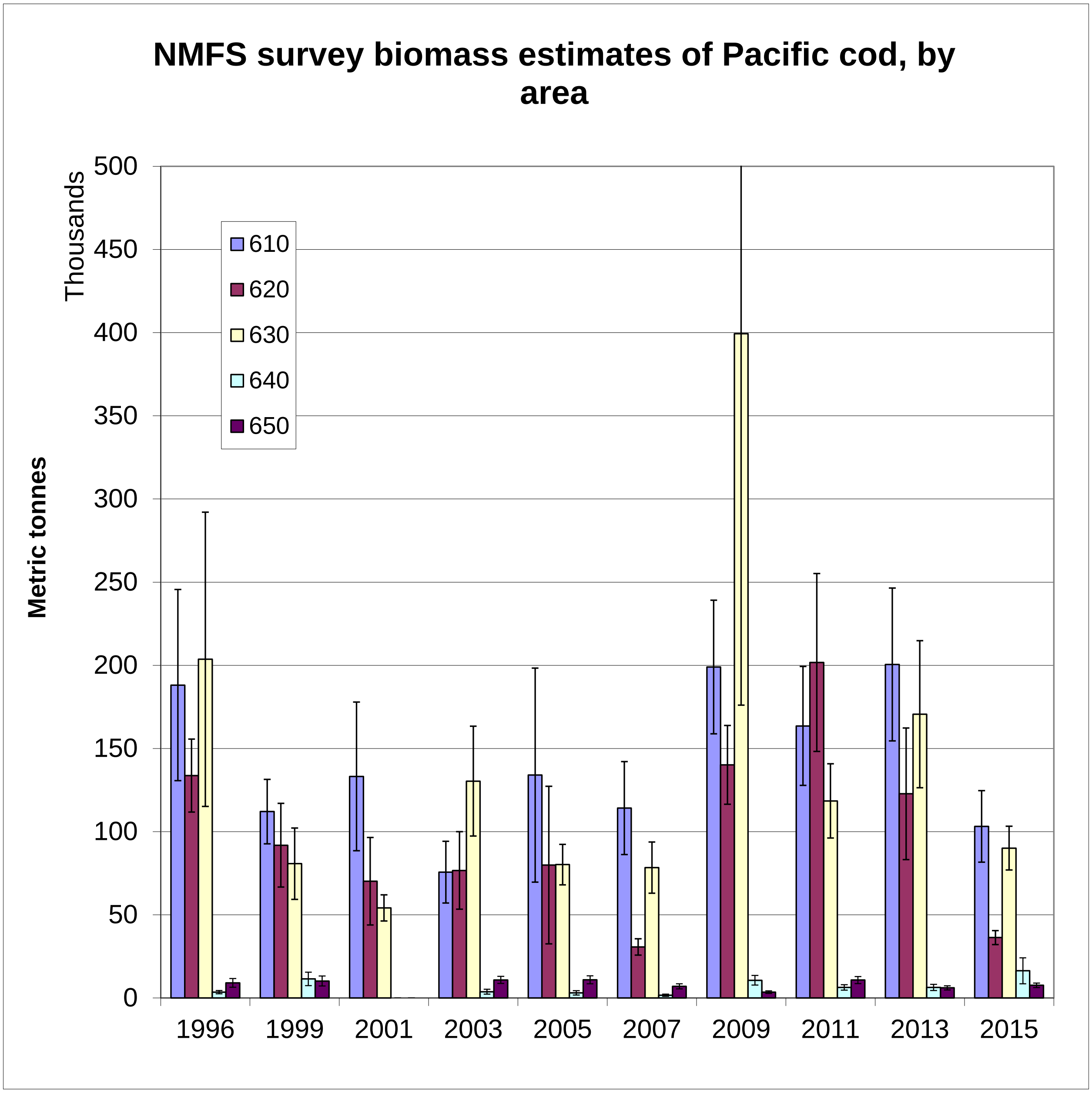


Fig. 2.5 – GOA NMFS bottom trawl survey abundance estimates by area (in numbers)

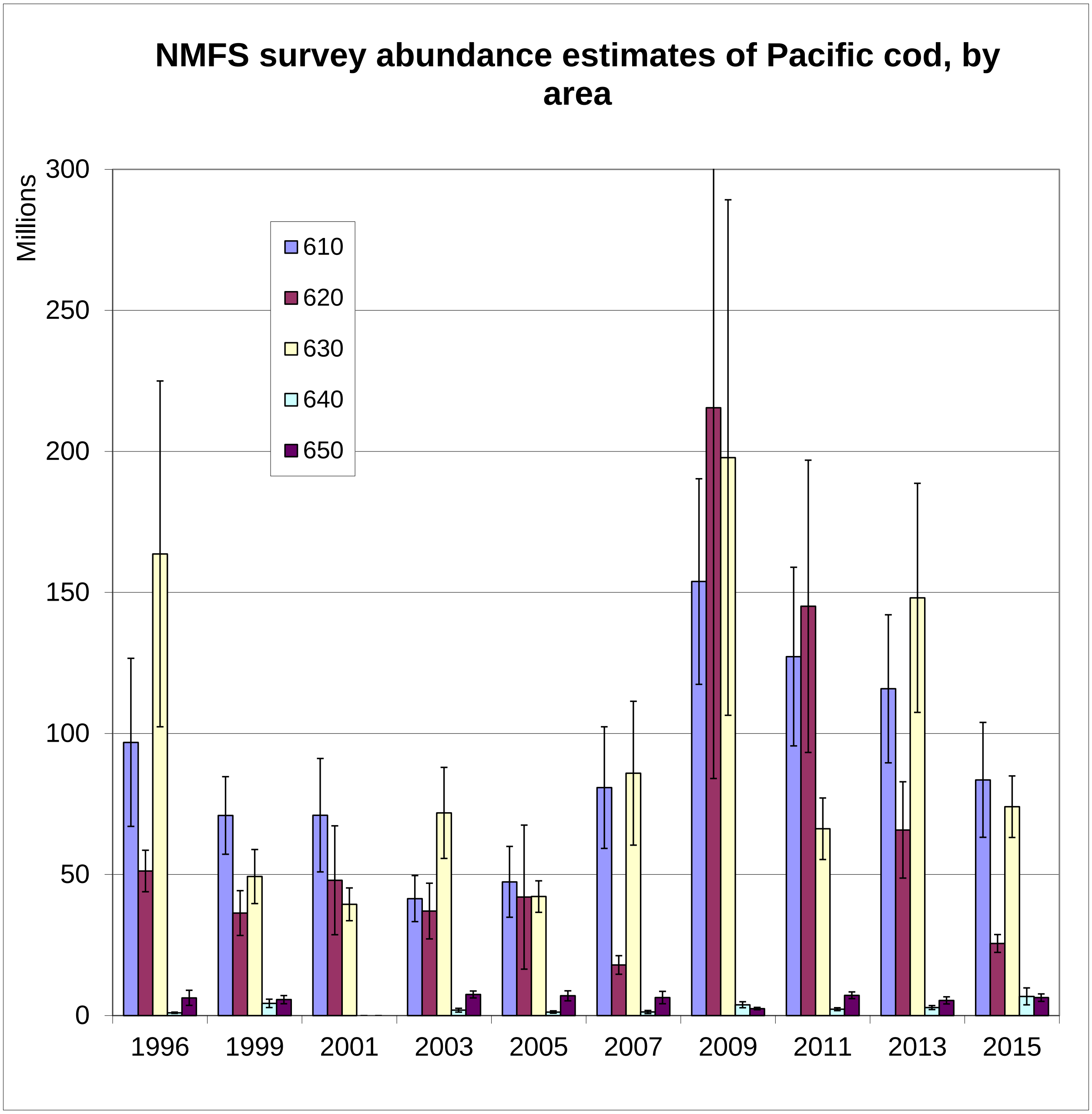


Fig. 2.6 – GOA NMFS bottom trawl survey population length composition estimates for Pacific cod, by cm

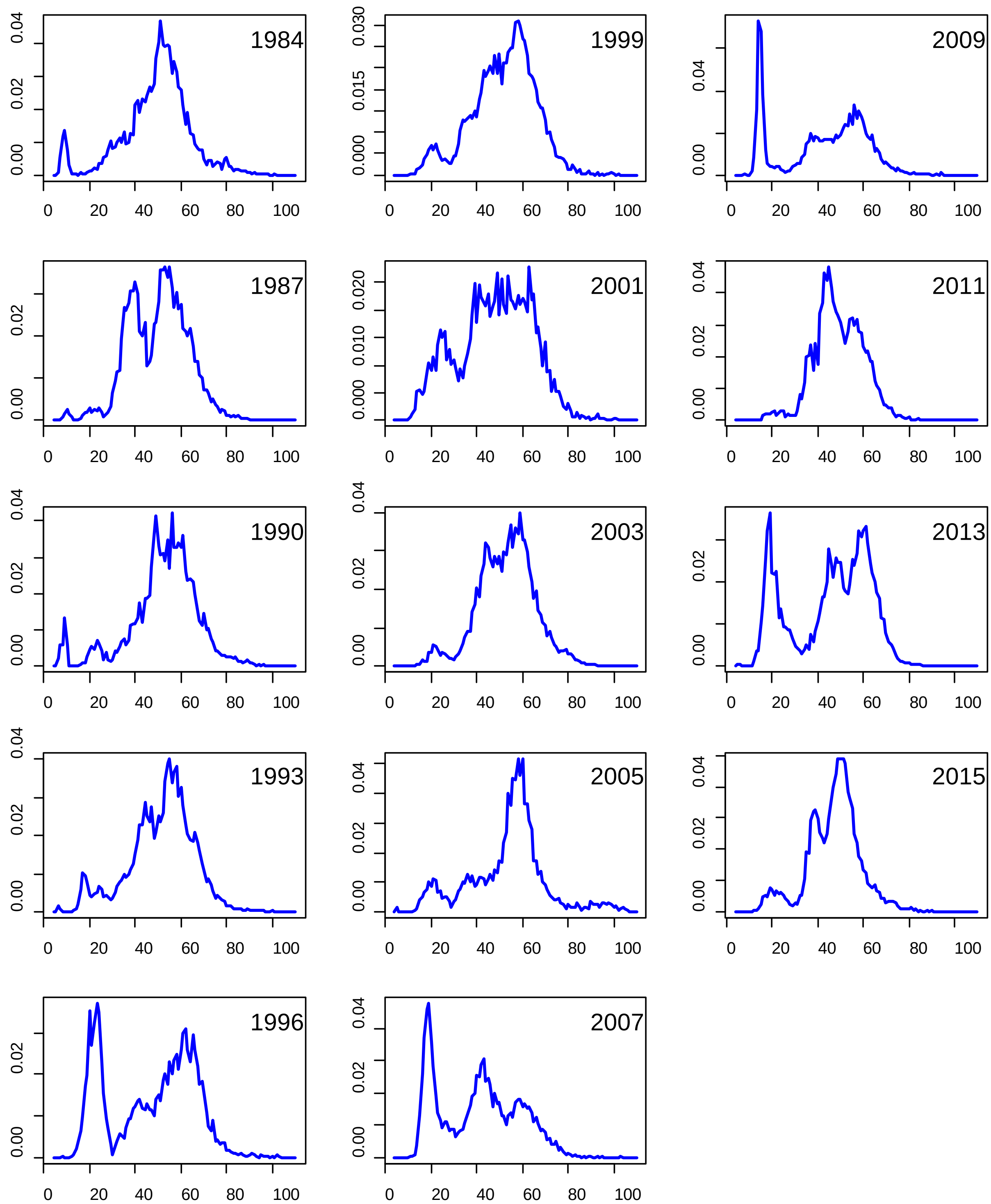


Fig. 2.7 – GOA NMFS bottom trawl survey population age composition estimates for Pacific cod

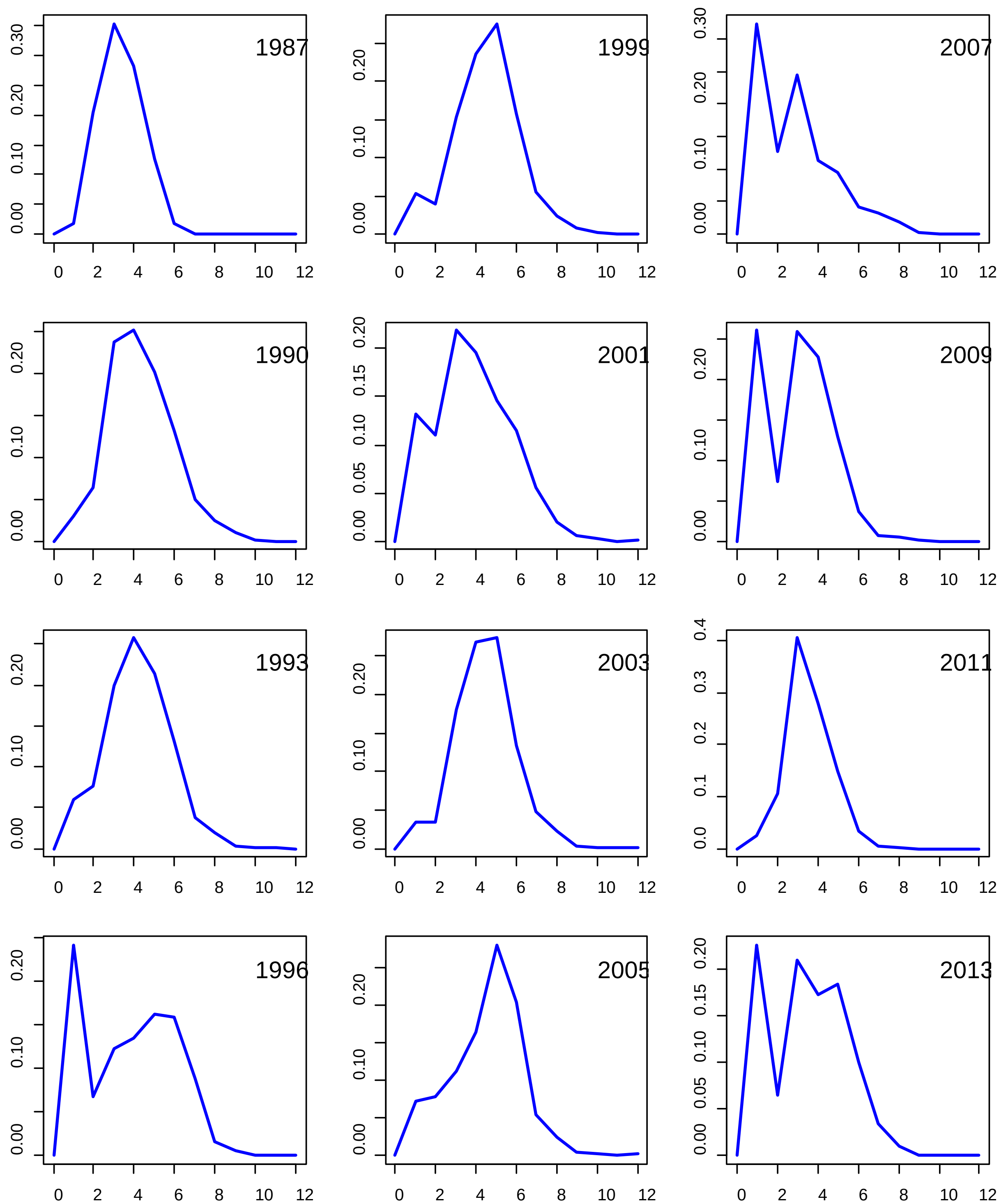


Fig. 2.8 – Estimates of spawning biomass for Models 0, 1, 2, and 3

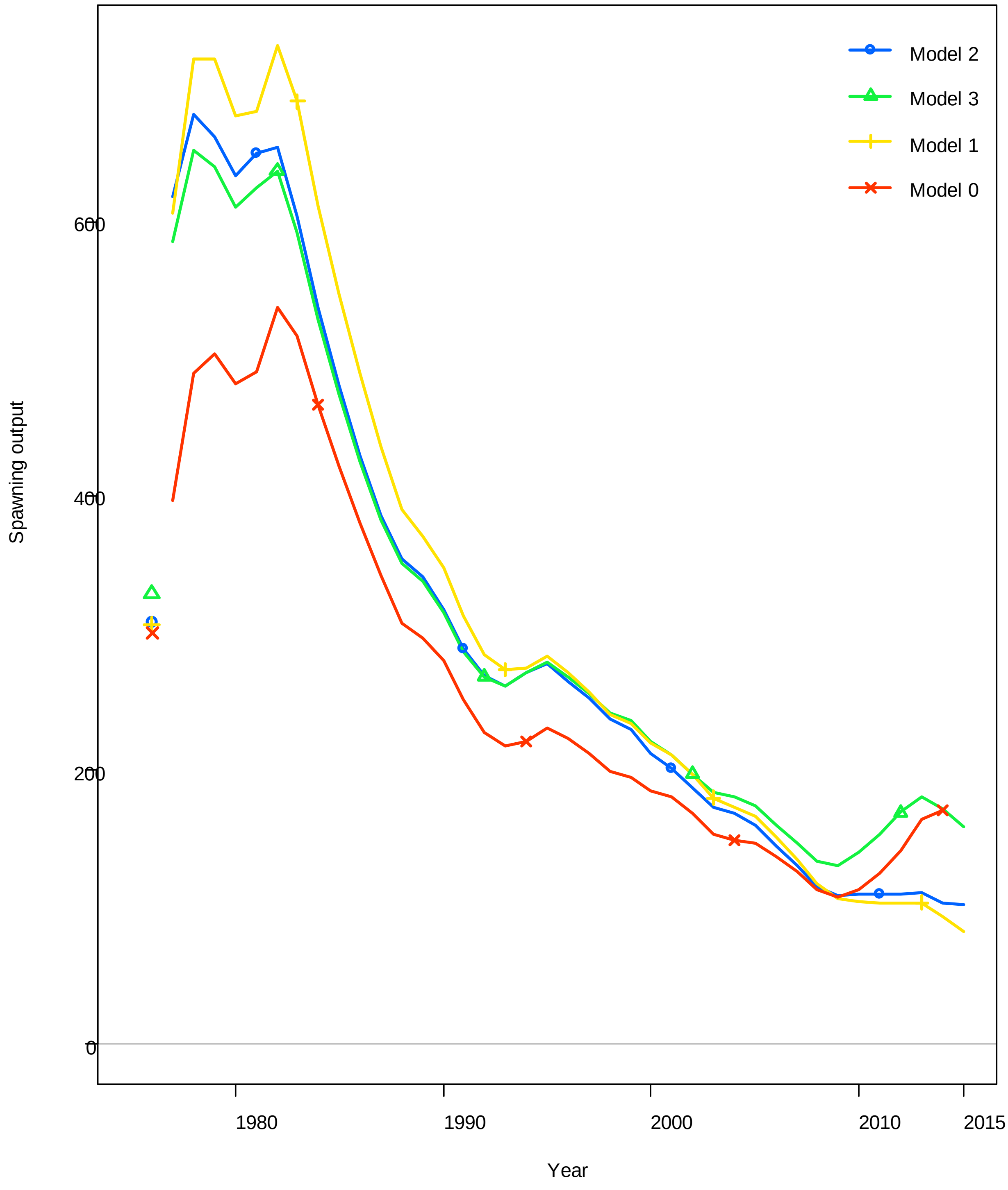


Fig. 2.9 – Estimates of age-0 recruits (billions) for Models 0, 1, 2, and 3

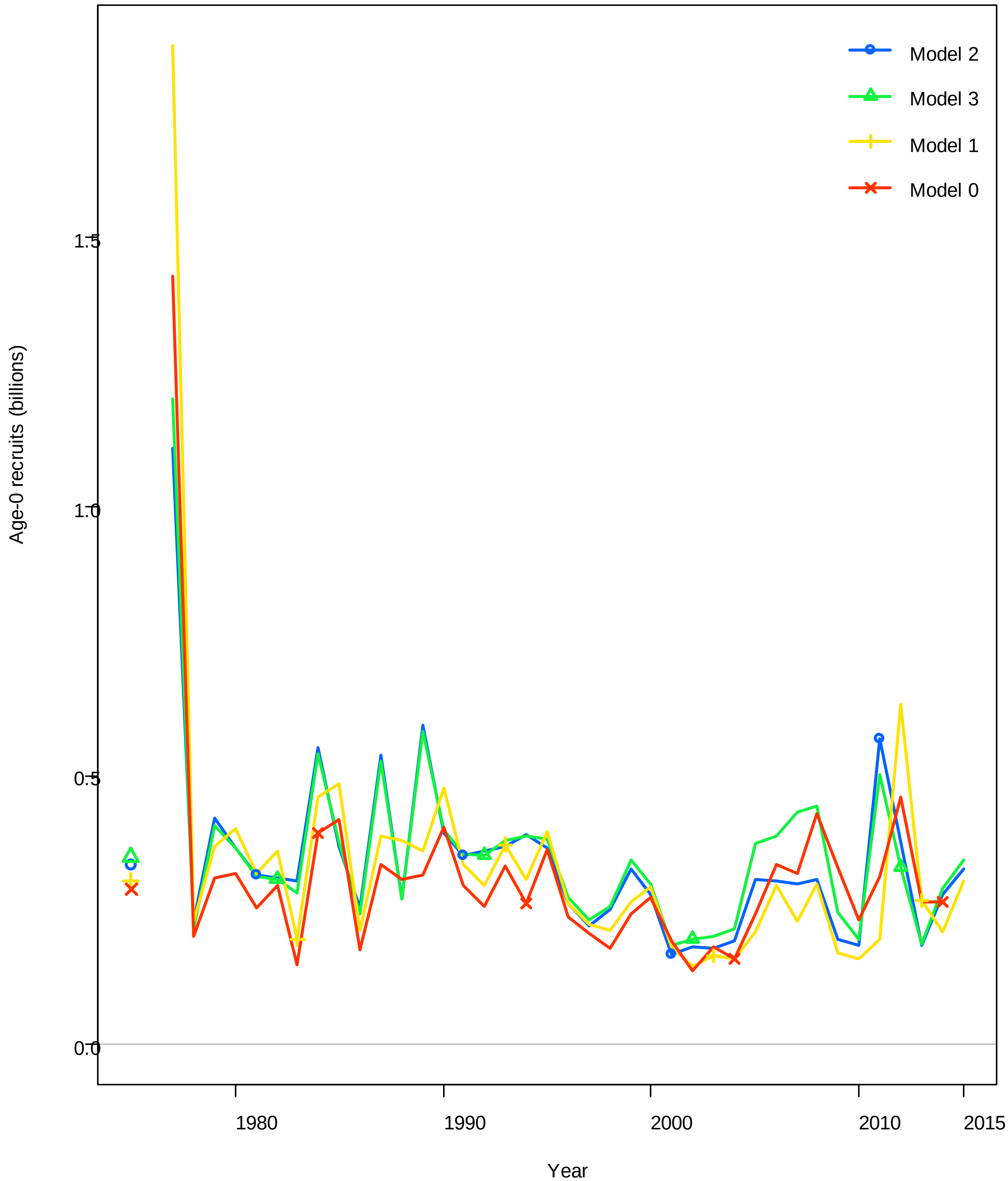


Fig. 2.10 – Fits (solid lines) to the 27-plus survey abundance estimates (solid circles, with 95% confidence intervals) for Models 2 and 3, and the full survey abundance estimates (solid circles, with 95% confidence intervals) for Models 0 and 1

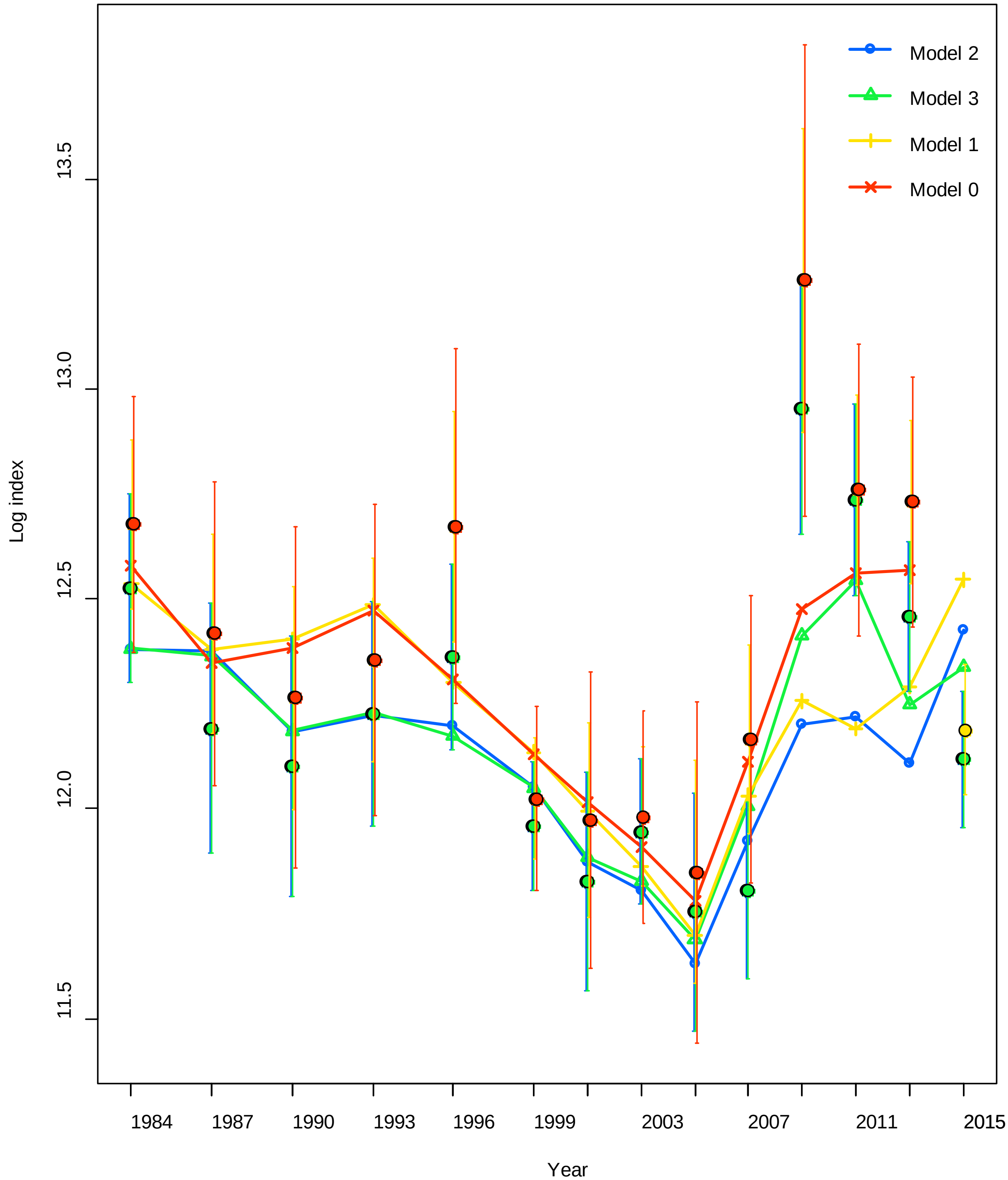


Figure 2.11 – Estimates of spawning biomass for Models 2 and 3 with different weights on fitting to the fishery catch-at-length data

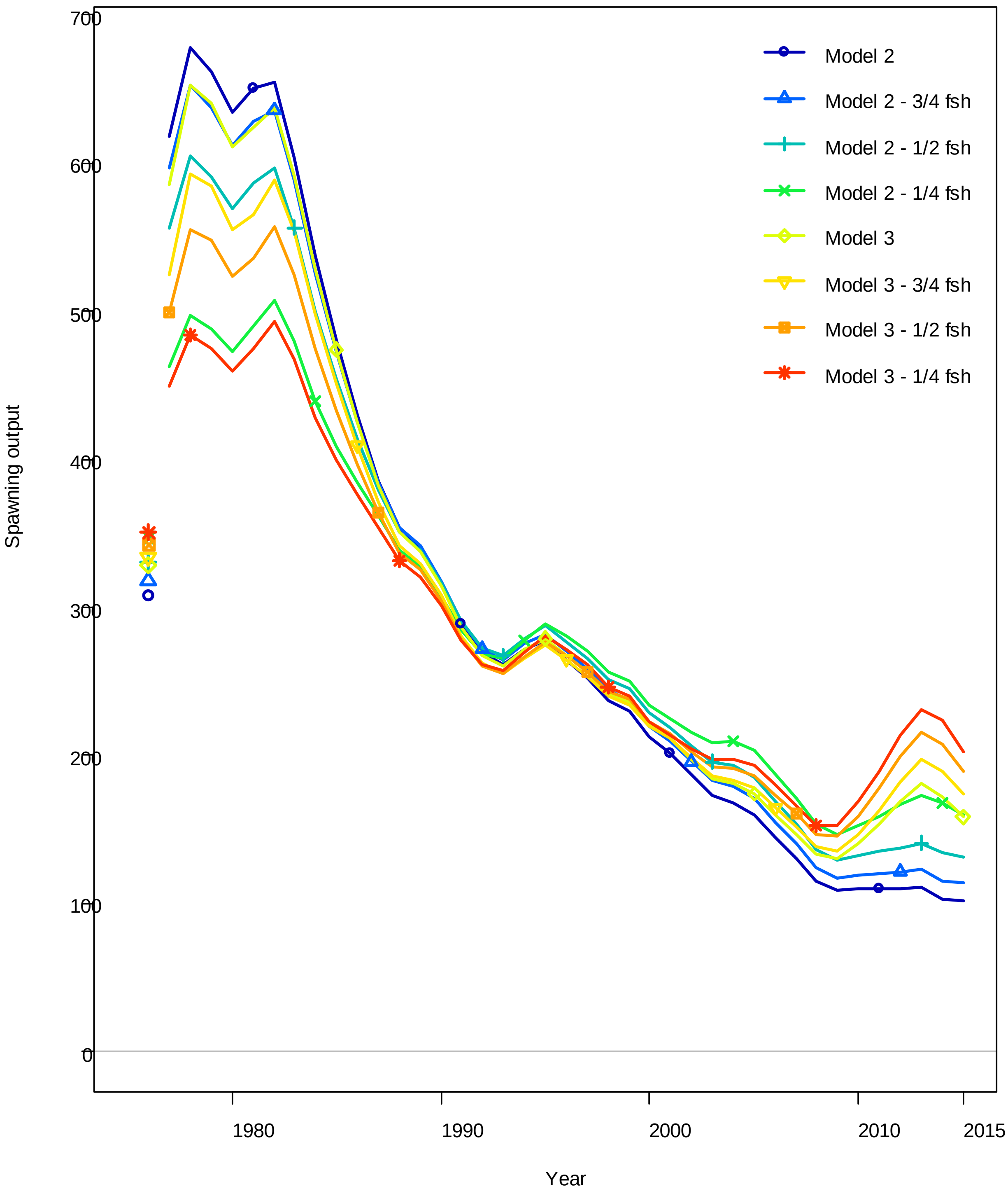


Figure 2.12 – Estimates of age-0 recruits for Models 2 and 3 with different weights on fitting to the fishery catch-at-length data

