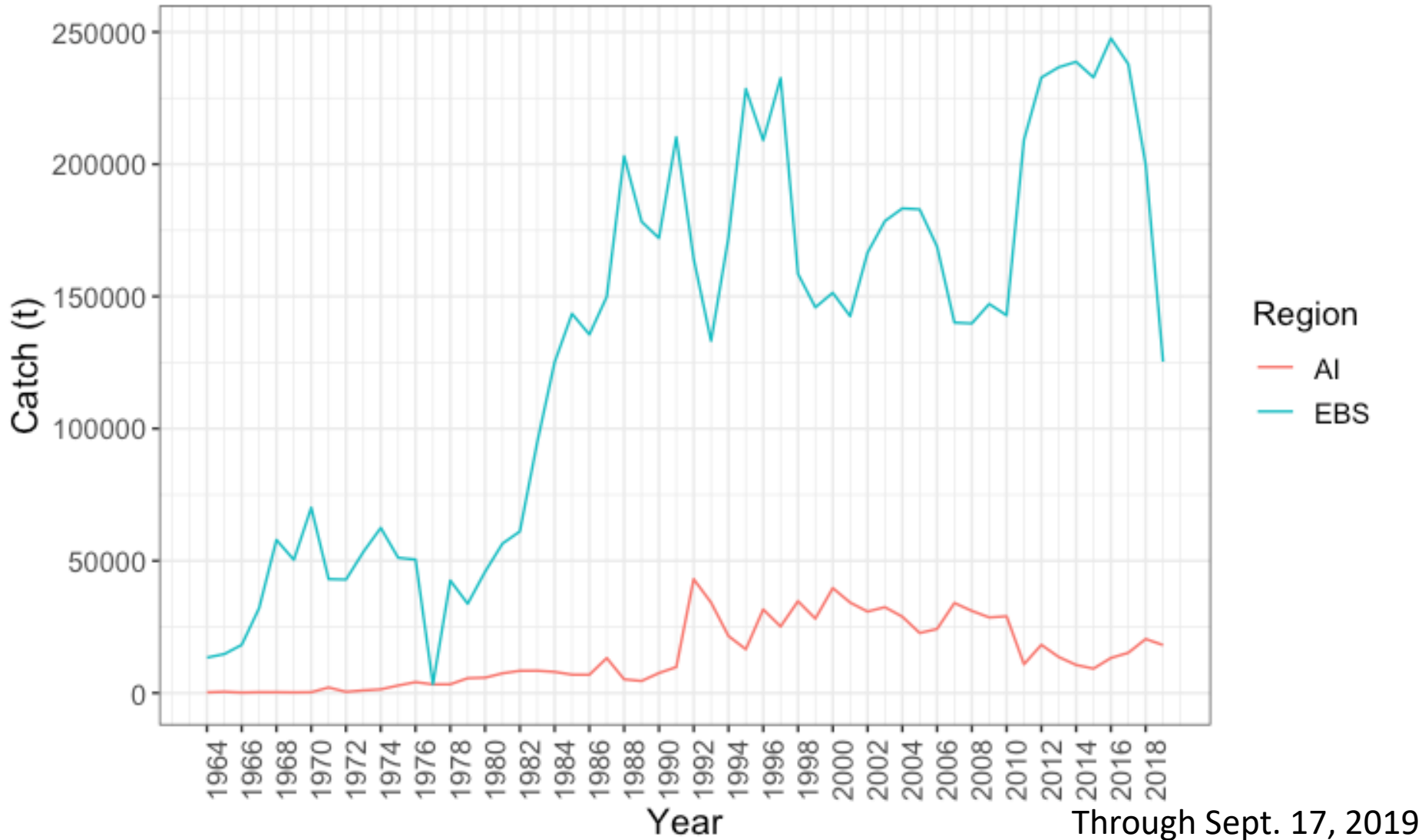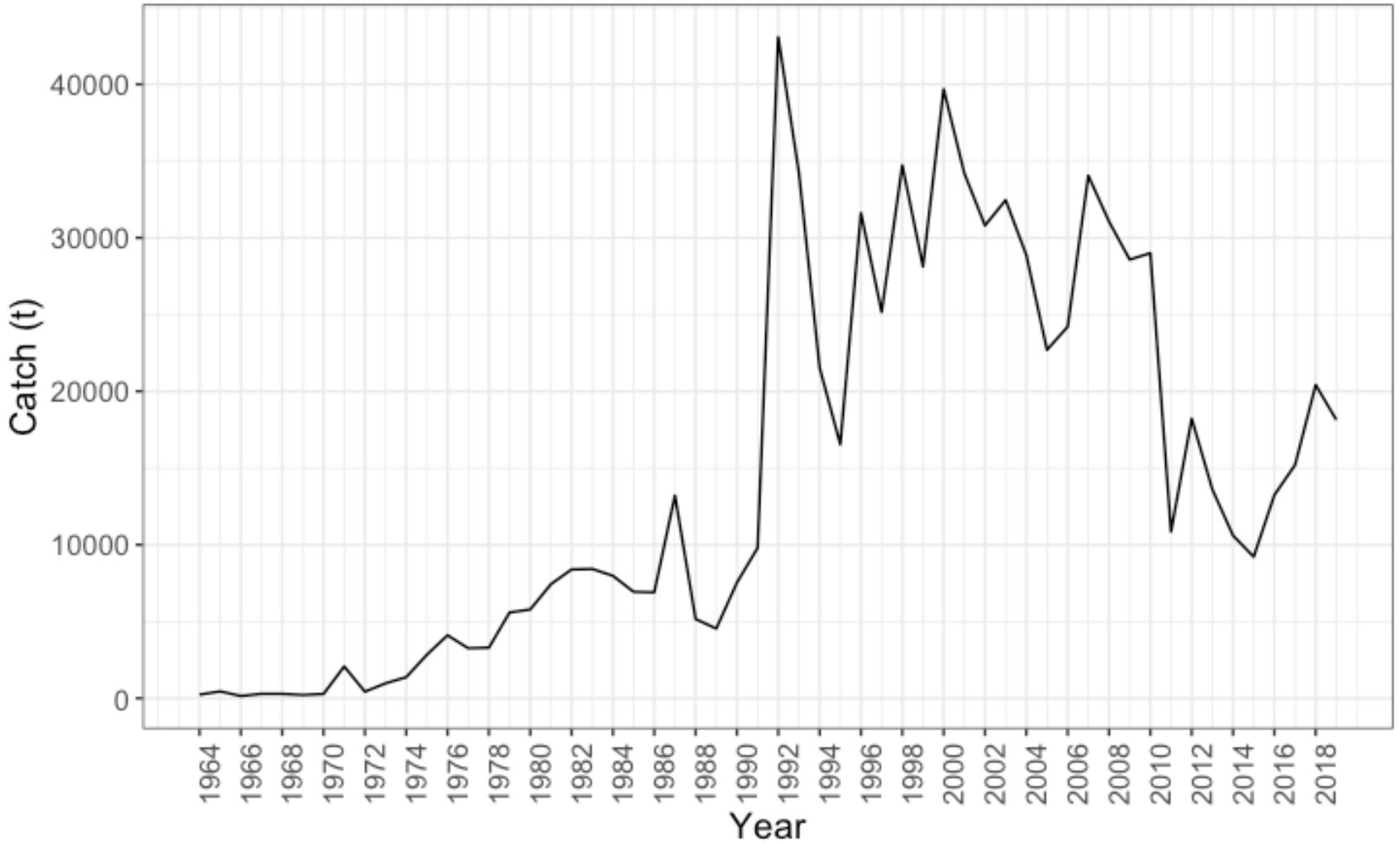# Preliminary age structured assessment model of the Pacific cod stock in the Aleutian Islands 2019

Ingrid Spies, Grant G. Thompson, Steve Barbeaux, and James N. Ianelli

Cod catch in the Bering Sea and Aleutian Islands, 1964-2019
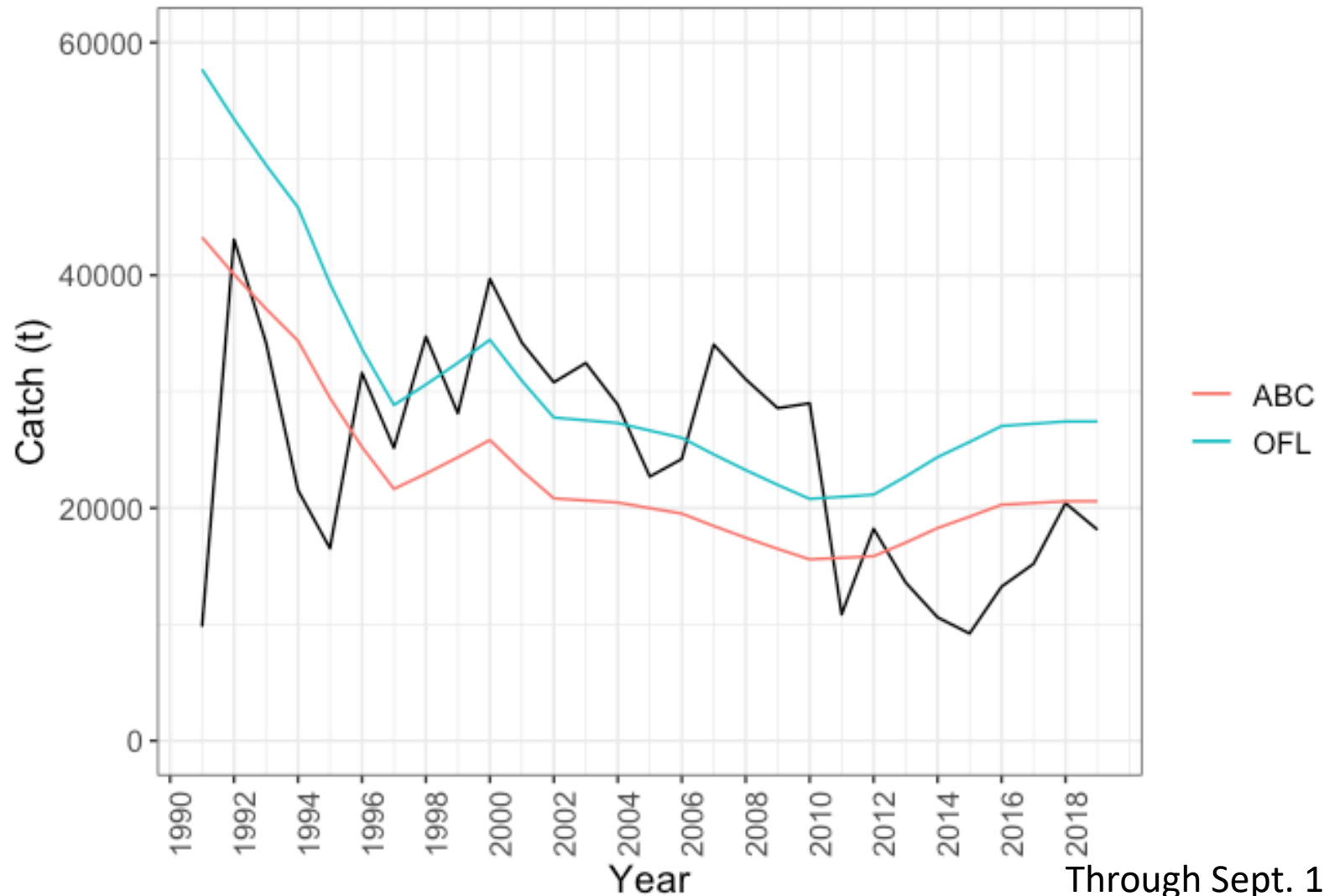

Through Sept. 17, 2019

Cod catch in the Aleutian Islands, 1964-2019

Through Sept. 17, 2019

Catch (black line) with Tier 5 ABC and OFL, 1990-2018

Through Sept. 17, 2019

The initial age structured model presented by Grant Thompson in 2012

- a single season,

- one fishery,

- AI-specific weight-length parameters,

- 1 cm length bins to 150cm,

- fishery selectivity constant over time,

- forced asymptotic fishery selectivity,

- survey samples age 1 fish at true age 1.5,

- ageing bias not estimated,

- catchability (q) tuned to match value from archival tagging data relevant to GOA/AI survey net.

