Preliminary age structured assessment model of the Pacific cod stock in the Aleutian Islands 2021

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Aleutian Islands cod model history

- Aleutian Islands Pacific cod: Tier 5 with random effects model since 2013.

- Initial age structured model presented by Grant Thompson in 2012.

- The 2020 BSAI GPT recommended presentation of an age-structured assessment at the BSAI GPT meeting in September 2021.

Model features (2021)

- One fishery, one gear type, one season per year.
- Single sex model.
- Logistic age-based selectivity for both the fishery and survey.
- External estimation of a single growth curve (vonBertalanffy) for length at age, weight at age.
- An ageing error matrix for ages 1 through 10+.
- All parameters constant over time except for recruitment and fishing mortality.

Model features (2021)

- Internal estimation of fishing mortality, catchability, and selectivity parameters.
- Recruitment estimated as a mean with lognormally distributed deviations
- Natural mortality was fixed in the model using M=0.34 (and M = 0.4).
- Survey catchability was estimated within the model as a constant multiplier on fishery selectivity.
- Maturity at age was estimated using observer data, consistent with the Gulf of Alaska Pacific cod assessment.

Four age structured models.

- Model 19.0: Base model with M=0.34, maturity ogive derived from observer collections of maturity values from Aleutian Islands cod.

- Model 19.0a: Base model except M=0.40.

- Model 19.0b: Base model except Stark (2007) maturity ogive.

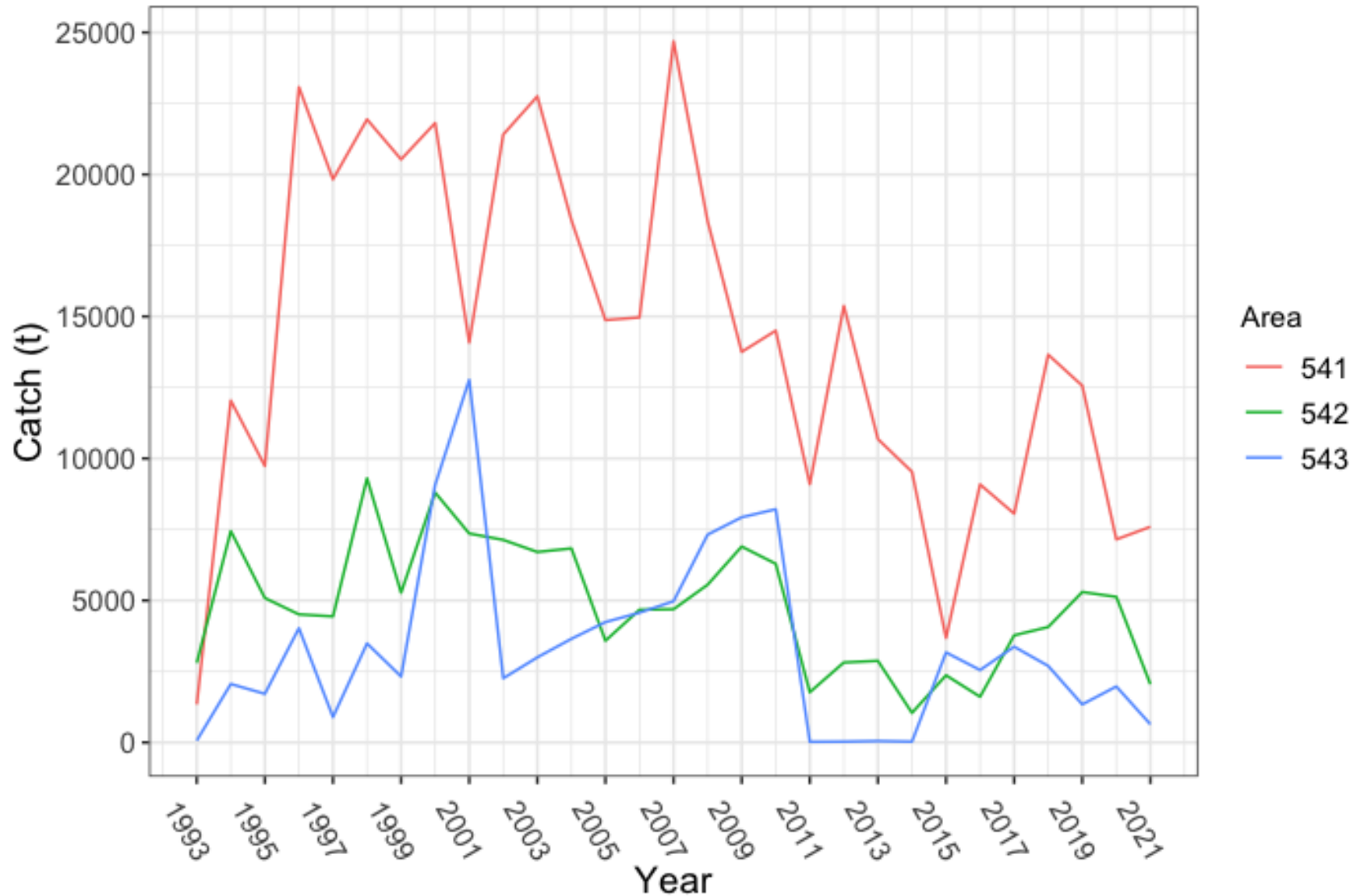- Model 19.0c: Base model with no fishery length data likelihood.

