



# ASSESSMENT OF THE PACIFIC COD STOCK IN THE ALEUTIAN ISLANDS

INGRID SPIES, NOVEMBER 16, 2021



# ALEUTIAN ISLANDS PACIFIC COD

## *BSAI Plan Team Comments, September 2019*

The estimated growth curve when corrected for observed lengths in the population did not fit the observed length at age data. The Team recommended one potential solution of using a three parameter Richards growth curve, which with its increased flexibility may better model Pacific cod growth.

## *Authors' response*

In the 2019 model, there was an issue with the age-length Bayesian correction. The issue has been resolved in the current assessment model. Nonetheless, we evaluated several growth curves (Richards, Von Bertalanffy, Logistic, and Gompertz) to determine the best choice for the Pacific cod data. This is presented in the assessment.



# ALEUTIAN ISLANDS PACIFIC COD

*BSAI Plan Team Comments, September 2019*

In addition to those recommendations the authors should consider fitting the two maturity curves inside the model similar to some of the GOA rockfish assessments.

*Authors' response:*

Fitting the maturity curve outside the model allows for a maturity curve fit without any confounding factors such as ageing error. The authors are open to more feedback if the SSC feels strongly about fitting the maturity curve within the model.



# ALEUTIAN ISLANDS PACIFIC COD

## *BSAI Plan Team Comments, September 2019*

There was a risk table overall score based on ecosystem concerns of 2. Unlike the EBS, the condition factor for the AI is quite low and continues to be low. However, given the Tier 5 estimates are more conservative than what was estimated for all of the Tier 3 models presented, the SSC concluded that no ABC reduction was necessary.

### *Authors' response:*

This year is similar to 2019, as the risk table overall score is 2. Authors recommend the Tier 5 ABC, as it is more conservative than Tier 3 ABCs.



# ALEUTIAN ISLANDS PACIFIC COD

*BSAI Plan Team Comments, September 2019*

The SSC also recommends exploring the “Barefoot Ecologist” online tool for developing an appropriate prior distribution when estimating natural mortality in next year’s agestructured model.

*Authors’ response:*

This tool was used for exploring estimates of natural mortality.



# ALEUTIAN ISLANDS PACIFIC COD

## *BSAI Plan Team Comments, September 2019*

Two maturity curves were estimated, one from visual observations collected by observers and the other from a histological study reported by Stark (2007). The observer data have the benefit of a large sample size (over 2000 samples) collected in January through March since 2008, while Stark (2007) histologically analyzed 129 samples collected from Unimak pass in February 2003. The Team supported the authors' recommendation that the observer data are more representative, but look forward to verifying the visual samples with histological studies. The Team recommended that model runs with both maturity curves be reported in the future until an appropriate curve can be identified.

## *Authors' response:*

Models with both maturity curves are presented (Models 19.0 and 19.0a) and will revisit verification with histological studies when they are available.



# ALEUTIAN ISLANDS PACIFIC COD

*SSC Comments, September 2021*

The author of the assessment requested input from the BSAI GPT on data weighting and the BSAI GPT noted that all stock assessment authors would benefit from additional guidance on data weighting.

*Authors' response:*

No further data weighting was explored in the models presented in this assessment. This may be an issue for further investigation.



# ALEUTIAN ISLANDS PACIFIC COD

*SSC Comments, September 2021*

The SSC has been looking forward to the development of an age-structured assessment model for consideration to move the stock to Tier 3. The SSC concurs with the BSAI GPT to bring forward results from age-structured assessment models 19.0, 19.0a and 19.0b, in addition to a Tier 5 assessment, for consideration in November. The SSC agrees with the BSAI GPT that model 19.0c should be used for a sensitivity analysis only to assess the influence of the fishery length information on model fits. This might help reconcile differences between survey and fishery data to support the use of the fishery length data.

*Authors' response:*

The model with no fishery length data has been used for sensitivity analysis only and is not presented as a full model in this assessment.





# ALEUTIAN ISLANDS PACIFIC COD

*SSC Comments, September 2021*

The SSC appreciates the thorough exploration of natural mortality and agrees that a model with a natural mortality of  $M=0.4$ , corresponding to the mode of previous estimates of  $M$  across a range of Pacific cod stocks, is a reasonable starting point for model 19.0b.

*Authors' response:*

Natural mortality of  $M=0.4$  was implemented in Model 19.0b.

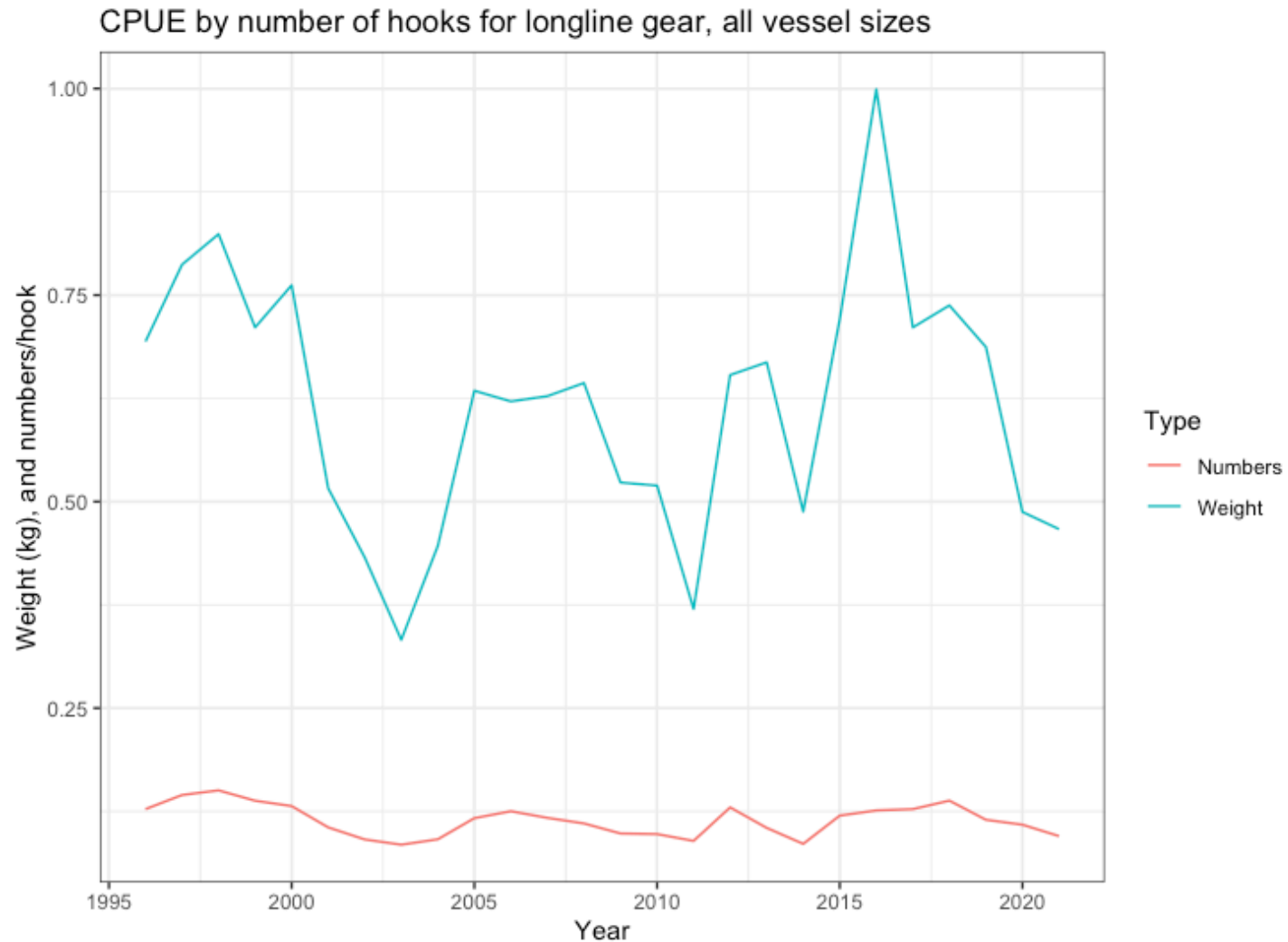


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What do we know about  
the Aleutian islands cod  
stock status  
(without a recent survey)?

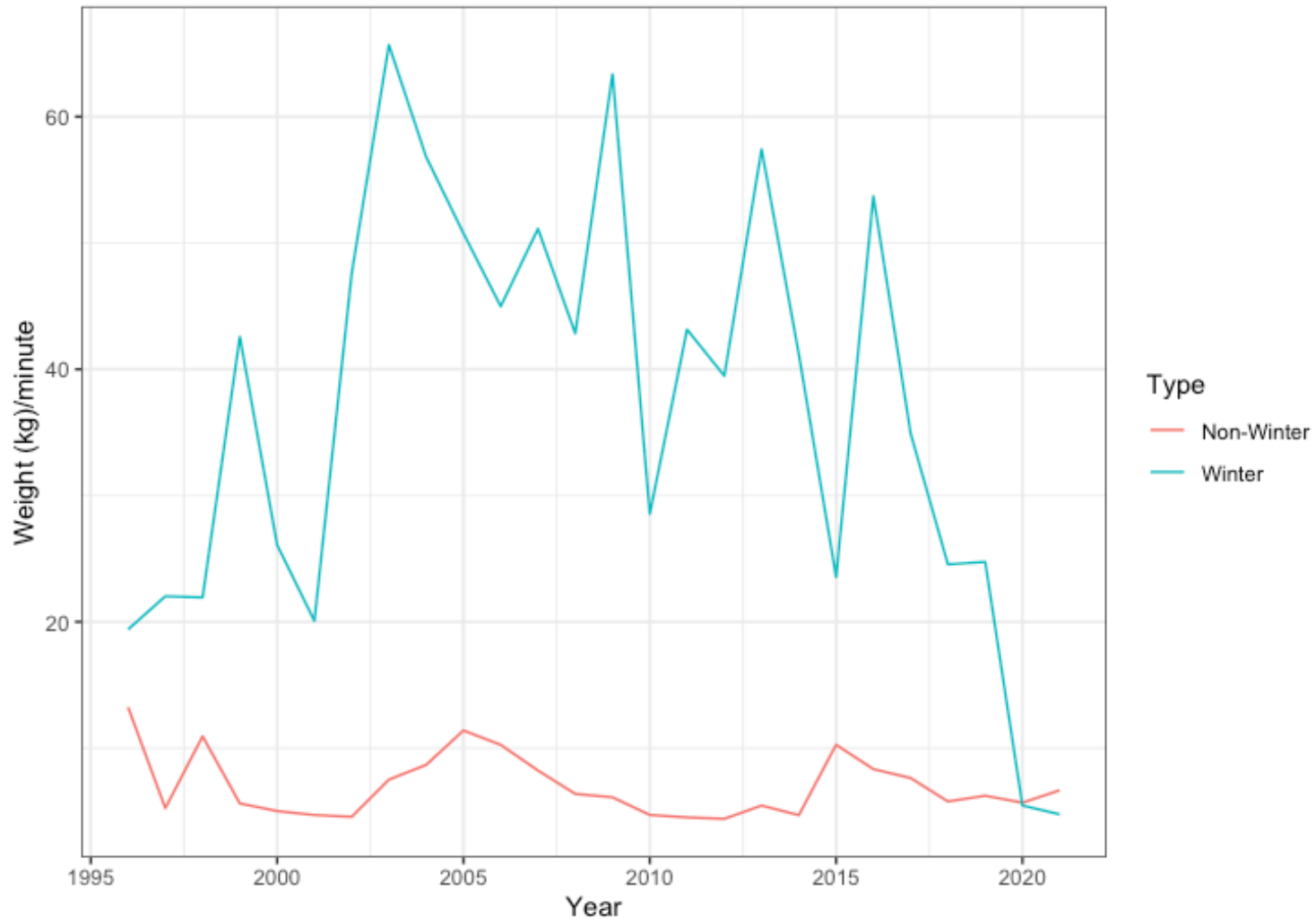


# CATCH PER UNIT EFFORT FOR AI COD LONGLINE VESSELS, 1996-2021, NUMBERS AND WEIGHT



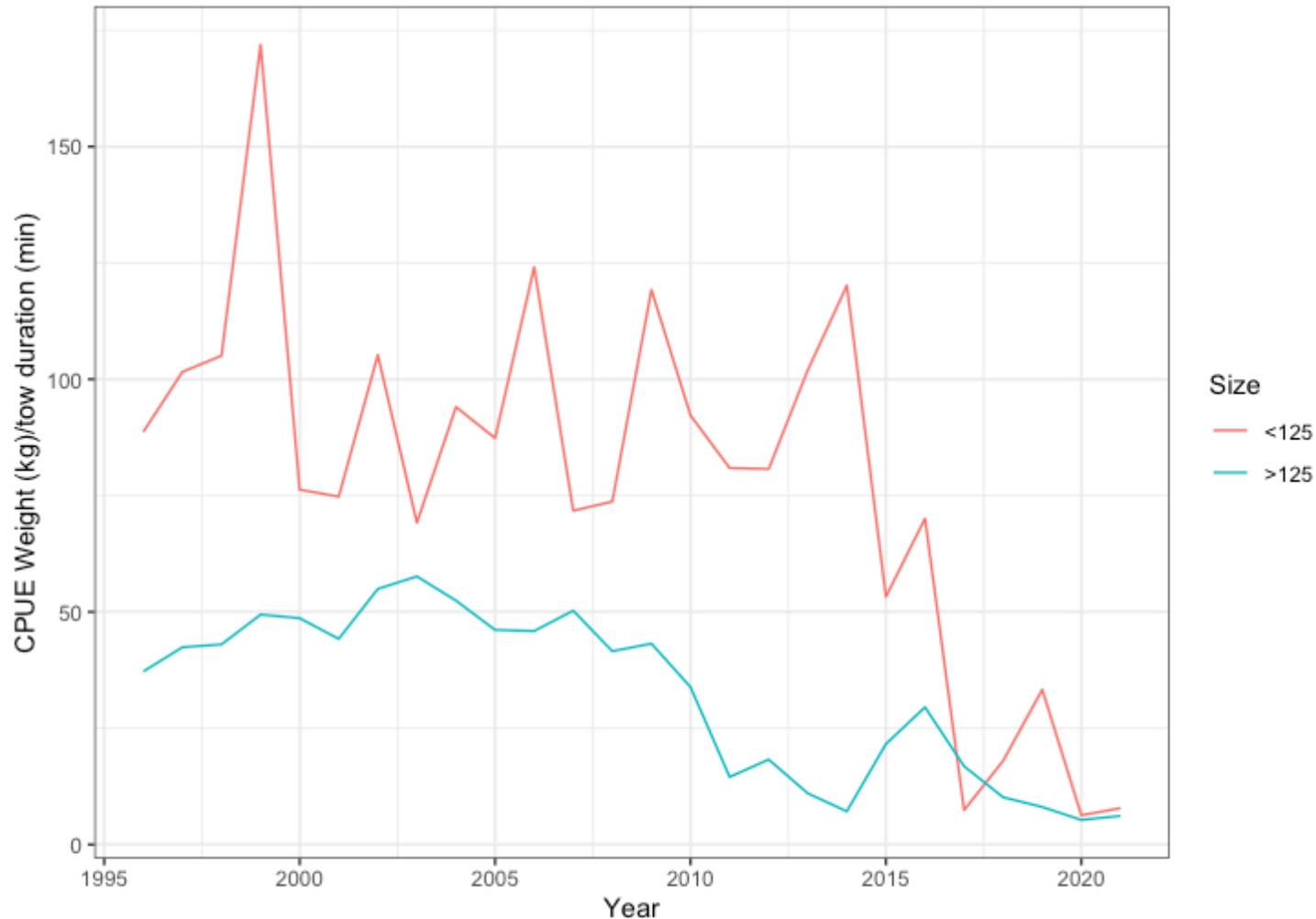
# CATCH PER UNIT EFFORT FOR AI COD TRAWLERS, 1996-2021 NON-WINTER (MAY-DEC), WINTER (JAN-APR)

CPUE by weight for trawl gear, all vessel sizes, by season



# CATCH PER UNIT EFFORT FOR AI COD TRAWLERS, 1996-2021, BY VESSEL SIZE

CPUE Weight/Duration for trawl gear, Vessel size cutoff 125 ft.



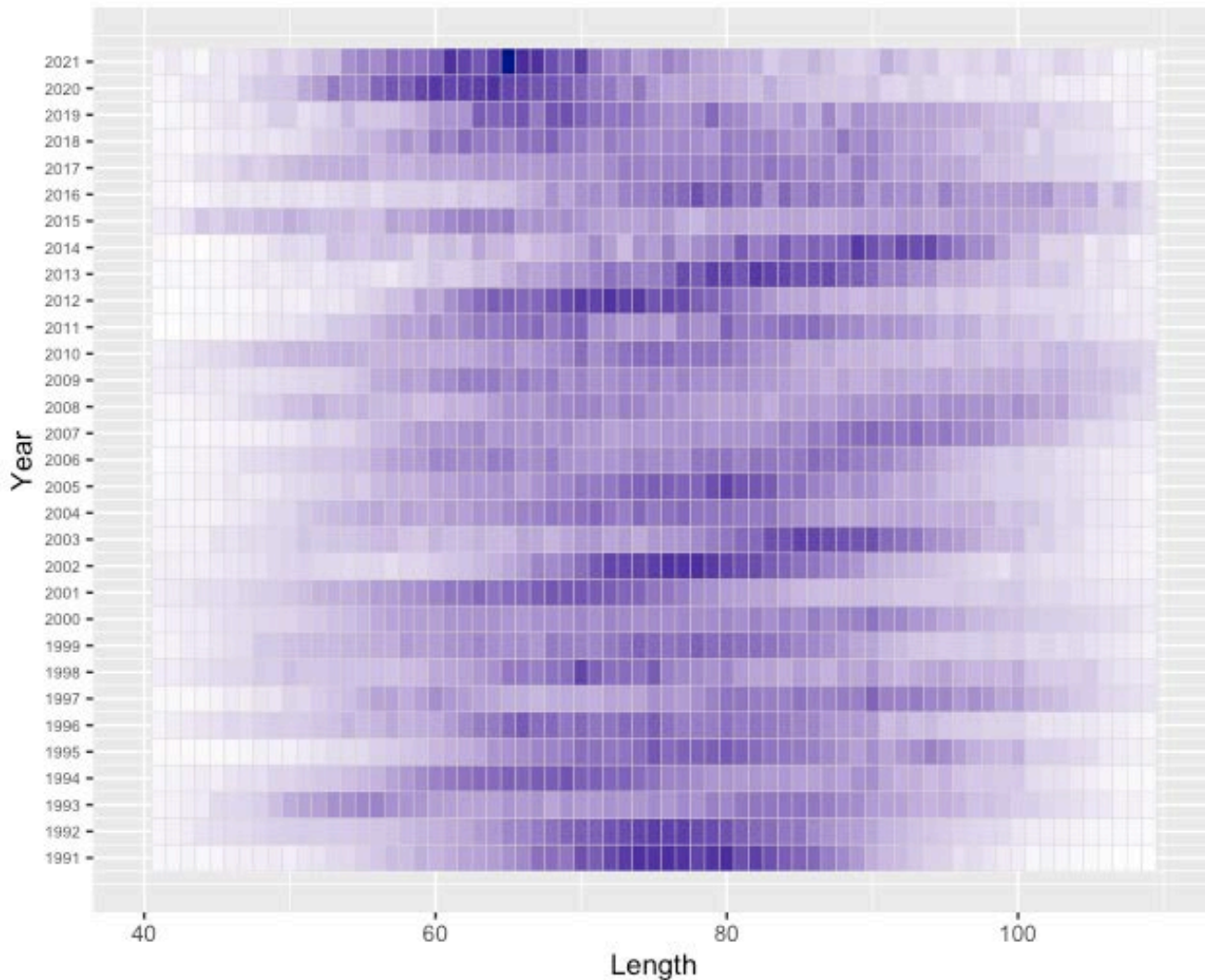
# FURTHER DETAIL ON THE FISHERY

- For the trawl CVs, for the A season the catch rates in the BS are often better, and the Bering Sea is easier to access.
- Cod aggregate in the Bering Sea before the AI cod aggregate (for spawning).
- The Adak processor hasn't been open to take P. cod deliveries in 2020 and 2021, so it's harder for smaller vessels pot and hook-and-line.
- Some reports indicate that P. cod are too large in the AI. Reports indicate poor fishing CPUE this fall.
- The non-CDQ Bering Sea Pacific cod fisheries were closed to directed fishing September 17, 2021, so that moved some vessels to the AI for the rest of 2021.
- October Council meeting - Pacific cod catch share program for BSAI trawl catcher vessel Pacific cod sector to promote fishing by this sector in the AI in A/B season (Jan to June 10), in place in 2024.

