Update on work for EBS pollock assessment

Jim Ianelli
AFSC

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SSC Recommendations

- Ongoing genetic studies to determine the relationship between pollock in the NBS and EBS, and nearby GOA and AI regions.
- The 2019 BSAI GPT recommendation to revisit and evaluate the treatment of variance parameters within the assessment, with particular attention to those that are fixed.
- Efforts to quantify pollock movement and abundance along the US-Russia EEZ boundary.
- Geostatistical analyses of combined trawl and acoustic data to provide a single time-series, statistically accounting for the overlap between these data, for informing stock trends.

The SSC provides the following additional recommendations:

- Exploration of young-of-year pollock density and quality estimates from NMFS BASIS surveys to inform pollock recruitment.
- Consideration of whether the observed sensitivity in the SRR to prior specification should constitute an increased risk level specification within the assessment or population dynamicsrelated considerations. This could provide a clearer justification for the use of the Tier 3 calculation as the basis for harvest specification.
- Given the time-varying specification of fishery selectivity within the assessment model and the large change in the estimated 2021 FOFL between the 2019 and 2020 assessments, the authors should provide a retrospective comparison of the selectivity assumed in projections to that estimated with the addition of new data.
- Consideration of whether risk table specifications should account for the importance of pollock as a key forage species in the EBS ecosystem to better justify the use of a Tier 3 ABC determination as a precautionary measure for this Tier 1 stock.
- Given the apparent disappearance of the second and large mode in fishery length compositions as the 2020 B-season progressed, exploration of within-season spatial variation in fishery length composition would be useful in evaluating whether these larger pollock simply moved out of the area of fishing effort, or died as a result of natural or fishing mortality.

EBS pollock SSC/Plan Team recommendations

Ongoing genetic studies to determine the relationship between pollock in the NBS and EBS, and nearby GOA and AI regions.

- Results by the assessment deadline (sometime in October)
- lcWGS was conducted on 600 walleye pollock from throughout their range in Alaska
- Analyses are underway

The 2019 BSAI GPT recommendation to **revisit and evaluate the treatment of variance** parameters …

Alternative weightings of indices will be evalued in the coming assessment including variance specification

Efforts to quantify pollock movement and abundance along the US-Russia EEZ boundary.

- Upward looking sonar/ecosounder data evaluation continues, no new information to report on yet!
- Two papers in 2020…studying ways to incorporate factors

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ELSEVIER

Environmental impacts on walleye pollock (*Gadus chalcogrammus*) distribution across the Bering Sea shelf

Lisa B. Eisner[a,*], Yury I. Zuenko[b], Eugene O. Basyuk[b], Lyle L. Britt[a], Janet T. Duffy-Anderson[a], Stan Kotwicki[a], Carol Ladd[c], Wei Cheng[c,d]

[a] NOAA Alaska Fisheries Science Center, Seattle, WA, USA
[b] Russian Research Institute of Fisheries and Oceanography, Pacific Branch (TINRO), Vladivostok, Russia
[c] NOAA Pacific Marine Environmental Lab, Seattle, WA, USA
[d] University of Washington, Cooperative Institute for Climate, Ocean and Ecosystem Studies, Seattle, WA, USA

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RESEARCH ARTICLE

Journal of Applied Ecology BRITISH ECOLOGICAL SOCIETY

Estimating spatiotemporal availability of transboundary fishes to fishery-independent surveys

Cecilia A. O'Leary[1,5] | Stan Kotwicki[1] | Gerald R. Hoff[1] | James T. Thorson[2] | Vladimir V. Kulik[3] | James N. Ianelli[4] | Robert R. Lauth[1] | Daniel G. Nichol[1] | Jason Conner[1] | André E. Punt[5]

Geostatistical analyses of **combined trawl and acoustic data** to provide a single time-series…

Paper was published but no new combined data will be available until after the 2022 survey (summer) season for EBS trawl and acoustic data

ICES Journal of Marine Science

ICES CIEM International Council for the Exploration of the Sea Conseil International pour l'Exploration de la Mer

ICES Journal of Marine Science (2021), doi:10.1093/icesjms/fsab085

Incorporating vertical distribution in index standardization accounts for spatiotemporal availability to acoustic and bottom trawl gear for semi-pelagic species

Cole C. Monnahan [1,2]*, James T. Thorson [1], Stan Kotwicki [1], Nathan Lauffenburger[1], James N. Ianelli[1], and Andre E. Punt [2]

[1]*Alaska Fisheries Science Center, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Seattle, WA 98115, USA*
[2]*School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA 98195, USA*

**Corresponding author: e-mail: cole.monnahan@noaa.gov.*

Monnahan, C. C., Thorson, J. T., Kotwicki, S., Lauffenburger, N., Ianelli, J. N., and Punt, A. E. Incorporating vertical distribution in index standardization accounts for spatiotemporal availability to acoustic and bottom trawl gear for semi-pelagic species. – ICES Journal of Marine Science, doi:10.1093/icesjms/fsab085.

Received 12 August 2020; revised 7 April 2021; accepted 12 April 2021.

Exploration of young-of-year pollock density and quality estimates from NMFS BASIS surveys to inform pollock recruitment

- No further work on including these data has been developed
- Yasumiishi’s copepod index examined

EBS pollock SSC/Plan Team recommendations

Consideration of whether the observed sensitivity in the SRR to prior specification should constitute an increased risk level specification within the assessment or population dynamics related considerations. This could provide a clearer justification for the use of the Tier 3 calculation as the basis for harvest specification.

- Alternative impacts as specified through ACLIM research activities is underway. No conclusions as of yet…

Given the time-varying specification of fishery selectivity within the assessment model and the large change in the estimated 2021 FOFL between the 2019 and 2020 assessments, the authors should provide a retrospective comparison of the selectivity assumed in projections to that estimated with the addition of new data.

- Further study supports the inclination to make 2021 ABC recommendations (below max(ABC)) given the tendency towards smaller (younger) pollock in 2021
- Alternative diagnostics on how selectivity has changed retrospectively will be attempted

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EBS pollock SSC/Plan Team recommendations

Consideration of whether risk table specifications should account for the importance of pollock as **a key forage species** in the EBS ecosystem to better justify the use of a Tier 3 ABC determination as a precautionary measure for this Tier 1 stock.

Work on this limited

CEATTLE notes importance as prey

Seeking further advice!

EBS pollock SSC/Plan Team recommendations

Given the apparent disappearance of the second and large mode in fishery length compositions as the 2020 B-season progressed, exploration of within-season spatial variation in fishery length composition would be useful in evaluating whether these larger pollock simply moved out of the area of fishing effort, or died as a result of natural or fishing mortality.

- Patterns of 2020 and 2021 size composition suggest that the larger (older) age-classes are less abundant in the catch
- Resolution on shifts in the relative year-class strengths are affected vs new recruitment is an important area of research/support given available data

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Hypotheses being considered as part of ACLIM project

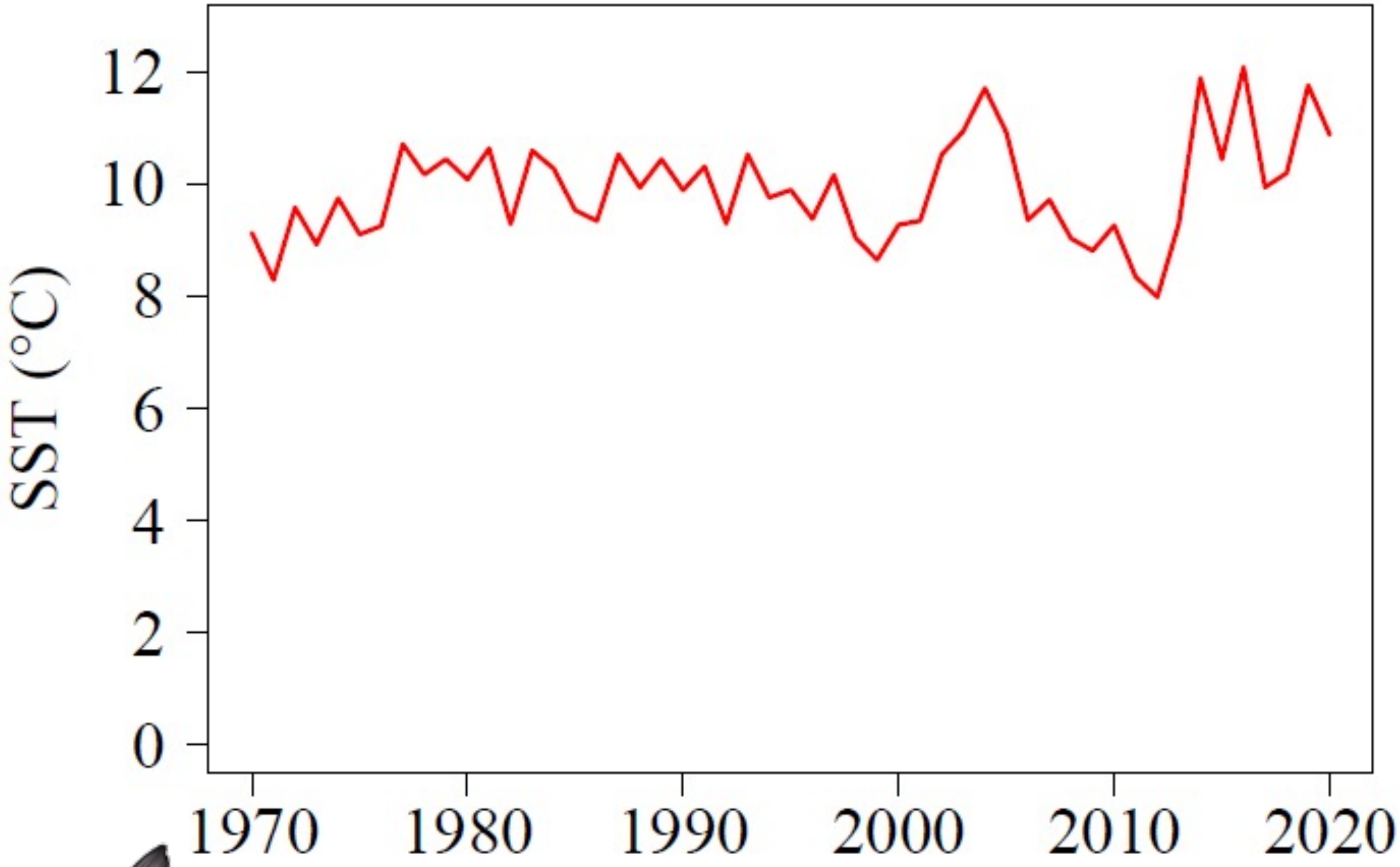
Some being considered for EBS pollock

- Recruitment is related to temperature
- Survival to age 3 related to large copepods
- Natural mortality can be drawn reasonably from CEATTLE
- Growth increment is related to temperature

Recruitment is related to temperature

Temperature moderated recruitment

Hindcast eastern Bering Sea summer sea surface temperature



From Bering Sea high resolution 10K regional ocean model

(Kearney et al. 2020. Geosci. Model Dev., 13: 597–650)

Courtesy Paul Spencer

Temperature moderated recruitment

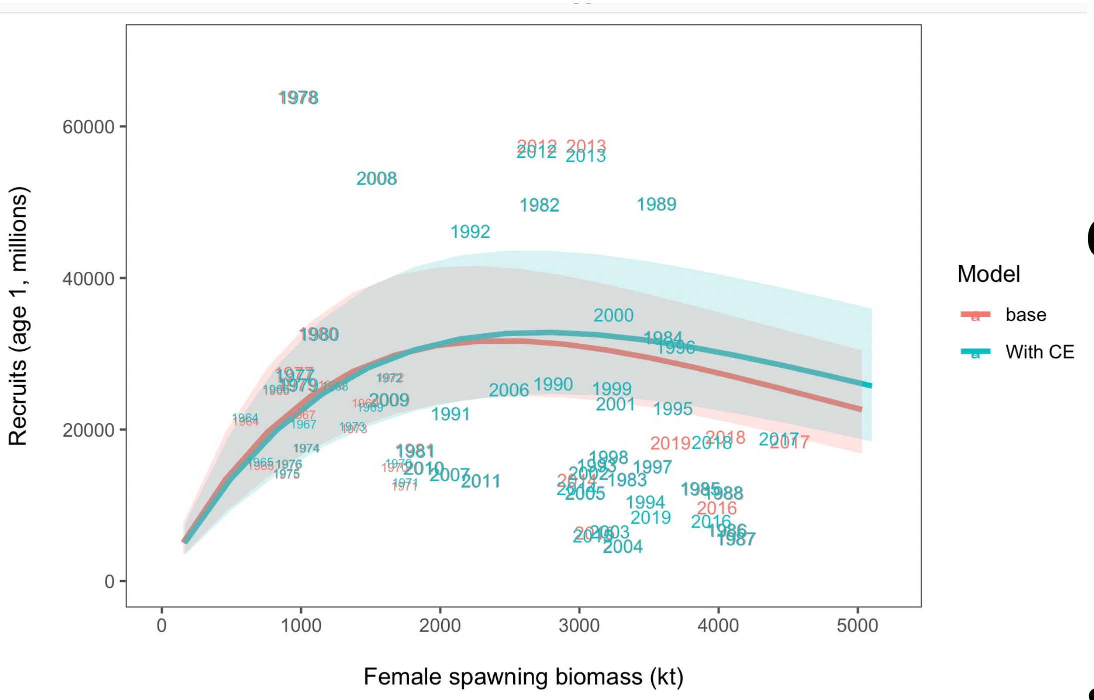
Hypothesis:	Support:
• Pollock recruitment declines at high temperatures	• Mueter et al. (2011) • Spencer et al. (2016)

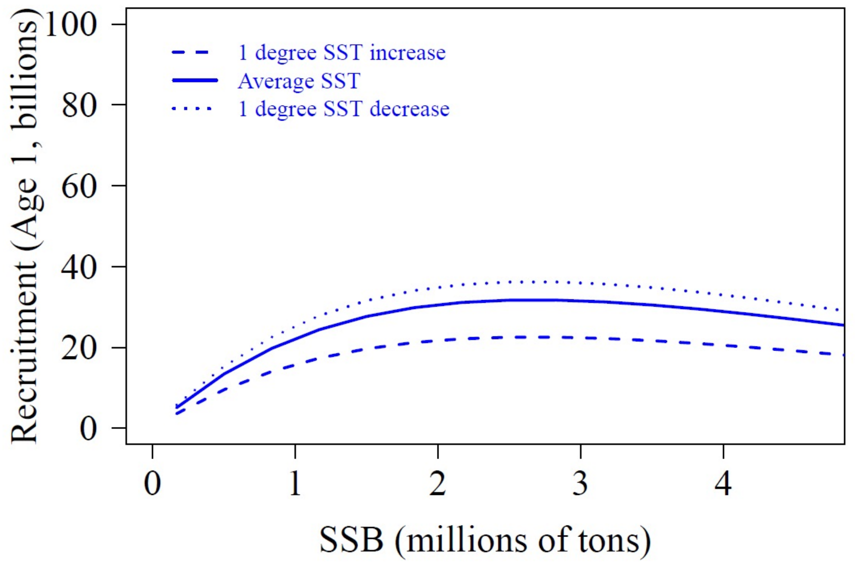
Implementation within pollock assessment model:

$$R_t = f(SSB_{t-a})e^{\propto + x_1 SST_{t-a} + x_2 SST_{t-a}^2} e^{\varepsilon_t}$$

Courtesy Paul Spencer

Stock-recruit relationship





Climate-enhanced model

- Minor impact on recruits and spawning biomass
- Due to extensive age composition data
- Curves similar (at average temperature)

- However, as temperature increases, the expected recruitment substantially decreases

- This would affect estimated reference points and harvest recommendations.