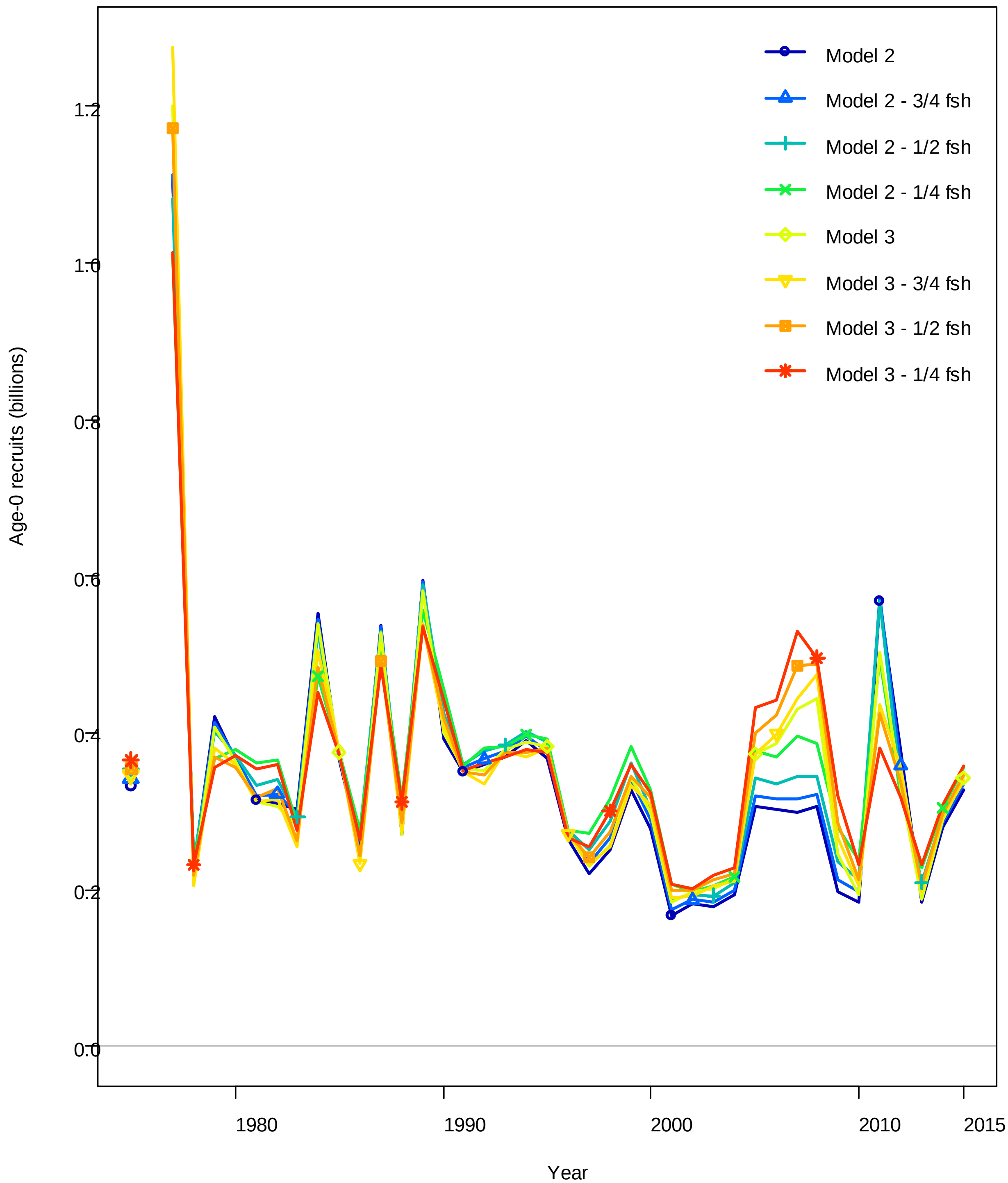


Figure 2.13 – Fits (solid lines) to the 27-plus survey abundance estimates (solid circles, with 95% confidence intervals) for Models 2 and 3 with different weights on fitting to the fishery catch-at-length data

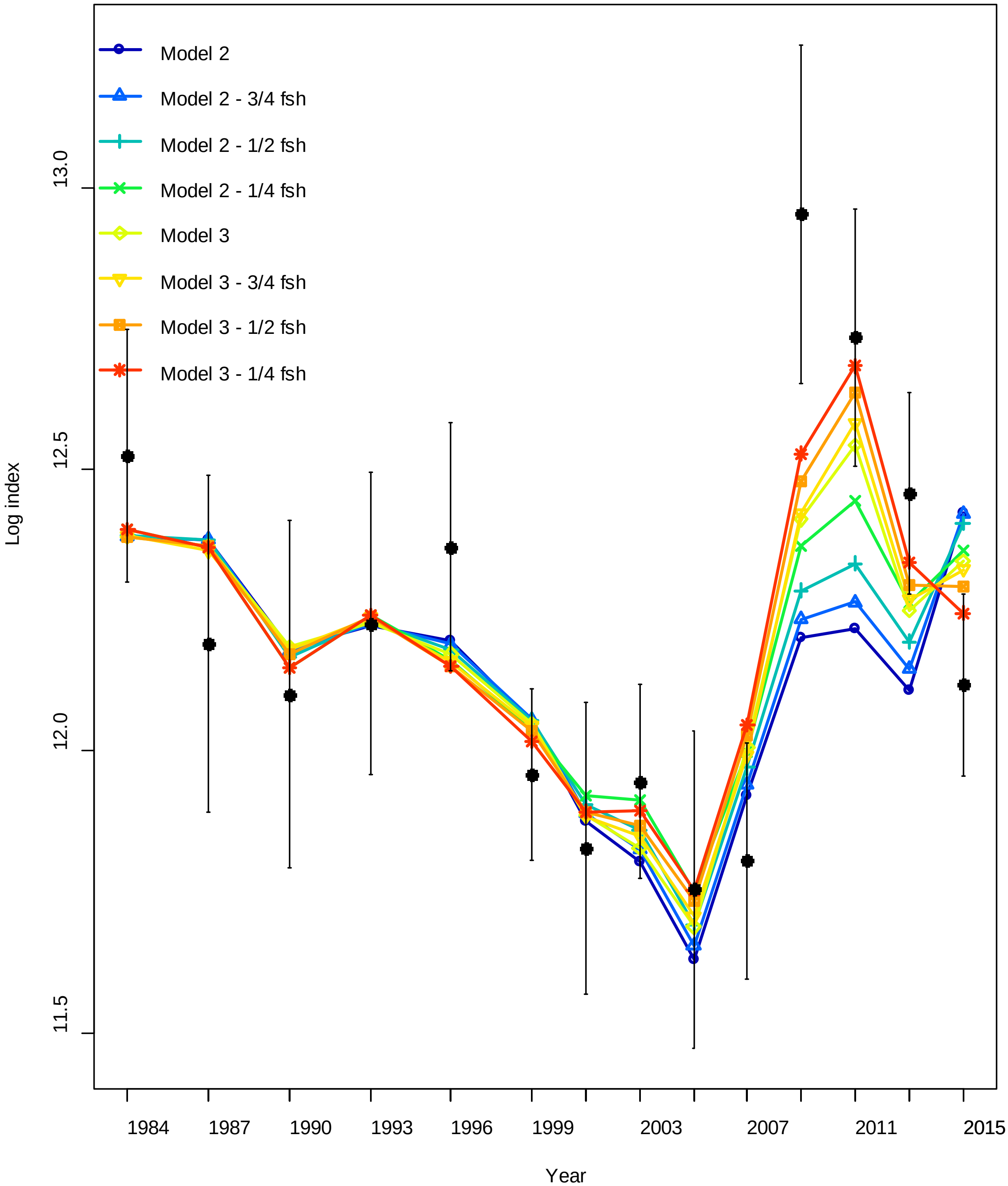


Fig. 2.14 – Estimates of total (age 0+) biomass for Model 3 – ¼ fsh

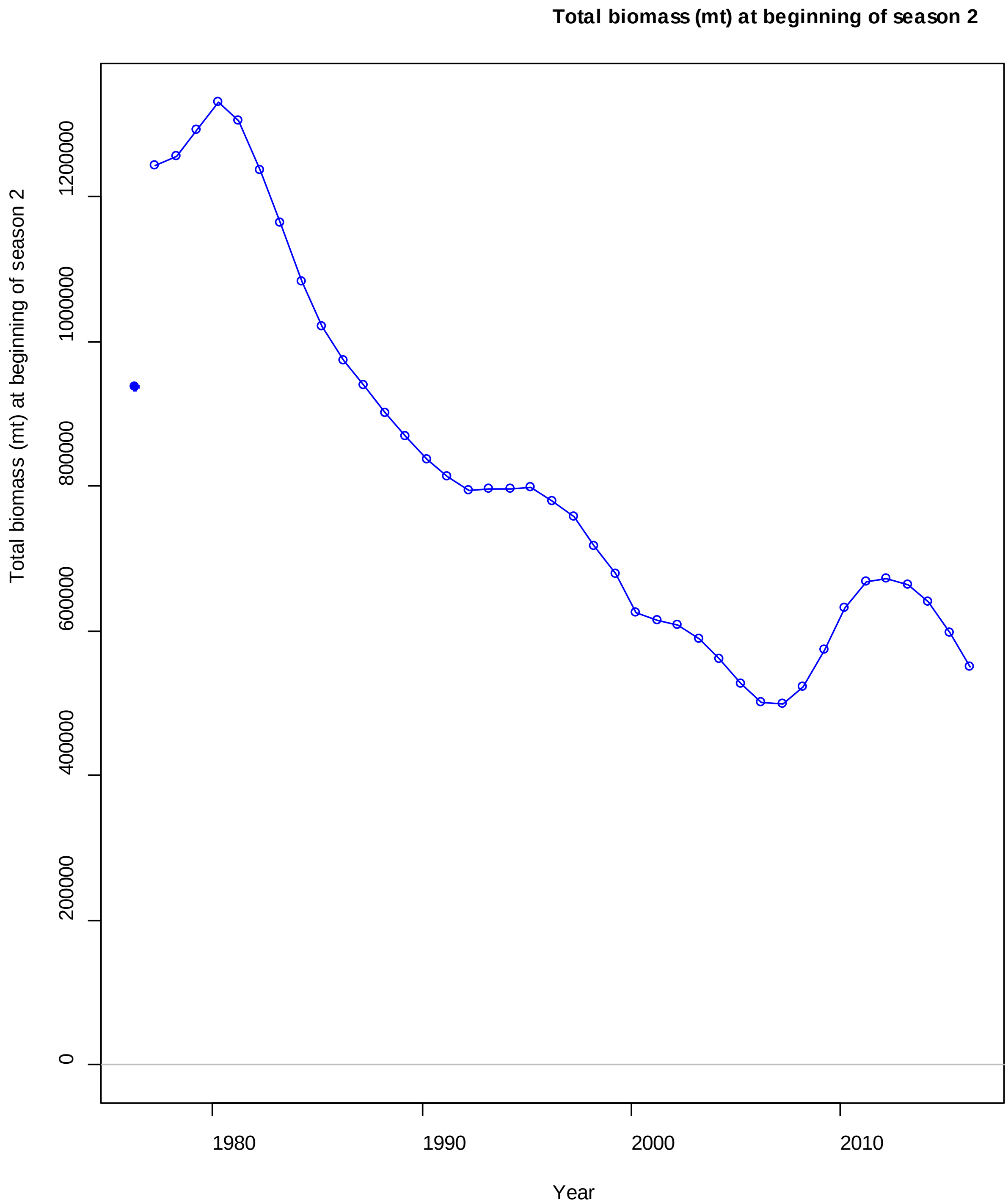


Fig. 2.15 – Estimates of female spawning biomass for Model 3 – ¼ fsh

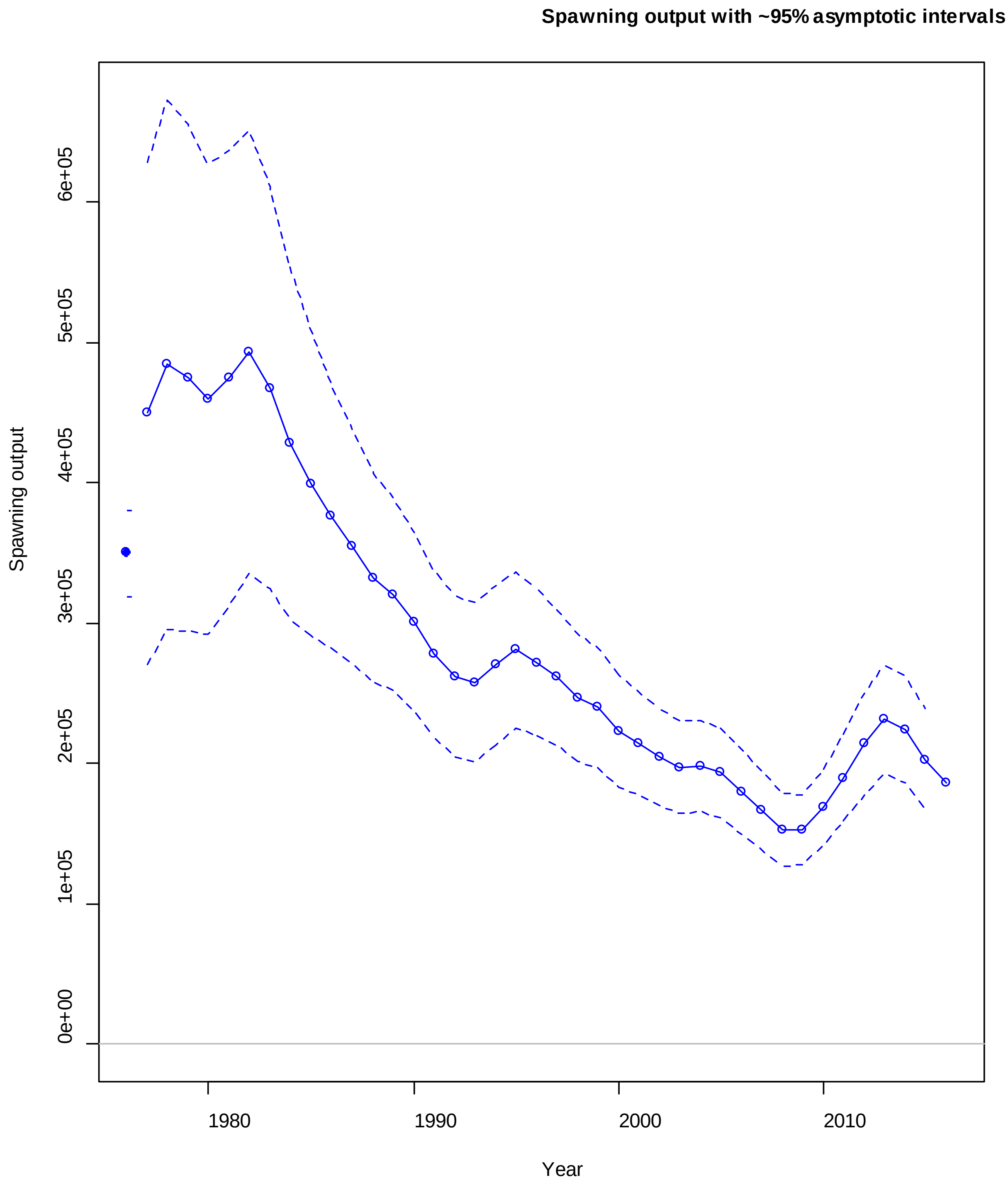


Fig. 2.16 – Estimates of age-0 recruits for Model 3 – ¼ fsh

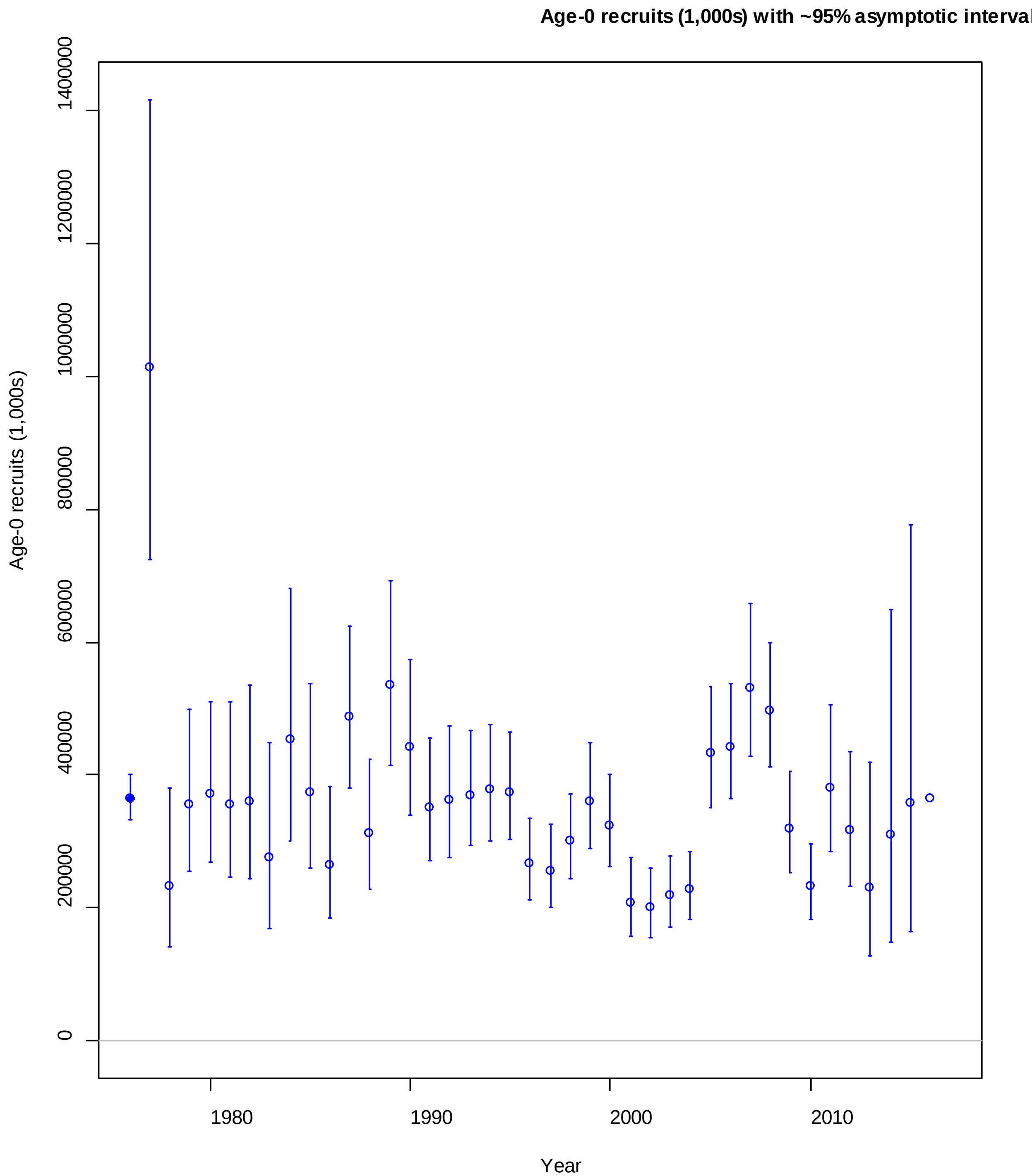
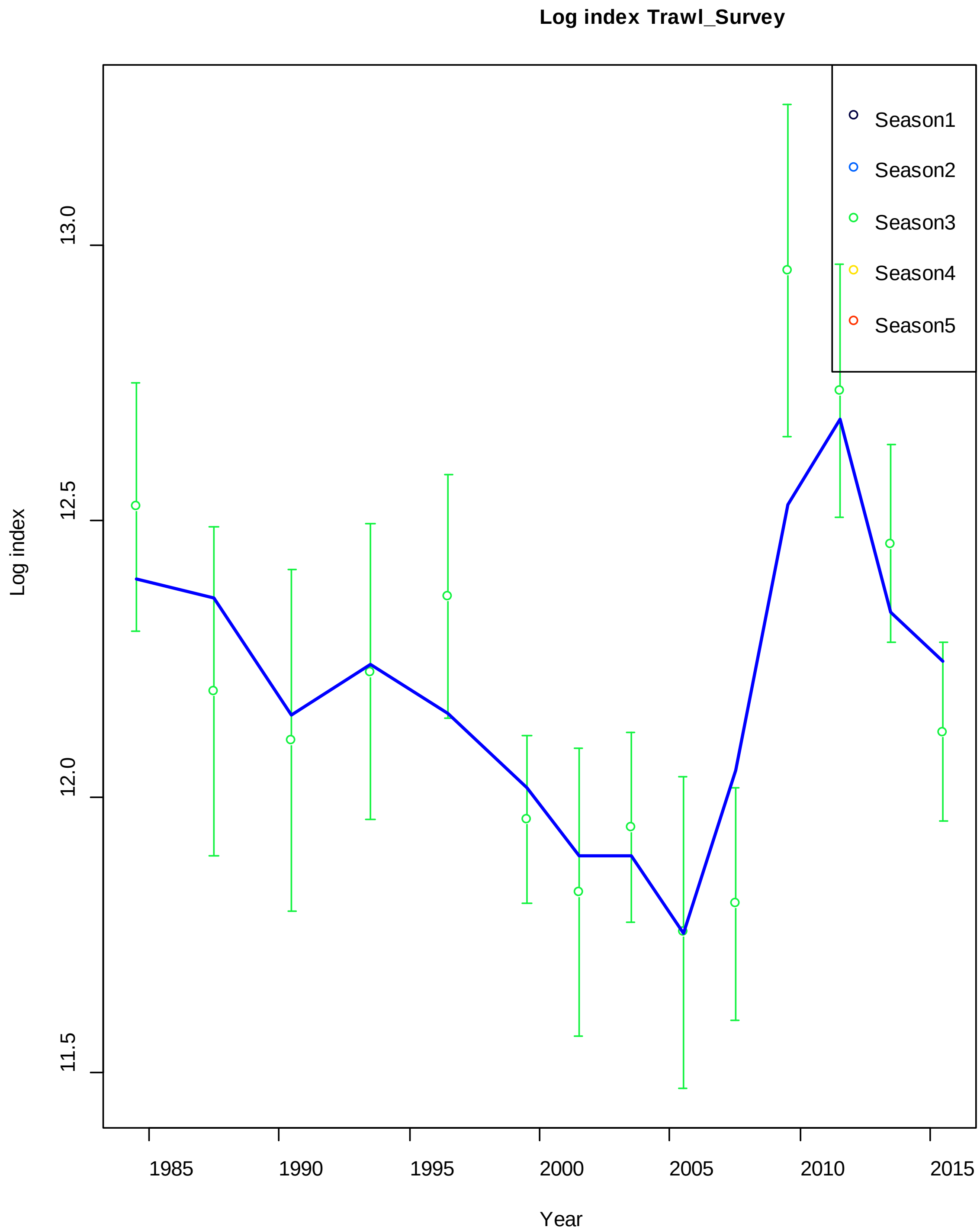


Fig. 2.17 – Fit to the survey abundance estimates with 95% confidence intervals for Model 3 – ¼ fsh



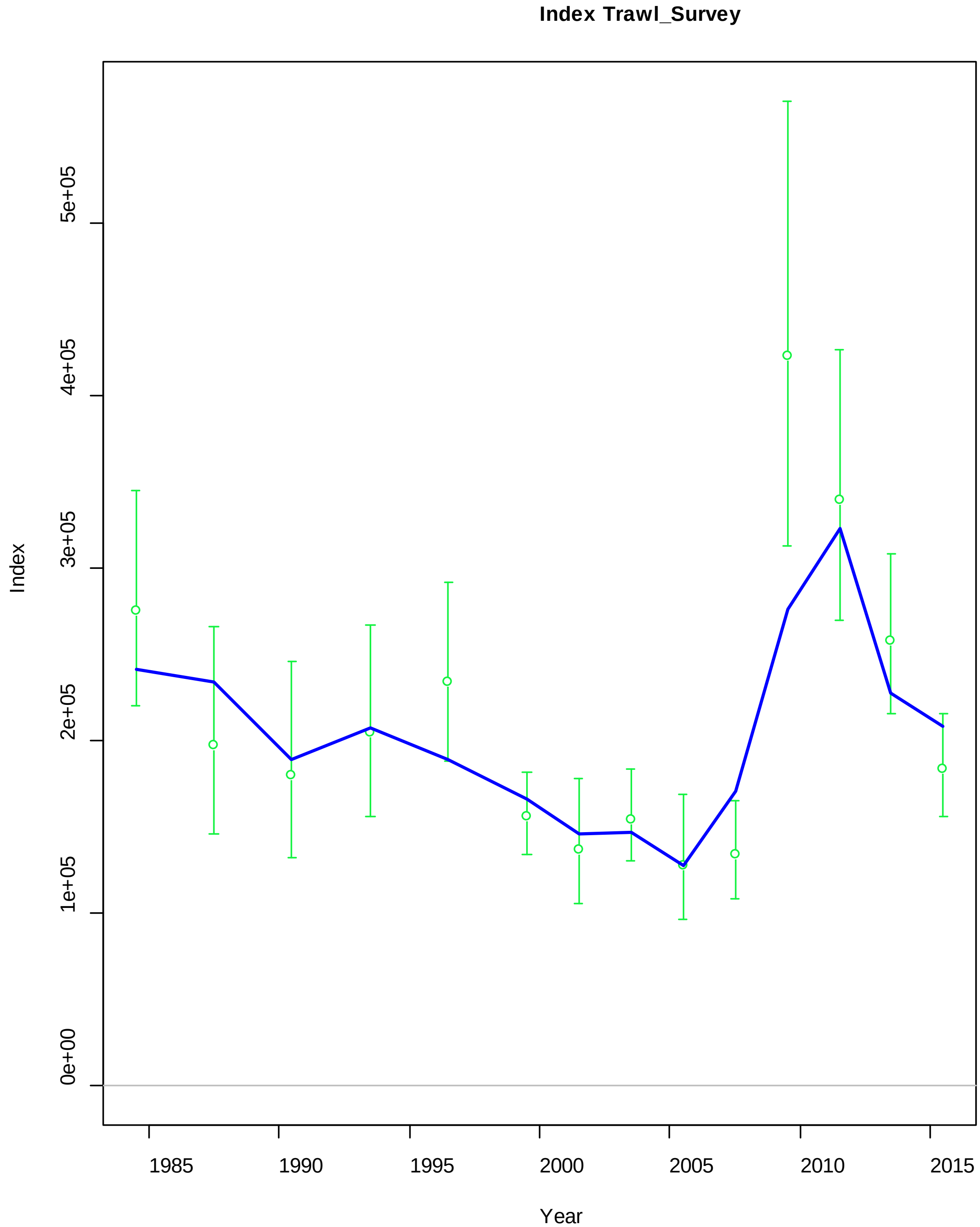

Index Trawl_Survey
Index
0e+00
1e+05
2e+05
3e+05
4e+05
5e+05
1985
1990
1995
2000
2005
2010
2015
Year

Fig. 2.18 – Estimates of spawning biomass (t) and age-0 recruits for Model 3 – ¼ fsh; the solid black line is the median, and the solid green line is the bias-adjusted median

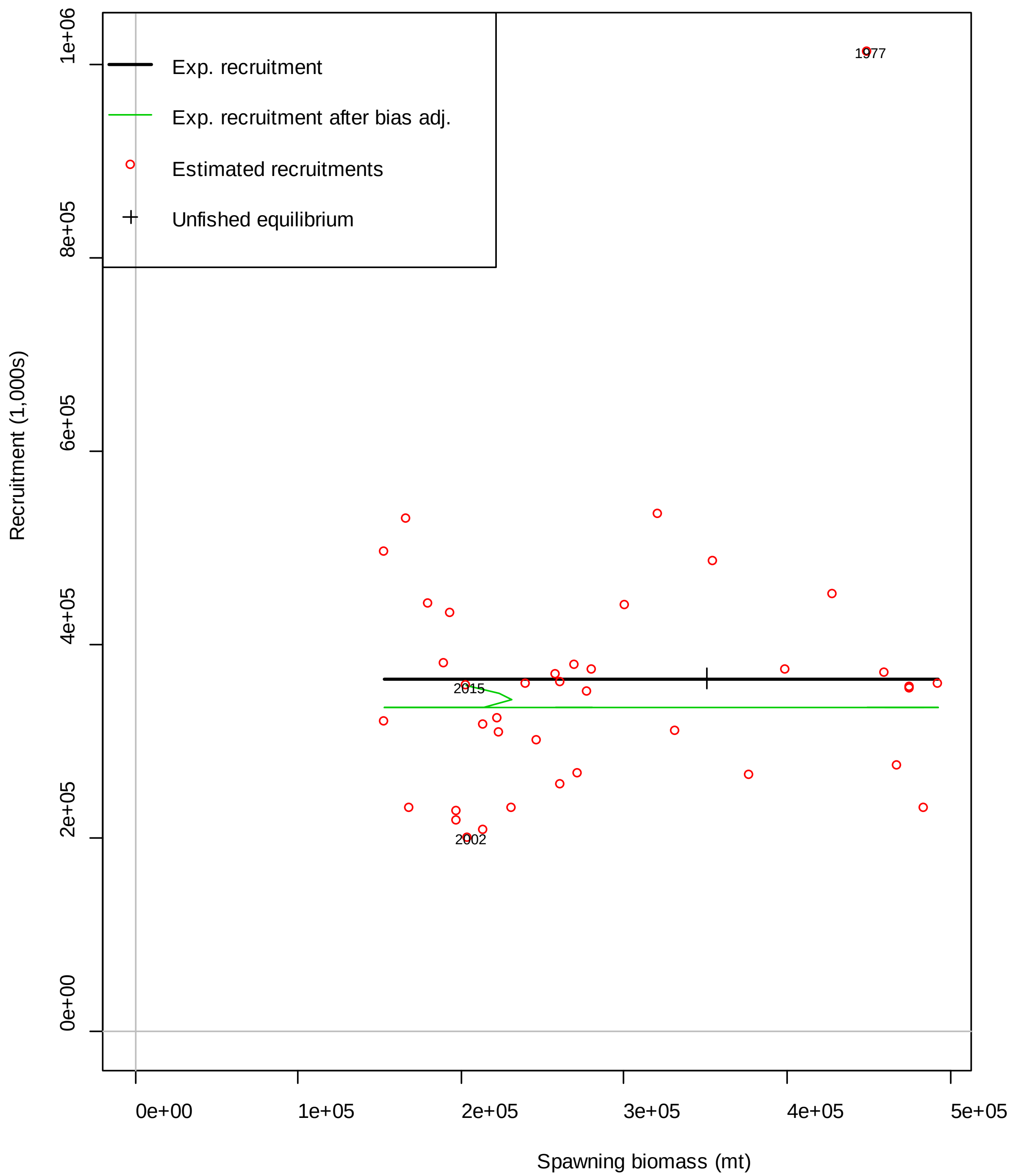


Figure 2.19 – Estimates of the survey population length composition data (not used in model fitting) for Model 3 – ¼ fsh