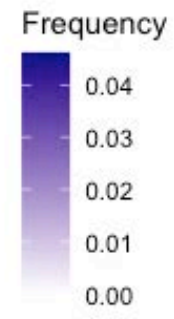


# FISHERY LENGTH FREQUENCIES SHOW THE 2016 YEAR CLASS AS THE PREDOMINANT COHORT

AI cod lengths - Fishery

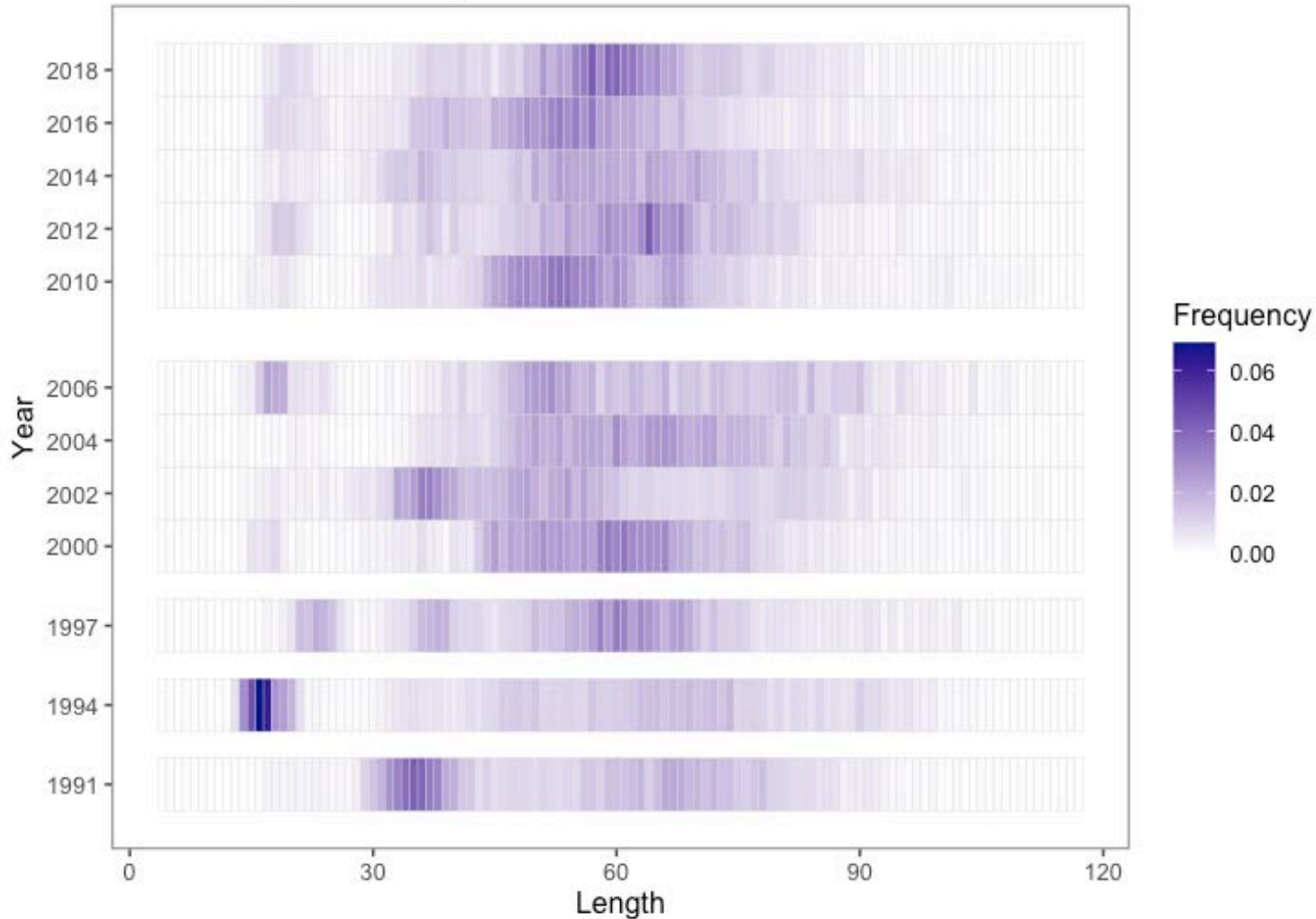


60-70 cm likely  
5 year olds spawned  
in 2016.



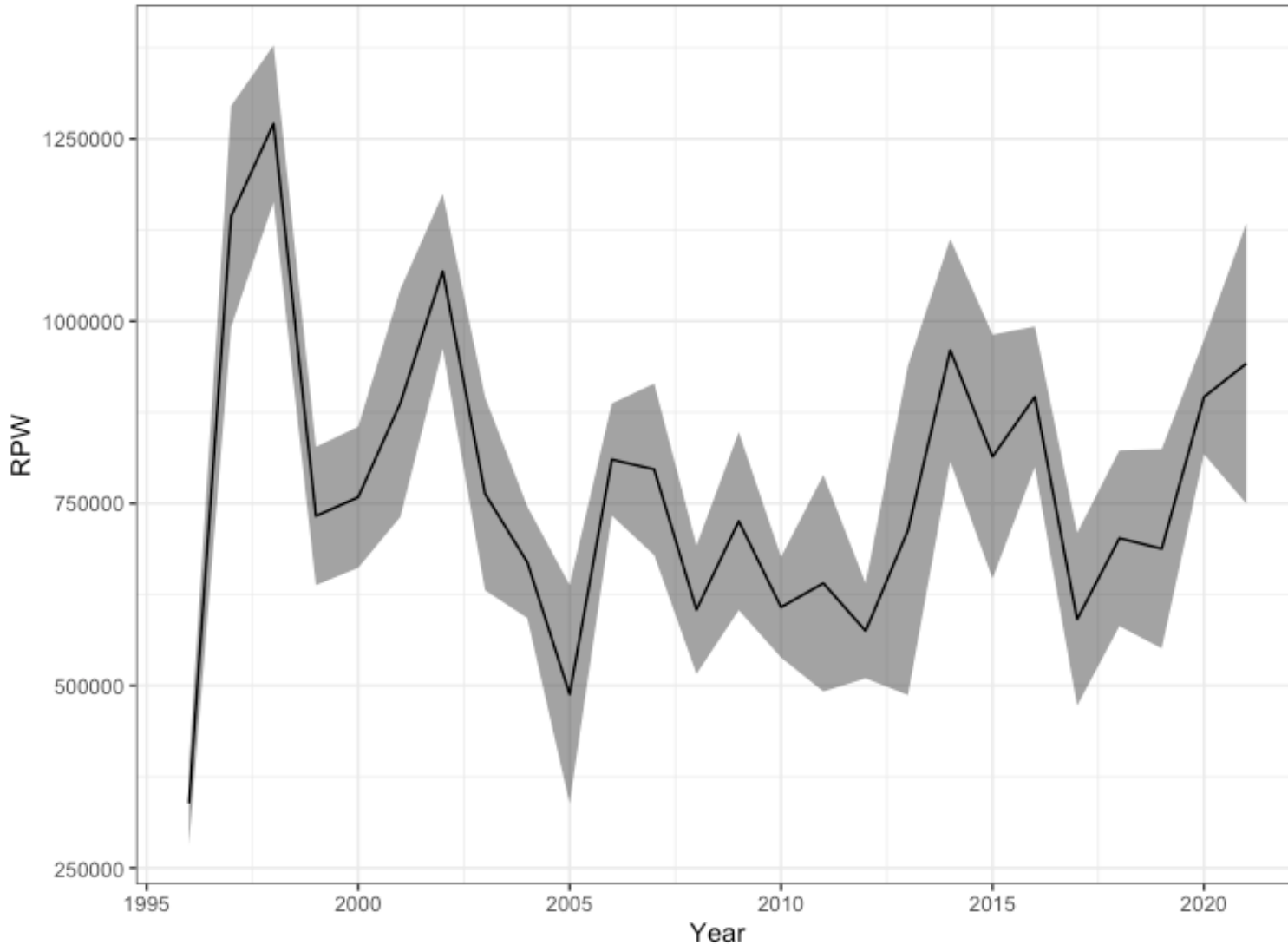
# LENGTH COMPOSITIONS FROM THE NMFS ALEUTIAN ISLANDS SURVEYS, 1991-2018.

AI cod lengths - Survey

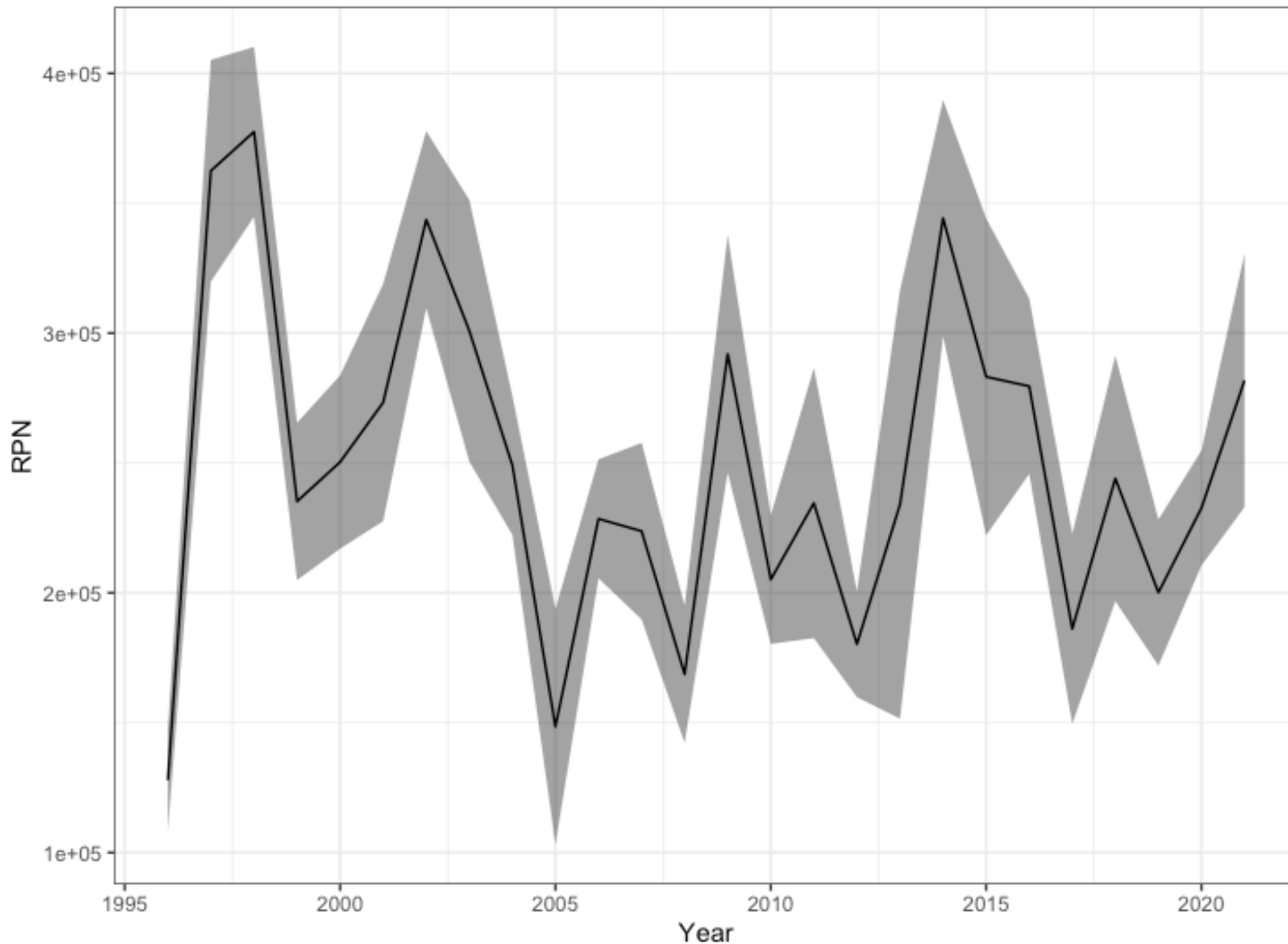




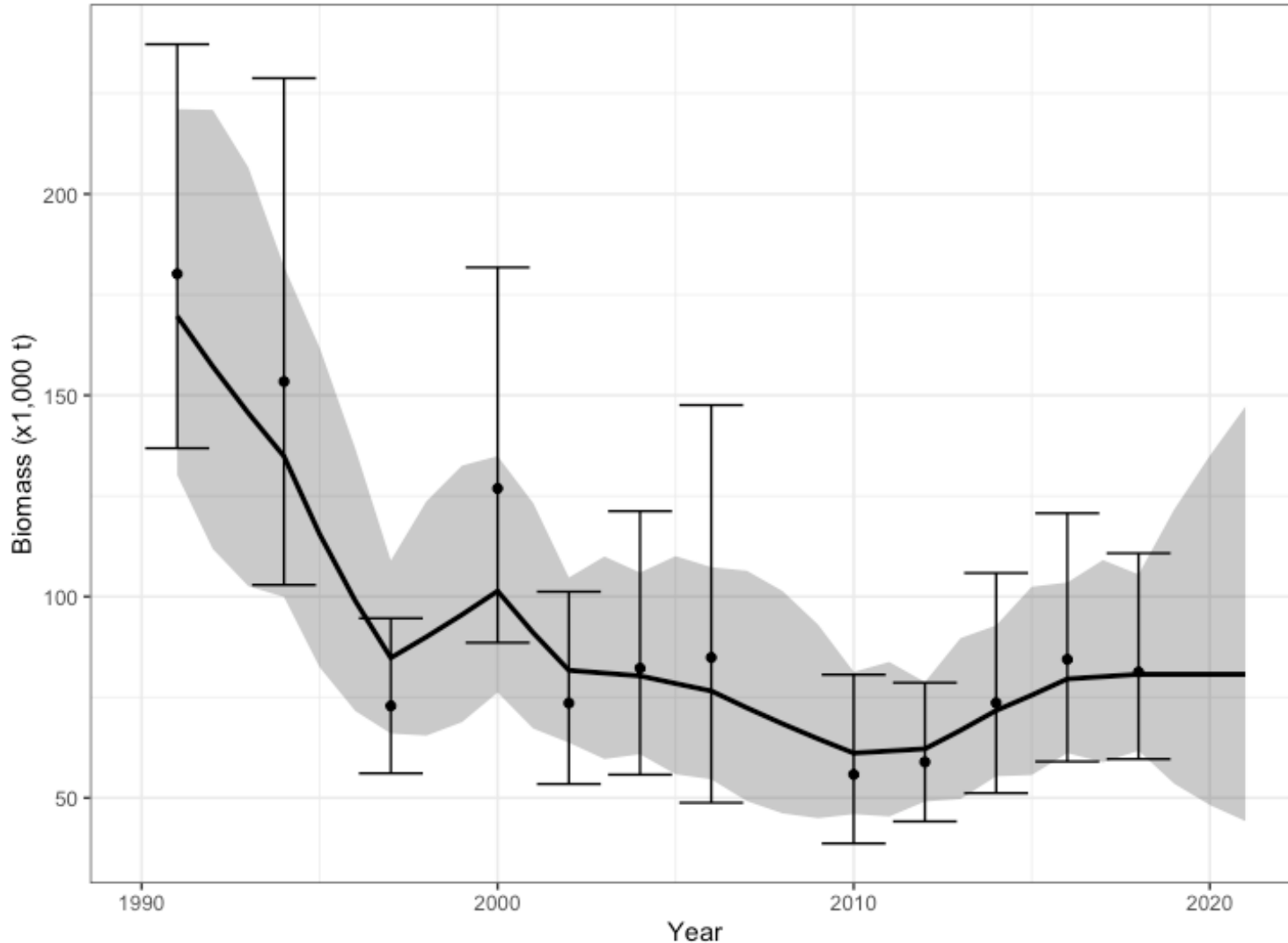
# LONGLINE SURVEY RELATIVE POPULATION WEIGHT – SHOWS INCREASE IN 2019-2021