Survey biomass in the Aleutian Islands declined after 1990, stable since 2010.
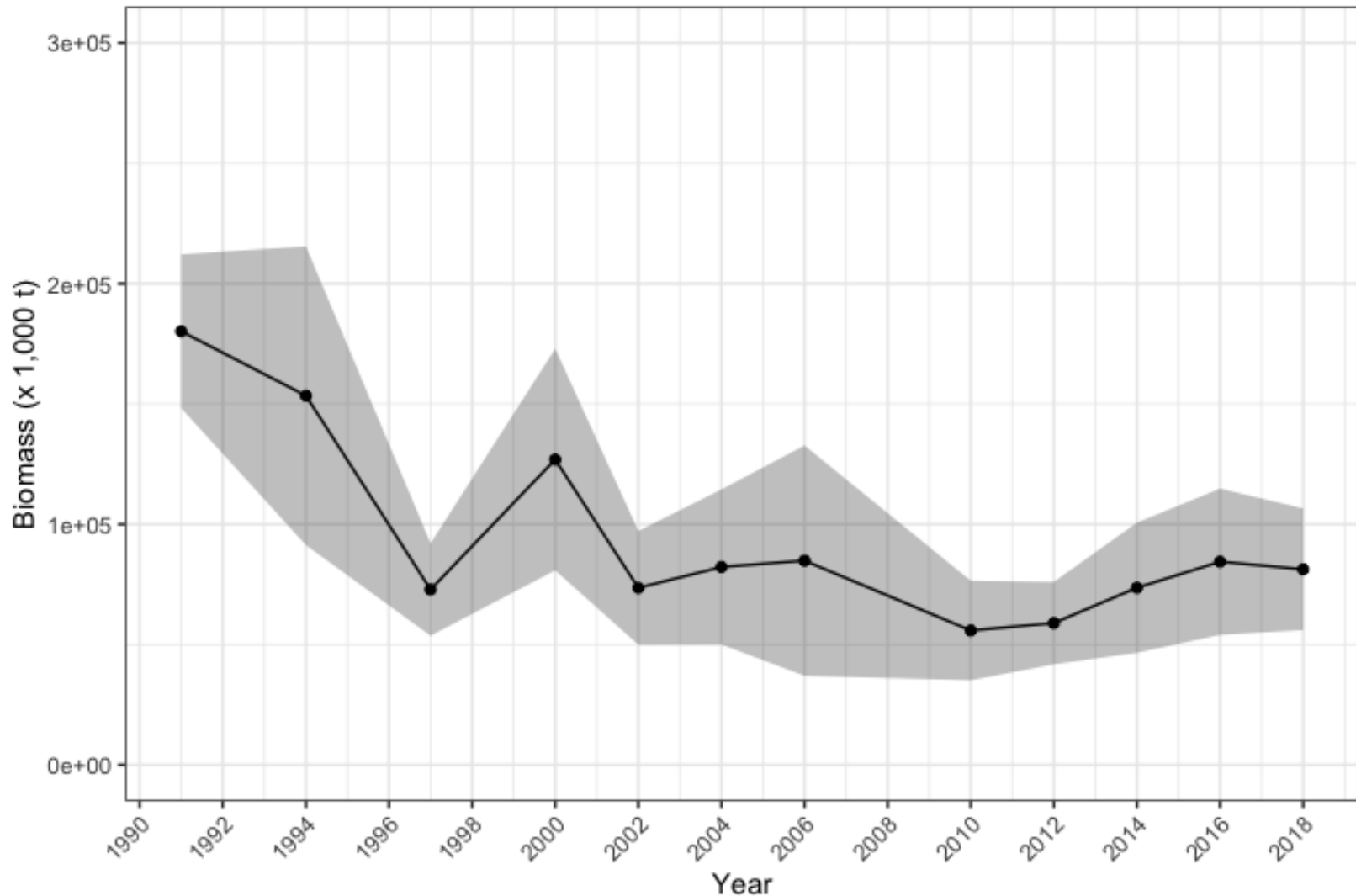
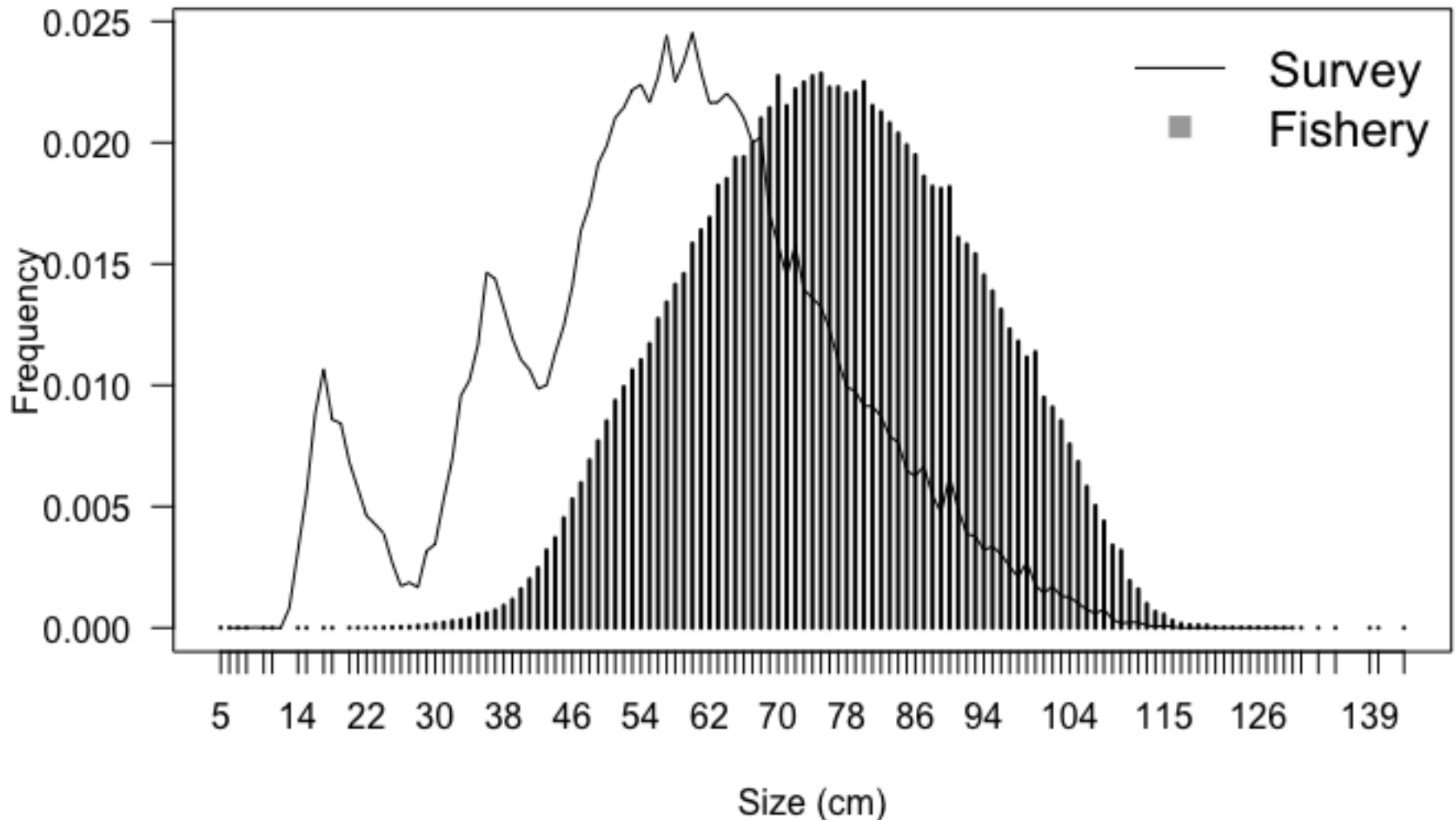# Fishery catches have remained at a relatively low level since 2011.
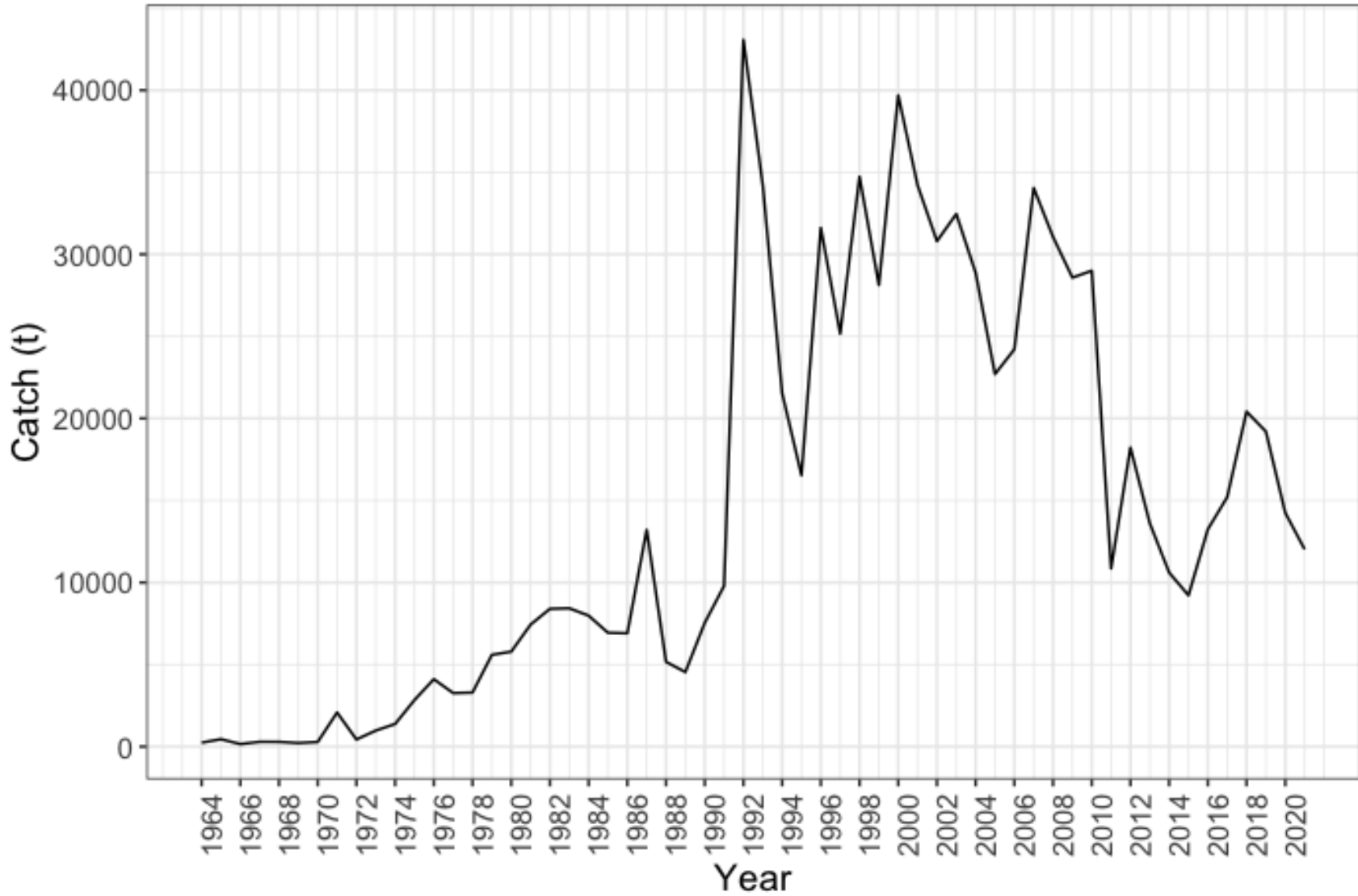
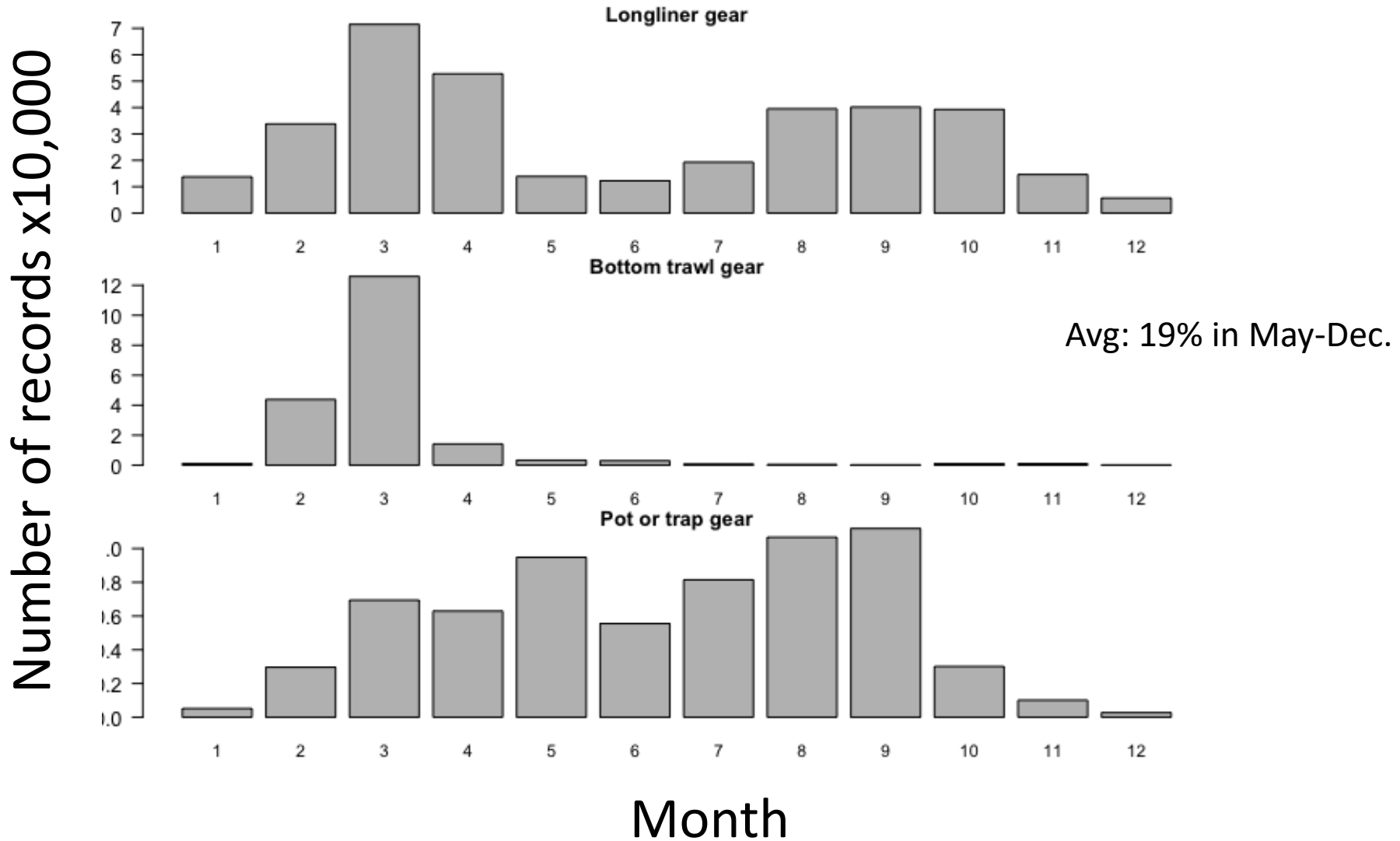# Catch by area is highest in the eastern Aleutian Islands.