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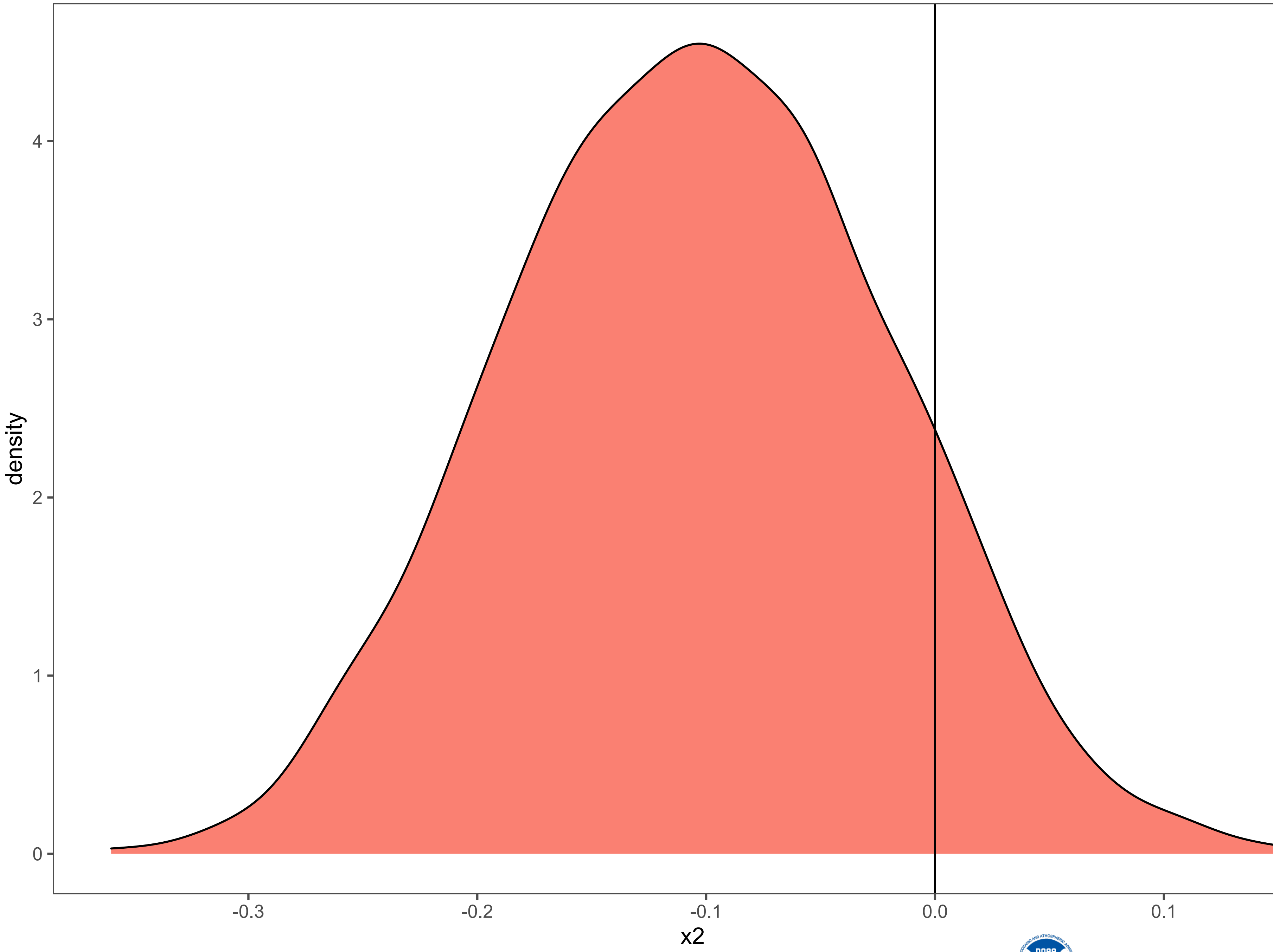
Testing coefficient influence



Courtesy Paul Spencer

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Survival to age 3 related to large copepods

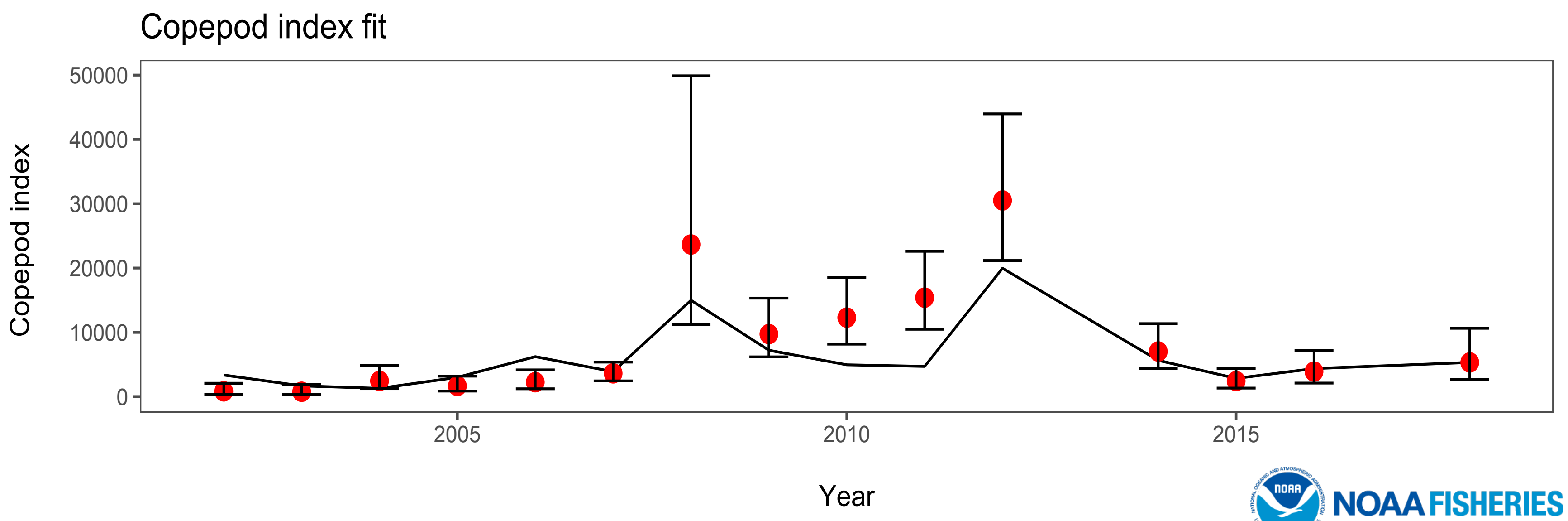
Copepod index affects survival to age 3

Hypothesis:	Support:
• Pollock age 0 survival affected by large zooplankton abundance	• Yasumiishi, Eisner, Kimmel (ref)

Implementation within pollock assessment model:

As a form of "data" related to age 3 model abundance

As yet, lacks linkage within assessment to mortality



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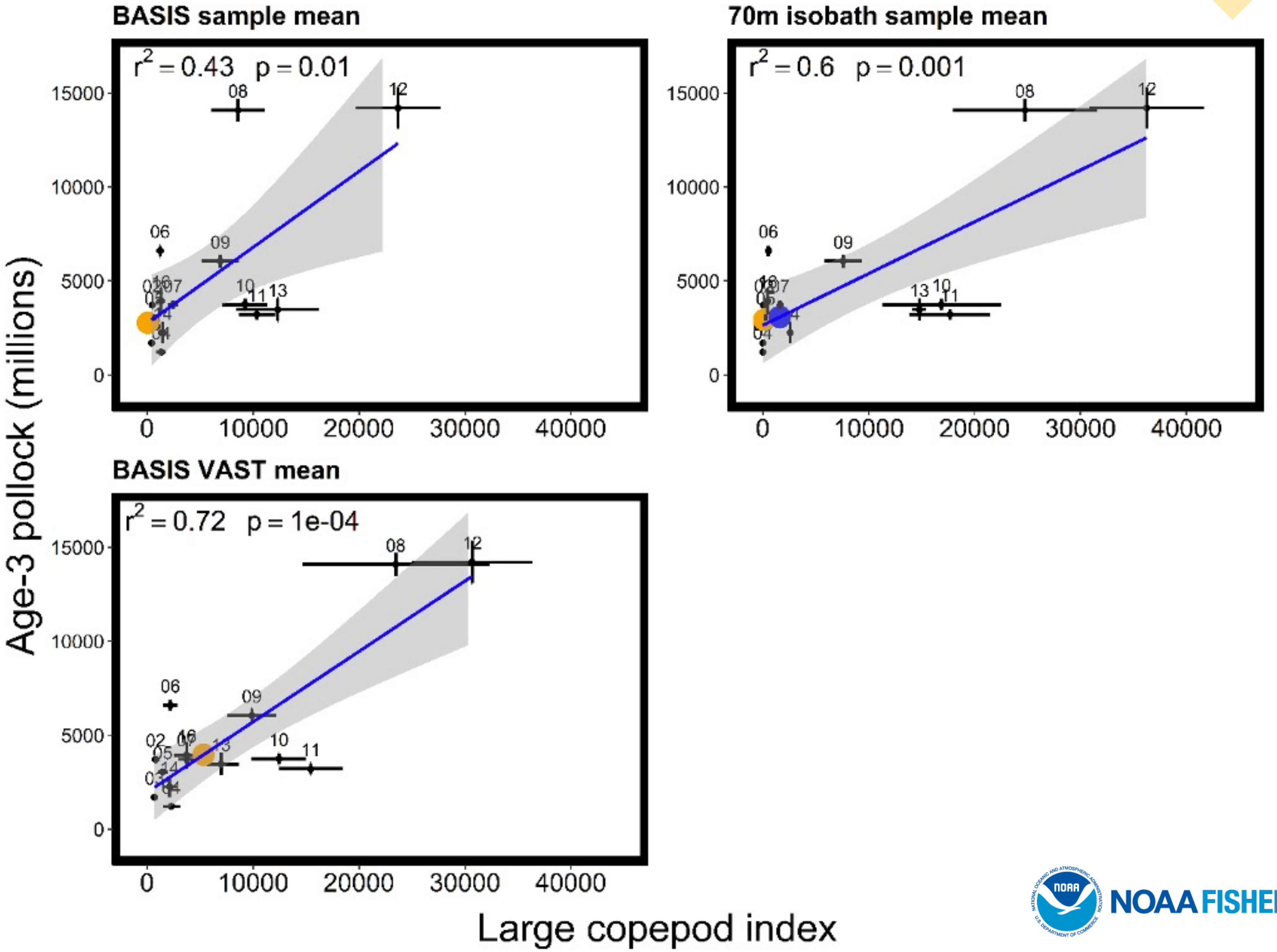
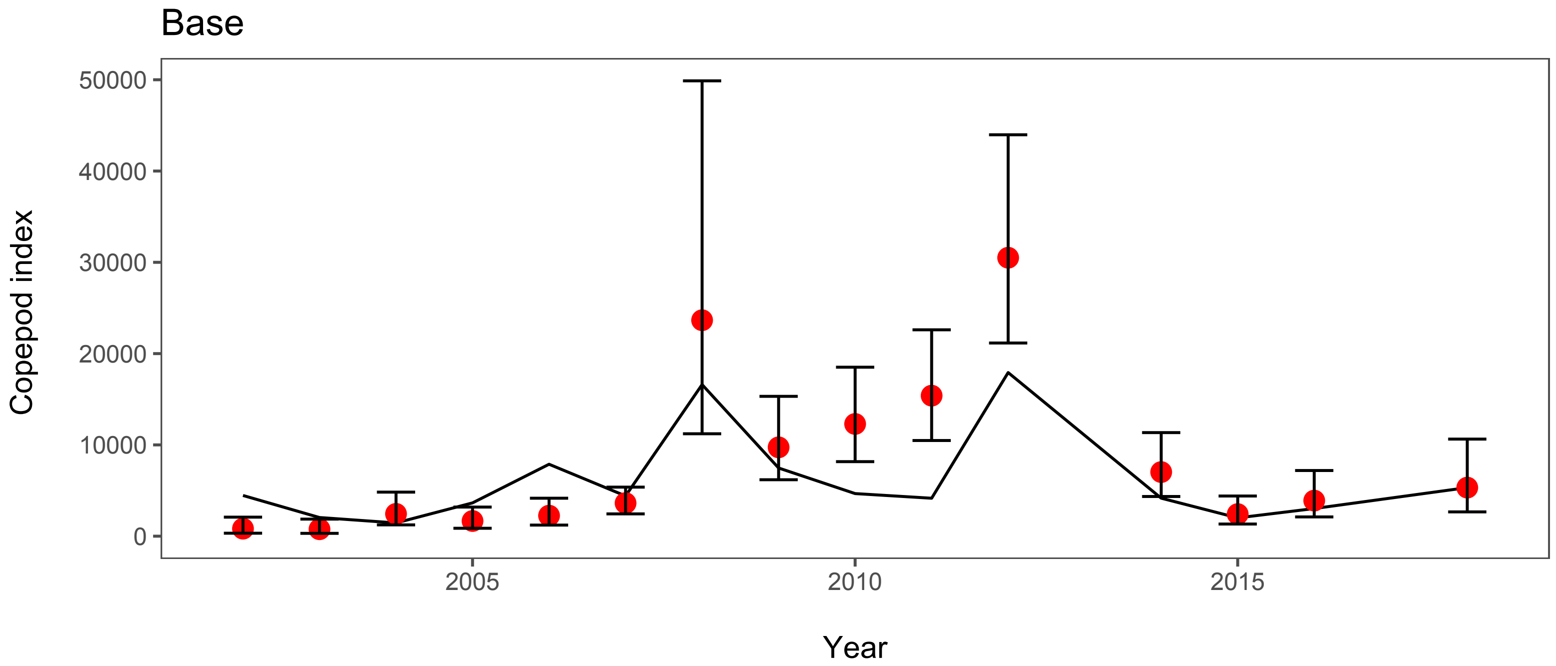
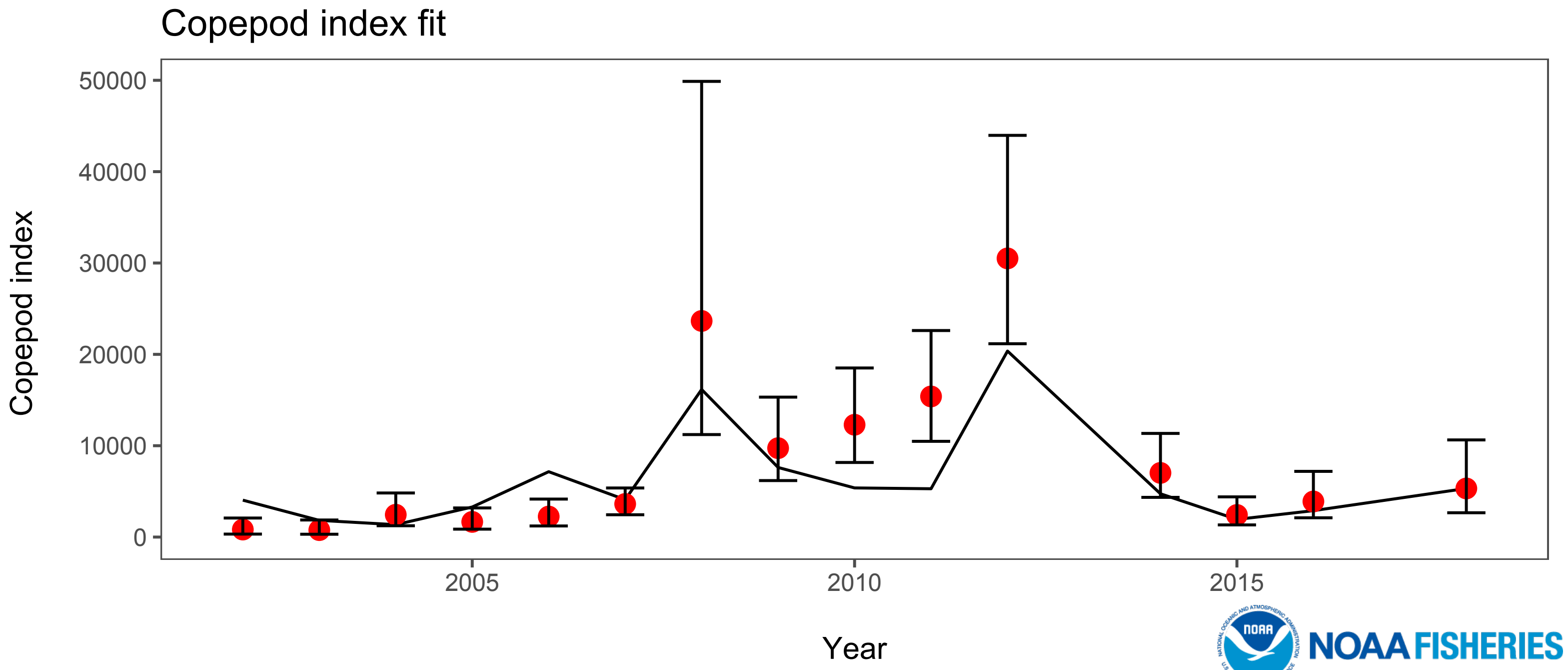
Large copepod for age-0 pollock

