Gulf of Alaska Pacific cod

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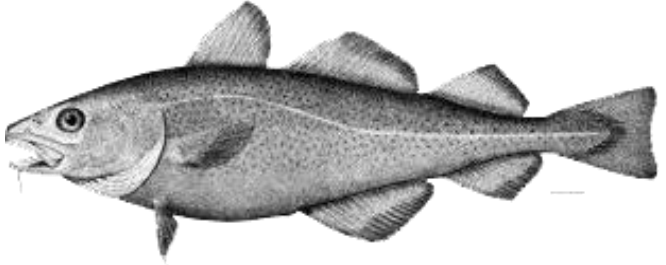
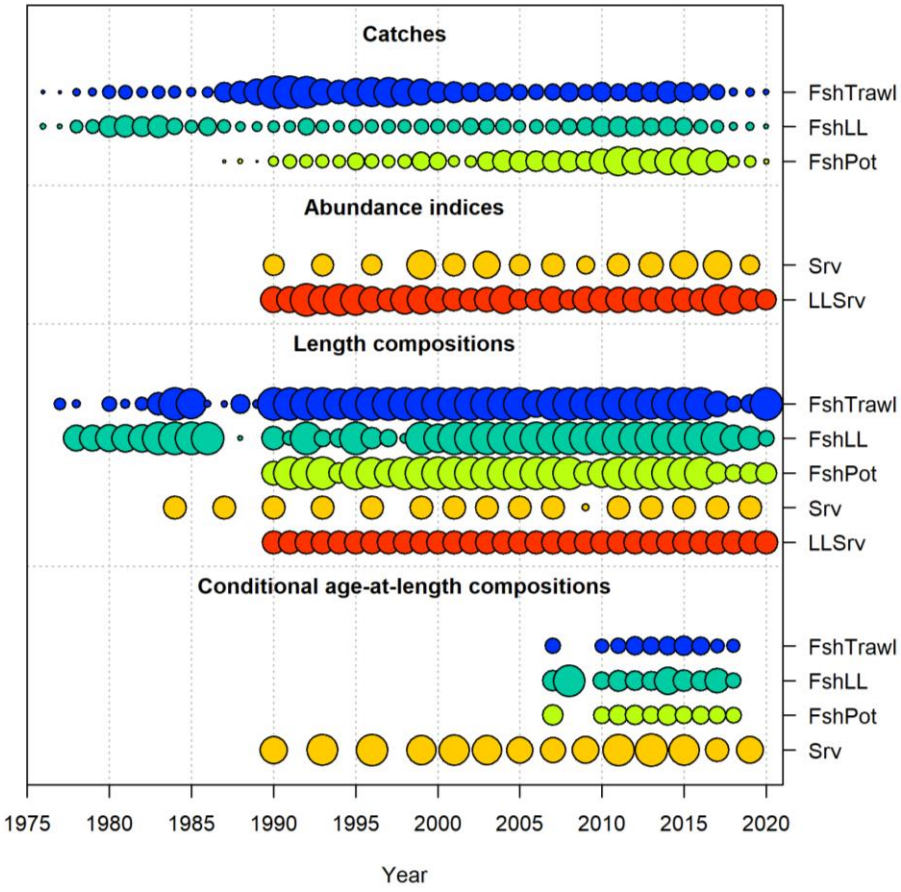
September 2021

Last year's model



- Fisheries – Longline, Pot, Trawl
- Indices – AFSC bottom trawl and AFSC longline surveys
- Length composition
  - All fisheries and indices
- Age data
  - 2007+ survey and Fishery conditional age-at-length



Last year's accepted model features

- 1-10+ age bins
- 1-117+cm length bins

Key estimated parameters:

- M lognormal prior, mean -0.81, CV 0.41
- Survey catchability uninformative prior
- M anomaly for the 2014-2016 period

Stock recruitment relationship: Beverton-Holt

- σ_R = 0.44, steepness = 1.0

Growth

- Three-parameter von Bertalanffy growth (informative priors based on 2007-2018 survey size at age data

Selectivity: length-based double normal

- Different periods for bottom trawl survey
- Longline and trawl
  - pre-1990 annually varying
  - blocks for post-1990

Longline survey catchability

- scaled to CFSR temperatures for 0-10 cm Pacific cod mean depth

Model configurations

	Environmental links			Data re-weighting	M-block to 2020
	Larval index	Growth	M	Recruits	
Base 19.1					
21.1a					
21.1b					
21.1c					
21.1d					
21.1e					
21.1g					
21.5a					
21.5c					

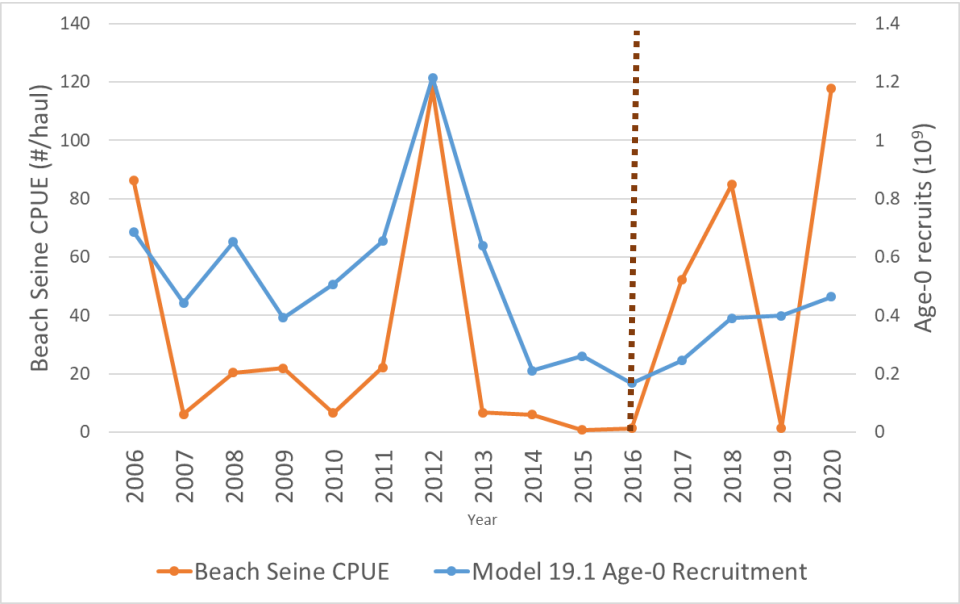
Model configurations

	Larval index	Environmental links: Growth	Environmental links: M	Environmental links: Recruits	Data re-weighting	M-block to 2020
Base 19.1						
21.1a	■					
21.1b	■	■				
21.1c	■		■			
21.1d	■			■		
21.1e	■	■	■	■		
21.1g	■	■	■	■	■	
21.5a	■	■	■	■		■
21.5c	■	■	■	■	■	■

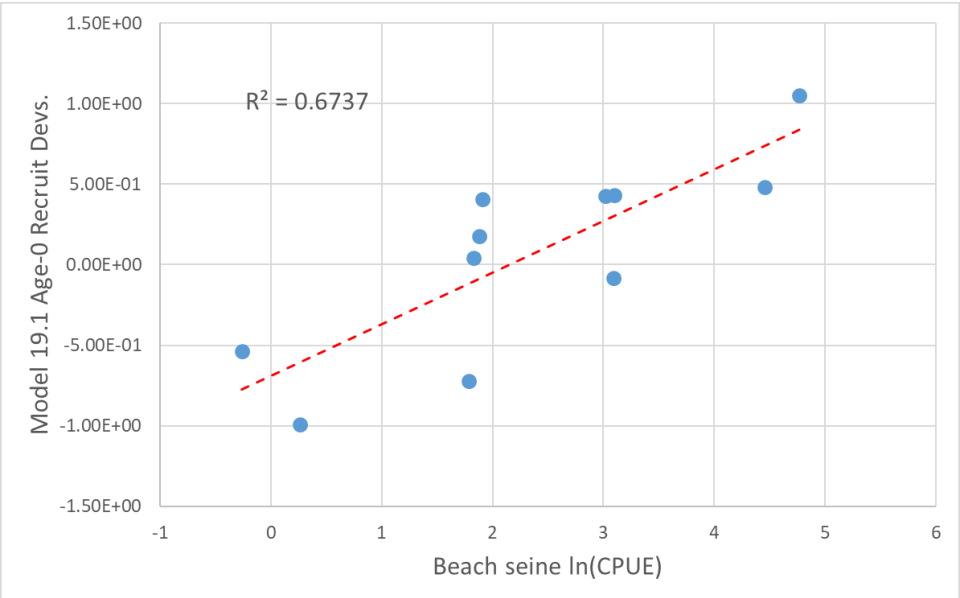
Age-0 Pacific cod beach seine index

Litzow, et al. (In Review) Predicting year class strength for climate-stressed gadid stocks in the Gulf of Alaska. Fisheries Research

2006-2020 Model 19.1
Recruitment vs Beach Seine CPUE

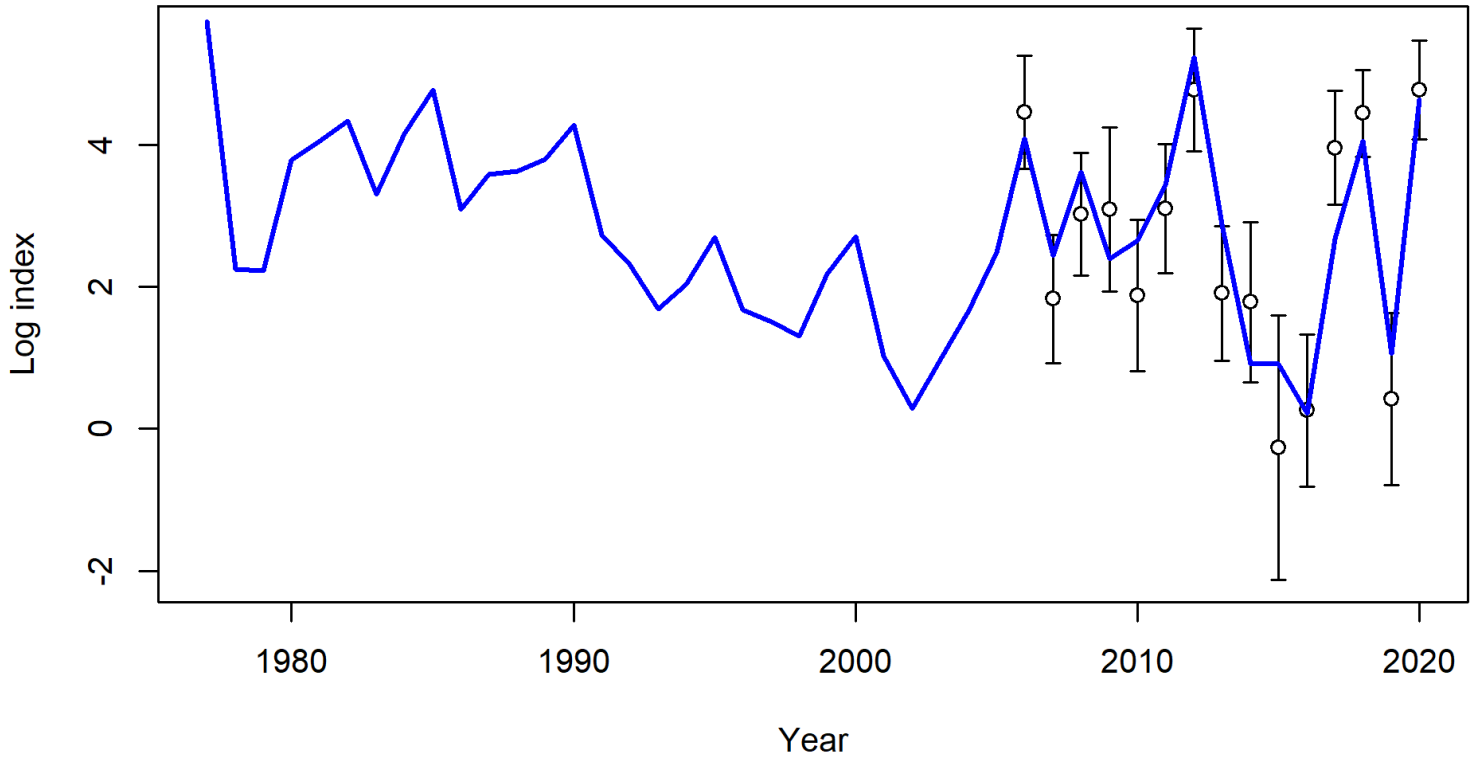


2006-2016 Model 19.1
Recruitment Devs. vs ln(Beach Seine CPUE)



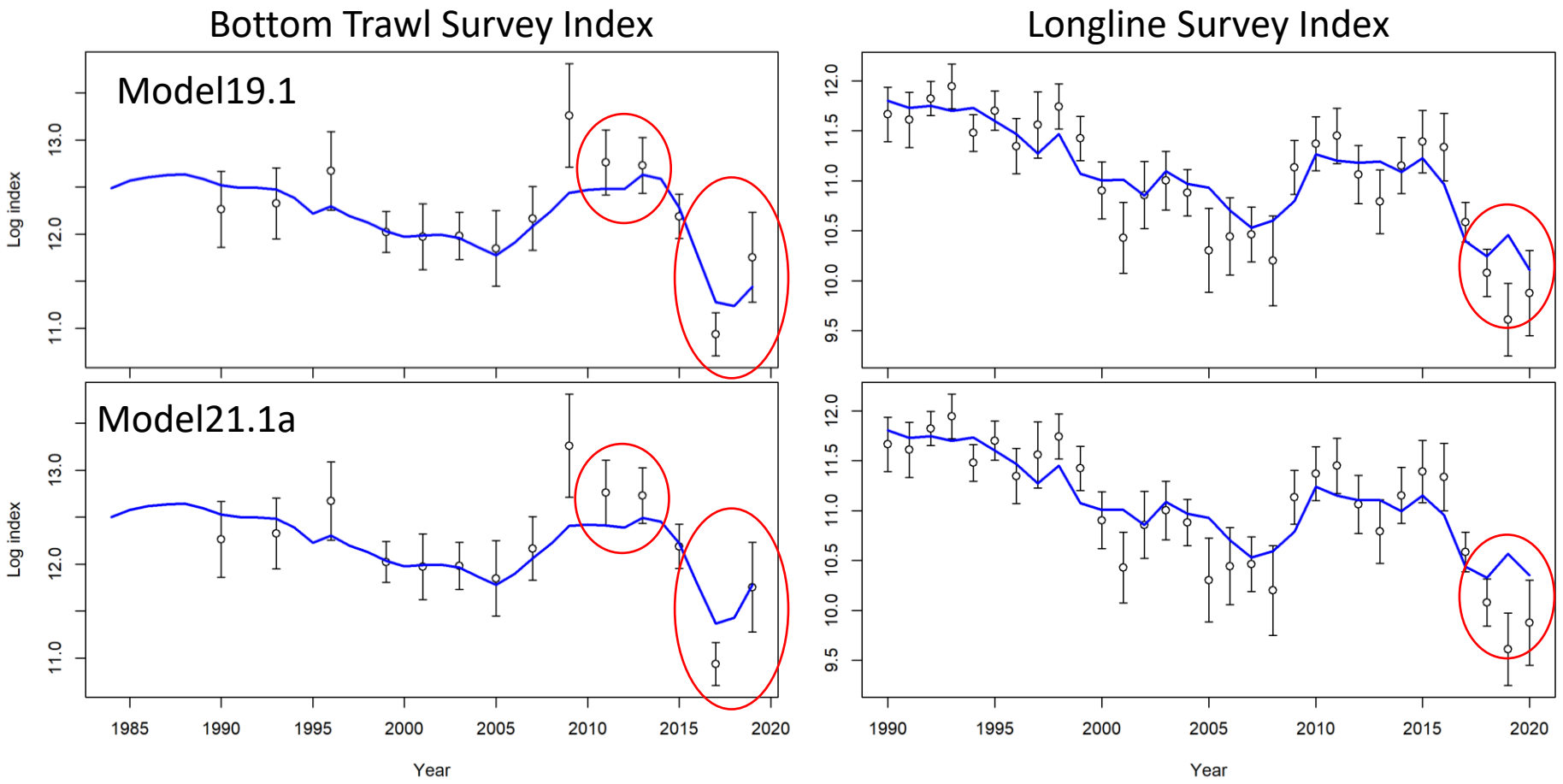
Model 21.1a vs. Model 19.1

- Addition of Age-0 beach seine index
  - Good fit to beach seine index



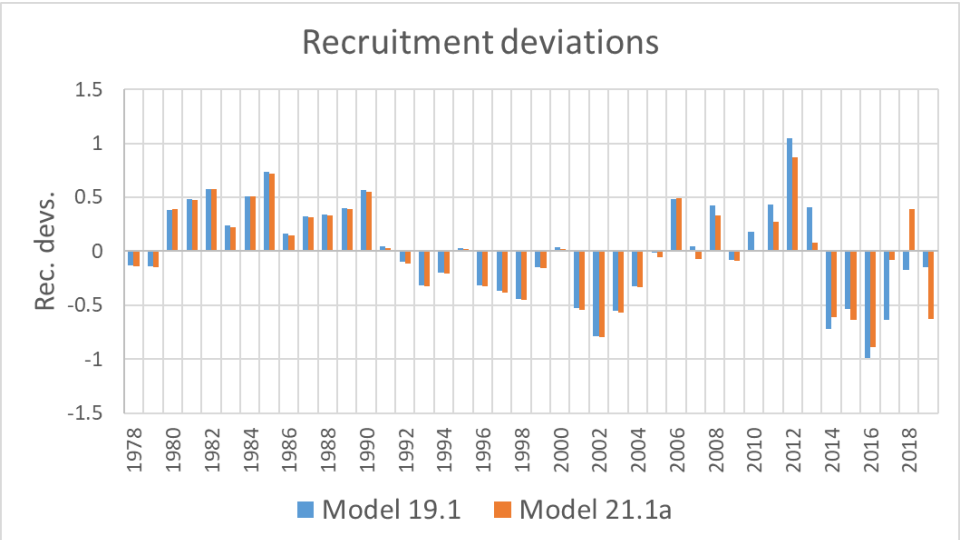
Model 21.1a vs. Model 19.1

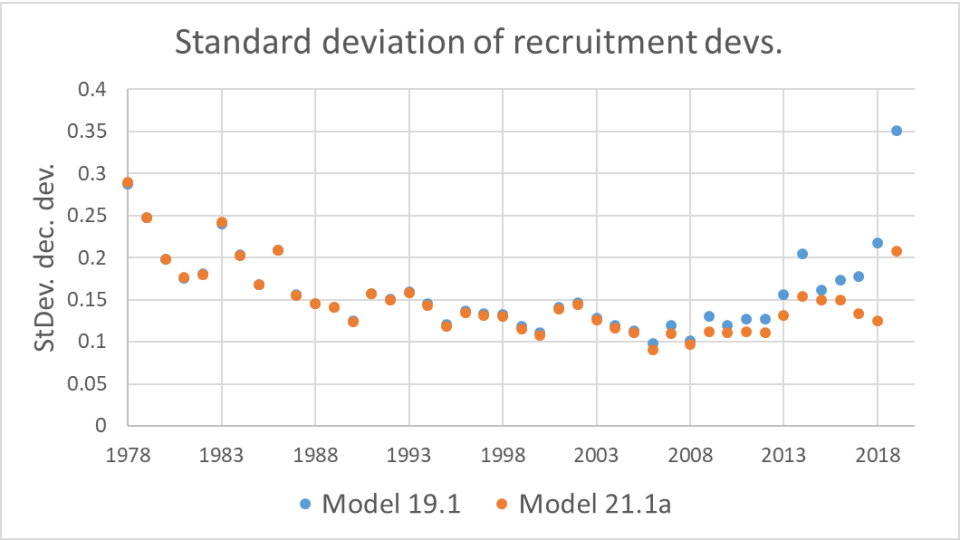
- Addition of Age-0 beach seine index
  - Good fit to beach seine index
  - Poorer fit to all other survey indices



Model 21.1a vs. Model 19.1

- Addition of Age-0 beach seine index
  - Good fit to beach seine index
  - Poorer fit to all other survey indices
  - Reduced rec. devs. and variance of rec. devs.
  - Reduced variance on reference points
  - Reduction in heatwave block M from 0.82 to 0.75
  - Mixed results for composition fits
  - Retrospective Rho's and RMSE remain close to the same