Length frequencies for Pacific cod caught in the Aleutians by fishery (1990-2021) and survey (1991-2018)

Proportion of fishery lengths taken by month for each gear type, 1990-2021

Number of records x10,000

Avg: 19% in May-Dec.

Month

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

Data used in the model

Source	Type	Years
Fishery	Catch biomass	1991-2021
Fishery	Size composition	1991-2020
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, 2018

Model starts in 1991.

Last year of fishery lengths was 2020 (very few records from 2021).

Survey age data used in the model.

- 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.

Year	Number aged	Number of hauls
1991	919	32
1994	1,178	67
1997	849	82
2000	829	93
2002	1,273	116
2004	777	97
2006	764	125
2010	680	101
2012	603	91
2014	564	78
2016	685	109
2018	575	143

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

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

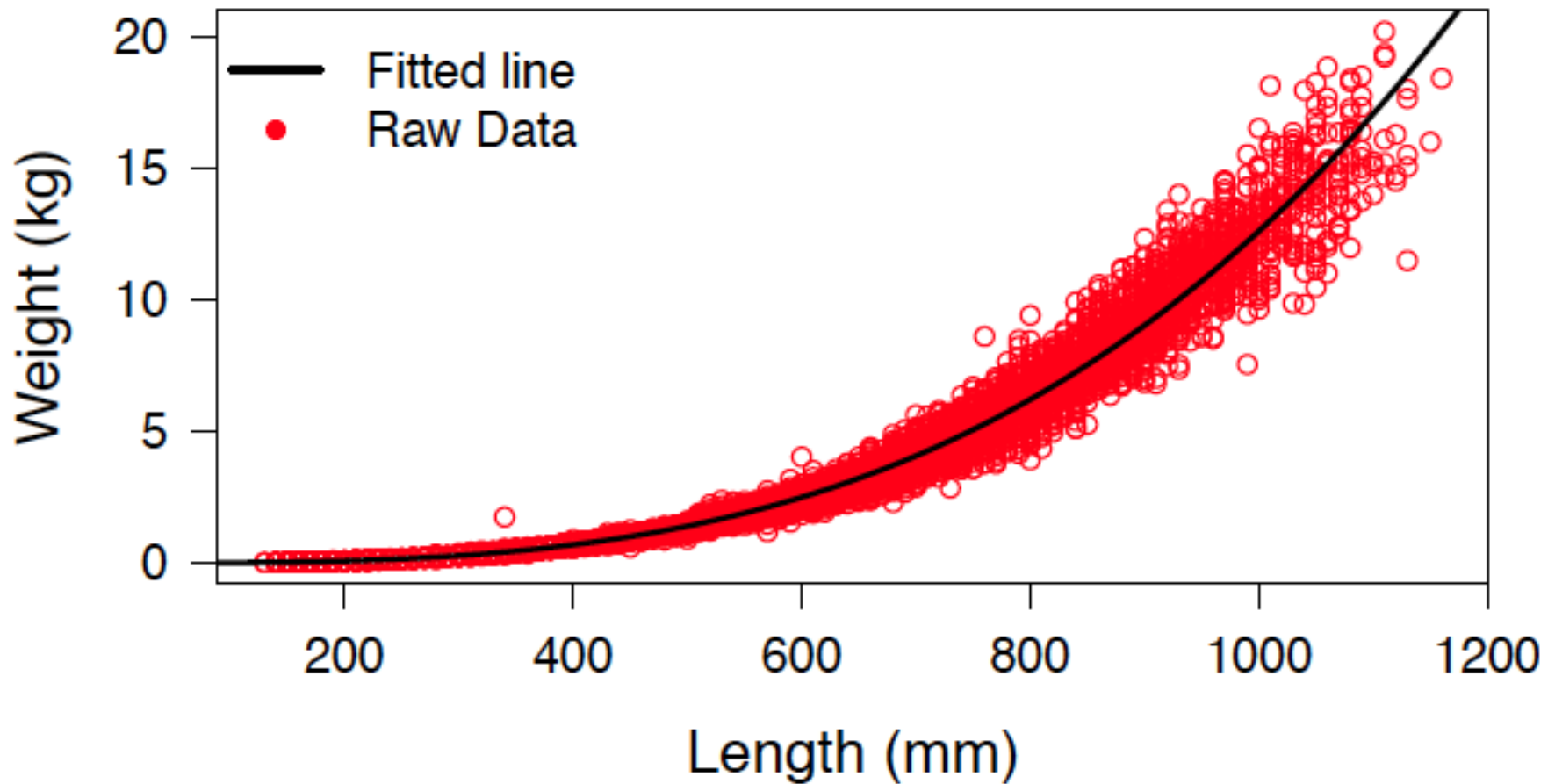# Raw lengths at age and vonBertalanffy growth curves (corrected vs. not for population length frequencies)
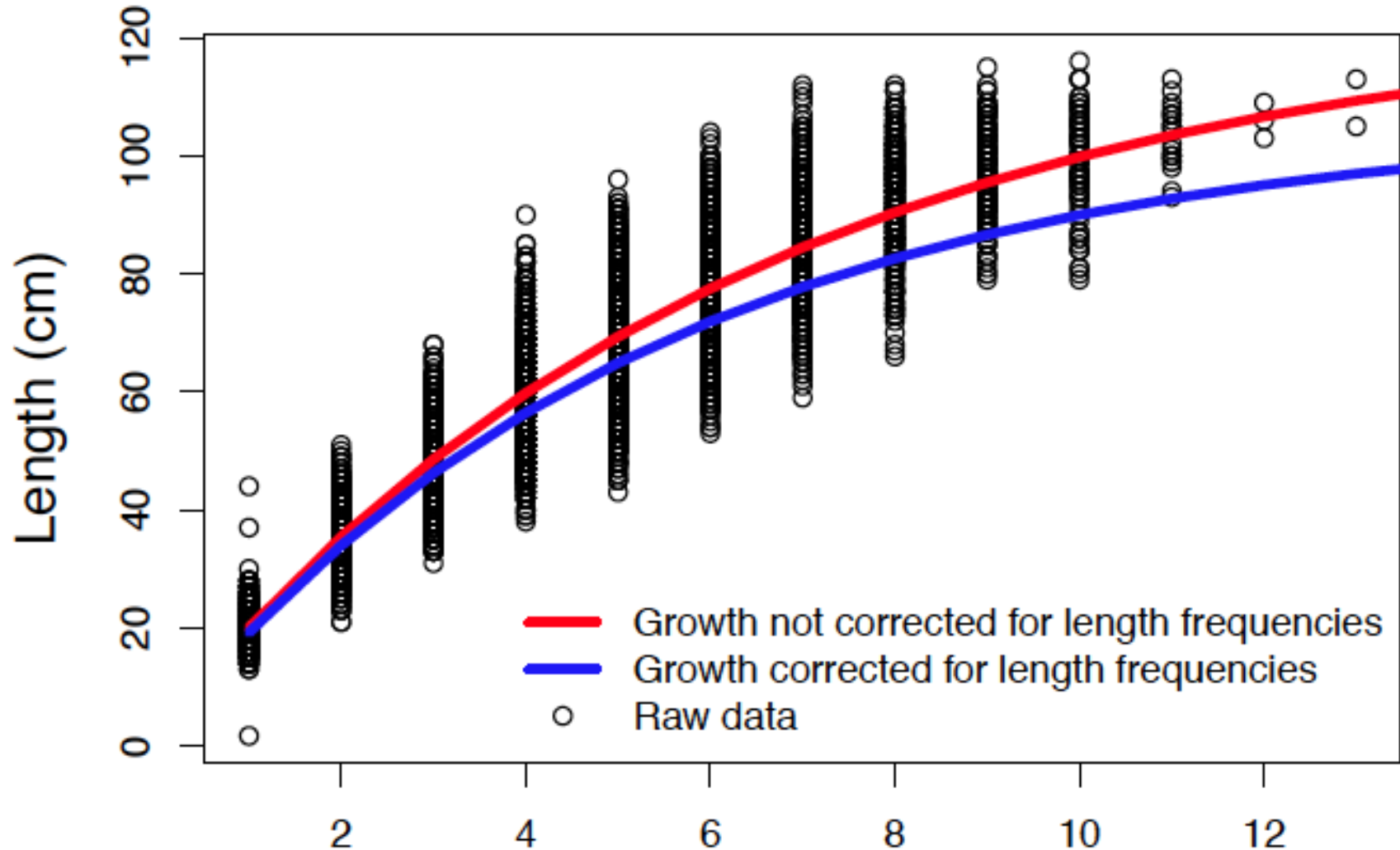
Length – age conversion matrix for AI Pacific cod
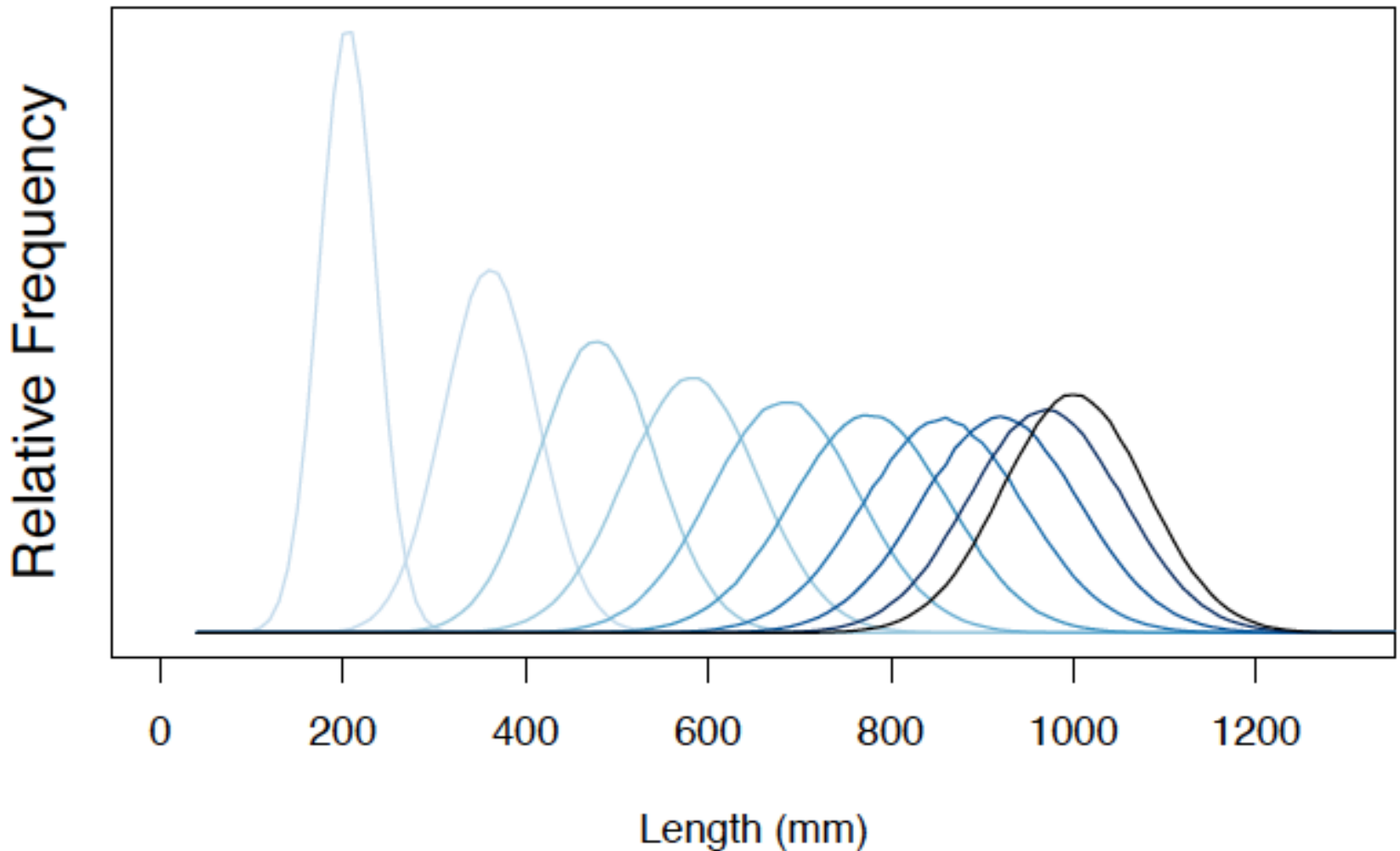
# Length-weight relationship for AI Pacific cod