From Yasumiishi, Eisner, and Kimmel

- Index sums *Calanus marshallae/glacialis* (copepodite stage 3 (C3)-adult), *Neocalanus spp*. (C3-adult), and *Metridia pacifica* (C4-adult),







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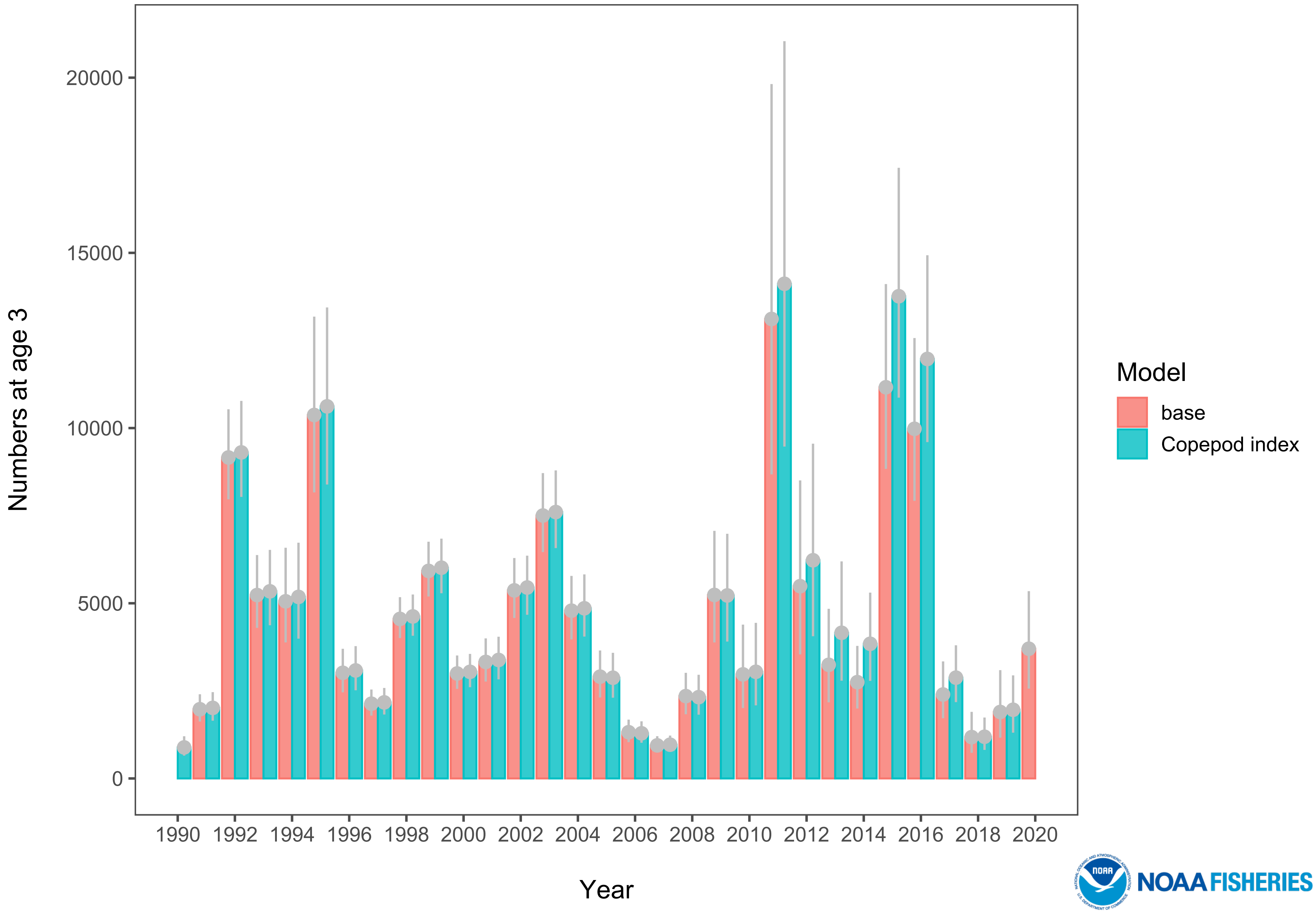
Copepod index on age 3 abundance



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Natural mortality can be drawn reasonably from CEATTLE

Apply CEATTLE results for natural mortality

Hypothesis:	Support:
• Pollock mortality varies over time and age due to predator diets	• Holsman et al. (various)

Implementation within pollock assessment model:

Matrix of natural mortality (years and ages) pre-specified

Does it improve fits to the assessment data?

CEATTLE

- M matrix

Year x age

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1978	2.24	0.42	0.35	0.32	0.31	0.31	0.30	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30
1979	2.45	0.41	0.34	0.32	0.30	0.31	0.30	0.30	0.31	0.30	0.30	0.30	0.30	0.30	0.30
1980	2.66	0.43	0.35	0.32	0.31	0.31	0.31	0.30	0.31	0.30	0.30	0.30	0.30	0.30	0.30
1981	2.87	0.46	0.36	0.33	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30
1982	2.83	0.46	0.36	0.33	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.31	0.31	0.31	0.31
1983	3.19	0.49	0.38	0.34	0.31	0.31	0.31	0.31	0.32	0.30	0.30	0.31	0.31	0.31	0.31
1984	3.18	0.48	0.37	0.33	0.31	0.31	0.31	0.31	0.32	0.30	0.30	0.31	0.31	0.31	0.31
1985	3.27	0.49	0.37	0.34	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30
1986	3.47	0.52	0.39	0.34	0.31	0.31	0.31	0.31	0.31	0.30	0.31	0.31	0.31	0.31	0.31
1987	3.35	0.53	0.39	0.34	0.31	0.31	0.31	0.31	0.31	0.30	0.31	0.31	0.31	0.31	0.31
1988	3.31	0.56	0.41	0.35	0.31	0.31	0.31	0.31	0.32	0.30	0.31	0.31	0.31	0.31	0.31
1989	2.83	0.49	0.38	0.34	0.31	0.31	0.31	0.31	0.32	0.30	0.30	0.31	0.31	0.31	0.31
1990	2.86	0.46	0.37	0.33	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.31	0.31	0.31	0.31
1991	2.90	0.44	0.35	0.33	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30
1992	2.88	0.43	0.35	0.32	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30
1993	3.13	0.45	0.35	0.32	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30
1994	3.20	0.47	0.36	0.33	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.31	0.31	0.31	0.31
1995	3.01	0.47	0.36	0.33	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.31	0.31	0.31	0.31
1996	2.84	0.46	0.36	0.33	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30
1997	3.12	0.48	0.37	0.33	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.31	0.31	0.31	0.31
1998	2.85	0.45	0.36	0.32	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30
1999	2.93	0.46	0.36	0.33	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30
2000	2.79	0.45	0.36	0.32	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30
2001	2.91	0.45	0.36	0.32	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30
2002	3.04	0.46	0.36	0.33	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30
2003	3.05	0.48	0.37	0.33	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30
2004	3.08	0.51	0.38	0.33	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.31	0.31	0.31	0.31
2005	3.01	0.50	0.38	0.33	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.31	0.31	0.31	0.31
2006	2.76	0.47	0.37	0.33	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30
2007	2.81	0.47	0.36	0.33	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30
2008	2.61	0.45	0.36	0.32	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30
2009	2.83	0.46	0.36	0.32	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30
2010	2.96	0.46	0.36	0.33	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30
2011	2.92	0.47	0.36	0.33	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30
2012	2.74	0.45	0.36	0.32	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30
2013	3.01	0.46	0.36	0.32	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30
2014	3.42	0.47	0.36	0.33	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30
2015	3.72	0.52	0.38	0.33	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.31	0.31	0.31	0.31
2016	3.21	0.51	0.38	0.33	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.31	0.31	0.31	0.31
2017	3.19	0.51	0.39	0.34	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.31	0.31	0.31	0.31
2018	2.98	0.48	0.37	0.33	0.31	0.31	0.31	0.31	0.31	0.30	0.30	[illegible]	0.31	0.31	0.31
2019	2.98	0.48	0.37	0.33	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.31	0.31	0.31	0.31

Draft

A suite of pollock models with some climate enhancements

Models crossed w/ some indicators

<table>
<tr><th>Name</th><th>SST Climate enhanced recruit</th><th>M-matrix from CEATTLE</th><th>Copepod index</th></tr>
<tr><td>base</td><td></td><td></td><td></td></tr>
<tr><td>With CE</td><td style="background:#ED7D31"></td><td></td><td></td></tr>
<tr><td>CEATTLE M</td><td></td><td style="background:#ED7D31"></td><td></td></tr>
<tr><td>CEATTLE M CE</td><td style="background:#ED7D31"></td><td style="background:#ED7D31"></td><td></td></tr>
<tr><td>Copepod index</td><td></td><td></td><td style="background:#ED7D31"></td></tr>
<tr><td>Copepod index+ CE</td><td style="background:#ED7D31"></td><td></td><td style="background:#ED7D31"></td></tr>
<tr><td>Copepod index + CE + M</td><td style="background:#ED7D31"></td><td style="background:#ED7D31"></td><td style="background:#ED7D31"></td></tr>
</table>

Fits to indices, root mean squared errors

Component	base	With CE	CEATTLE_M	CEATTLE_M_CE	Copepod index	Cope+ CE	Cope+CE +CE_M
RMSE BTS	0.16	0.16	0.16	0.16	0.16	0.16	0.16
RMSE ATS	0.22	0.22	0.22	0.22	0.23	0.23	0.24
RMSE AVO	0.2	0.2	0.27	0.2	0.25	0.25	0.32
RMSE CPUE	0.09	0.08	0.08	0.08	0.09	0.08	0.08

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Negative log-posterior (NLL) by model (columns)

Component	base	With CE	CEATTLE_M	CEATTLE_M_CE	Copepod index	Cope+ CE	Cope+CE +CE_M
BTS NLL	25.7	25.8	26.8	25.8	25.5	25.5	26.6
ATS NLL	8.7	8.5	8.2	8.5	11.6	11.4	11.5
AVO NLL	10.1	9.7	9.5	9.7	10.3	9.9	9.6
Copepod NLL	0.0	0.0	0.0	0.0	48.0	48.0	46.5
Fish Age NLL	148.8	148.9	150.3	148.9	147.5	147.8	149.0
BTS Age NLL	146.4	147.1	145.8	147.1	147.5	148.0	147.4
ATS Age NLL	25.0	24.7	25.4	24.7	24.5	24.4	24.6
Data NLL	380.1	379.8	389.3	379.8	433.9	433.8	440.2
Total NLL	593.3	588.0	626.4	588.0	649.2	644.0	679.6

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Negative log-posterior (NLL) by model (columns)

Relative to “Base” (but w/o copepod in totals)

Component	base	With CE	CEATTLE_M	CEATTLE_M_CE	Copepod index	Cope+ CE	Cope+CE +CE_M
BTS NLL	0.0	0.1	1.1	0.1	-0.2	-0.2	0.9
ATS NLL	0.0	-0.2	-0.4	-0.2	3.0	2.8	2.8
AVO NLL	0.0	-0.4	-0.6	-0.4	0.2	-0.2	-0.5
Copepod NLL	0.0	0.0	0.0	0.0	48.0	48.0	46.5
Fish Age NLL	0.0	0.1	1.4	0.1	-1.3	-1.0	0.1
BTS Age NLL	0.0	0.6	-0.6	0.6	1.1	1.6	1.0
ATS Age NLL	0.0	-0.3	0.4	-0.3	-0.5	-0.6	-0.4
Data NLL	0.0	-0.3	9.2	-0.3	5.8	5.7	13.6
Total NLL	0.0	-5.3	33.2	-5.3	7.9	2.8	39.9

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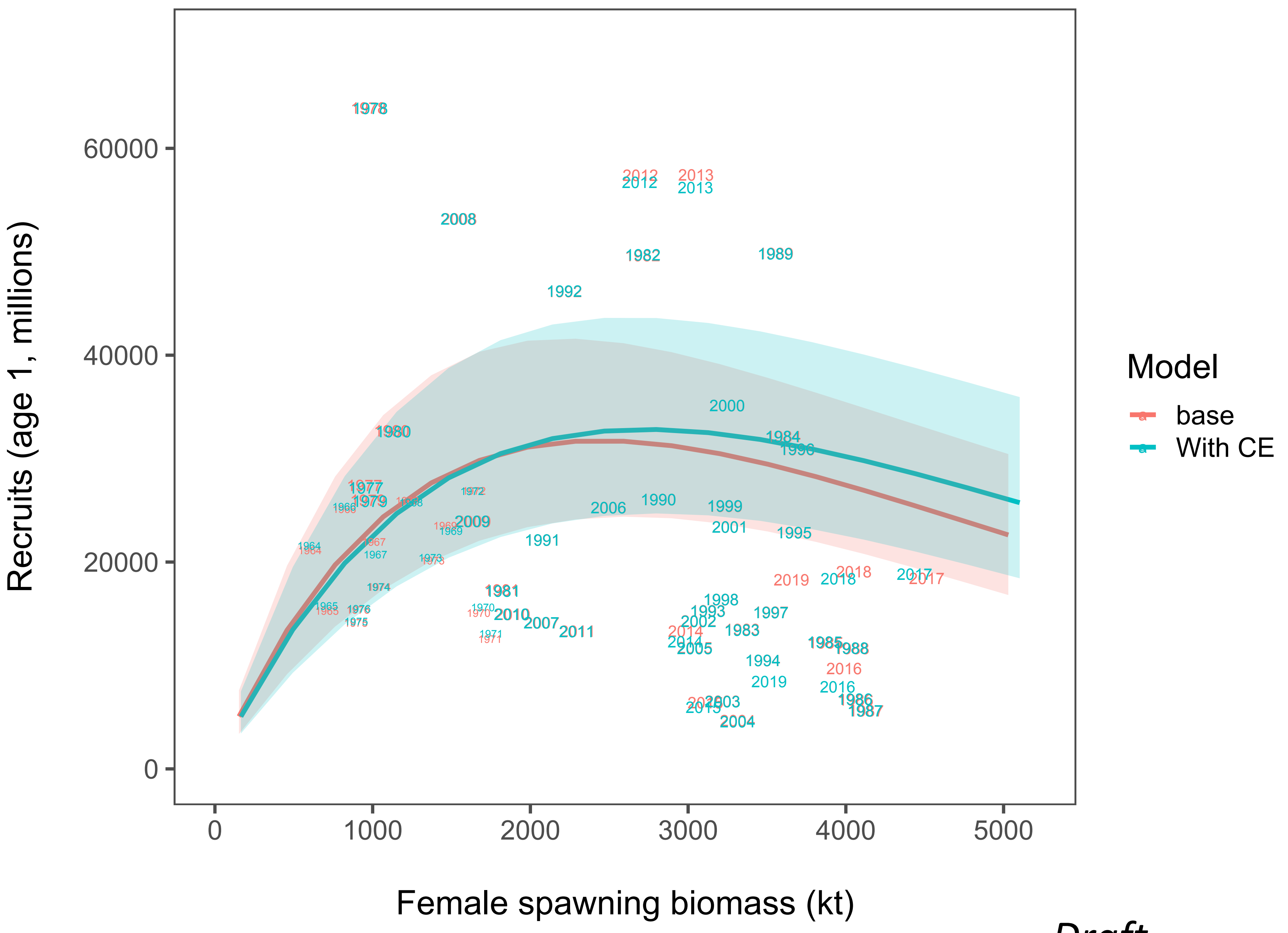
Comparing these model configurations