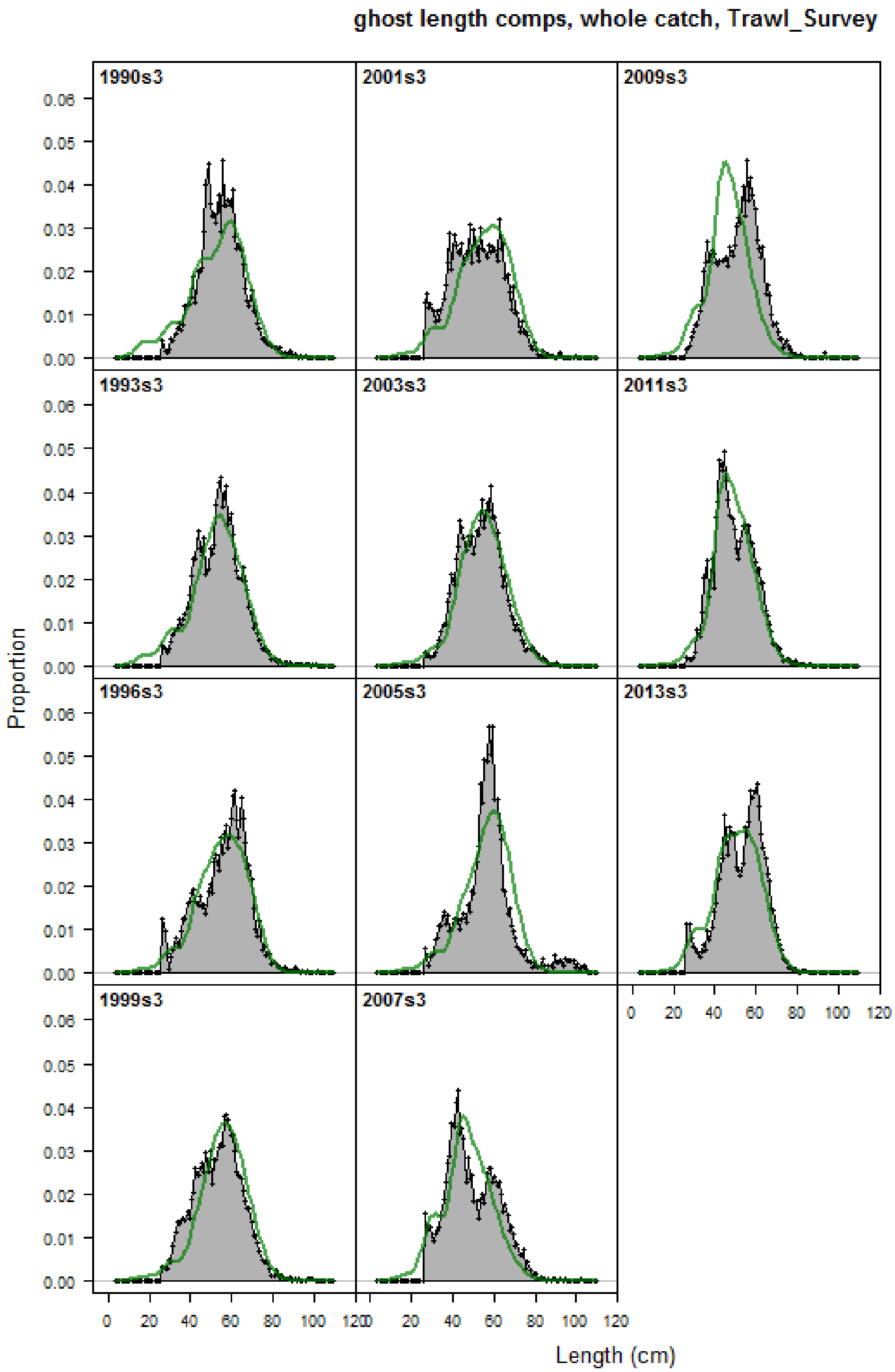


Figure 2.20 – Fits to the survey population age composition data for Model 3 – ¼ fsh

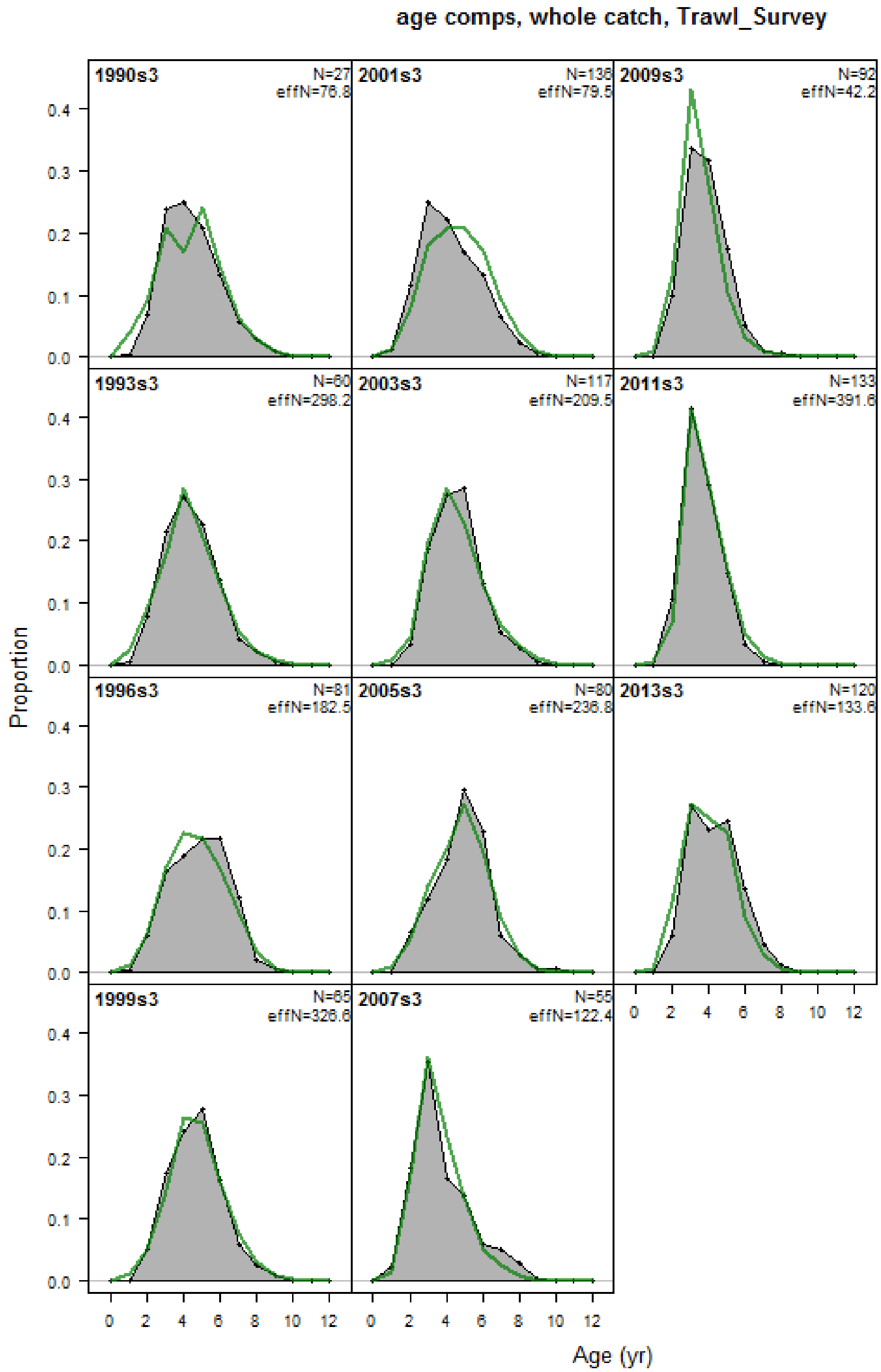


Fig. 2.21 – Fits to the survey population length composition data for Model 3 – ¼ fsh

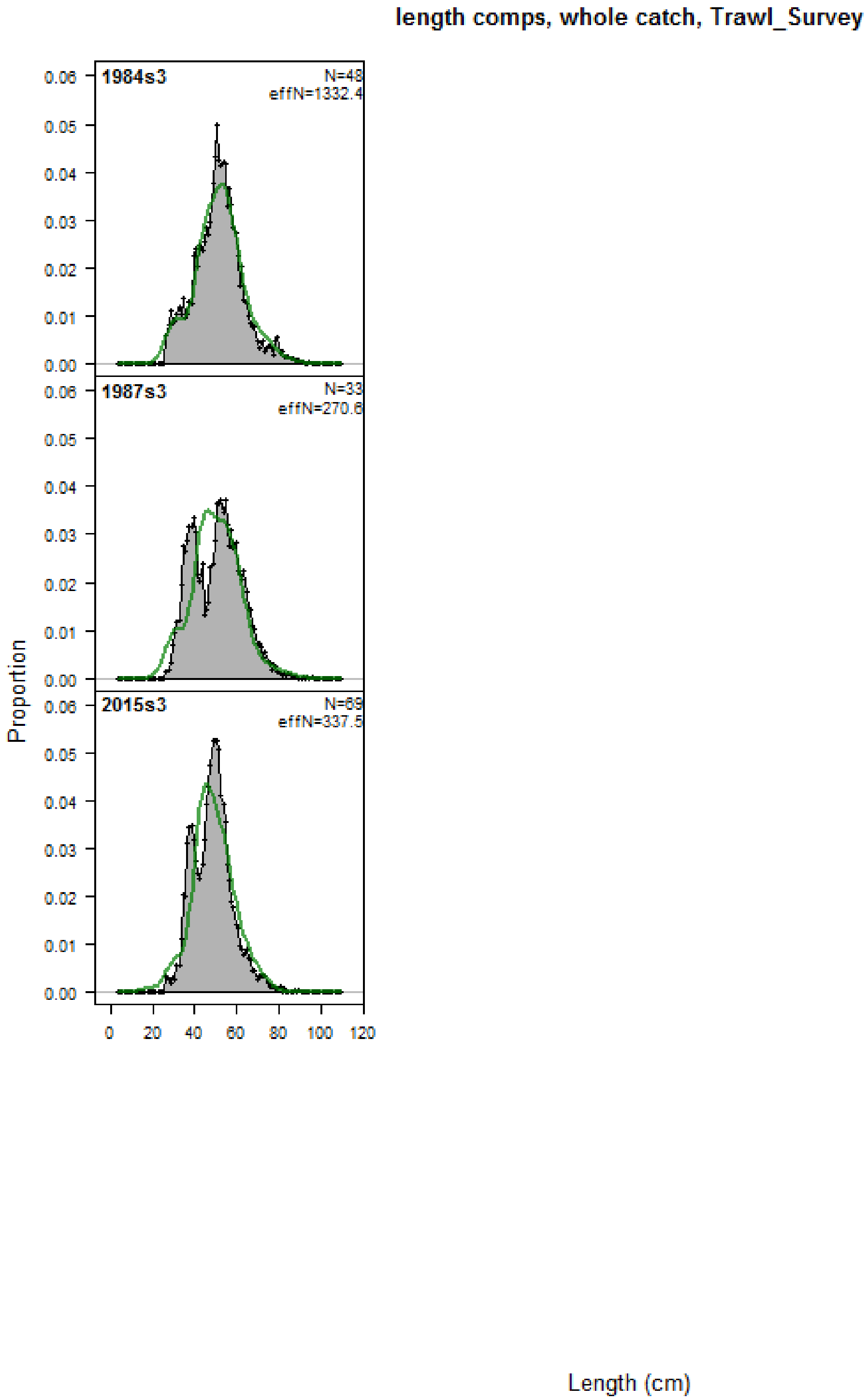
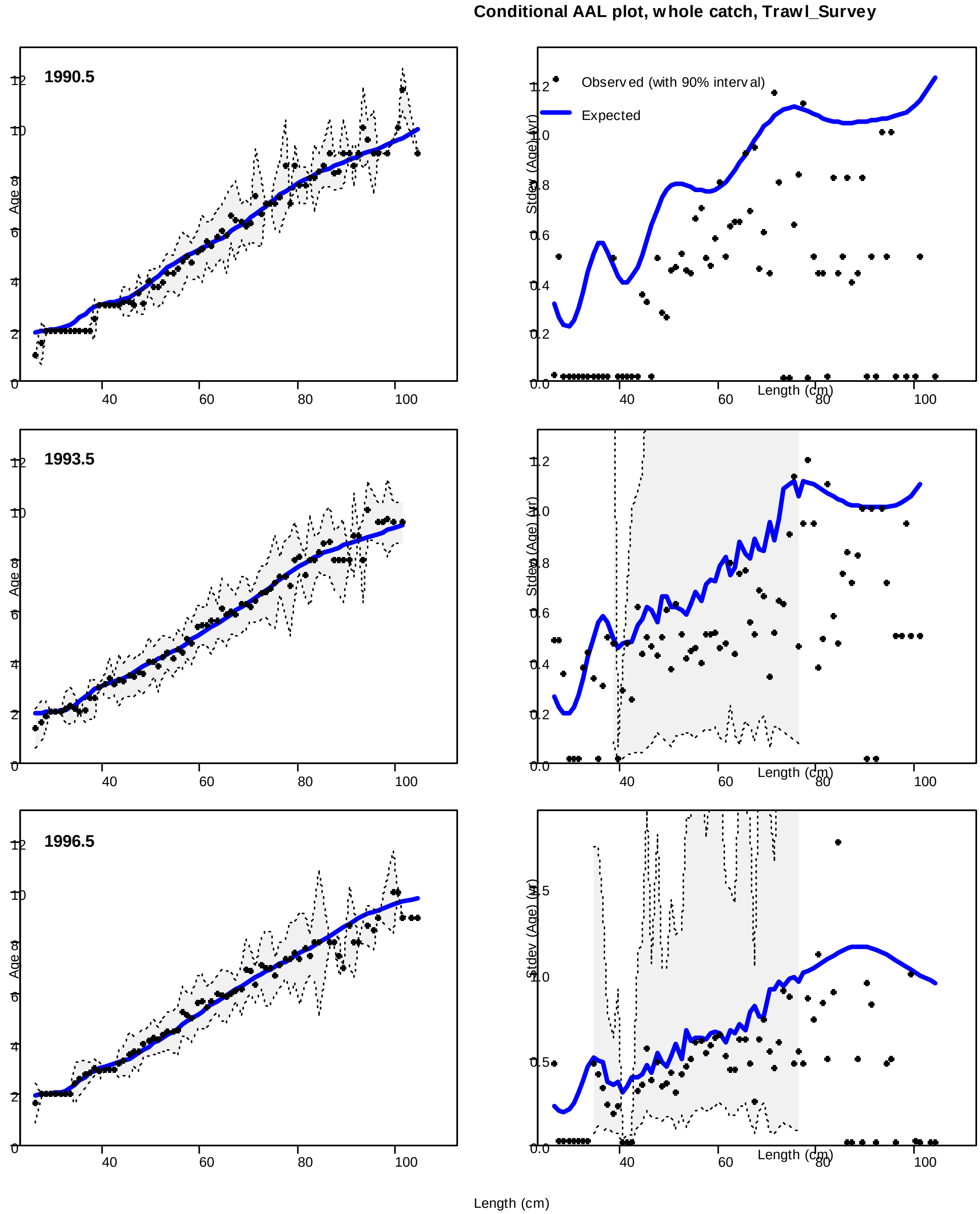
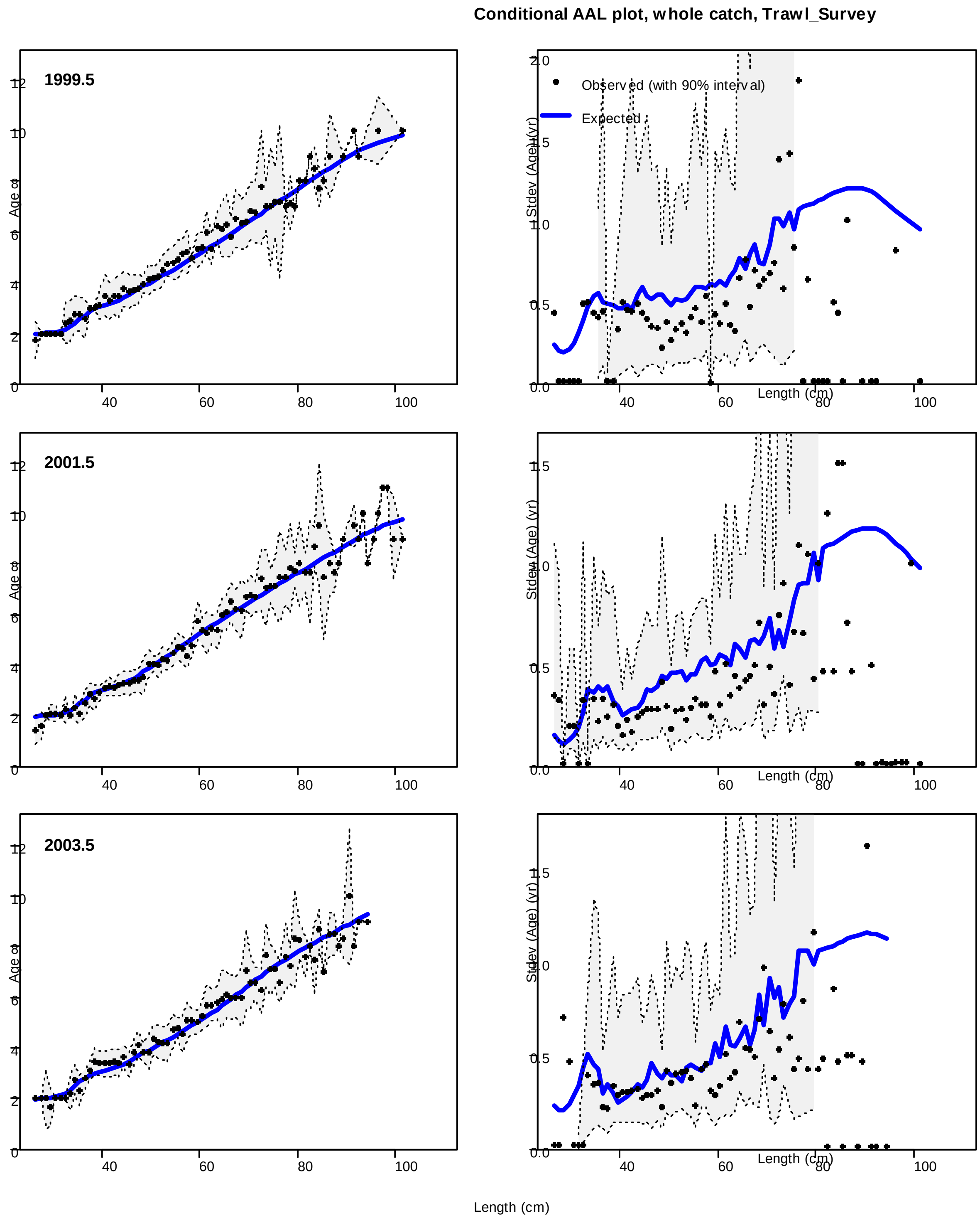


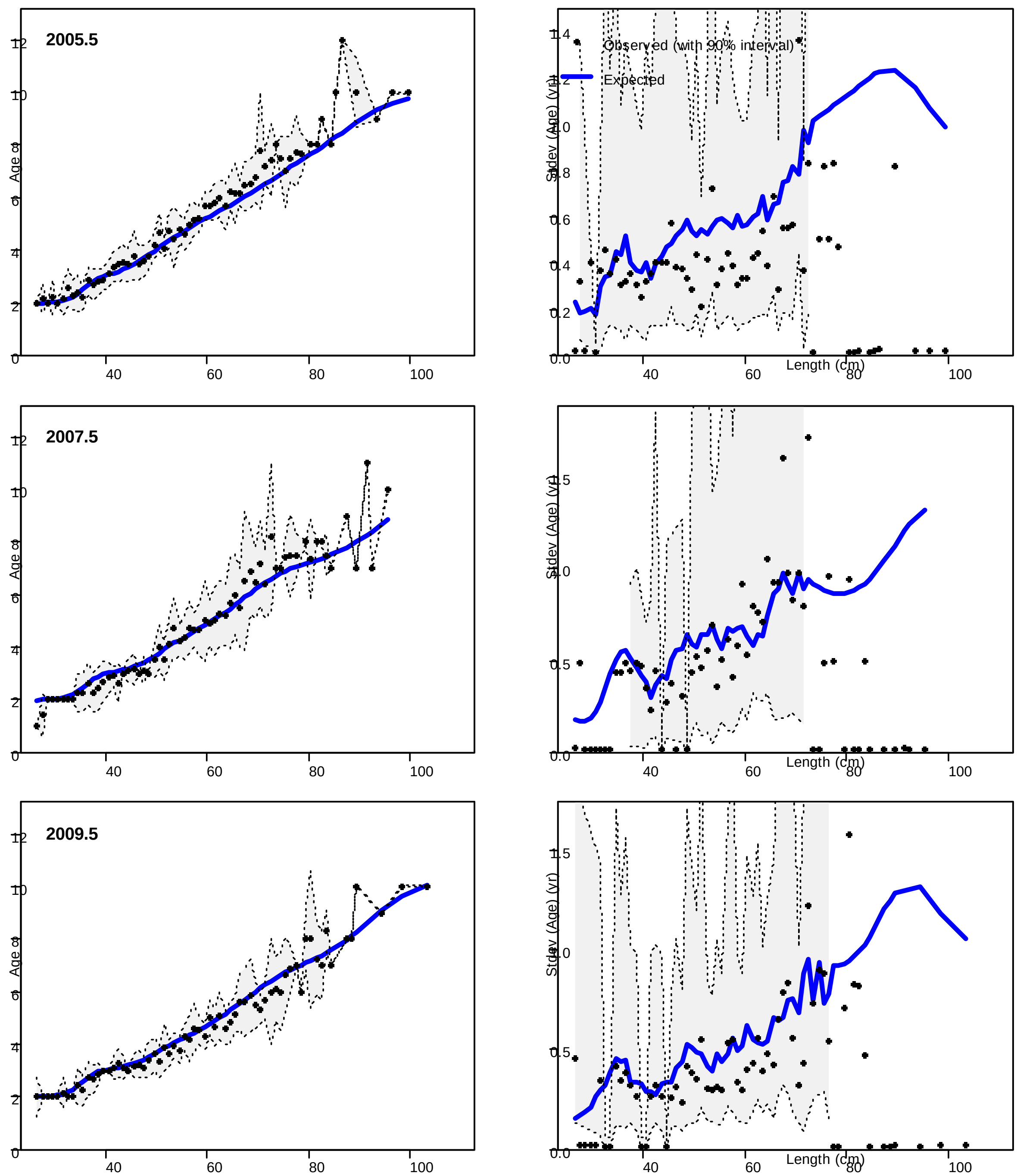
Fig. 2.22 – Fits to the survey conditional age-at-length data for Model 3 – ¼ fsh





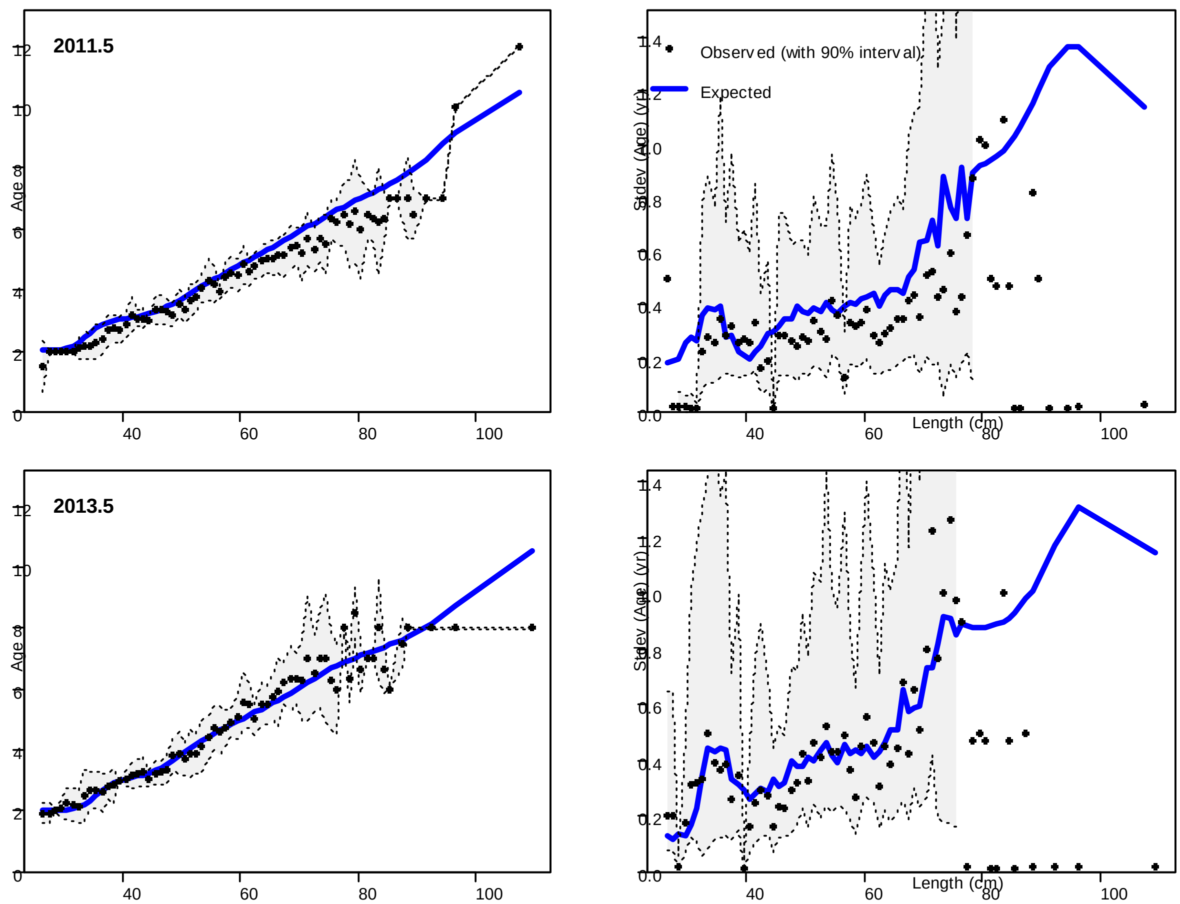
Conditional AAL plot, whole catch, Trawl_Survey
1999.5
2001.5
2003.5
Age
Stdev (Age) (yr)
Observed (with 90% interval)
Expected
Length (cm)

Conditional AAL plot, whole catch, Trawl_Survey



Length (cm)

Conditional AAL plot, whole catch, Trawl_Survey



Length (cm)