Maturity estimation

- Stark (2007) 129 female fish from Unimak Pass in February 2003.
  - 50% maturity at 4.88 years, 58 cm.

- 1,331 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
2008	545
2009	35
2010	116
2011	56
2012	129
2013	61
2014	94
2015	78
2016	79
2017	42
2018	26
2019	57
2020	13

Proportion mature by age, using Stark (2007) and observer maturity at length data
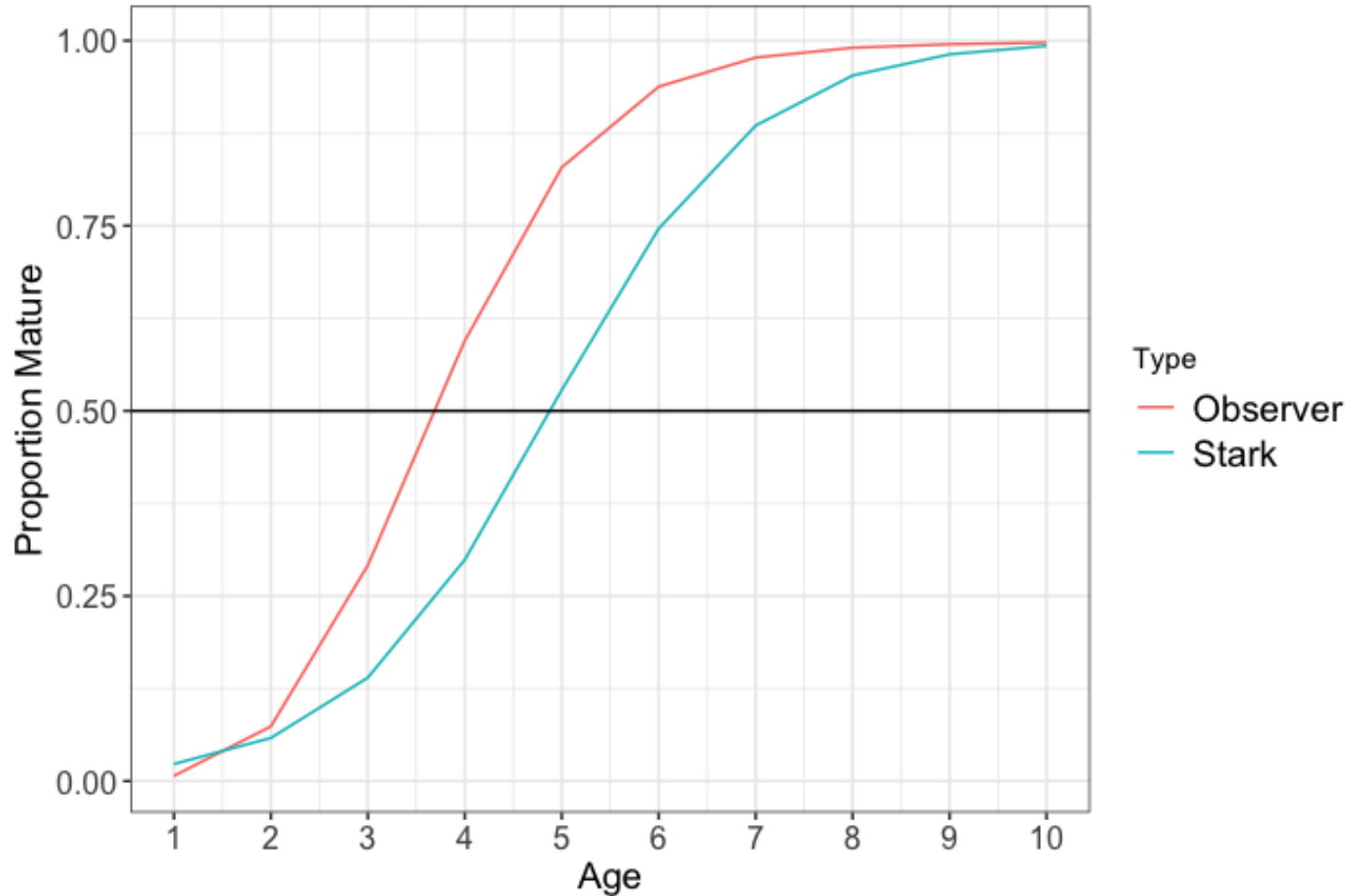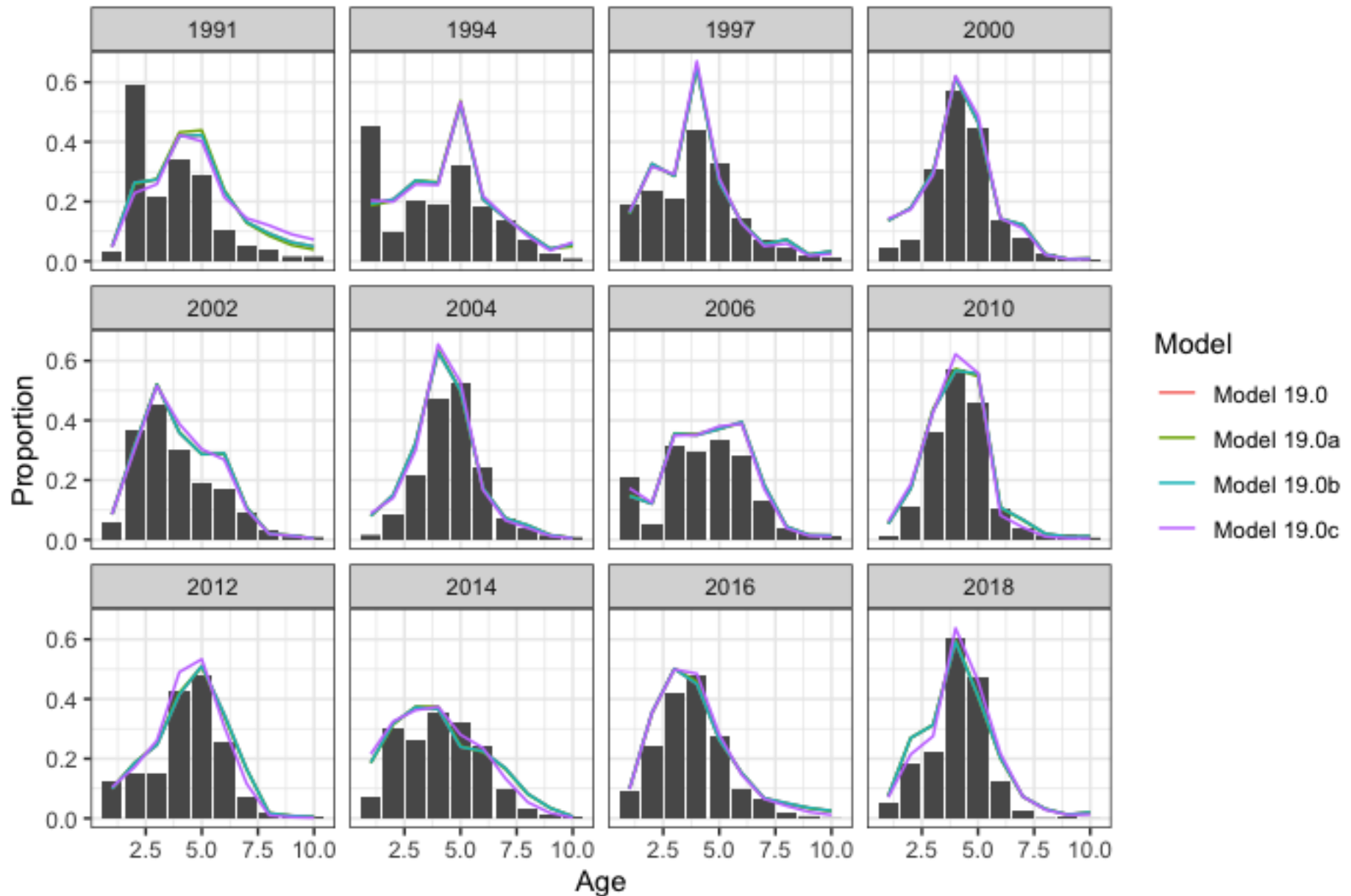
Data weighting