- Stock-recruit relationship plots



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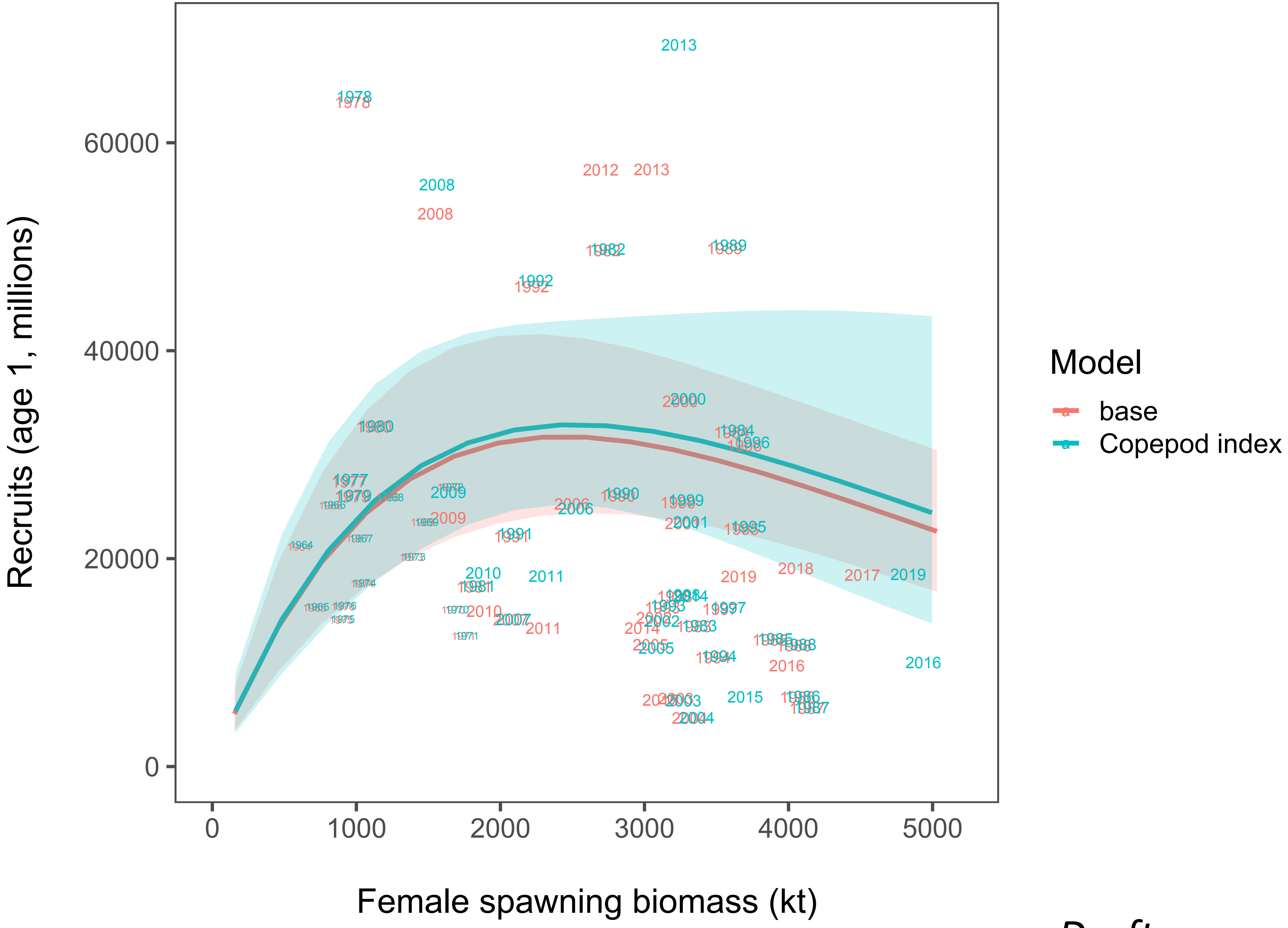

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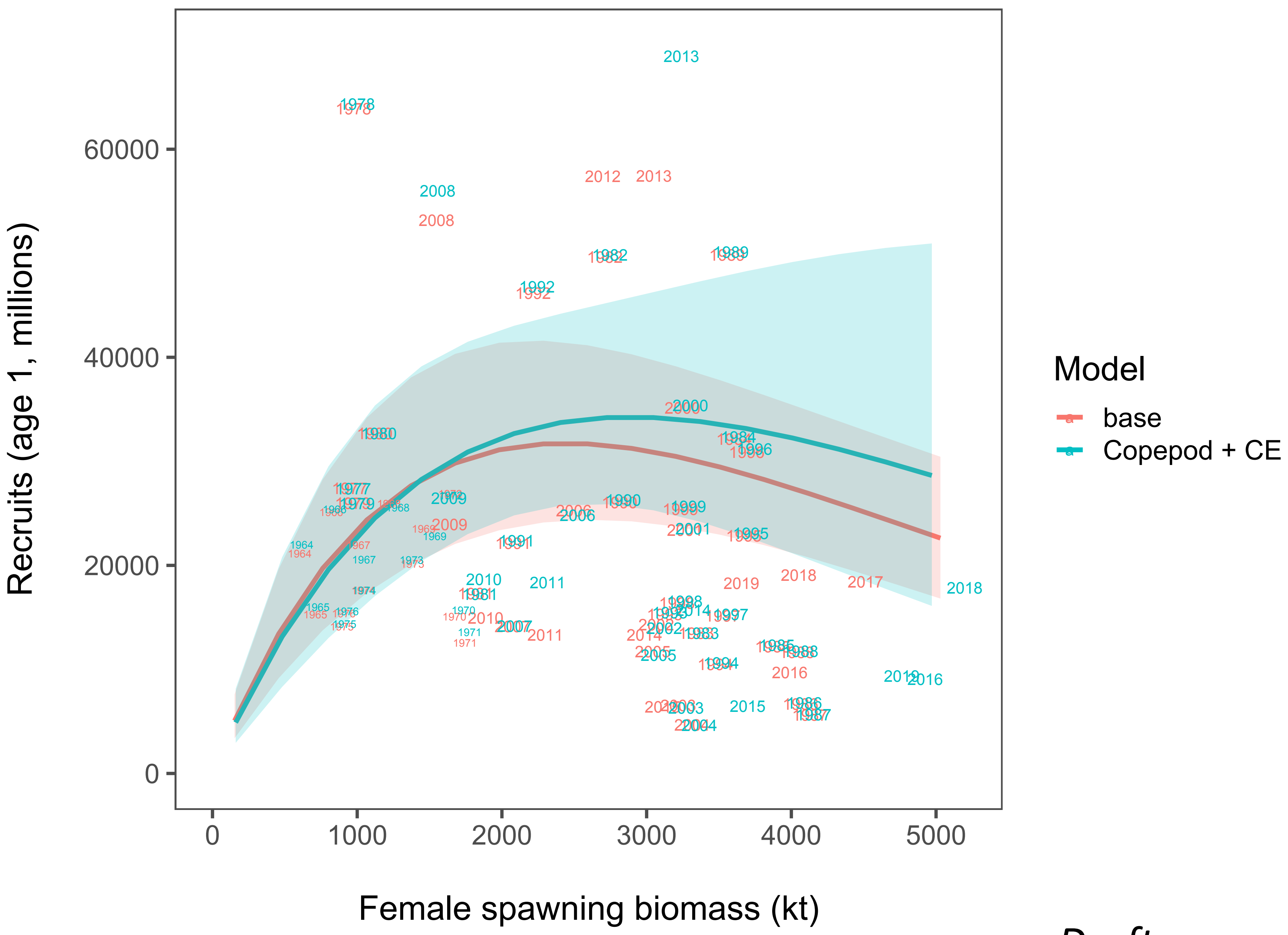
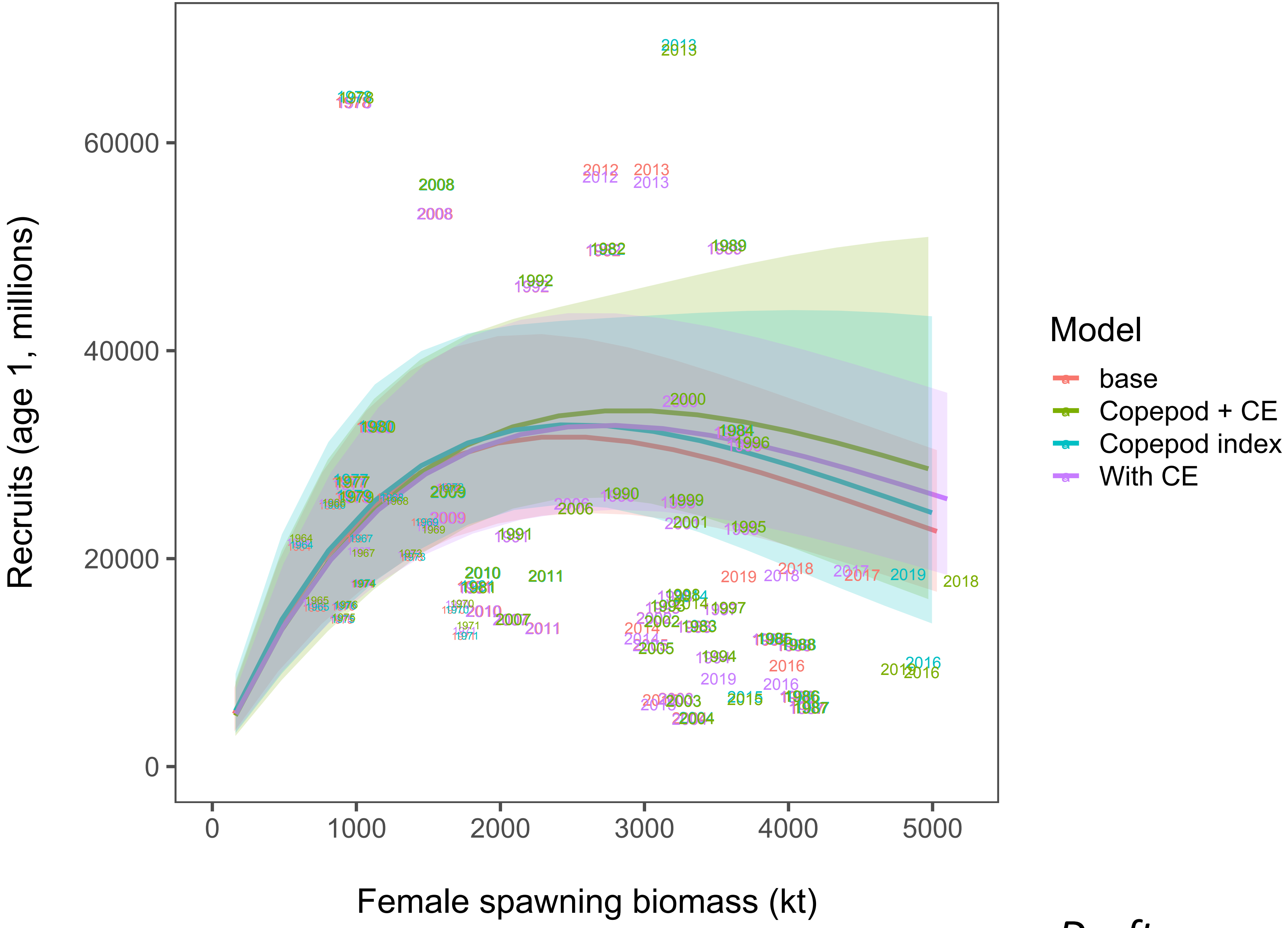

Recruits (age 1, millions)
60000
40000
20000
0
0
1000
2000
3000
4000
5000
Female spawning biomass (kt)
Model
base
Copepod + CE

Draft


Recruits (age 1, millions)
60000
40000
20000
0
0
1000
2000
3000
4000
5000
Female spawning biomass (kt)
Model
base
Copepod + CE
Copepod index
With CE

Draft

Preliminary conclusion

Climate enhanced recruitment model improves fit

- This was also shown to be the case for the posterior predictive loss approach (next slide from Paul)

Current M-matrix from CEATTLE degraded fit

- Needs revisiting/cross checking
- Reference point calculations affected
- Projection mode?

Model selection and prediction of new data?

Posterior Predictive Loss (PPL; Gelfand and Gnosh 1998)

Based on decision theory, and a loss function

$$PPL = \mathcal{L}(\tilde{y}_i, \hat{y}_i) + w\mathcal{L}(y_i, \hat{y}_i)$$

Goodness of fit to observed data

$\tilde{y}_i$ = Replicate data drawn from posterior predictive distribution of the data

Precision of estimation (i.e., how well the model fits new data not used in model fitting)