Blue indicate new features of 2019 model

Summary of SSC, Plan Team comments to initial model(s).

- In 2013 the SSC supported a model with the development of two models 1. fixed M fixed and q fixed at 1 and freely estimated selectivity. 2. M fixed, q estimated with a prior, and asymptotic survey selectivity.

- In 2014 the Plan Team recommended only data from 1991 onward.

- In 2015 the Plan Team did not consider any of the age structured models credible but encouraged further work on an age-structured model.

Model features (2019)

- One fishery, one gear type, one season per year (single sex).
- Single growth curve: length at age, weight at age.
- Internal estimation of fishing mortality, catchability, and selectivity parameters, growth.
- Parameters constant over time (annually varying recruitment and fishing mortality).
- Recruitment - mean with normally distributed deviations.
- An ageing error matrix for ages 1 through 10.
- Logistic age-based selectivity for both the fishery and survey.
- Natural mortality was fixed in the model, and estimated with input from likelihood profiles performed using the model.
- Survey catchability estimated within the model as a constant multiplier on survey selectivity (fishery catchability fixed at 1).
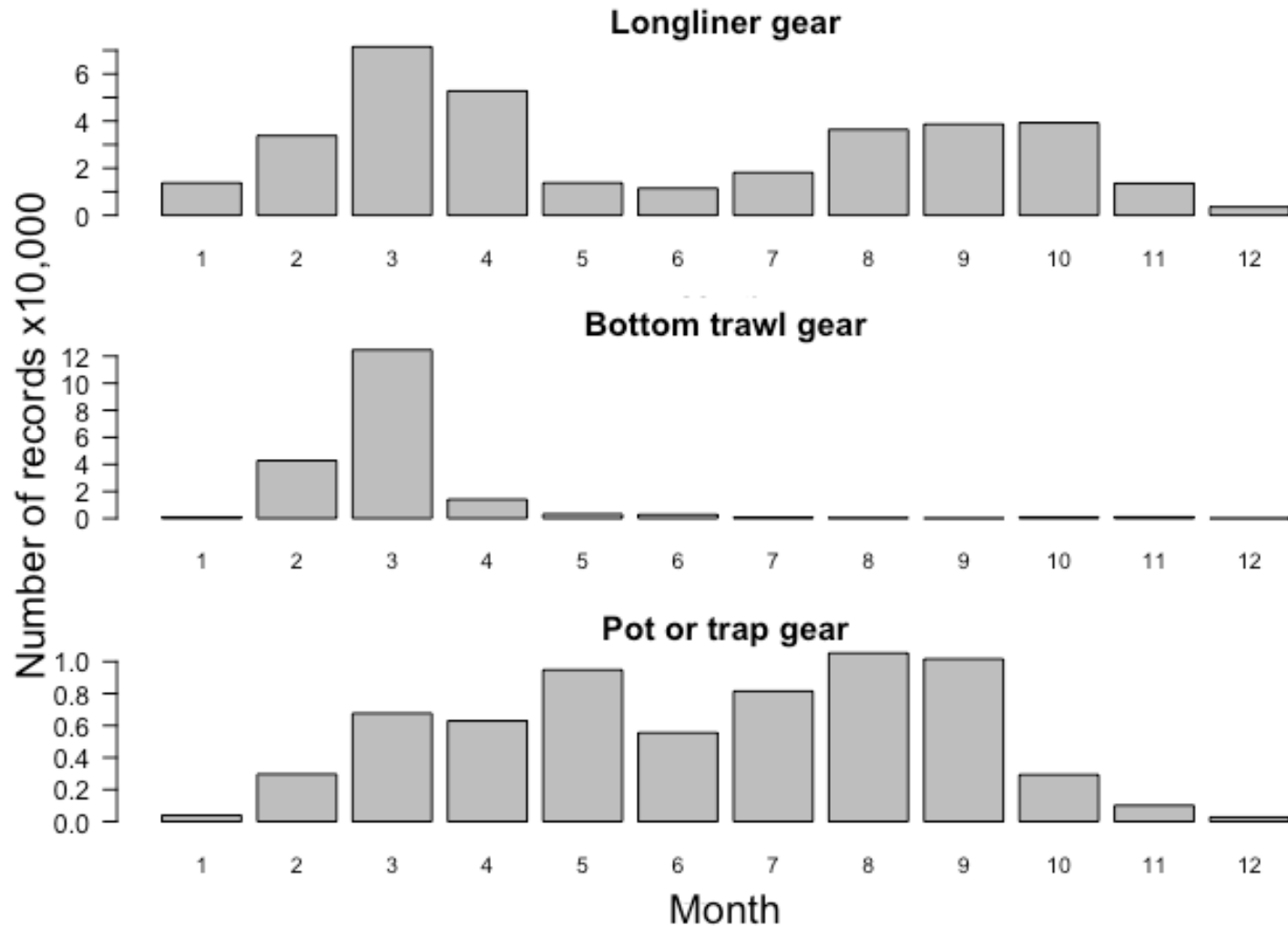
Blue indicate new features of 2019 model

Length frequencies for Pacific cod caught in the Aleutians by fishery (1990-2018) and survey (1991-2018)
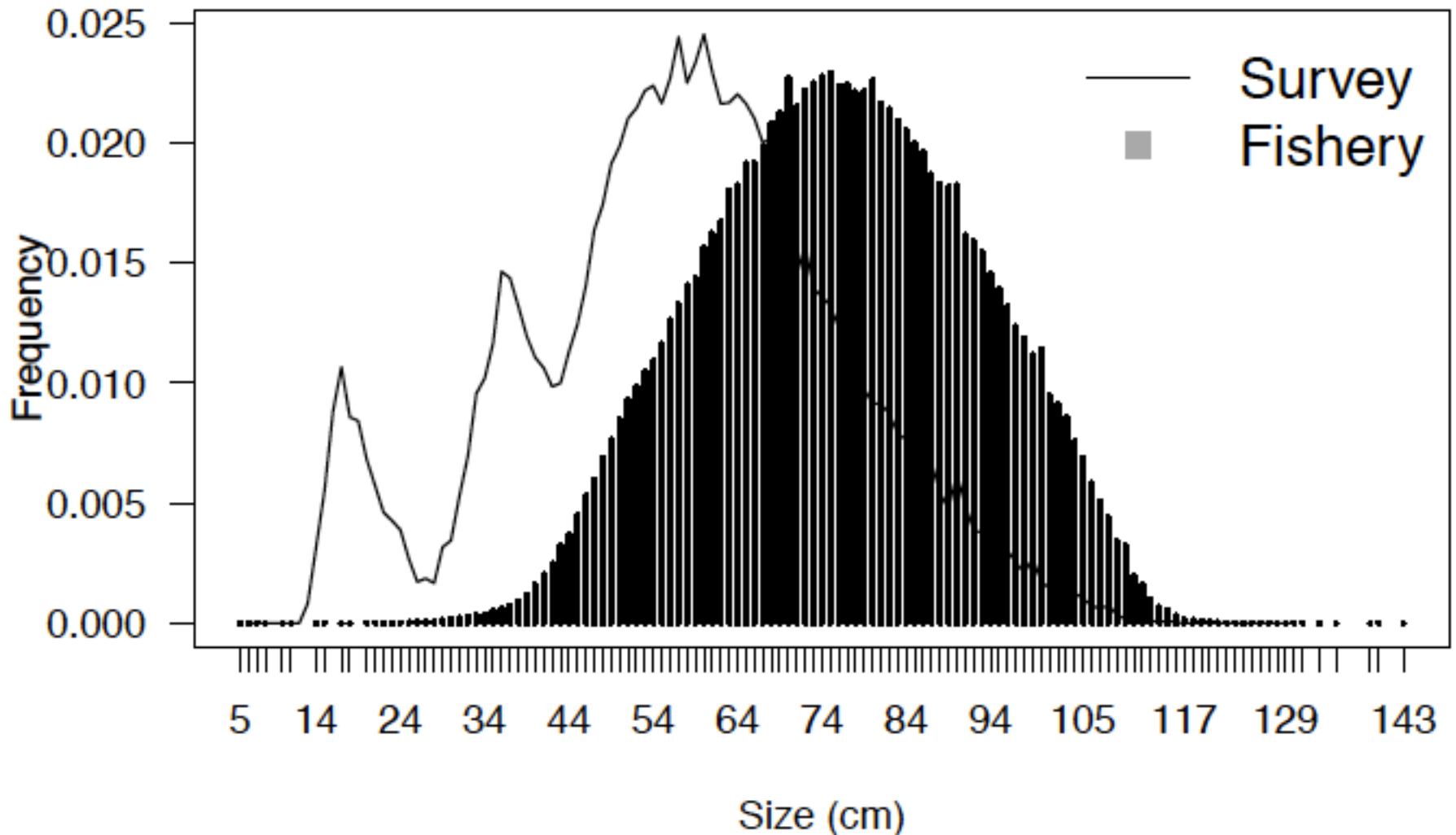
Proportion of fishery lengths taken by month for each gear type, 1990-2018

Length frequency by age of cod collected from surveys from 1990-2018

Data used in the model

Source	Type	Years
Fishery	Catch biomass	1990-2018*
Fishery	Size composition	1990-2018
AI bottom trawl survey	Biomass estimate	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, 2016, 2018
AI bottom trawl survey	Age composition	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, 2016

Age data used in the model (2018 data will be available for 2019).

Year	Number aged
1991	919
1994	1,174
1997	845
2000	828
2002	1,270
2004	775
2006	754
2010	673
2012	598
2014	557
2016	681

- Growth estimated from length and age data from AI surveys from 1991 to 2016.

- All otoliths were aged after 2007, as there was a shift in our understanding of the first two checks deposited at early ages in Pacific cod.

- Prior to 2007 they were thought to be true annuli, but subsequently determined not to be.

Length at age

Stratified otolith collections are typically adjusted for survey length frequencies for which there is typically much more data, which are assumed to be a better representation of length frequencies in the population than lengths of the aged fish.

$$P(Age|Length) = P(Length|Age) * P(Age)/P(Length)$$

There are 489,000 length observations from surveys 1991-2016.