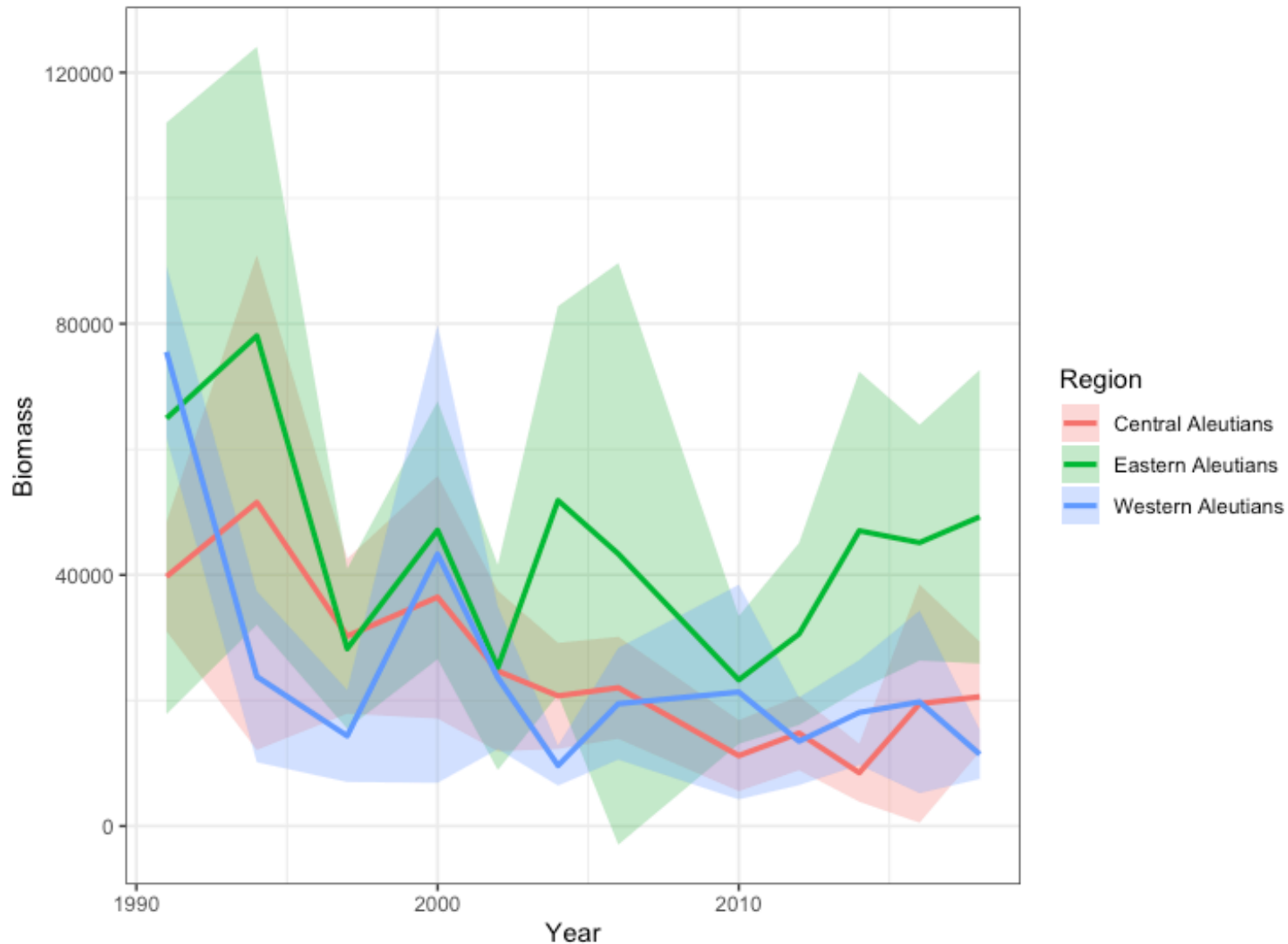
# LONGLINE SURVEY RELATIVE POPULATION NUMBERS SHOWS INCREASE IN 2019-2021



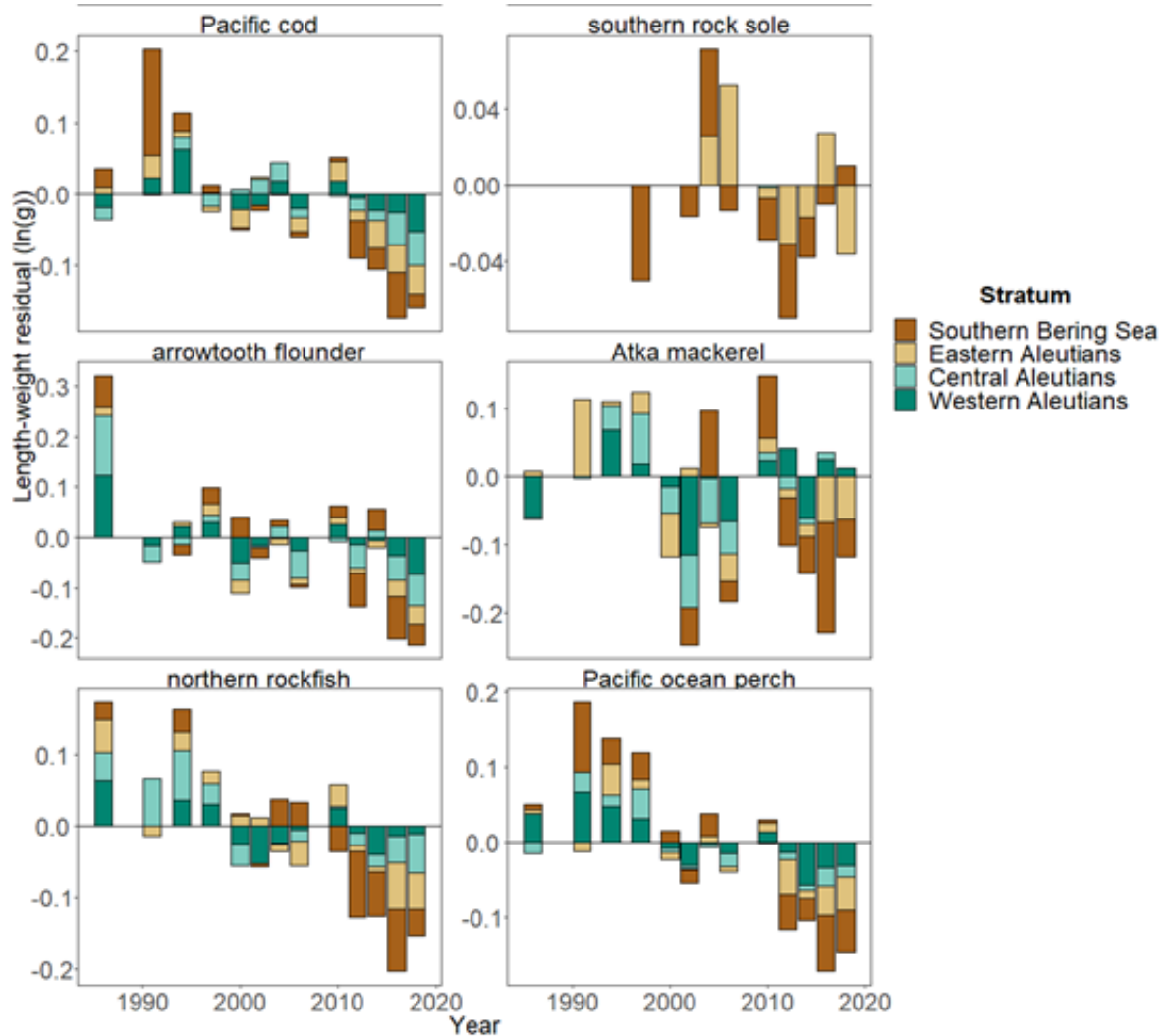
# ALEUTIAN ISLANDS TRAWL SURVEY THROUGH 2018, FIT TO RANDOM EFFECTS MODEL



# SURVEY ESTIMATES AND 95% CONFIDENCE INTERVALS; WESTERN, CENTRAL, AND EASTERN AI.



# ALEUTIAN ISLANDS PACIFIC COD LENGTH-WEIGHT RESIDUALS THROUGH 2019

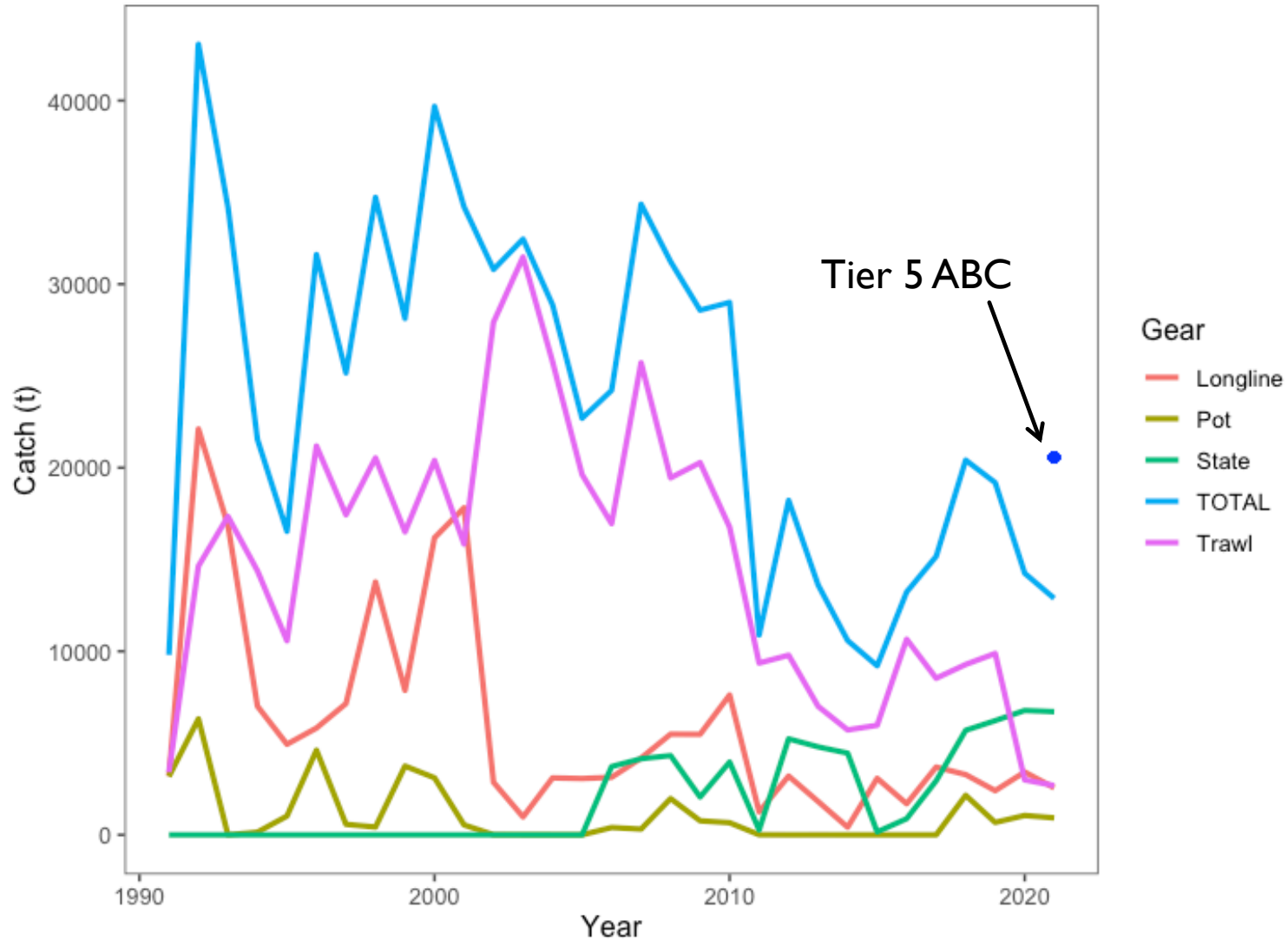


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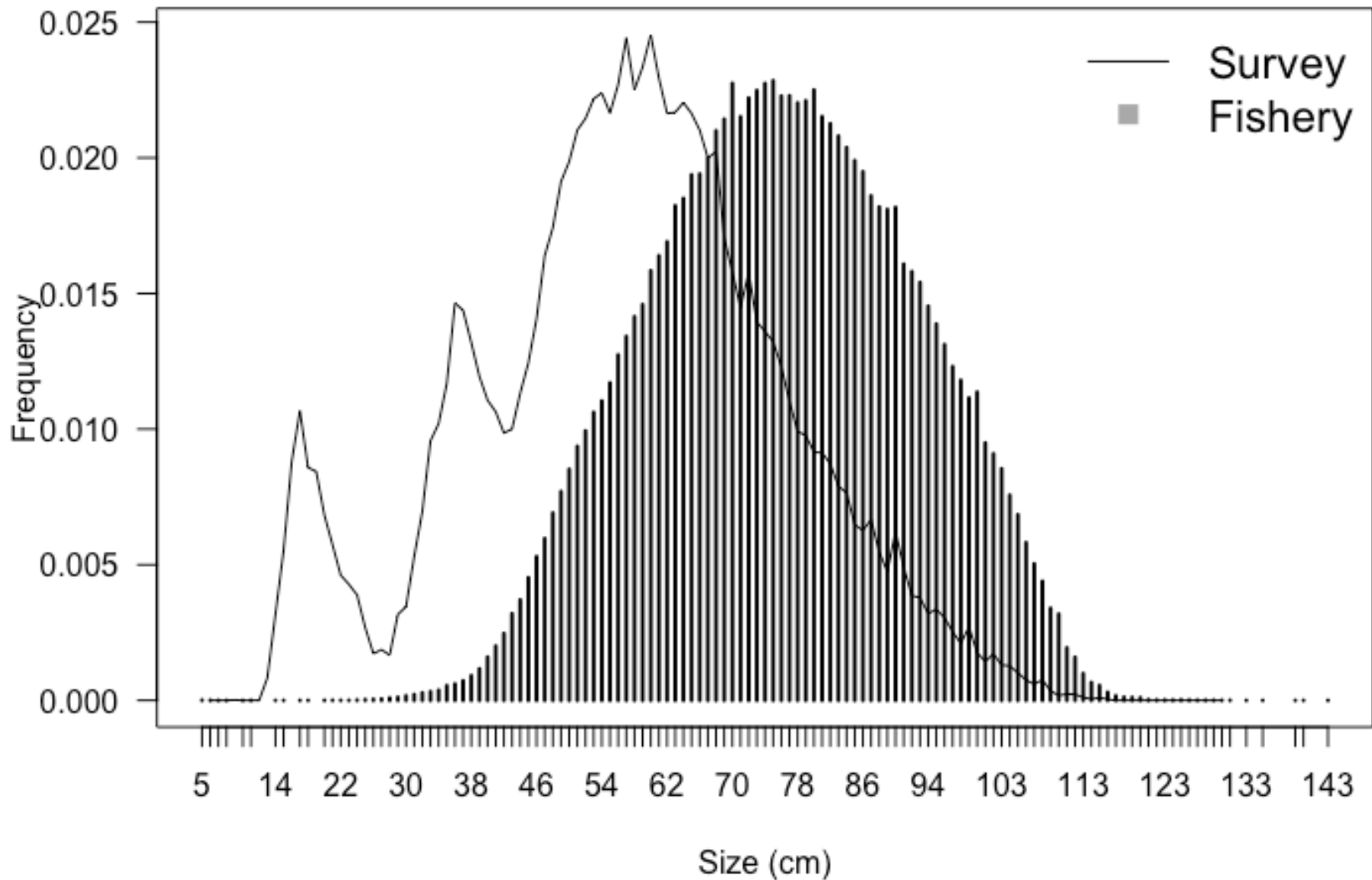
# Catch



# ALEUTIAN ISLANDS PACIFIC COD CATCH HISTORY, BY GEAR TYPE



# LENGTH FREQUENCIES FOR PACIFIC COD CAUGHT IN THE AI FISHERY (1990-2021) AND SURVEY (1991-2018)



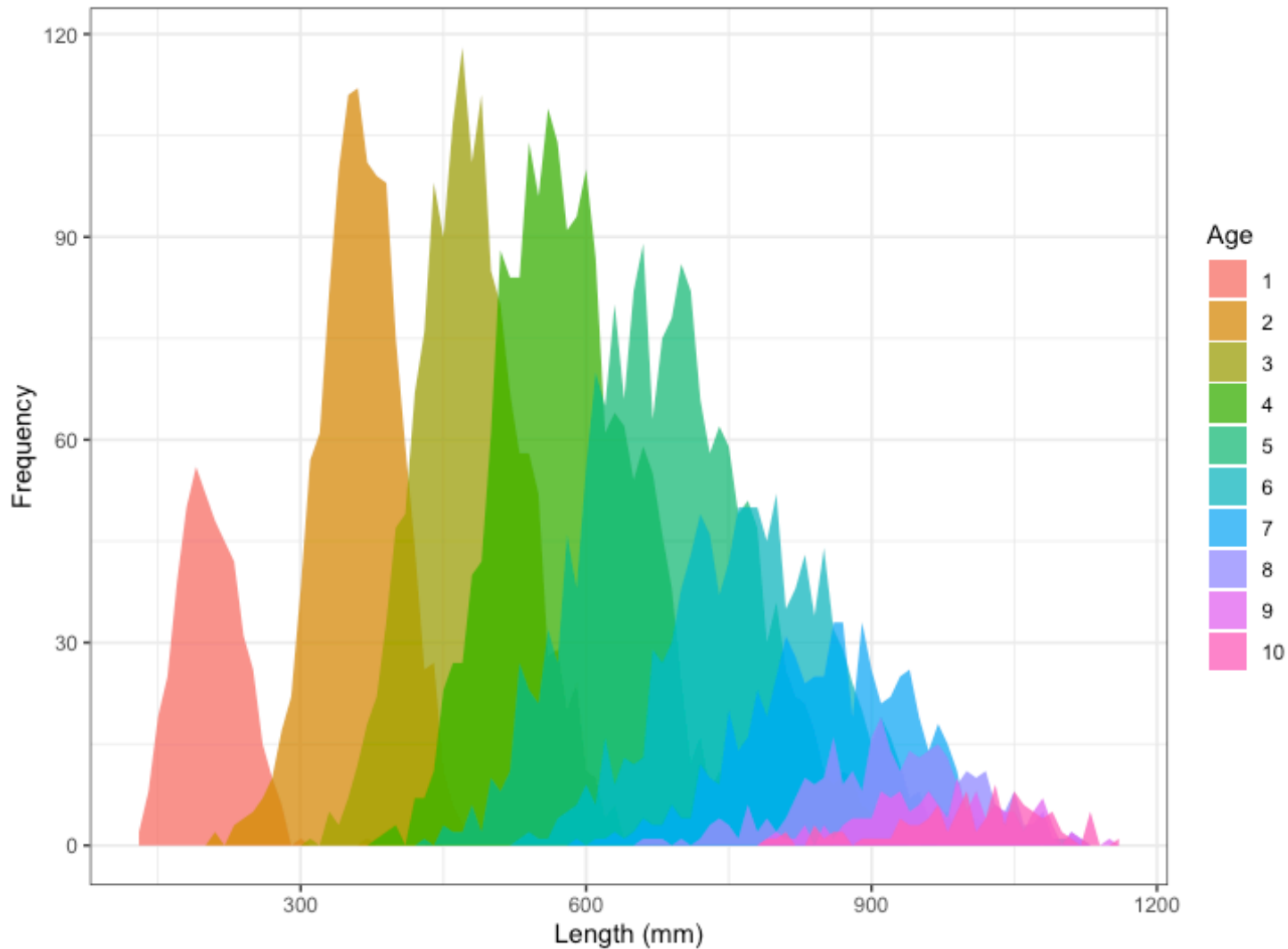


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# Biology (Growth)