- Survey ages compositional data weighted by number of hauls in each year.

- Fishery length compositional data weighted by the number of lengths per year, such that the average was 10.
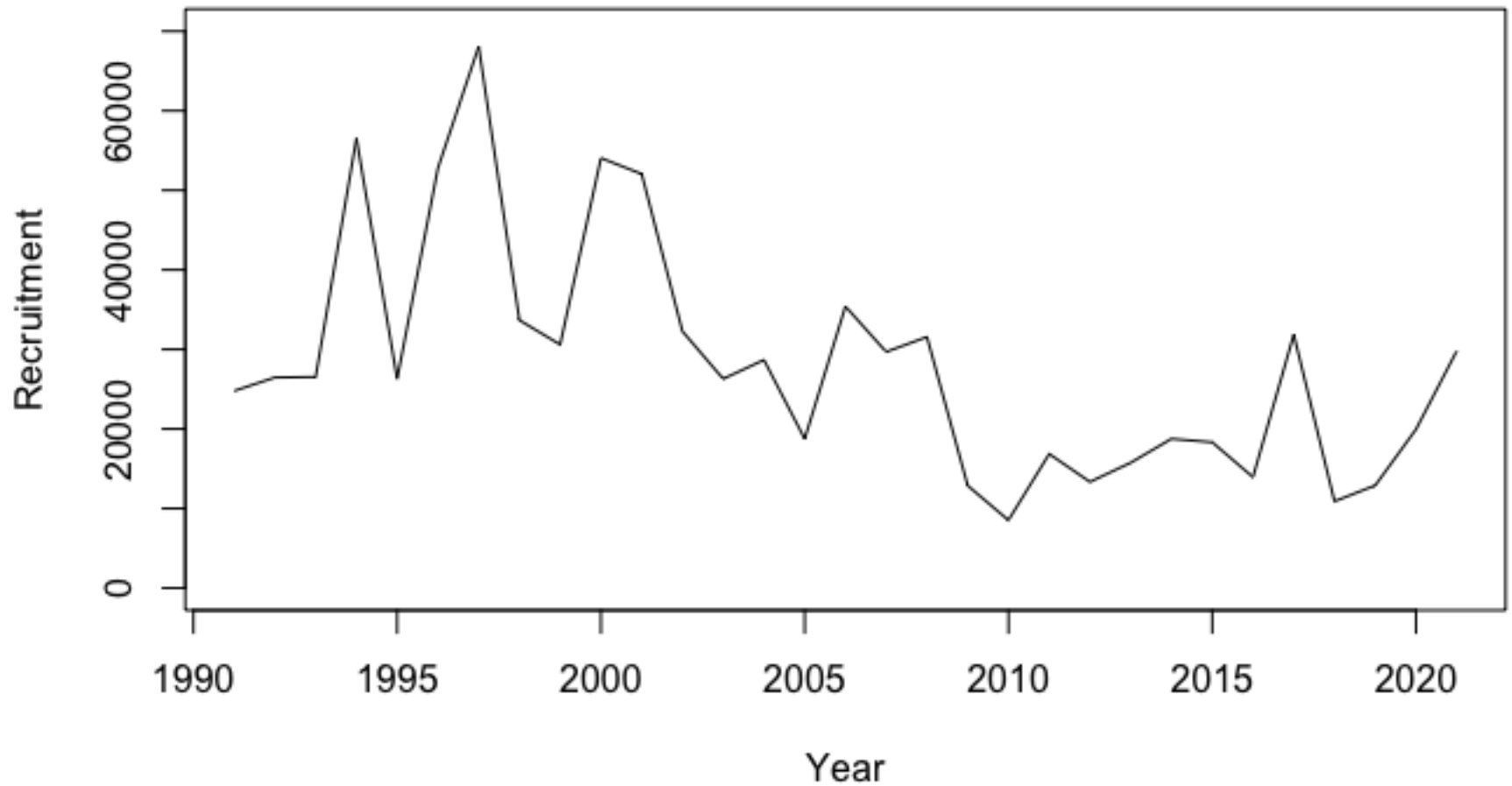
Stewart and Monahan 2017
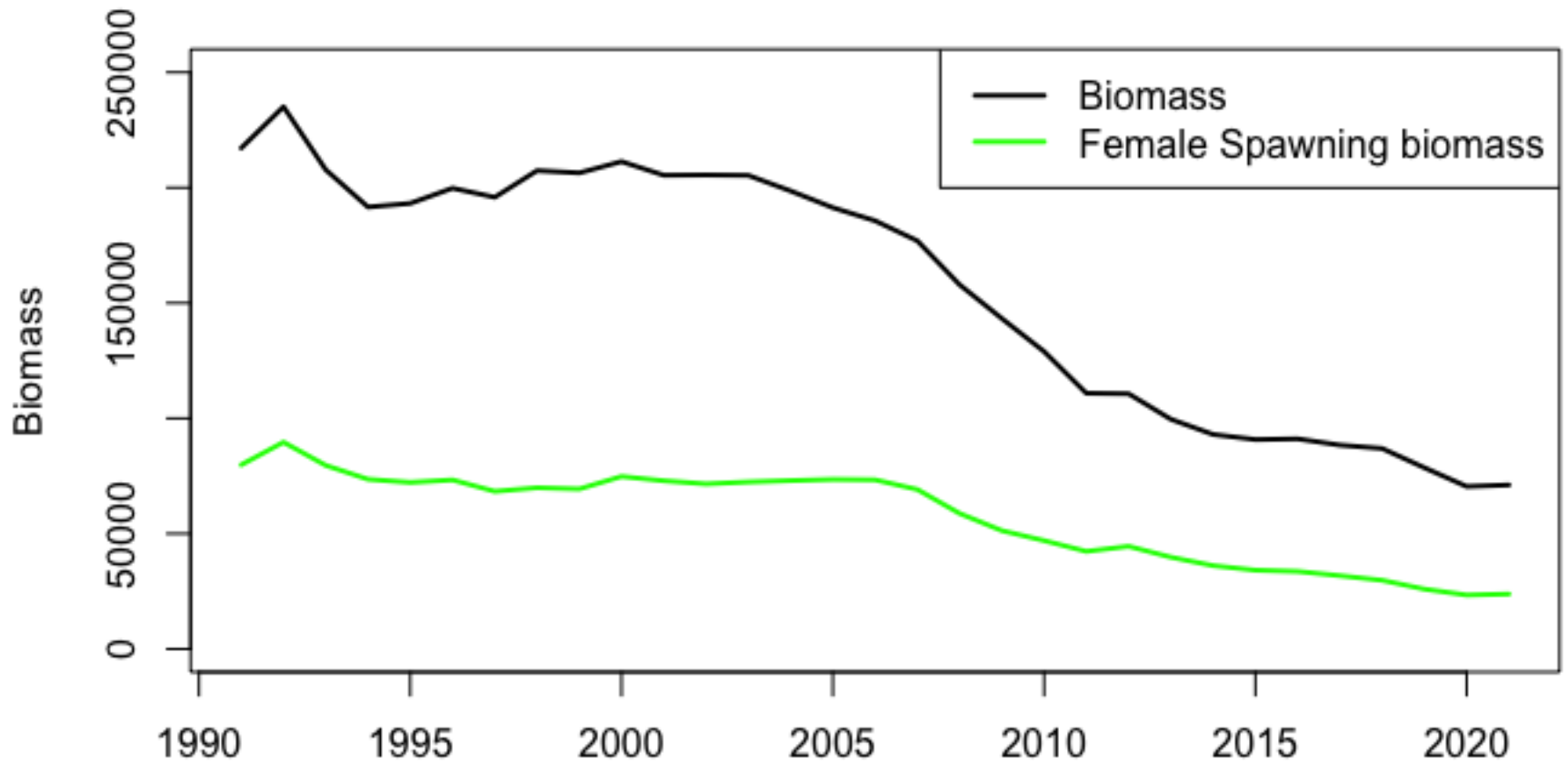
Four models fit to survey biomass
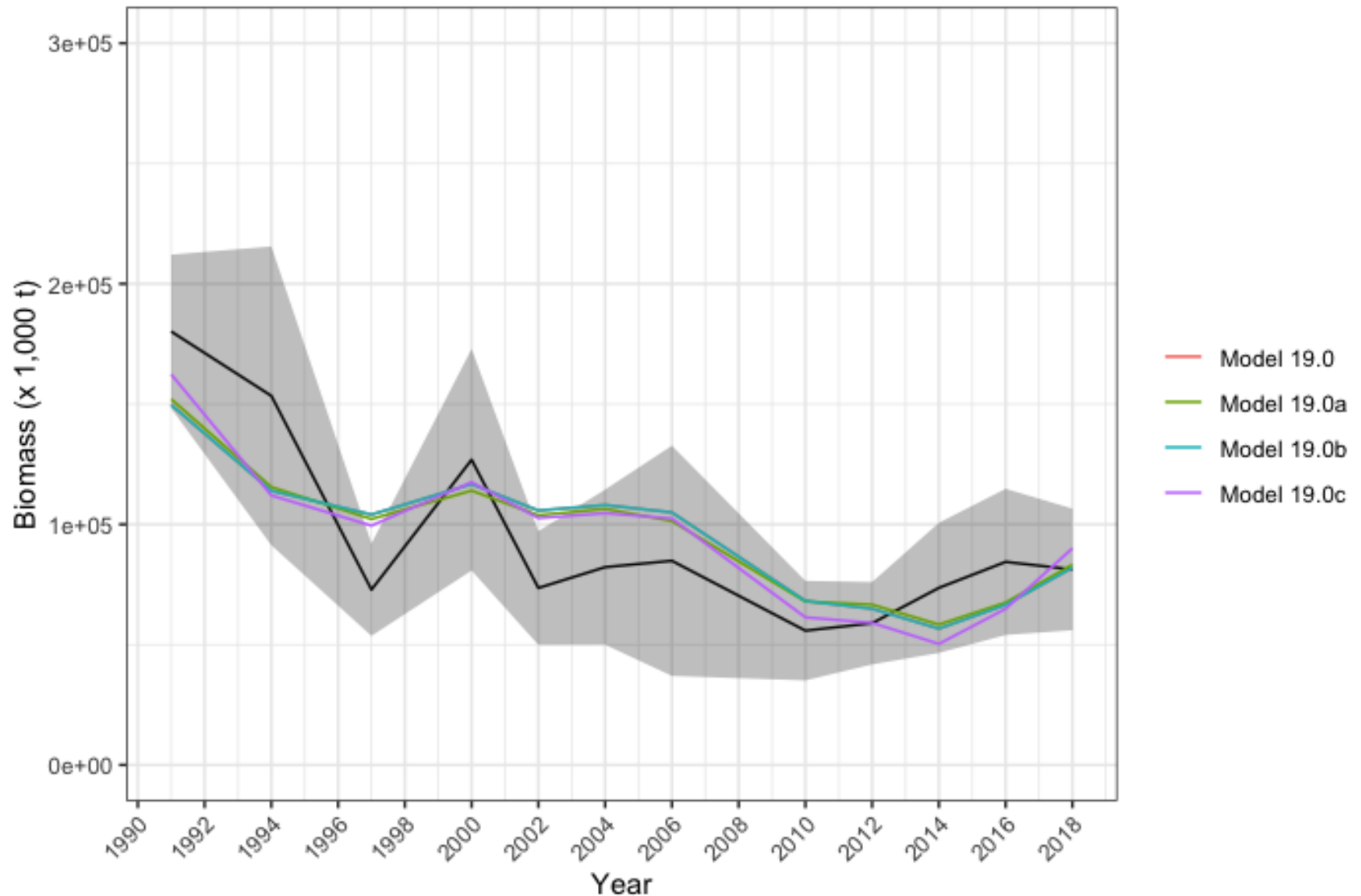
Model fit to age frequencies