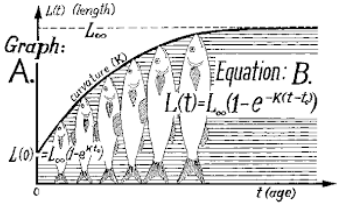
Model configurations

	Larval index	Environmental links: Growth	Environmental links: M	Environmental links: Recruits	Data re-weighting	M-block to 2020
Base 19.1						
21.1a	■					
21.1b	■	■				
21.1c	■		■			
21.1d	■			■		
21.1e	■	■	■	■		
21.1g	■	■	■	■	■	
21.5a	■	■	■	■		■
21.5c	■	■	■	■	■	■

Environmental links

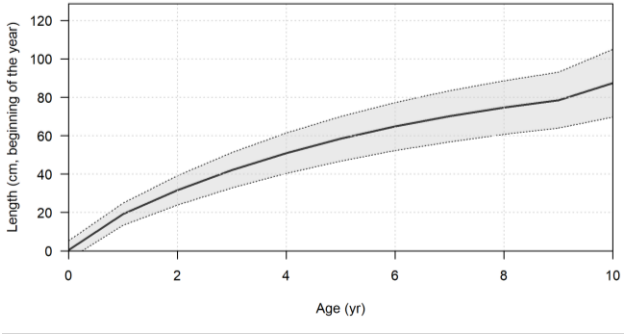
- Growth
  - June CFSR temps for 0-20 cm cod
  - Larval growth index based on June CFSR temps
- Mortality
  - Annual heatwave index
- Recruitment
  - Spawning heatwave index

Growth



- Model 19.1 standard Stock Synthesis von Bertalanfy

$$L_a = L_2 - (L_2 - L_1)e^{-ak}$$



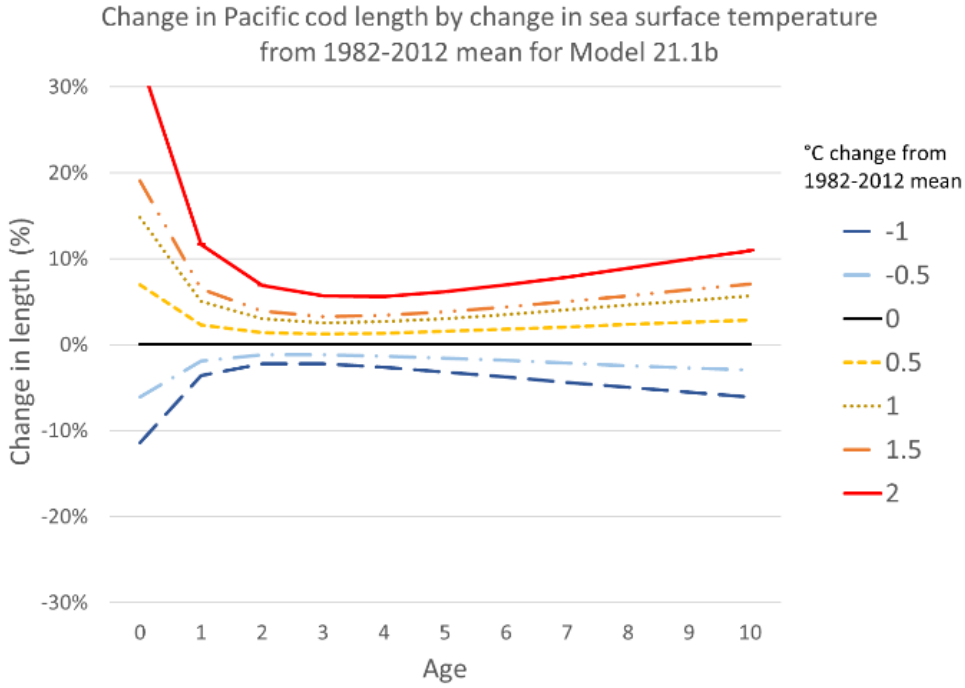
- June temp. anomaly-linked von Bertalanfy with Laurel *et al.* (2015) larval growth index

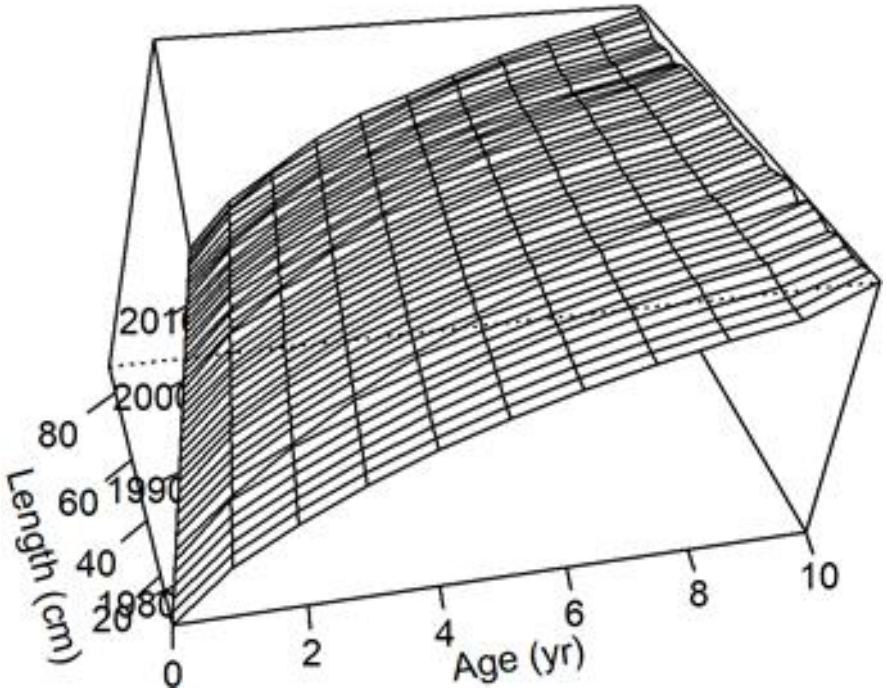
$$L_{ay} = L_{2y} - (L_{2y} - L_{1y})e^{-ak\left(e^{\varphi f_{Jy}}\right)}$$

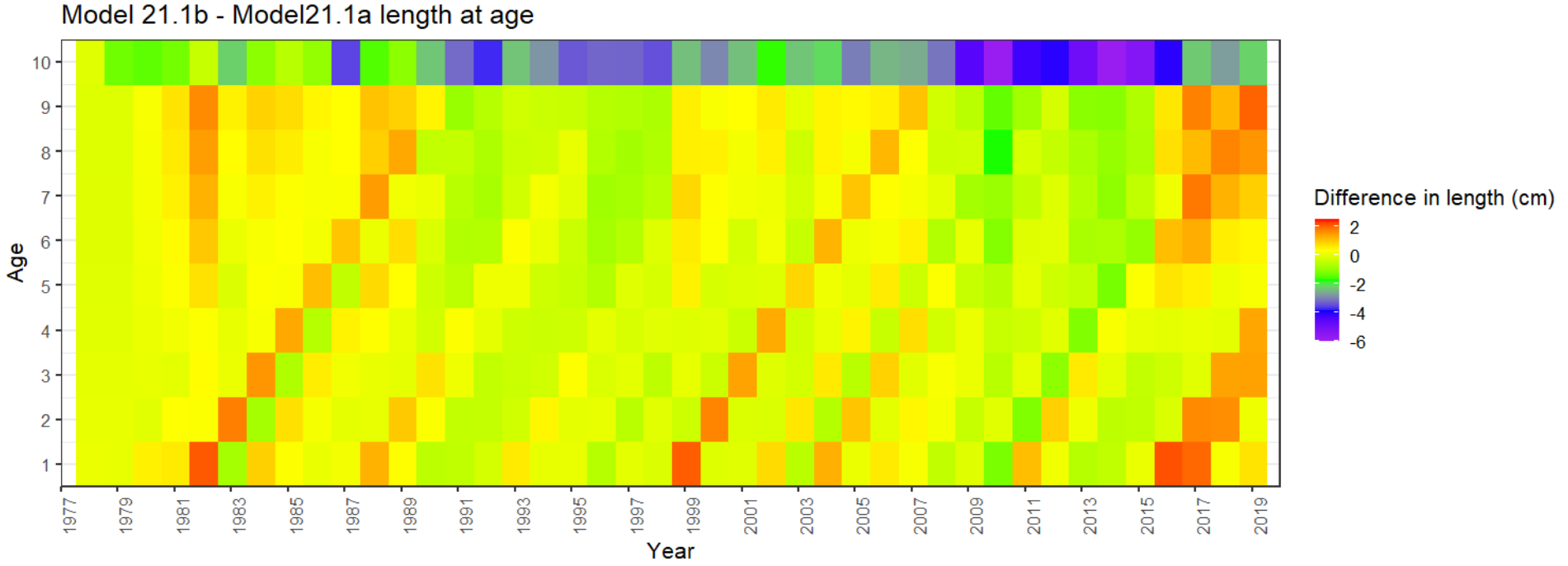
$$L_{1y} = \bar{L}_1 e^{\left(\gamma \frac{e^{\left(0.2494+0.3216\left(\bar{t}+f_{Jy}\right)-0.0069\left(\bar{t}+f_{Jy}\right)^2-0.0004\left(\bar{t}+f_{Jy}\right)^3\right)}}{e^{\left(0.2494+0.3216(\bar{t})-0.0069(\bar{t})^2-0.0004(\bar{t})^3\right)}}\right)}$$

$$L_{2y} = \bar{L}_2 e^{\upsilon f_{Jy}}$$

f_{Jy} = June temperature anomaly; $\bar{t}$ = 1982-2012 mean temp.


Change in Pacific cod length by change in sea surface temperature from 1982-2012 mean for Model 21.1b
30%
20%
10%
0%
-10%
-20%
-30%
Change in length (%)
0 1 2 3 4 5 6 7 8 9 10
Age
°C change from 1982-2012 mean
-1
-0.5
0
0.5
1
1.5
2


Length (cm)
80
60
40
20
0
2
4
6
8
10
Age (yr)


Model 21.1b - Model21.1a length at age
Age
10
9
8
7
6
5
4
3
2
1
1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015 2017 2019
Year
Difference in length (cm)
2
0
-2
-4
-6

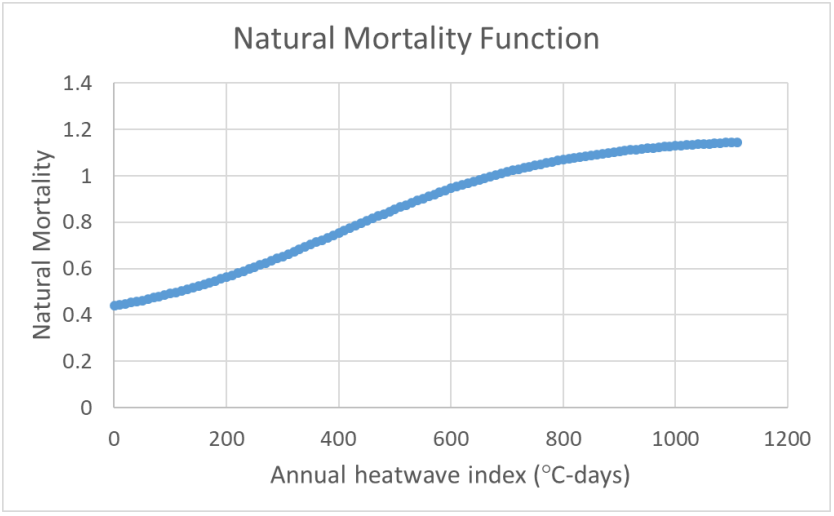
Natural Mortality

- Model 19.1, 21.1a, 21.1b,and 21.1d: separate block for 2014-2016
- Model 21.1c, 21.1e, and 21.1g: annual heatwave linked natural mortality with asymptote

$$\mathrm{M_y} = \widehat{M} + \boldsymbol{\eta} l_y$$

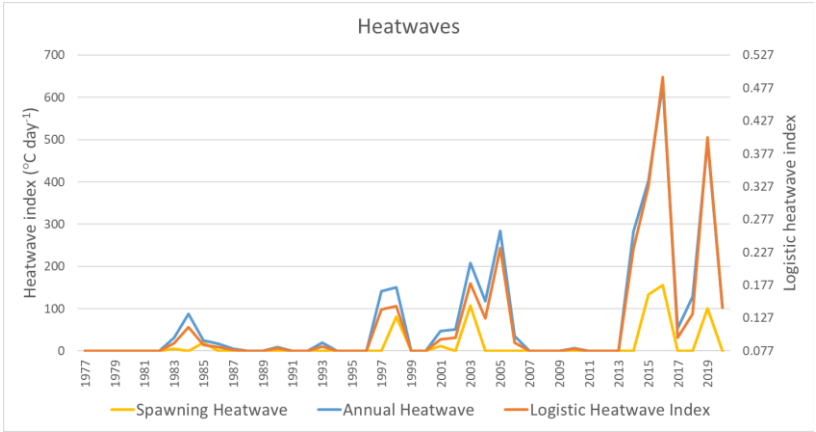
$$l_y = \lambda / \left(1 + e^{-\varsigma(I_{Ay} - \psi)}\right)$$ Logistic function for asymptotic M

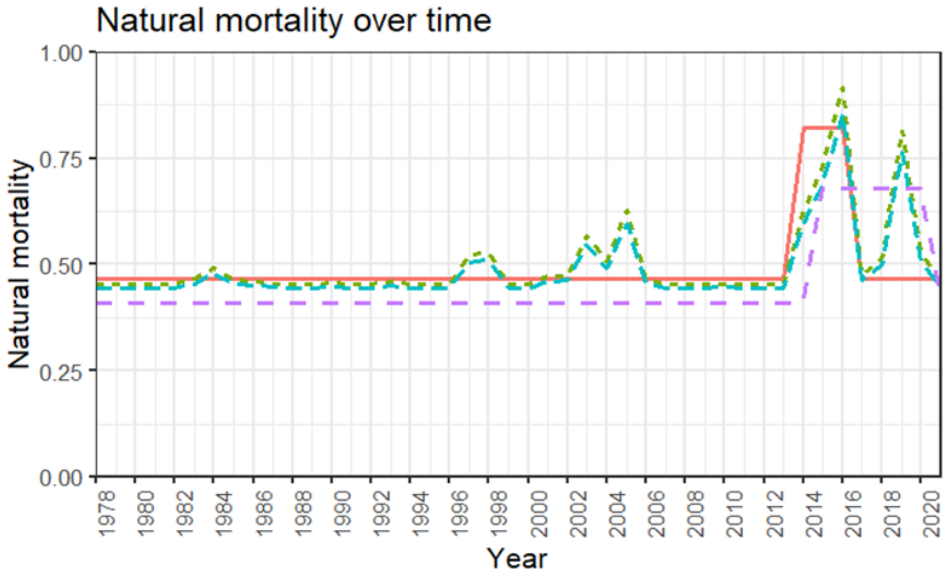
  - Logistic function fit iteratively
    - λ = 0.65
    - ς = 0.05
    - ψ = 400



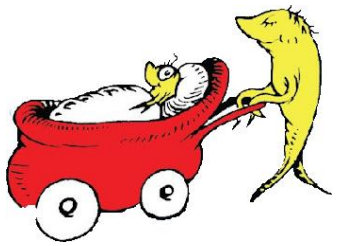
Natural Mortality

- Model 21.5 series
  - Iteratively fit annual natural mortality
  - Best fit model with lowest objective value had a separate block for 2015-2020





Recruitment



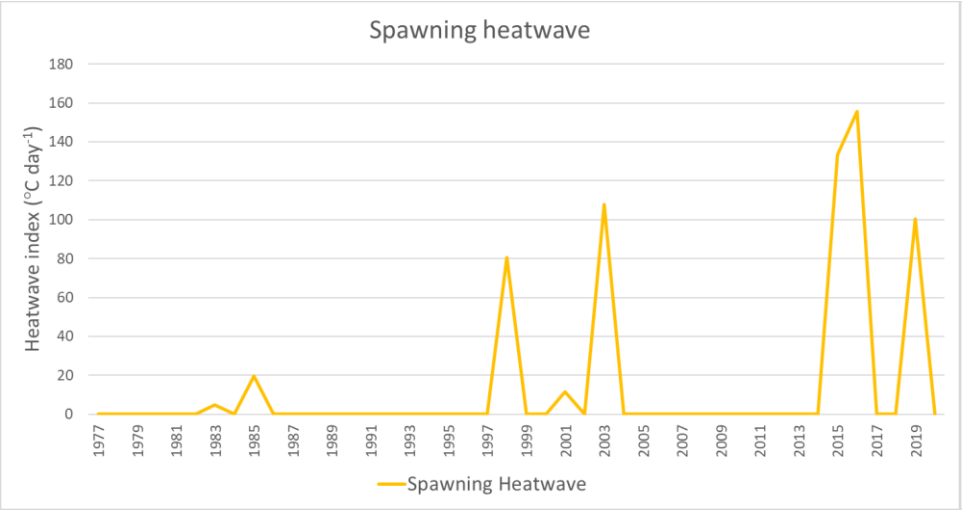
- Standard Tier 3 recruitment

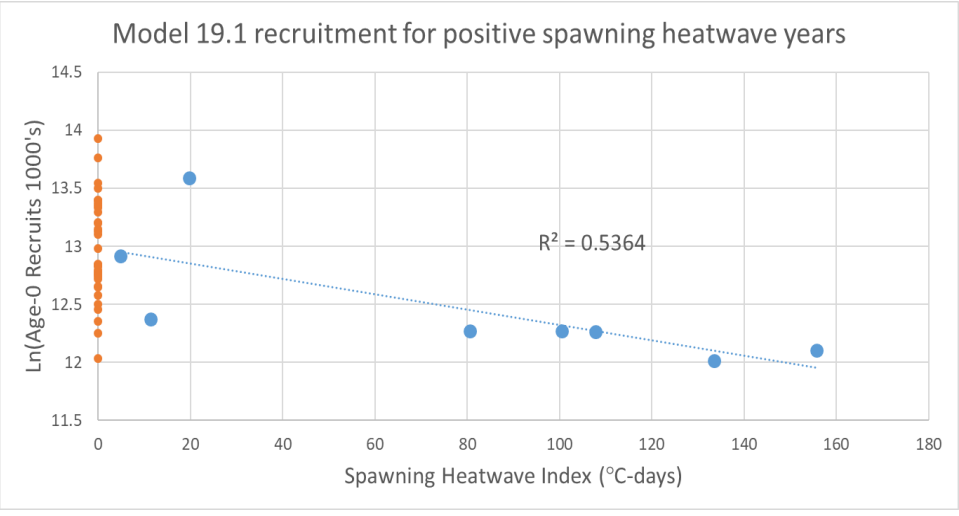
$$R_y = (R_0 e^{\vartheta}) e^{-0.5 b_y \sigma_R^2 + \tilde{R}_y} \text{ , if } y \geq 1977 \rightarrow \vartheta = 0, \text{ where } \tilde{R}_y = N(0;\ \sigma_R^2)$$

- Spawning heatwave-linked recruitment

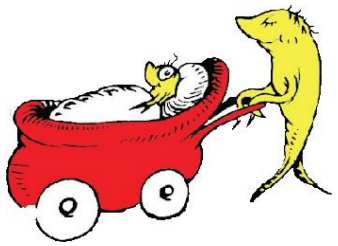
$$R_y = \frac{4h\left(e^{\vartheta + \ln\left(R_0 e^{\omega I_{Sy}^{\frac{1}{3}}}\right)}\right) SB_y}{SB_0(1-h) + SB_y(5h-1)} e^{-0.5 b_y \sigma_R^2 + \tilde{R}_y}, \text{ if } y \geq 1977 \rightarrow \vartheta = 0 \text{ where } \tilde{R}_Y = N(0;\ \sigma_R^2)$$