Fig. 2.23 – Estimated length-at-age (cm) for Model 3 – ¼ fsh

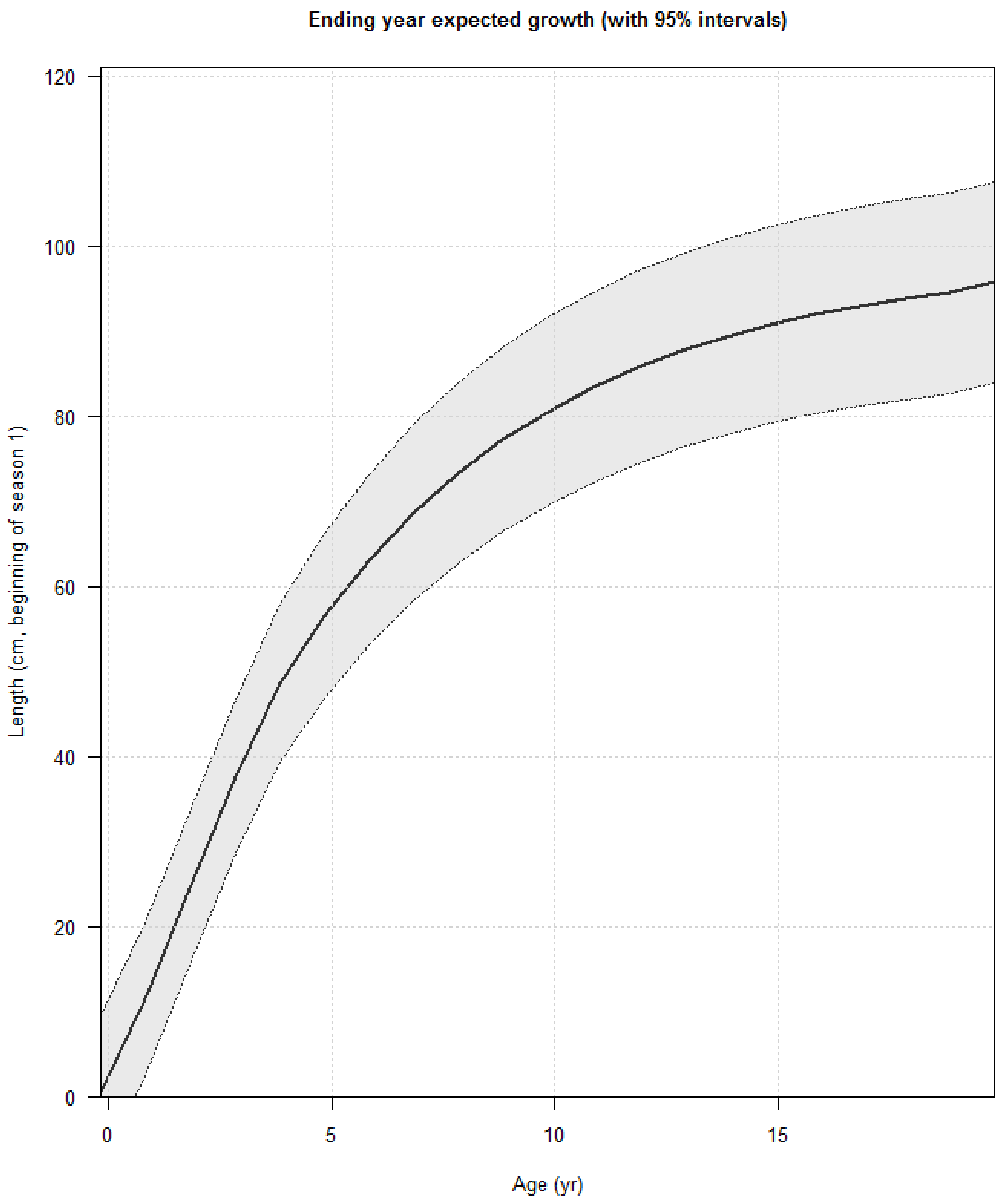


Fig. 2.24 – Survey selectivity-at-age for Model 3 – ¼ fsh

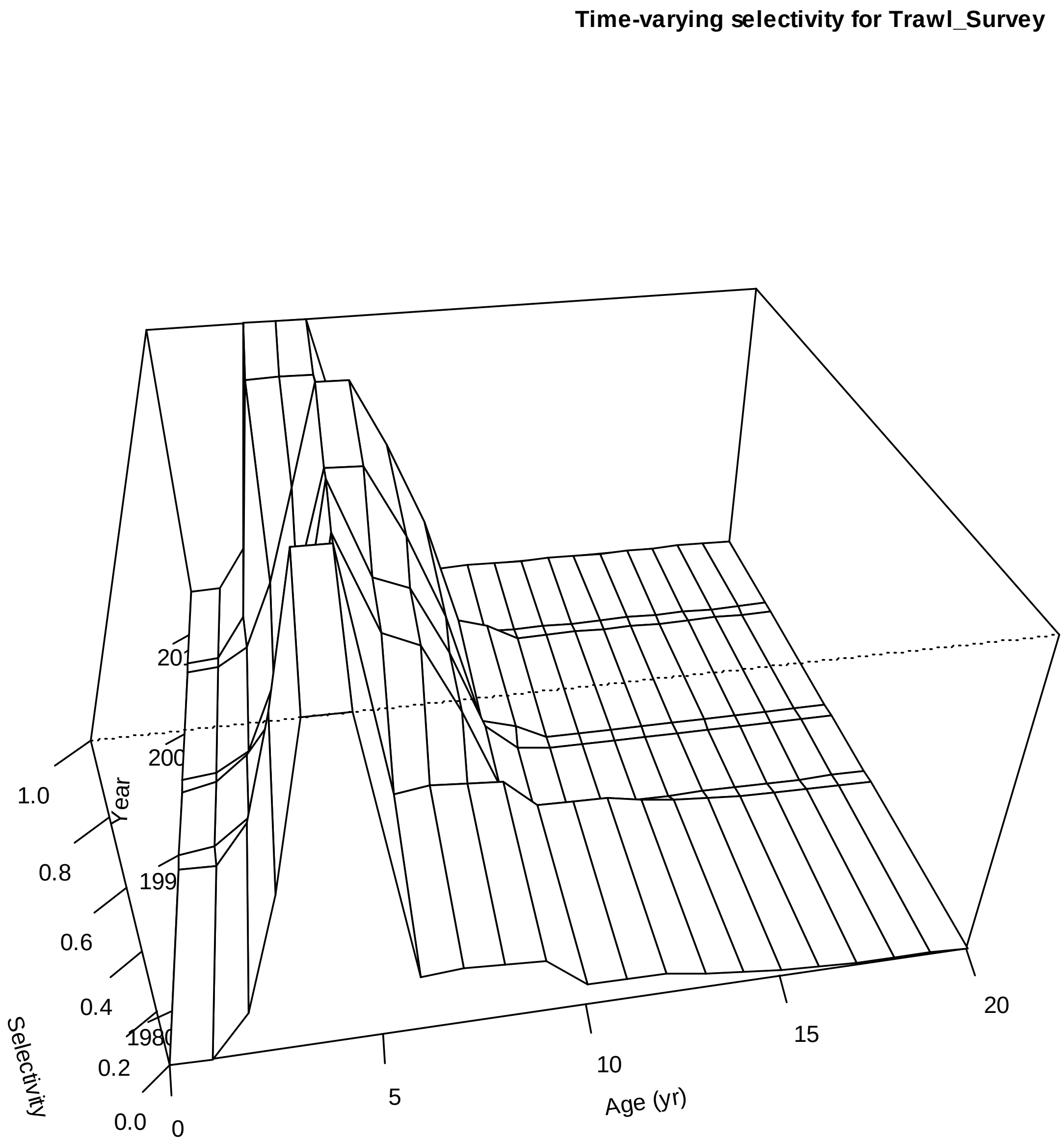
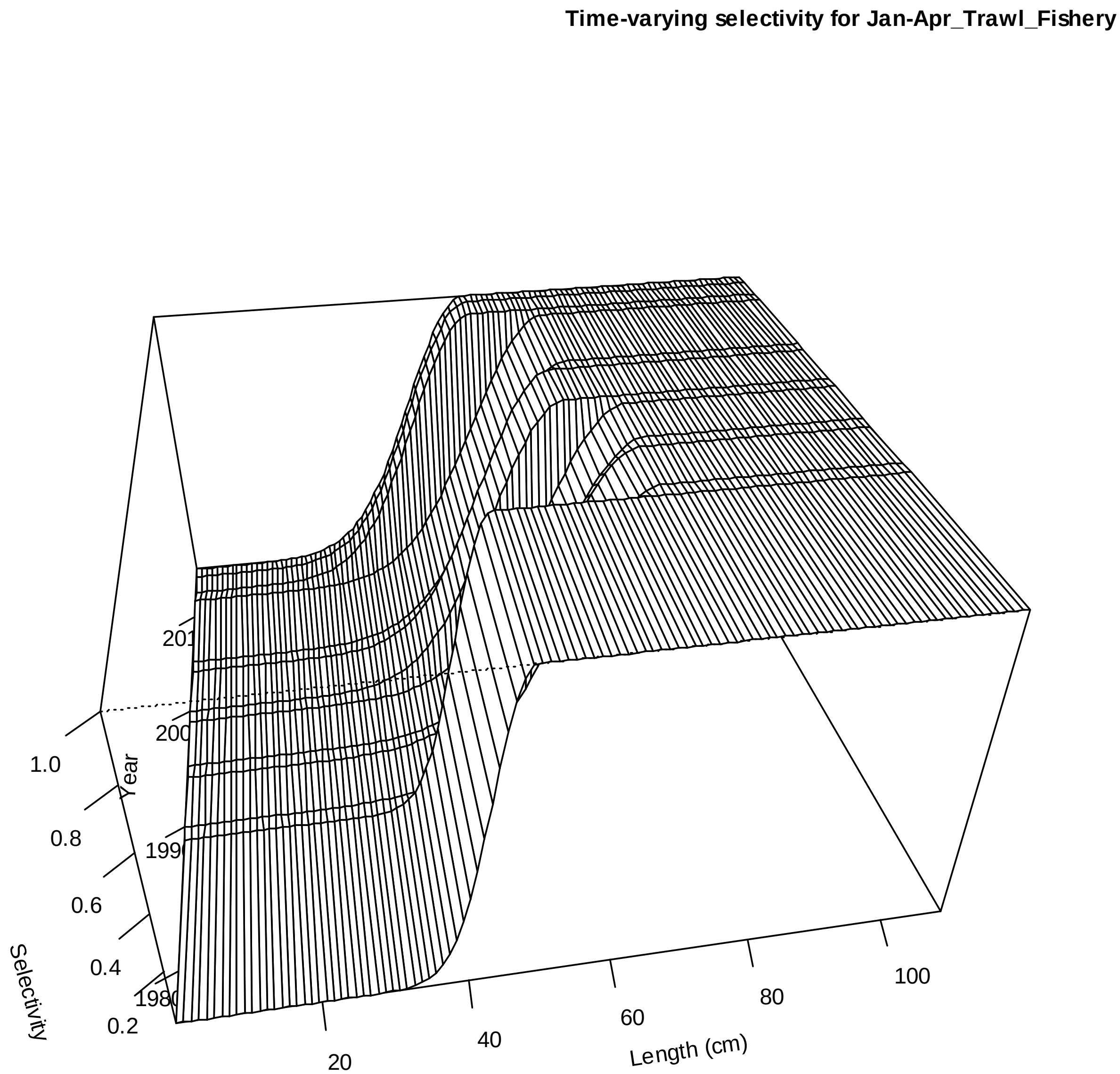
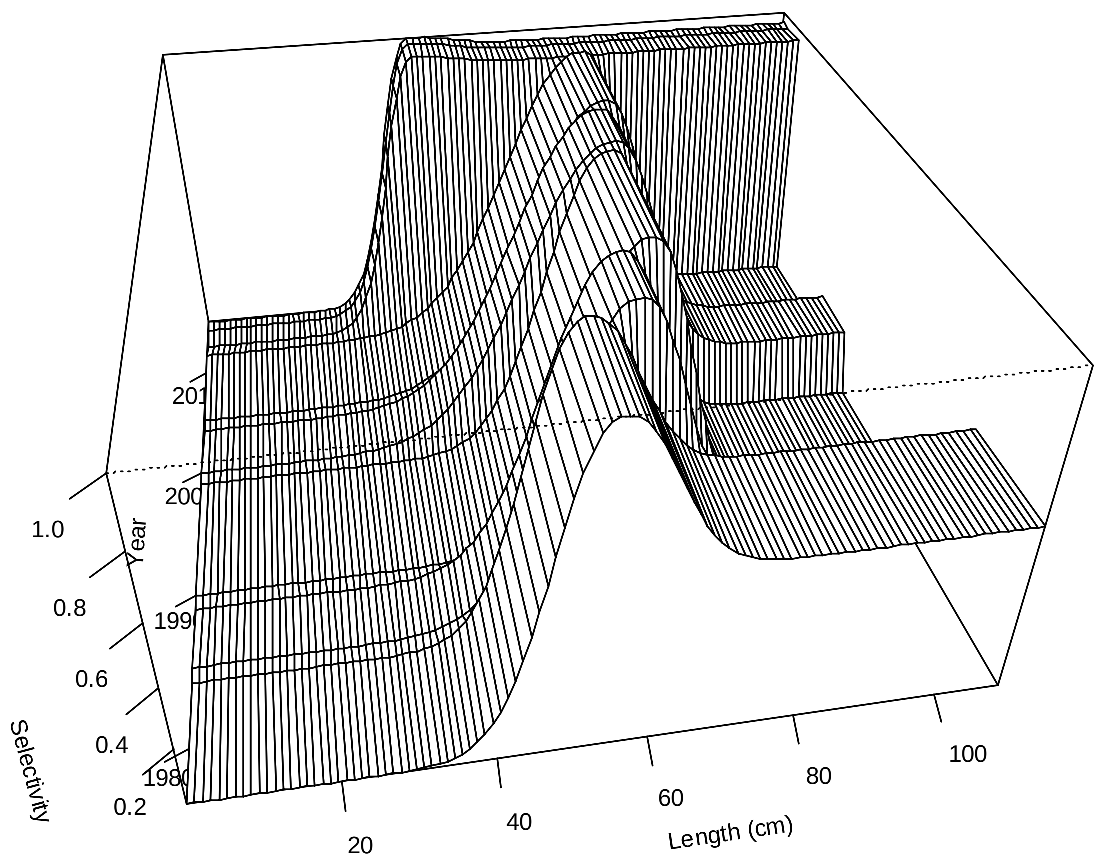
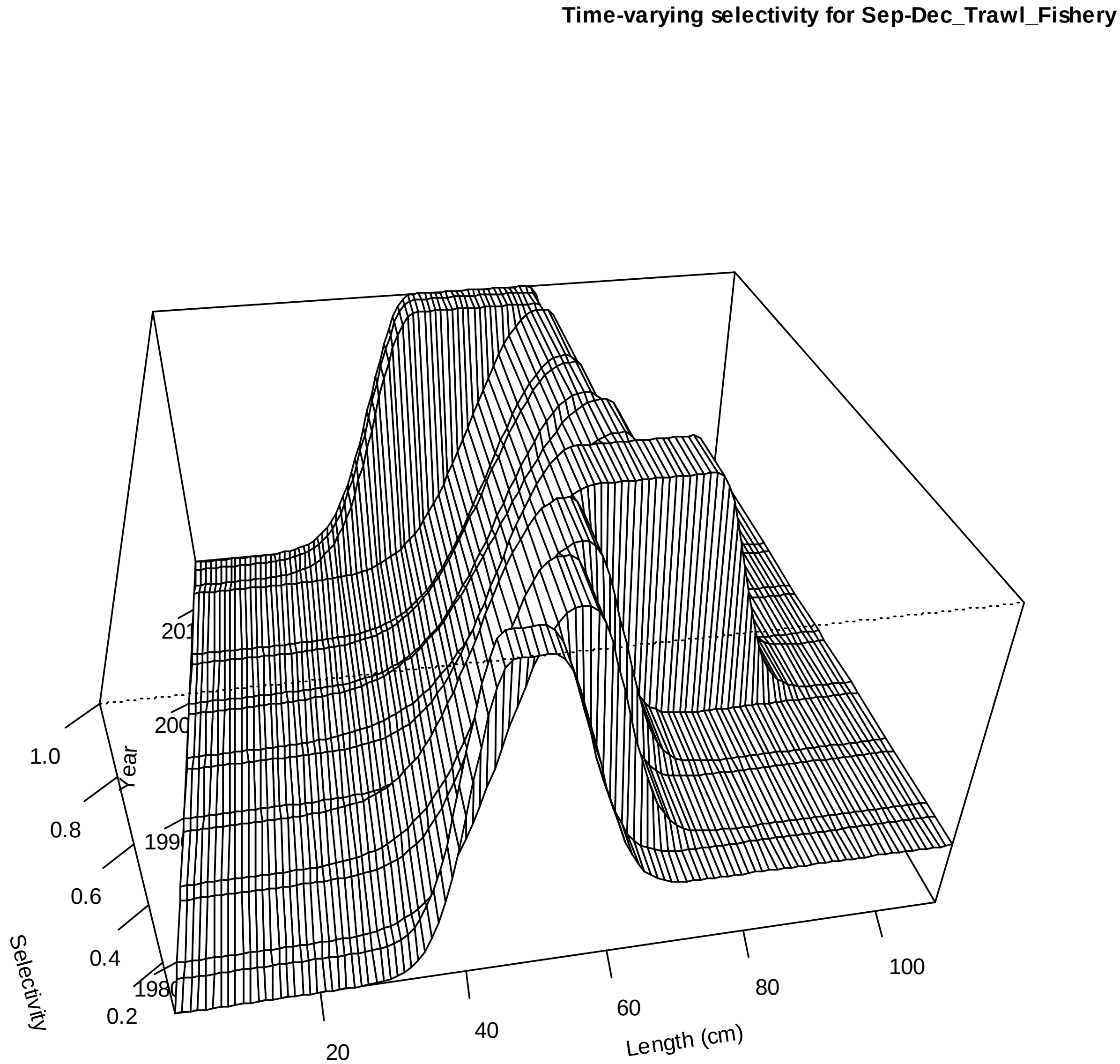


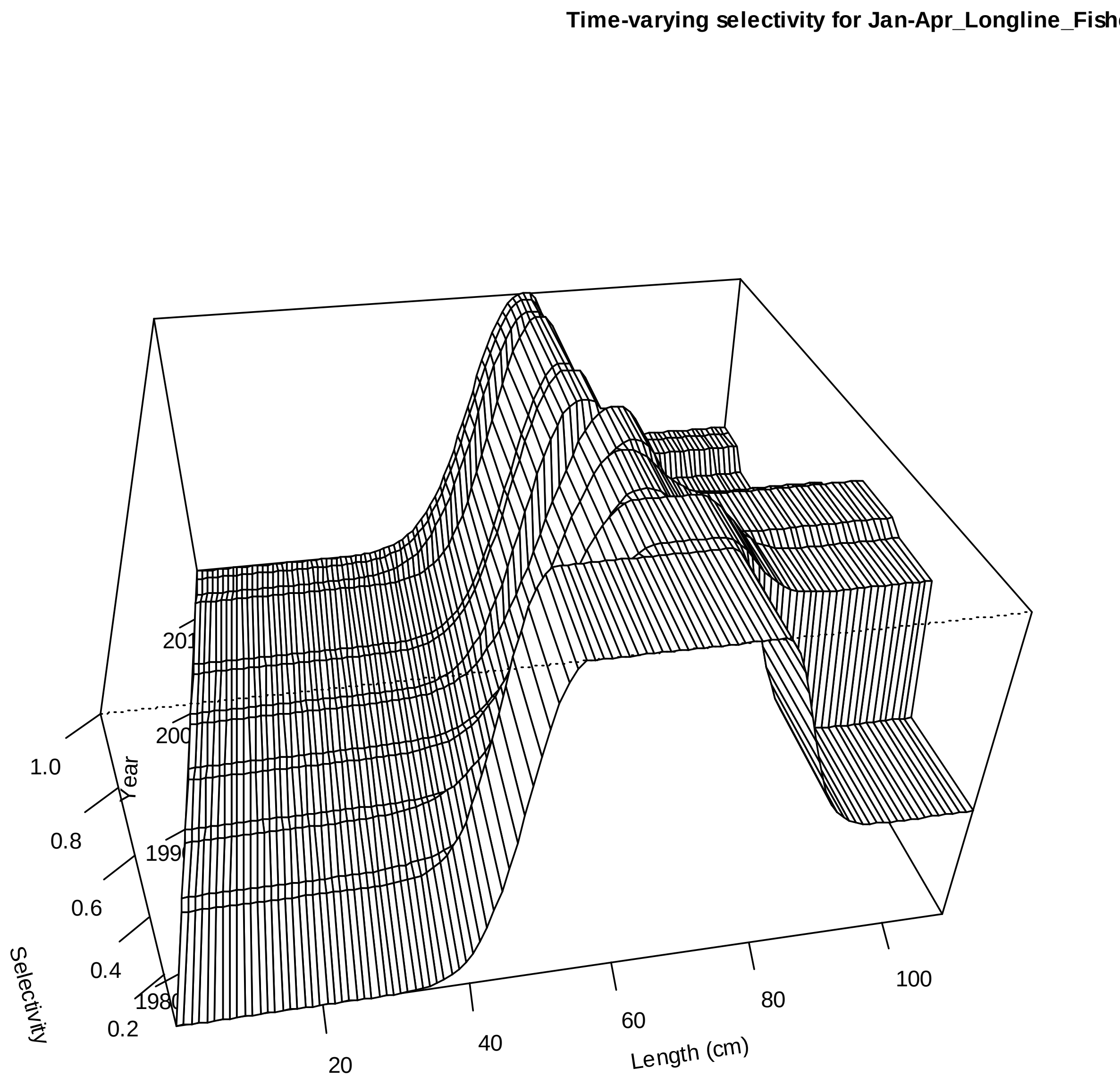
Fig. 2.25 – Fishery selectivity-at-length by gear and season for Model 3 – ¼ fsh



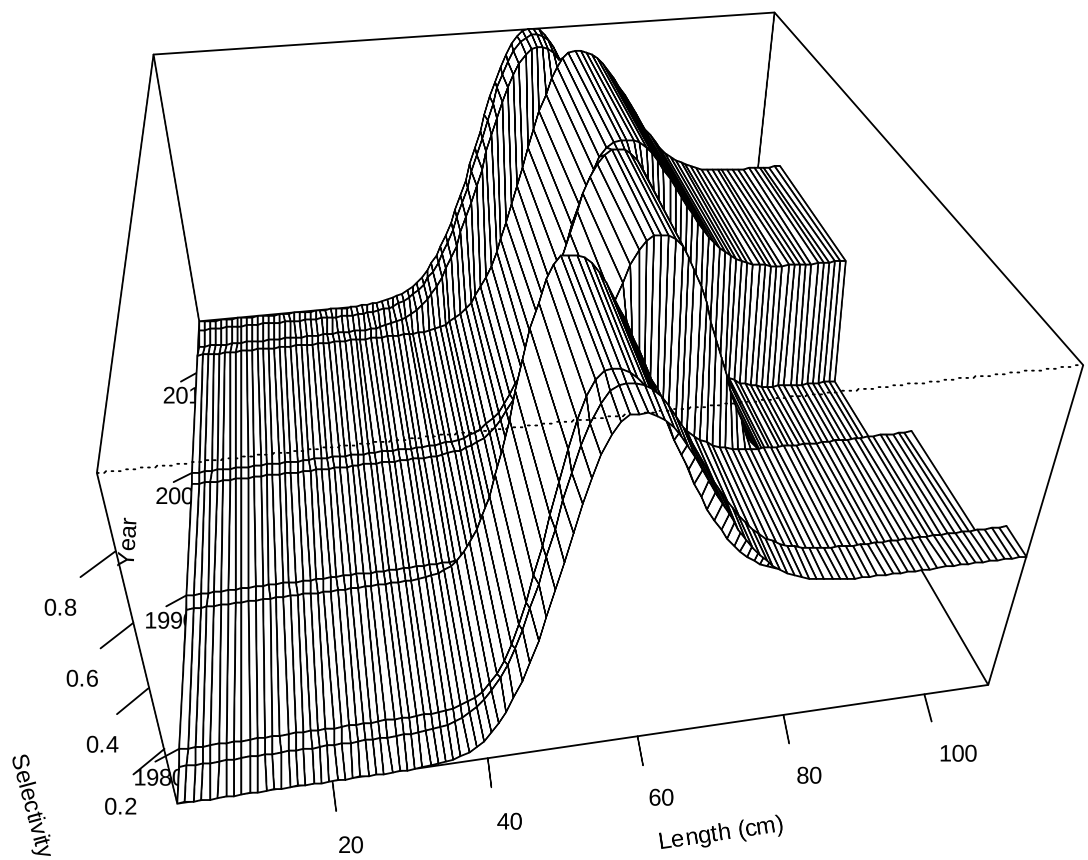
Time-varying selectivity for May-Aug_Trawl_Fishery

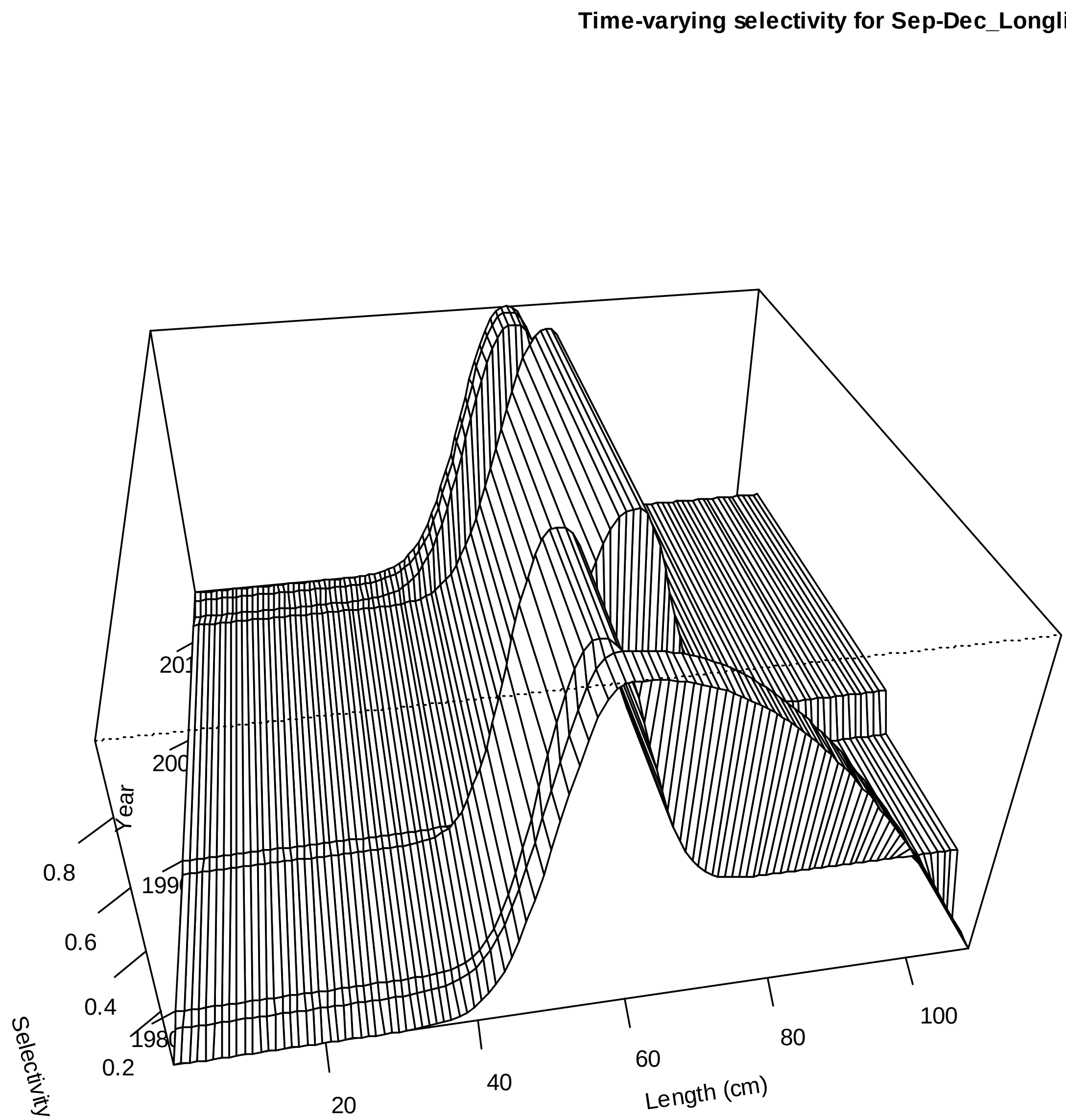


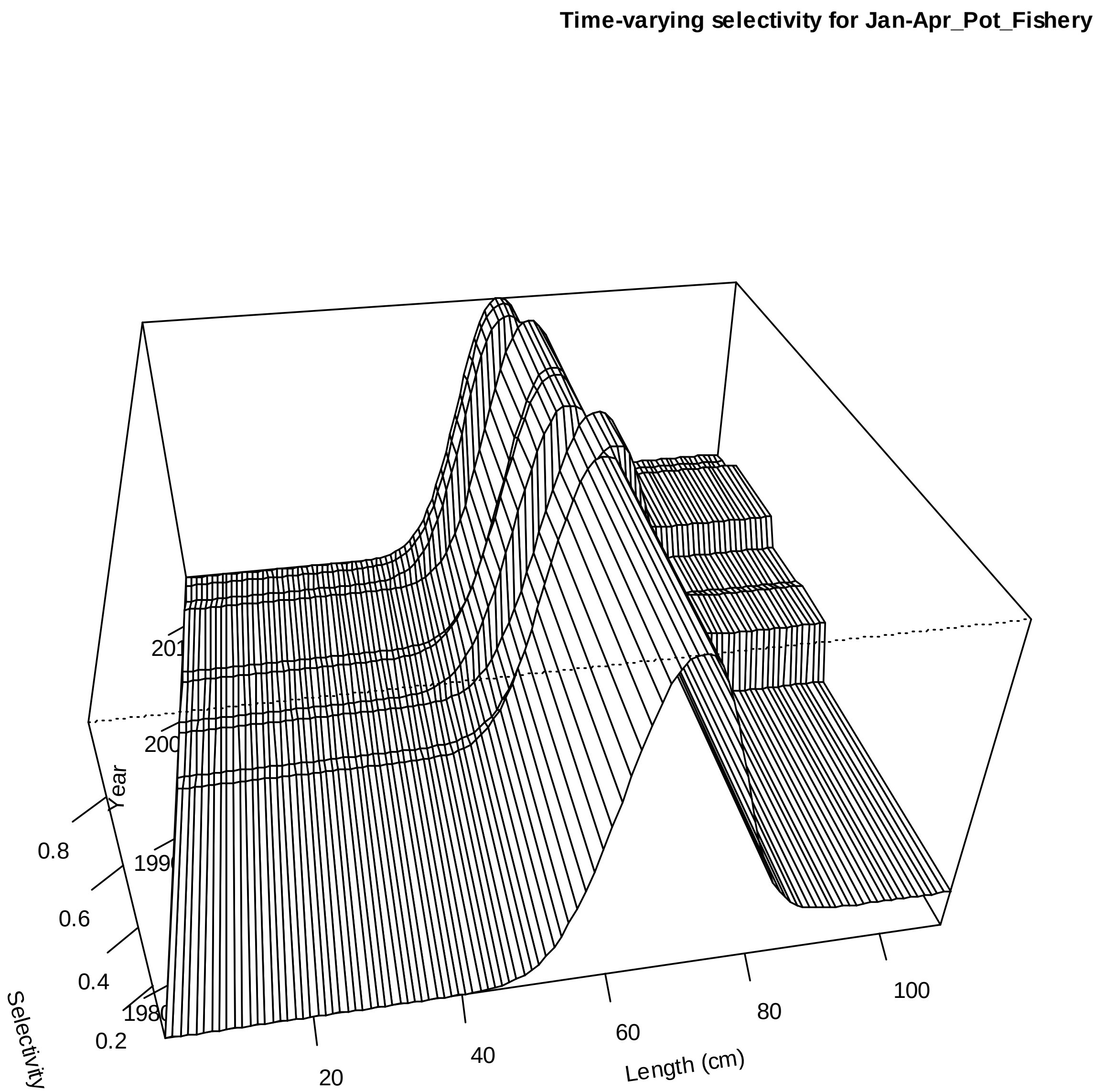

Time-varying selectivity for Sep-Dec_Trawl_Fishery
Selectivity
1.0
0.8
0.6
0.4
0.2
Year
1980
1990
2000
2010
20
40
60
80
100
Length (cm)

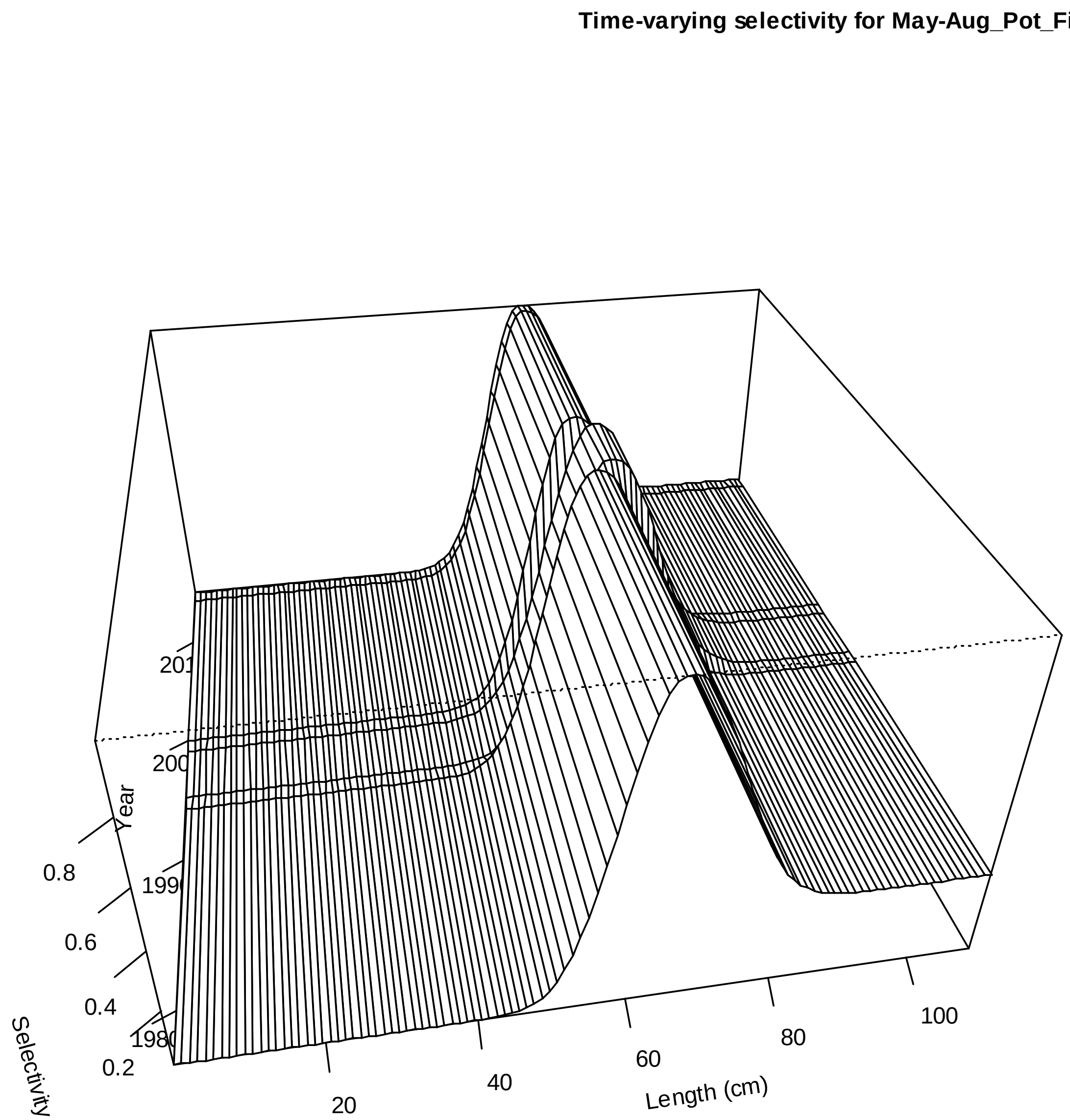

Time-varying selectivity for Jan-Apr_Longline_Fishe
Selectivity
0.2
0.4
0.6
0.8
1.0
Year
198
199
200
201
20
40
60
80
100
Length (cm)

Time-varying selectivity for May-Aug_Longline_Fish




Time-varying selectivity for Sep-Dec_Longline_Fish
Selectivity
0.2
0.4
0.6
0.8
Year
198
199
200
201
Length (cm)
20
40
60
80
100


Time-varying selectivity for Jan-Apr_Pot_Fishery
Selectivity
0.2
0.4
0.6
0.8
Year
1980
1990
200
201
Length (cm)
20
40
60
80
100