Input data	S_{inf}	K	t_0
Corrected Length at age	106.3310	0.18587	-0.07247
Uncorrected length at age	124.93646	0.15883	-0.09981

Length frequencies for Pacific cod caught in the Aleutians by fishery (1990-2018) and survey (1991-2018)
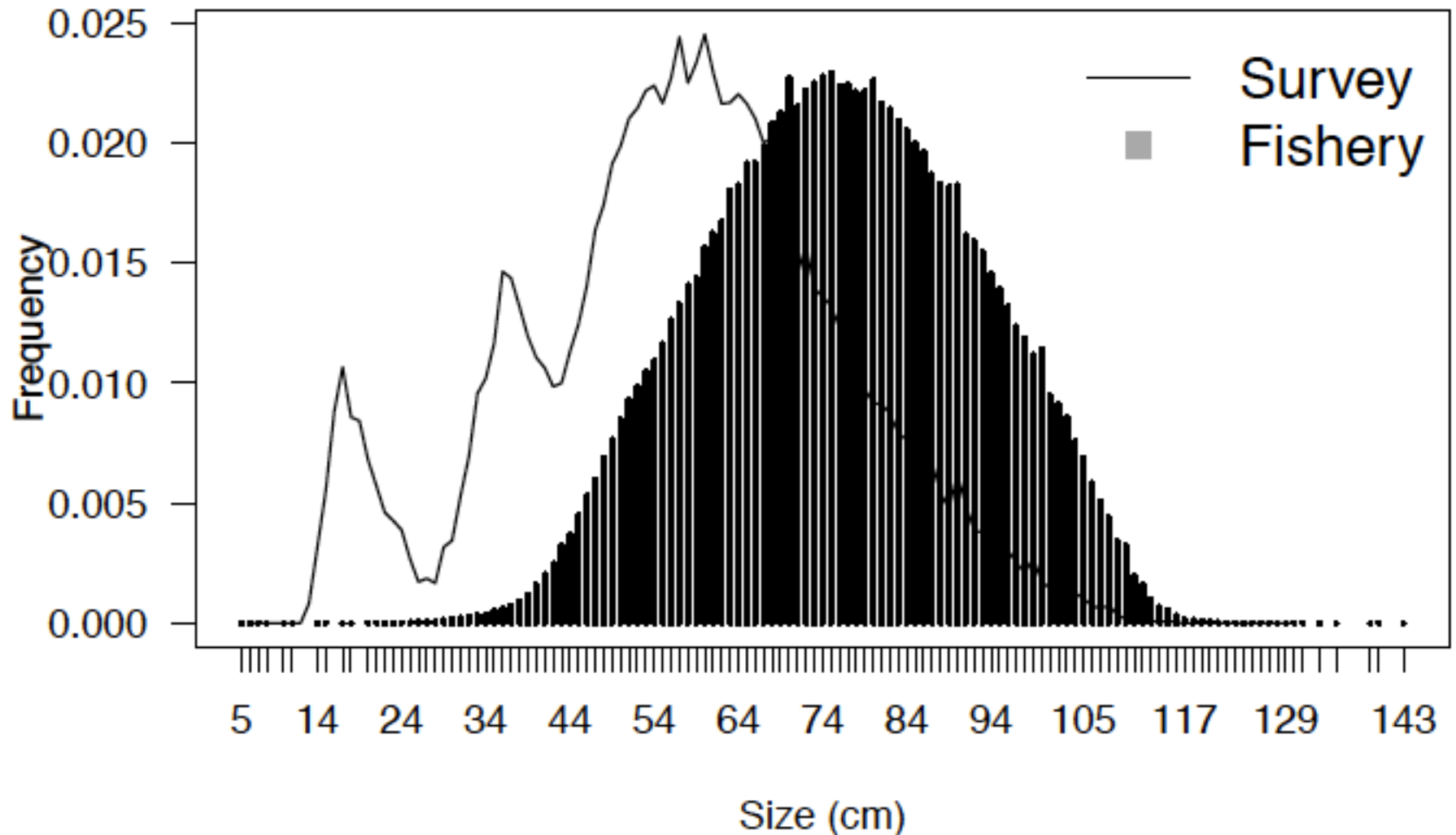
# Otolith sampling methodology for AI surveys 1991-2018

Year	Otolith sampling method
1991	Stratified random
1994	Sub-sampled from original random sample and stratified by size
1997	Stratified by size
1997	Stratified random
1997	Selectively sampled
1997	Sub-sampled from original random sample and stratified by size
2000	Stratified by size
2002	Stratified by size
2004	Sub-sampled from original random sample and stratified by size
2006	Stratified sex/length/area
2010	Stratified sex/length/area
2012	Stratified sex/length/area
2014	Stratified sex/length/area
2016	Randomly selected
2016	Stratified sex/length/area
2018	Randomly selected

Raw lengths at age and vonBertalanffy growth curves (corrected vs. not for population length frequencies)
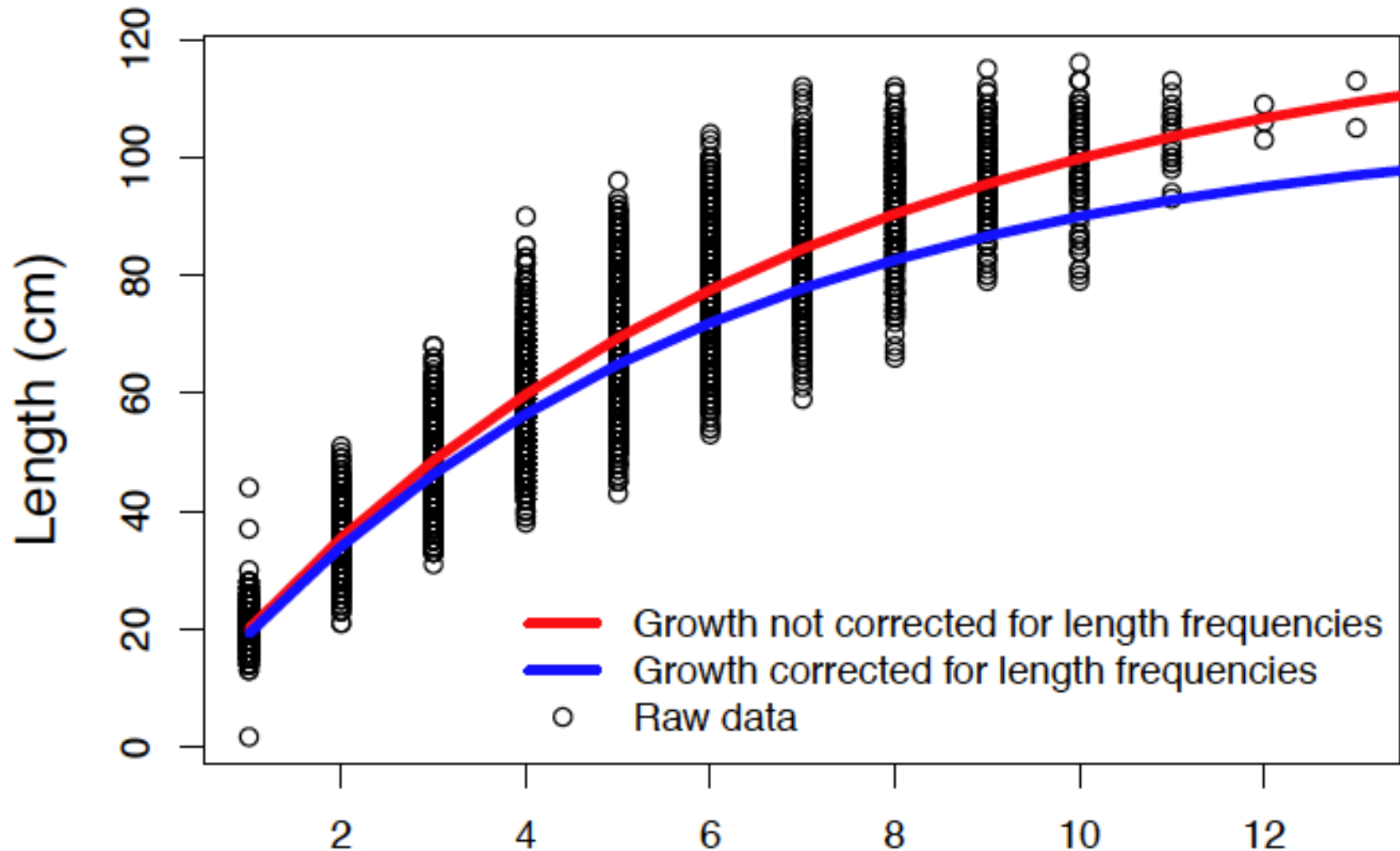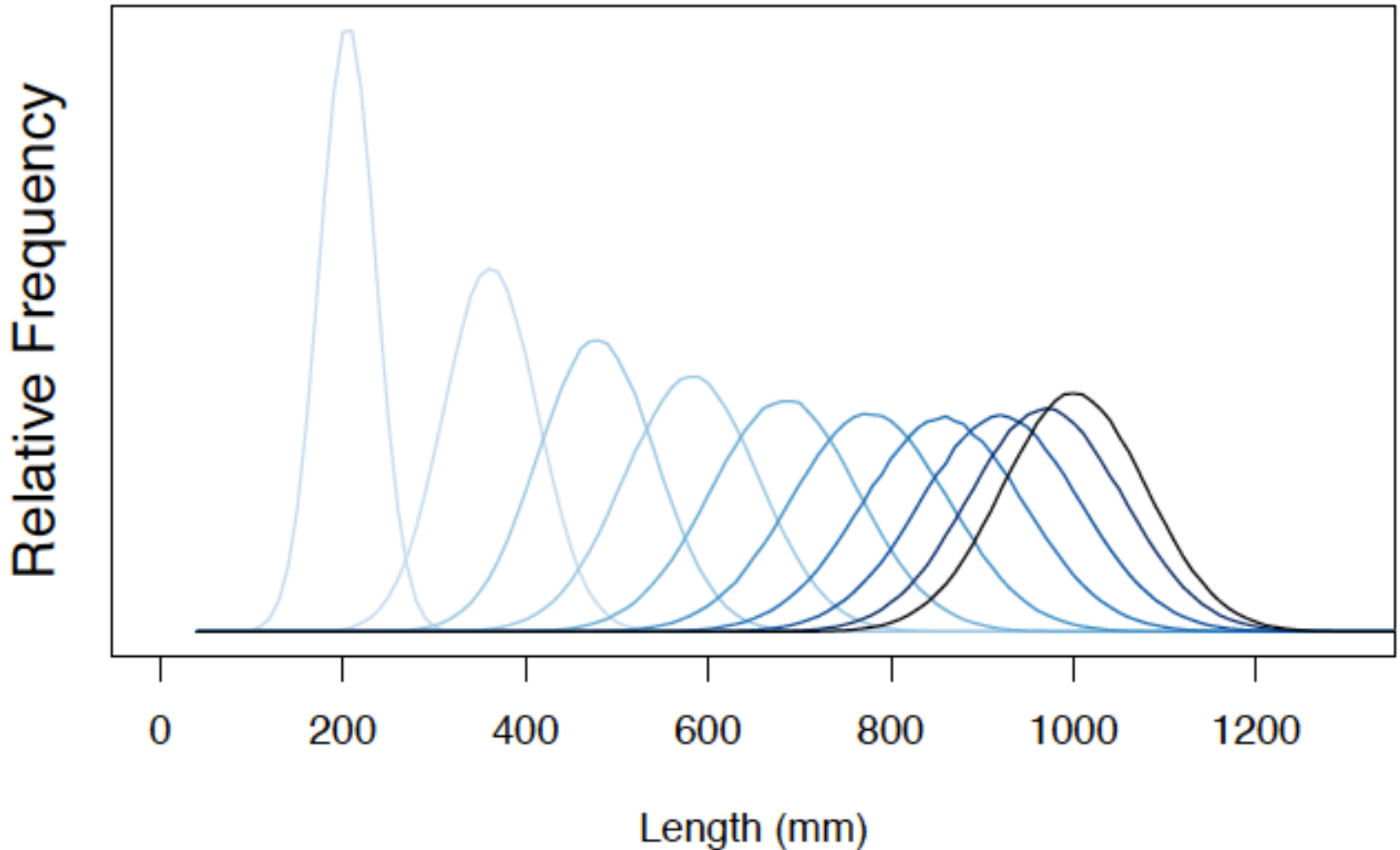
Length-weight relationship for AI Pacific cod
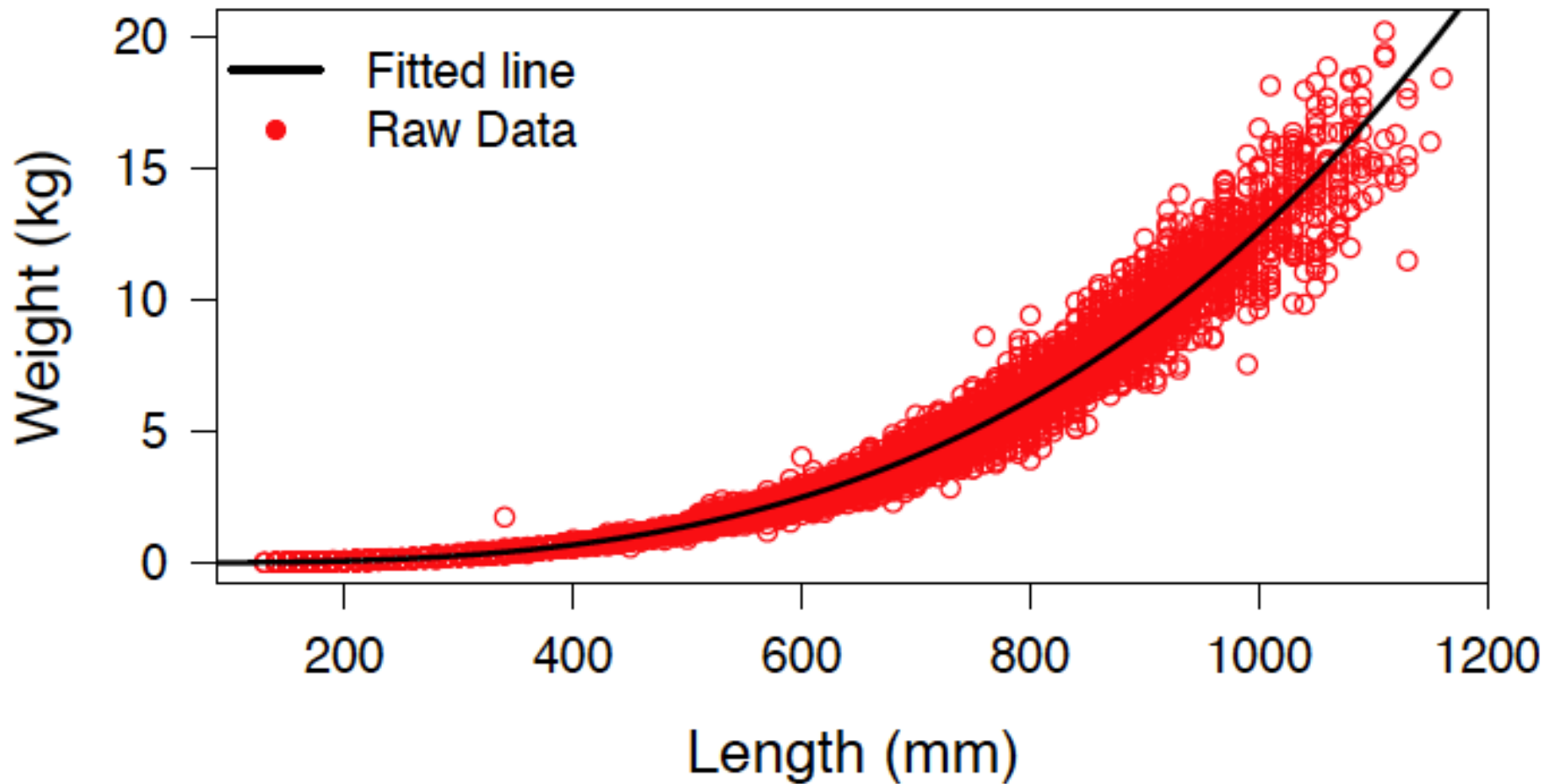
# Length – age conversion matrix for AI Pacific cod