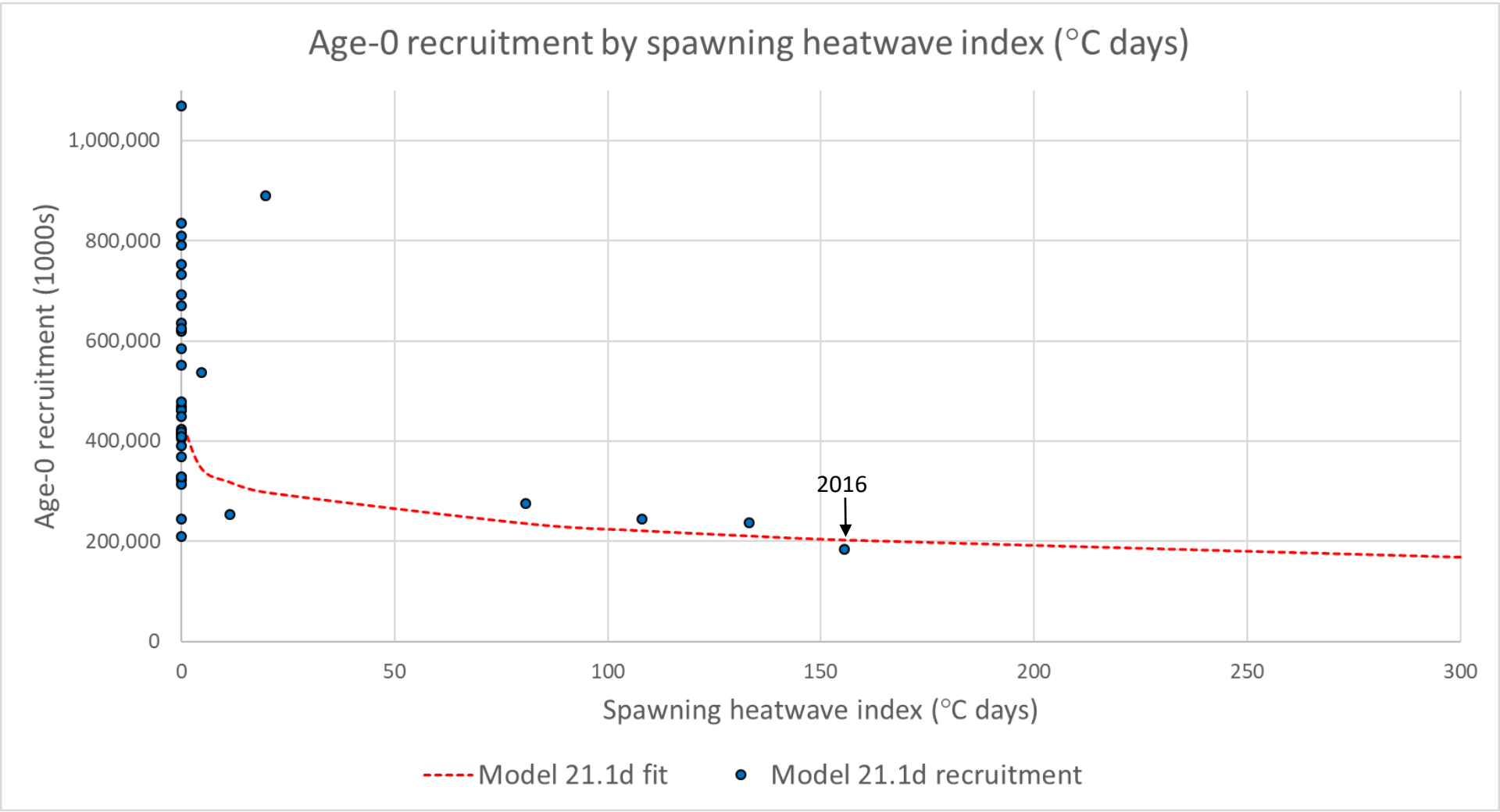
$$\text{Where } h = 1,\ R_y = e^{\vartheta + \ln\left(R_0 e^{\omega I_{Sy}^{\frac{1}{3}}}\right)} e^{-0.5 b_y \sigma_R^2 + \tilde{R}_y}$$





Model 21.1d recruitment

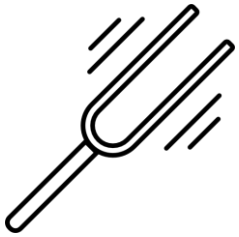




Model configurations

	Ecosystem Links					
	Larval index	Growth	M	Recruits	Data re-weighting	M-block to 2020
Base 19.1						
21.1a						
21.1b						
21.1c						
21.1d						
21.1e						
21.1g						
21.5a						
21.5c						

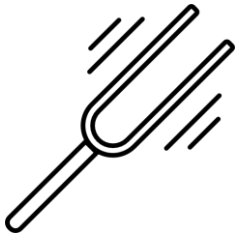
Model tuning



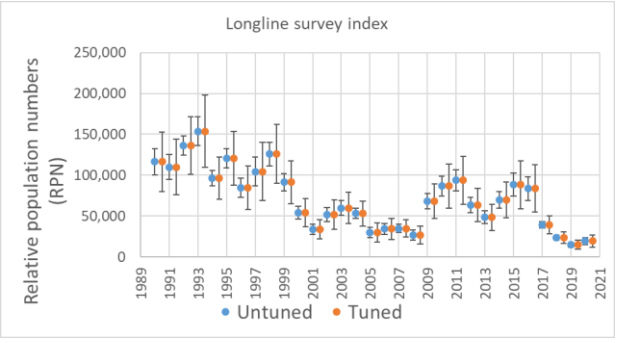
- Indices
  - Standard Error + adjustment tuned to RMSE
- Age and length sample size
  - Francis 1A.18 method as implemented in R4SS
  - Reduced sample size for all composition data

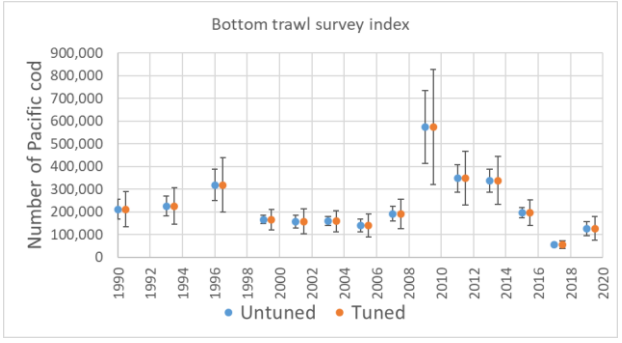
- Tuning results
  - All data components were given higher variance/lower sample size
    - Increased emphasis on model structure and priors
  - More weight on indices with slight overfitting based on RMSSR < 1.0
    - Additional tuning of indices necessary
  - High survey catchability (> 1.4)

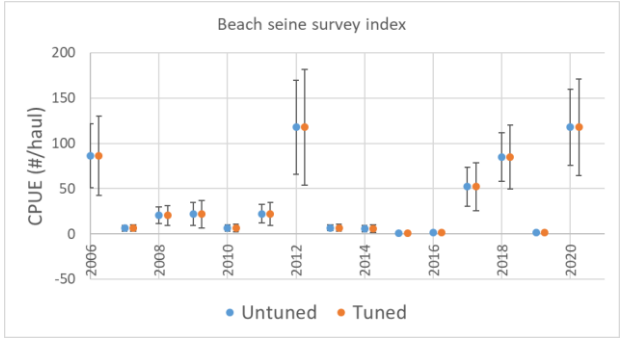
Model tuning



Component		Tuning	Model 21.1g	Model 21.5c
Index	Beach seine survey	add_to_survey_CV	0.100	0.100
	Bottom trawl survey	add_to_survey_CV	0.162	0.162
	Longline survey	add_to_survey_CV	0.171	0.171
Length	Trawl fishery	mult_by_lencomp_N	0.256	0.257
	Longline fishery	mult_by_lencomp_N	0.417	0.423
	Pot fishery	mult_by_lencomp_N	0.156	0.152
	Bottom trawl survey	mult_by_lencomp_N	0.432	0.420
	Longline survey	mult_by_lencomp_N	0.403	0.412
Age	Trawl fishery	mult_by_agecomp_N	0.511	0.532
	Longline fishery	mult_by_agecomp_N	0.572	0.577
	Pot Fishery	mult_by_agecomp_N	0.346	0.358
	Bottom trawl survey	mult_by_agecomp_N	0.196	0.192







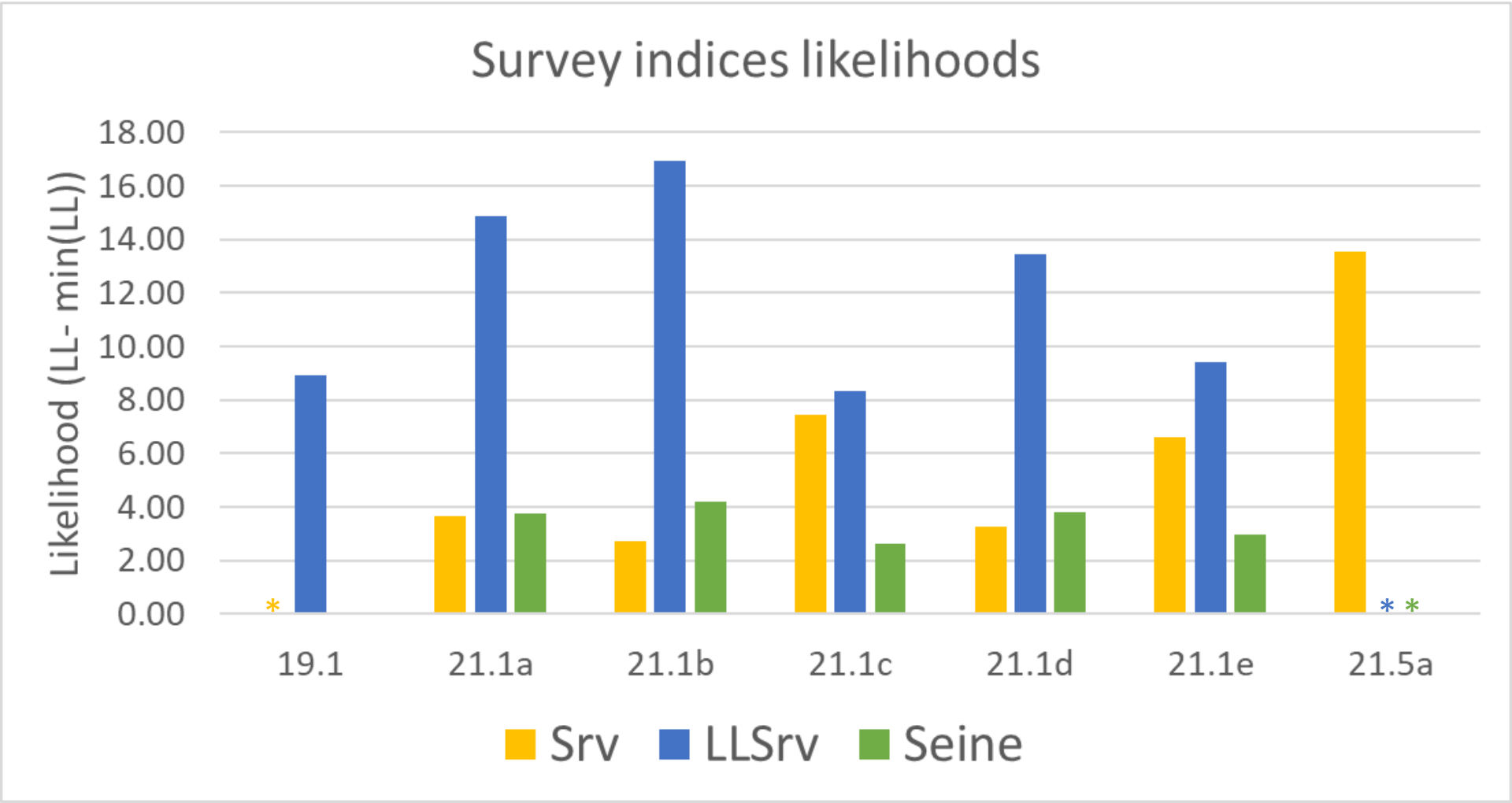
Model evaluation

	Attributes	# Parameters	-Log likelihood	AIC	-Marginal log likelihood	Marginal AIC	Retrospective analysis (SSB) ρ	Woodshole ρ	RMSE
Model 19.1		201	3,190.0	6,782.0	3,356.6	7,115.3	0.081	0.085	0.152
Model 21.1a		202	3,210.5	6,825.1	3,368.7	7,139.3	0.087	0.071	0.162
Model 21.1b	G	204	3,202.8	6,813.7	3,372.1	7,152.3	0.129	0.080	0.178
Model 21.1c	Mh	201	3,194.1	6,790.2	3,352.2	7,106.4	0.101	0.063	0.159
Model 21.1d	R	203	3,205.1	6,816.1	3,368.7	7,141.5	0.086	0.067	0.145
Model 21.1e	G, R, Mh	205	3,182.1	6,774.2	3,356.3	7,122.6	0.164	0.072	0.183
Model 21.1g	G, R, Mh, T	205	2,039.6	4,489.2	2,149.1	4,708.2	0.164	0.120	0.198
Model 21.5a	G,R,M20	205	3,168.7	6,747.4	3,343.6	7,097.2	0.132	0.121	0.223
Model 21.5c	G,R,T	205	2,036.4	4,482.9	2,149.8	4,709.5	-0.047	-0.015	0.078

- Can’t compare full objective values or AIC across all models with addition of new data and reweighting

- Of the comparable models Model 21.5a had the best overall fit by improving fit to longline survey data at a cost to other model data and possibly unreasonably high catchability (Q=1.36)

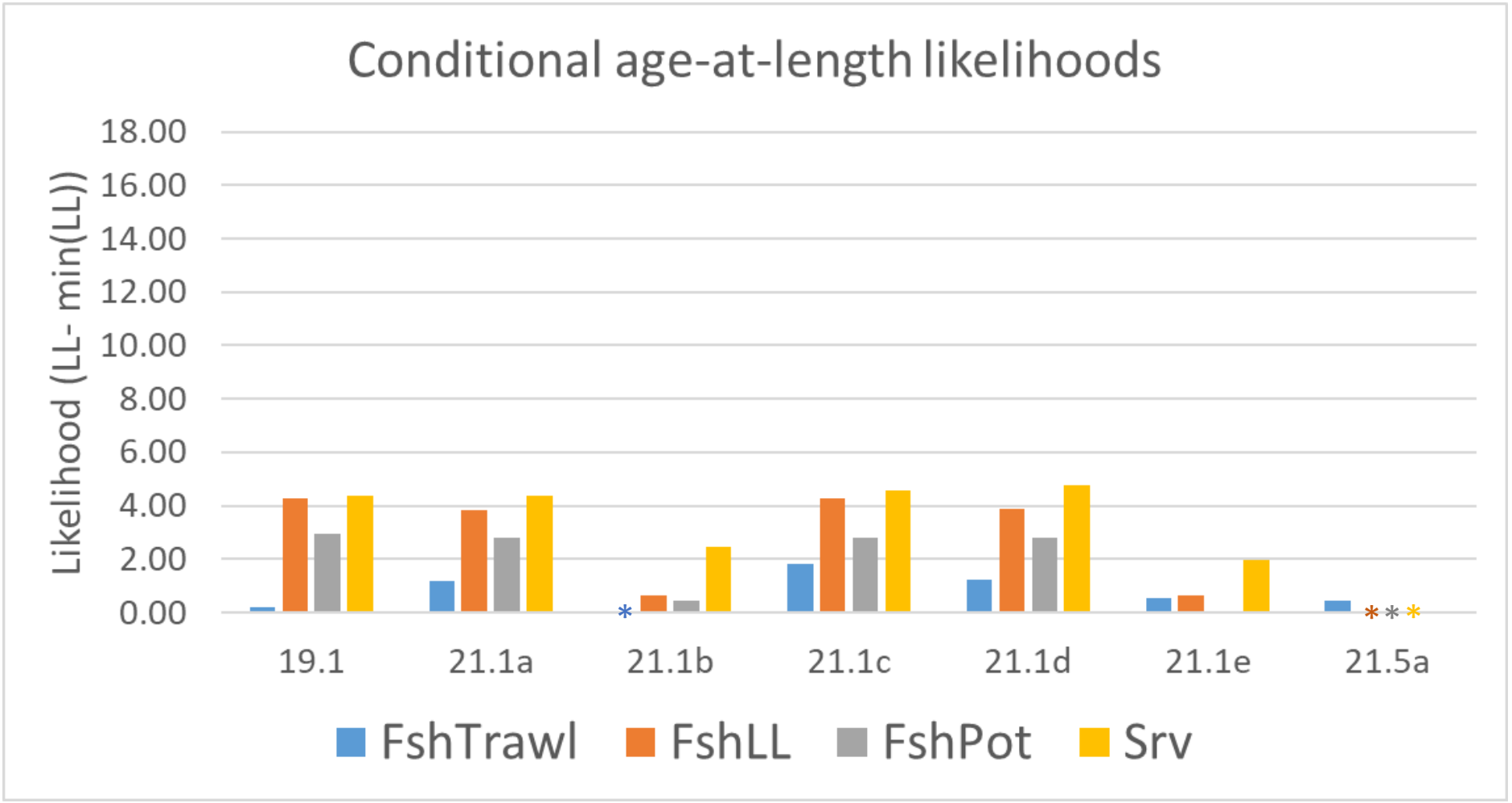
Likelihood components



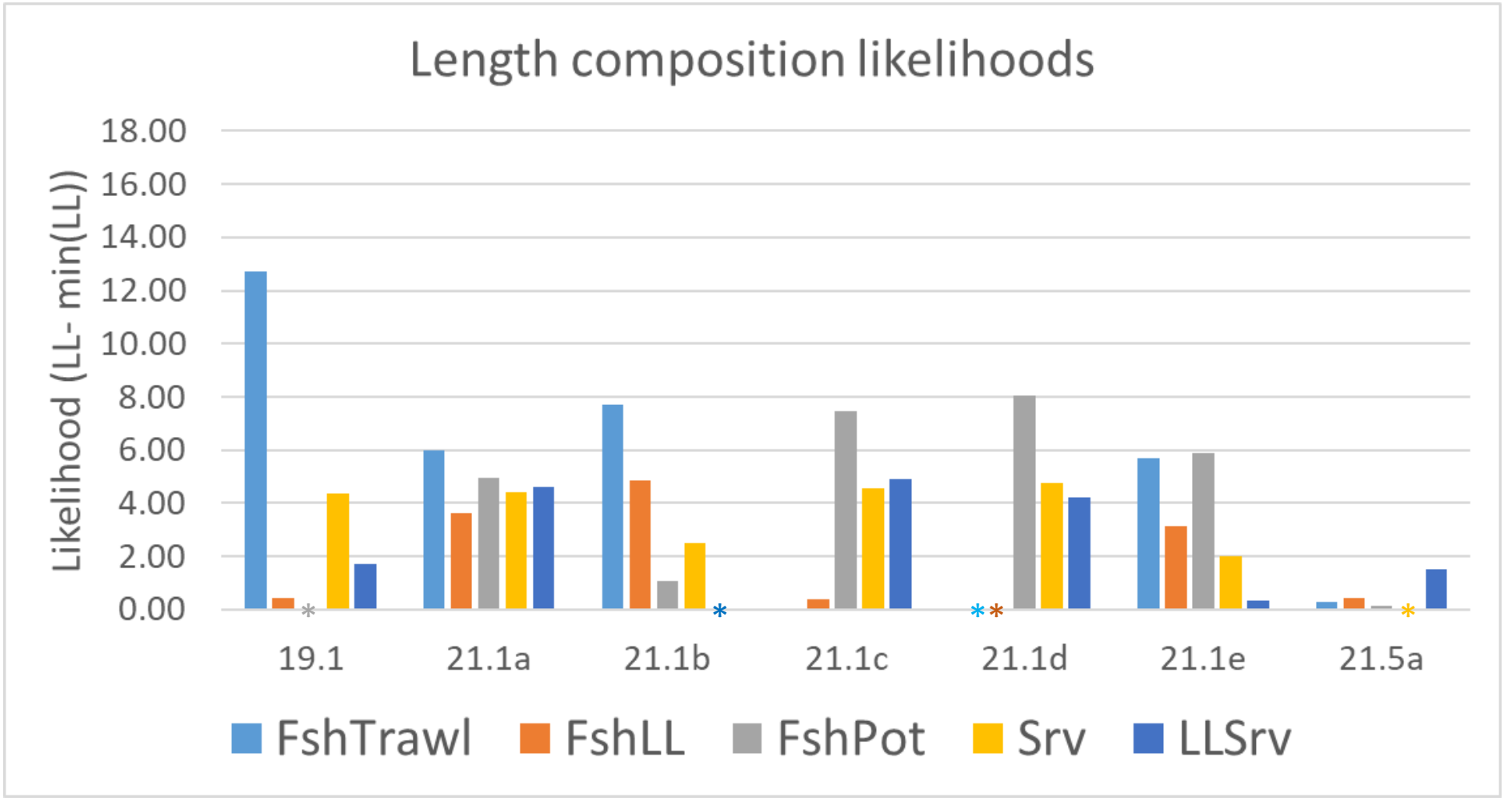
Likelihood components

- Recruitment likelihood improved for beach seine index models
- Temperature dependent growth increased recruitment devs