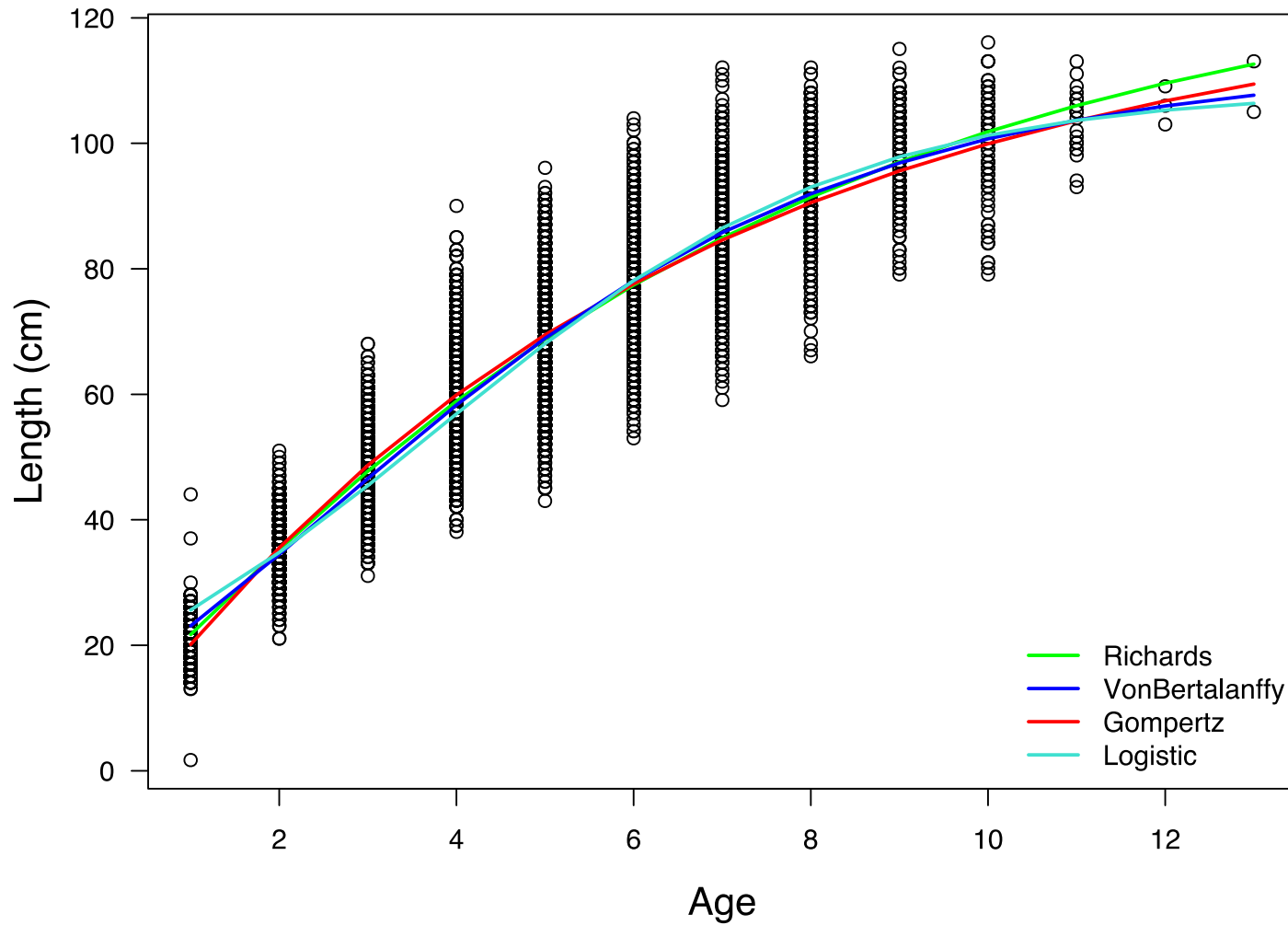


# RAW SIZE RANGES OF SURVEY AGED COD, AGE 1-10



# FOUR GROWTH CURVES FIT TO LENGTH AT AGE DATA

Raw Data compared with different growth curves



# COMPARISON OF FOUR GROWTH CURVES FIT TO RAW LENGTH AT AGE DATA

	Richards	Von Bertalanffy	Gompertz	Logistic
SSR	696.649853	700.963949	700.664739	713.820945
SSRmean	6.673260	3.603178	4.135476	7.188336
Number of parameters	4.000000	3.000000	3.000000	3.000000
AIC	-5.092566	-7.104913	-7.104059	-7.141264

The sum of squared residuals were fit to each individual data point (SSR) and the mean of the data at each age (SSRmean)



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# Models presented



## FOUR MODELS PRESENTED IN THIS ASSESSMENT

- Model 19.0: Base age structured model with  $M=0.34$ , maturity ogive derived from observer collections of maturity values from Aleutian Islands cod.
- Model 19.0a: Base age structured model except Stark (2007) maturity ogive.
- Model 19.0b: Base age structured model except  $M=0.40$ .
- Model 13.4: is the Tier 5 random effects model.



# DATA USED IN THE (AGE STRUCTURED) MODELS

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 FEATURES (1 OF 2)

- One fishery, one gear type, one season per year.
- Single sex model, 1:1 male female ratio.
- Logistic age based selectivity for both the fishery and survey.
- External estimation of a single growth curve (Von Bertalanffy) 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.
- Internal estimation of fishing mortality, catchability, and selectivity parameters.



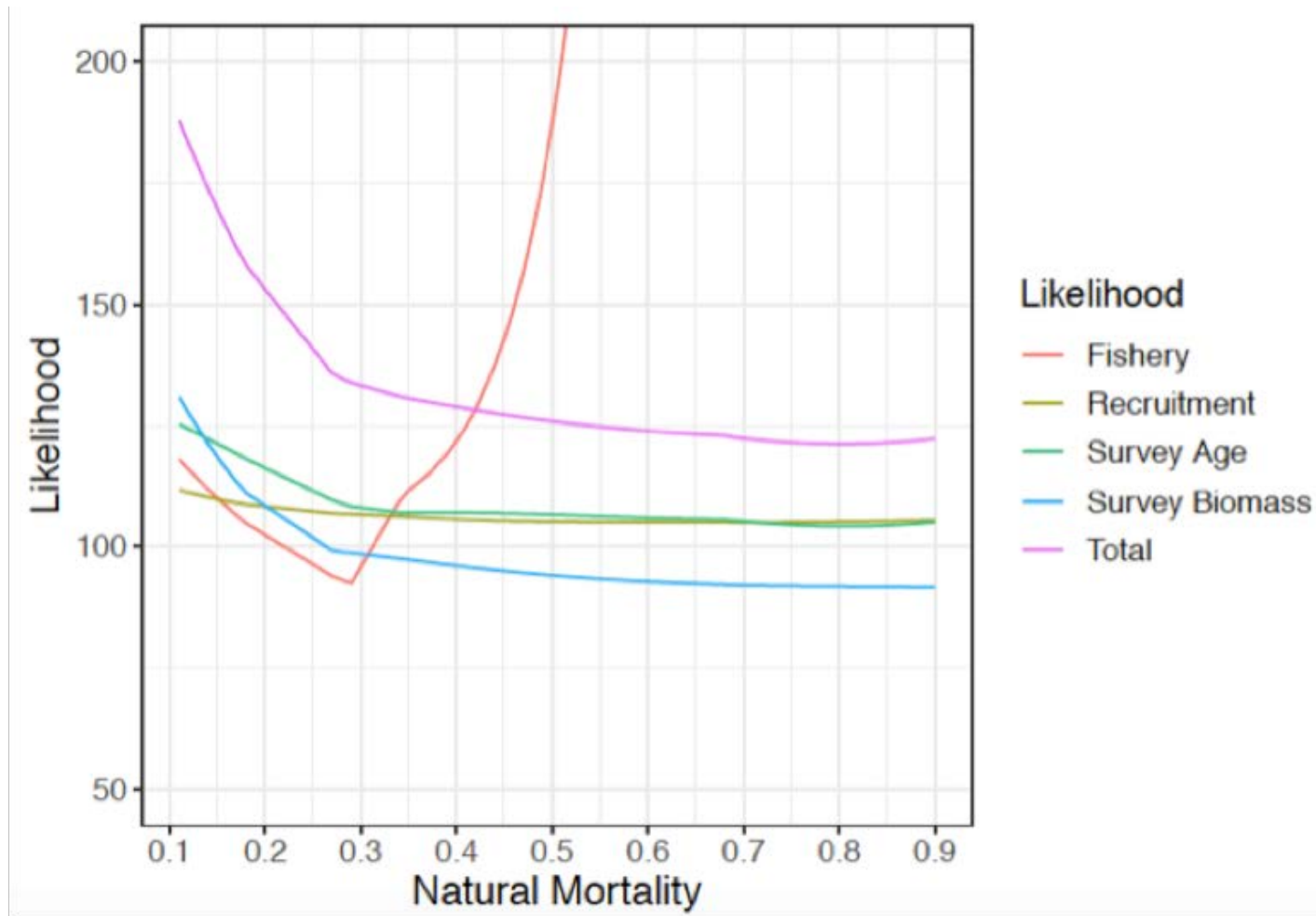


## MODEL FEATURES (2 OF 2)

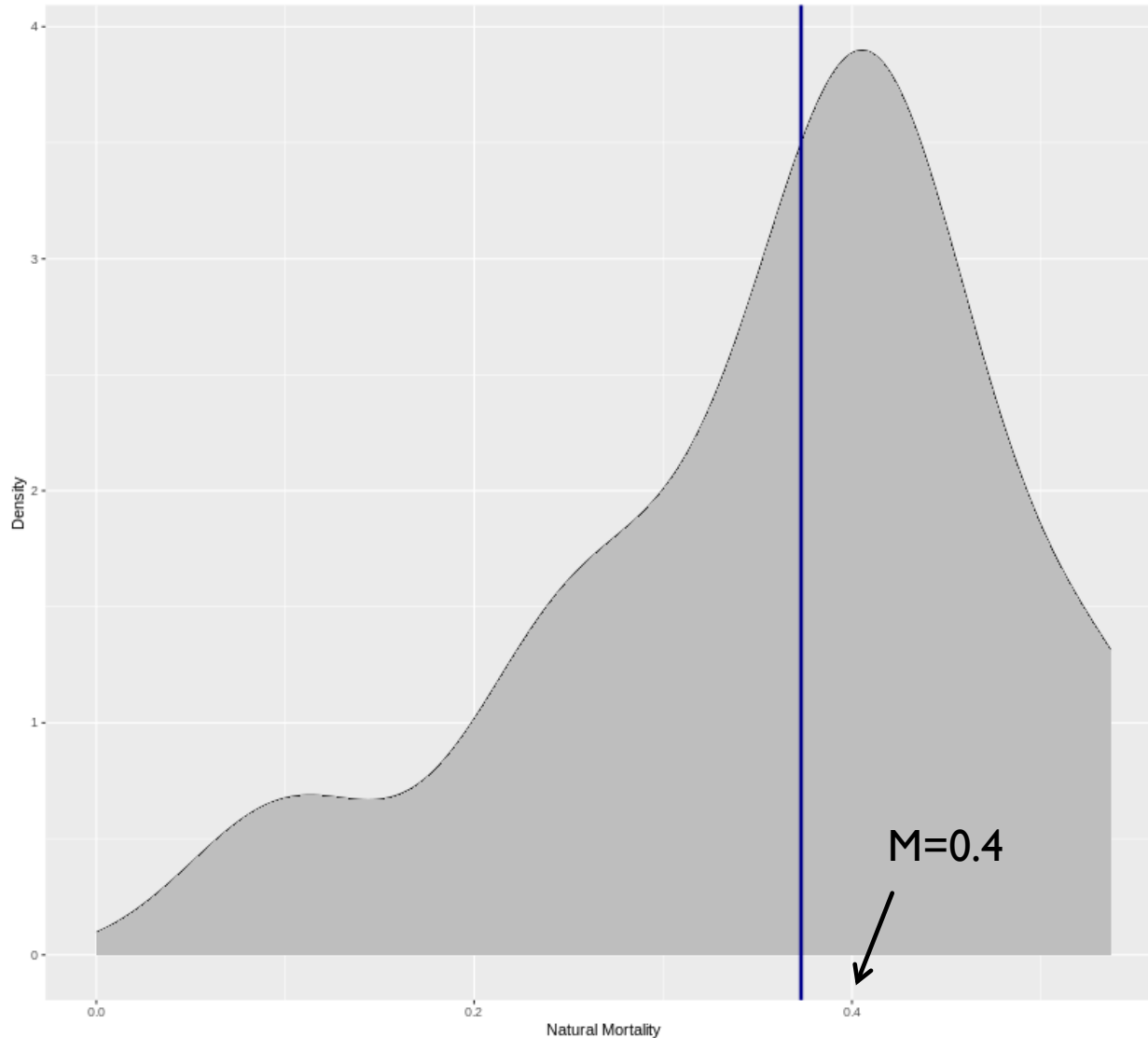
- Recruitment estimated as a mean with lognormally distributed deviations
- Natural mortality was fixed in the model using  $M=0.34$  for consistency with previous Aleutian Islands Pacific cod assessments.
- Survey catchability was estimated within the model as a constant multiplier on survey selectivity.
- Maturity at age was estimated using observer data. This is consistent with the Gulf of Alaska Pacific cod assessment.
- Fishery length frequencies were weighted by the relative catch by year in the three NMFS areas (541, 542, and 543).



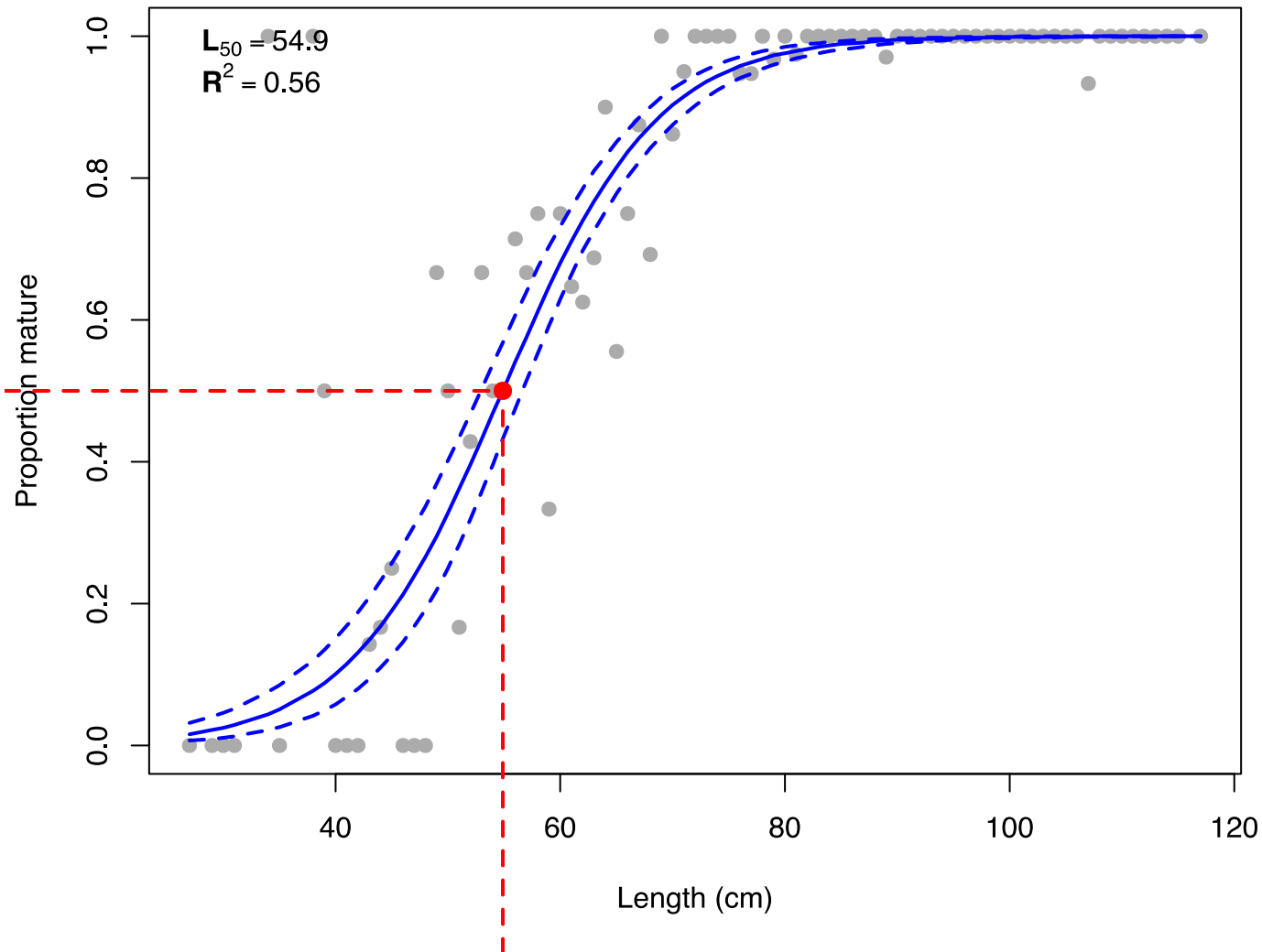
# LIKELIHOOD PROFILE FOR NATURAL MORTALITY, AGE, FISHERY LENGTH, RECRUITMENT, SURVEY BIOMASS