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

Time-varying selectivity for Sep-Dec_Pot_Fishery

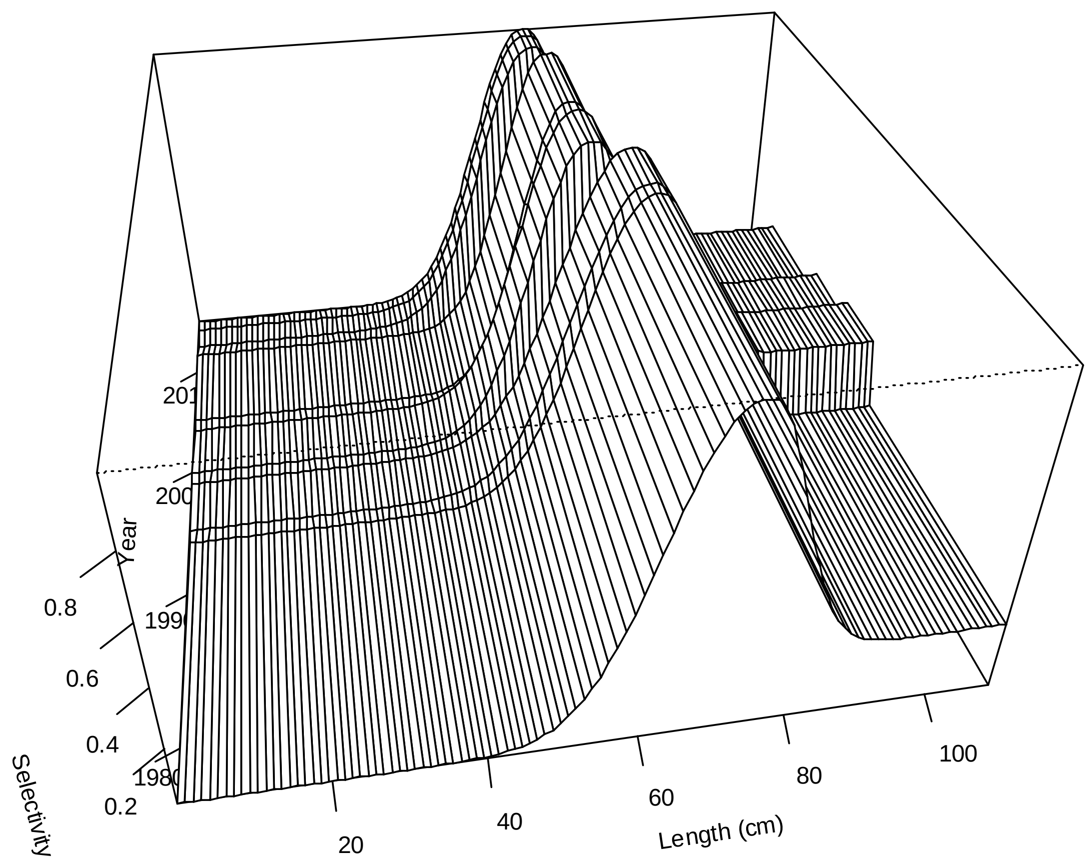


Fig. 2.26 – Summary of fits (solid lines) to fishery and survey length composition data, for season-gear groupings for Model 3 – ¼ fsh

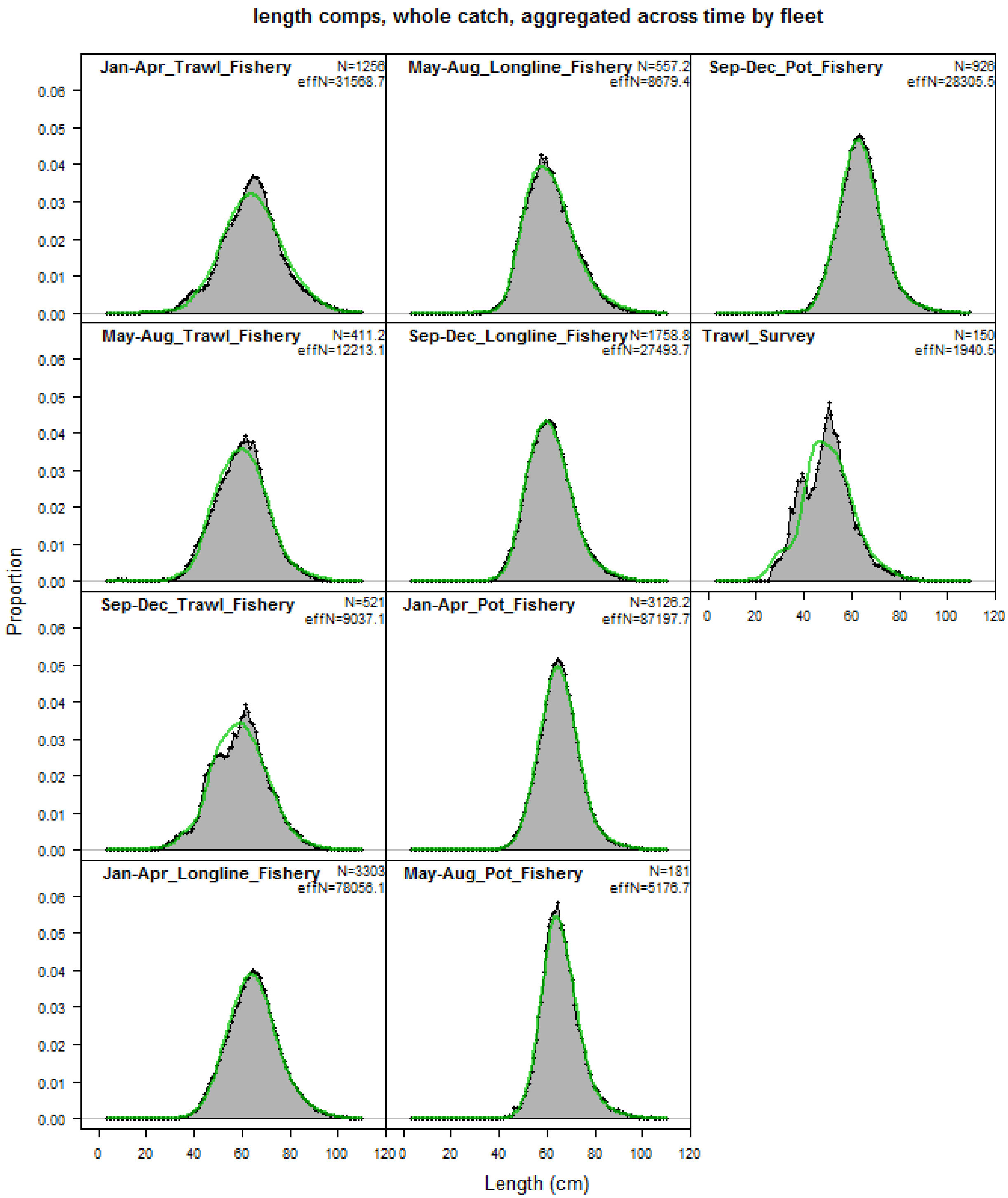
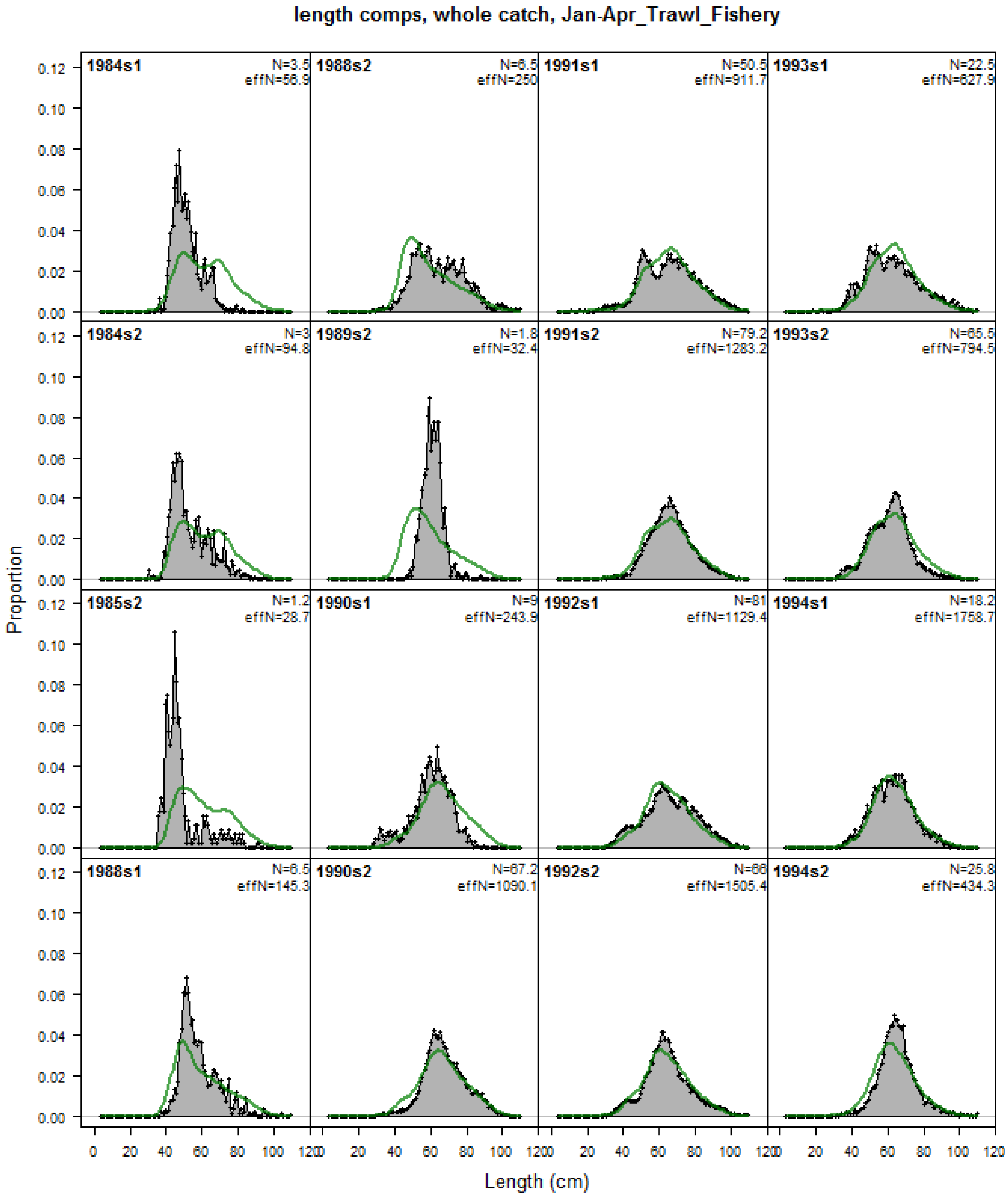
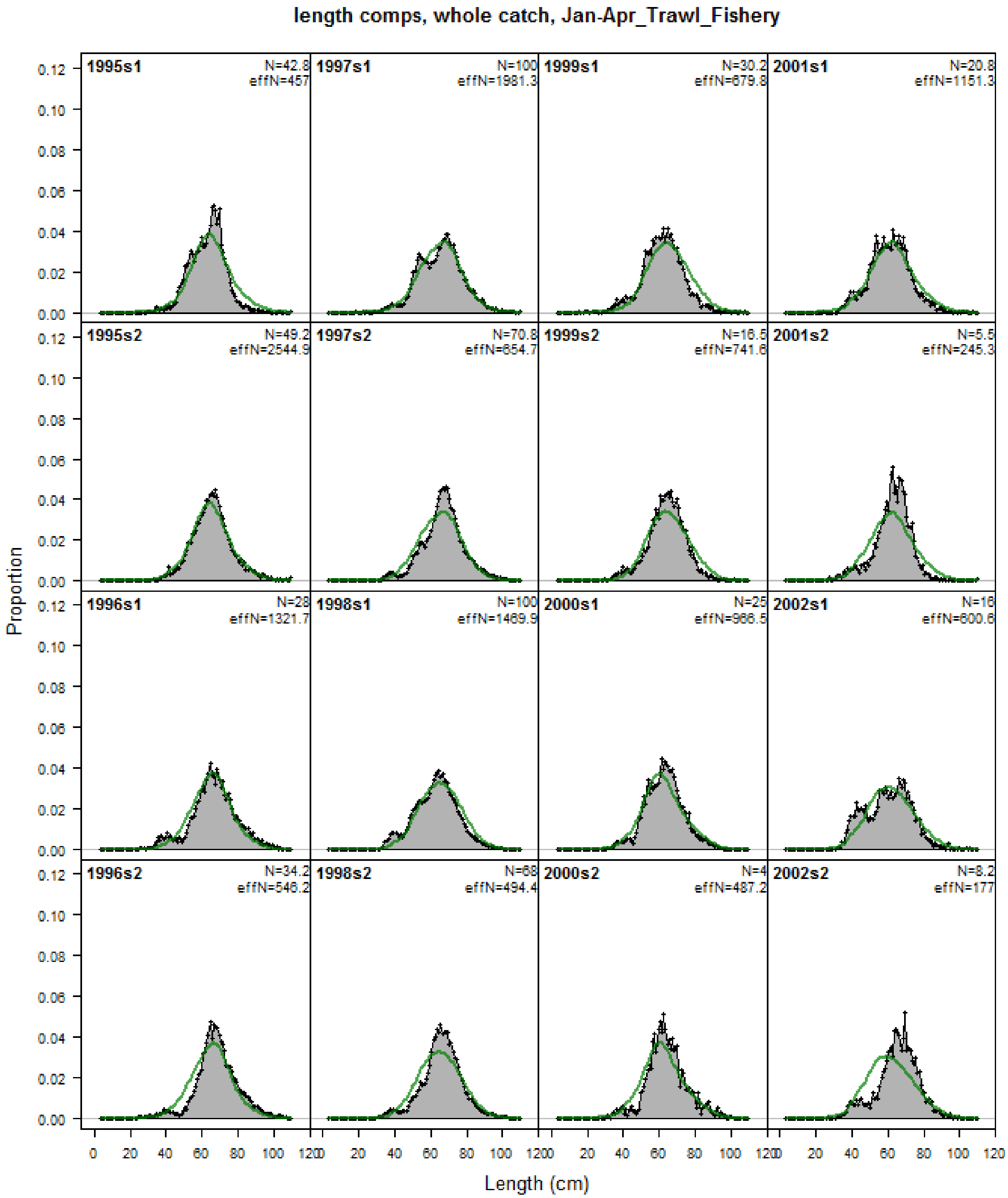
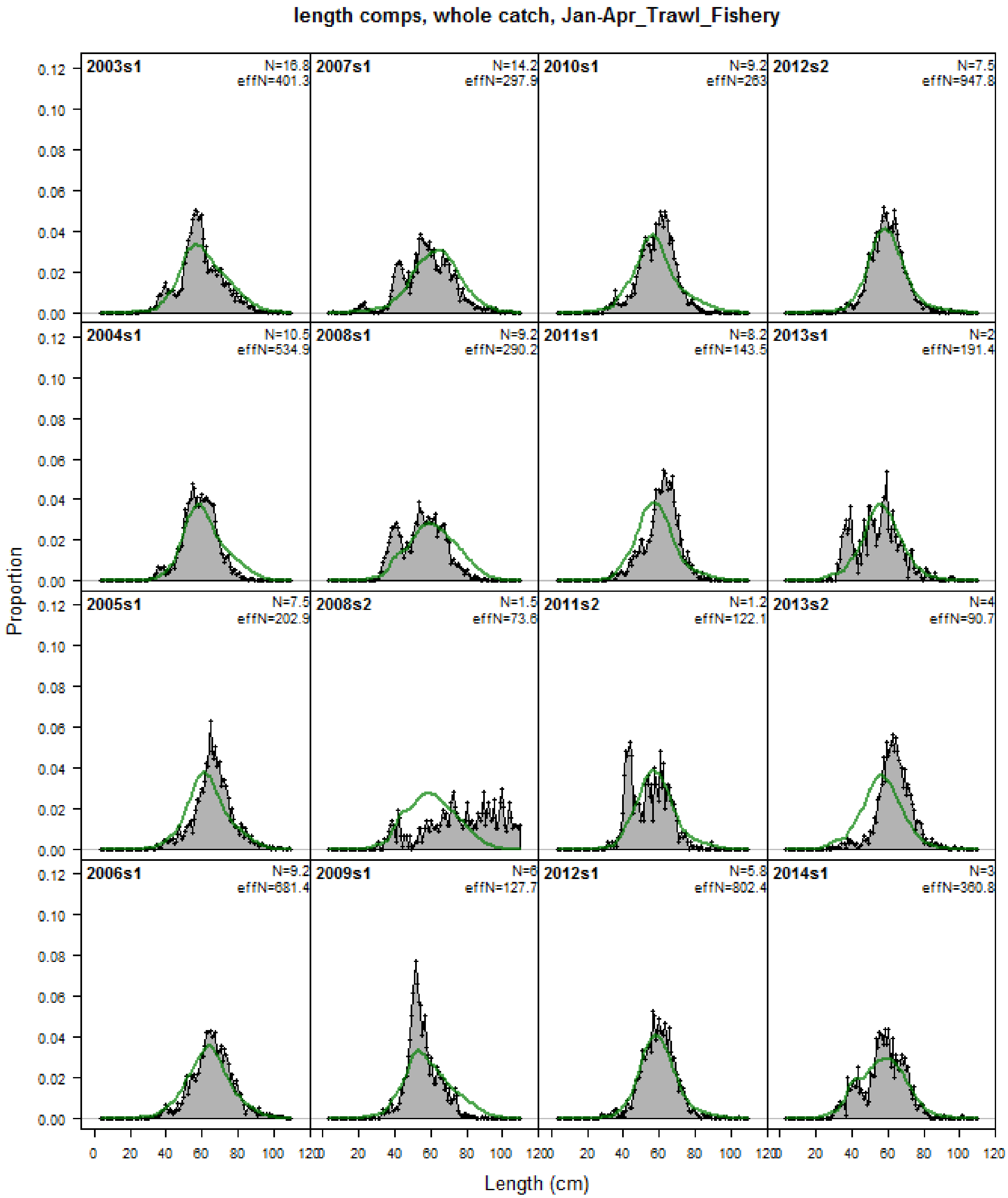
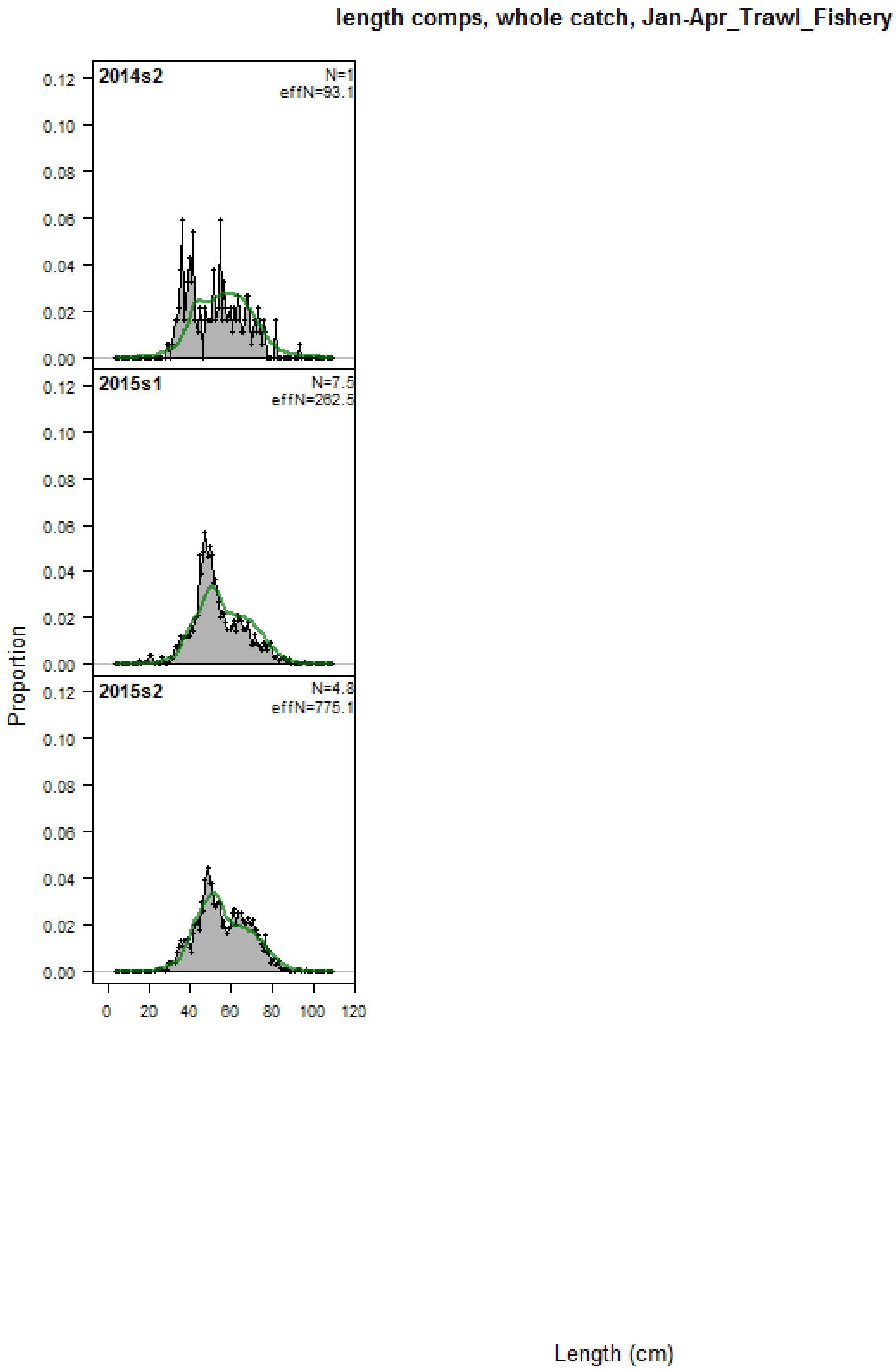


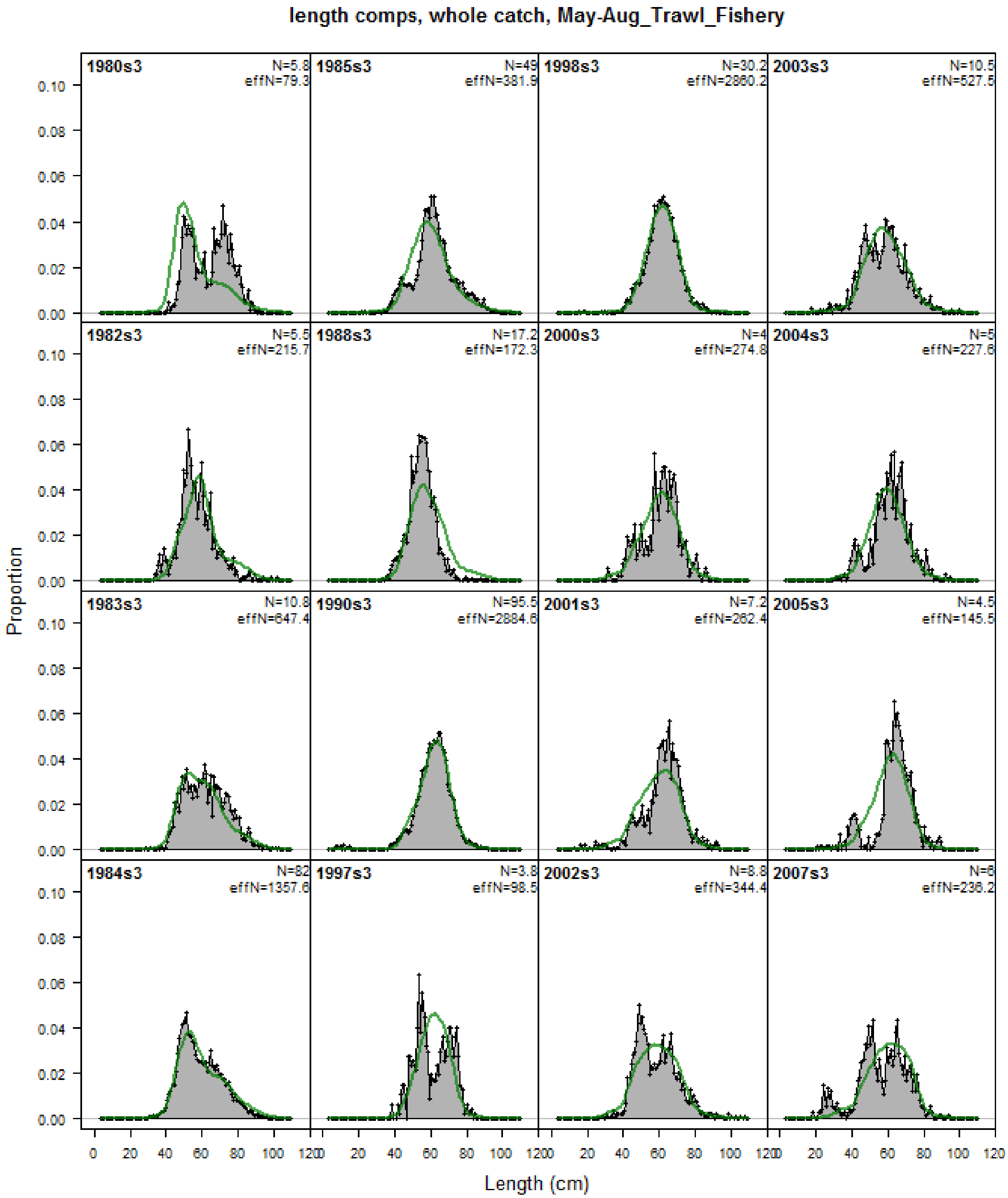
Fig. 2.27 – Fits (solid lines) to fishery catch-at-length data, by season and gear type, for Model 3 – ¼ fsh

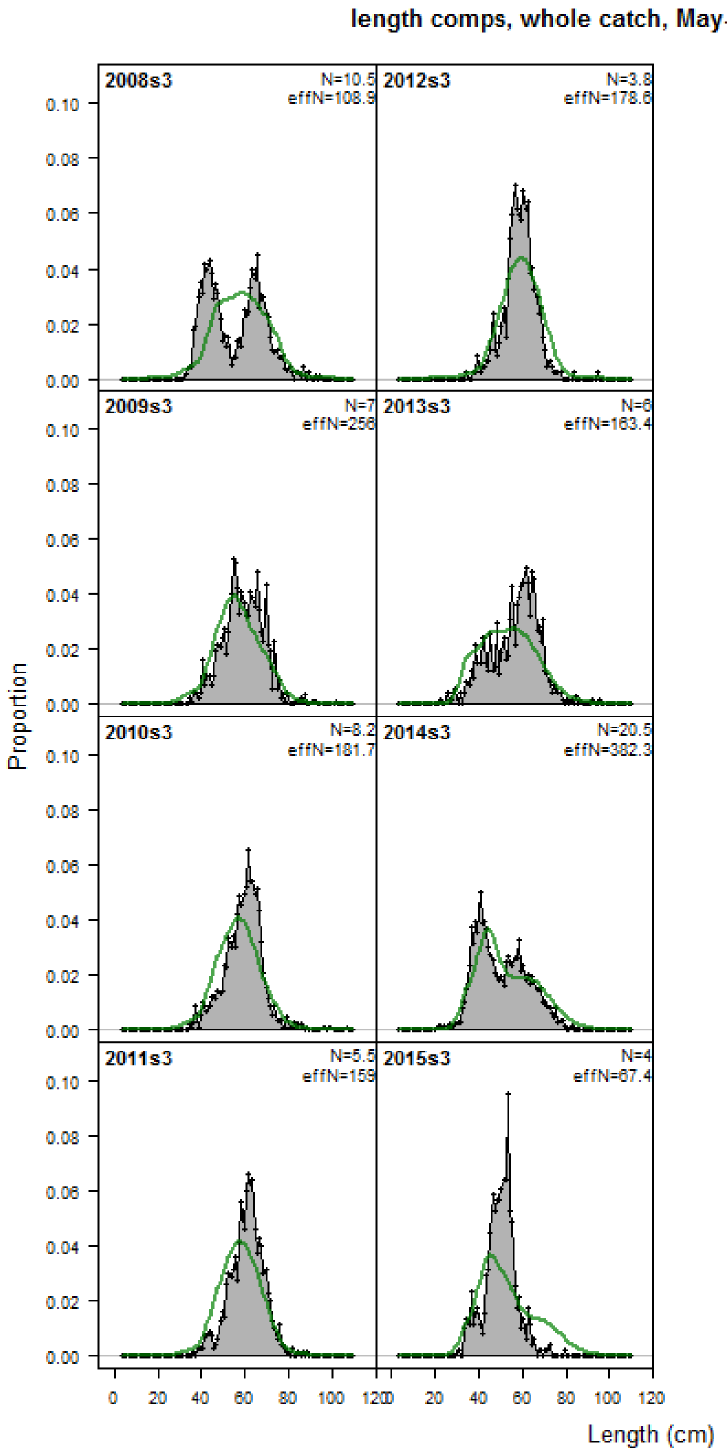


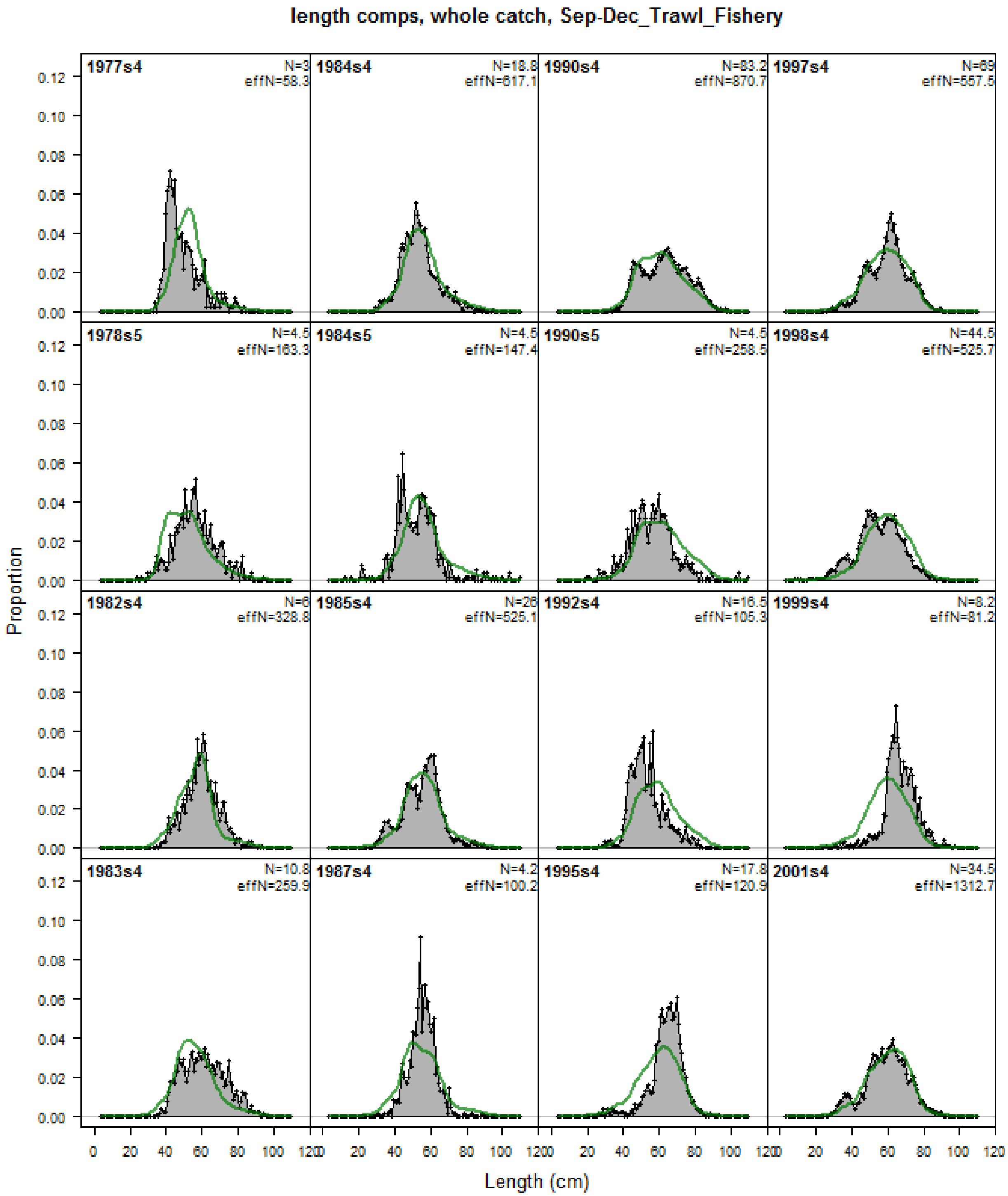

length comps, whole catch, Jan-Apr_Trawl_Fishery
1995s1 N=42.8 effN=457
1997s1 N=100 effN=1981.3
1999s1 N=30.2 effN=679.8
2001s1 N=20.8 effN=1151.3
1995s2 N=49.2 effN=2544.9
1997s2 N=70.8 effN=654.7
1999s2 N=16.5 effN=741.6
2001s2 N=5.5 effN=245.3
1996s1 N=28 effN=1321.7
1998s1 N=100 effN=1469.9
2000s1 N=25 effN=966.5
2002s1 N=16 effN=600.6
1996s2 N=34.2 effN=546.2
1998s2 N=68 effN=494.4
2000s2 N=4 effN=487.2
2002s2 N=8.2 effN=177
Proportion
Length (cm)