Likelihood components

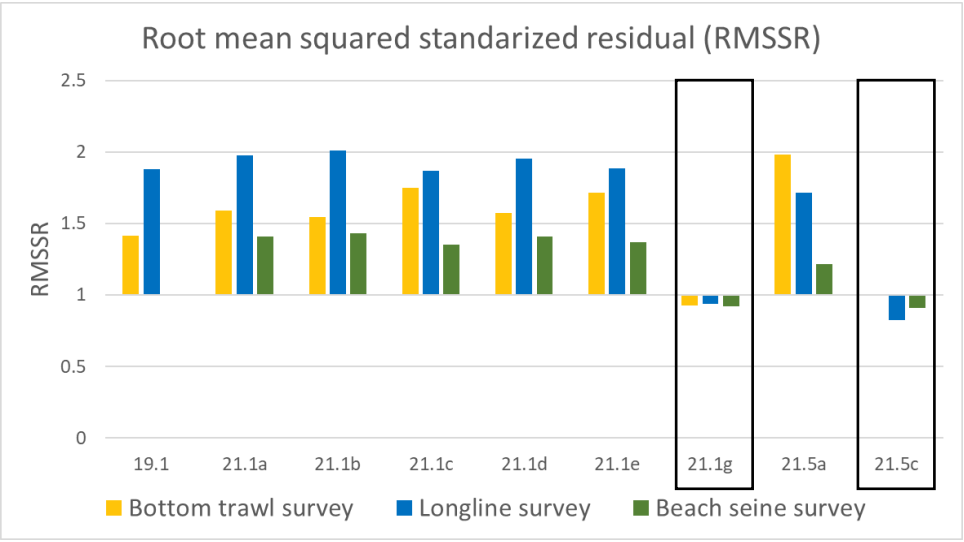


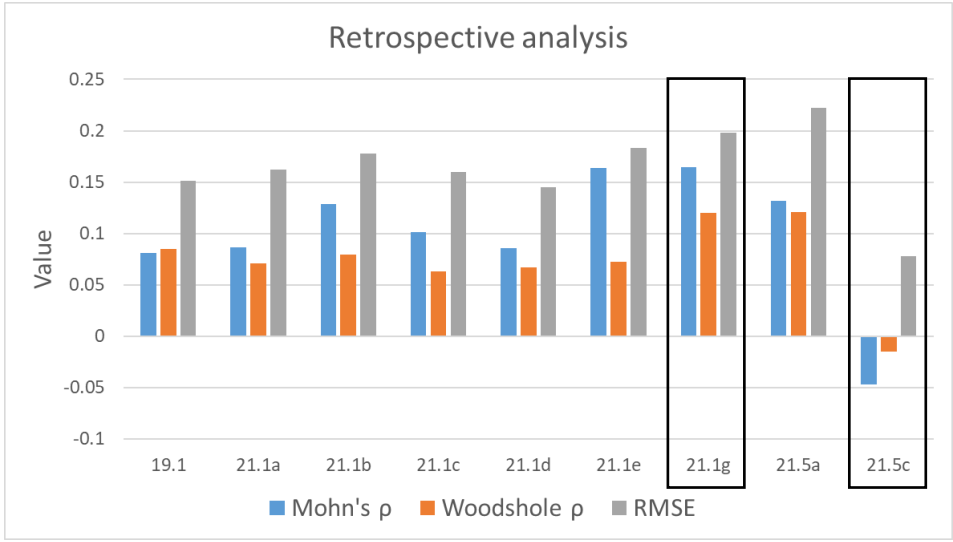
Likelihood components

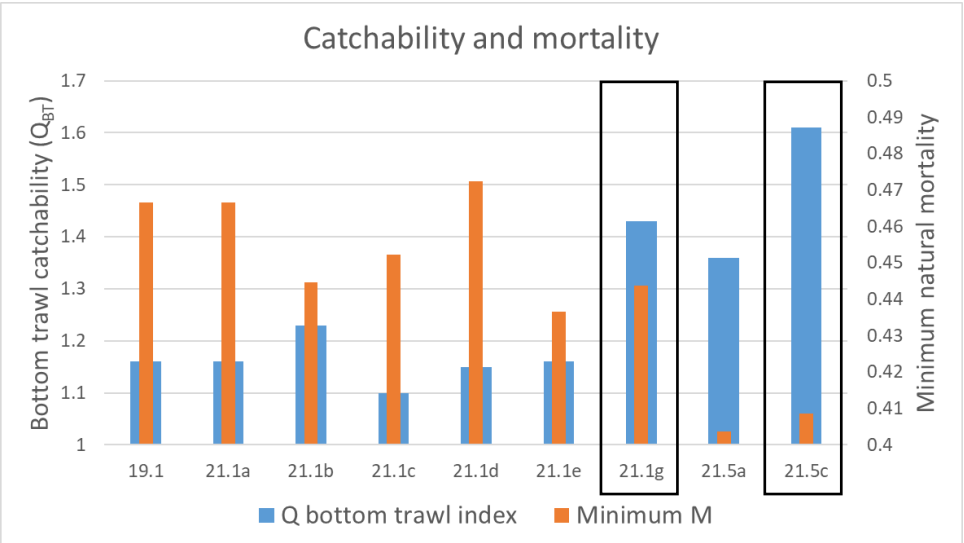


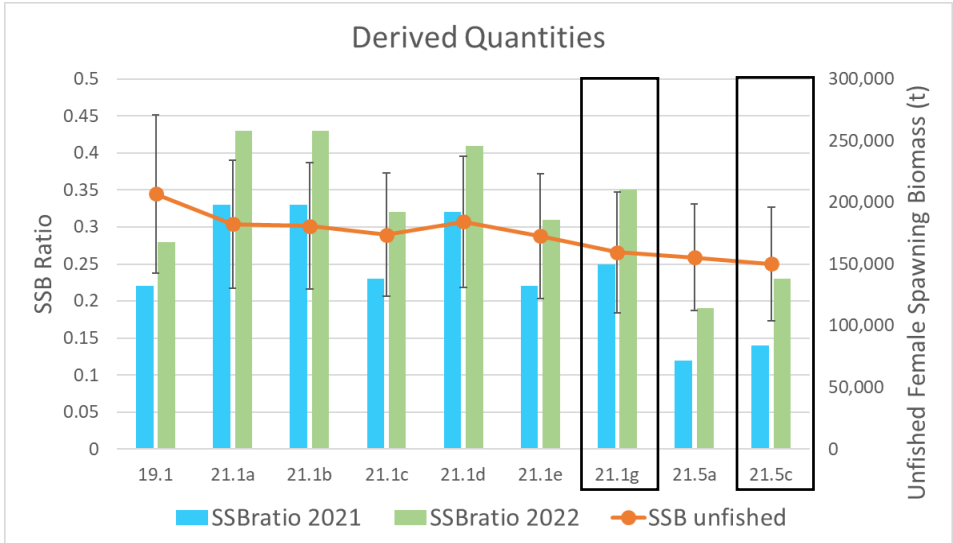
Model evaluation

=Tuned models





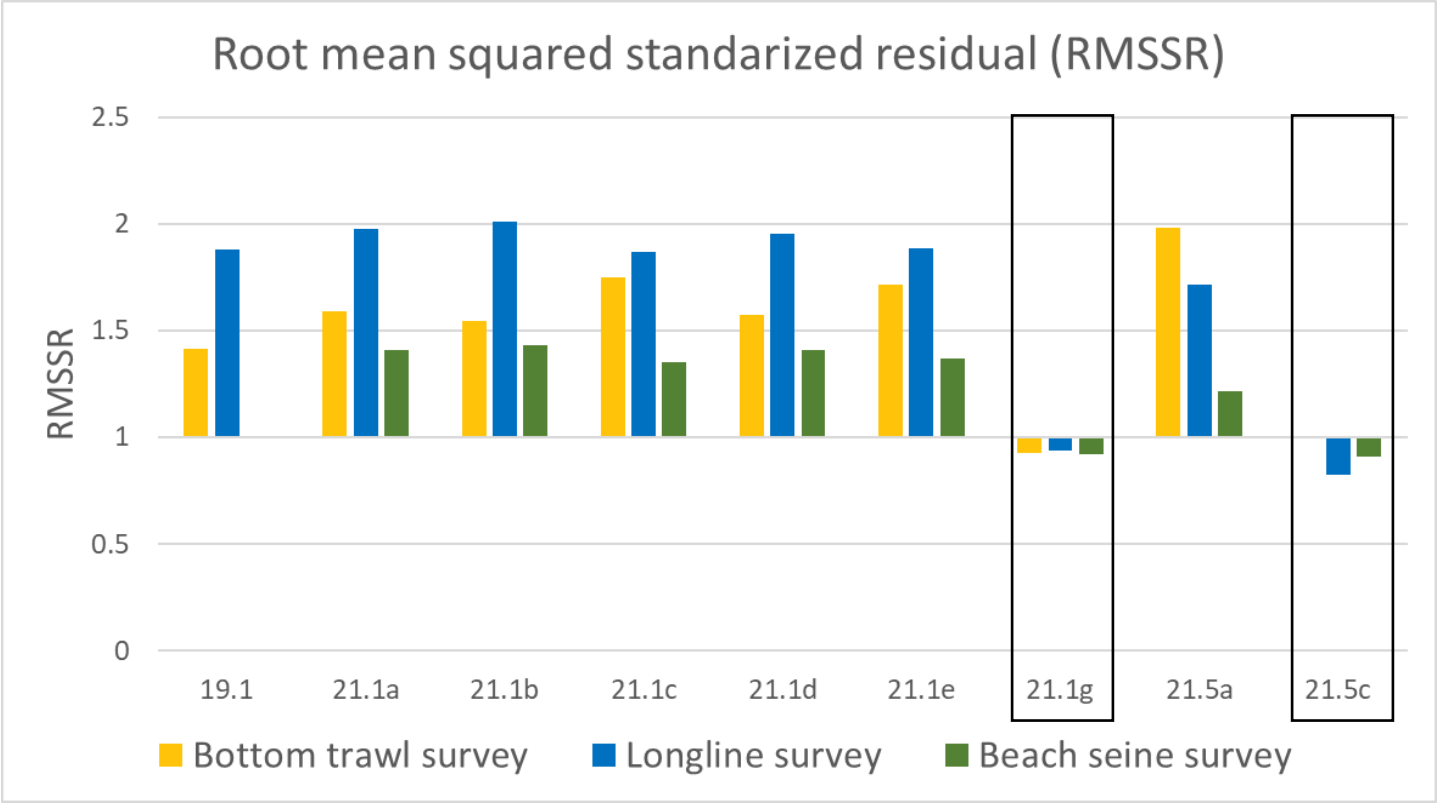




Model evaluation

=Tuned models

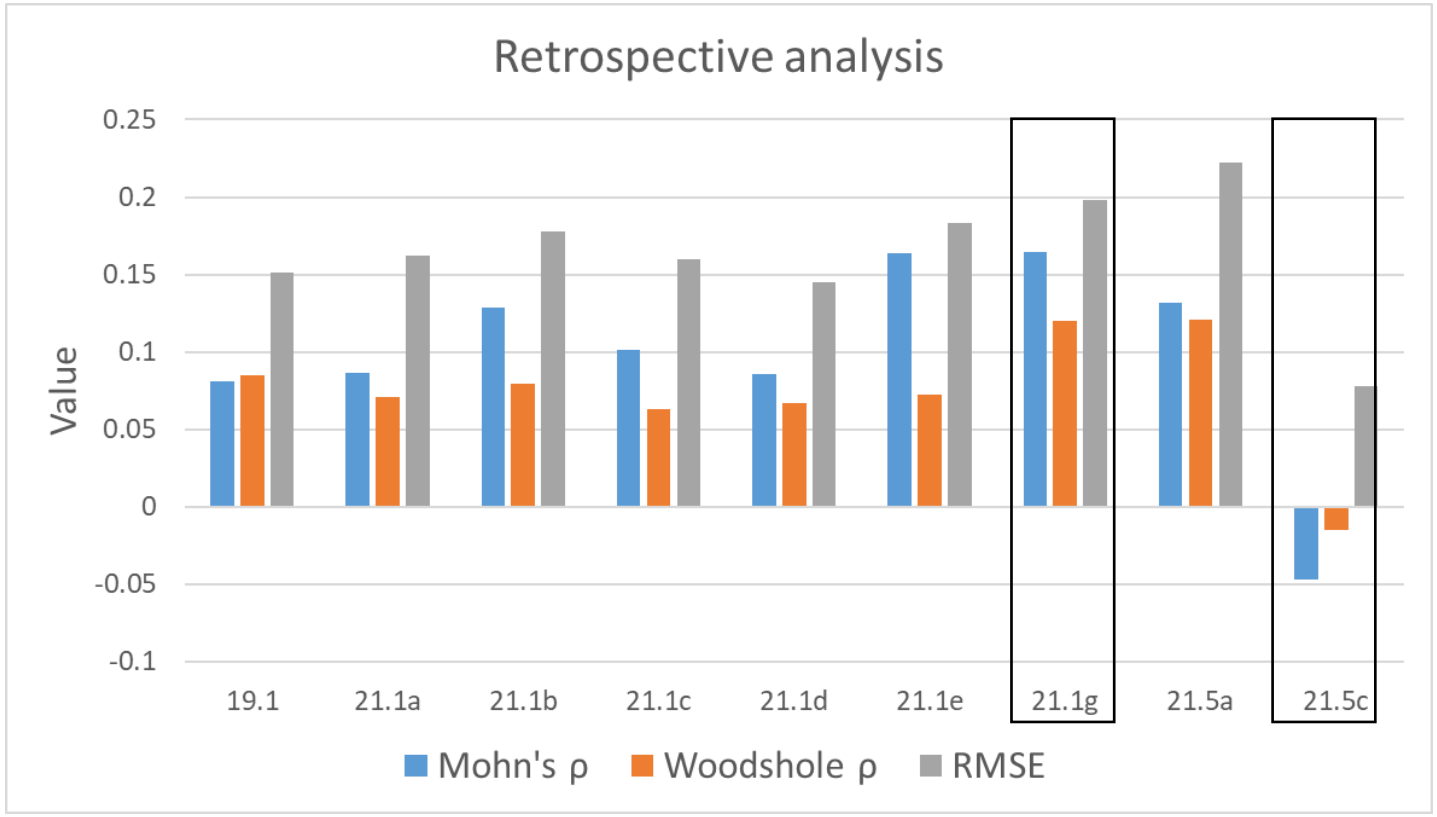
- Increased RMSSR for longline and bottom trawl survey with the addition of the beach seine survey index
- RMSSR > 1 indicates possible underfitting, < 1 overfitting.



Model evaluation

=Tuned models

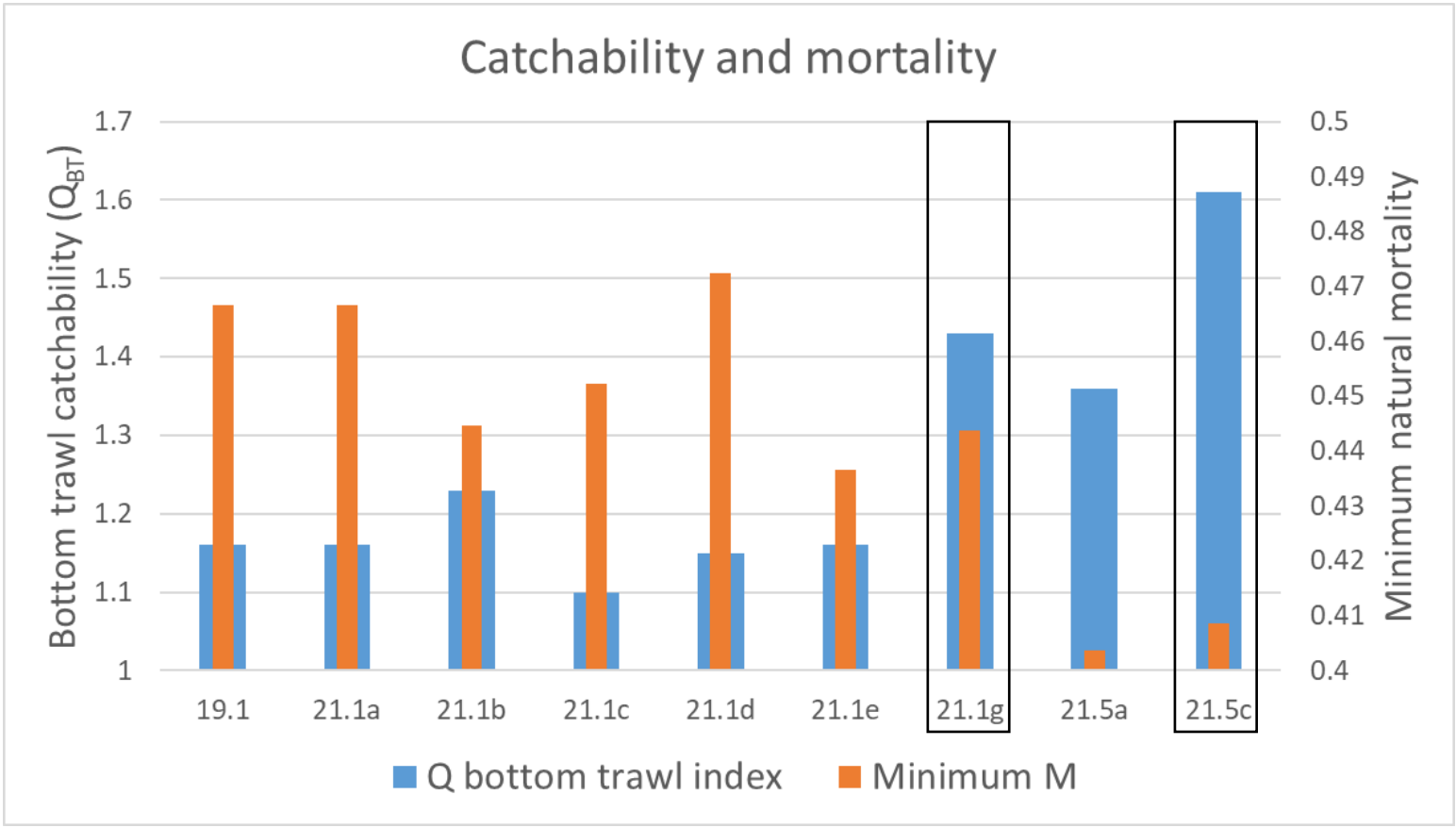
- Positive bias in SSB for all models except 21.5c
- Mohn's Rho within acceptable bounds for all models