Recruitment (Model 19.0)

Biomass (Model 19.0)

Key parameters from the 4 models

	Model 19.0	Model 19.0a (M=0.4)
Survey		
Catchability	0.4229 (0.035)	0.3679 (0.0338)
Survey a50	3.0888 (0.144)	3.2601 (0.142)
Survey slope	1.2683 (0.091)	1.2836 (0.084)
Fishery a50	5.2069 (0.189)	5.2747 (0.190)
Fishery slope	1.7969 (0.183)	1.8095 (0.177)

	Model 19.0b (Stark maturity)	Model 19.0c (no fish length likelihood)
Survey		
Catchability	0.4229 (0.035)	0.6083 (0.116)
Survey a50	3.0888 (0.144)	3.6978 (0.330)
Survey slope	1.2683 (0.091)	1.114 (0.092)
Fishery a50	5.2069 (0.189)	4.6706 (0.568)
Fishery slope	1.7969 (0.183)	1.3258 (0.645)

Key parameters from the 4 models

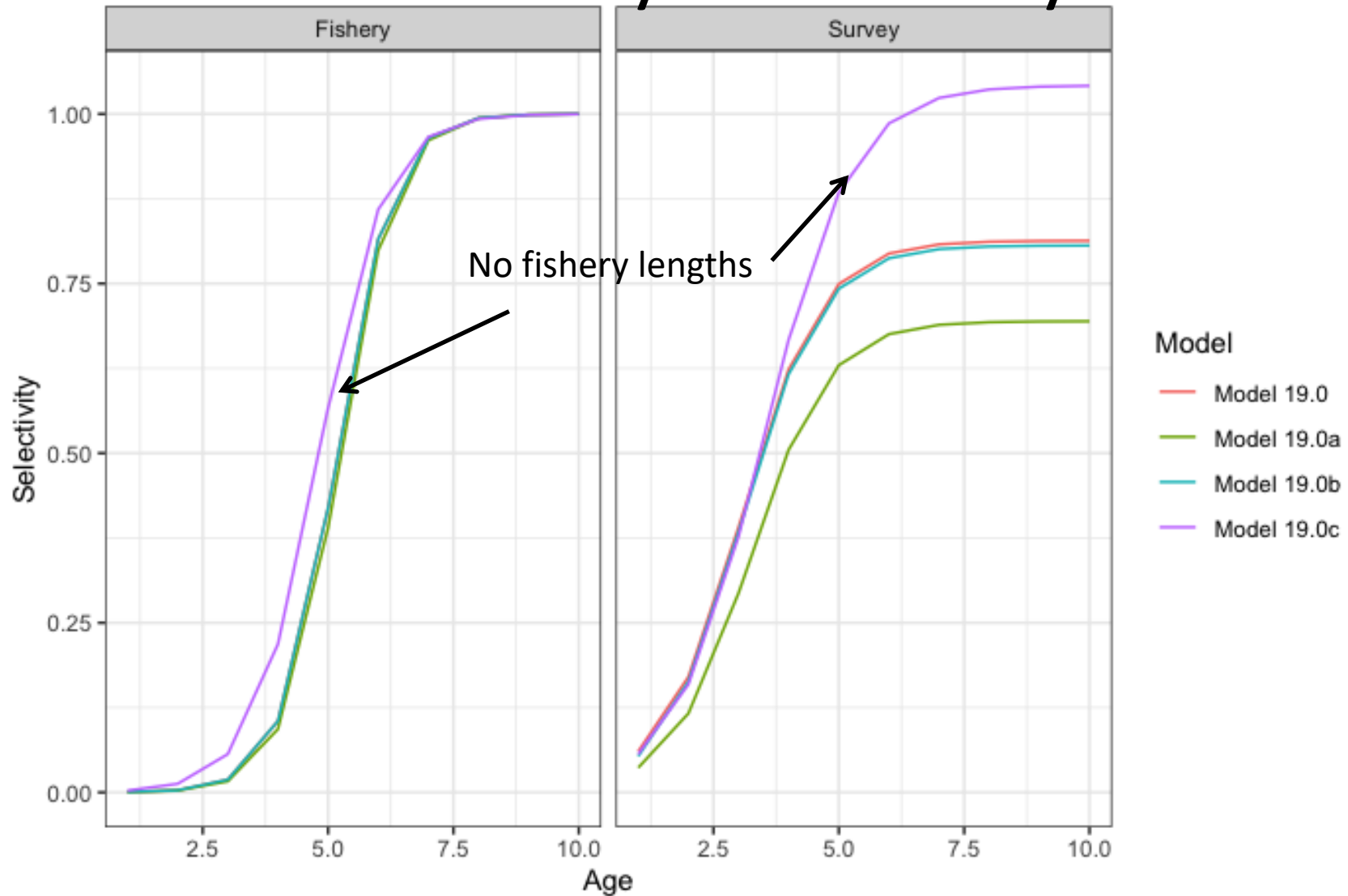|	Model 19.0	Model 19.0a (M=0.4)
Survey Catchability	0.8062 (0.069)	0.6945 (0.065)
Survey a50	3.0750 (0.143)	3.2408 (0.139)
Survey slope	1.2752 (0.091)	1.2923 (0.084)
Fishery a50	5.1801 (0.186)	5.2447 (0.188)
Fishery slope	1.8139 (0.187)	1.8273 (0.180)

|	Model 19.0b (Stark maturity)	Model 19.0c (no fish length likelihood)
Survey Catchability	0.8062 (0.069)	1.0421 (0.169)
Survey a50	3.0749 (0.142)	3.496 (0.289)
Survey slope	1.2752 (0.091)	1.1455 (0.094)
Fishery a50	5.1801 (0.187)	4.8265 (0.489)
Fishery slope	1.8139 (0.187)	1.5421 (0.762)

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Model estimates of selectivity for survey and fishery