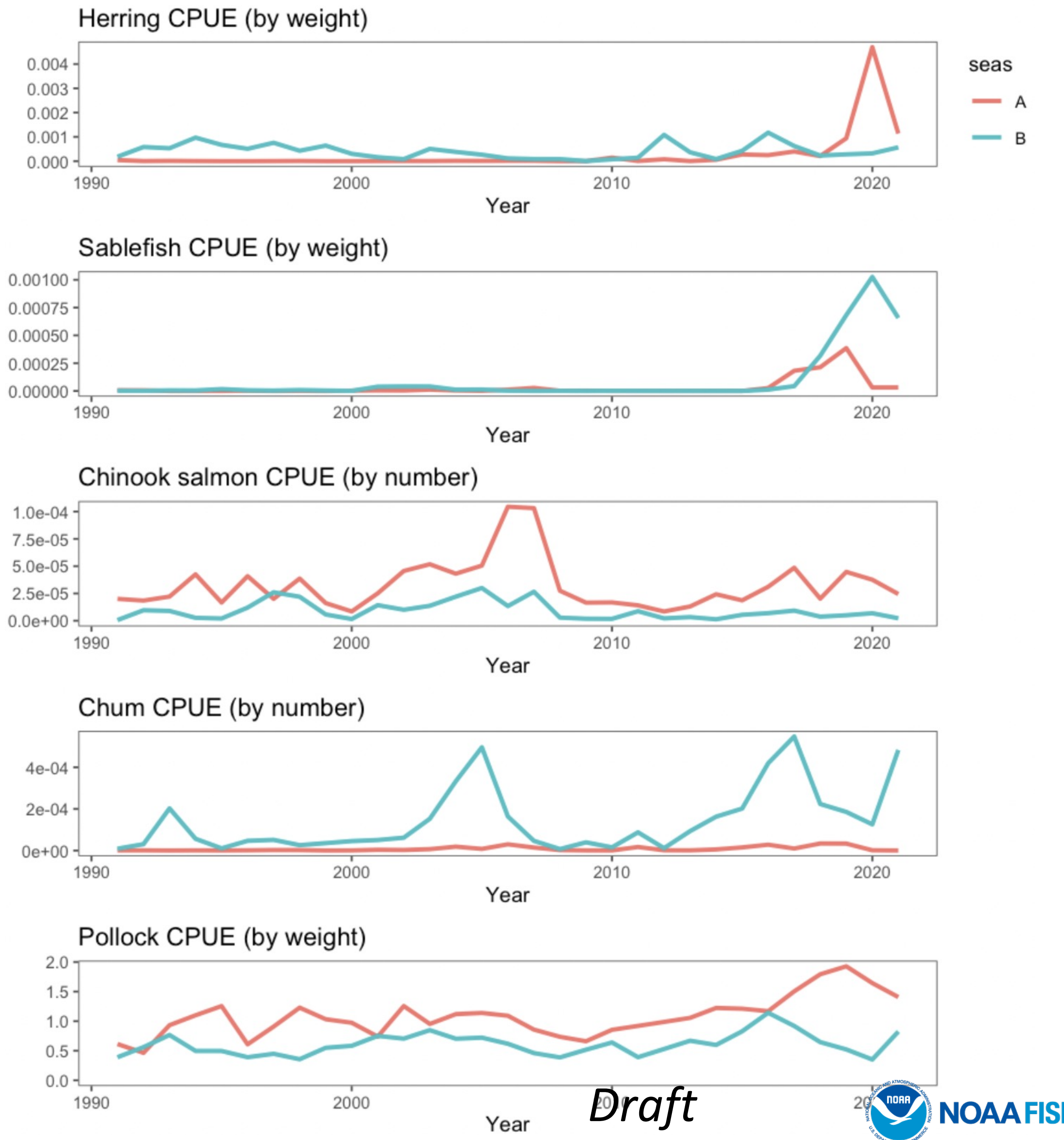
Squared error loss function

$$\mathcal{L}(x, y) = (x - y)^2$$

Courtesy Paul Spencer

Fishery conditions

- Catch rates of pollock and selected bycatch species
- B-season through August



Draft

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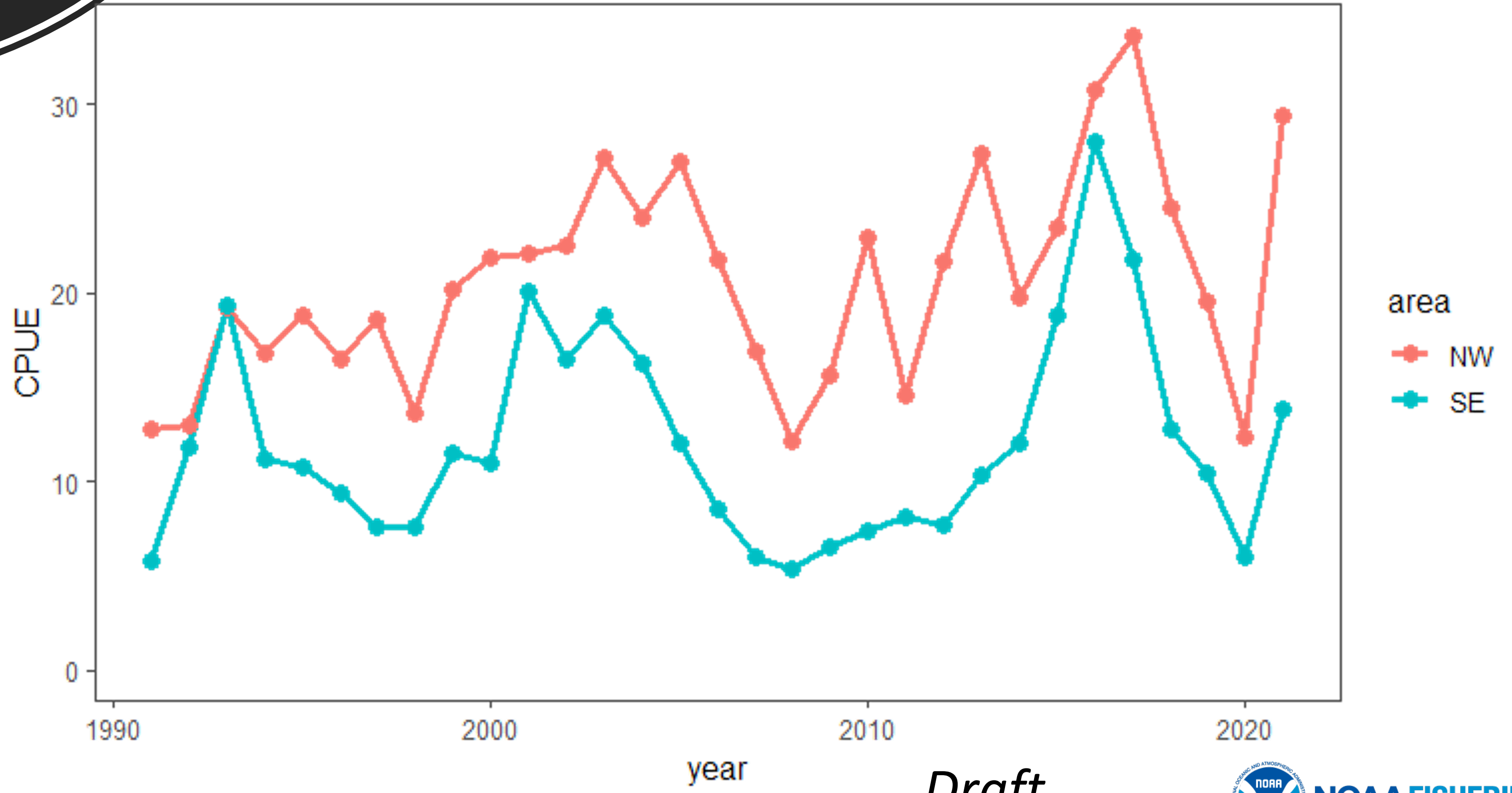
June-August
Pollock fishery CPUE by area (E and W of 170)



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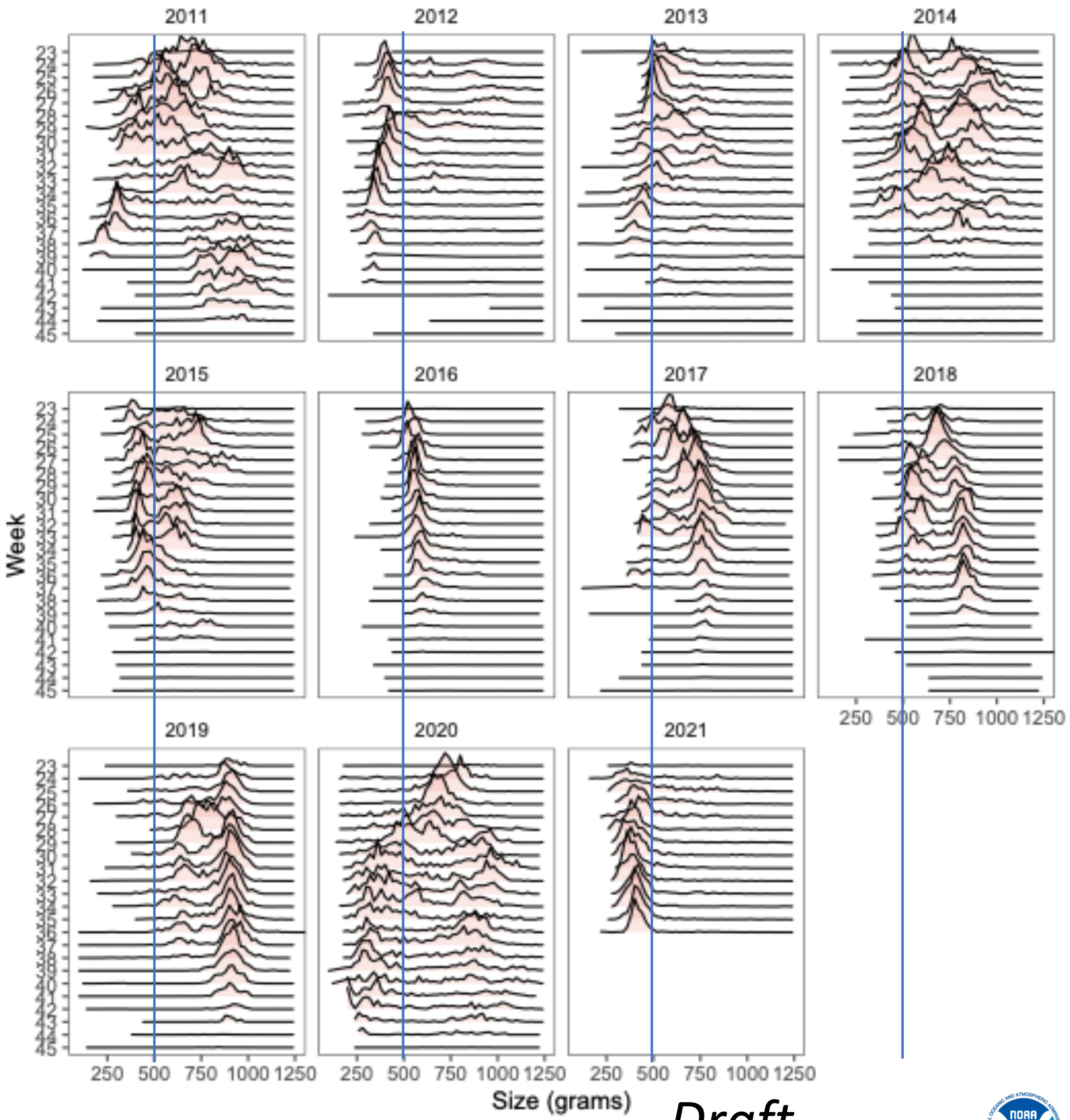
Weight frequency (by haul)

Pollock sample wt/no



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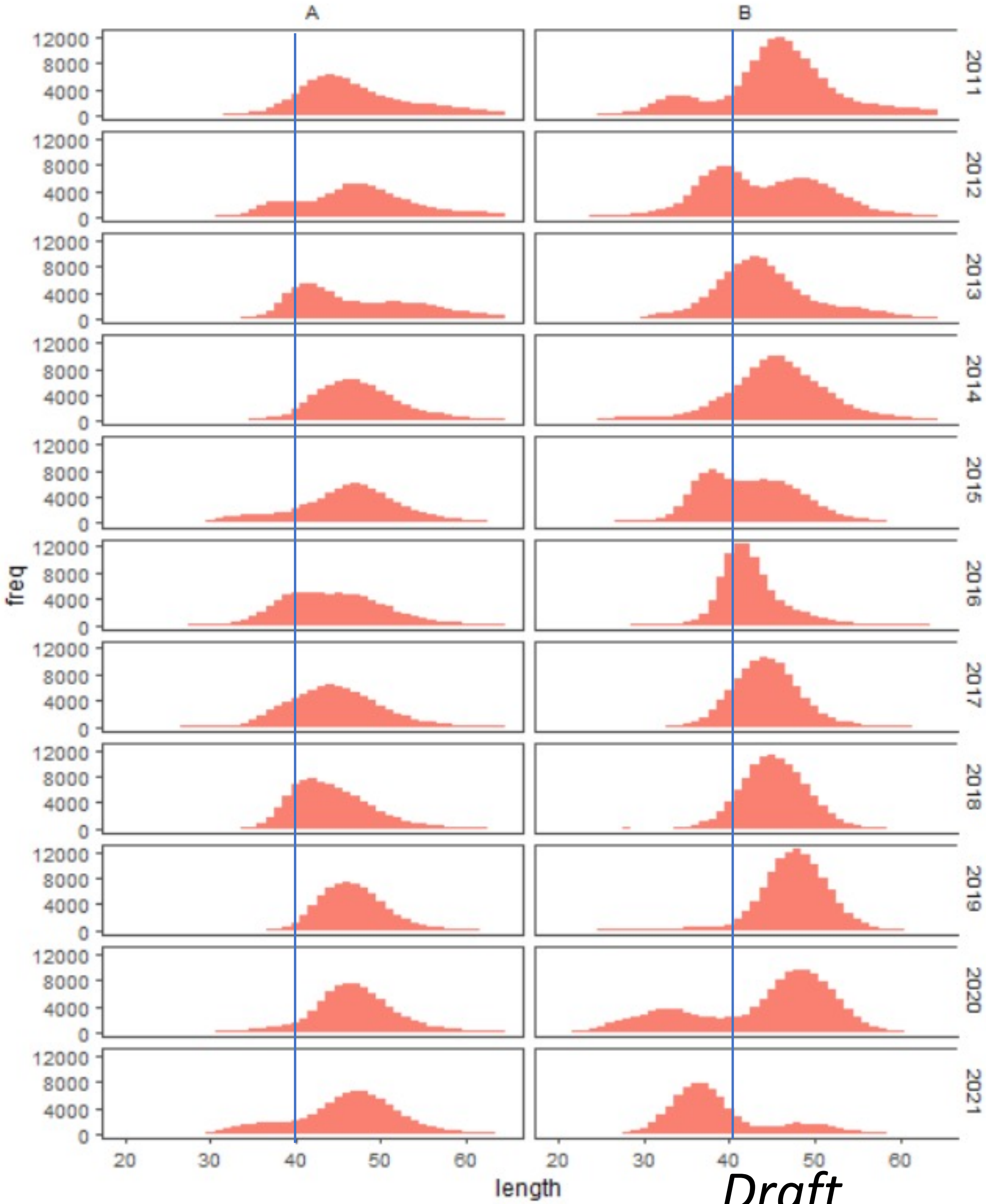
Pollock fishery length frequency by season



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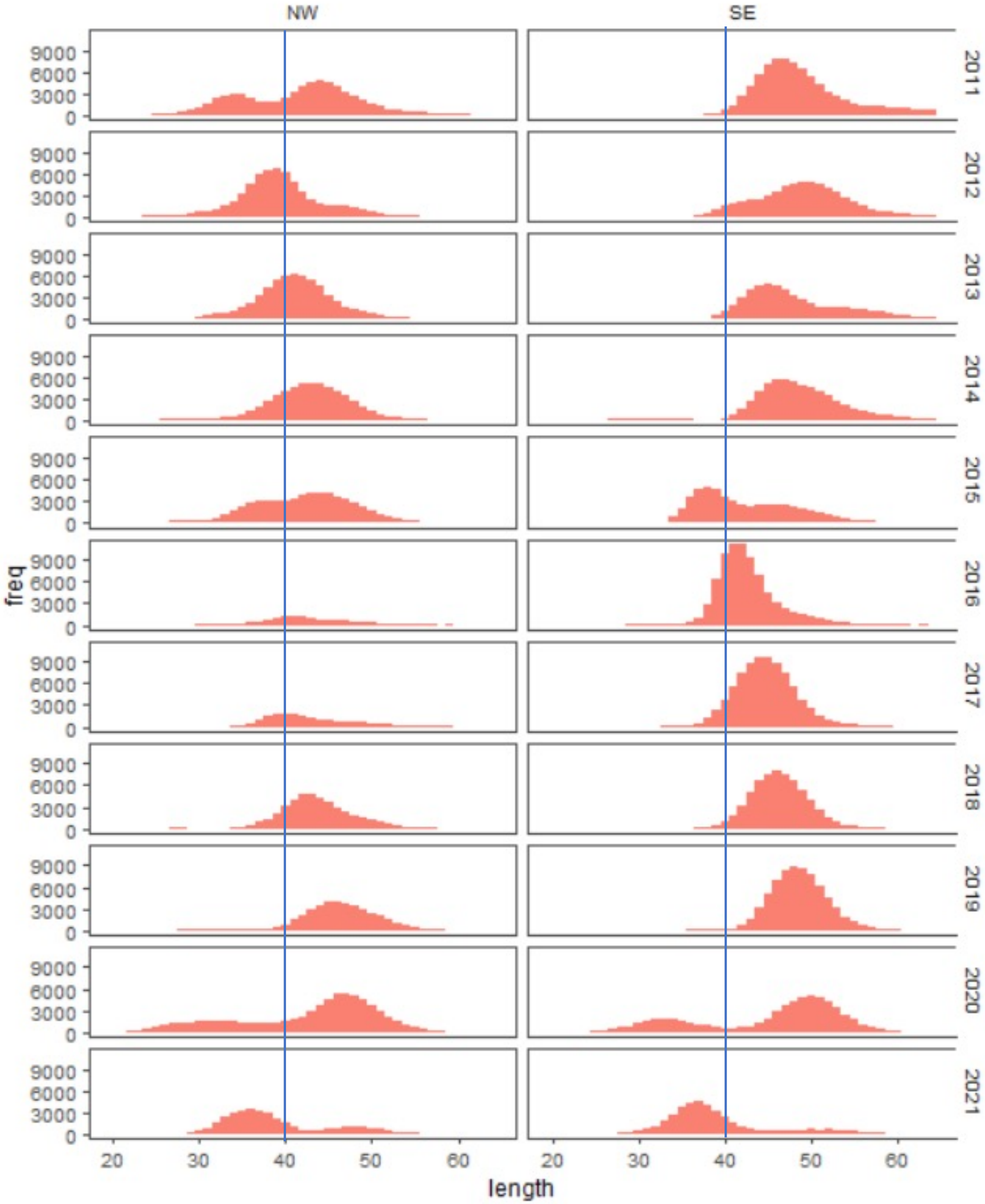
B-season
(E and W of 170)

Pollock fishery length frequency by **area**



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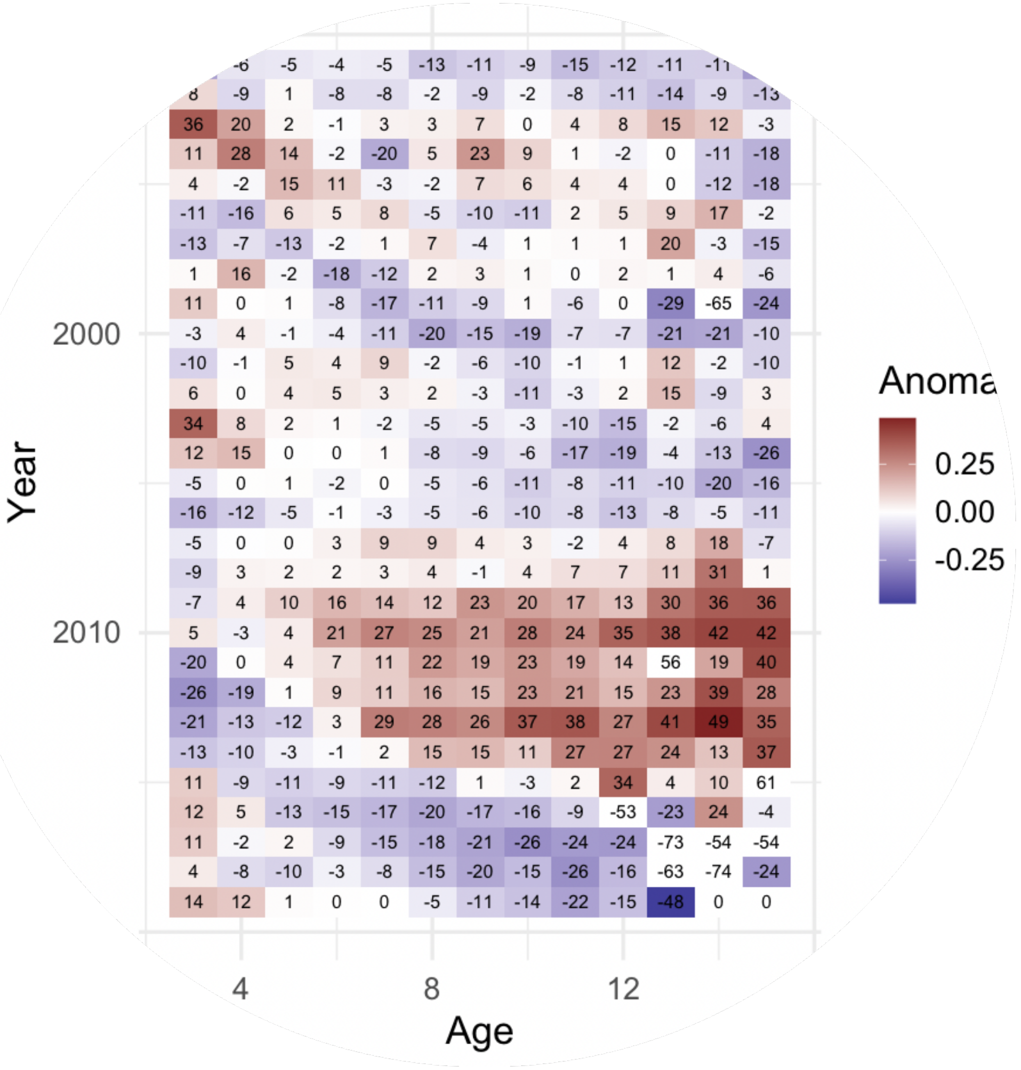

Body mass-at-age

- Can it be considered w/ an environmental index?