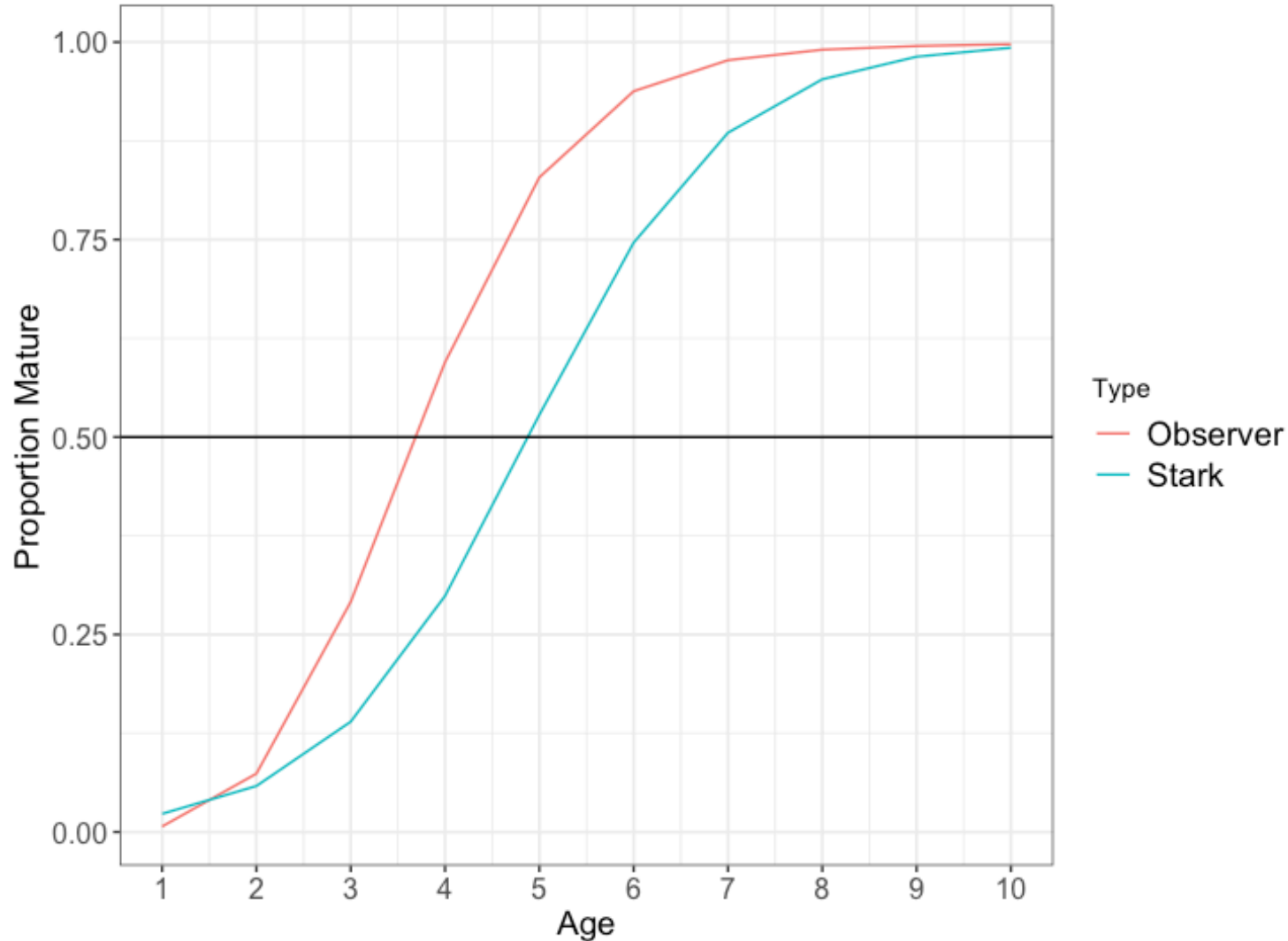
# MEDIAN VALUE FOR NATURAL MORTALITY FOR ALEUTIAN ISLANDS PACIFIC COD ( $M=0.36$ )



# FIT TO THE PROPORTION OF ALEUTIAN ISLANDS COD MATURE BY LENGTH 2008-2021, JANUARY MARCH

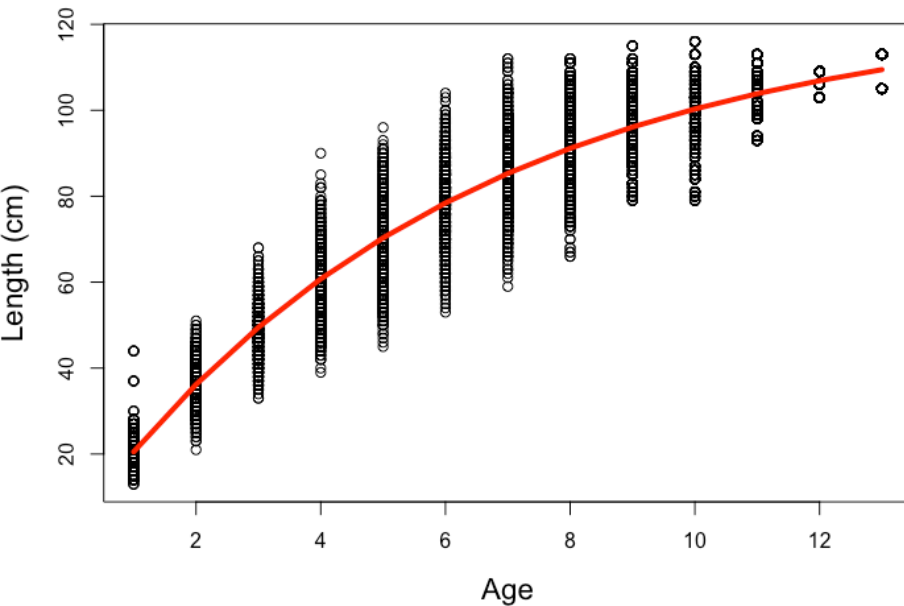


# PROPORTION MATURE BY AGE, OBSERVER AND STARK (2007) MATURITY

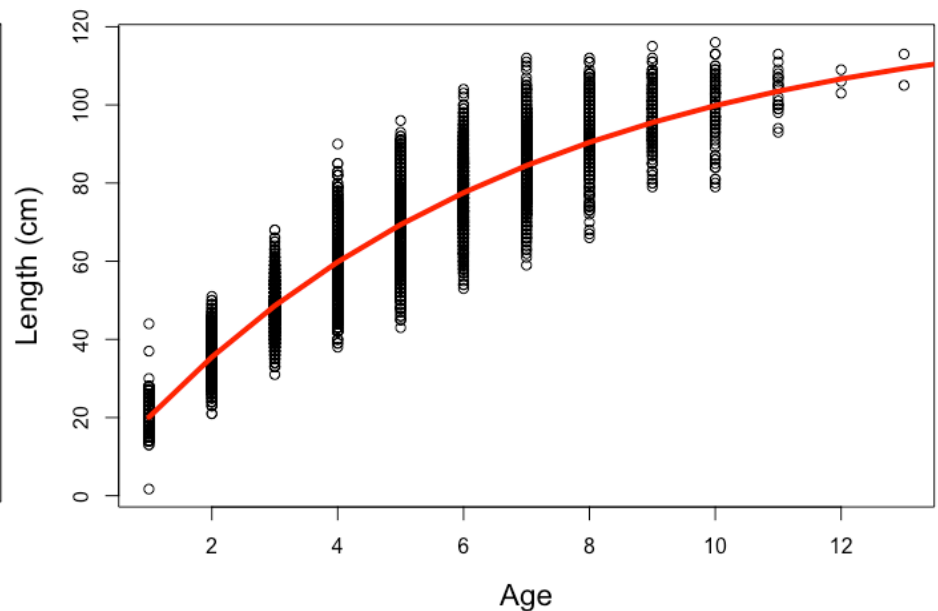


# FIT TO RAW LENGTH AT AGE DATA, AND BAYESIAN CORRECTED DATA

Bayesian converted data compared with VB fit



Raw Data compared with VB fit



$$P(\text{Age}|\text{Length}) = P(\text{Length}|\text{Age})P(\text{Age})/P(\text{Length})$$

Input data	$L_{inf}$	$K$	$t_0$
Corrected Length at age	123.8012	0.1645	-0.1020
Uncorrected length at age	124.9502	0.1587	-0.1045

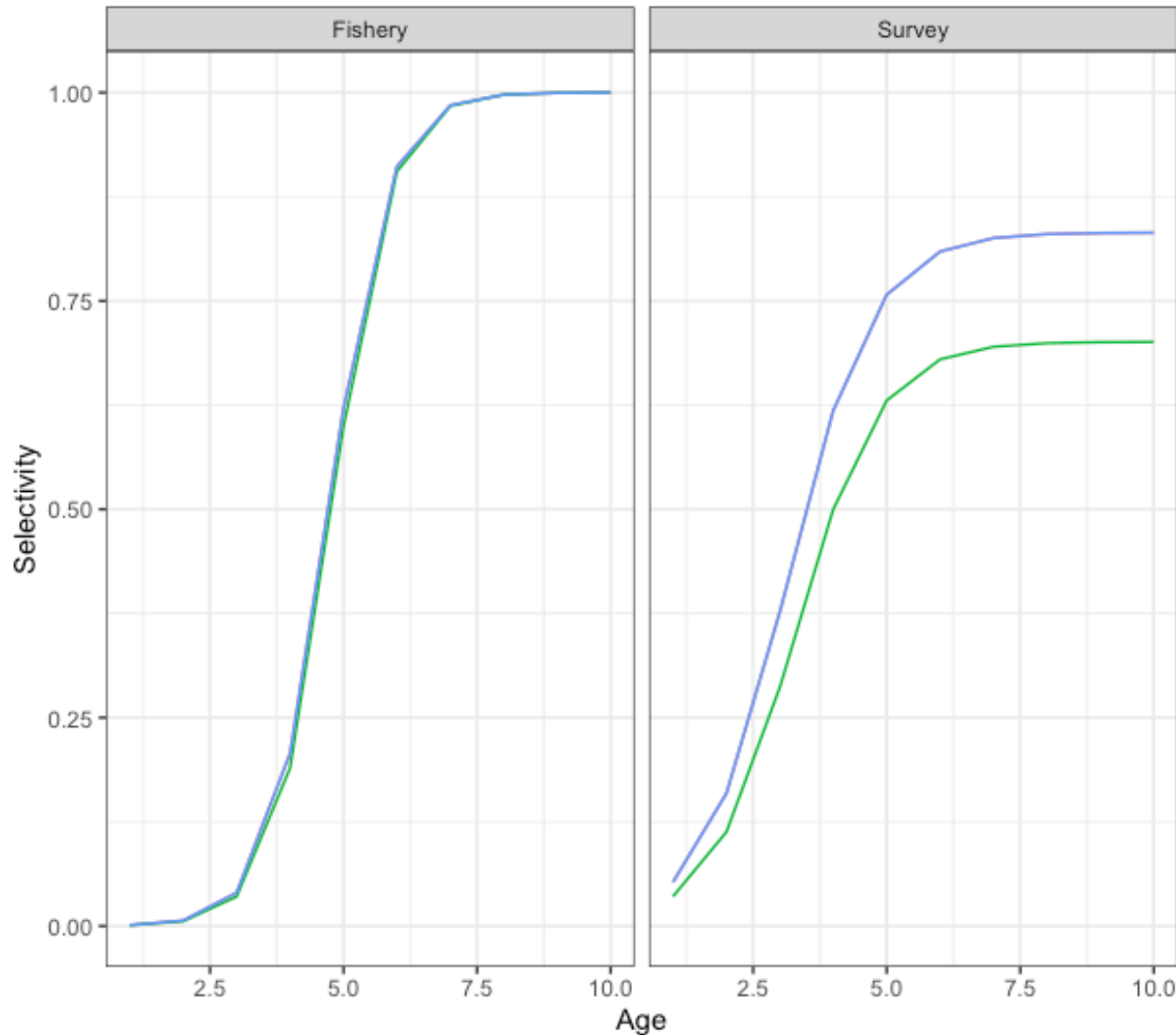


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# Results and model comparison



# MODEL ESTIMATES FOR SELECTIVITY FOR THE SURVEY AND THE FISHERY.



Model 19.0 and Model 19.0b have identical values.

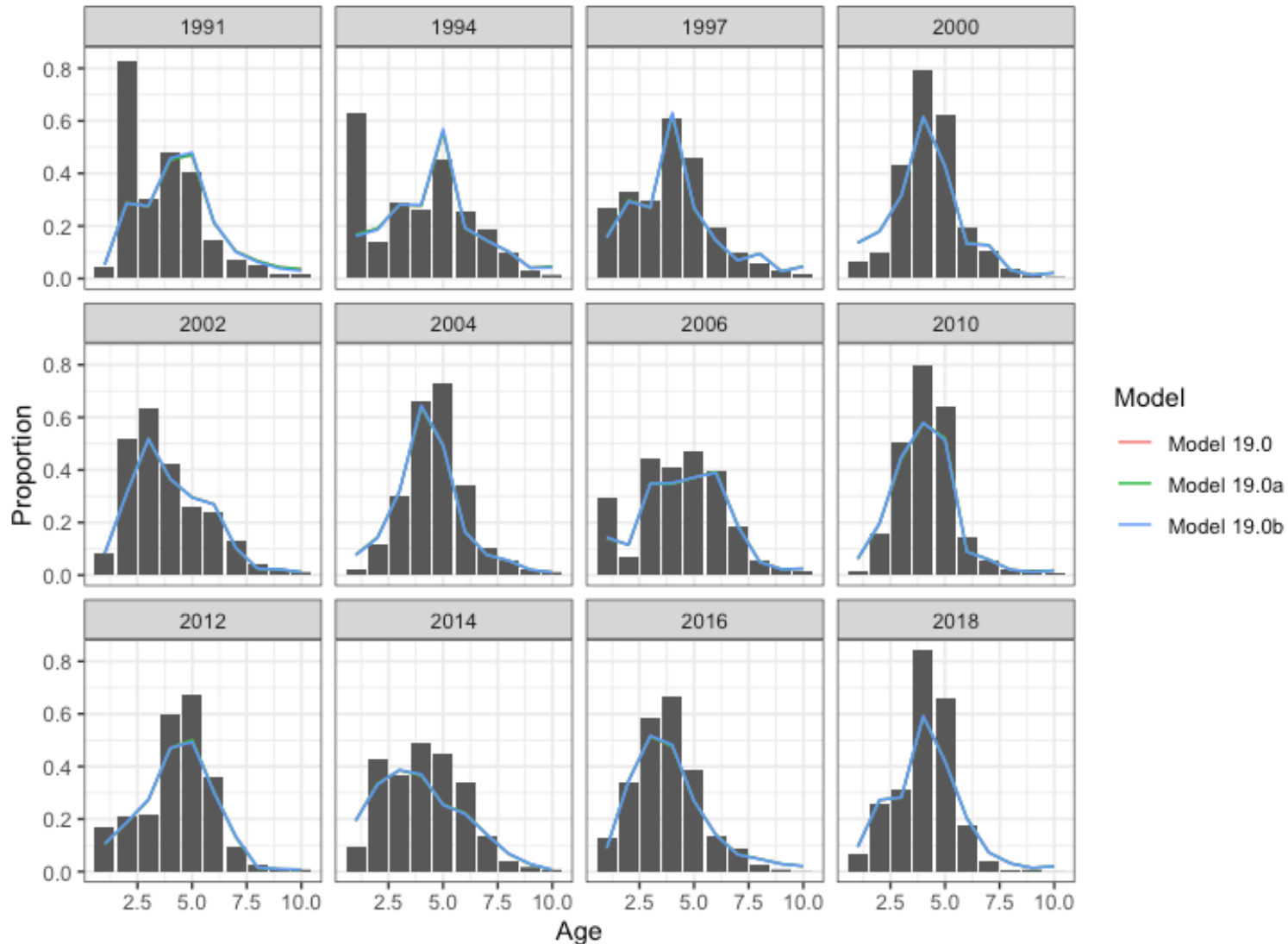
## Model

- Model 19.0
- Model 19.0a
- Model 19.0b

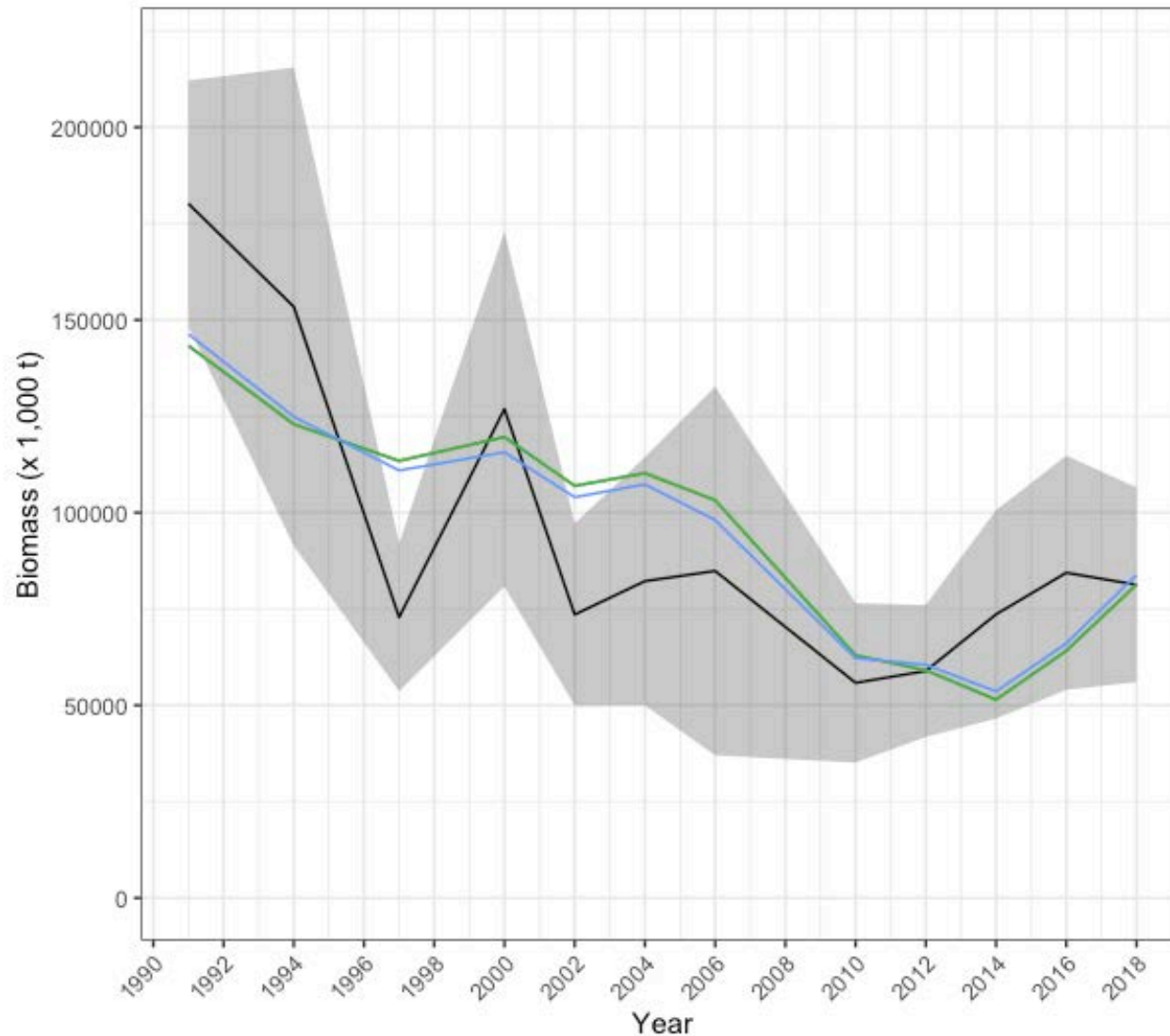




# SURVEY AGE FREQUENCY FIT TO MODEL 19.0, 19.0A, AND 19.0B, SOLID LINE IS MODEL ESTIMATE



# NMFS ALEUTIAN ISLANDS SURVEY BIOMASS ESTIMATES, WITH 95% CI'S AND MODEL ESTIMATES



Model 19.0b and Model 19.0a have very similar biomass estimates.