Model estimates of selectivity for survey and fishery
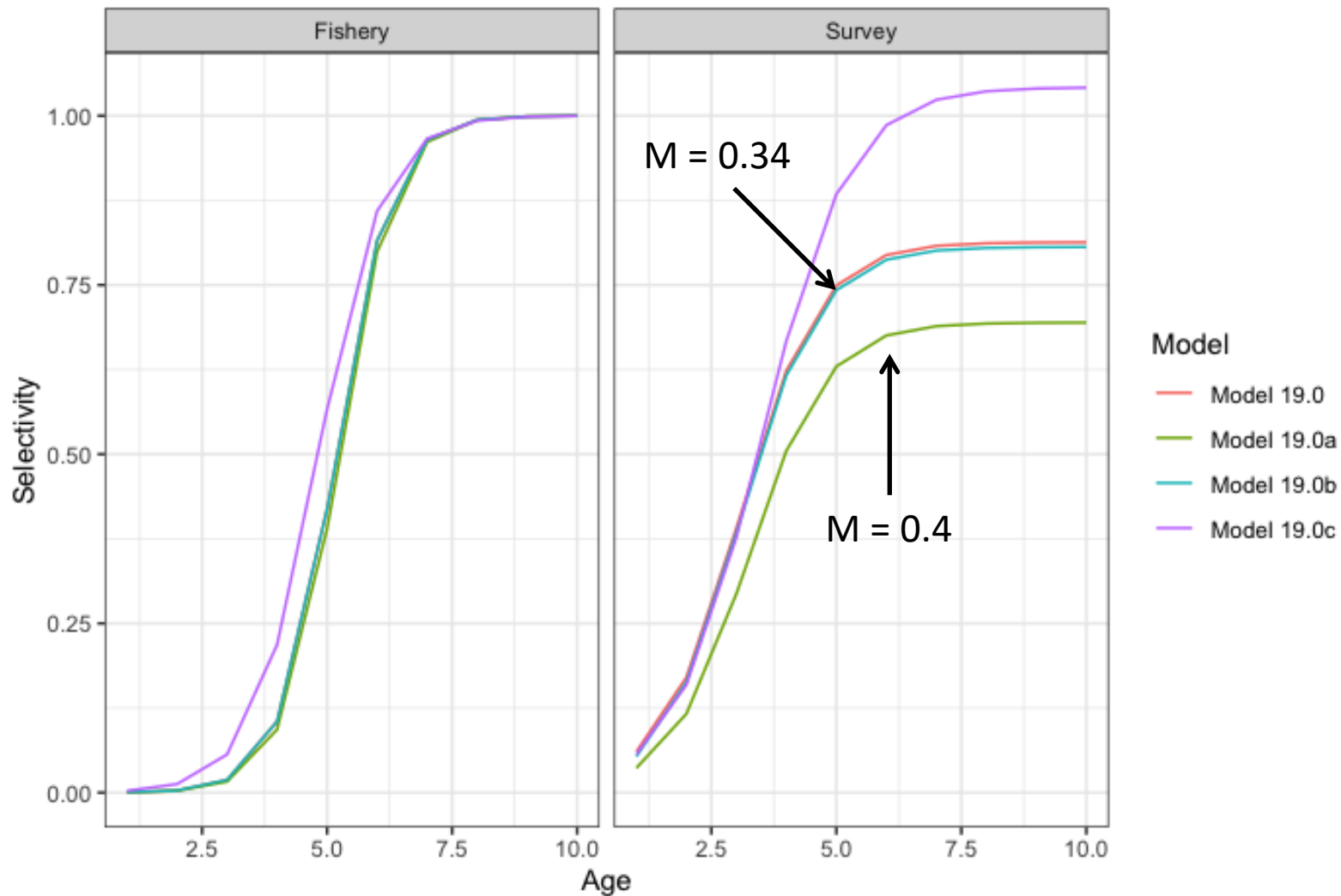
Error estimation

	Model 19.0	Model 19.0a	Model 19.0b	Model 19.0c
CV of RMSD for biomass	0.2819	0.2698	0.2819	0.2514
SSD for survey age	0.4195	0.4201	0.4195	0.4043
SSD for fishery lengths	0.2281	0.2254	0.2281	0.2937
SDNR	1.6141	1.567	1.6141	1.6638

RMSD: Root mean squared deviations

SSD: Sum of squared deviations

SDNR: Standard deviation of normalized residuals

# Likelihood components for the four models

	Model 19.0	Model 19.0a	Model 19.0b	Model 19.0c
Recruitment	5.153	4.951	5.153	5.054
Survey age	57.933	56.705	57.933	51.267
Survey biomass	12.284	10.954	12.284	10.745
Catch	0.001	0.001	0.001	0.001
Fishery Length	39.54	39.132	39.54	95.207
Total	114.91	111.743	114.91	162.274