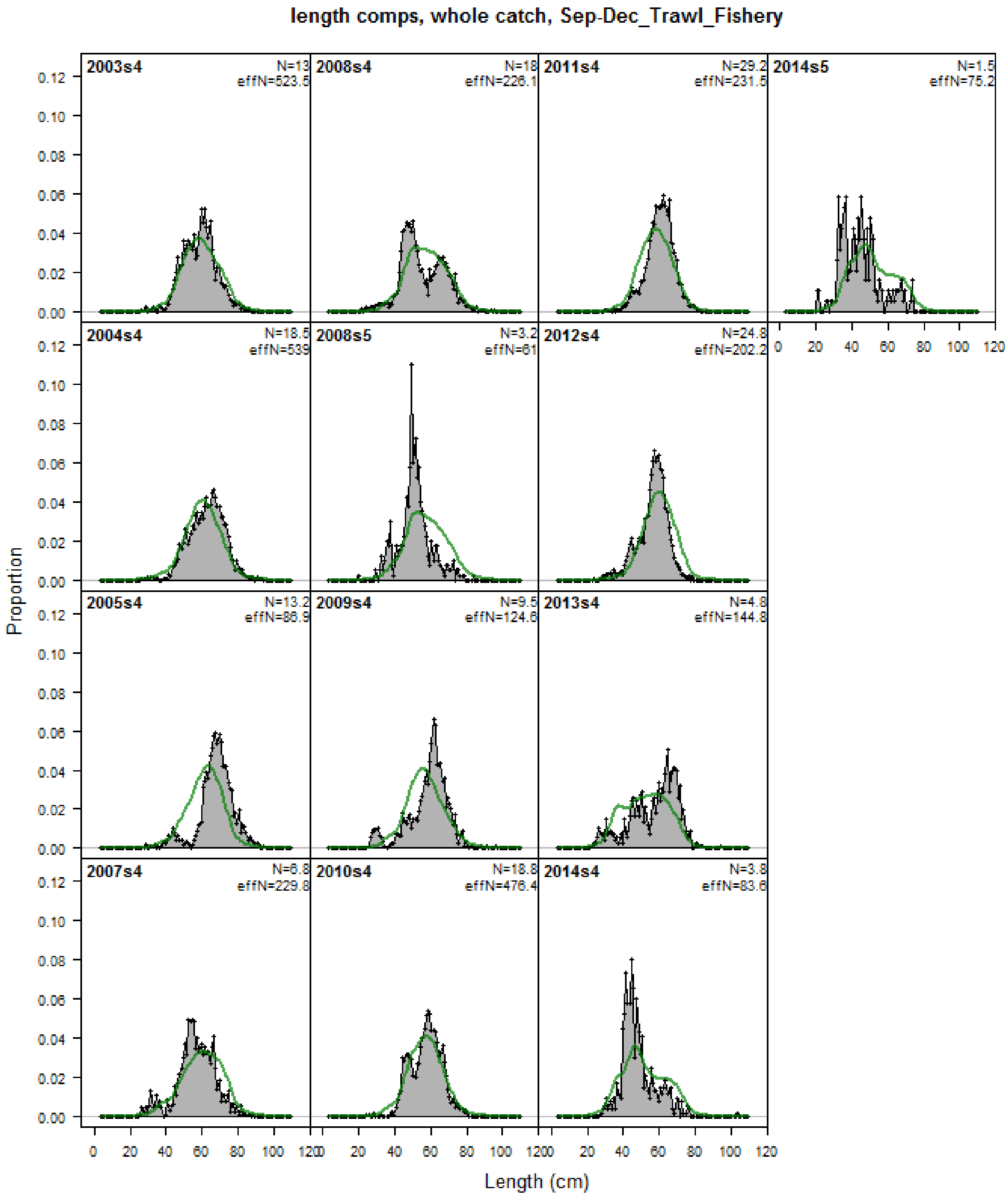

length comps, whole catch, Jan-Apr_Trawl_Fishery
2003s1
N=16.8
effN=401.3
2007s1
N=14.2
effN=297.9
2010s1
N=9.2
effN=263
2012s2
N=7.5
effN=947.8
2004s1
N=10.5
effN=534.9
2008s1
N=9.2
effN=290.2
2011s1
N=8.2
effN=143.5
2013s1
N=2
effN=191.4
2005s1
N=7.5
effN=202.9
2008s2
N=1.5
effN=73.6
2011s2
N=1.2
effN=122.1
2013s2
N=4
effN=90.7
2006s1
N=9.2
effN=681.4
2009s1
N=6
effN=127.7
2012s1
N=5.8
effN=802.4
2014s1
N=3
effN=360.8
Proportion
Length (cm)

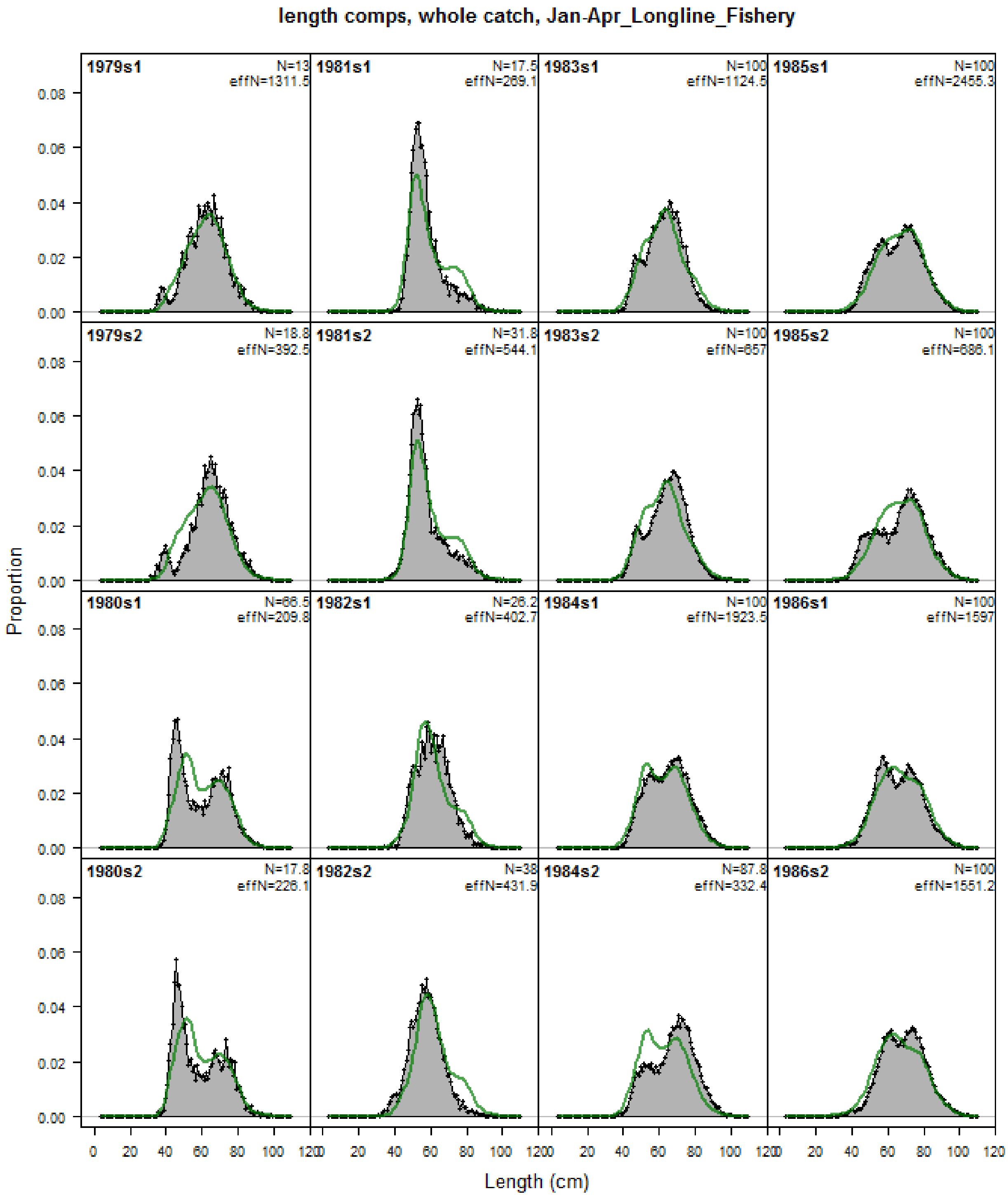

length comps, whole catch, Jan-Apr_Trawl_Fishery
2014s2
N=1
effN=93.1
2015s1
N=7.5
effN=262.5
2015s2
N=4.8
effN=775.1
Proportion
Length (cm)

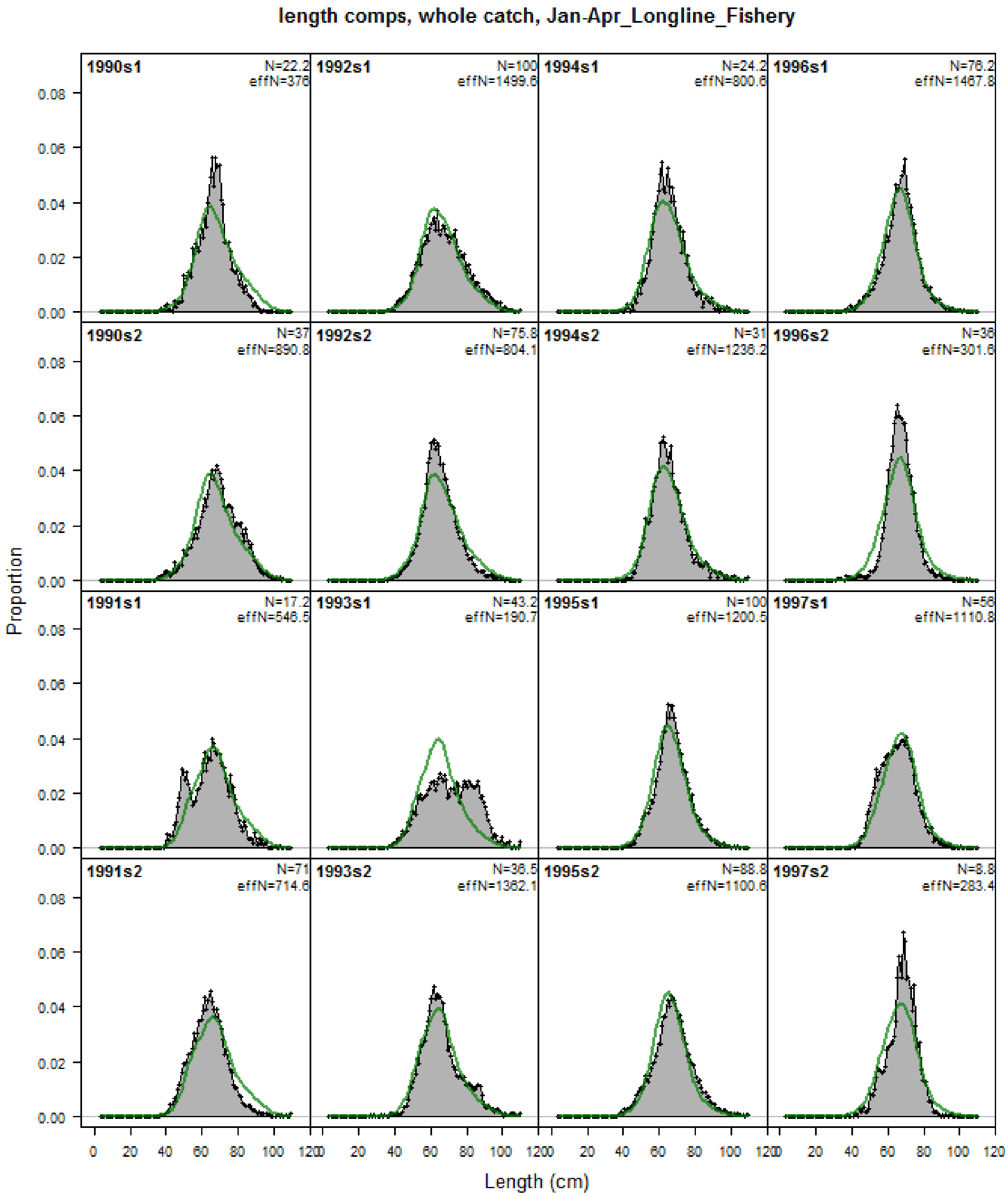

length comps, whole catch, May-Aug_Trawl_Fishery
1980s3
N=5.8
effN=79.3
1985s3
N=49
effN=381.9
1998s3
N=30.2
effN=2860.2
2003s3
N=10.5
effN=527.5
1982s3
N=5.5
effN=215.7
1988s3
N=17.2
effN=172.3
2000s3
N=4
effN=274.8
2004s3
N=5
effN=227.6
1983s3
N=10.8
effN=647.4
1990s3
N=95.5
effN=2884.6
2001s3
N=7.2
effN=262.4
2005s3
N=4.5
effN=145.5
1984s3
N=82
effN=1357.6
1997s3
N=3.8
effN=98.5
2002s3
N=8.8
effN=344.4
2007s3
N=6
effN=236.2
Proportion
0.00
0.02
0.04
0.06
0.08
0.10
Length (cm)
0
20
40
60
80
100
120

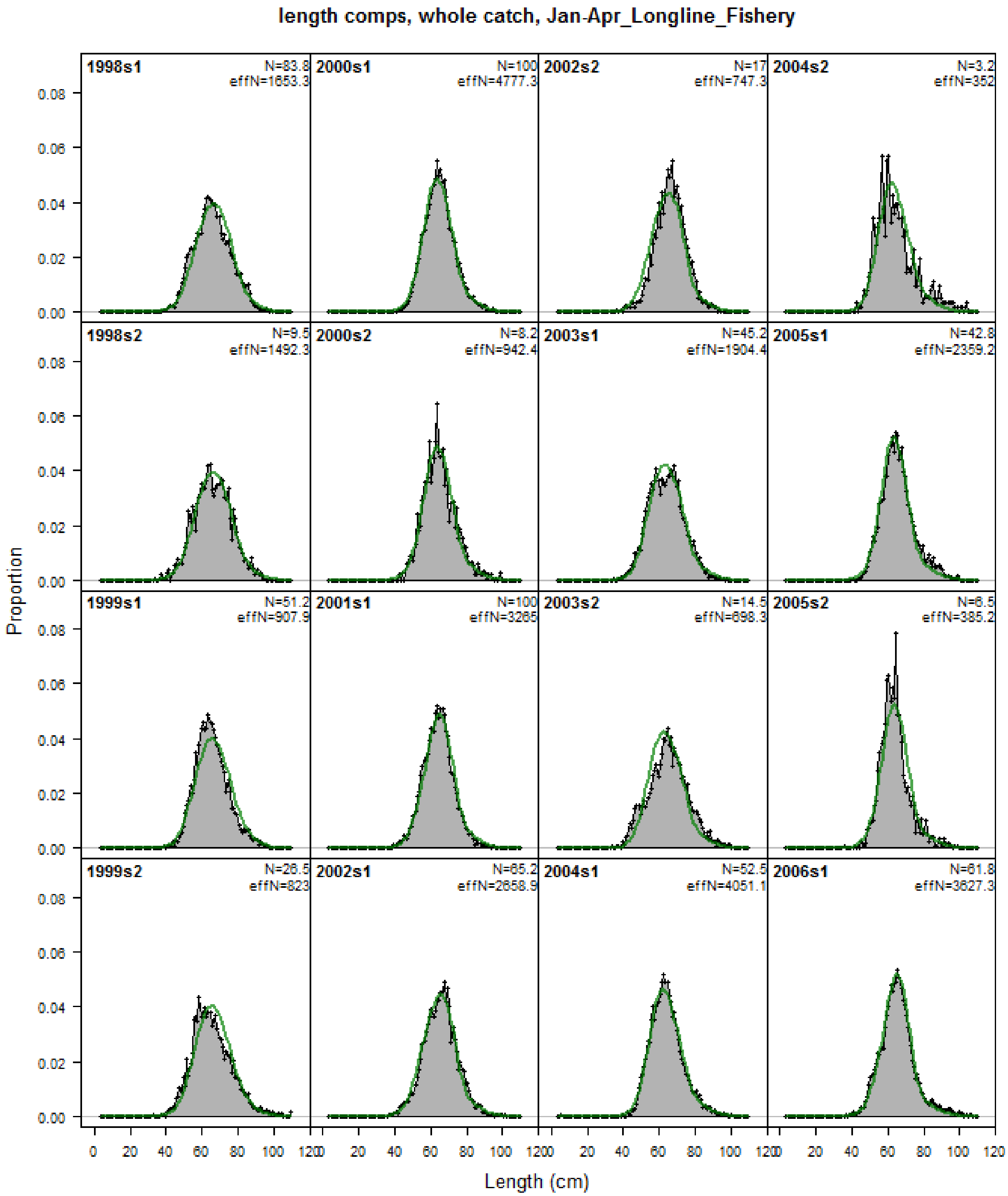

length comps, whole catch, May-Aug_Trawl_Fishery
2008s3
N=10.5
effN=108.9
2012s3
N=3.8
effN=178.6
2009s3
N=7
effN=256
2013s3
N=6
effN=163.4
2010s3
N=8.2
effN=181.7
2014s3
N=20.5
effN=382.3
2011s3
N=5.5
effN=159
2015s3
N=4
effN=67.4
Proportion
Length (cm)

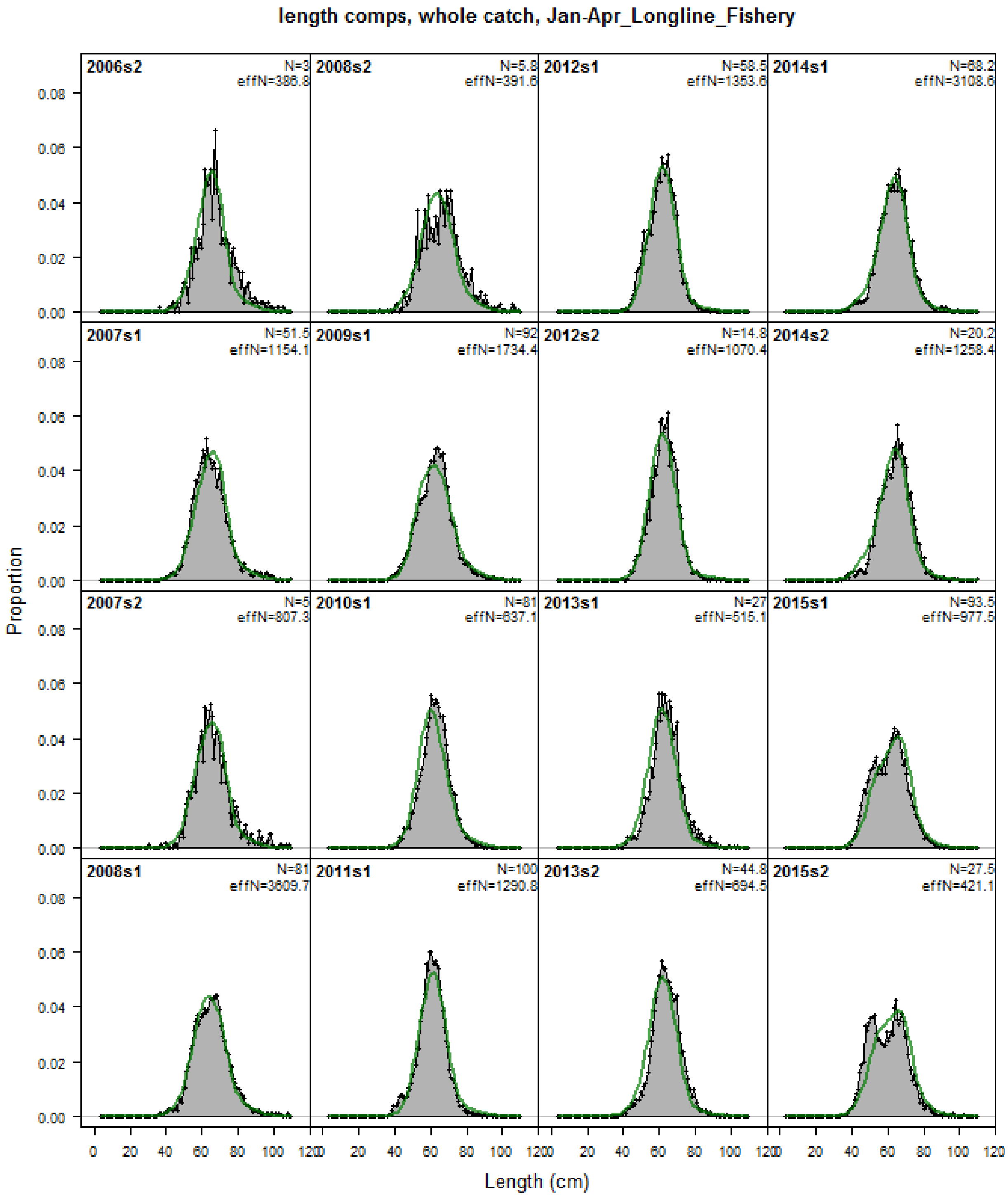

length comps, whole catch, Sep-Dec_Trawl_Fishery
1977s4 N=3 effN=58.3
1984s4 N=18.8 effN=617.1
1990s4 N=83.2 effN=870.7
1997s4 N=69 effN=557.5
1978s5 N=4.5 effN=163.3
1984s5 N=4.5 effN=147.4
1990s5 N=4.5 effN=258.5
1998s4 N=44.5 effN=525.7
1982s4 N=6 effN=328.8
1985s4 N=26 effN=525.1
1992s4 N=16.5 effN=105.3
1999s4 N=8.2 effN=81.2
1983s4 N=10.8 effN=259.9
1987s4 N=4.2 effN=100.2
1995s4 N=17.8 effN=120.9
2001s4 N=34.5 effN=1312.7
Proportion
Length (cm)

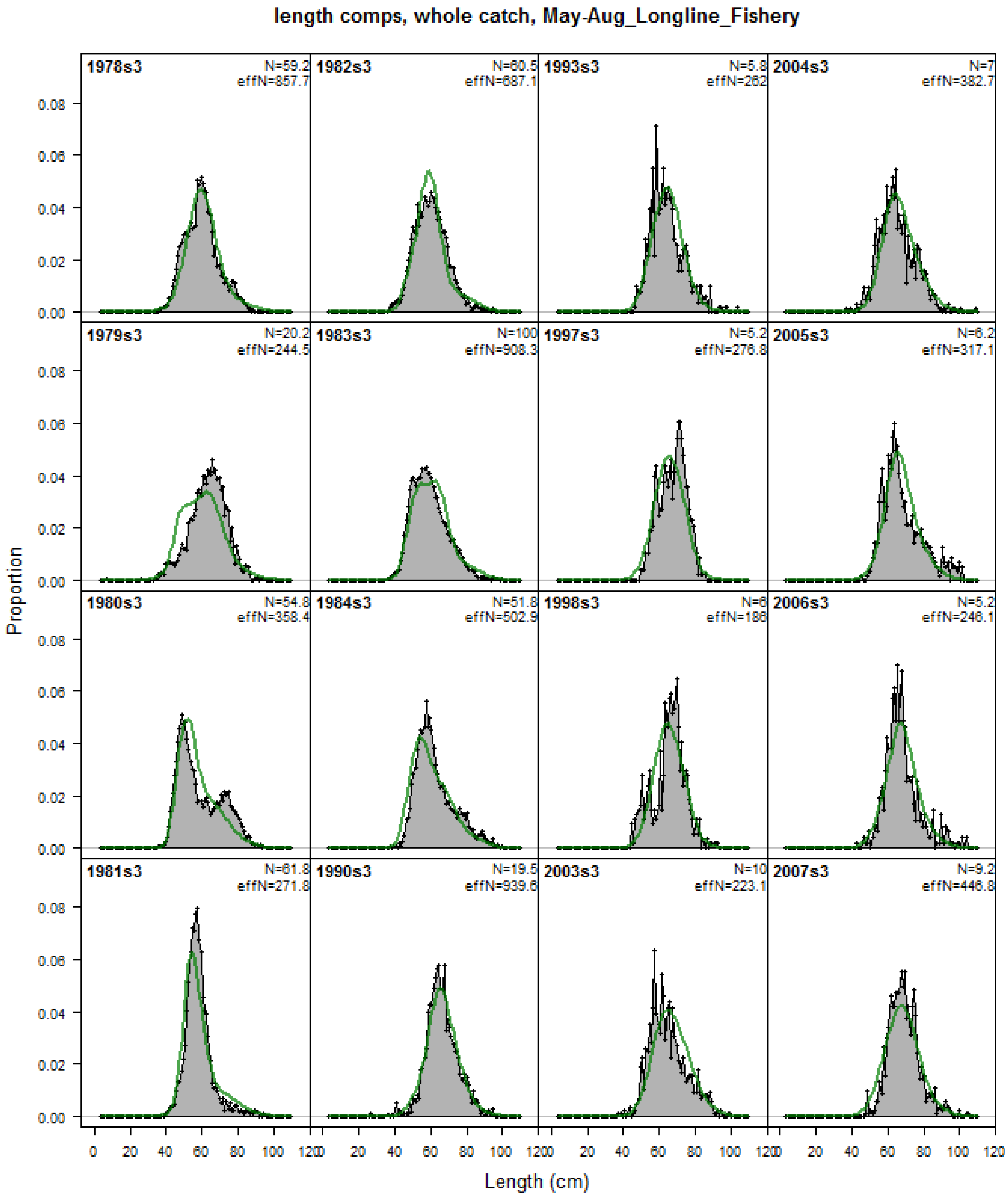

length comps, whole catch, Sep-Dec_Trawl_Fishery
2003s4
N=13
effN=523.5
2008s4
N=18
effN=226.1
2011s4
N=29.2
effN=231.5
2014s5
N=1.5
effN=75.2
2004s4
N=18.5
effN=539
2008s5
N=3.2
effN=61
2012s4
N=24.8
effN=202.2
2005s4
N=13.2
effN=86.9
2009s4
N=9.5
effN=124.6
2013s4
N=4.8
effN=144.8
2007s4
N=6.8
effN=229.8
2010s4
N=18.8
effN=476.4
2014s4
N=3.8
effN=83.6
Proportion
Length (cm)

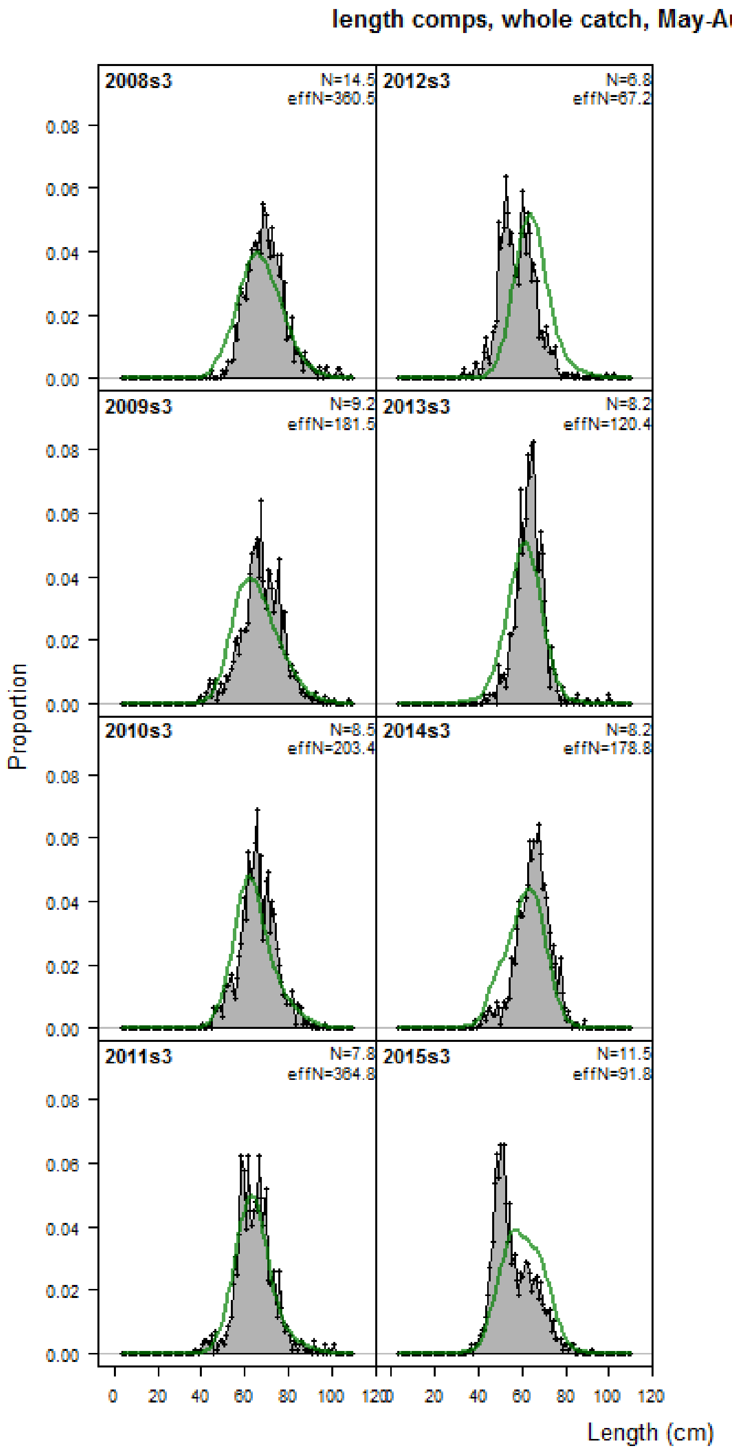

length comps, whole catch, Jan-Apr_Longline_Fishery
1979s1 N=13 effN=1311.5
1981s1 N=17.5 effN=269.1
1983s1 N=100 effN=1124.5
1985s1 N=100 effN=2455.3
1979s2 N=18.8 effN=392.5
1981s2 N=31.8 effN=544.1
1983s2 N=100 effN=657
1985s2 N=100 effN=686.1
1980s1 N=66.5 effN=209.8
1982s1 N=26.2 effN=402.7
1984s1 N=100 effN=1923.5
1986s1 N=100 effN=1597
1980s2 N=17.8 effN=226.1
1982s2 N=38 effN=431.9
1984s2 N=87.8 effN=332.4
1986s2 N=100 effN=1551.2
Proportion
Length (cm)