Maturity estimation

- Stark (2007) 129 female fish from Unimak Pass in February 2003.

  - 50% maturity at 4.88 years, 58 cm.

- 2,098 observer records of maturity at length collected since 2008 during January-March.

  - Maturity at length relationship fit to the data.
  - Converted to maturity at age using length age
  - conversion matrix.

$$Maturity_{age} = \frac{1}{1 + e^{-(A + B*age)}}$$

| Year	Number of records
2008	1185
2009	35
2010	156
2011	80
2012	151
2013	61
2014	128
2015	78
2016	79
2017	42
2018	26
2019	77

Proportion mature by age, using Stark (2007) and observer maturity at length data
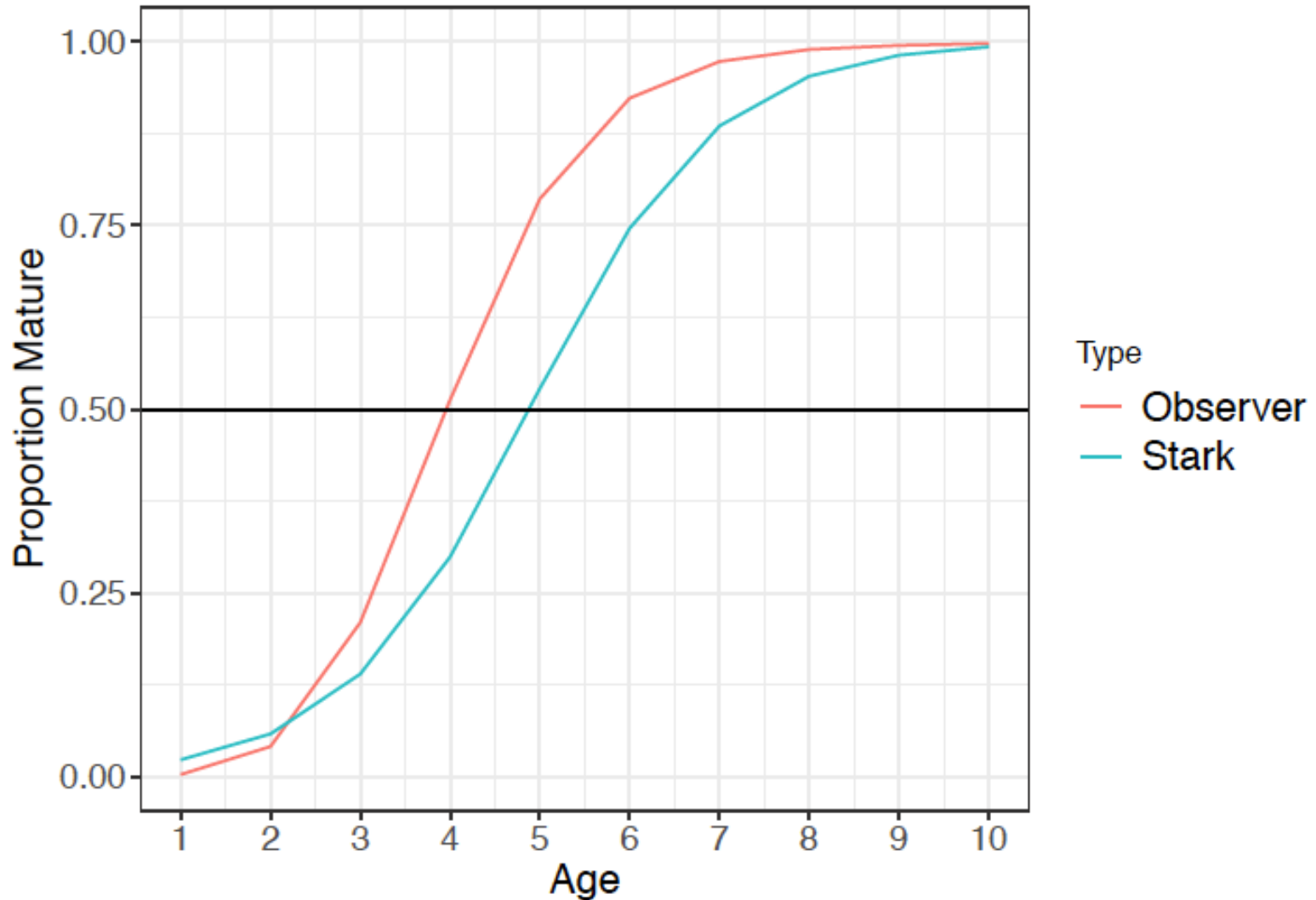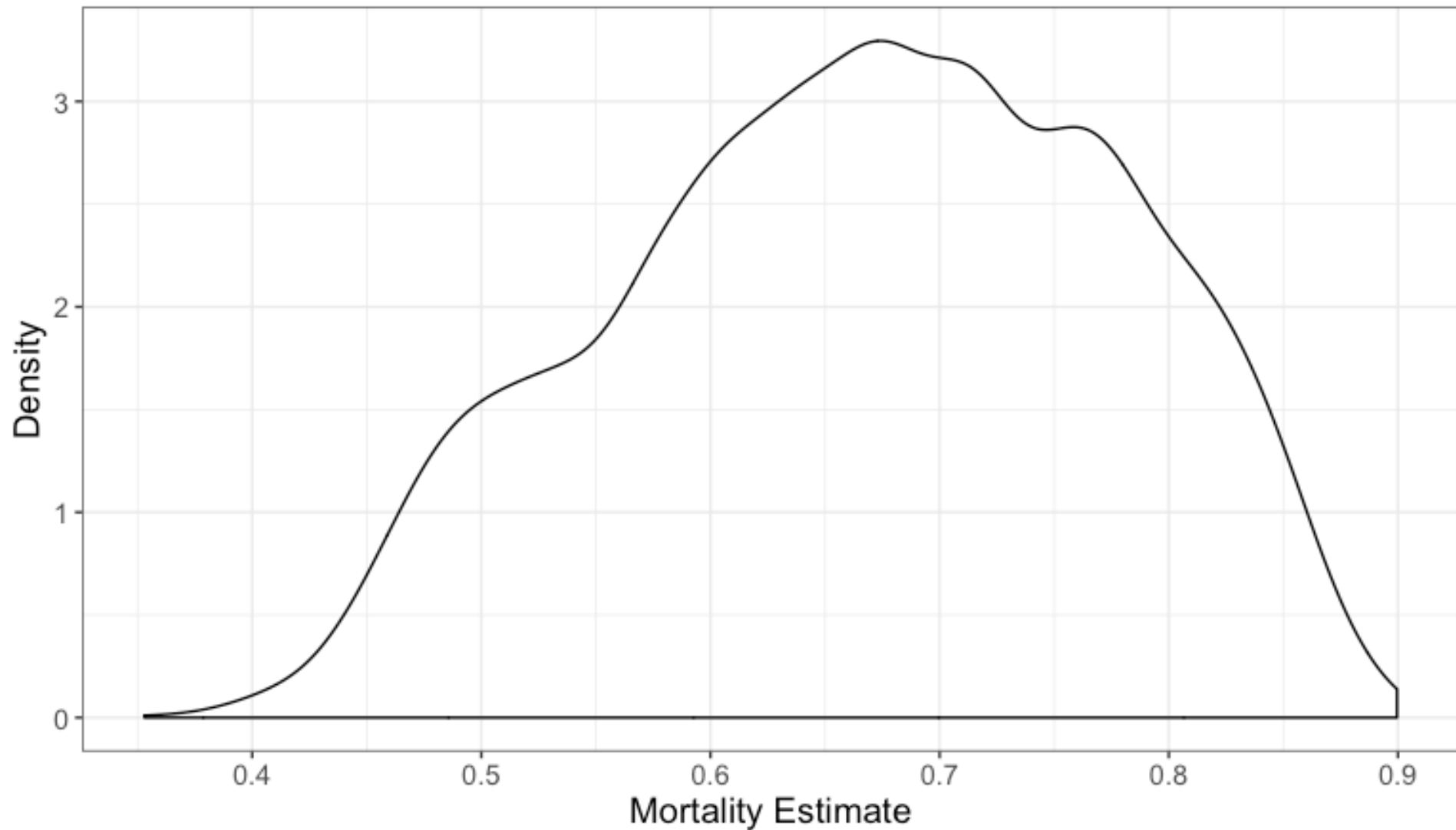
Model estimates of selectivity for survey and fishery