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Start with body mass at age

0.29	0.48	0.6	0.73	0.84	0.87	1.01	1.13
0.39	0.46	0.65	0.7	0.81	0.98	1.03	1.21
0.5	0.61	0.65	0.75	0.9	1.04	1.21	1.23
0.41	0.65	0.73	0.75	0.71	1.06	1.39	1.35
0.38	0.5	0.74	0.84	0.86	0.99	1.22	1.31
0.32	0.43	0.68	0.79	0.95	0.95	1.02	1.1
0.32	0.47	0.56	0.75	0.89	1.07	1.09	1.24
0.37	0.59	0.63	0.62	0.78	1.03	1.17	1.25
0.4	0.51	0.64	0.7	0.73	0.89	1.04	1.25
0.35	0.53	0.63	0.73	0.78	0.81	0.97	1.01
0.33	0.5	0.67	0.79	0.96	0.99	1.06	1.12
0.39	0.51	0.67	0.79	0.91	1.03	1.1	1.09
0.49	0.55	0.65	0.77	0.86	0.95	1.08	1.2
0.41	0.58	0.64	0.76	0.89	0.92	1.04	1.16
0.35	0.51	0.64	0.74	0.88	0.95	1.06	1.1
0.31	0.45	0.61	0.75	0.85	0.95	1.06	1.11
0.35	0.51	0.64	0.78	0.96	1.1	1.18	1.27
0.33	0.52	0.65	0.77	0.9	1.05	1.12	1.28
0.34	0.53	0.7	0.88	1	1.13	1.4	1.49
0.38	0.49	0.66	0.92	1.12	1.26	1.37	1.59
0.29	0.51	0.67	0.81	0.98	1.22	1.35	1.52
0.27	0.41	0.64	0.82	0.97	1.17	1.31	1.52
0.29	0.44	0.56	0.78	1.13	1.28	1.43	1.69
0.32	0.45	0.62	0.75	0.89	1.15	1.31	1.37
0.4	0.46	0.57	0.69	0.79	0.89	1.15	1.2
0.41	0.53	0.56	0.65	0.73	0.8	0.94	1.04
0.4	0.5	0.65	0.69	0.75	0.83	0.89	0.91
0.38	0.47	0.57	0.73	0.81	0.85	0.9	1.05
0.42	0.57	0.64	0.76	0.88	0.96	1.01	1.06

Year axis: 1990, 2000, 2010, 2020

Age axis: 4, 6, 8, 10

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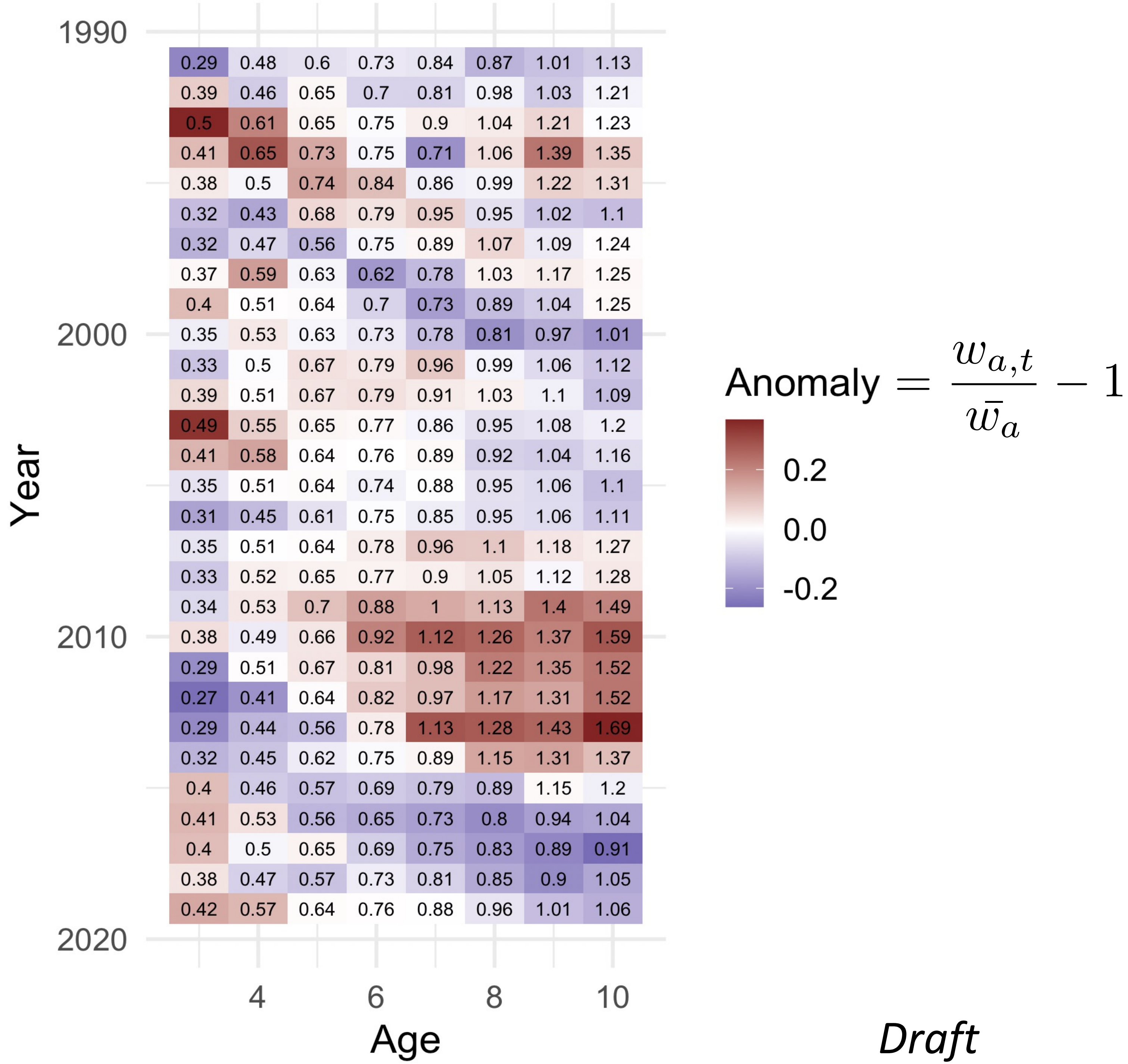

1990
2000
2010
2020
Year
Age
4
6
8
10
0.29 0.48 0.6 0.73 0.84 0.87 1.01 1.13
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0.49 0.55 0.65 0.77 0.86 0.95 1.08 1.2
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0.35 0.51 0.64 0.74 0.88 0.95 1.06 1.1
0.31 0.45 0.61 0.75 0.85 0.95 1.06 1.11
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0.29 0.51 0.67 0.81 0.98 1.22 1.35 1.52
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Anomaly $= \frac{w_{a,t}}{\bar{w_a}} - 1$
0.2
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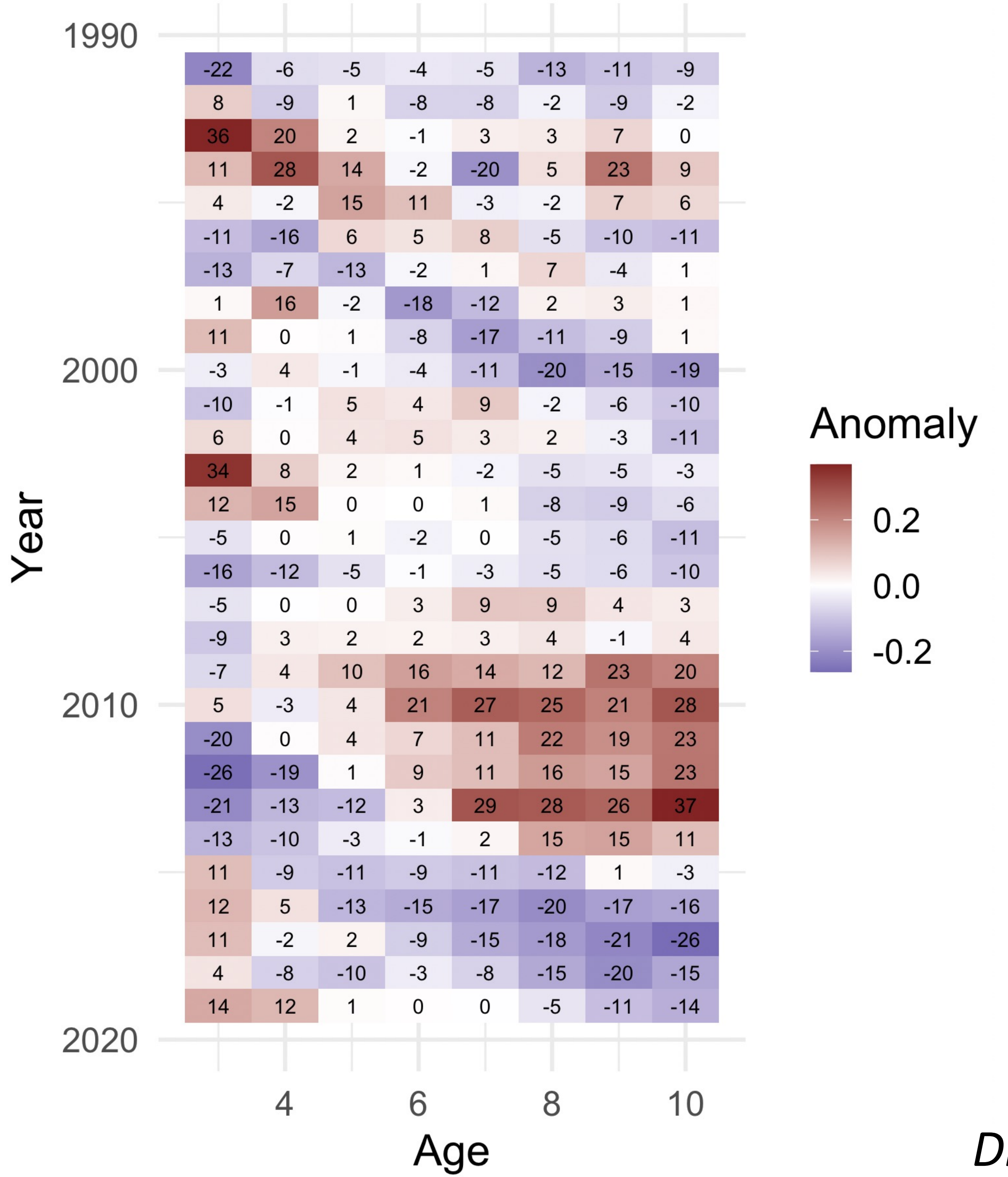
Draft



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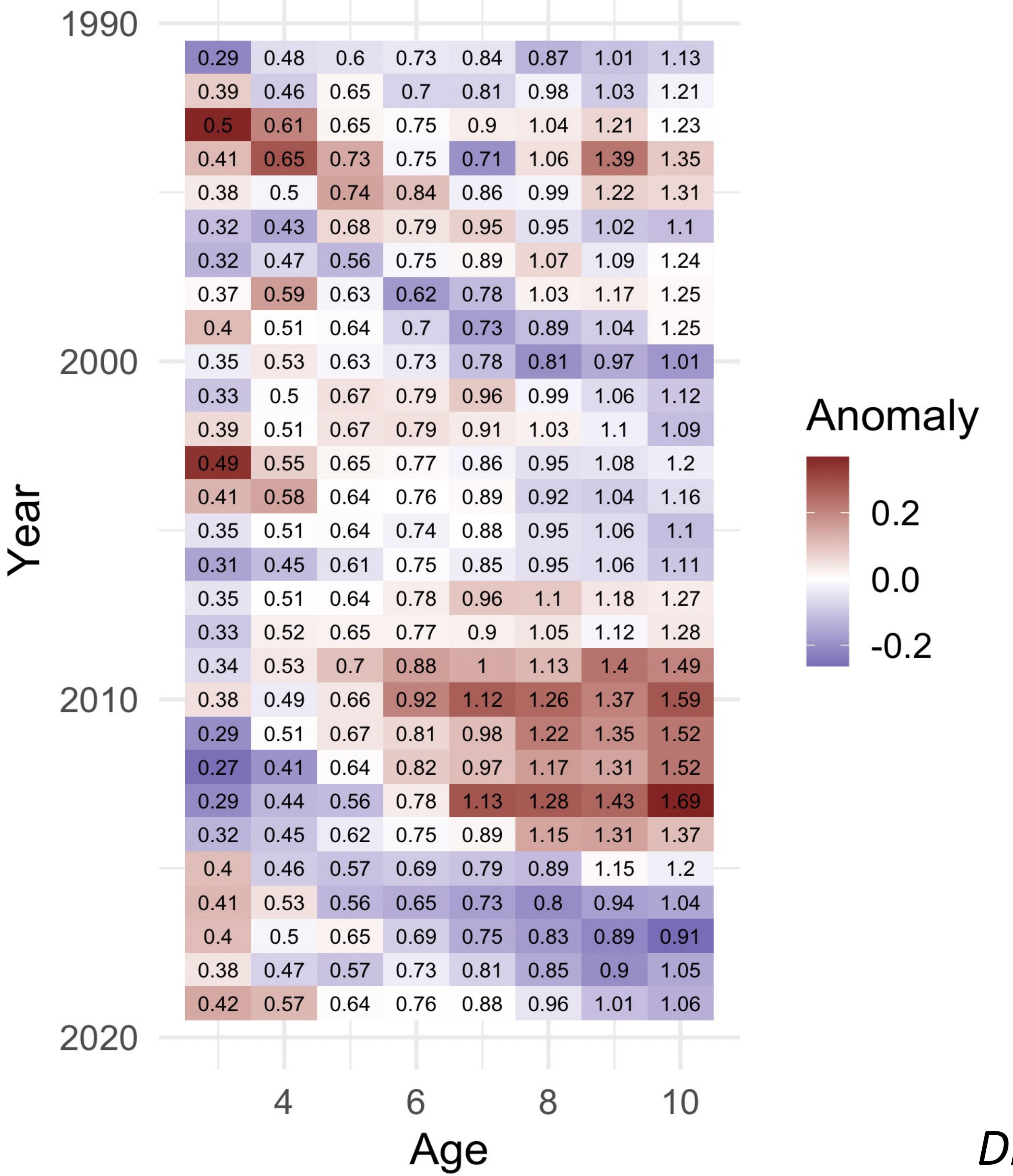
Fishery data…