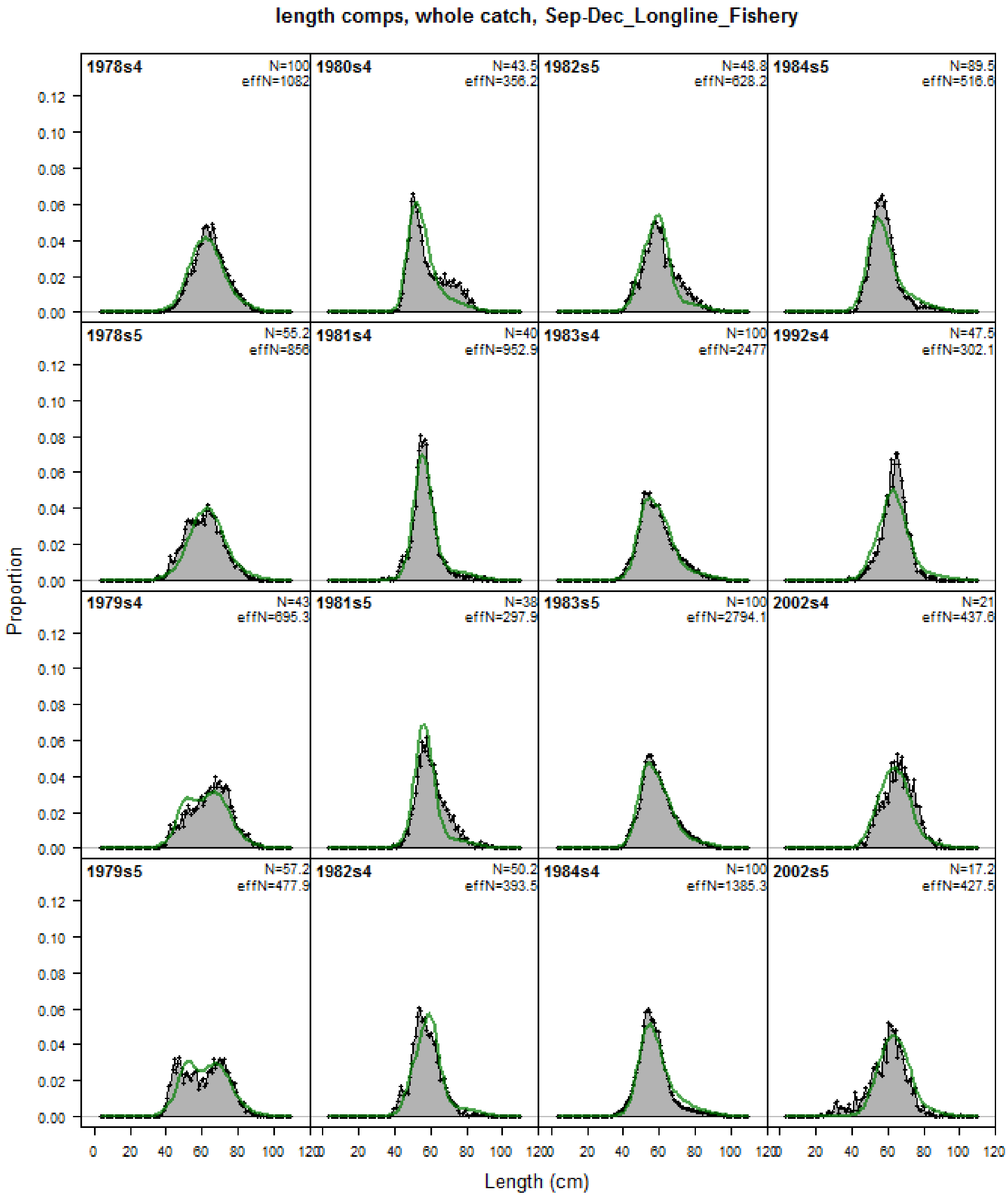

length comps, whole catch, Jan-Apr_Longline_Fishery
1990s1 N=22.2 effN=376
1992s1 N=100 effN=1499.6
1994s1 N=24.2 effN=800.6
1996s1 N=76.2 effN=1467.8
1990s2 N=37 effN=890.8
1992s2 N=75.8 effN=804.1
1994s2 N=31 effN=1236.2
1996s2 N=36 effN=301.6
1991s1 N=17.2 effN=546.5
1993s1 N=43.2 effN=190.7
1995s1 N=100 effN=1200.5
1997s1 N=56 effN=1110.8
1991s2 N=71 effN=714.6
1993s2 N=36.5 effN=1362.1
1995s2 N=88.8 effN=1100.6
1997s2 N=8.8 effN=283.4
Proportion
Length (cm)

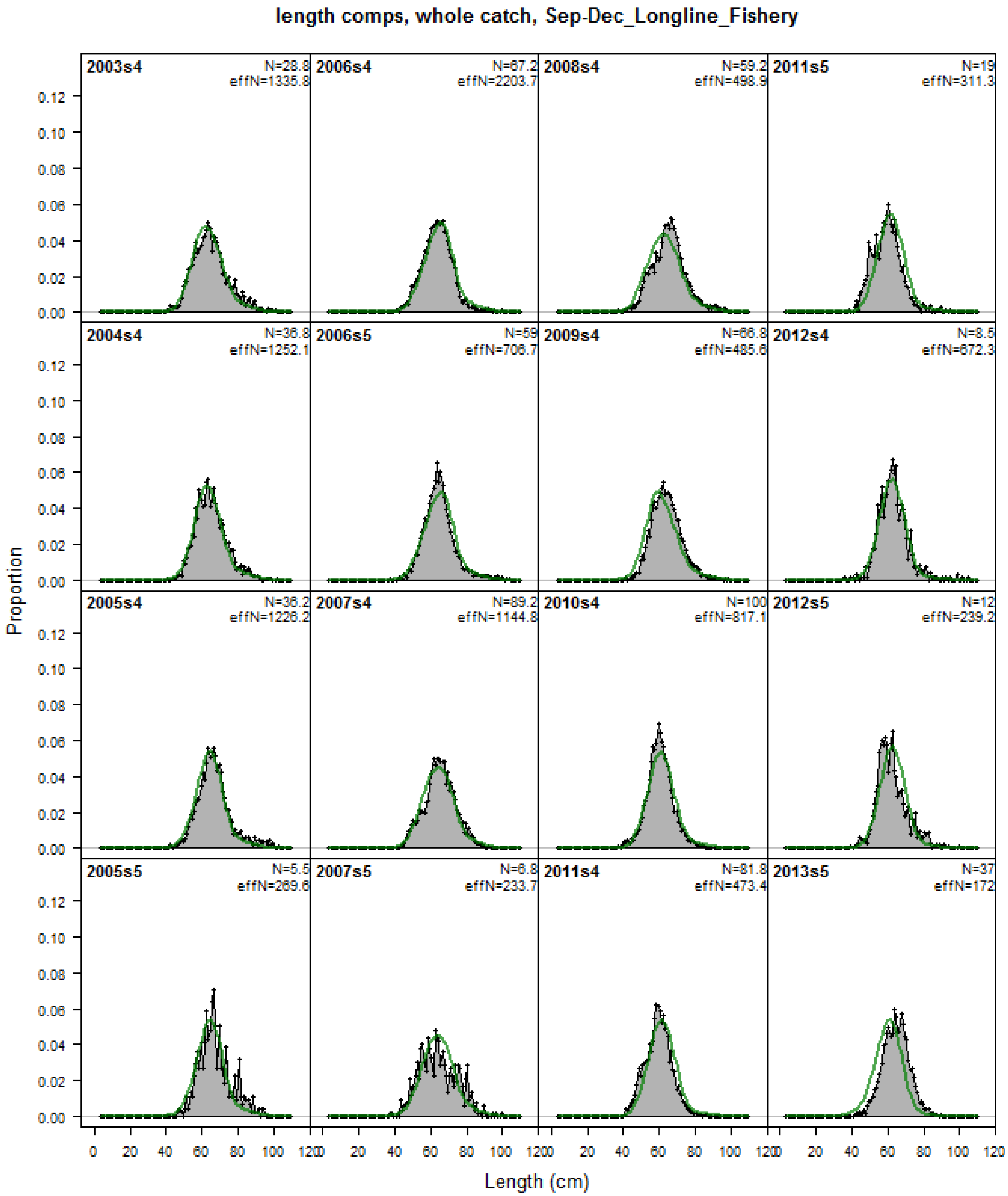

length comps, whole catch, Jan-Apr_Longline_Fishery
1998s1 N=83.8 effN=1653.3
2000s1 N=100 effN=4777.3
2002s2 N=17 effN=747.3
2004s2 N=3.2 effN=352
1998s2 N=9.5 effN=1492.3
2000s2 N=8.2 effN=942.4
2003s1 N=45.2 effN=1904.4
2005s1 N=42.8 effN=2359.2
1999s1 N=51.2 effN=907.9
2001s1 N=100 effN=3265
2003s2 N=14.5 effN=698.3
2005s2 N=6.5 effN=385.2
1999s2 N=26.5 effN=823
2002s1 N=65.2 effN=2658.9
2004s1 N=52.5 effN=4051.1
2006s1 N=61.8 effN=3627.3
Proportion
Length (cm)

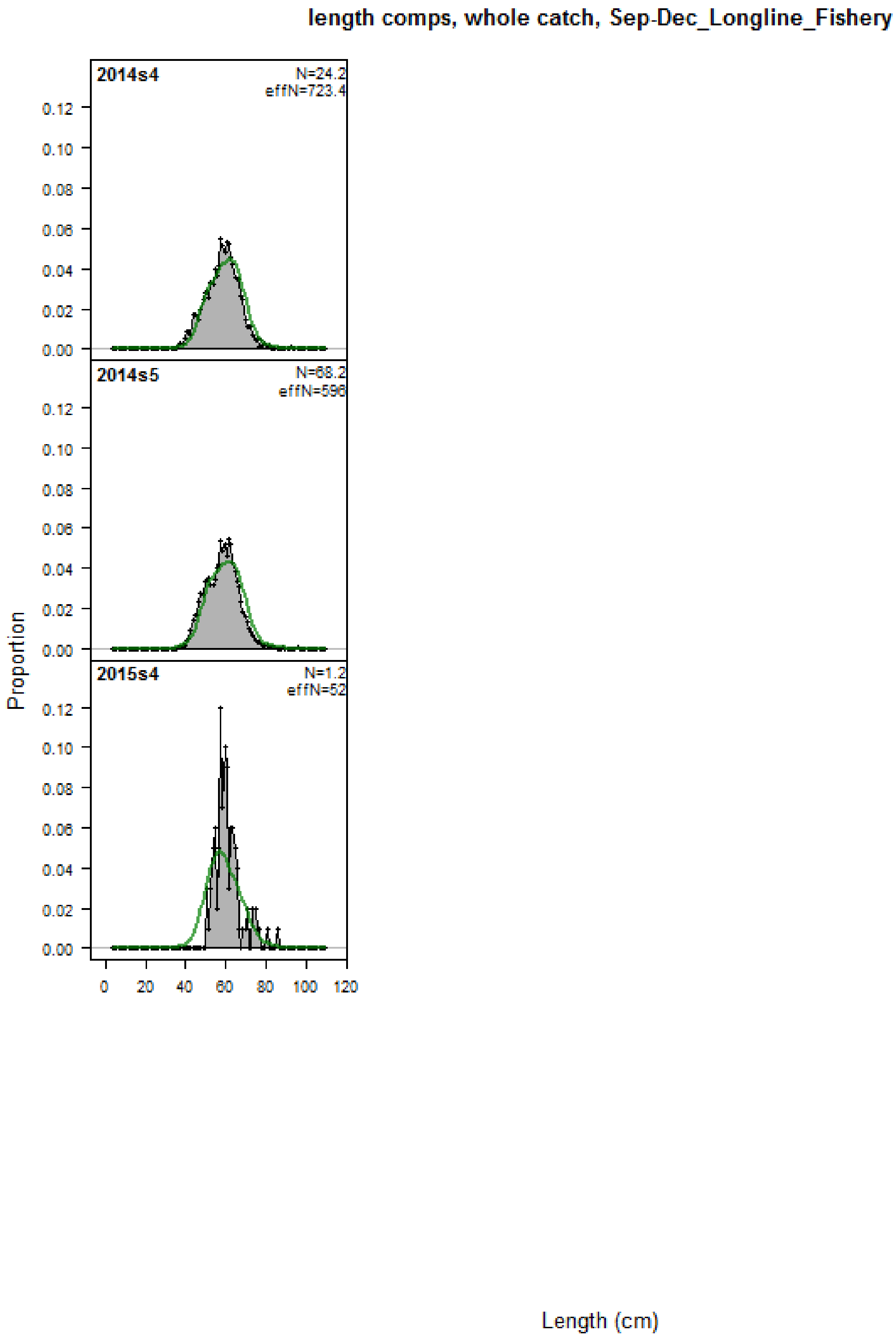

length comps, whole catch, Jan-Apr_Longline_Fishery
2006s2 N=3 effN=386.8
2008s2 N=5.8 effN=391.6
2012s1 N=58.5 effN=1353.6
2014s1 N=68.2 effN=3108.6
2007s1 N=51.5 effN=1154.1
2009s1 N=92 effN=1734.4
2012s2 N=14.8 effN=1070.4
2014s2 N=20.2 effN=1258.4
2007s2 N=5 effN=807.3
2010s1 N=81 effN=637.1
2013s1 N=27 effN=515.1
2015s1 N=93.5 effN=977.5
2008s1 N=81 effN=3609.7
2011s1 N=100 effN=1290.8
2013s2 N=44.8 effN=694.5
2015s2 N=27.5 effN=421.1
Proportion
Length (cm)

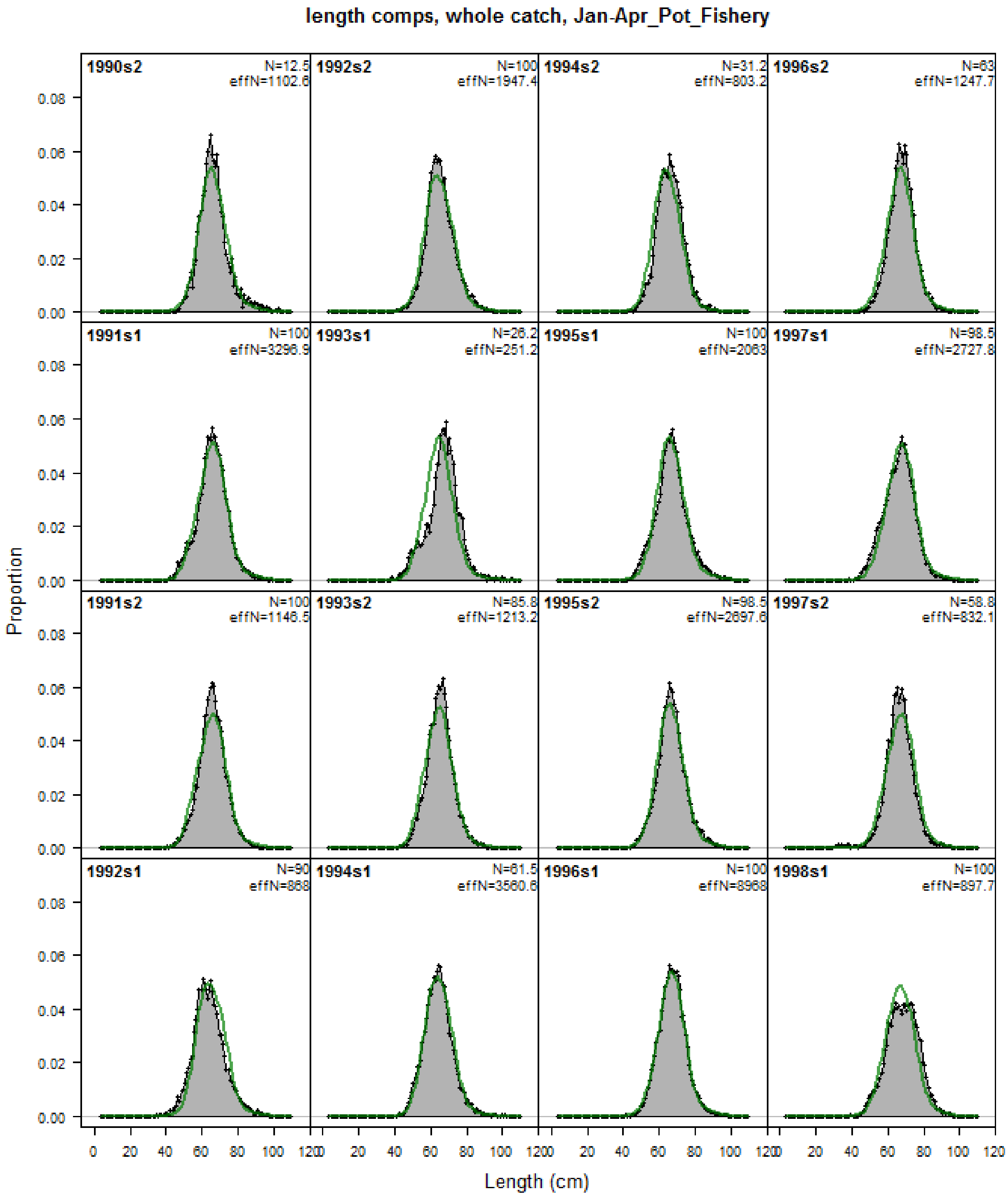

length comps, whole catch, May-Aug_Longline_Fishery
1978s3
N=59.2
effN=857.7
1982s3
N=60.5
effN=687.1
1993s3
N=5.8
effN=262
2004s3
N=7
effN=382.7
1979s3
N=20.2
effN=244.5
1983s3
N=100
effN=908.3
1997s3
N=5.2
effN=276.8
2005s3
N=6.2
effN=317.1
1980s3
N=54.8
effN=358.4
1984s3
N=51.8
effN=502.9
1998s3
N=6
effN=186
2006s3
N=5.2
effN=246.1
1981s3
N=61.8
effN=271.8
1990s3
N=19.5
effN=939.6
2003s3
N=10
effN=223.1
2007s3
N=9.2
effN=446.8
Proportion
Length (cm)

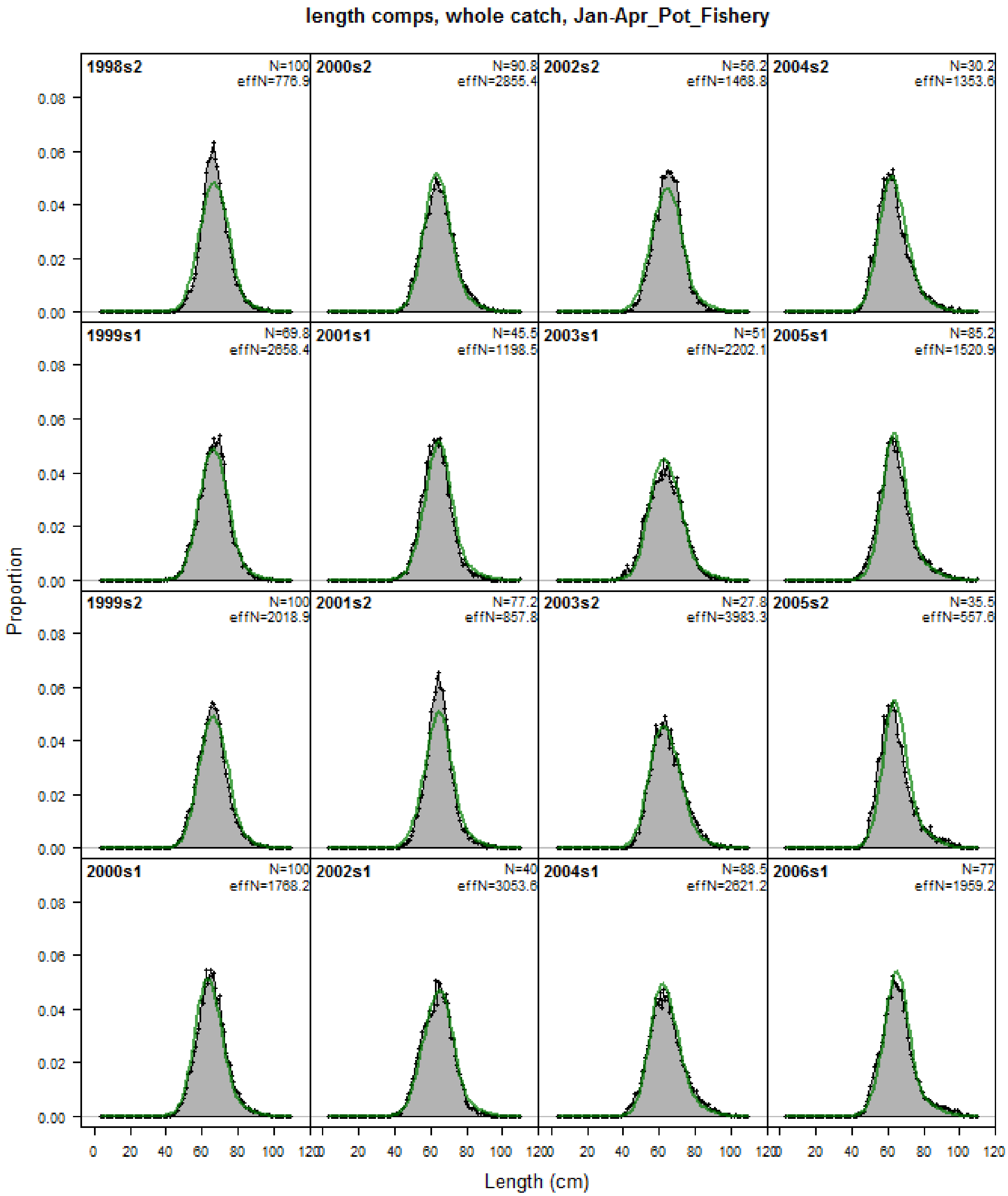

length comps, whole catch, May-Aug_Longline_Fishery
2008s3
N=14.5
effN=360.5
2012s3
N=6.8
effN=67.2
2009s3
N=9.2
effN=181.5
2013s3
N=8.2
effN=120.4
2010s3
N=8.5
effN=203.4
2014s3
N=8.2
effN=178.8
2011s3
N=7.8
effN=364.8
2015s3
N=11.5
effN=91.8
Proportion
Length (cm)

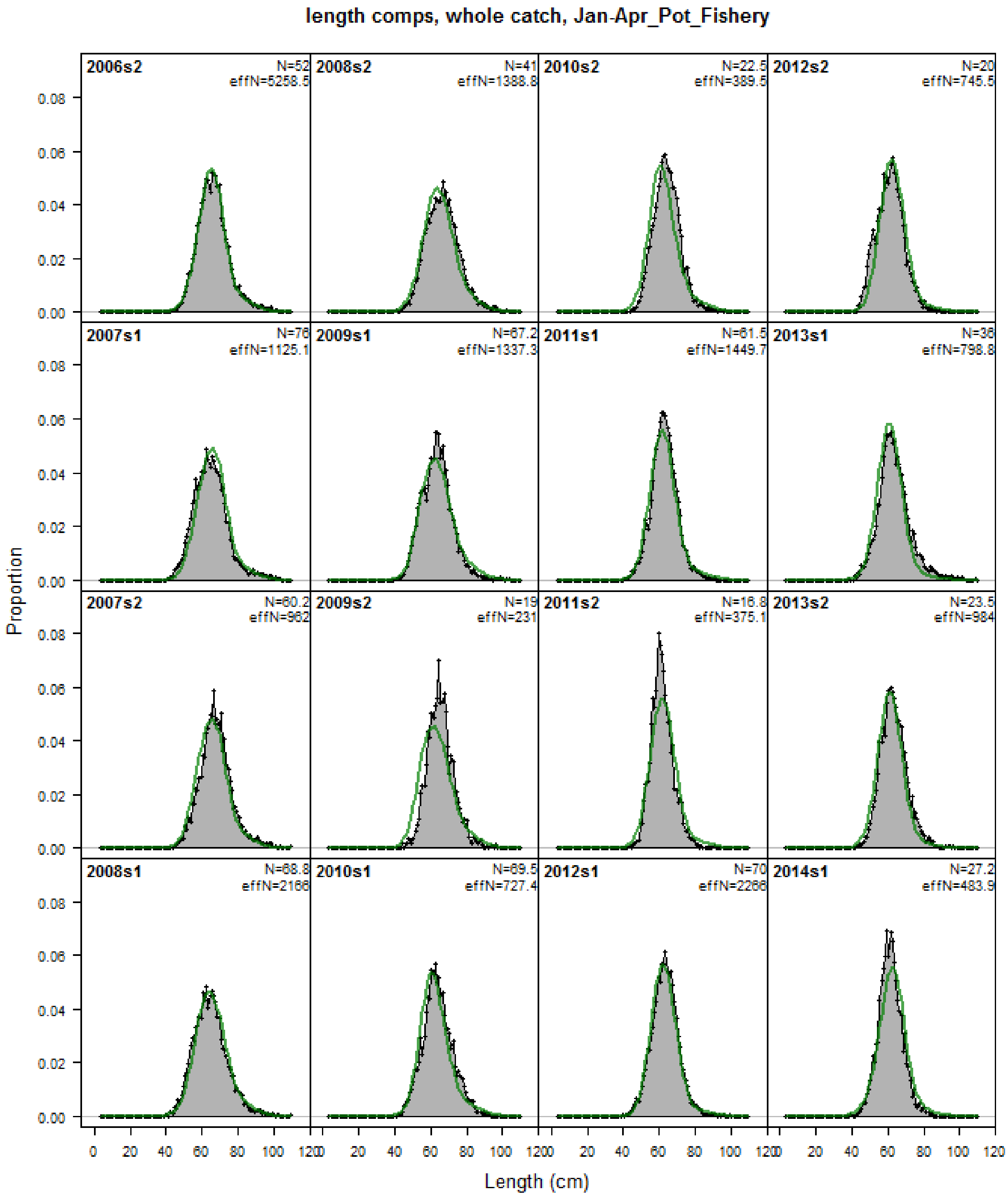

length comps, whole catch, Sep-Dec_Longline_Fishery
1978s4
N=100
effN=1082
1980s4
N=43.5
effN=356.2
1982s5
N=48.8
effN=628.2
1984s5
N=89.5
effN=516.6
1978s5
N=55.2
effN=856
1981s4
N=40
effN=952.9
1983s4
N=100
effN=2477
1992s4
N=47.5
effN=302.1
1979s4
N=43
effN=695.3
1981s5
N=38
effN=297.9
1983s5
N=100
effN=2794.1
2002s4
N=21
effN=437.6
1979s5
N=57.2
effN=477.9
1982s4
N=50.2
effN=393.5
1984s4
N=100
effN=1385.3
2002s5
N=17.2
effN=427.5
Proportion
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0
20
40
60
80
100
120
Length (cm)

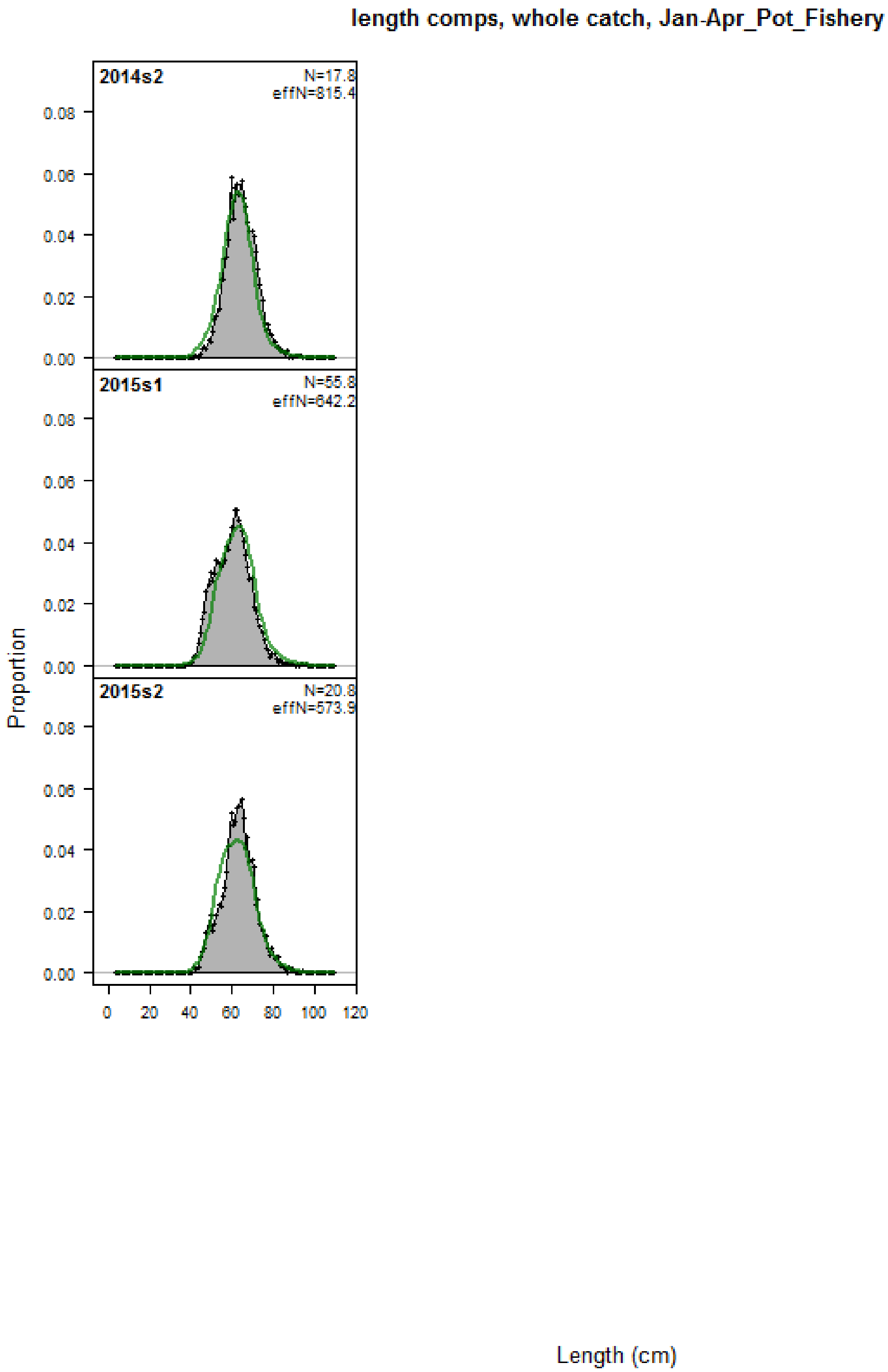

length comps, whole catch, Sep-Dec_Longline_Fishery
2003s4
N=28.8
effN=1335.8
2006s4
N=67.2
effN=2203.7
2008s4
N=59.2
effN=498.9
2011s5
N=19
effN=311.3
2004s4
N=36.8
effN=1252.1
2006s5
N=59
effN=706.7
2009s4
N=66.8
effN=485.6
2012s4
N=8.5
effN=672.3
2005s4
N=36.2
effN=1226.2
2007s4
N=89.2
effN=1144.8
2010s4
N=100
effN=817.1
2012s5
N=12
effN=239.2
2005s5
N=5.5
effN=269.6
2007s5
N=6.8
effN=233.7
2011s4
N=81.8
effN=473.4
2013s5
N=37
effN=172
Proportion
0.00
0.02
0.04
0.06
0.08
0.10
0.12
Length (cm)
0
20
40
60
80
100
120