$$Selectivity_{age} = \frac{1}{1 + e^{-(slope*age - a_{50})}}$$
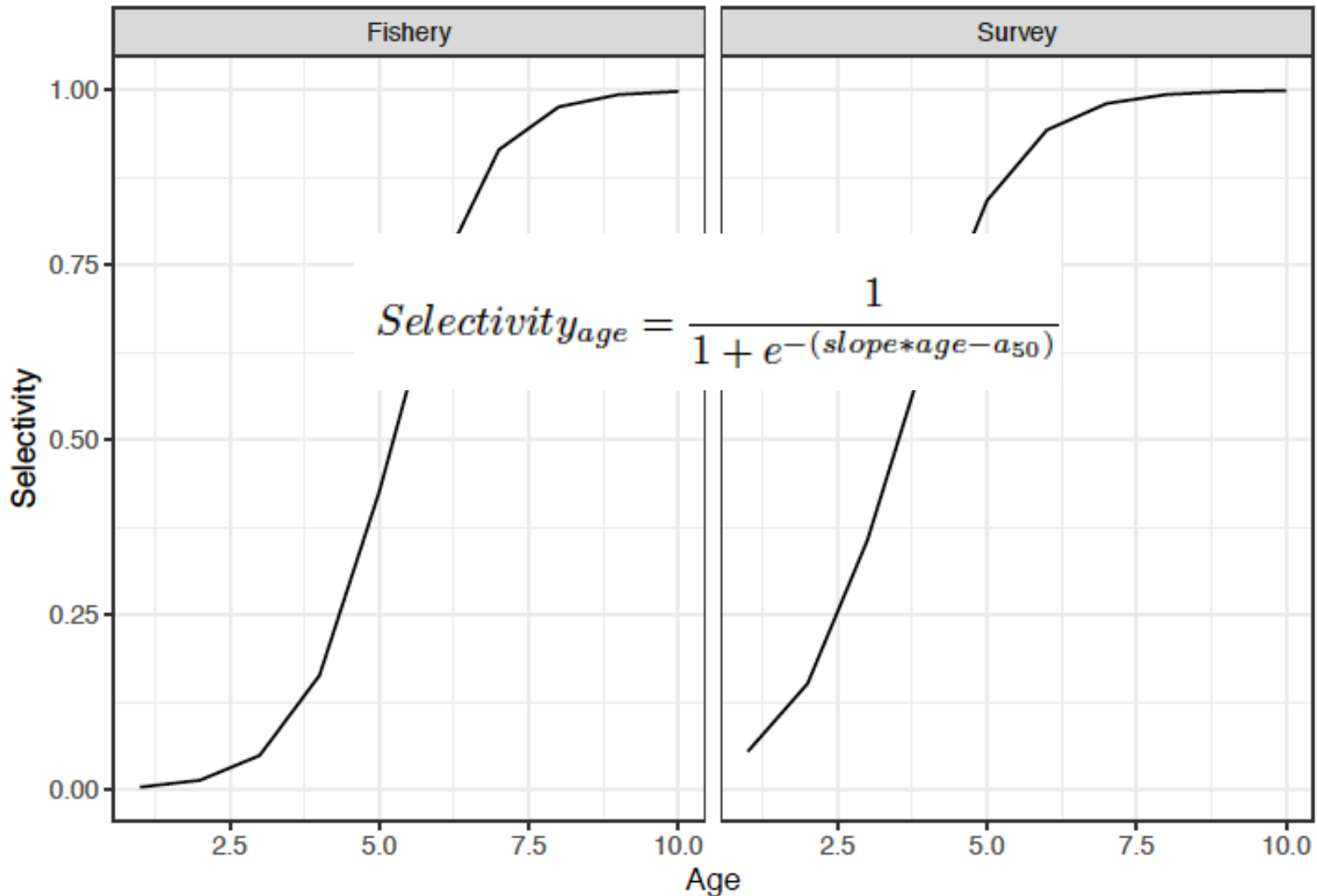
Likelihood profile for natural mortality for fishery length, recruitment, survey biomass, and age likelihood components.
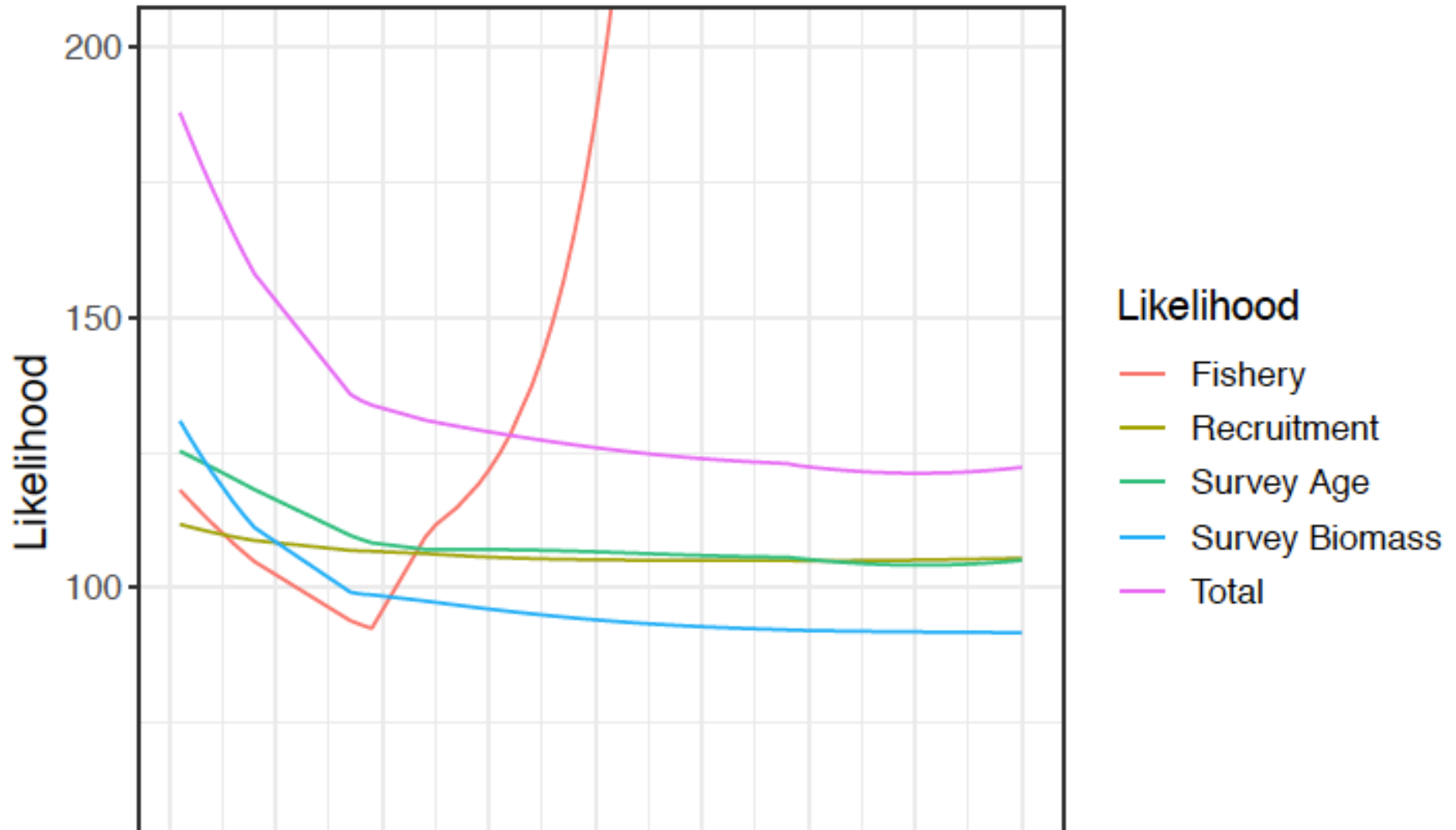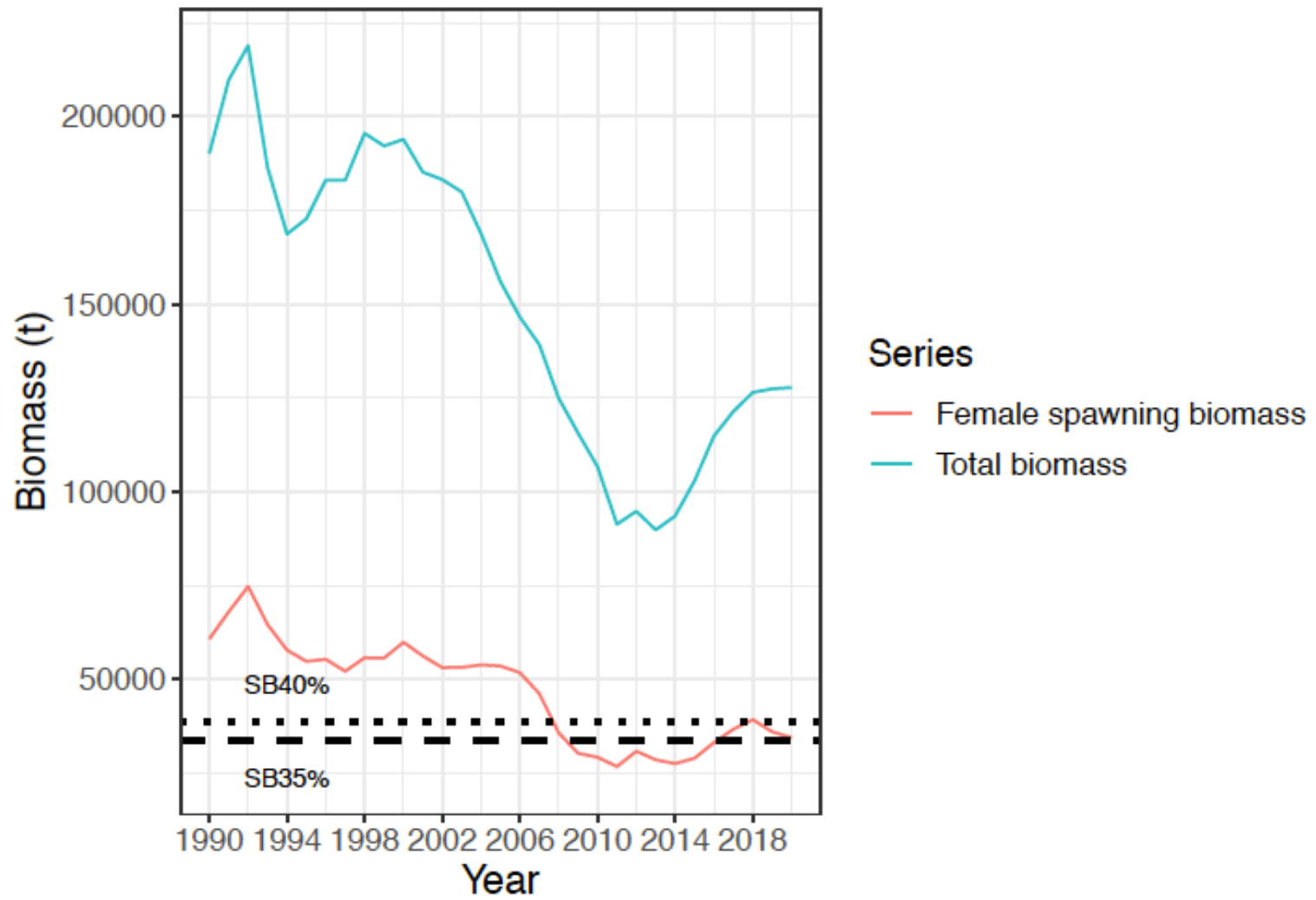
MCMC estimate of M: 0.67

Estimation of M, natural mortality

- Fishery data ~0.3
- Survey data >>0.4
- MCMC: 0.67.