- Model 19.0
- Model 19.0a
- Model 19.0b



# COMPARISON OF LIKELIHOOD VALUES FOR THE THREE MODELS

	Model 19.0	Model 19.0a	Model 19.0b
Likelihood Component	Base Model	Stark (2007) maturity	M=0.40
Recruitment	5.91	5.91	5.424
Survey age	56.055	56.055	56.228
Survey biomass	16.309	16.309	13.932
Catch	0.002	0.002	0.001
Fishery length	47.231	47.231	46.768
Total	125.507	125.507	122.354
Mohn's rho	0.225	0.255	0.154



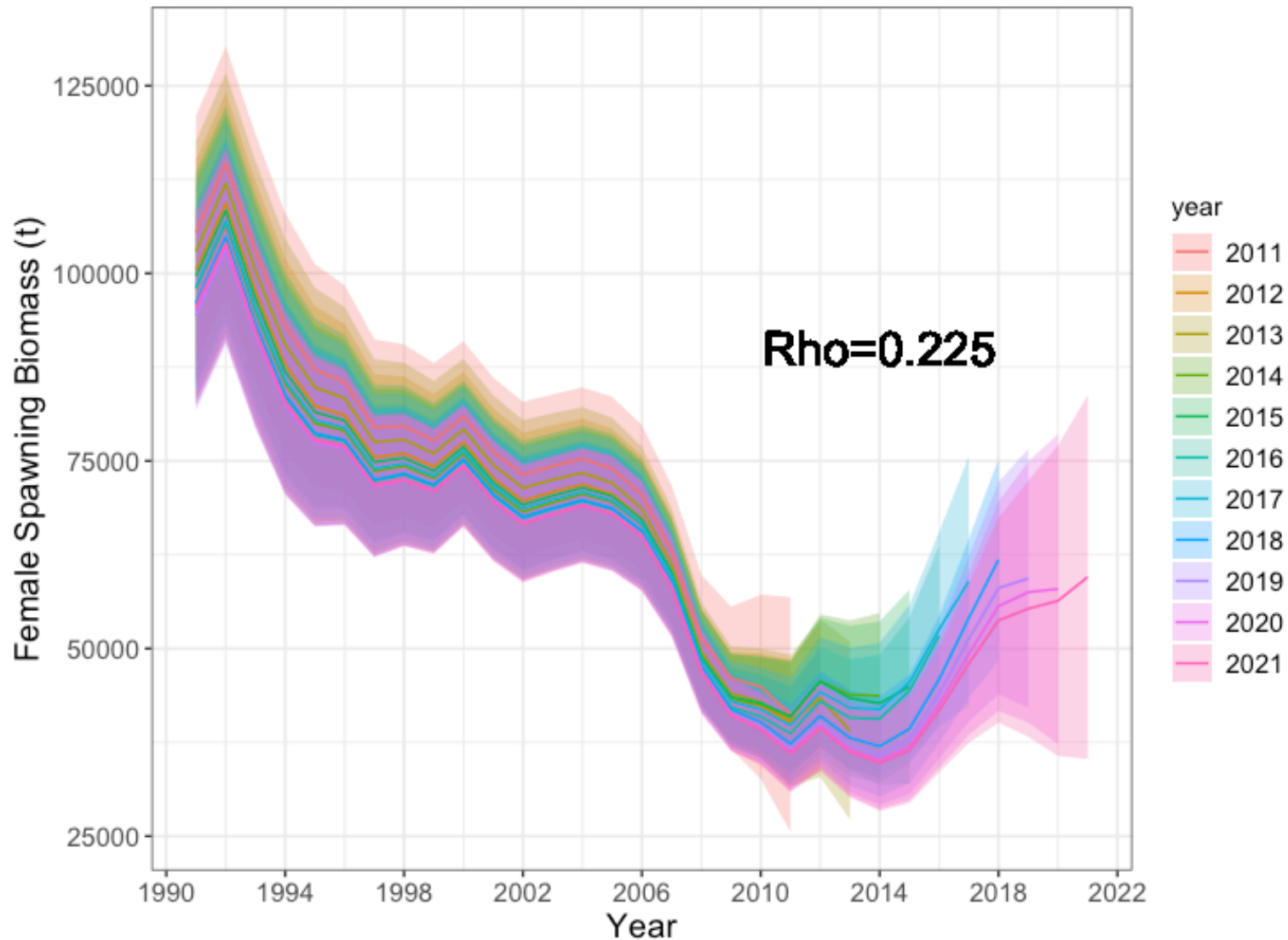
## GOODNESS OF FIT TESTS FOR THE FOUR MODELS

Test statistic	Model 19.0	Model 19.0a	Model 19.0b
CV of RMSD for biomass	0.315	0.305	0.312
SSD for survey age	0.413	0.413	0.417
SSD for fishery lengths	0.248	0.248	0.247
SDNR	1.745	1.745	1.649
Survey catchability	0.832041	0.832042	0.700969

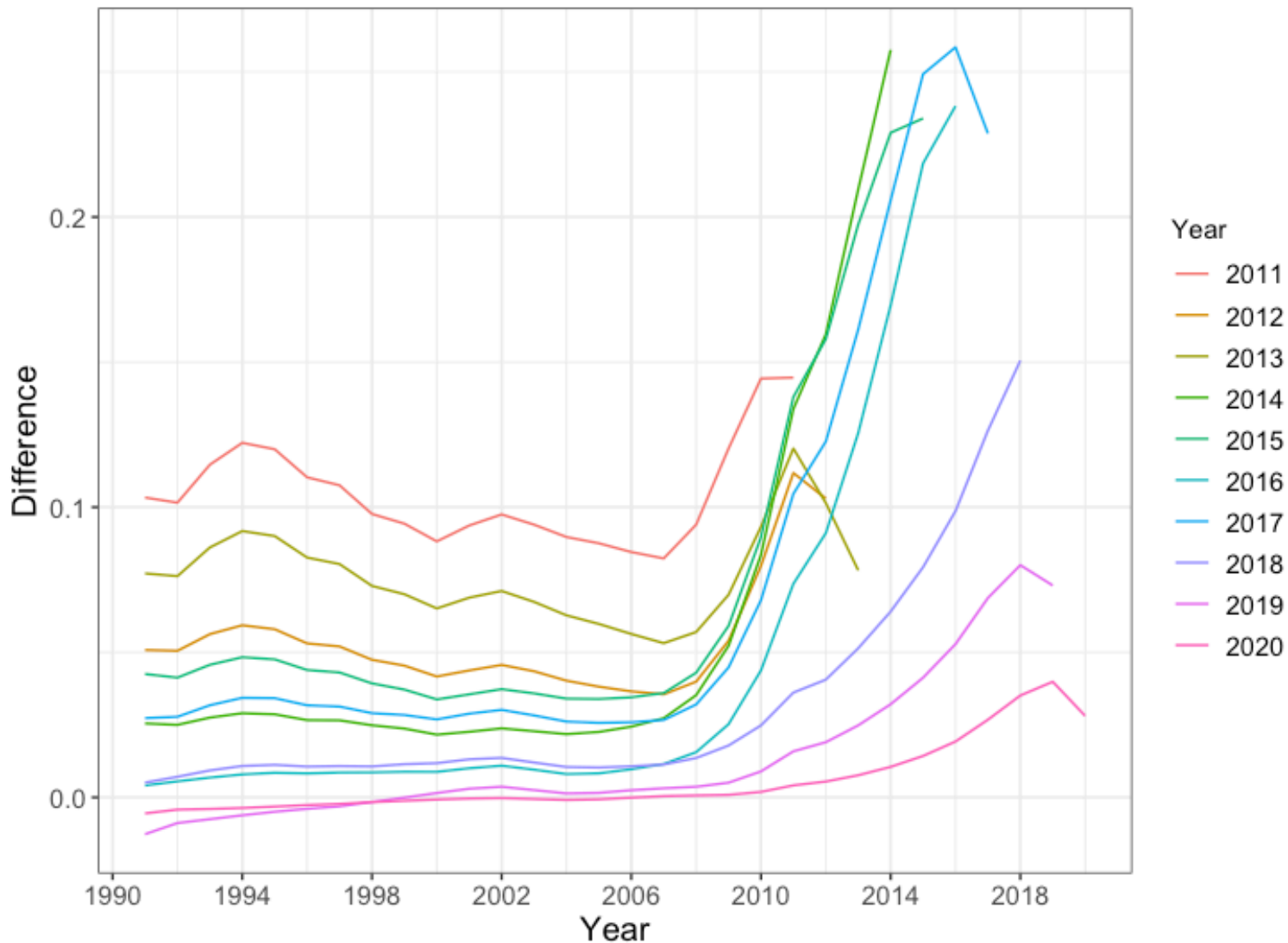
- The sum of squared differences (SSD) for survey ages, and fishery lengths
- The coefficient of variation for the RMSD (root mean squared deviation) for fit to biomass,
- The square root of the standard deviation of normalized residuals for biomass



# RETROSPECTIVE PLOT OF FEMALE SPAWNING BIOMASS, MODEL 19.0, 2011-2021.



# RELATIVE DIFFERENCES IN ESTIMATES OF SPAWNING BIOMASS BETWEEN 2021 & RETROSPECTIVE PEELS



# INTERPRETATION OF MOHN'S RHO

- If Mohn's rho were entirely dependent on M (likely an oversimplification), then an equation for the lower and upper limits could be developed from these guidelines as follows (Hurtado-Ferro 2015):
- $\text{Rho (lowerbound)} = -0.8 - 0.35 * M$
- $\text{Rho (upperbound)} = 0.10 + 0.50 * M$ .

Model 19.0 bounds (M=0.34): -0.199 - 0.27. True value 0.225.

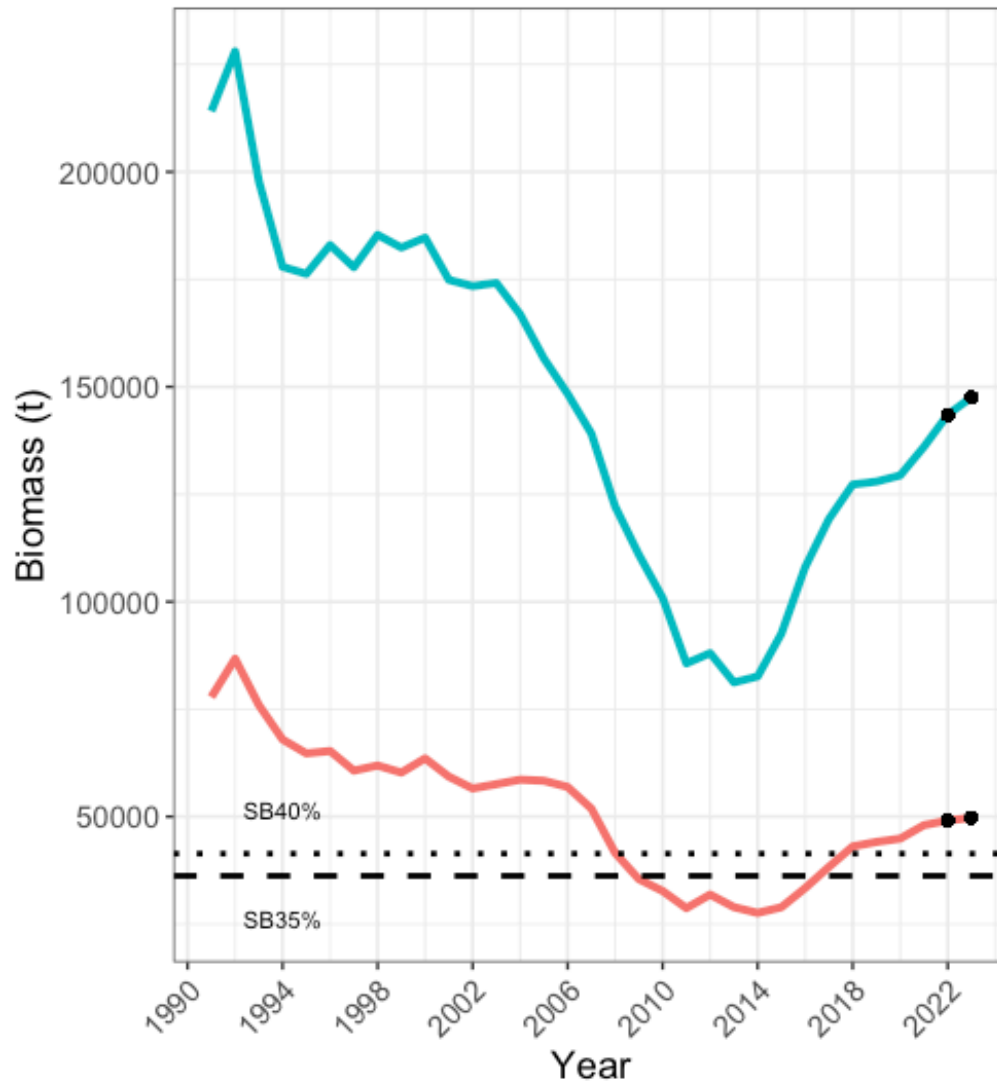
Model 19.0b bounds (M = 0.40): -0.22 and 0.3. True value 0.154.

The estimates of Mohn's do not surpass these confidence intervals, but they are still considerable.

On average over the past 10 assessment years, the model's estimates of female spawning biomass in the terminal year would have exceeded the model's current estimate of female spawning biomass in that year by about 22.5%.



# MODEL 19.0 ESTIMATES FOR TOTAL (AGE 1+) BIOMASS AND FSB, 1991-2021



Projection model estimates for 2022 and 2023 are presented. Reference points  $SB_{40\%}$  and  $SB_{35\%}$  are shown as horizontal lines.