Model evaluation

=Tuned models

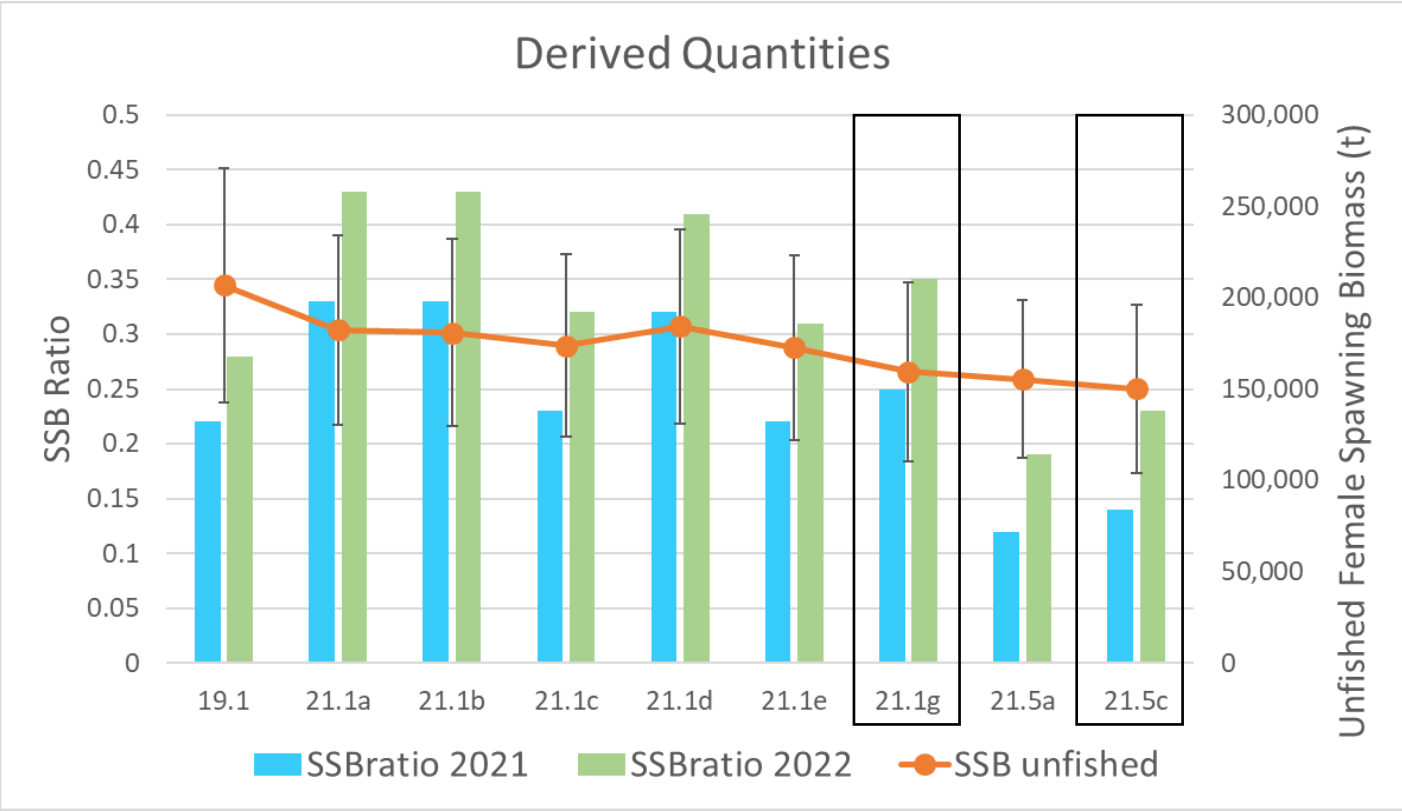
- Very high survey catchability in 21.5 series and tuned models
  - Unreasonable?
- Minimum M between 0.40 and 0.47 for all models



Model evaluation

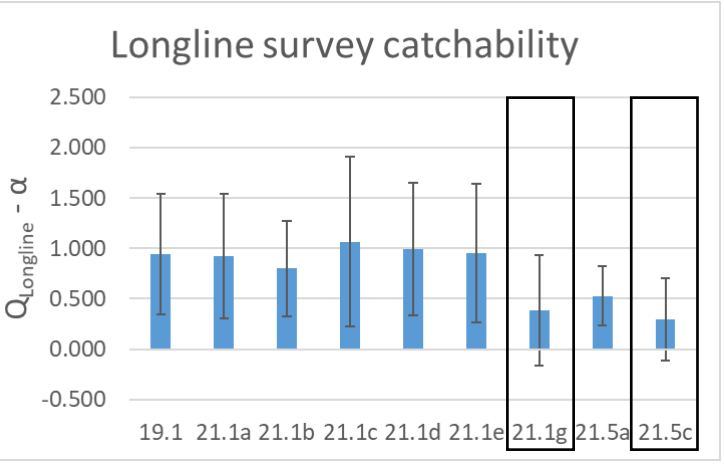
=Tuned models

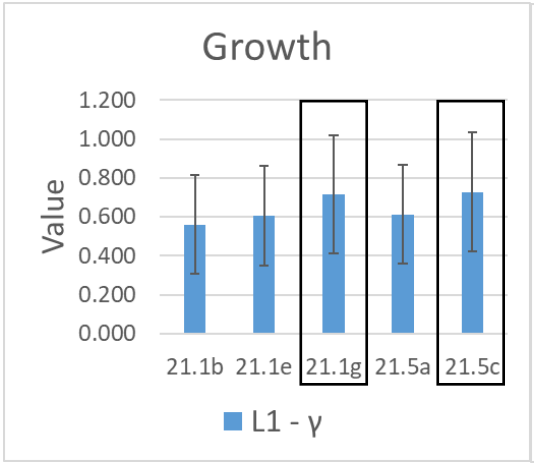
- Unfished spawning biomass similar for all 21.1 series models
- Lower uncertainty for reference points in models with beach seine index
- All models agree with increasing spawning biomass in 2022

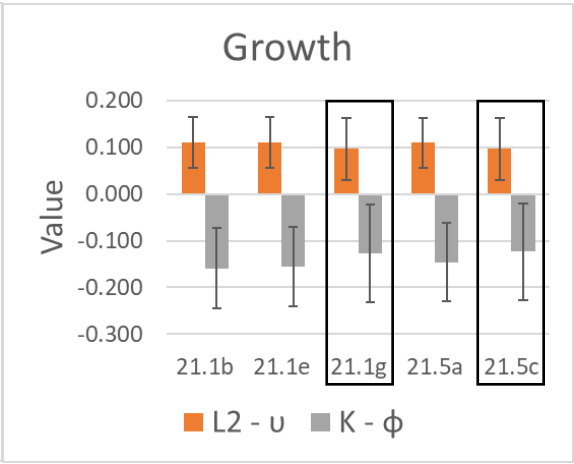


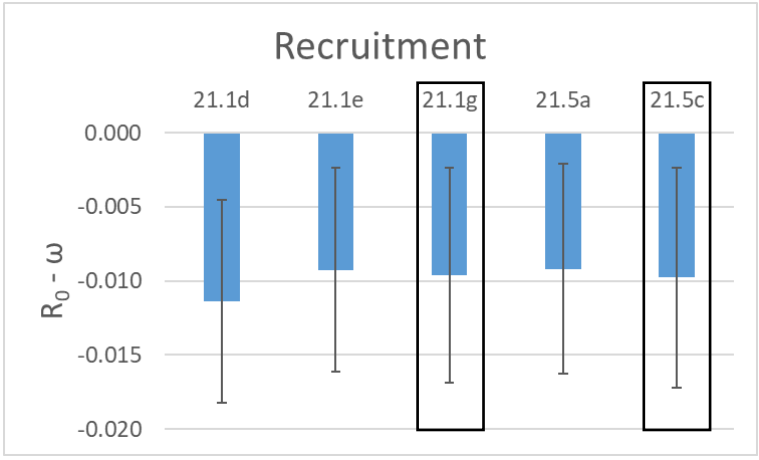
Model evaluation
Environmental-link parameters

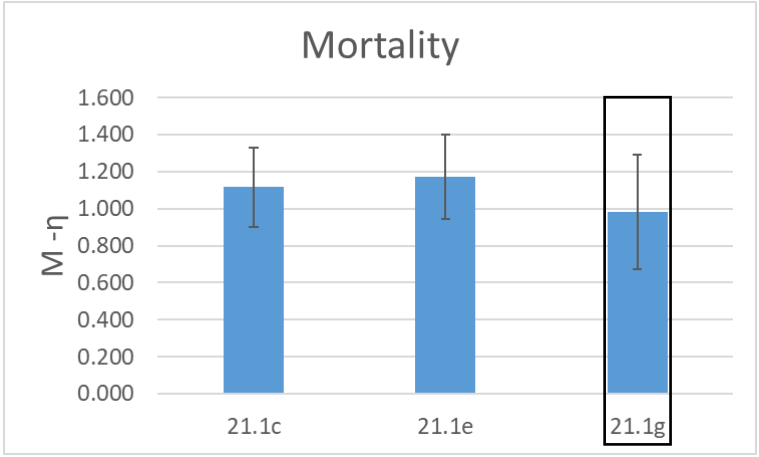
=Tuned models







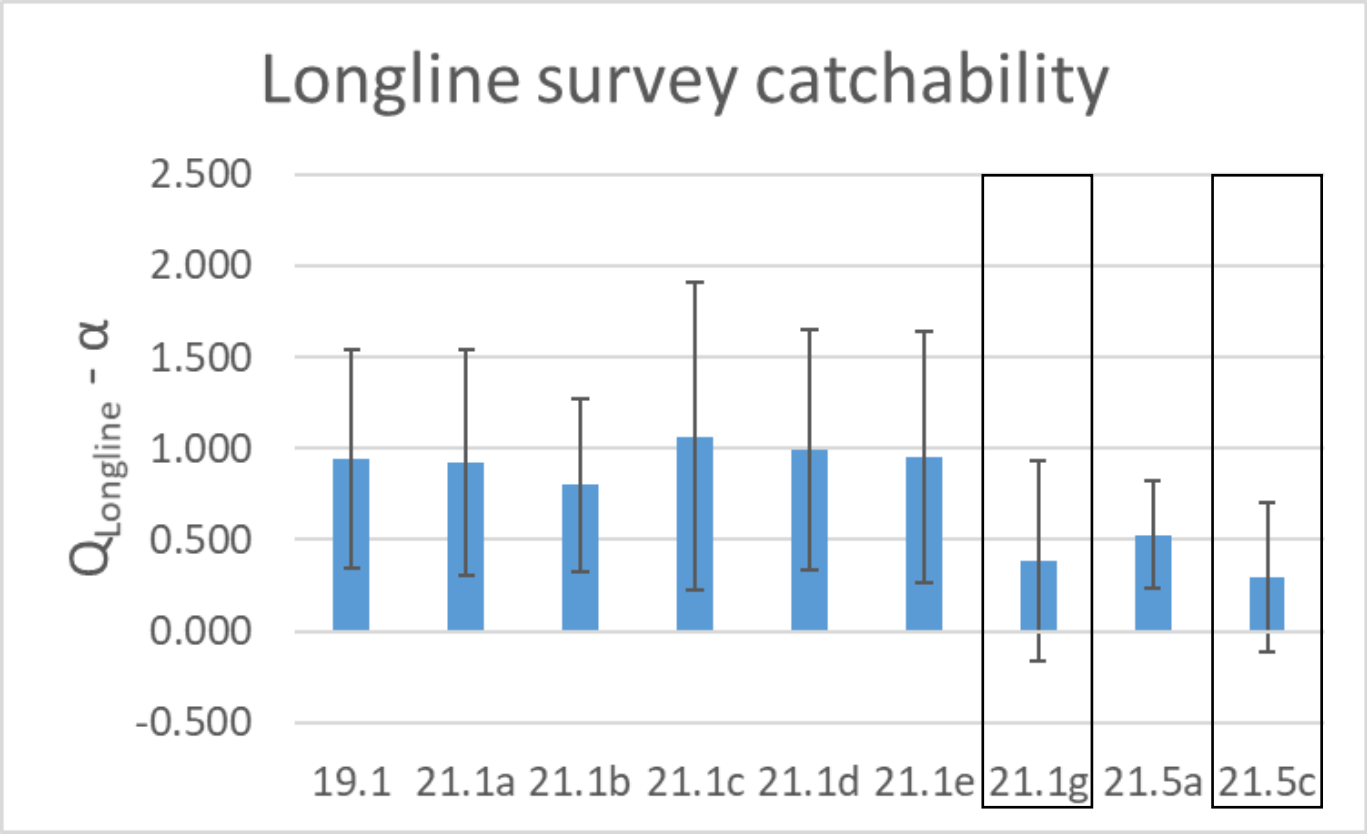




Model evaluation
Environmental-link parameters

=Tuned models

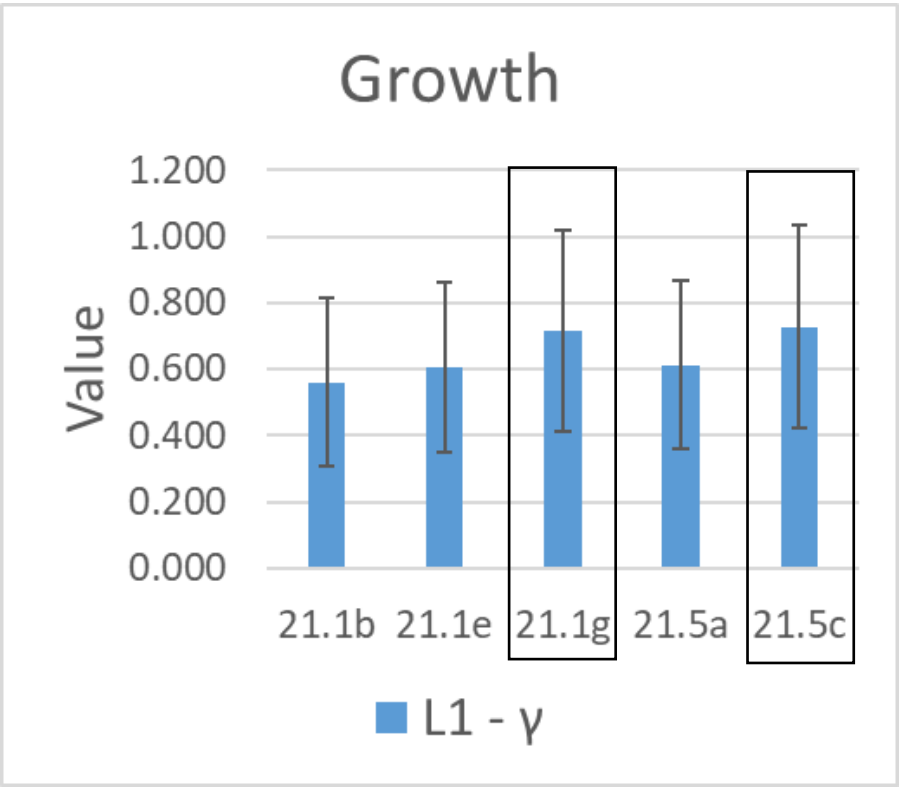
- Re-weighting resulted in less influence of temperature on longline survey catchability

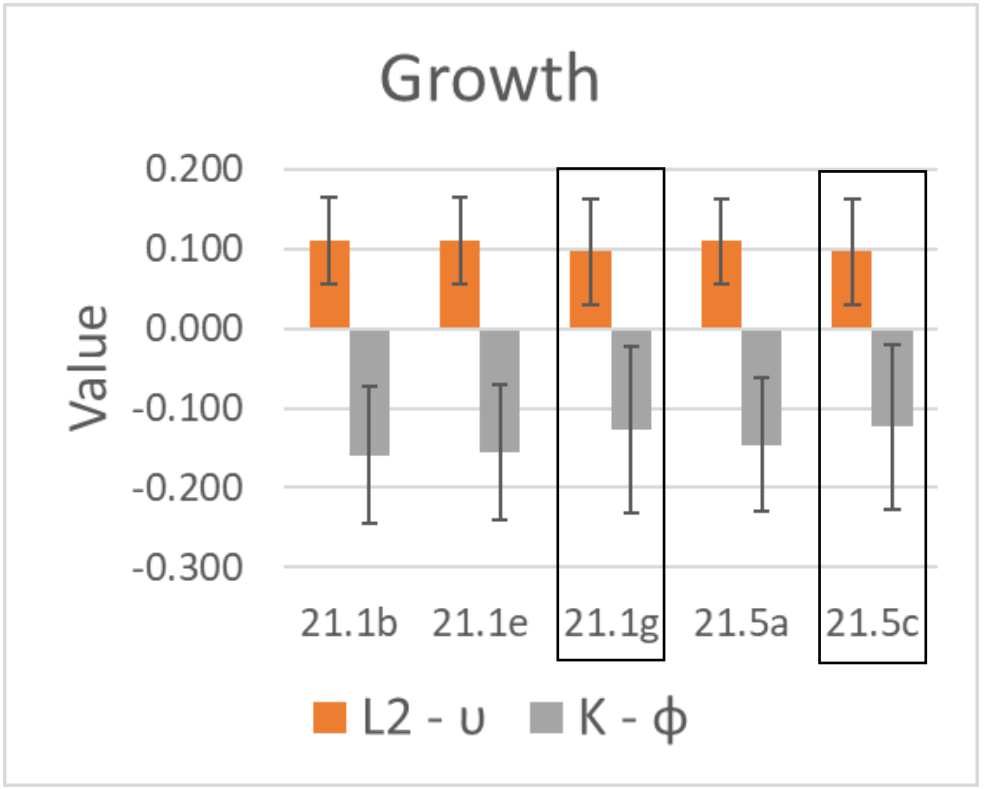


Model evaluation
Environmental-link parameters

=Tuned models

- Consistent growth link parameters over all models.

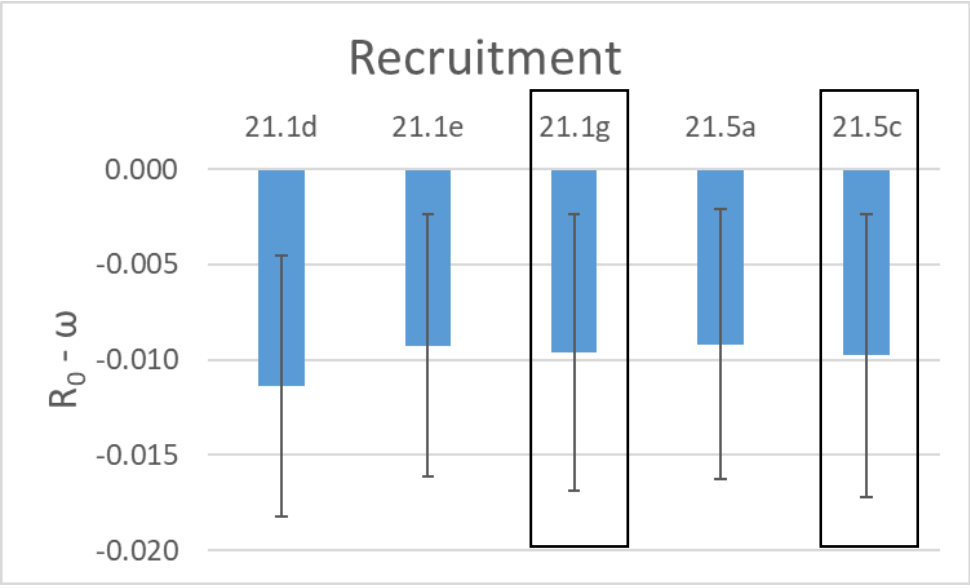


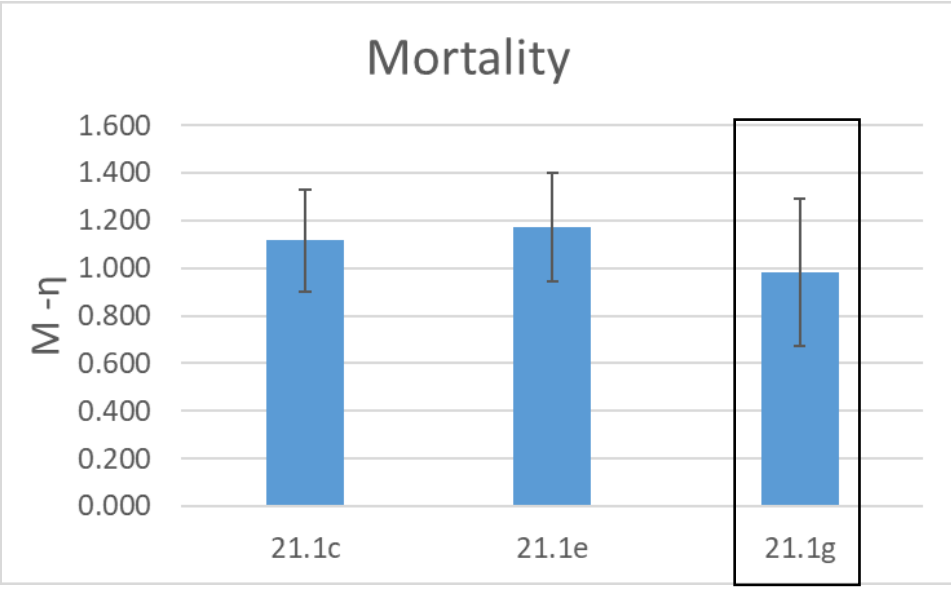


Model evaluation
Environmental-link parameters

=Tuned models

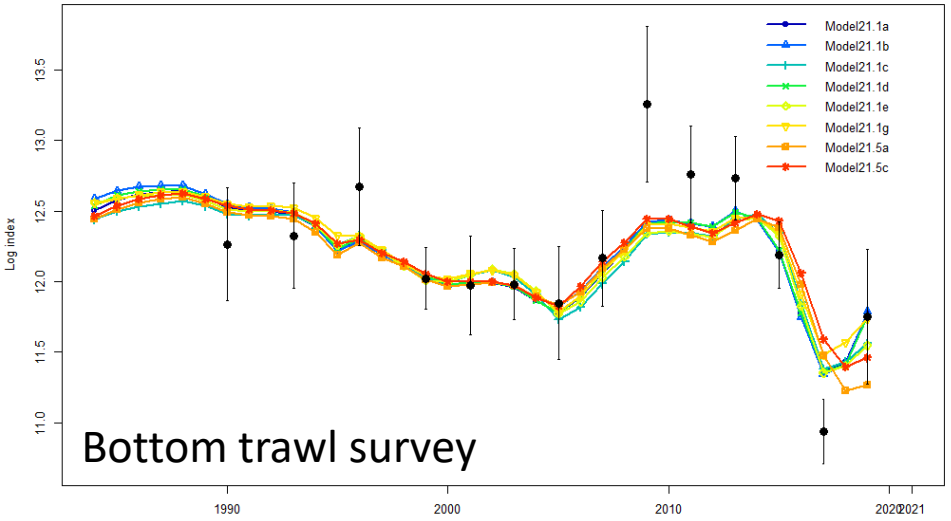
- Recruitment heatwave link parameter
  - Somewhat uncertain, but stable
- Mortality heatwave link parameter
  - Well fit in all three models resulting in similar maximum M