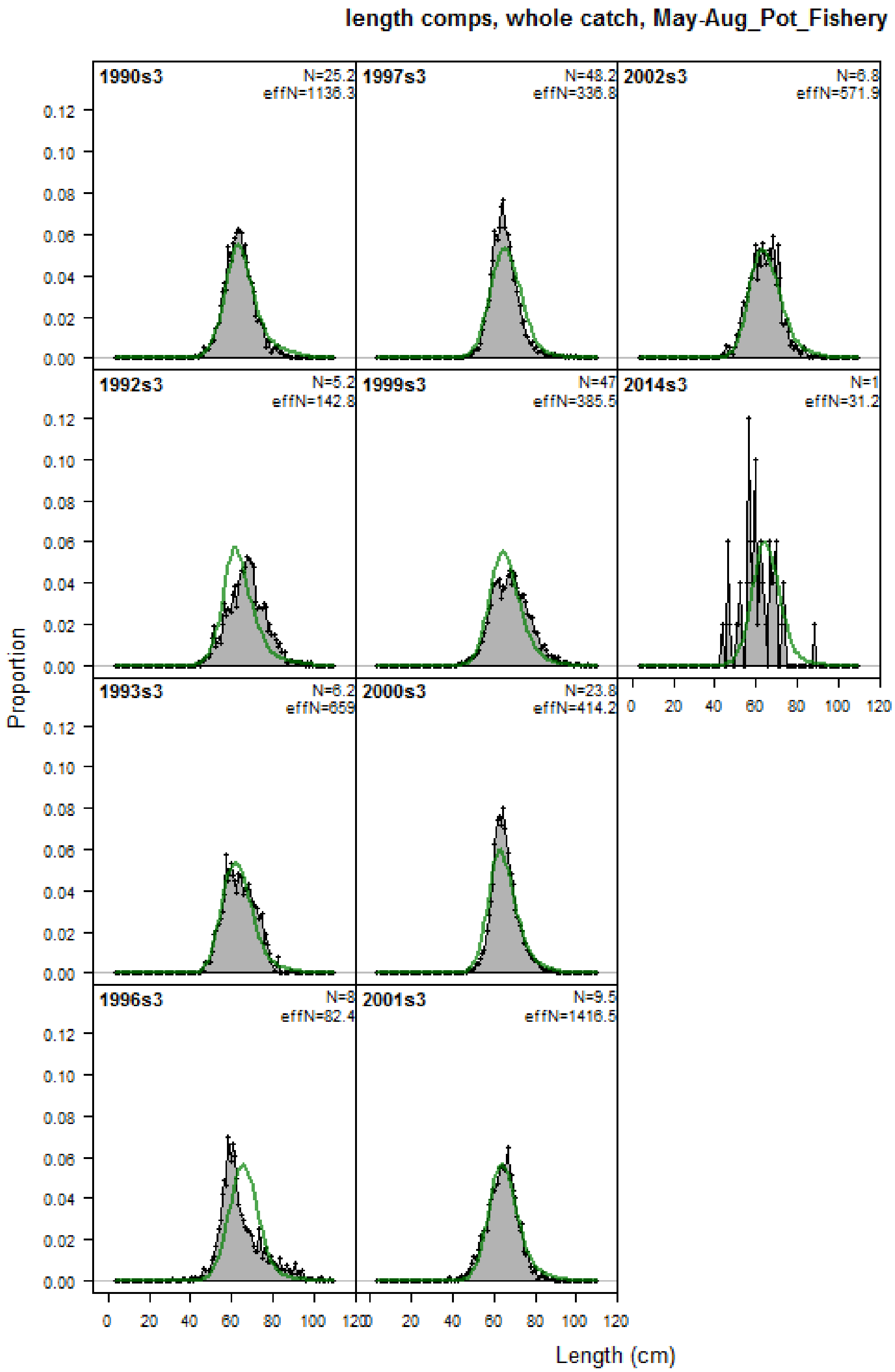

length comps, whole catch, Sep-Dec_Longline_Fishery
2014s4
N=24.2
effN=723.4
2014s5
N=68.2
effN=596
2015s4
N=1.2
effN=52
Proportion
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
20
40
60
80
100
120
Length (cm)

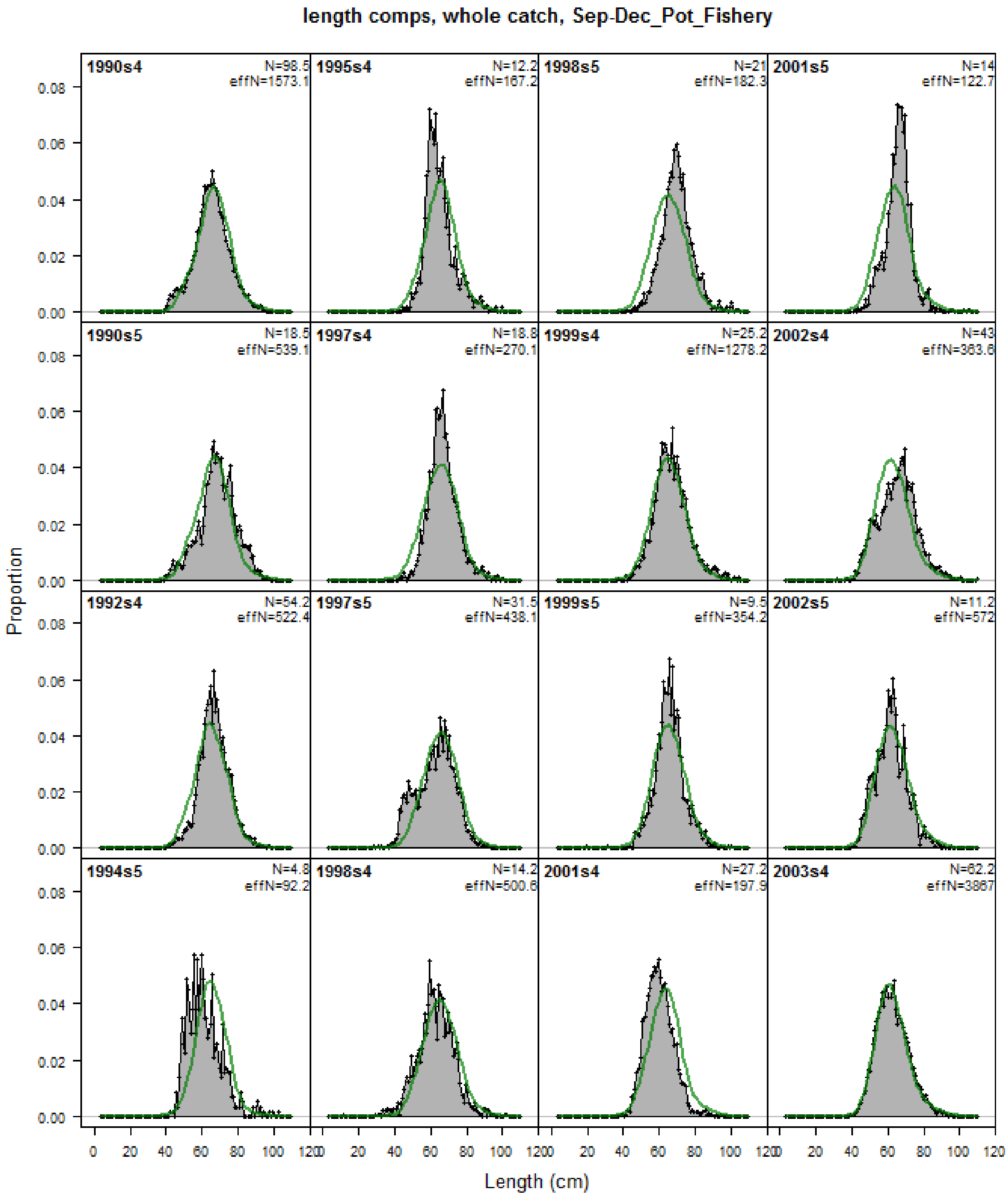

length comps, whole catch, Jan-Apr_Pot_Fishery
1990s2 N=12.5 effN=1102.6
1992s2 N=100 effN=1947.4
1994s2 N=31.2 effN=803.2
1996s2 N=63 effN=1247.7
1991s1 N=100 effN=3296.9
1993s1 N=26.2 effN=251.2
1995s1 N=100 effN=2063
1997s1 N=98.5 effN=2727.8
1991s2 N=100 effN=1146.5
1993s2 N=85.8 effN=1213.2
1995s2 N=98.5 effN=2697.6
1997s2 N=58.8 effN=832.1
1992s1 N=90 effN=868
1994s1 N=61.5 effN=3560.6
1996s1 N=100 effN=8968
1998s1 N=100 effN=897.7
Proportion
Length (cm)

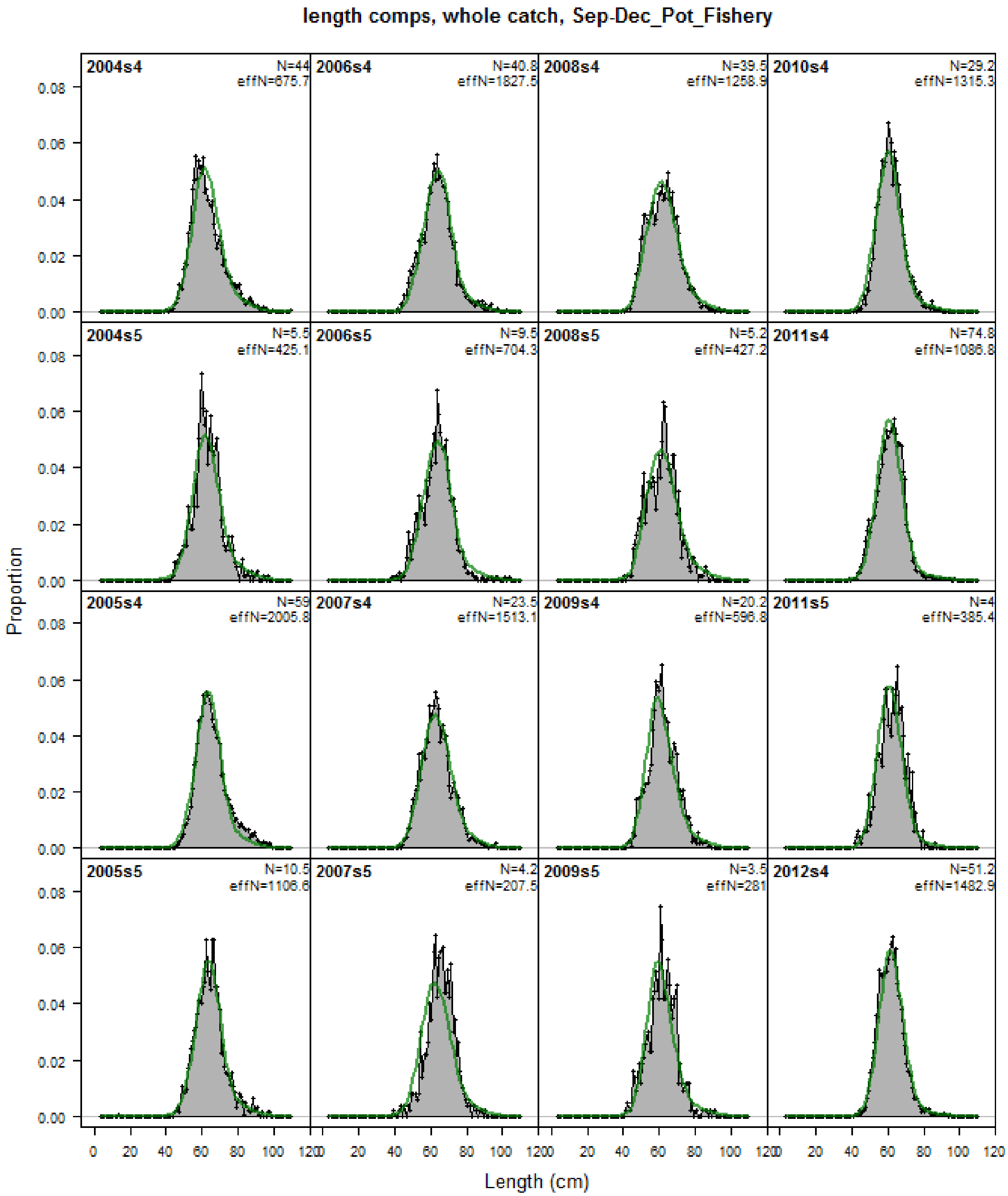

length comps, whole catch, Jan-Apr_Pot_Fishery
1998s2 N=100 effN=776.9
2000s2 N=90.8 effN=2855.4
2002s2 N=56.2 effN=1468.8
2004s2 N=30.2 effN=1353.6
1999s1 N=69.8 effN=2658.4
2001s1 N=45.5 effN=1198.5
2003s1 N=51 effN=2202.1
2005s1 N=85.2 effN=1520.9
1999s2 N=100 effN=2018.9
2001s2 N=77.2 effN=857.8
2003s2 N=27.8 effN=3983.3
2005s2 N=35.5 effN=557.6
2000s1 N=100 effN=1768.2
2002s1 N=40 effN=3053.6
2004s1 N=88.5 effN=2621.2
2006s1 N=77 effN=1959.2
Proportion
Length (cm)


length comps, whole catch, Jan-Apr_Pot_Fishery
2006s2 N=52 effN=5258.5
2008s2 N=41 effN=1388.8
2010s2 N=22.5 effN=389.5
2012s2 N=20 effN=745.5
2007s1 N=76 effN=1125.1
2009s1 N=67.2 effN=1337.3
2011s1 N=61.5 effN=1449.7
2013s1 N=36 effN=798.8
2007s2 N=60.2 effN=962
2009s2 N=19 effN=231
2011s2 N=16.8 effN=375.1
2013s2 N=23.5 effN=984
2008s1 N=68.8 effN=2166
2010s1 N=69.5 effN=727.4
2012s1 N=70 effN=2266
2014s1 N=27.2 effN=483.9
Proportion
0.00
0.02
0.04
0.06
0.08
0
20
40
60
80
100
120
Length (cm)


length comps, whole catch, Jan-Apr_Pot_Fishery
2014s2
N=17.8
effN=815.4
2015s1
N=55.8
effN=642.2
2015s2
N=20.8
effN=573.9
Proportion
Length (cm)
0.00
0.02
0.04
0.06
0.08
0
20
40
60
80
100
120


length comps, whole catch, May-Aug_Pot_Fishery
1990s3 N=25.2 effN=1136.3
1997s3 N=48.2 effN=336.8
2002s3 N=6.8 effN=571.9
1992s3 N=5.2 effN=142.8
1999s3 N=47 effN=385.5
2014s3 N=1 effN=31.2
1993s3 N=6.2 effN=659
2000s3 N=23.8 effN=414.2
1996s3 N=8 effN=82.4
2001s3 N=9.5 effN=1416.5
Proportion
0.00 0.02 0.04 0.06 0.08 0.10 0.12
0 20 40 60 80 100 120
Length (cm)


length comps, whole catch, Sep-Dec_Pot_Fishery
1990s4 N=98.5 effN=1573.1
1995s4 N=12.2 effN=167.2
1998s5 N=21 effN=182.3
2001s5 N=14 effN=122.7
1990s5 N=18.5 effN=539.1
1997s4 N=18.8 effN=270.1
1999s4 N=25.2 effN=1278.2
2002s4 N=43 effN=363.6
1992s4 N=54.2 effN=522.4
1997s5 N=31.5 effN=438.1
1999s5 N=9.5 effN=354.2
2002s5 N=11.2 effN=572
1994s5 N=4.8 effN=92.2
1998s4 N=14.2 effN=500.6
2001s4 N=27.2 effN=197.9
2003s4 N=62.2 effN=3867
Proportion
Length (cm)


length comps, whole catch, Sep-Dec_Pot_Fishery
2004s4 N=44 effN=675.7
2006s4 N=40.8 effN=1827.5
2008s4 N=39.5 effN=1258.9
2010s4 N=29.2 effN=1315.3
2004s5 N=5.5 effN=425.1
2006s5 N=9.5 effN=704.3
2008s5 N=5.2 effN=427.2
2011s4 N=74.8 effN=1086.8
2005s4 N=59 effN=2005.8
2007s4 N=23.5 effN=1513.1
2009s4 N=20.2 effN=596.8
2011s5 N=4 effN=385.4
2005s5 N=10.5 effN=1106.6
2007s5 N=4.2 effN=207.5
2009s5 N=3.5 effN=281
2012s4 N=51.2 effN=1482.9
Proportion
0.00
0.02
0.04
0.06
0.08
Length (cm)
0
20
40
60
80
100
120

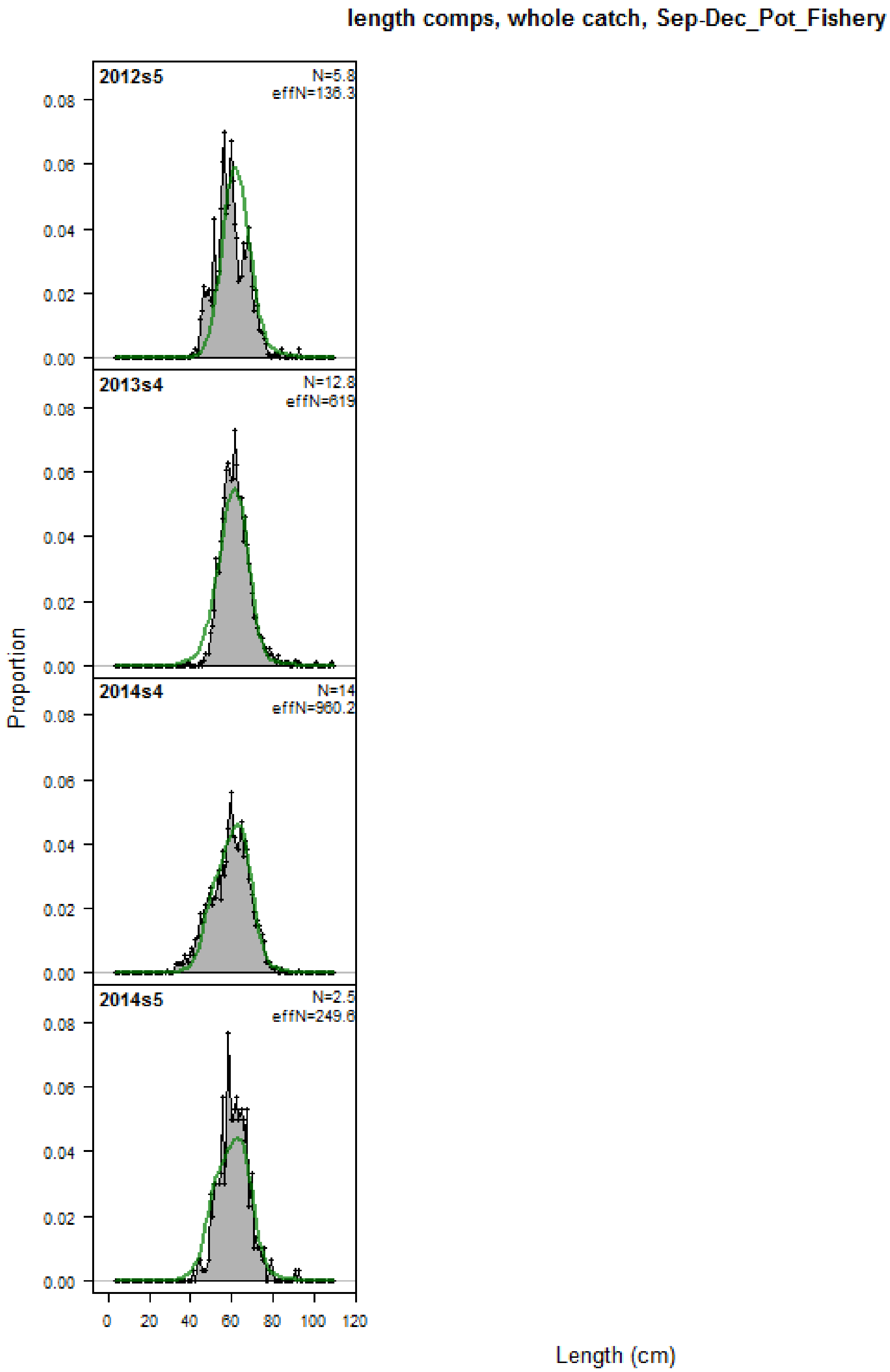

length comps, whole catch, Sep-Dec_Pot_Fishery
2012s5
N=5.8
effN=136.3
2013s4
N=12.8
effN=619
2014s4
N=14
effN=960.2
2014s5
N=2.5
effN=249.6
Proportion
0.00
0.02
0.04
0.06
0.08
0
20
40
60
80
100
120
Length (cm)

Figure 2.28 – Spawning biomass from the retrospective model runs for Model 3 – ¼ fsh

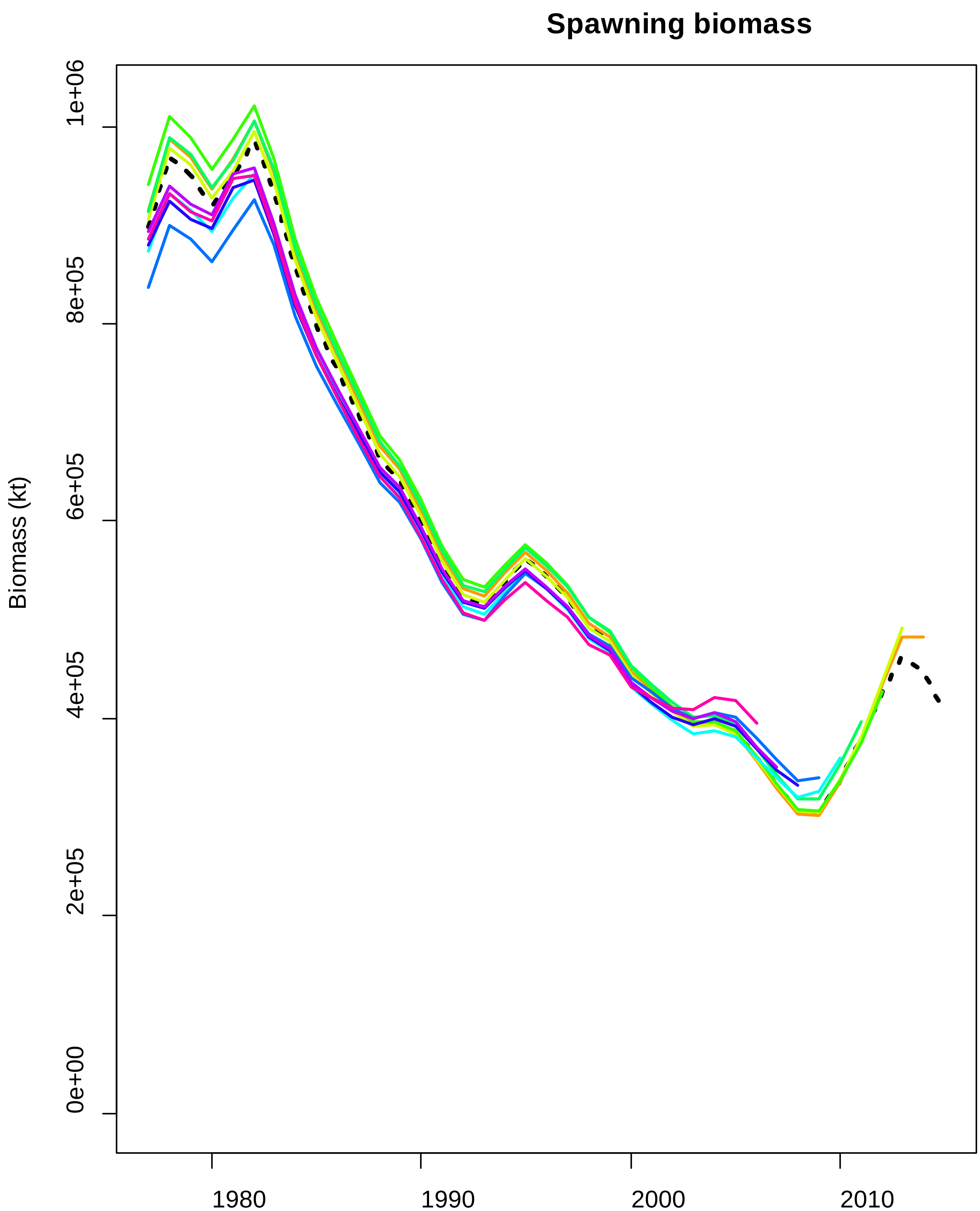


Figure 2.29 – Percent difference for spawning biomass from the retrospective model runs for Model 3 – ¼ fsh

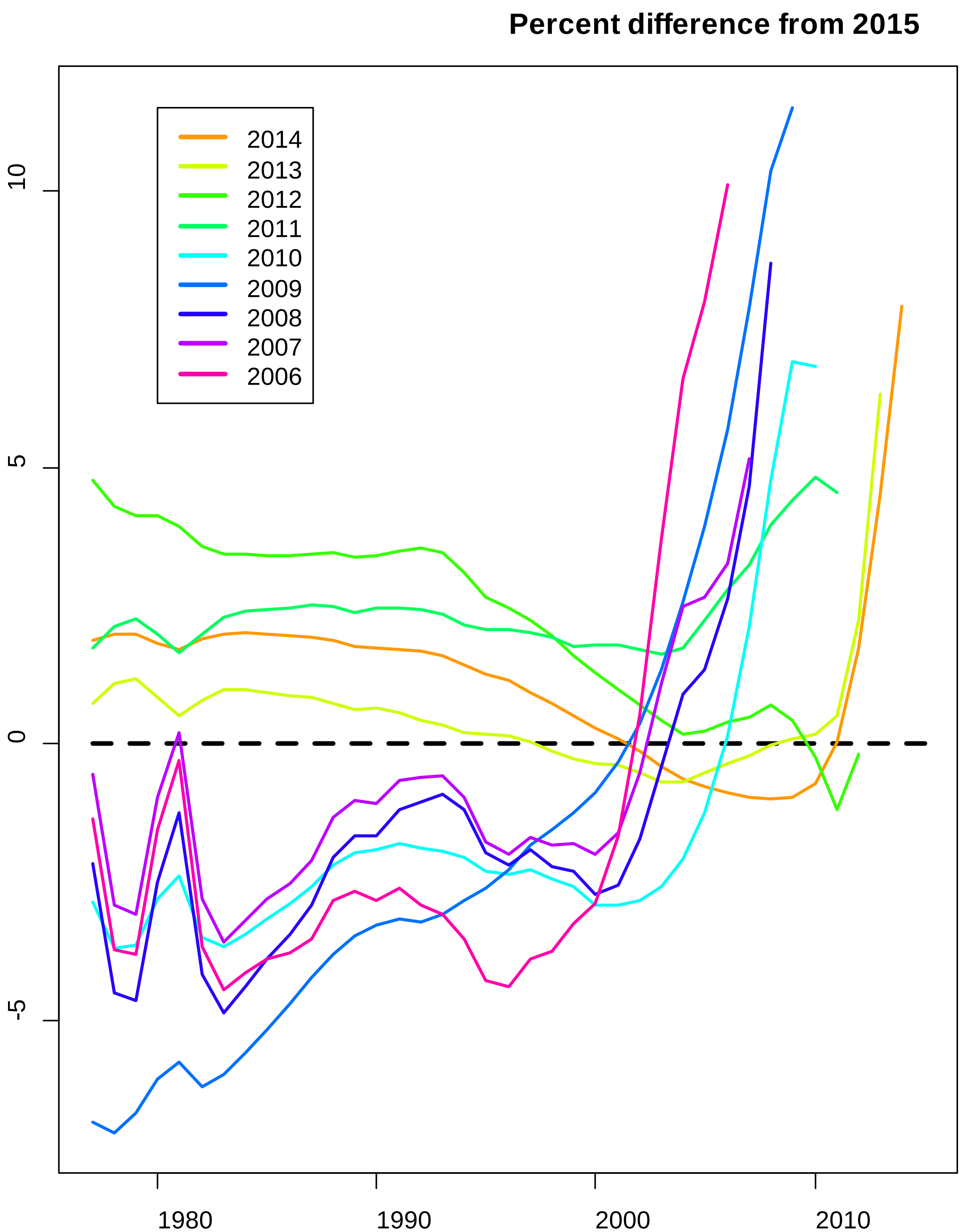
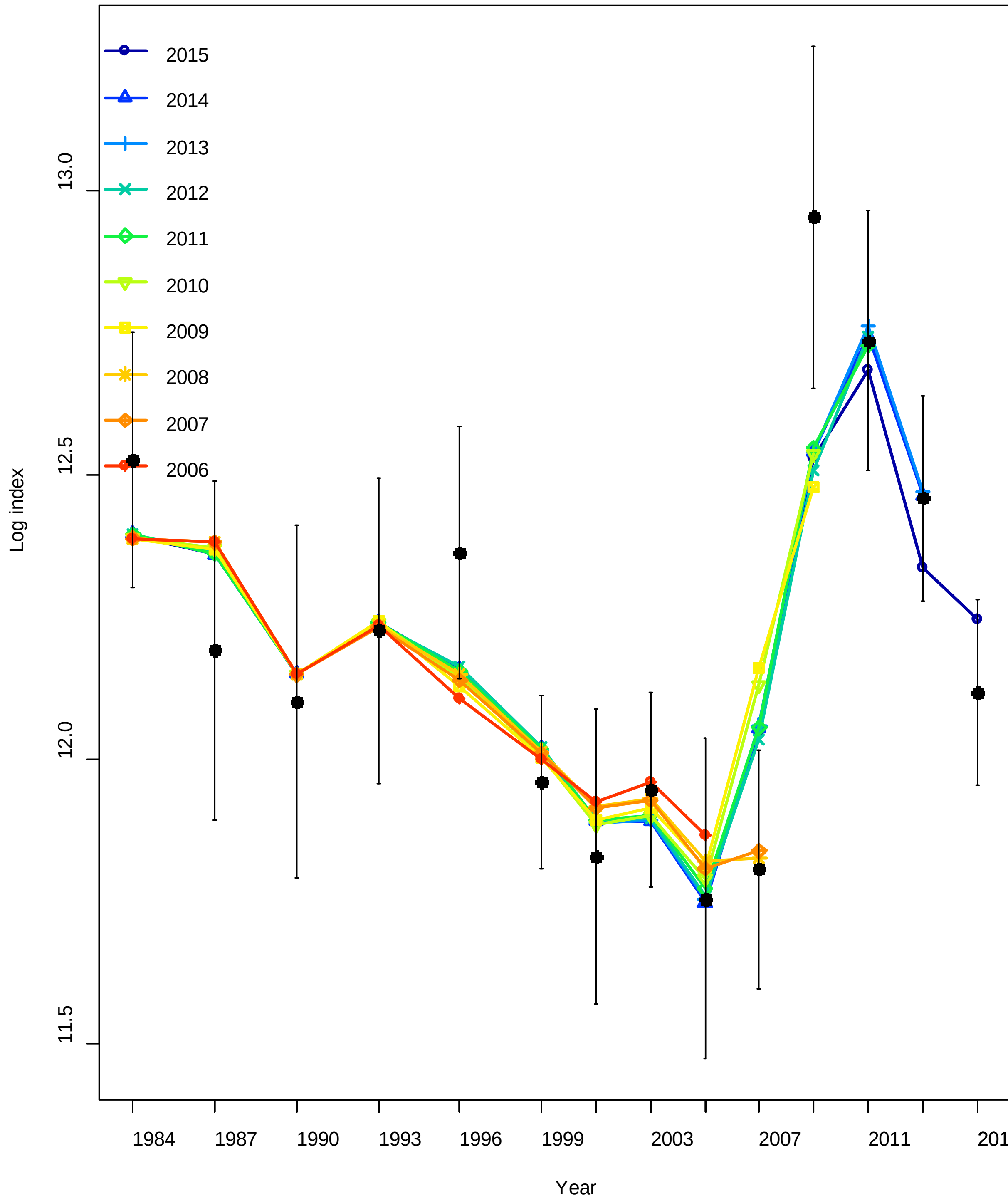


Figure 2.30 – Fits for the survey abundance index for the retrospective model runs for Model 3 – ¼ fsh



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