Likelihood profile for natural mortality for fishery length, recruitment, survey biomass, and age likelihood components.
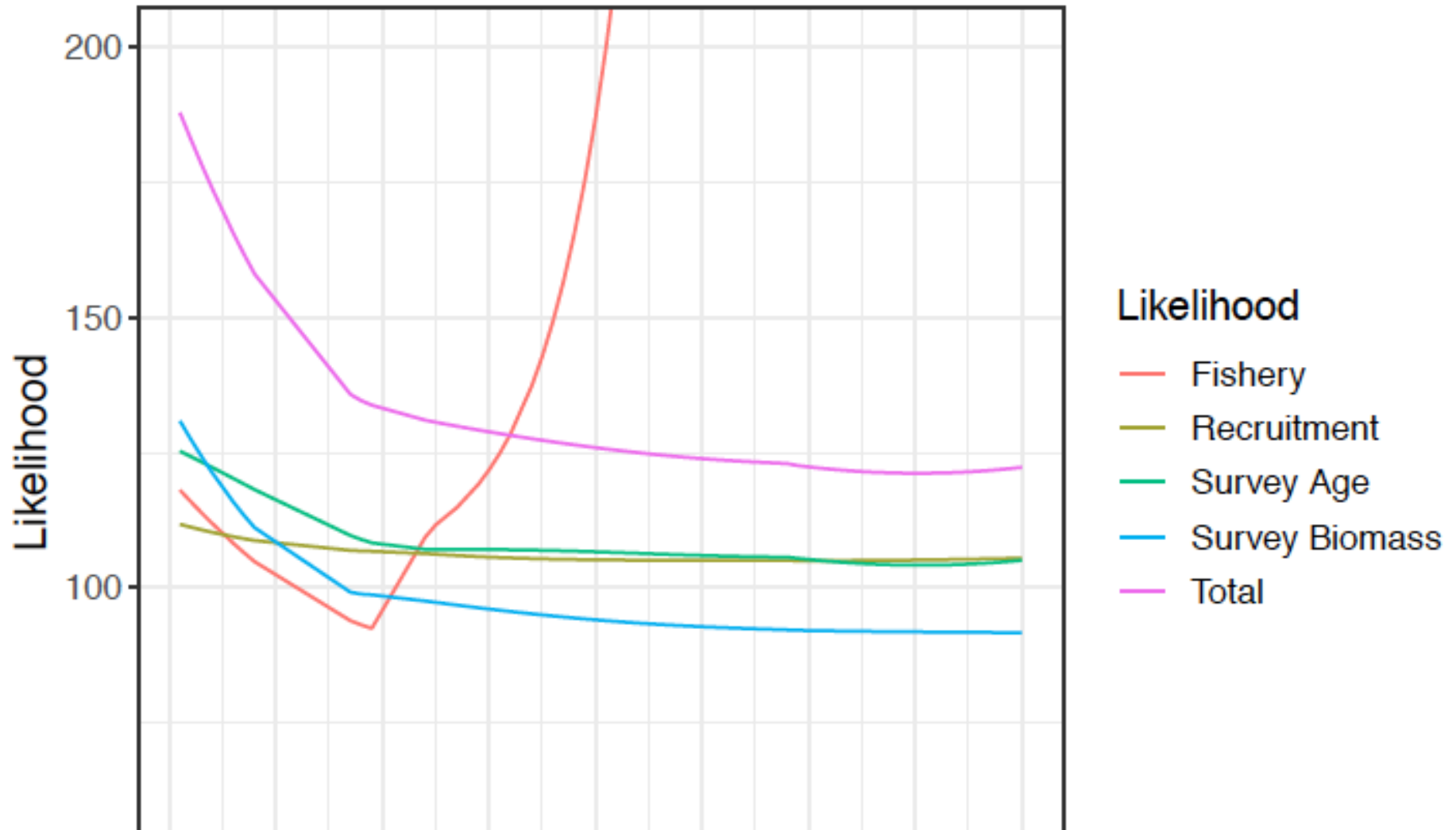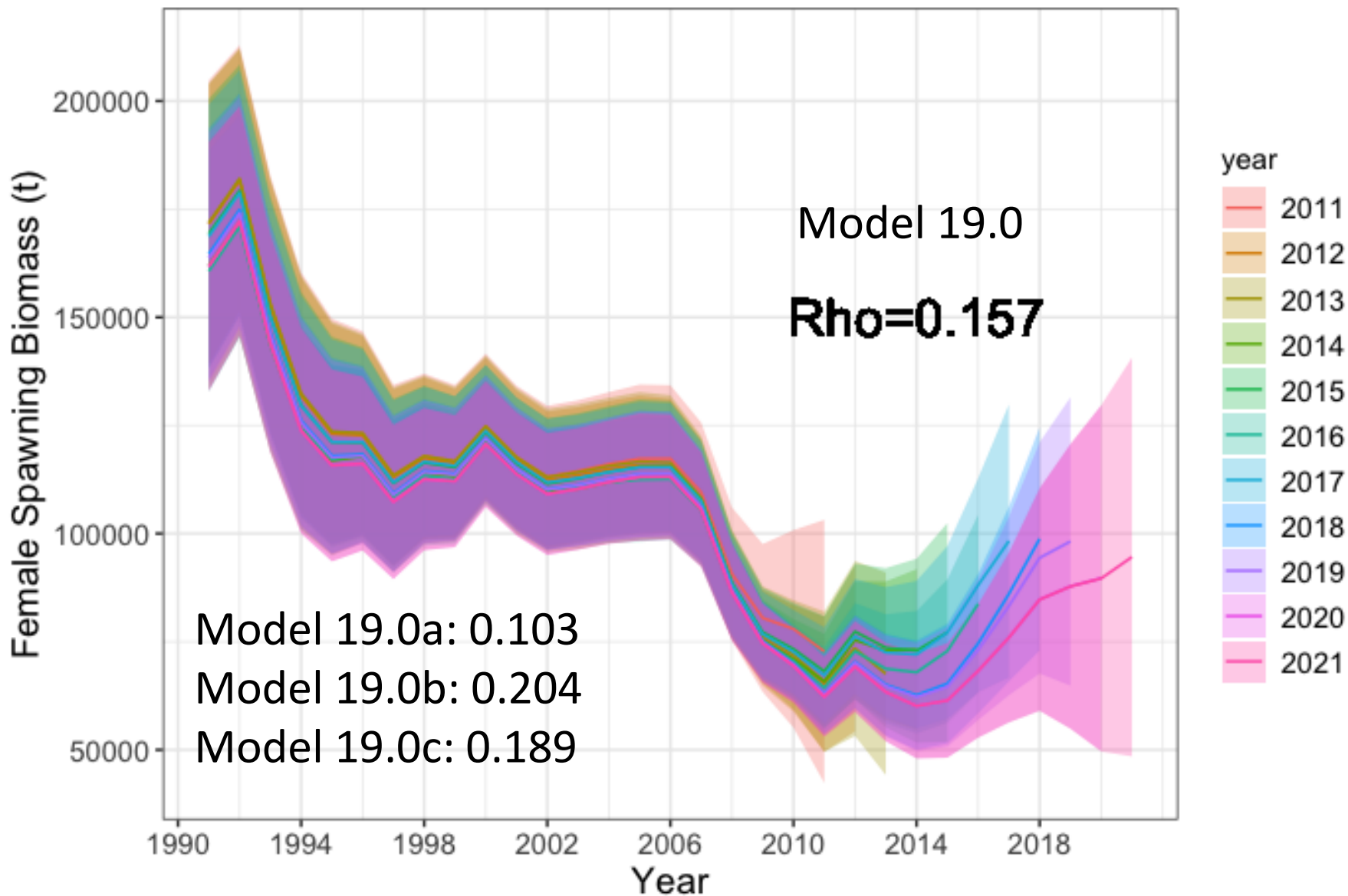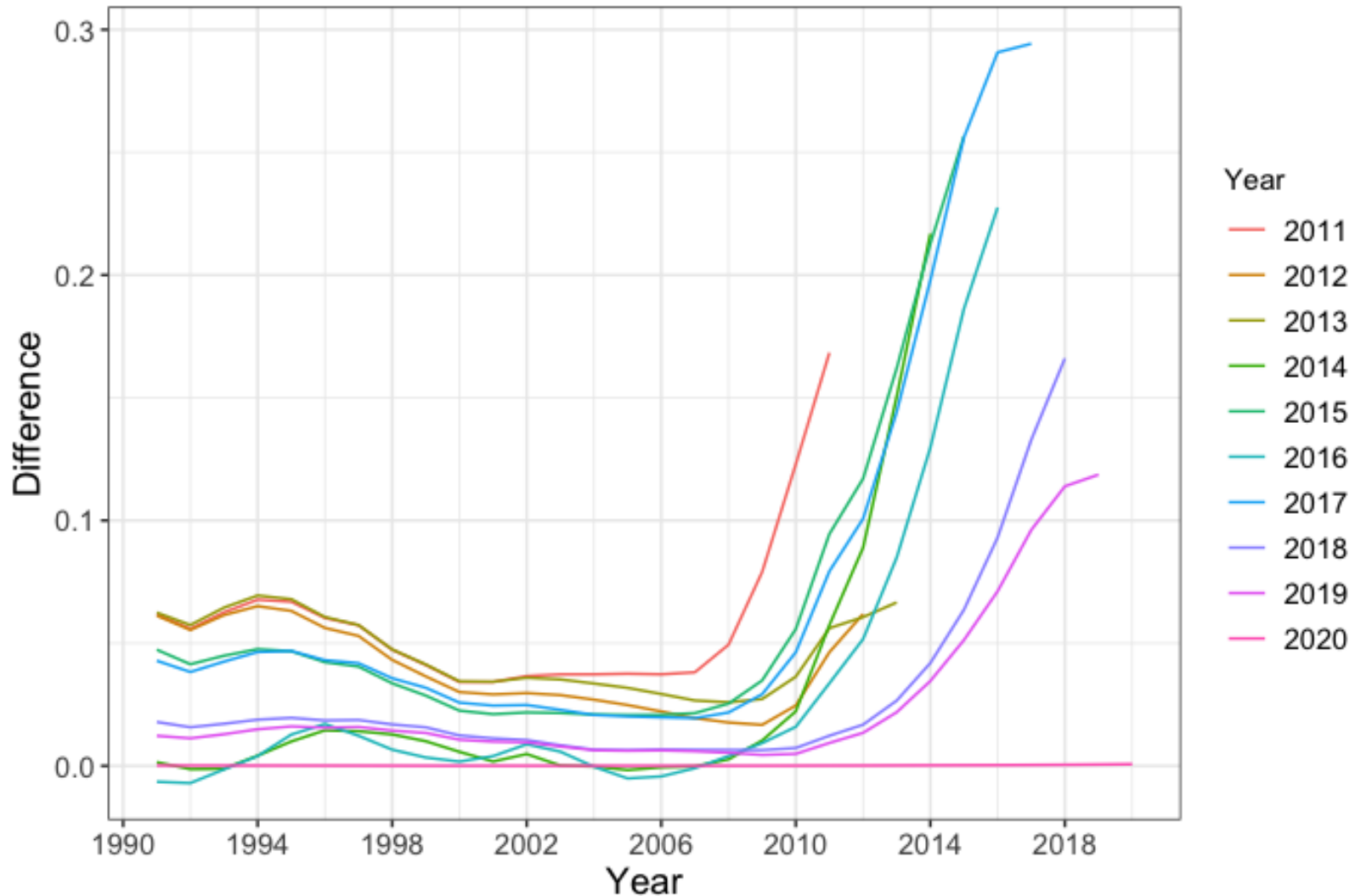
Model 19.0 MCMC estimate of M: 0.56
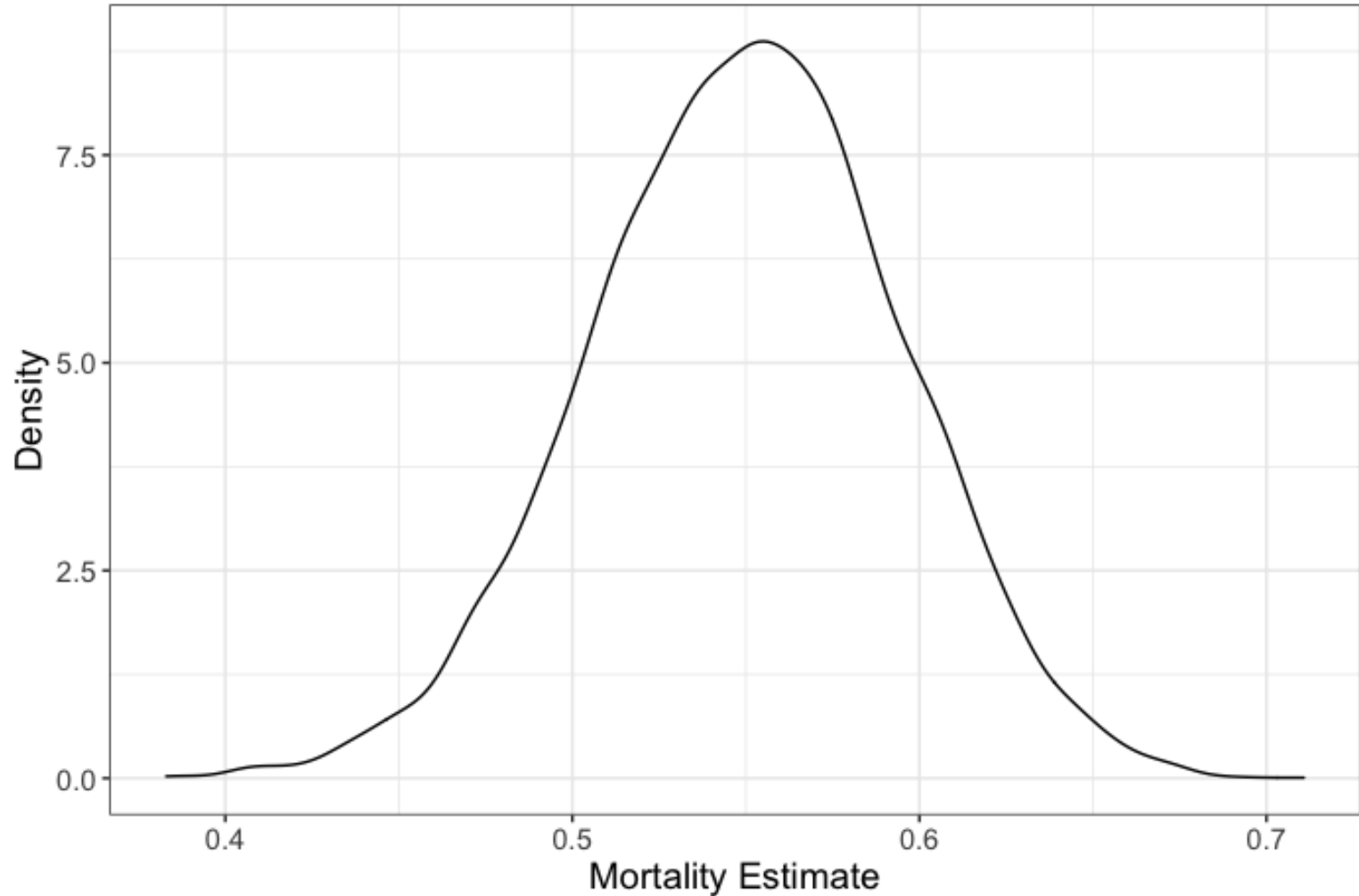
Estimation of M, natural mortality

- Fishery data ~0.3
- Survey data >>0.4
- MCMC: 0.56.

- Current Tier 5 methodology uses M=0.34.
- To balance the data and current methods, I started with M=0.4 in Model 19.0a.

Retrospective plot of female spawning biomass.

Relative differences in estimates of spawning biomass between Model 19.0 and 2011-2020.

Questions?

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

CV = −0.007971*Age+0.158246