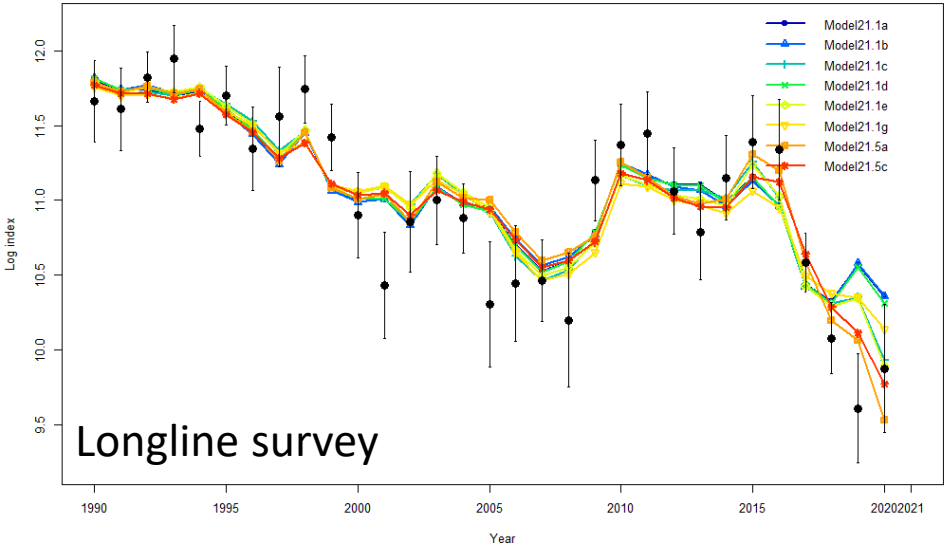


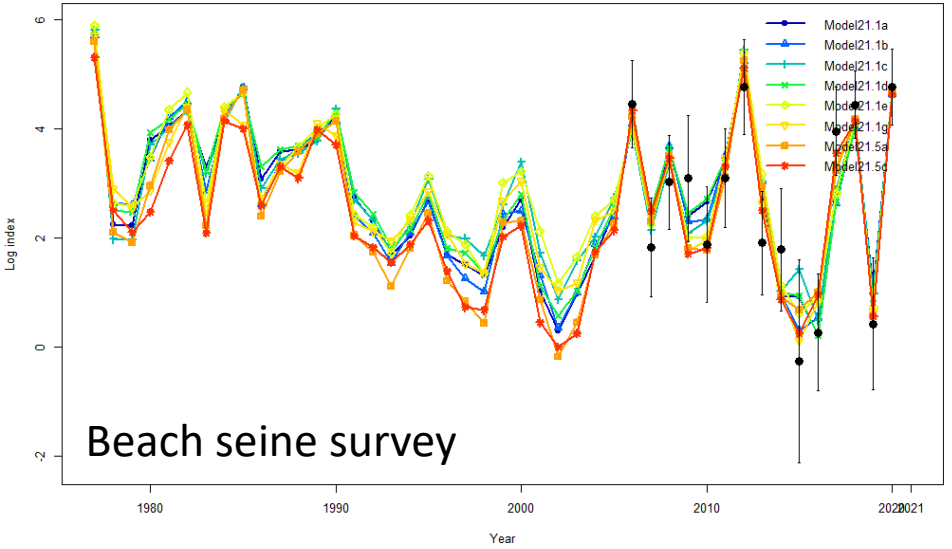


Models 21.1 and 21.5 series fits to indices

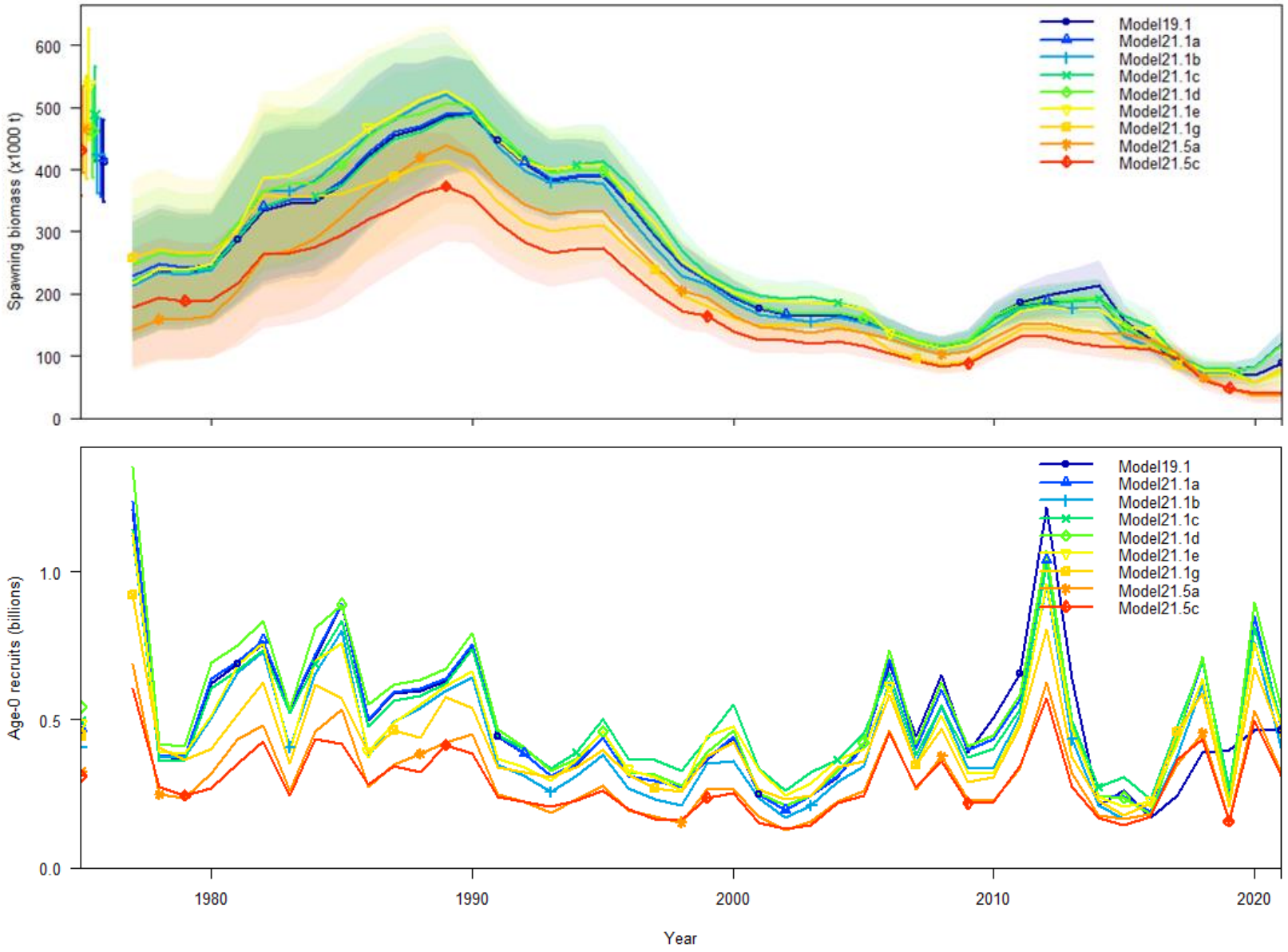
- Poor fit in all models to bottom trawl survey index for 2009-13 and 2017
- Largest differences in fit were to the 2017-2020 adult survey indices
- High agreement in all models to the larval beach seine survey index fit.



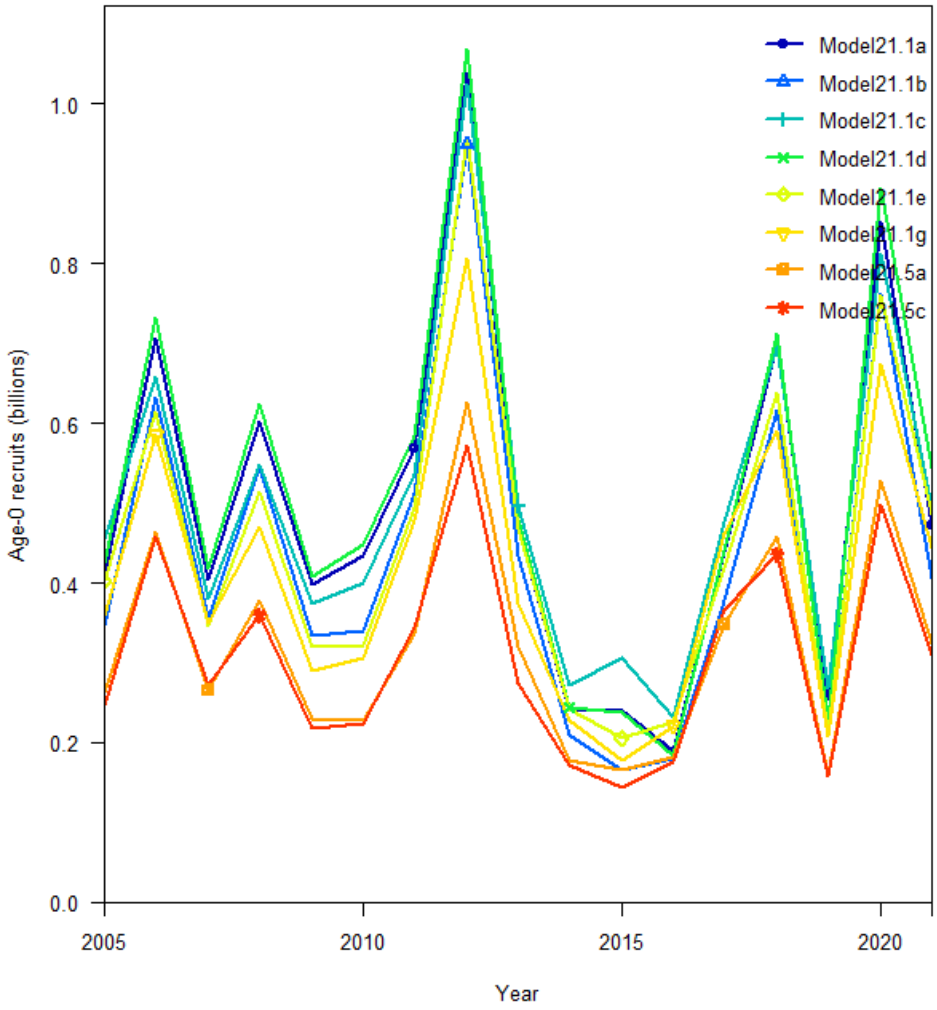


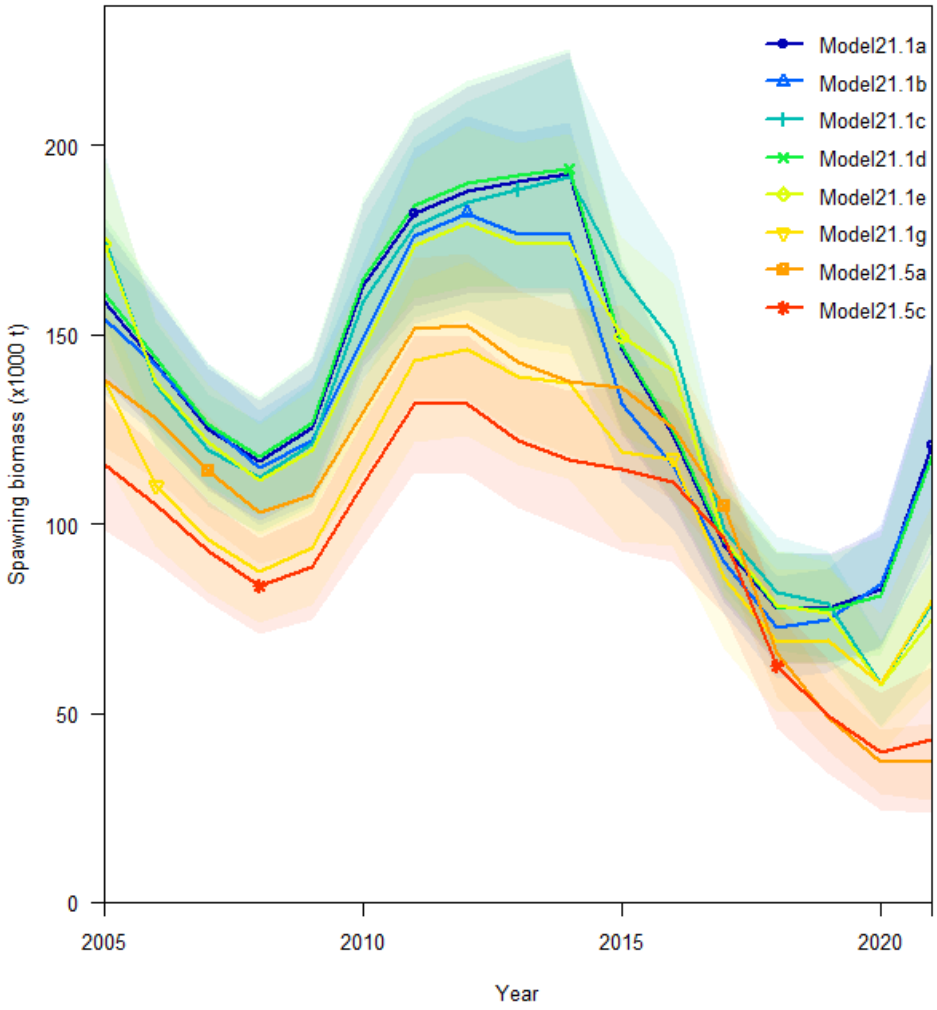


Model 21.1 and 21.5 series results



Model 21.1 and 21.5 series results





Summary

The age-0 beach seine index was consistent with previous estimates

- Pro: Including reduced uncertainty in recent recruitment estimates
- Con: Degraded fit to other indices

Addition of temperature impacts on key parameters was reasonable

- Relative to fitting available data

Data weighting impacted survey catchability estimates

- Further work needed to investigate why high Qs in tuned models

Small changes in environmental linkages or weighting led to large changes reference points

New Data to be added for November

- 2021 Observer fishery length composition data
- 2019-2020 observer fishery age data
- 2021 ADF&G port sampling fish length composition
- 2021 Bottom trawl survey and length composition
- 2021 Longline survey index and length composition
- 2021 Beach seine survey age-0 index

Proposed models for November

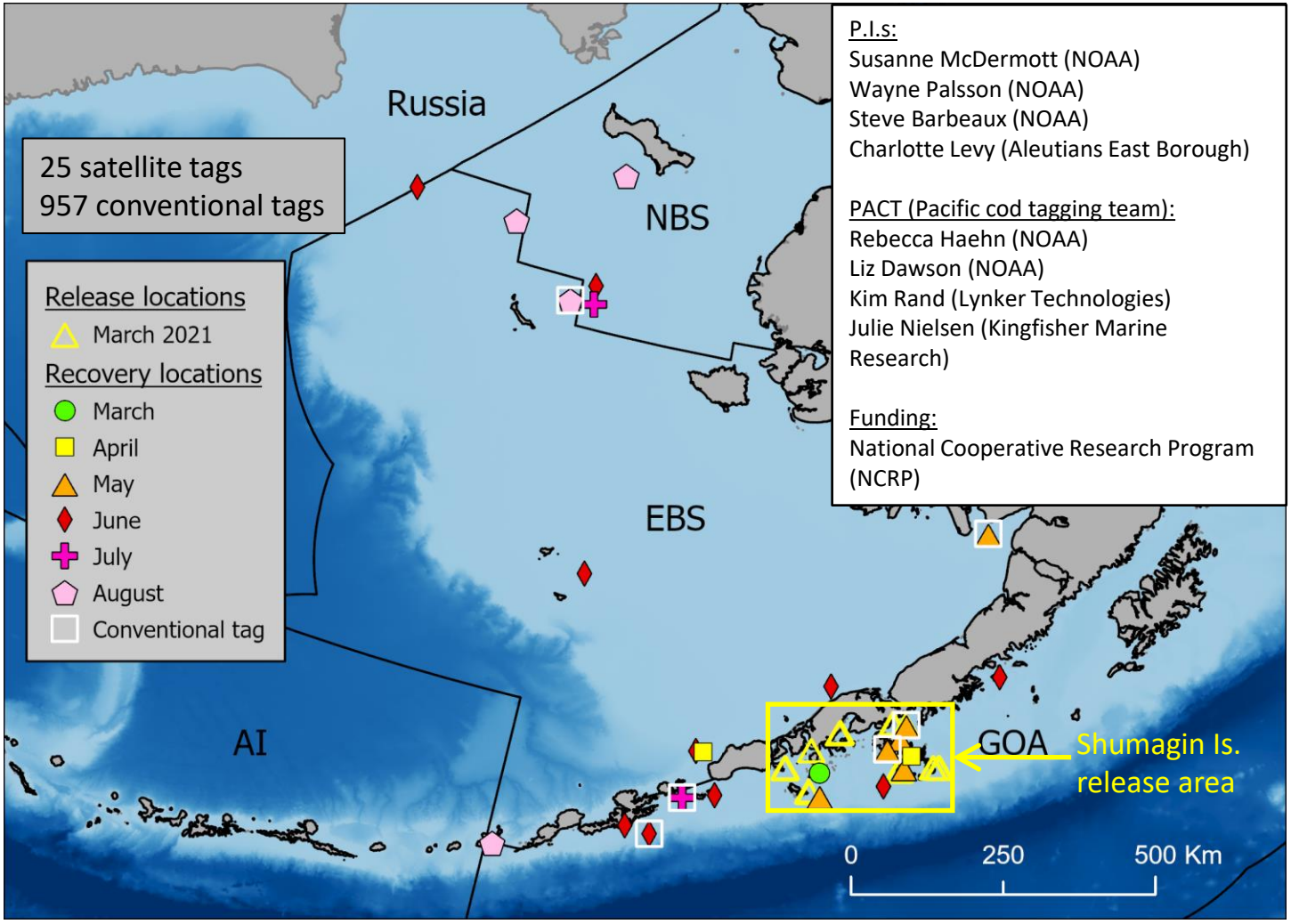
- Model 19.1
  - Base model
- Model 21.1e
  - Growth, mortality, and recruitment enviro-linked
- Model 21.1g
  - Growth, mortality, and recruitment enviro-linked
  - Retuned (RMSSR to 1.0, Francis 1A.18 for composition/Dirichlet)
- Model 21.5c
  - Growth and recruitment enviro-linked
  - Mortality block iteratively re-explored with new data
  - Retuned (RMSSR to 1.0, Francis 1A.18 for composition/Dirichlet)
- Model 21.6 – (Tuned Model21.1a) NEW!
  - Base model
  - Beach seine index
  - Retuned (RMSSR to 1.0, Francis 1A.18 for composition/Dirichlet)

November model evaluation?

- What specifically does the Team want to see for model selection?
  - Model fit criteria (likelihood, RMSSR, etc…)
  - Retrospective analysis
  - Key parameter estimates and variance
  - Leave-one-out analyses (variability in key parameters)?