Started with domestic fishery

(for pollock)

Eastern Bering Sea



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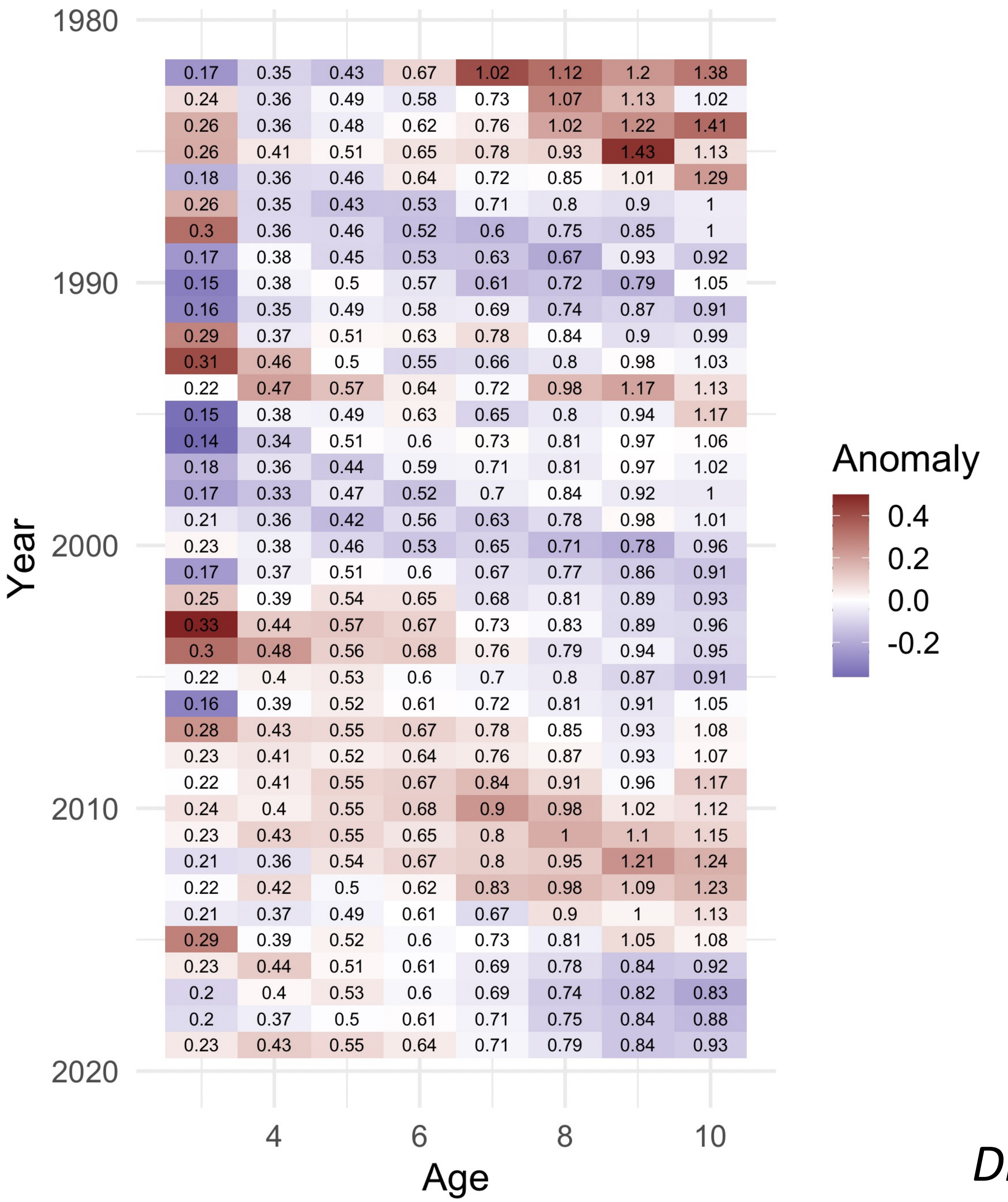
Survey data

Eastern Bering Sea



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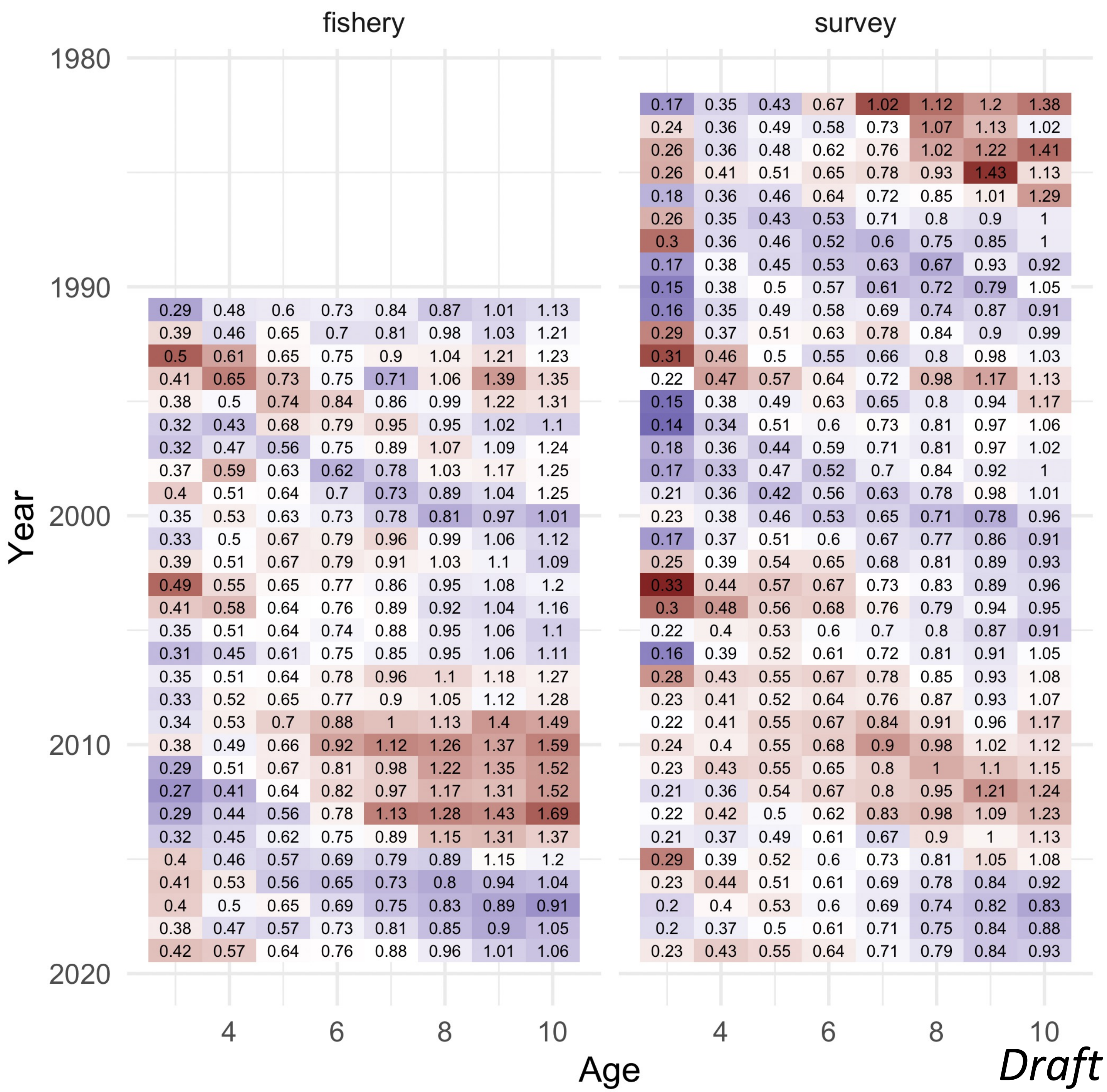
fishery
survey
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0.2 0.37 0.5 0.61 0.71 0.75 0.84 0.88
0.23 0.43 0.55 0.64 0.71 0.79 0.84 0.93

Draft

Fishery weight-at-age

Hypothesis:	Support:
• Pollock weight-at-age in fishery has year and cohort effects	• SAFE reports for EBS and GOA pollock

Implementation within pollock assessment model:

Modeled as random effects outside of model to get year and cohort effect variances

Those variances then used within model to estimate year and cohort effects as fixed

Future consideration: can cohort and year effects be effectively modeled as driven by the environment and/or density dependence?

Draft

Basic model for body mass-at-age

$$\hat{w}_{ta} = \bar{w}_a e_t^{\upsilon} \qquad a = 1,\ t \geq 1964$$

$$\hat{w}_{ta} = \hat{w}_{t-1,a-1} + \Delta_a e_t^{\psi} \qquad a > 1,\ t > 1964$$

$$\Delta_a = \bar{w}_{a+1} - \bar{w}_a \qquad a < A$$

$$\bar{w}_a = \alpha \left\{ L_1 + (L_2 - L_1) \left(\frac{1 - K^{a-1}}{1 - K^{A-1}} \right) \right\}^3$$

where the fixed effects parameters are $L_1, L_2, K,$ and α while the random effects parameters are υ_t and ψ_t.

$$nll_i = 0.5 \sum_{at} \frac{\ln(w_{at}/\hat{w}_{at})^2}{2\sigma^2_{w_{at}}}$$

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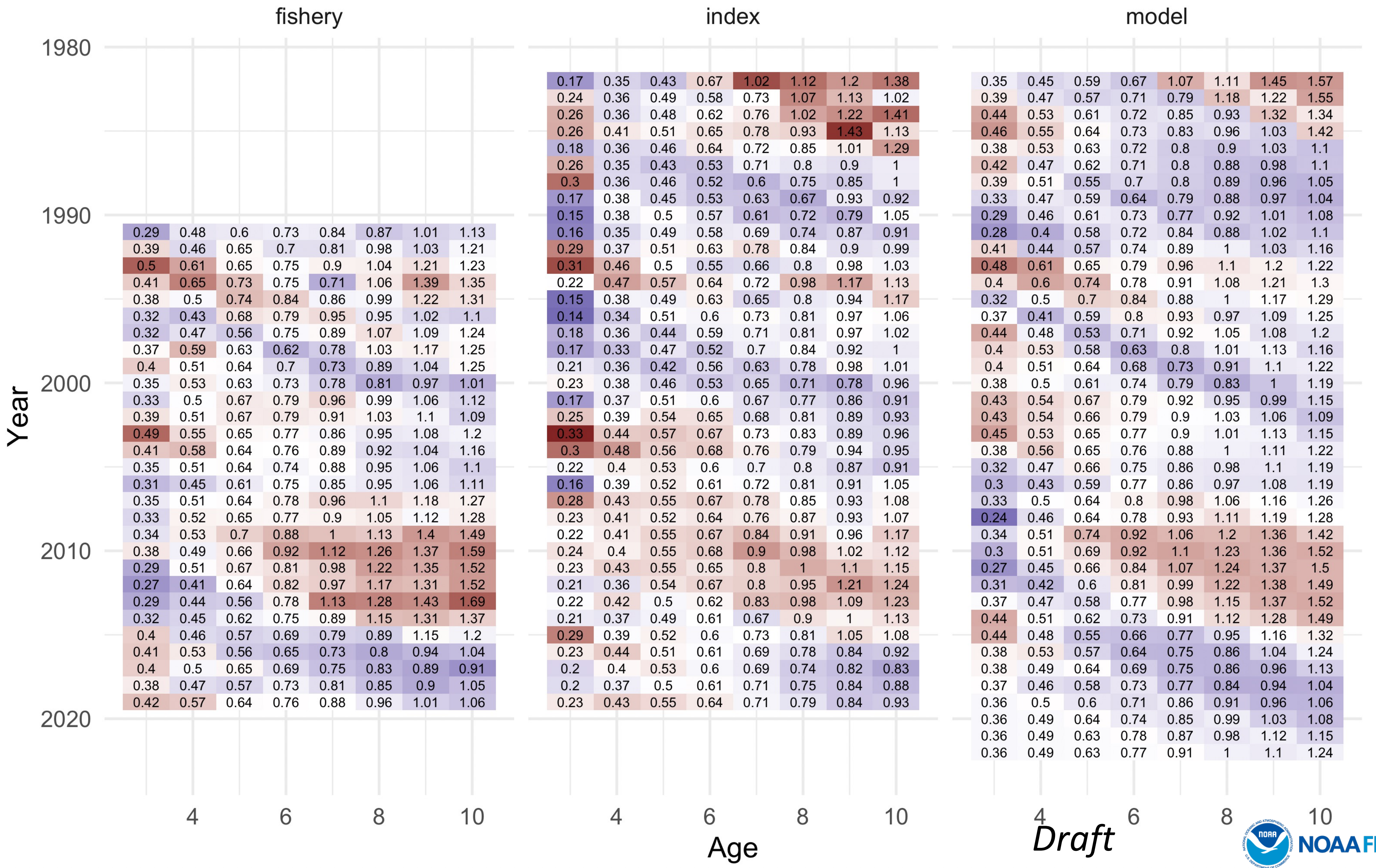