- Current Tier 5 methodology uses M=0.34.
- To balance the data and current methods, I started with M=0.4.

Model estimates for total (age 1+) biomass, FSB 1990-2019. Reference points for B40% and B35% are shown.

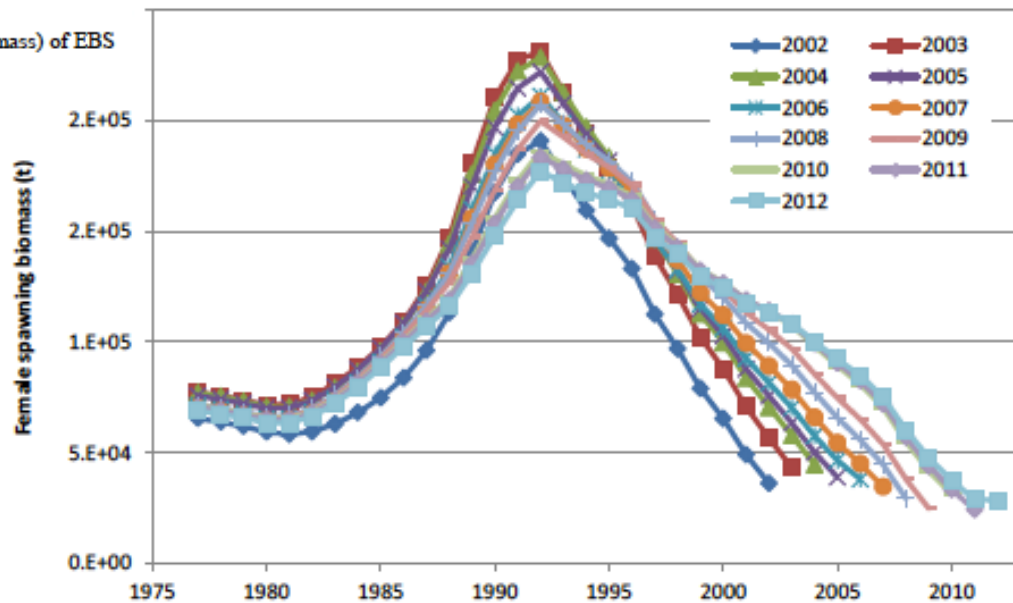# Total biomass and female spawning biomass for 2012 age structured AI assessment.
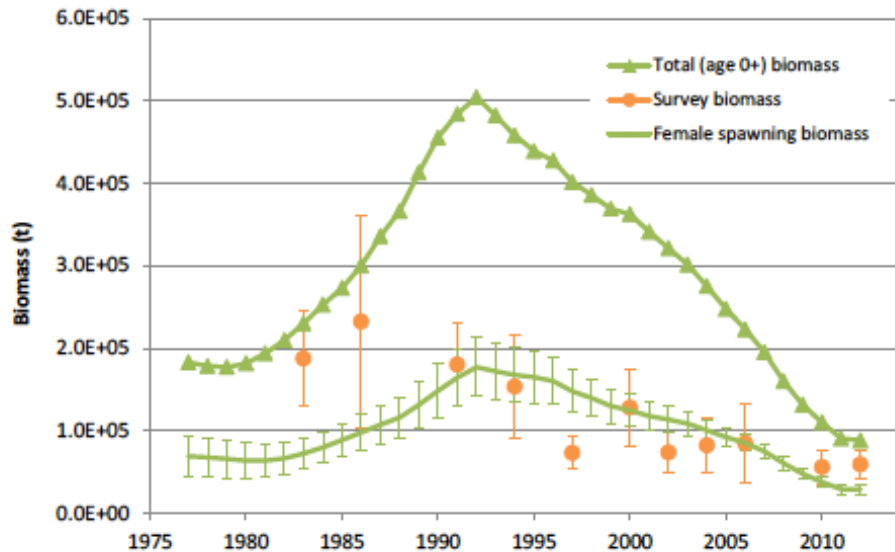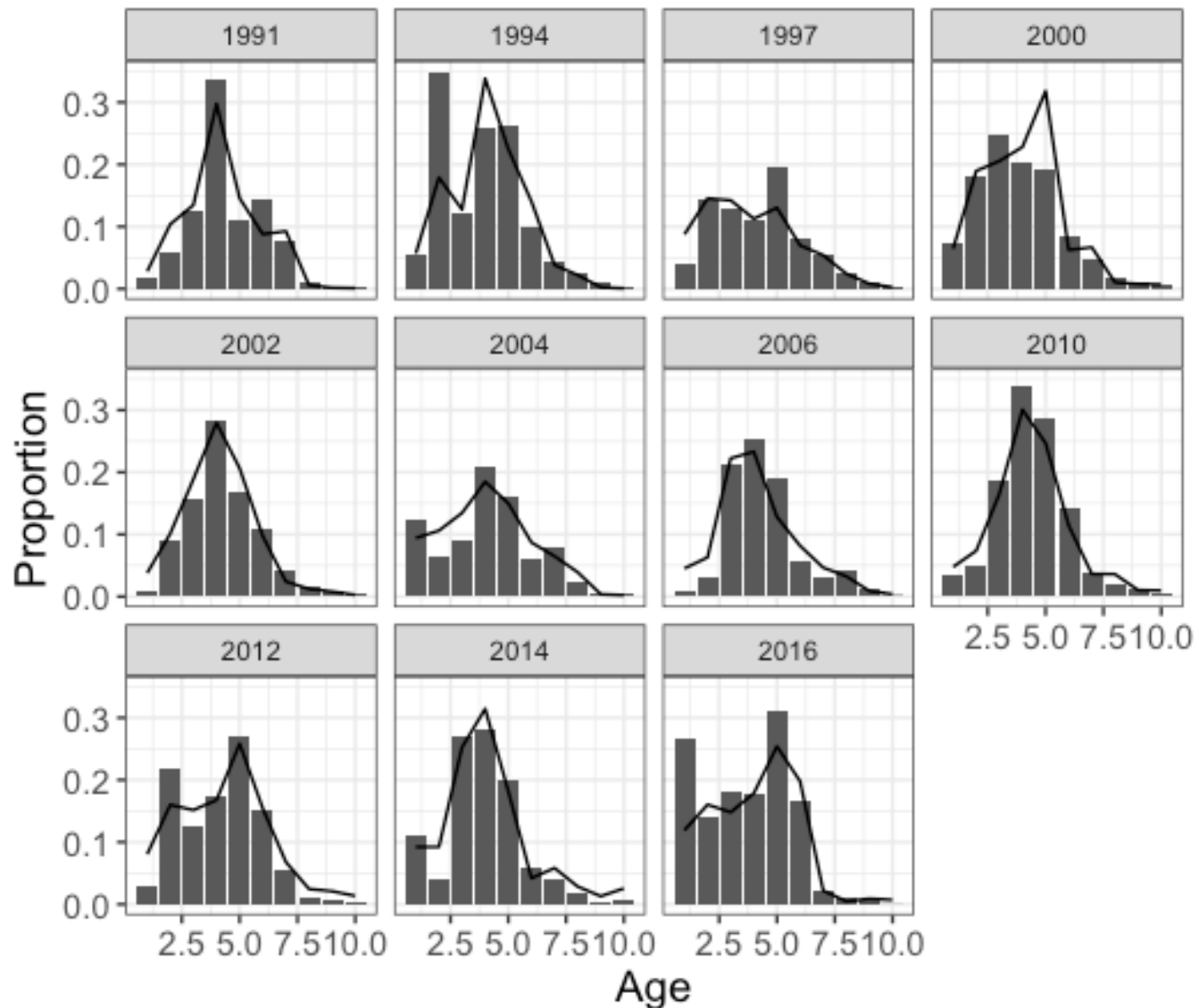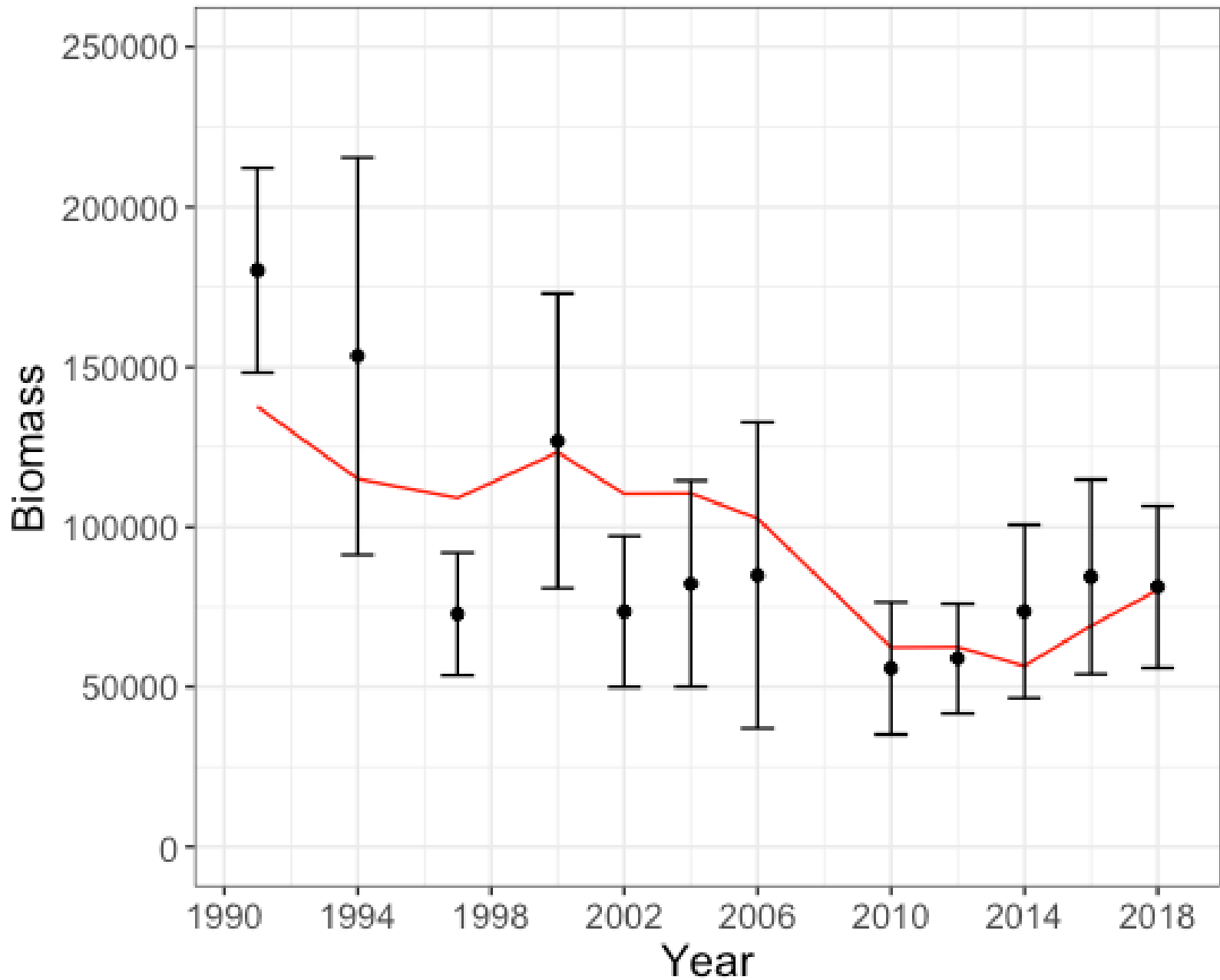