2021 Western Gulf Pacific cod tagging study

Collaboration with Aleutians East Borough

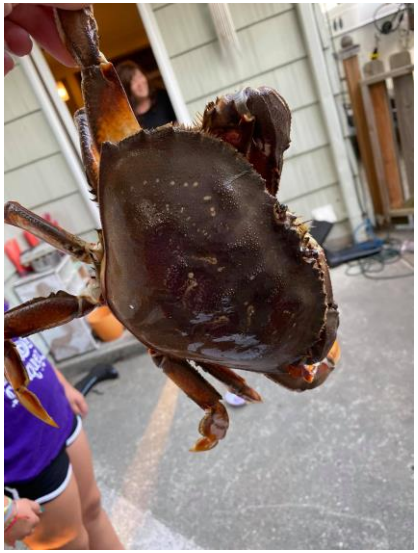


P.I.s:
Susanne McDermott (NOAA)
Wayne Palsson (NOAA)
Steve Barbeaux (NOAA)
Charlotte Levy (Aleutians East Borough)

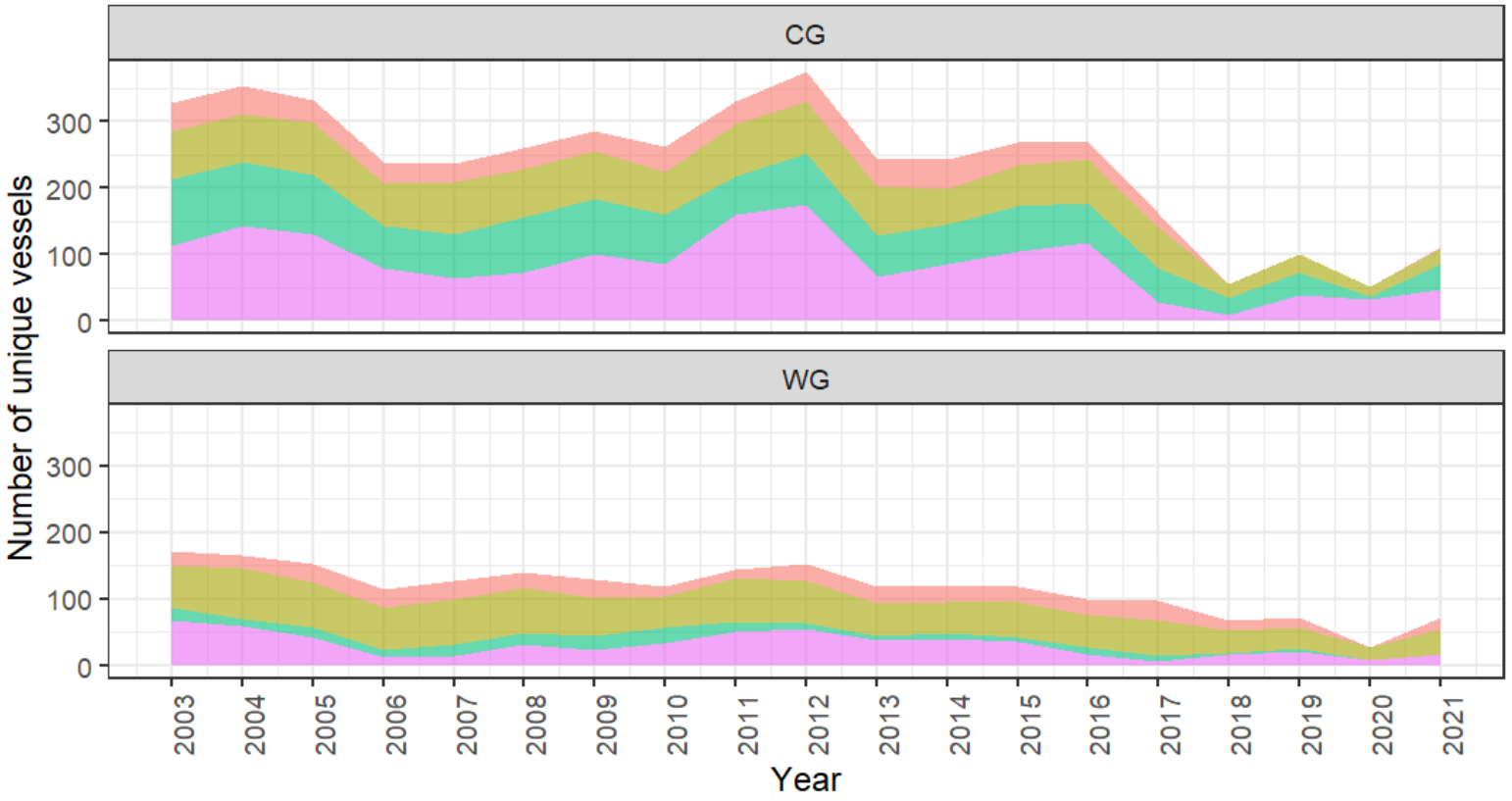
PACT (Pacific cod tagging team):
Rebecca Haehn (NOAA)
Liz Dawson (NOAA)
Kim Rand (Lynker Technologies)
Julie Nielsen (Kingfisher Marine Research)

Funding:
National Cooperative Research Program (NCRP)

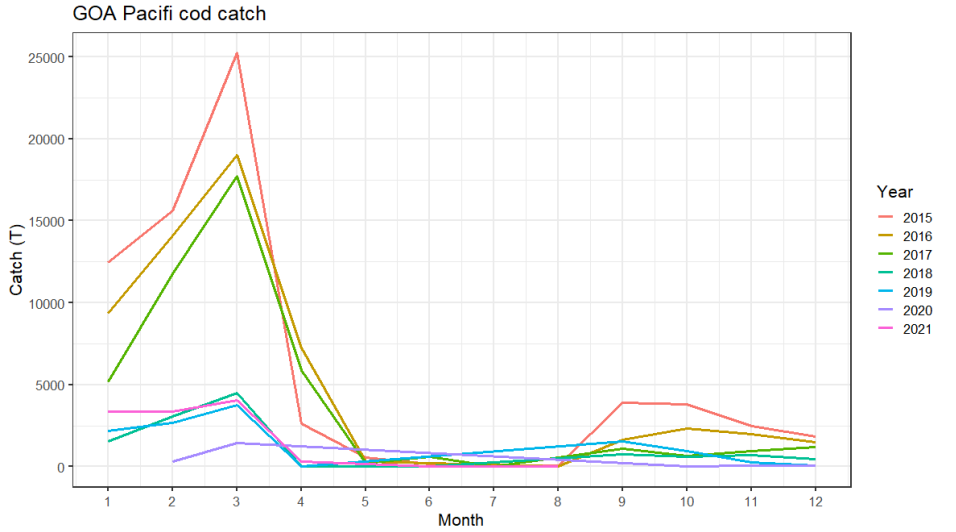
2021 Fishery Performance (if time allows)

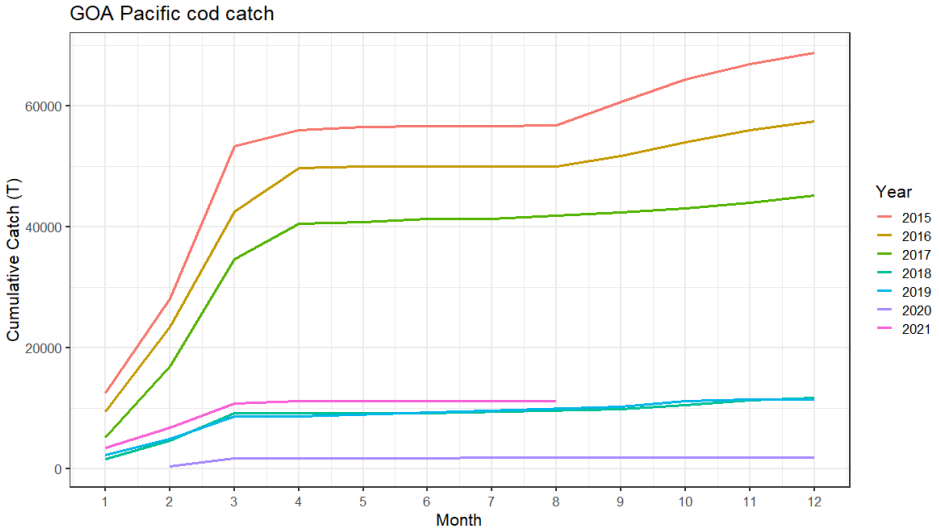


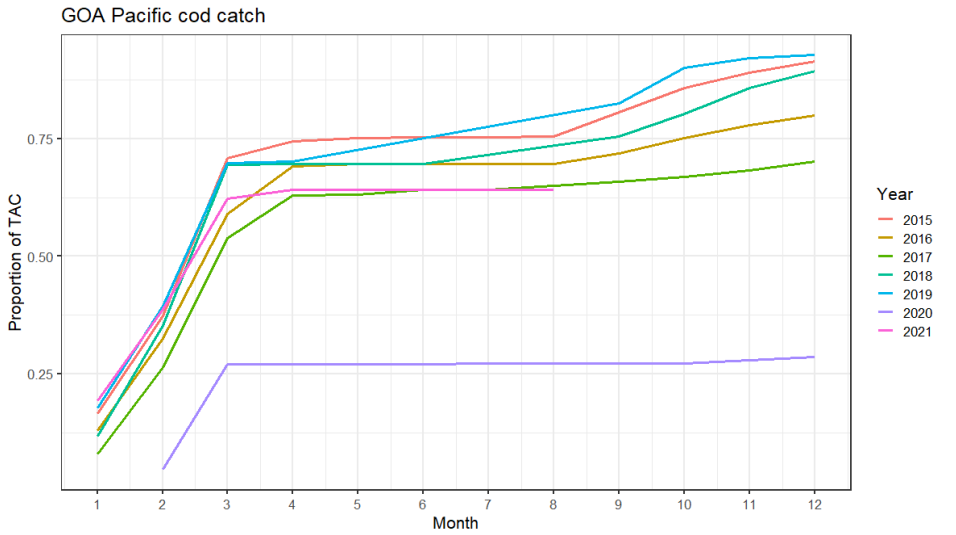
Vessels participating in GOA Pacific cod fishery



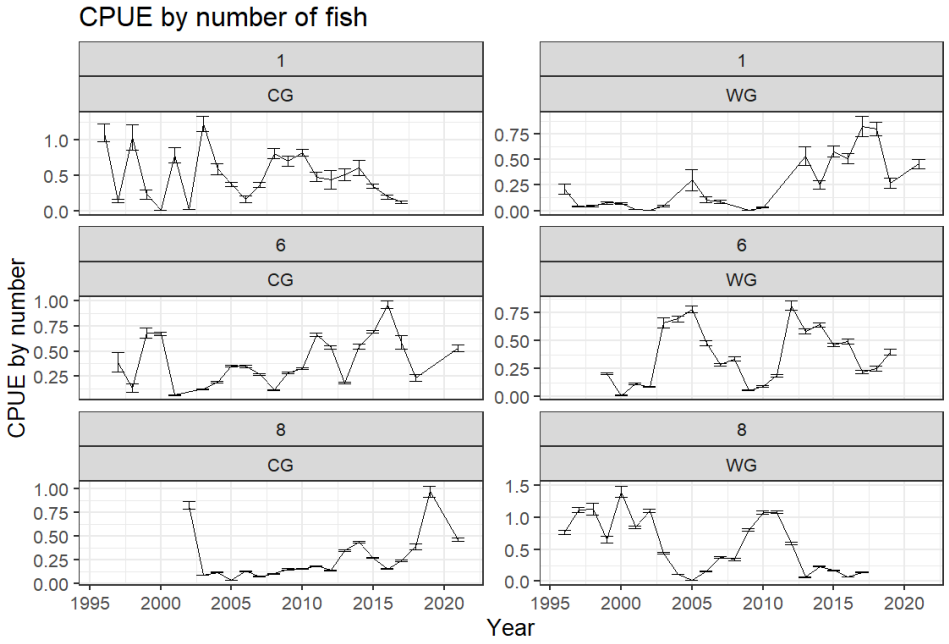
2021 GOA Pacific cod fishery performance

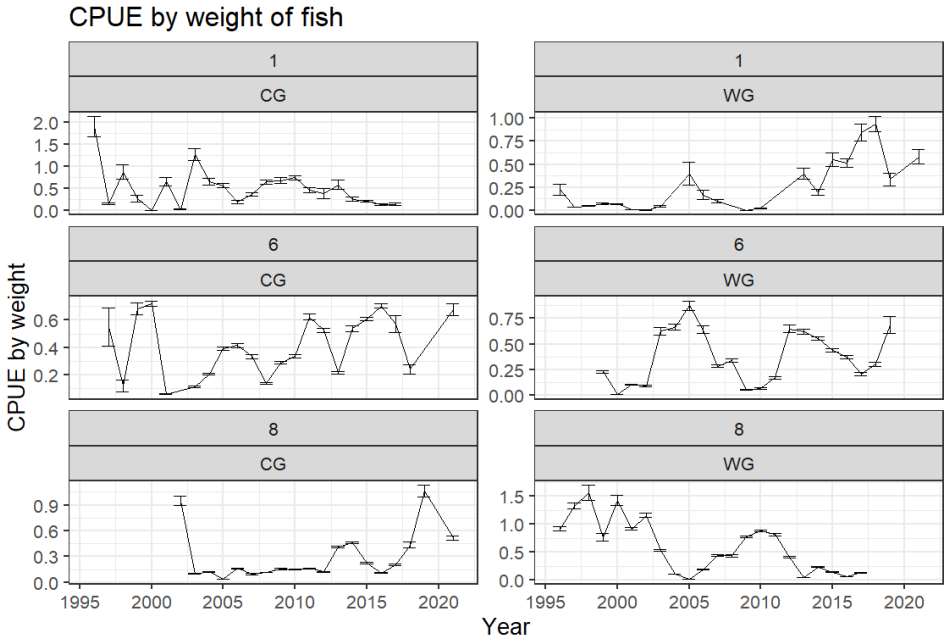




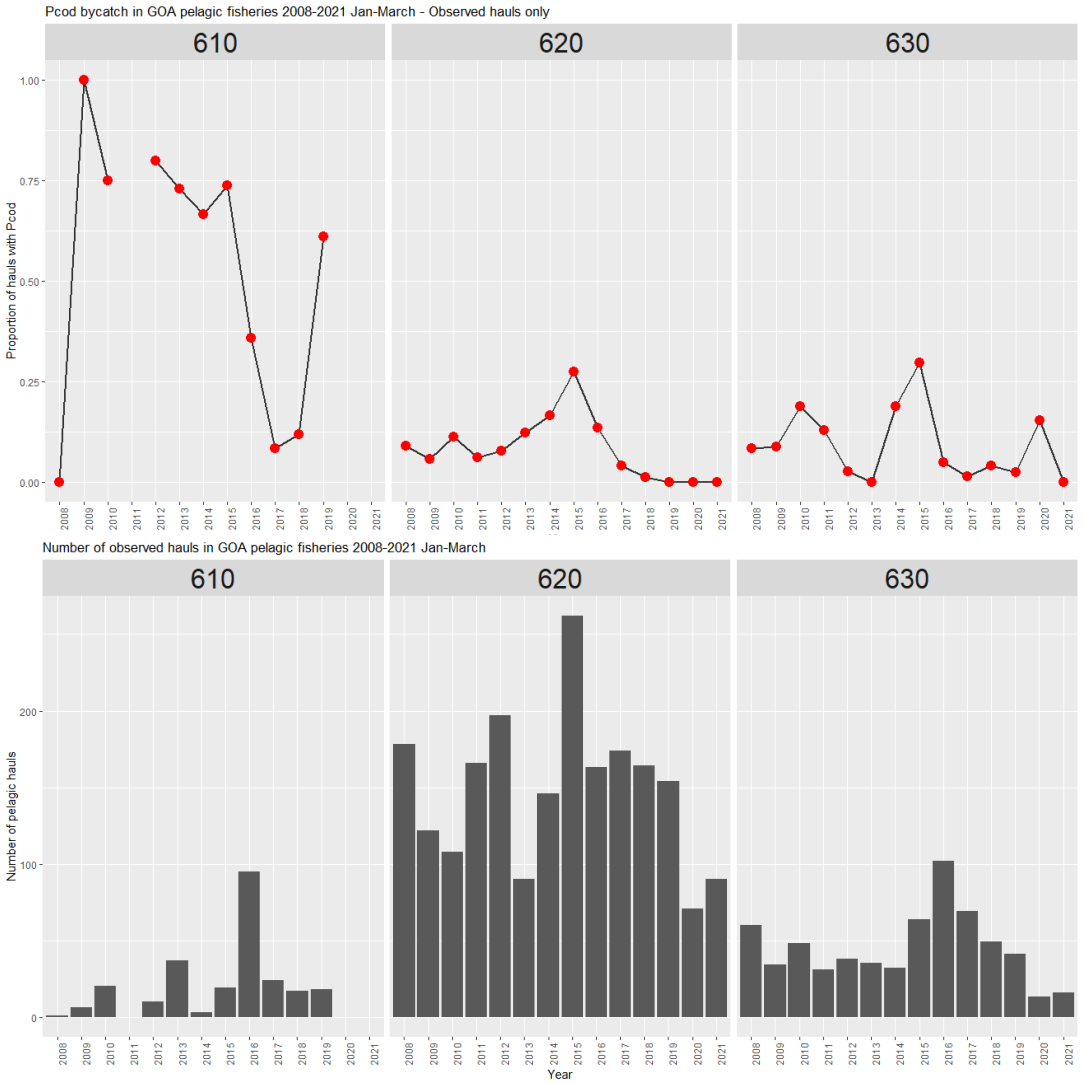


2021 GOA Pacific cod fishery CPUE by gear

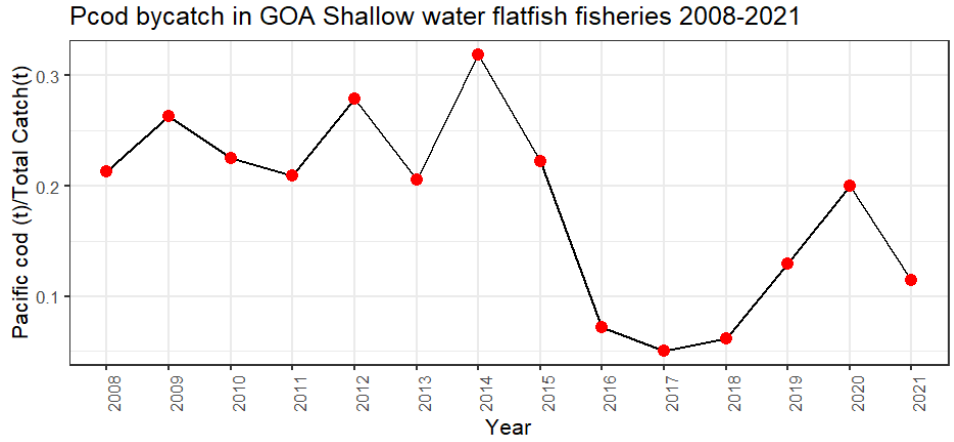


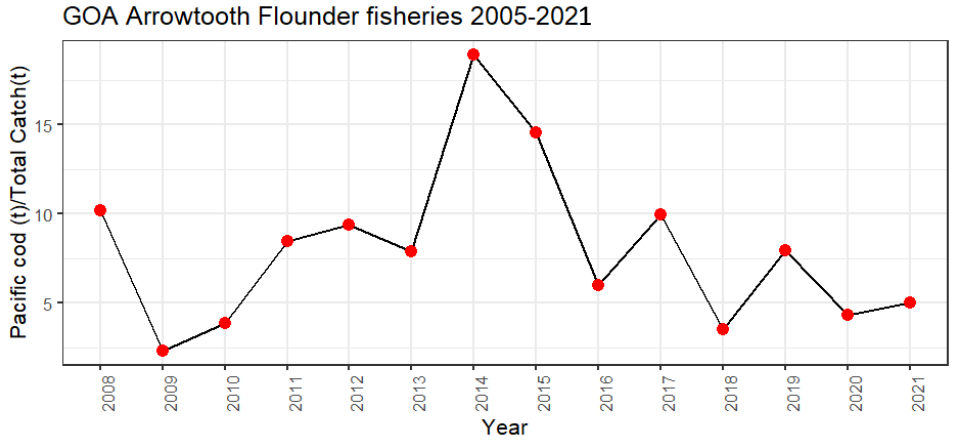


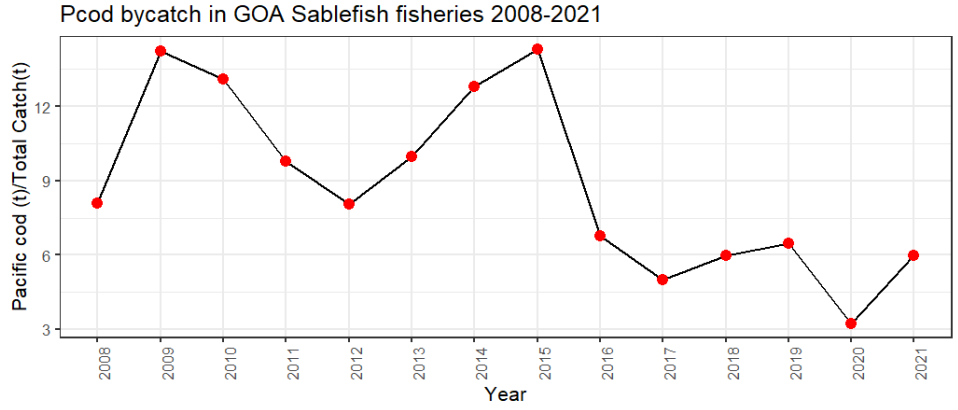
Bycatch of Pacific cod in the GOA pollock fishery