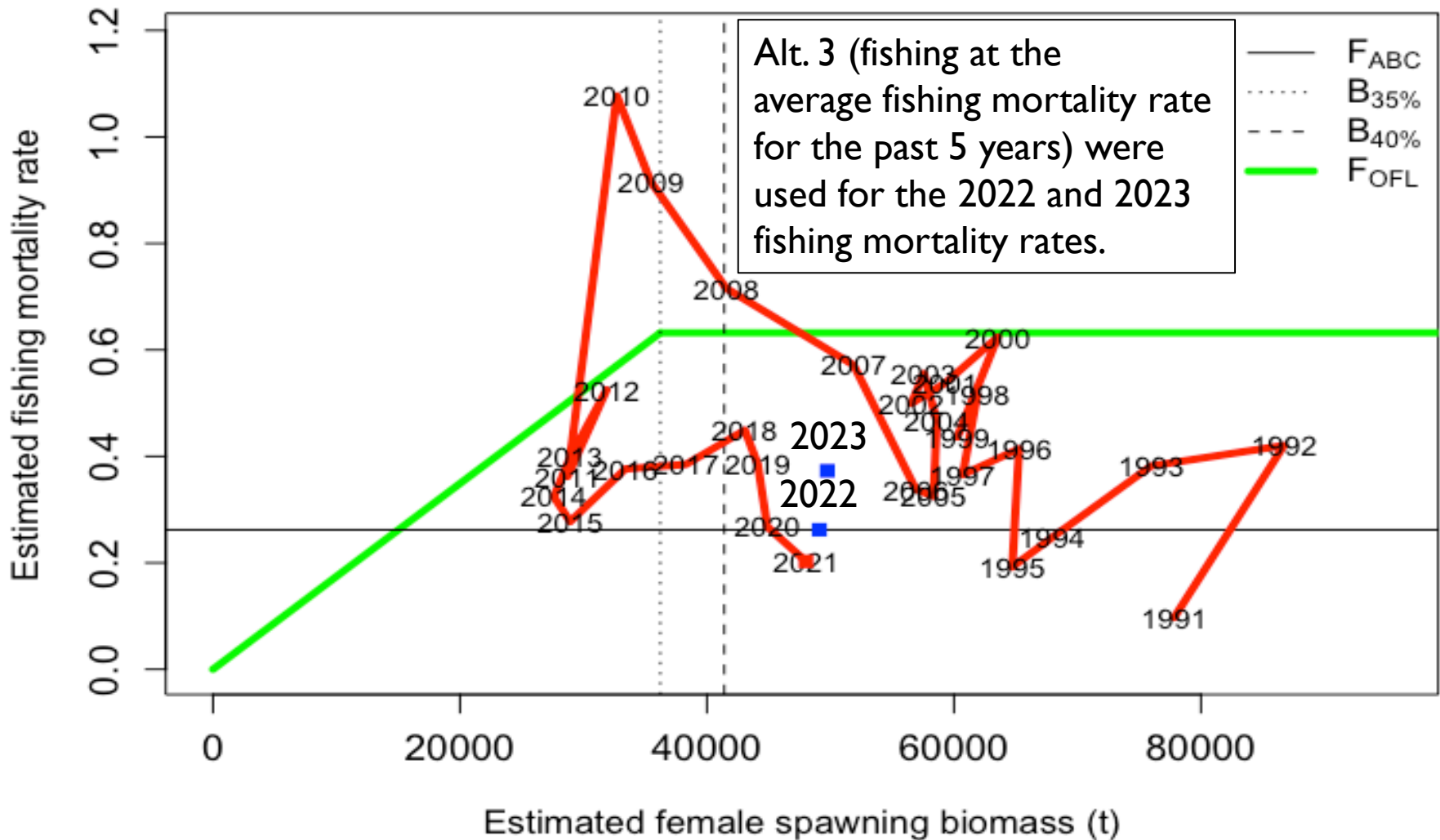
## Series

- Female spawning biomass
- Total biomass

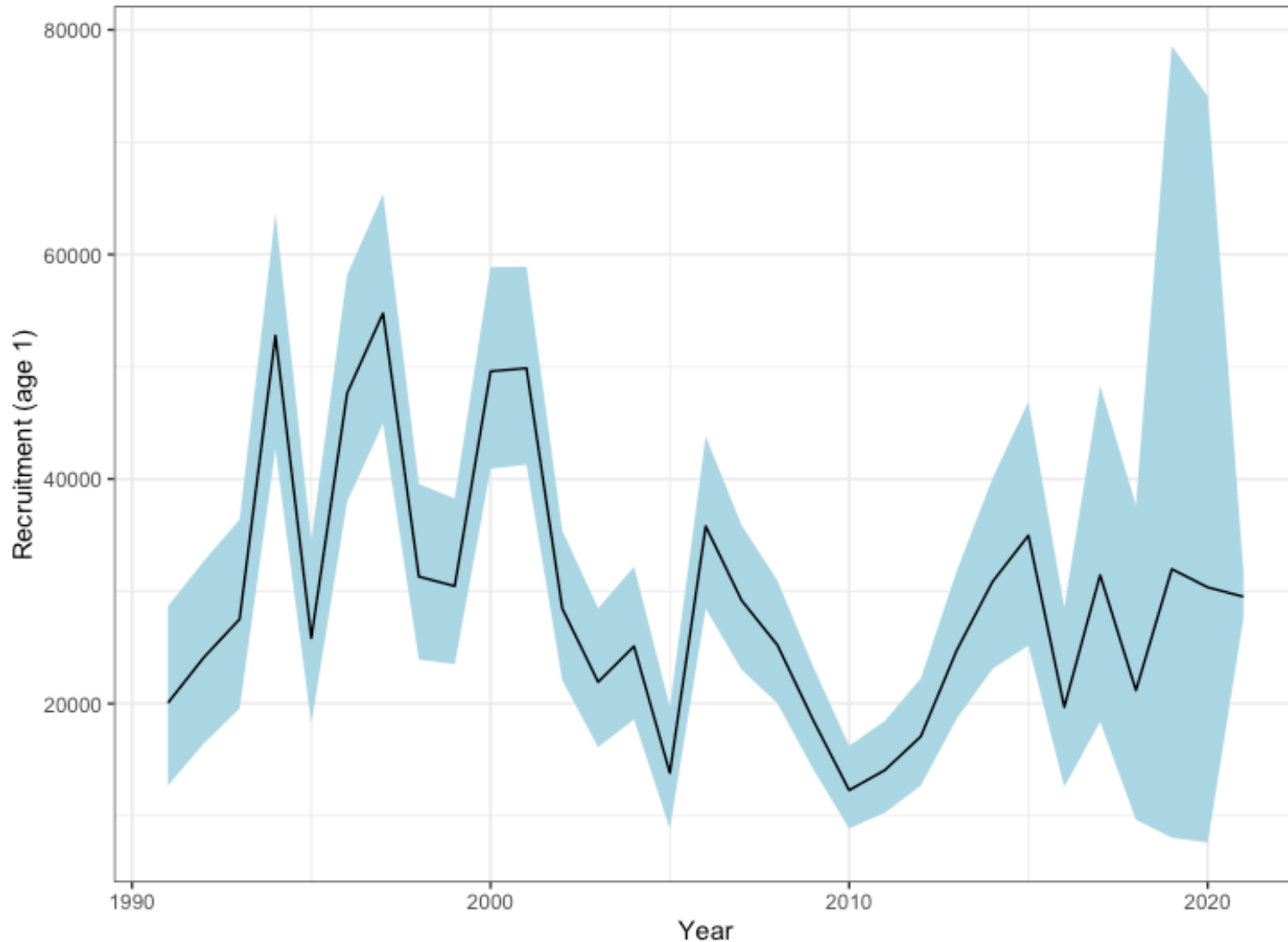




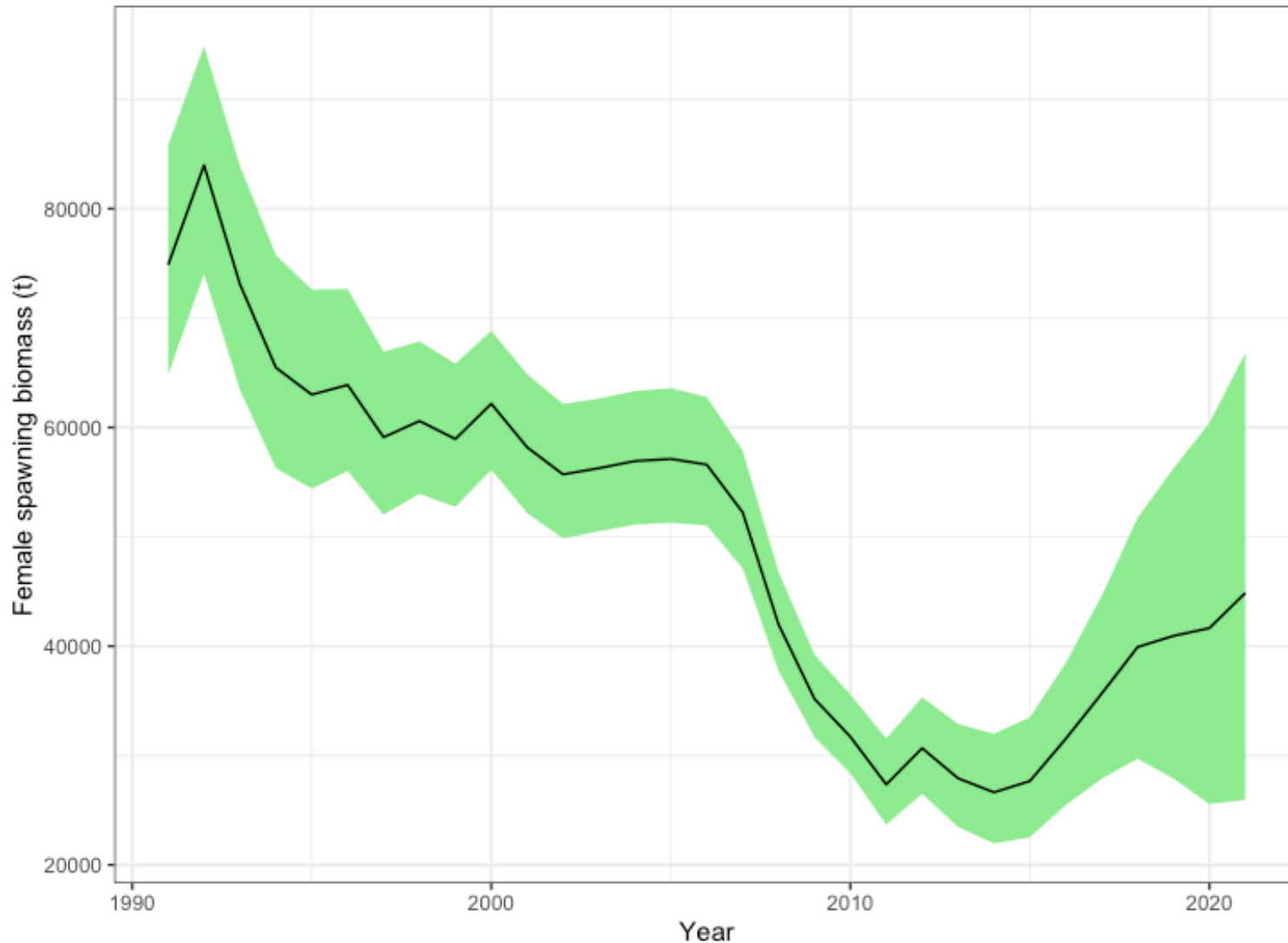
# MODEL 19.0 PHASE PLANE: FSB RELATIVE TO FISHING MORTALITY RATE & HARVEST CONTROL RULE



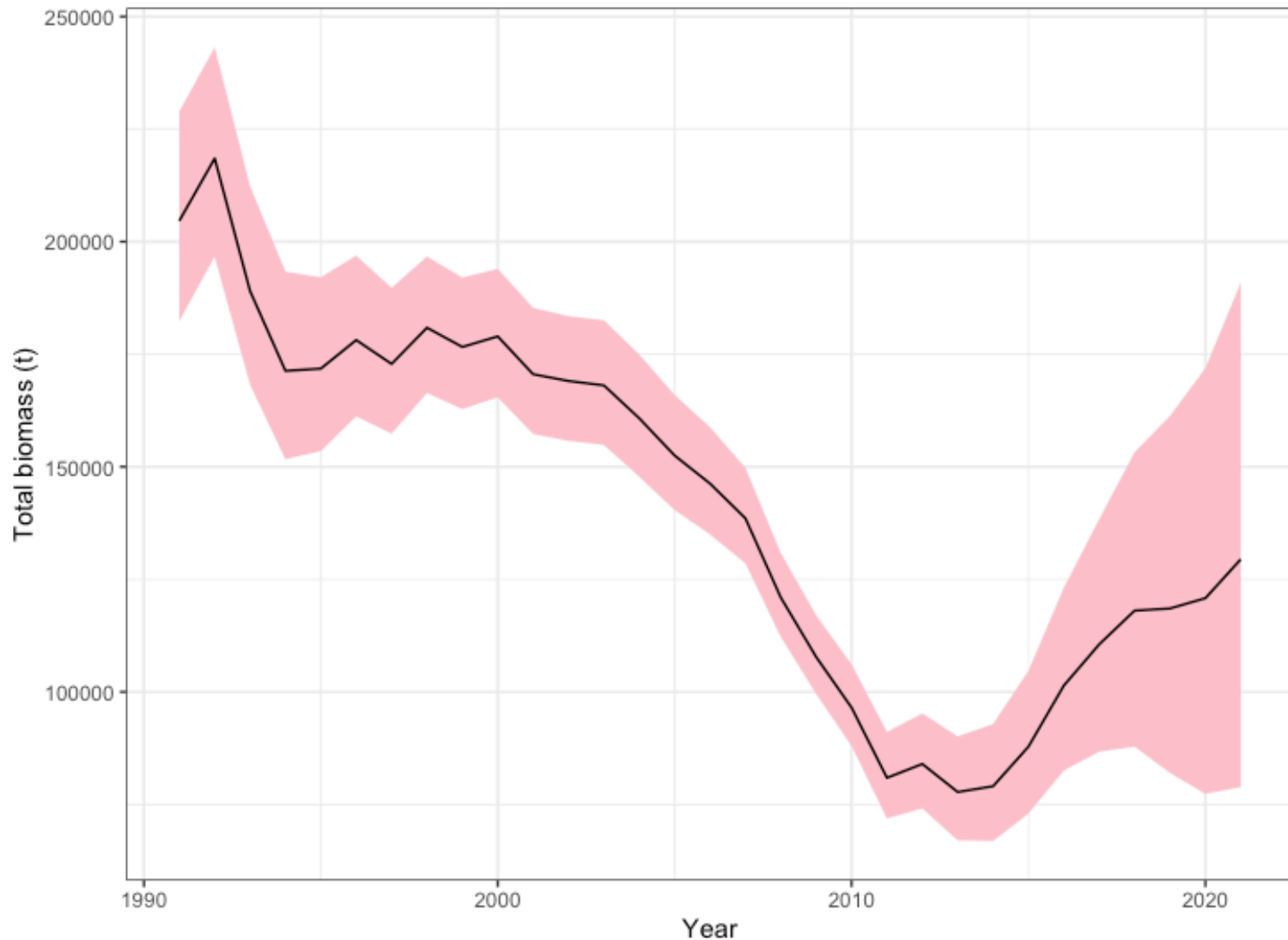
# MCMC ESTIMATES FOR MODEL 19.0 MEAN AND 95% CI FOR RECRUITMENT



# MCMC ESTIMATES FOR MODEL 19.0 MEAN AND 95% CI FOR FEMALE SPAWNING BIOMASS



# MCMC ESTIMATES FOR MODEL 19.0 MEAN AND 95% CI FOR TOTAL BIOMASS



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# Risk table assessment



# ASSESSMENT RELATED CONSIDERATIONS

## Pros:

- Age structured model incorporates more data sources than Tier 5.
- Three age structured models are relatively consistent.

## Cons:

- Lack of recent survey data.
- Poor fit to recent fishery length data.
- High Mohn's rho for Model 19.0 (improved using Model 19.0b).
- Model still under development.

Assessment considerations were rated as level 2 due to lack of survey data the relatively recent development of age-structured models (substantially increased concern).



# POPULATION DYNAMICS CONSIDERATIONS

- Although the long-term (1991-2018) survey biomass trend is downward, the trend between 2010-2018 was largely positive.
- The AFSC longline survey RPW shows a stable trend since approximately 2010, although the longline survey does not always track the AFSC bottom trawl survey in the Aleutian Islands.
- Fishery length frequencies also provide information on the relative size of fish encountered, and in 2021 the fish appeared to be smaller than average, but larger than fish encountered in 2020.

Population dynamics considerations were rated as level 2.



# ENVIRONMENTAL/ECOSYSTEM CONSIDERATIONS

- Persistent higher temperatures are considered a negative indicator for Pacific cod.
- The observed body condition of Pacific cod in the AI bottom trawl survey has been lower than the survey mean from 2012–2018 in the entire Aleutians.
- Taken together, the cooler temperatures and seabird data suggest that conditions were potentially better in 2021 for Pacific cod than in the past couple years.

Environmental/ecosystem considerations were rated as level 2 (some indicators showing an adverse signal relevant to the stock but the pattern is not consistent across all indicators).





# FISHERY PERFORMANCE CONSIDERATIONS

- Trends in CPUE were downward.
- However, other factors may have resulted in lack of fishing effort.
- Reports indicate poor fishing.

Fishery performance considerations were rated as level 2.



# RISK TABLE

Assessment consideration	Population dynamics	Environmental ecosystem	Fishery performance	Overall
Level 2: Substantially increased concern	Level 1: Normal	Level 2: Substantially increased concern	Level 2: Substantially increased concern	Level 2: Substantially increased concern

Overall, the risk table score is level 2.



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# Summary tables



# COMPARISON OF REFERENCE POINTS USING THE BASE MODEL 19.0, 19.0A, AND 19.0B.

Quantity	Model 19.0, Base model		Model 19.0a		Model 19.0b	
	2022	2023	2022	2023	2022	2023
<i>M</i> (natural mortality rate)	0.34	0.34	0.34	0.34	0.40	0.40
Tier	3b	3b	3b	3b	3b	3b
Projected total (age 1+) biomass (t)	143,502 t	147,565 t	143,501	147,565	179,370	182,203
Projected female spawning biomass (t)	49,099 t	49,749 t	37,371	38,356	59,722	58,993
$B_{100\%}$	103,498 t	103,498 t	88,745	88,745	100,508	100,508
$B_{40\%}$	41,399 t	41,399 t	35,498	35,498	40,203	40,203
$B_{35\%}$	36,224 t	36,224 t	31,060	31,060	35,177	35,177
$F_{OFL}$	0.632	0.632	0.464	0.464	0.892	0.892
$maxF_{ABC}$	0.493	0.493	0.376	0.376	0.679	0.679
$F_{ABC}$	0.493	0.493	0.376	0.376	0.679	0.679
$OFL$	34,674 t	35,781 t	27,052	27,919	51,913	52,900
$maxABC$	28,451 t	29,363 t	22,617	23,343	42,402	43,211
$ABC$	28,451 t	29,363 t	22,617	23,343	42,402	43,211
Status	2020	2021	2020	2021	2020	2021
Overfishing	No	n/a	No	n/a	No	n/a
Overfished	n/a	No	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No	n/a	No



# TIER 5 SUMMARY TABLE FOR ALEUTIAN ISLANDS PACIFIC COD

Quantity	As estimated or <i>specified</i> <i>last year for:</i>		As estimated or <i>recommended</i> <i>this year for:</i>	
	2021	2022	2022	2023
$M$ (natural mortality rate)	0.34	0.34	0.34	0.34
Tier	5	5	5	5
Biomass (t)	80,700	80,700	80,700	80,700
$F_{OFL}$	0.34	0.34	0.34	0.34
$maxF_{ABC}$	0.255	0.255	0.255	0.255
$F_{ABC}$	0.255	0.255	0.255	0.255
$OFL$	27,400	27,400	27,400	27,400
$maxABC$	20,600	20,600	20,600	20,600
$ABC$	20,600	20,600	20,600	20,600
Status	2019	2020	2020	2021
Overfishing	No	n/a	No	n/a



# TIER 3 SUMMARY TABLE (MODEL 19.0) FOR ALEUTIAN ISLANDS PACIFIC COD

Quantity	As estimated or <i>specified</i> <i>last year for:</i>		As estimated or <i>recommended</i> <i>this year for:</i>	
	2021	2022	2022	2023
$M$ (natural mortality rate)	0.34	0.34	0.34	0.34
Tier	5	5	3a	3b
Projected total (age 1+) biomass (t)	80,700	80,700	143,502 t	147,565 t
Projected female spawning biomass (t)	-	-	49,099 t	49,749 t
$B_{100\%}$	-	-	103,498 t	103,498 t
$B_{40\%}$	-	-	41,399 t	41,399 t
$B_{35\%}$	-	-	36,224 t	36,224 t
$F_{OFL}$	-	-	0.632	0.632
$maxF_{ABC}$	-	-	0.493	0.493
$F_{ABC}$	-	-	0.493	0.493
$OFL$	27,400	27,400	34,674 t	35,781 t
$maxABC$	20,600	20,600	28,451 t	29,363 t
$ABC$	20,600	20,600	20,600 t	20,600 t
Status	2019	2020	2020	2021
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

Note: Last year's assessment incorporated a Tier 5 model. Projections were based on annual catches of 13,351 t for 2021 and the mean of the past 5 years, 2017-2021 for 2022 (16,484 t).

For 2022 we recommend the Tier 5 reference points.  
 Tier 5 is more conservative than Tier 3.  
 Also elevated Risk Table concerns.



# ALLOCATION WITH RESPECT TO THE STATE FISHERY

Starting in 2006, the State of Alaska managed a fishery for AI Pacific cod inside State waters, with a guideline harvest level (GHL) equal to 3% of the BSAI ABC.

Beginning with the 2014 fishery, two separate GHL fisheries were established, one for the AI and one for the EBS.

This table shows the formulas used to set the State GHL for the AI.

Year	Formula
2014	$0.03 * (\text{EBS ABC} + \text{AI ABC})$
2015	$0.03 * (\text{EBS ABC} + \text{AI ABC})$
2016	$0.27 * \text{AI ABC}$
2017	$0.27 * \text{AI ABC}$
2018	$0.27 * \text{AI ABC}$
2019	$0.31 * \text{AI ABC}$
2020	$0.35 * \text{AI ABC}$ or 6,804 t, whichever is less
2021	$0.39 * \text{AI ABC}$ or 6,804 t, whichever is less



# AREA 543 PROPORTION

- Current Steller sea lion protection measures require an estimate of the proportion of the AI Pacific cod stock residing in Area 543.
- This will be used to set the harvest limit in 543 after subtraction of the State GHL from the overall AI ABC.
- In 2020 the biomass proportion in Area 543 was estimated by using the most recent estimate from Model 13.4 (15.7%). This was the percentage adopted last year for setting 2021 specifications, and is recommended for 2022 given the lack of new survey data.
- 15.7% of the Tier 5 ABC is 3234.2 t.