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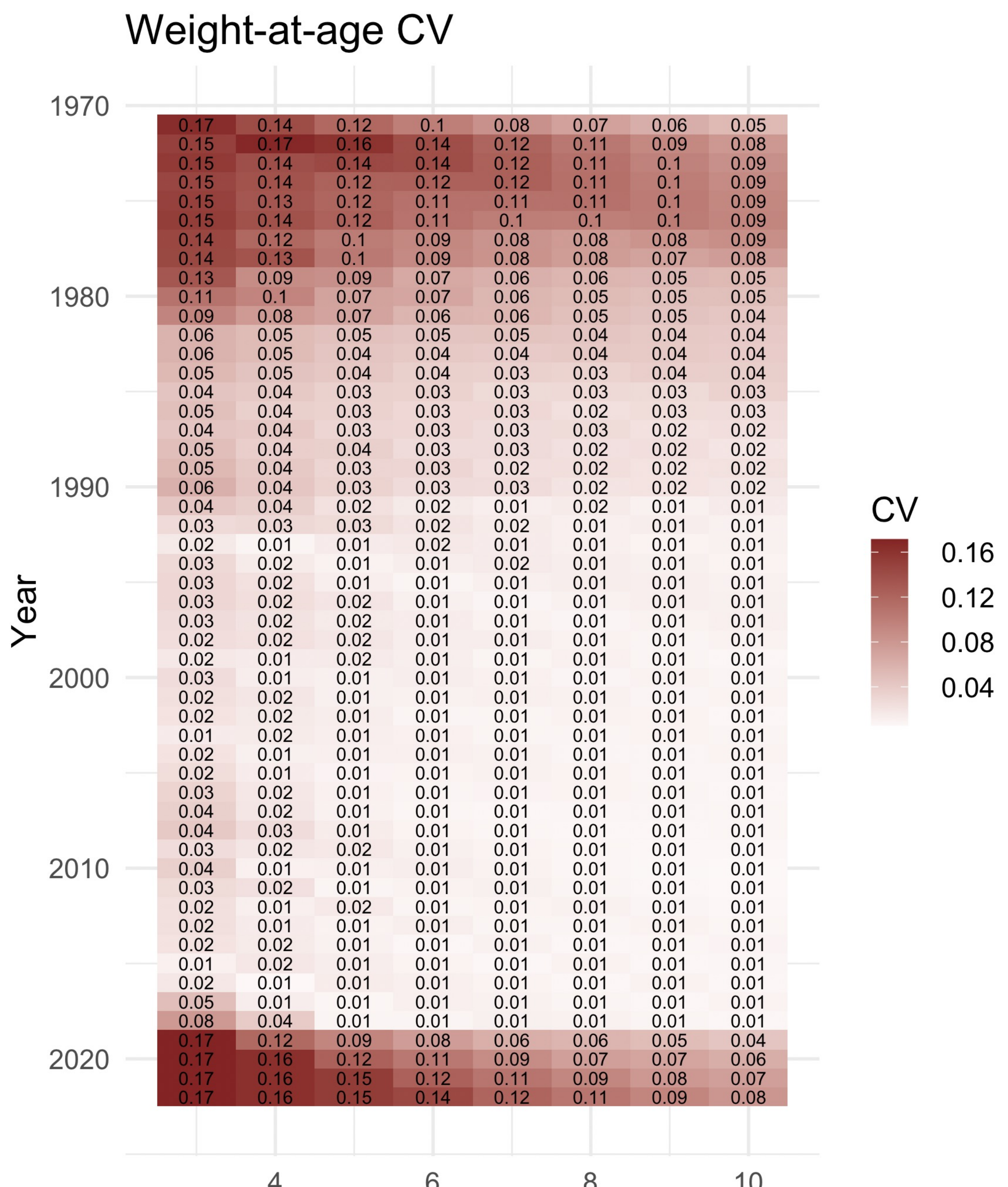
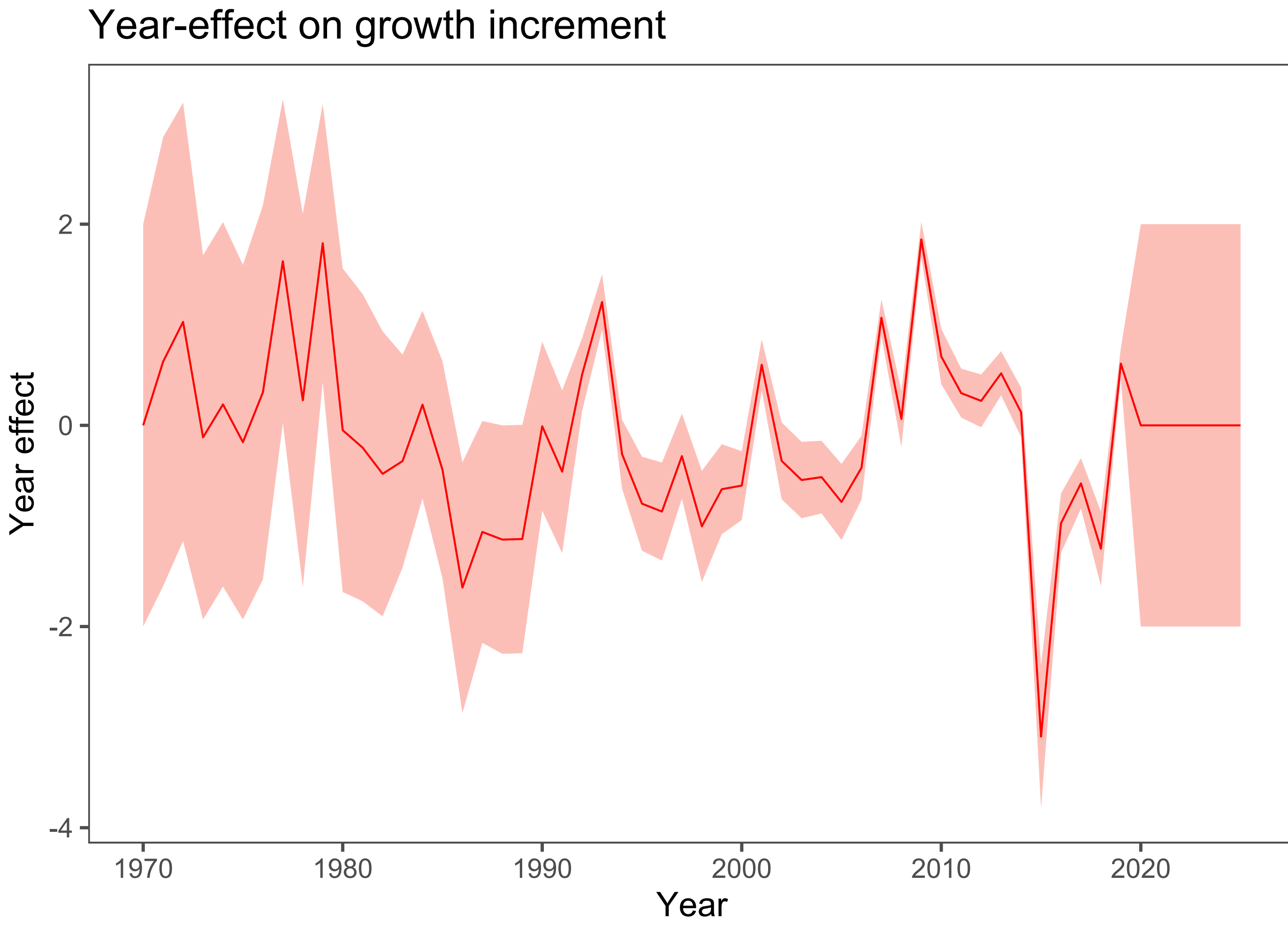
certainty propogation





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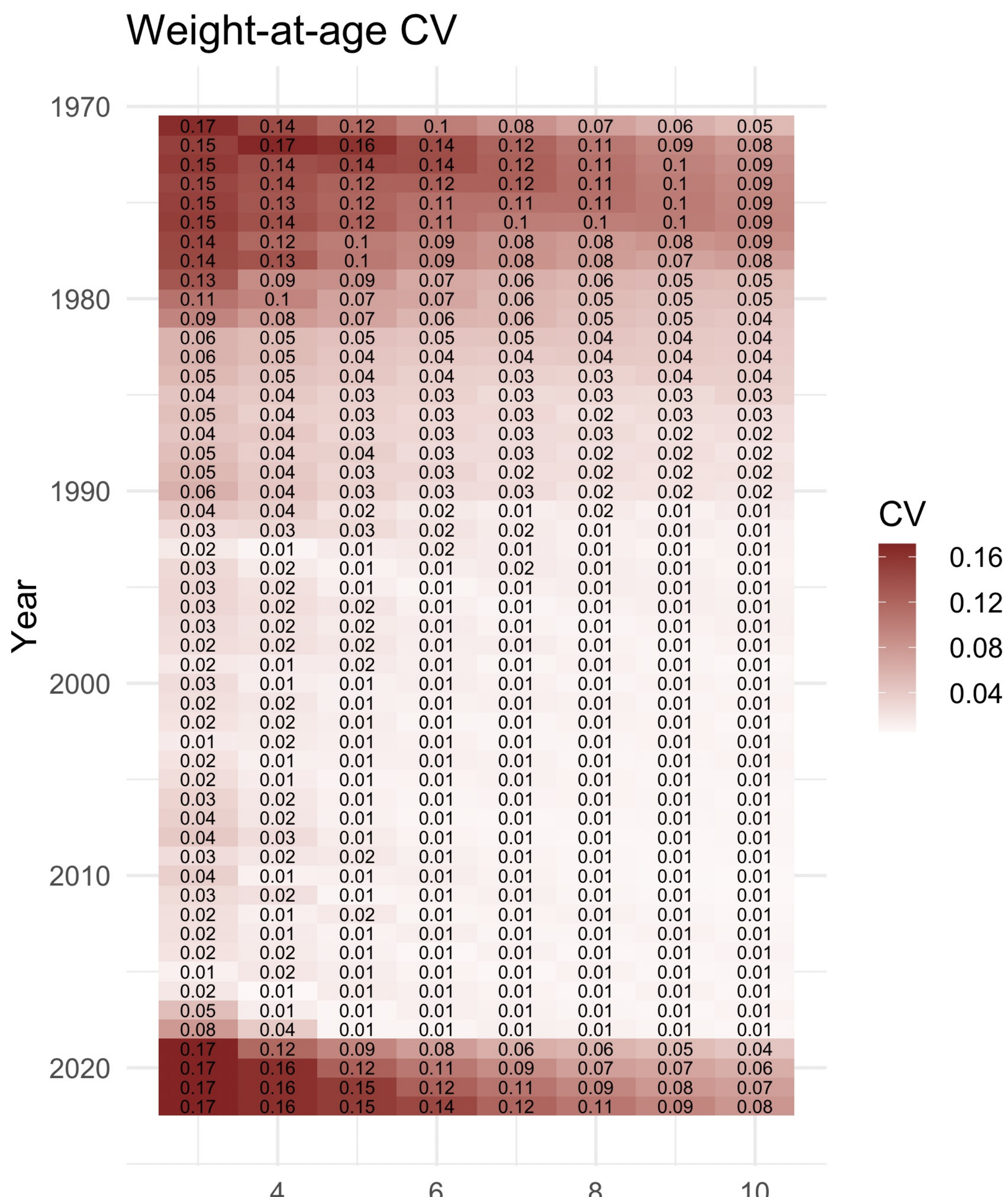
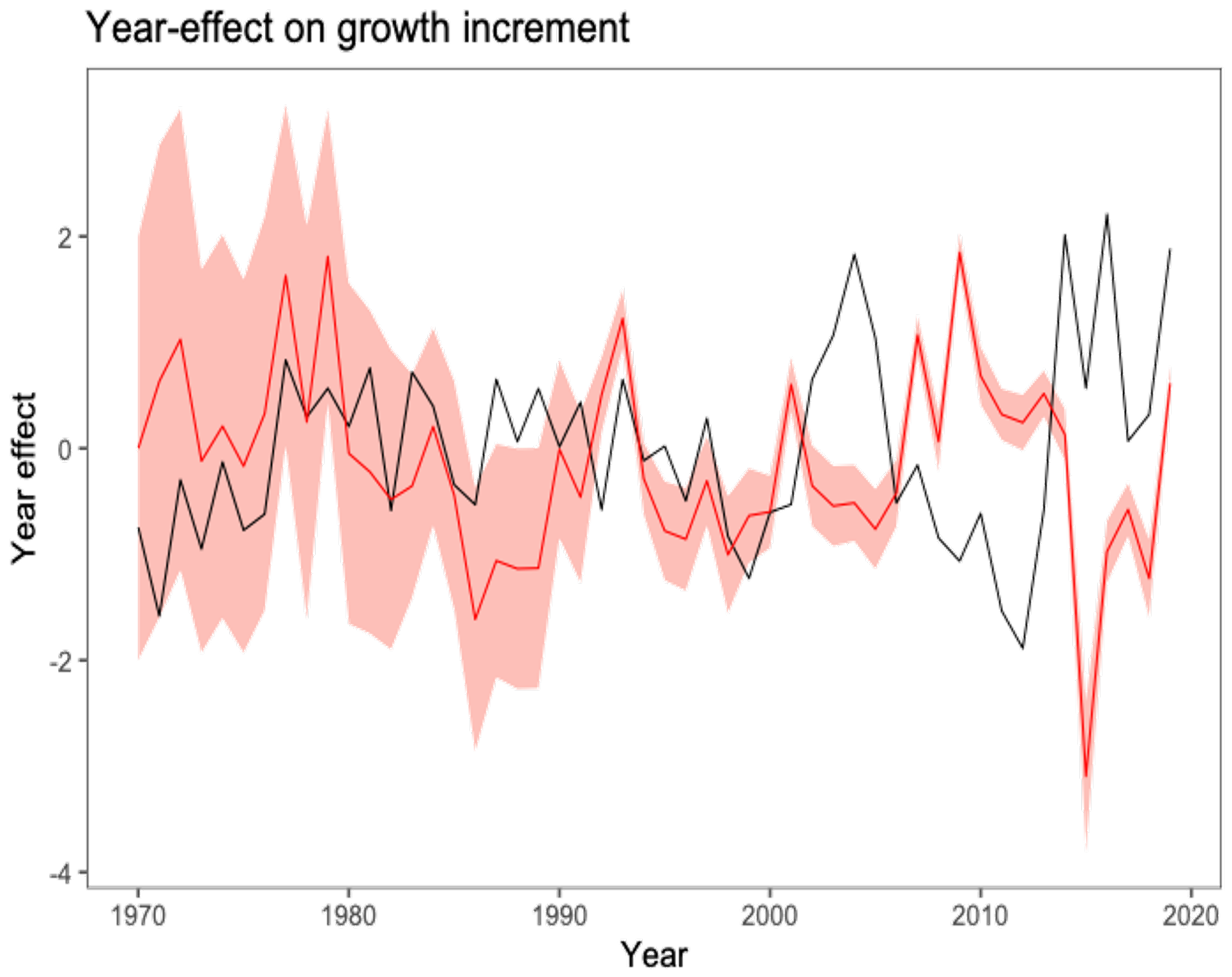
certainty propogation





Draft

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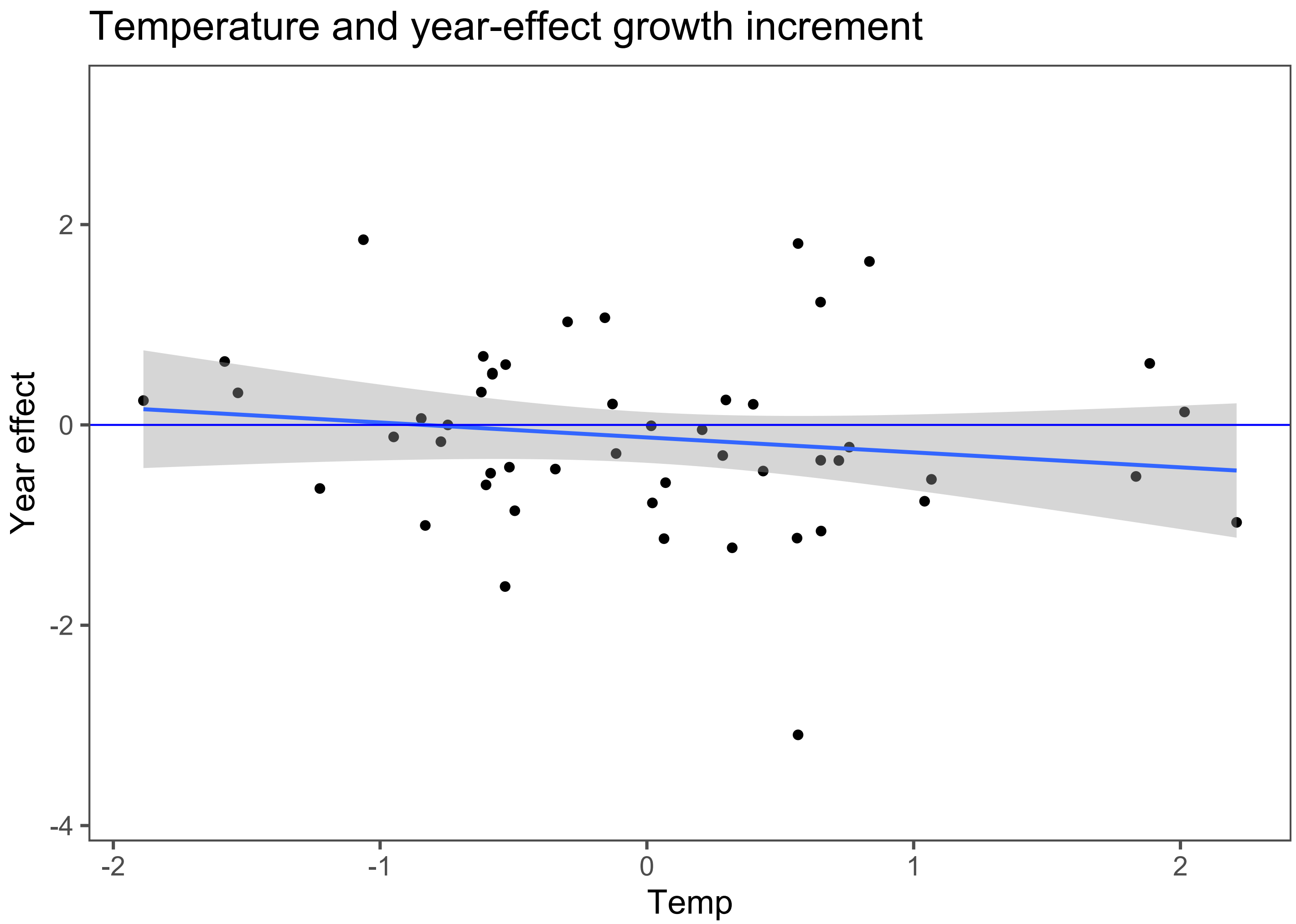
Comparing temperature on growth year-effect



Draft

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Summary

- New data for 2021:
  - Bottom trawl survey
    - Combined NBS+EBS
    - Age compositions (EBS only)
  - Acoustic vessels of opportunity (AVO)
  - Fishery 2020 age composition
  - Fishery updated weight-at-age
- Model
  - Standard from 2020
  - Some alternatives for reference point sensitivities