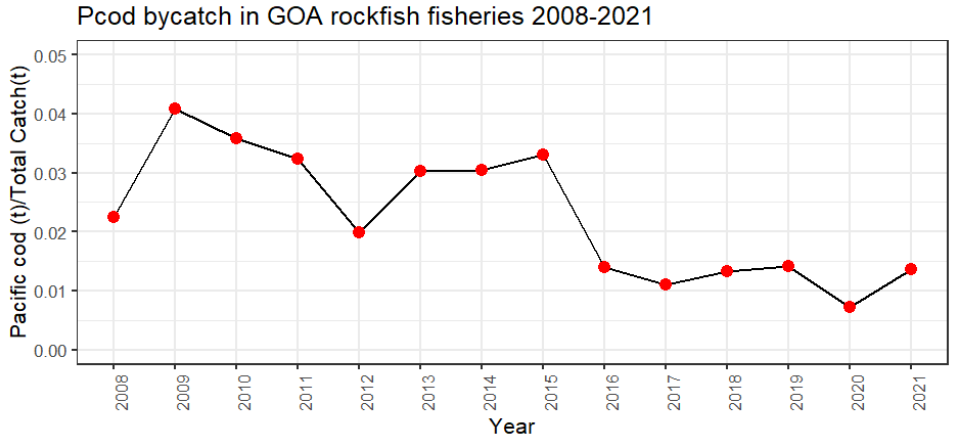


Bycatch of Pacific cod in other GOA fisheries

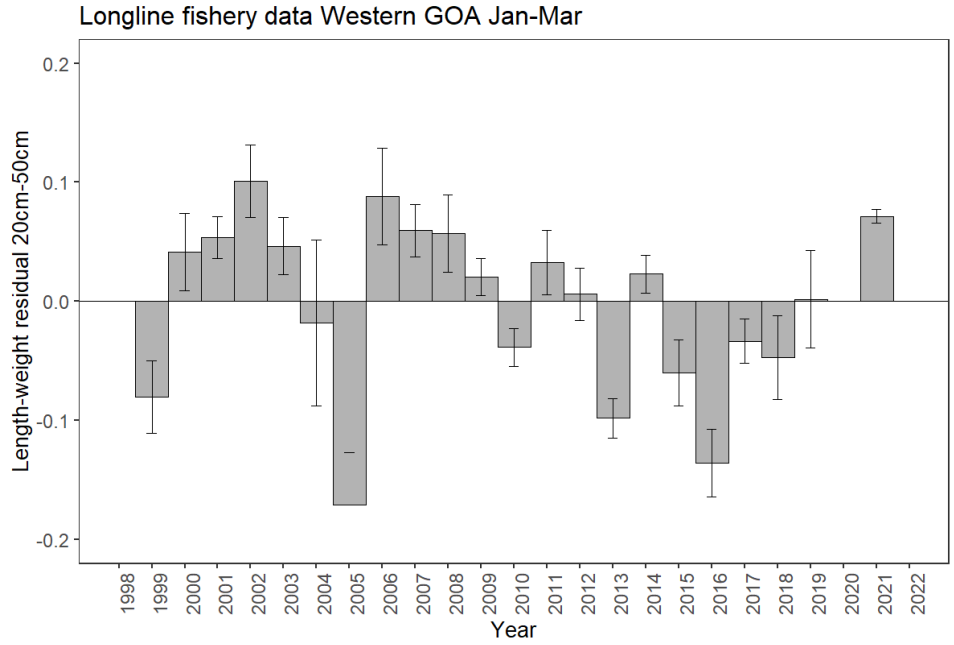


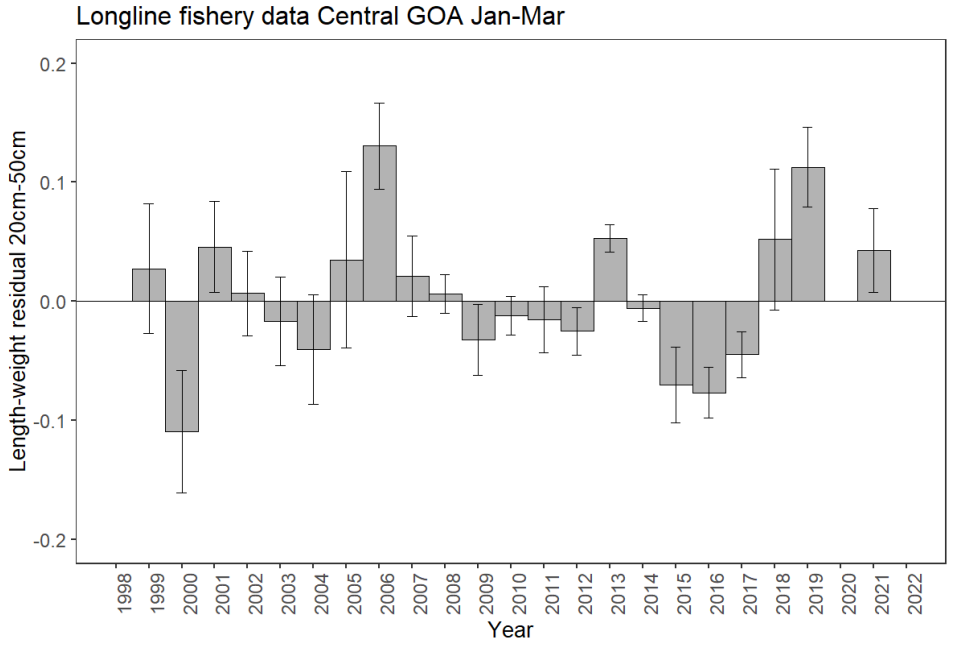


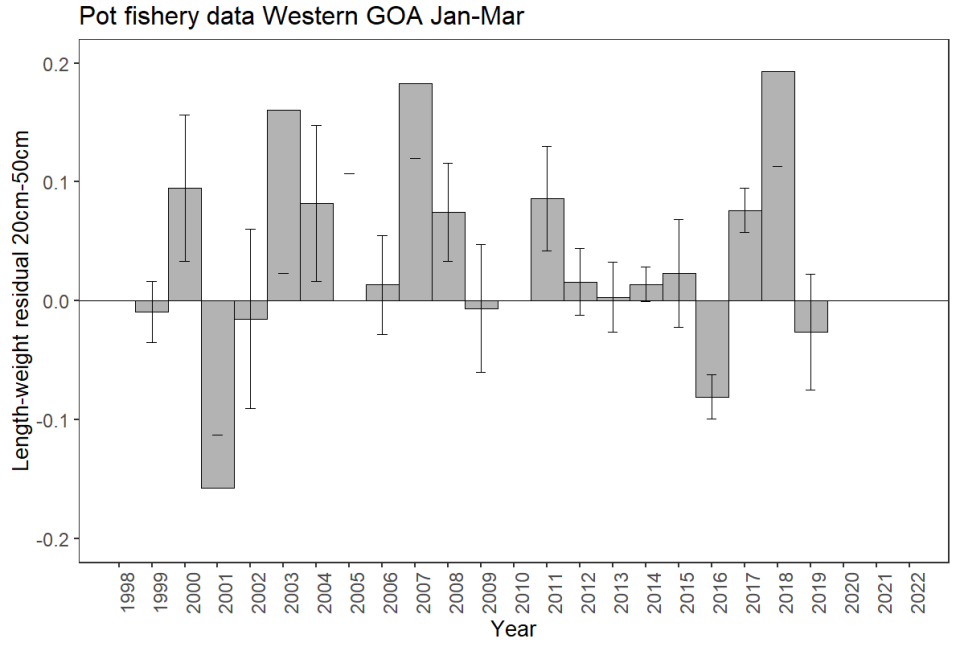


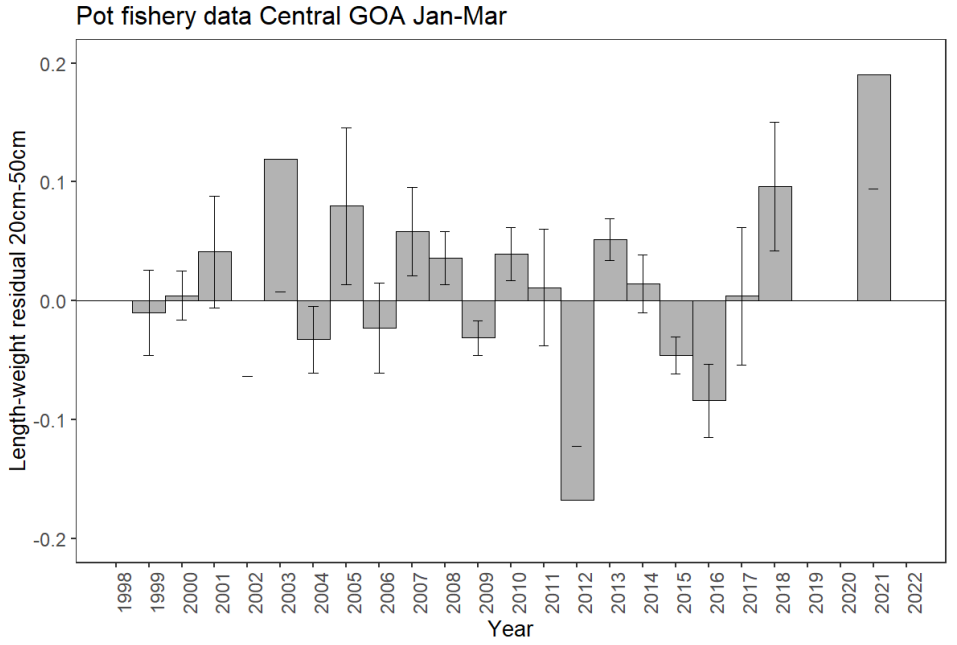


Pacific cod condition in the GOA longline and pot fisheries

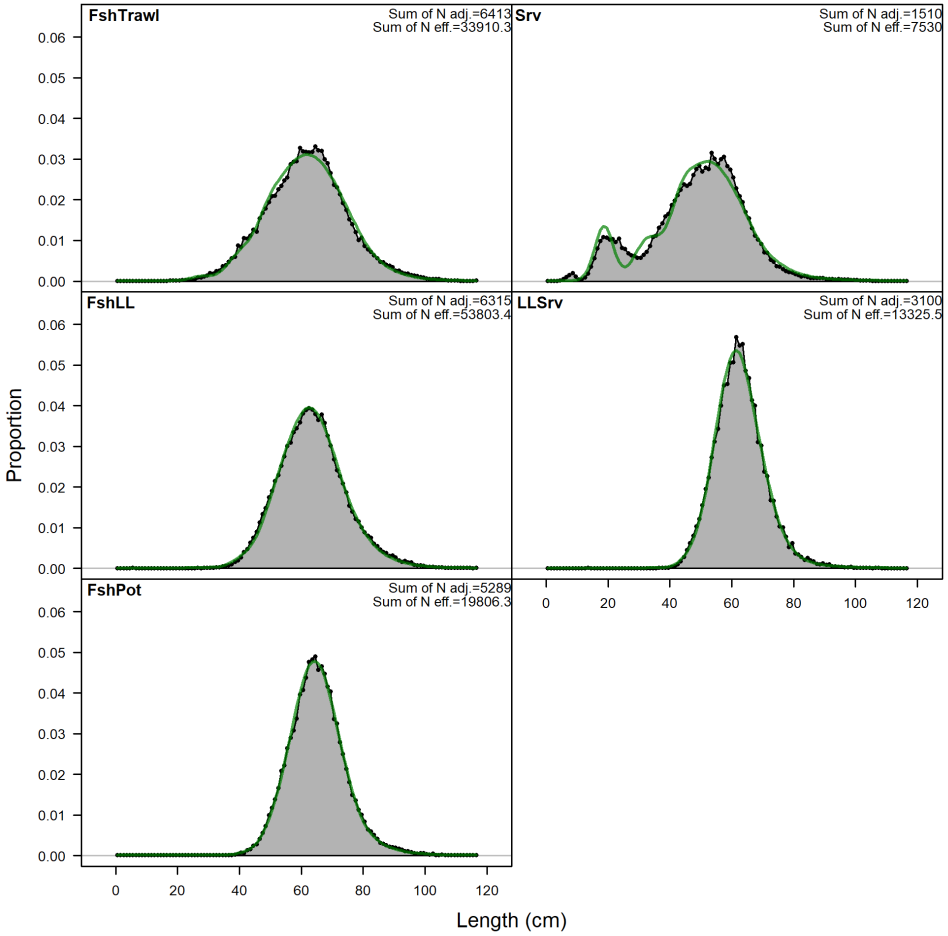




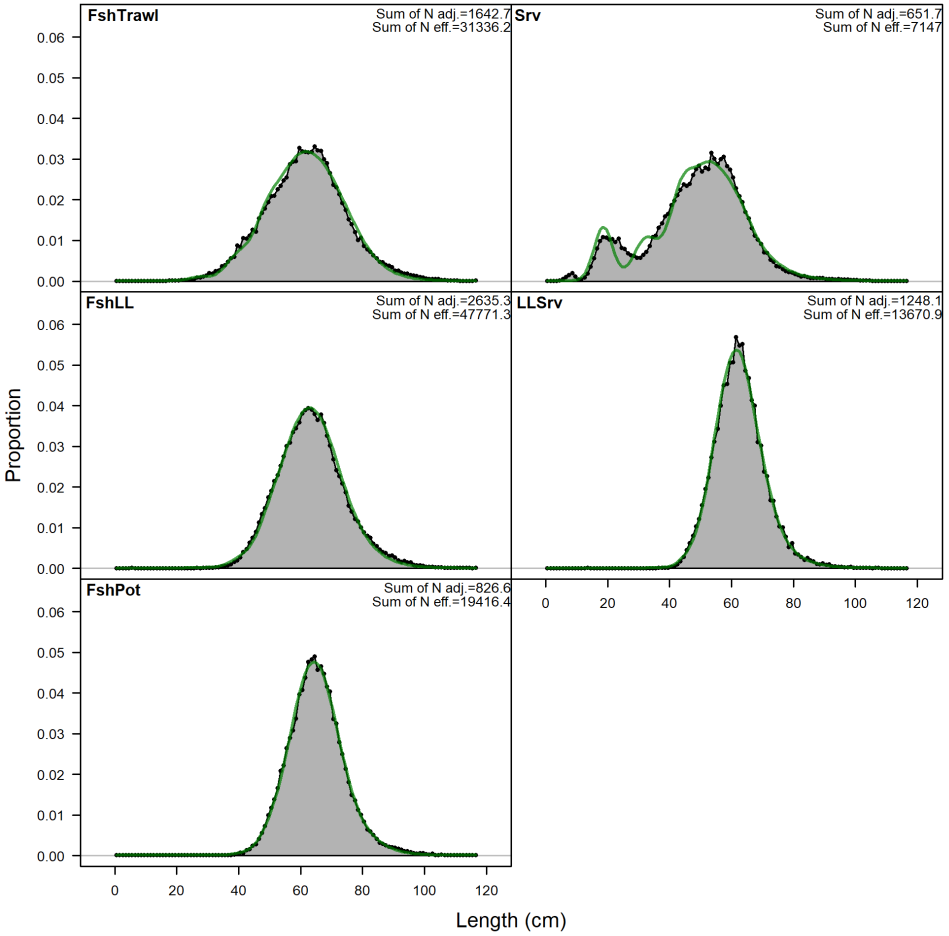


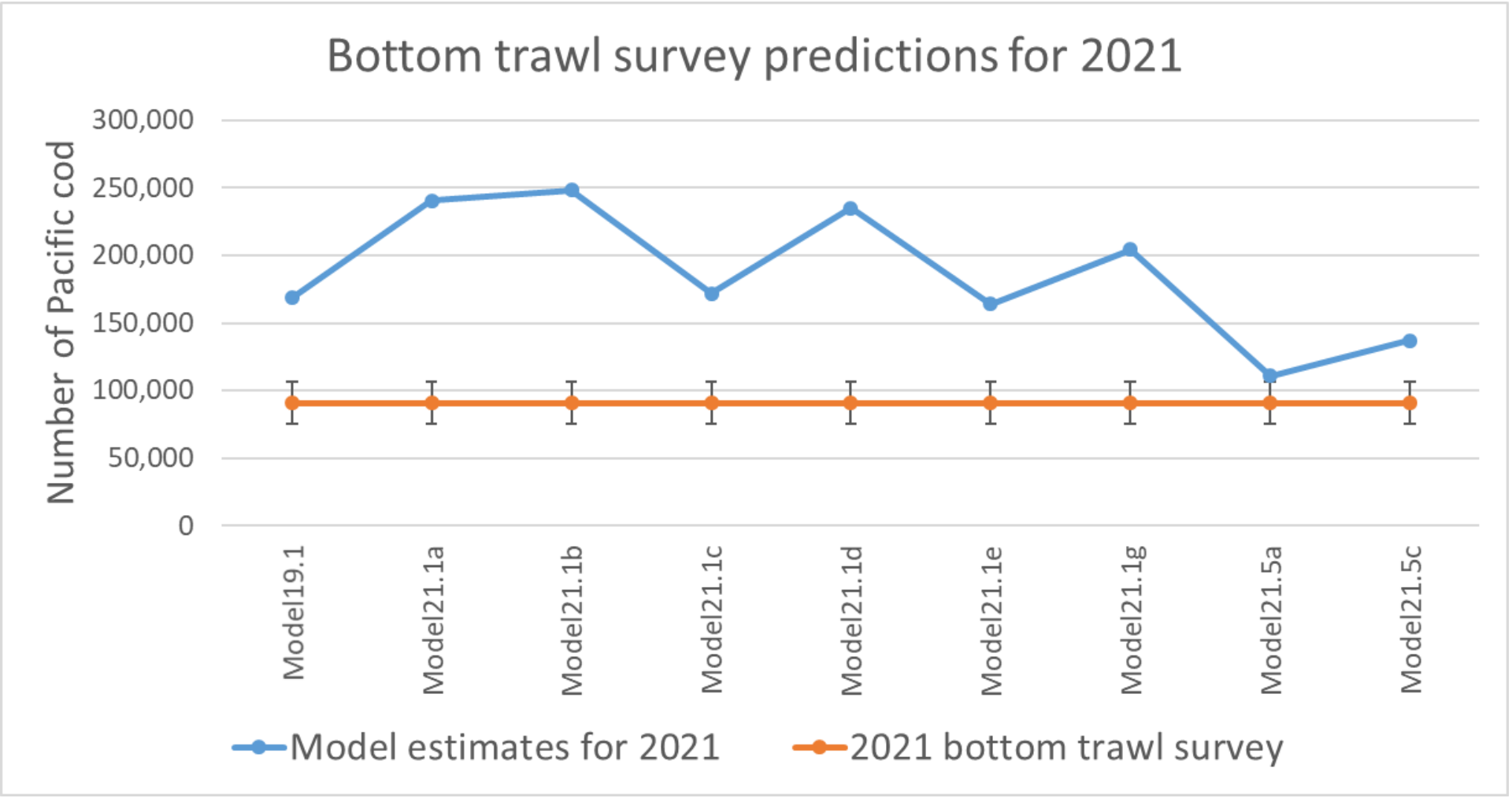


Model 19.1



Model 21.5c




Bottom trawl survey predictions for 2021
Number of Pacific cod
300,000
250,000
200,000
150,000
100,000
50,000
0
Model19.1
Model21.1a
Model21.1b
Model21.1c
Model21.1d
Model21.1e
Model21.1g
Model21.5a
Model21.5c
Model estimates for 2021
2021 bottom trawl survey