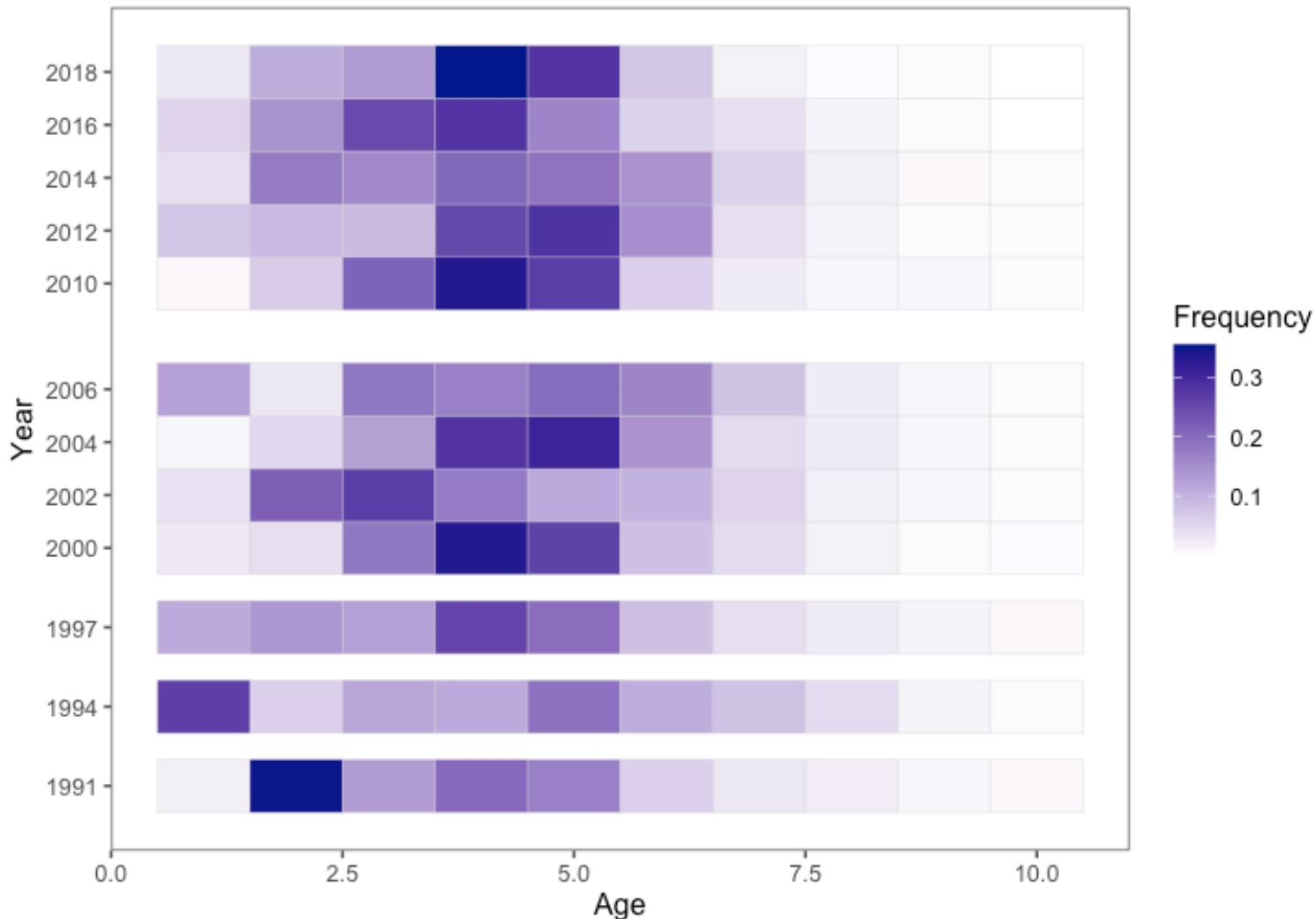
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# Questions?



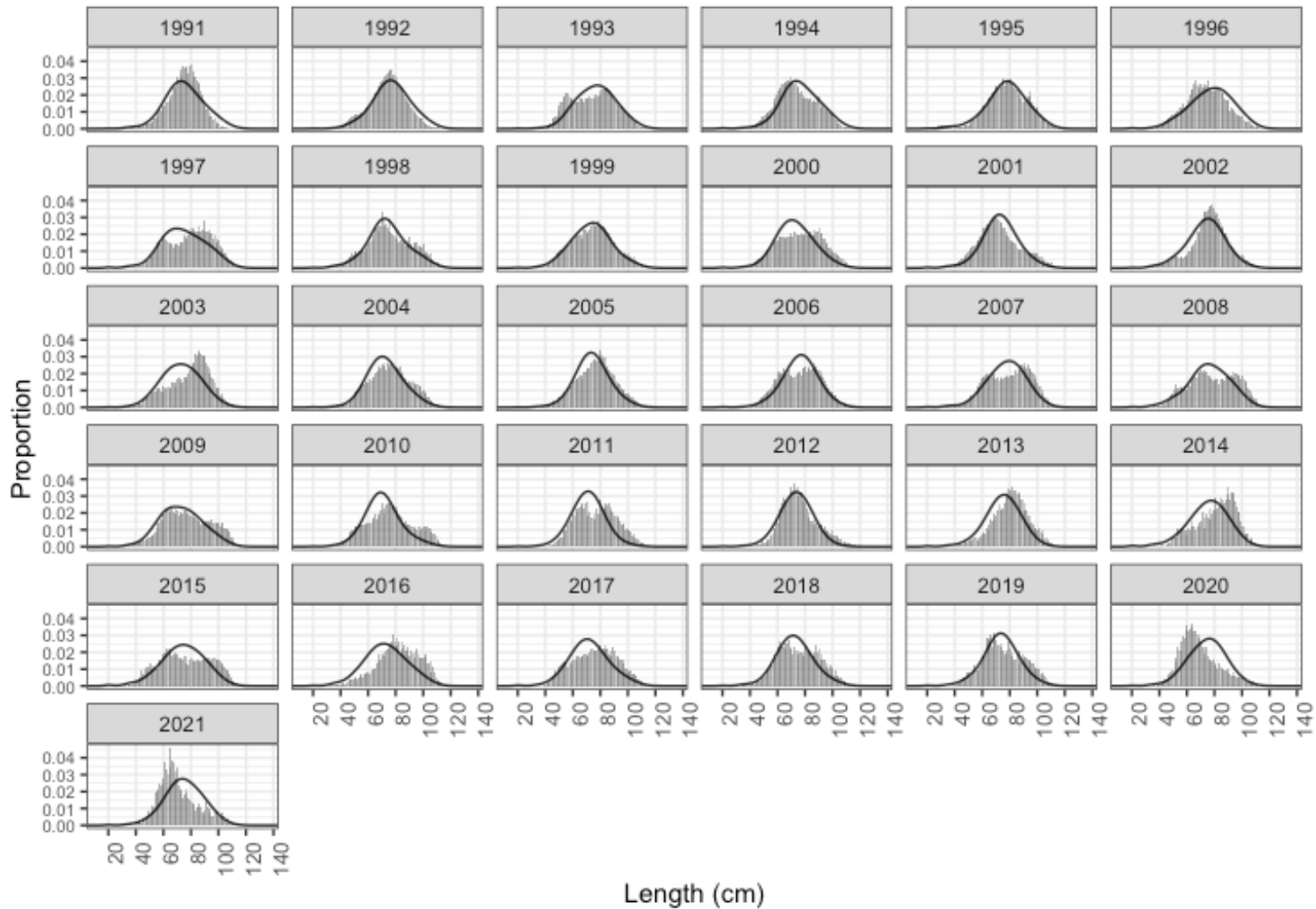
# AGE COMPOSITION FROM THE NMFS ALEUTIAN ISLANDS SURVEYS, 1991-2018.

AI cod survey ages

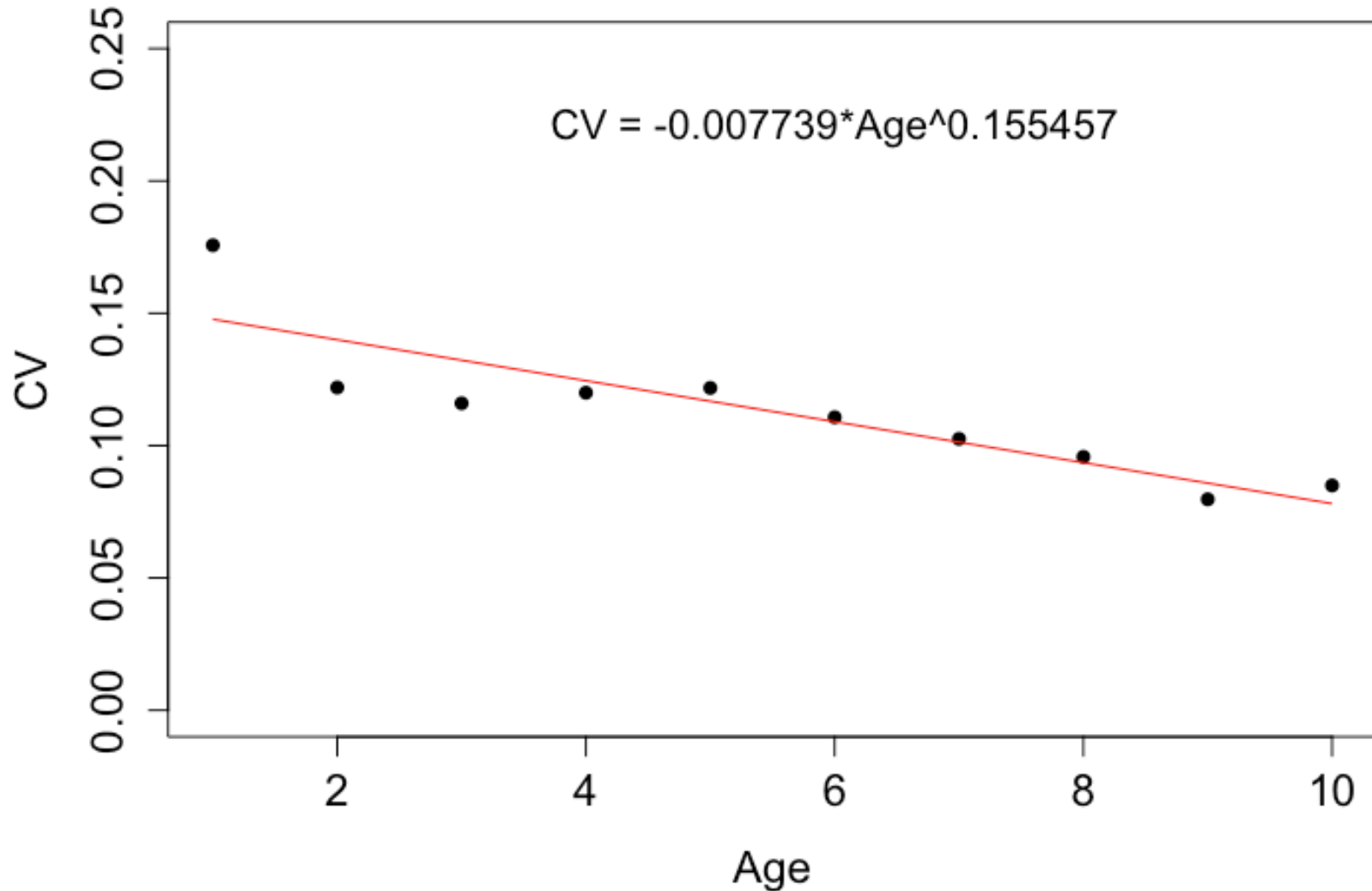


# MODEL 19.0 FIT TO FISHERY LENGTH COMPOSITIONS

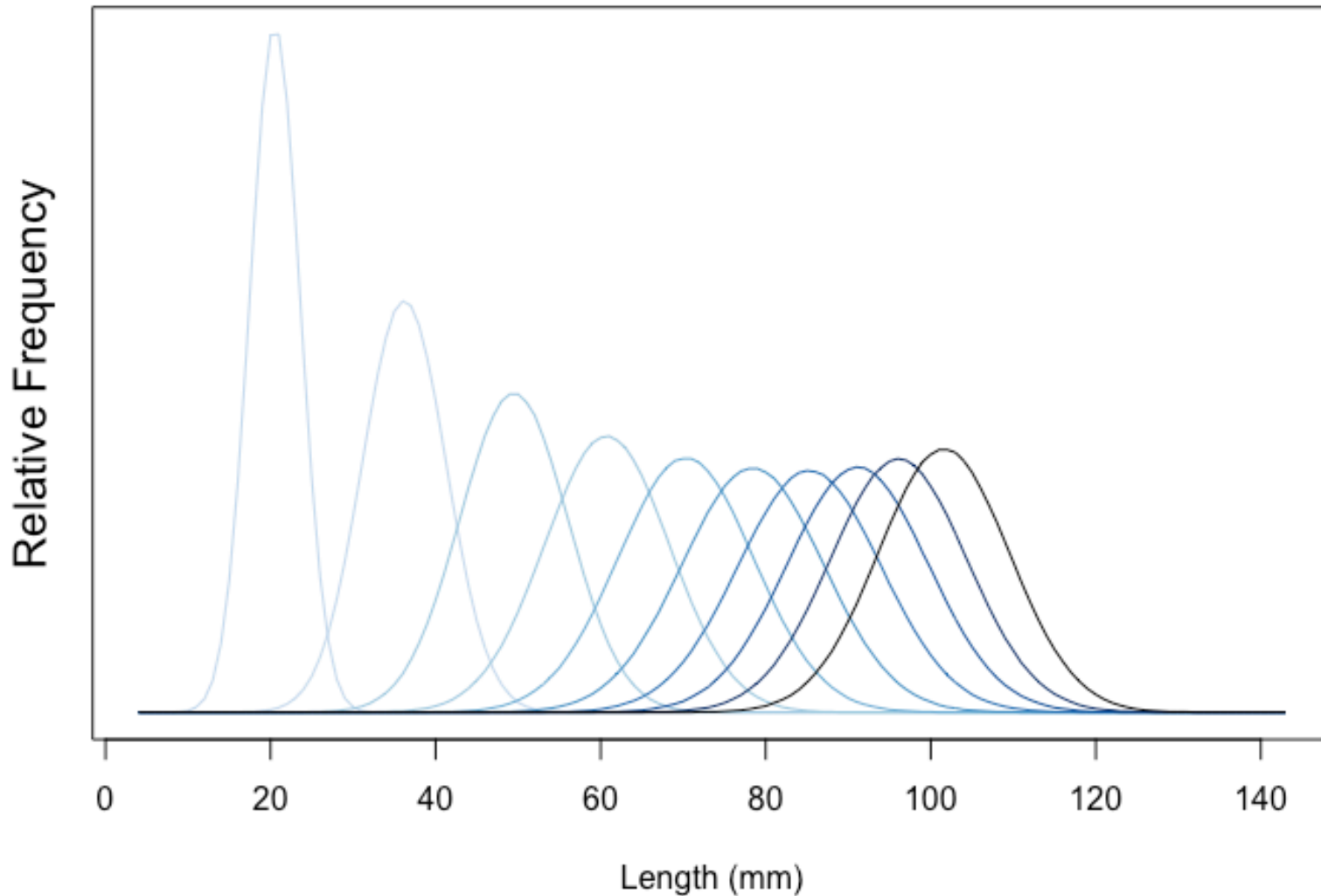
Fit to Fishery Length Compositions, Model 19.0



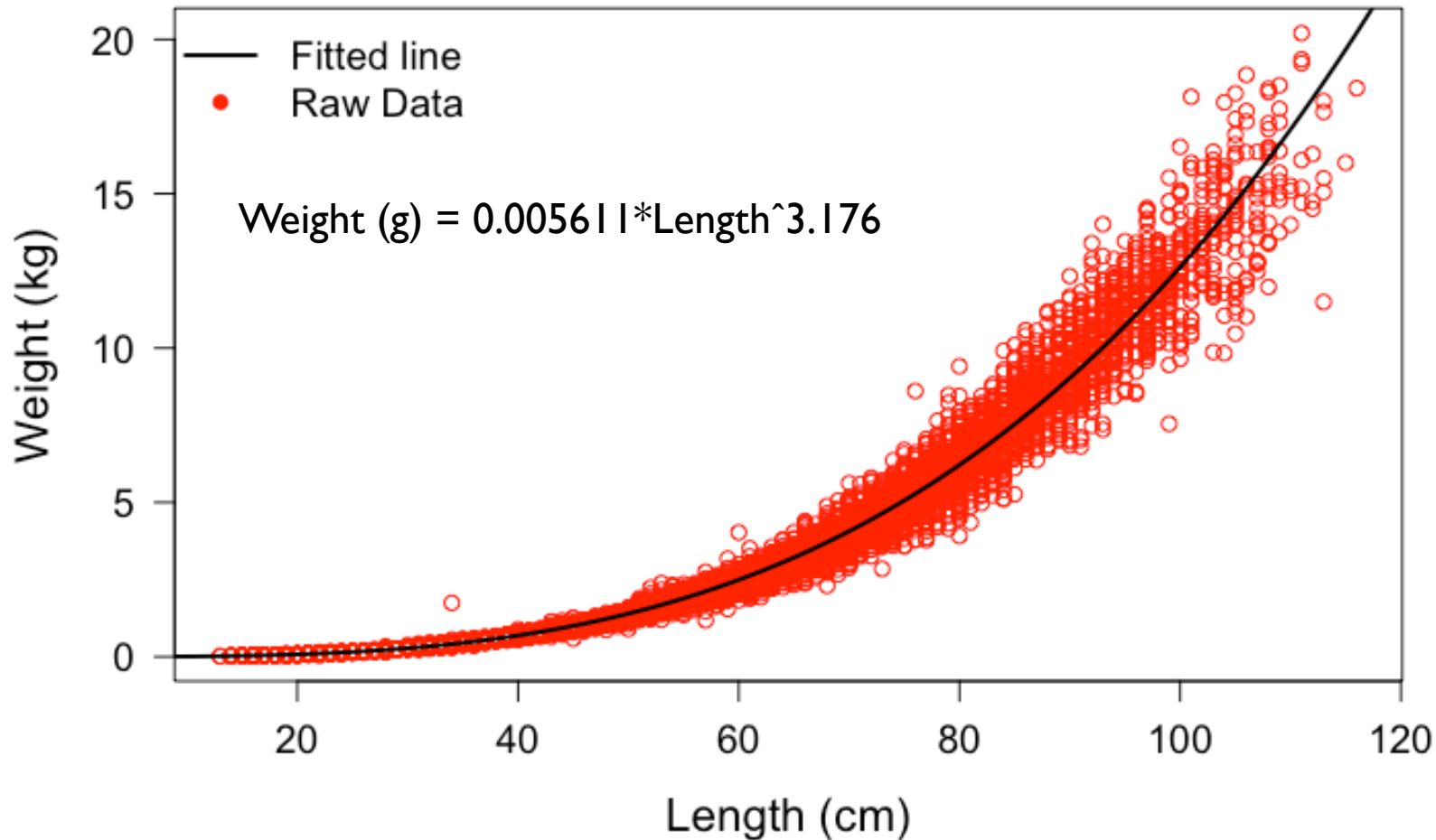
# COEFFICIENT OF VARIATION (CV) FITTED TO AGE (RED LINE), BASED ON RAW DATA (BLACK POINTS)



# LENGTH AGE CONVERSION MATRIX FOR ALEUTIAN ISLANDS PACIFIC COD, AGES 110+



# LENGTH-WEIGHT RELATIONSHIP FOR ALEUTIAN ISLANDS PACIFIC COD



# ESTIMATED NUMBERS AT AGE OF ALEUTIAN ISLANDS COD (X 1,000), BASED ON MODEL 19.0

Estimated numbers at age (x 1,000)