Figure 2.2.12—Biomass time trends (age 0+ biomass, female spawning biomass, survey biomass) of EBS Pacific cod as estimated by Model 3. Spawning biomass and survey biomass show 95% CI.
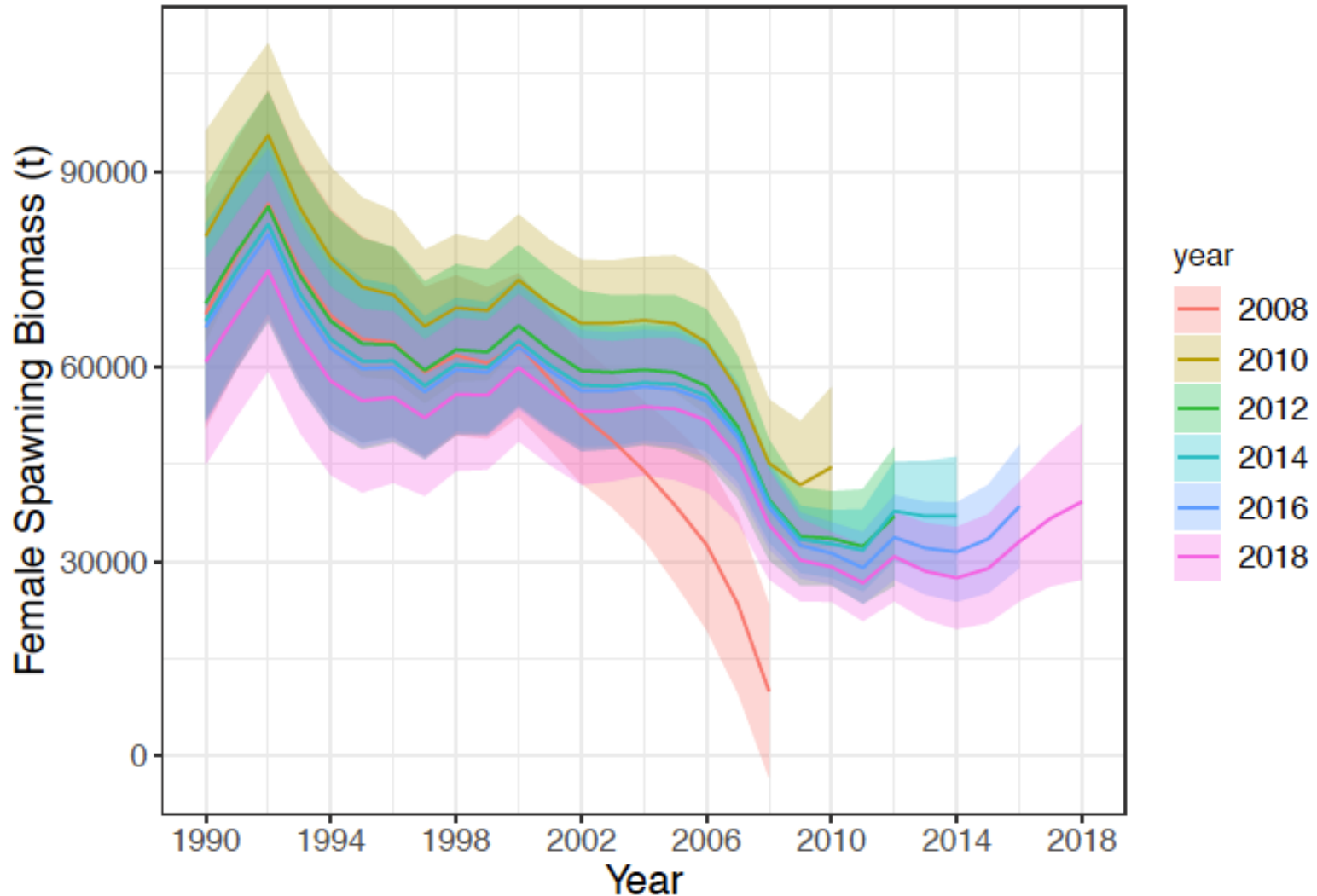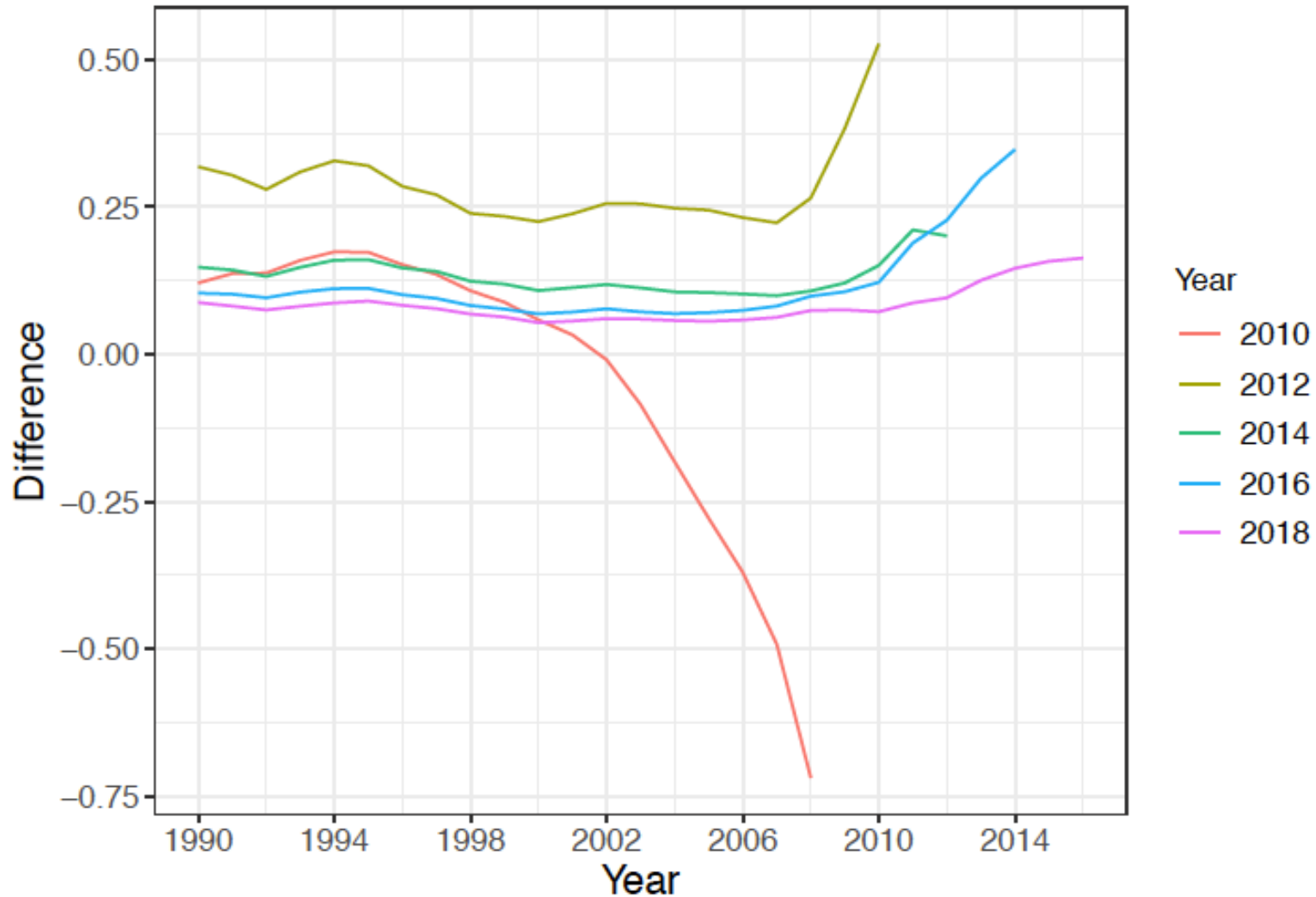
Results – fit to age frequencies
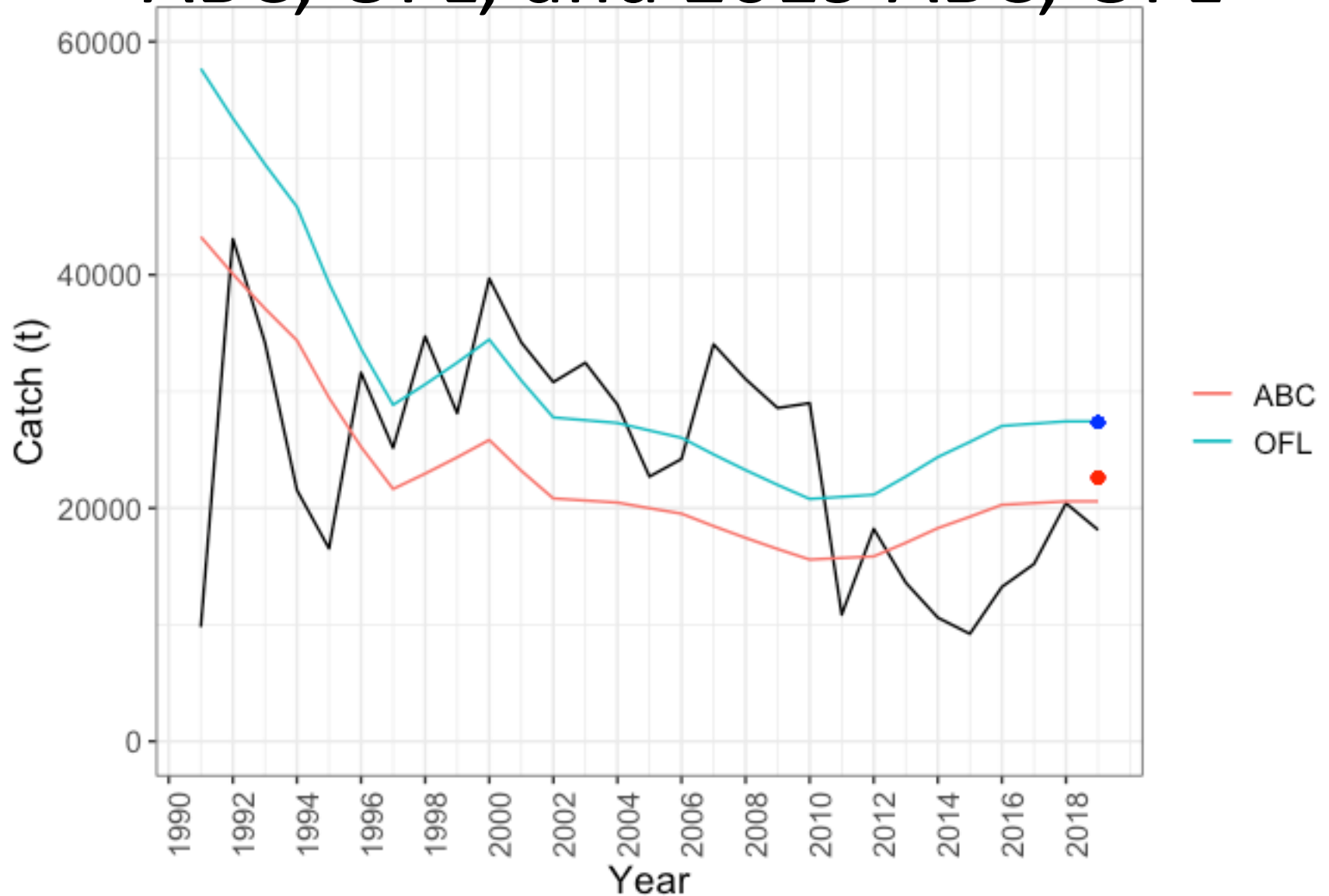
Fit to Aleutian Islands survey biomass

Retrospective plot of female spawning biomass. Retrospective runs obtained by removing 2 years of data at a time through
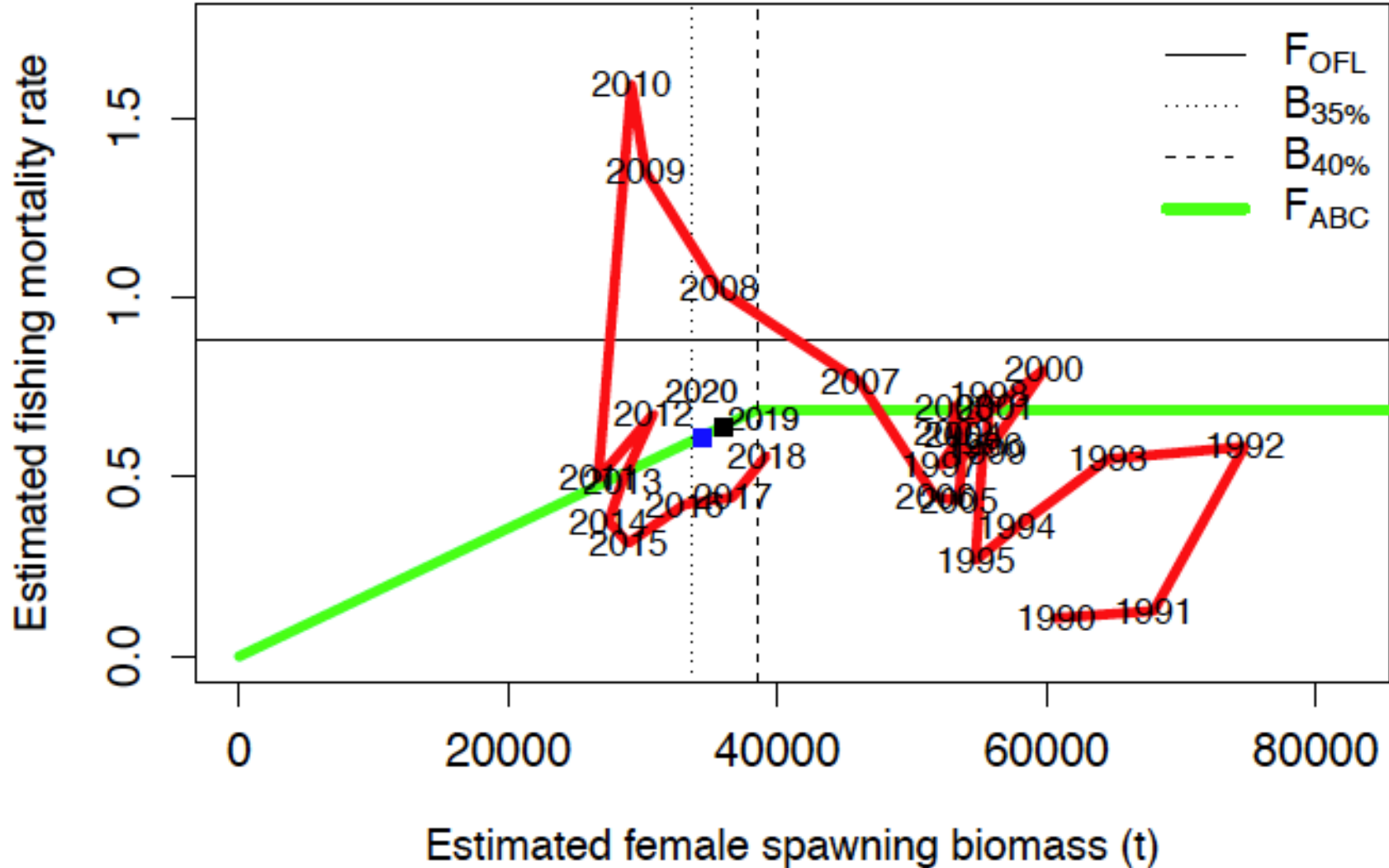
Relative differences in estimates of spawning biomass between 2018 model and retrospective model run 2018 -2008.

Catches, and Tier 5 estimates of ABC, OFL, and 2019 ABC, OFL

Phase plane diagram from 2012 AI age structured model

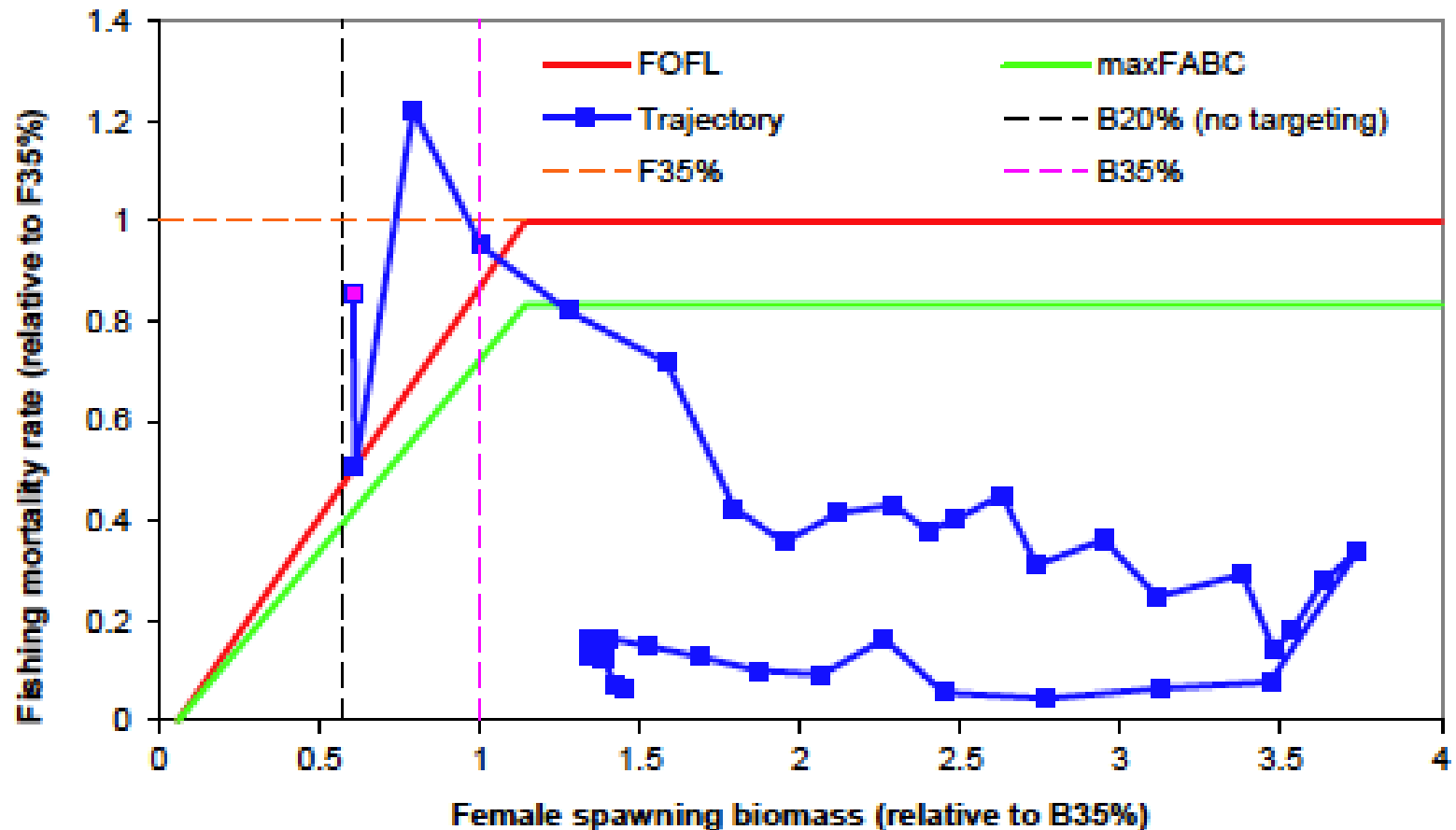# Phase plane diagram from 2012 AI age structured model

Figure 2.2.15—Trajectory of fishing mortality and female spawning biomass as estimated by Model 3, 1977-present (magenta square = 2012). These results are from SS, and are not exactly comparable to results obtained by the standard projection program.

Summary of results

Quantity	As estimated or *specified* last year for:		As estimated or *recommended* this year for:	
	2018	2019	2019	2020
M (natural mortality rate)	-	-	0.4	0.4
Tier	-	-	3b	3b
Projected total (age 1+) biomass (t)	-	-	127,419 t	127,751 t
Projected female spawning biomass (t)	-	-	35,939 t	34,348 t
$B_{100\%}$	-	-	96,132 t	96,132 t
$B_{40\%}$	-	-	38,453 t	38,453 t
$B_{35\%}$	-	-	33,646 t	33,646 t
F_{OFL}	-	-	0.880	0.880
$maxF_{ABC}$	-	-	0.686	0.686
F_{ABC}	-	-	0.686	0.686
OFL	-	-	27,343 t	24,645 t
$maxABC$	-	-	22,620 t	20,331 t
ABC	-	-	22,620 t	20,331 t
Status	2016	2017	2017	2018
Overfishing	-	-	No	n/a
Overfished	-	-	n/a	No
Approaching overfished	-	-	n/a	No

*Projections are based on annual catches of 20,414 t for 2019 and the 2019 ABC for 2020.

Questions?

Results – likelihood components

Likelihood Component	Value
Recruitment	5.695
Survey age	105.412
Survey biomass	16.138
Catch	0.002
Fishery length	41.82
Total	169.066

Coefficient of variation fitted to age, based on raw data (black points)

CV = −0.007971*Age+0.158246