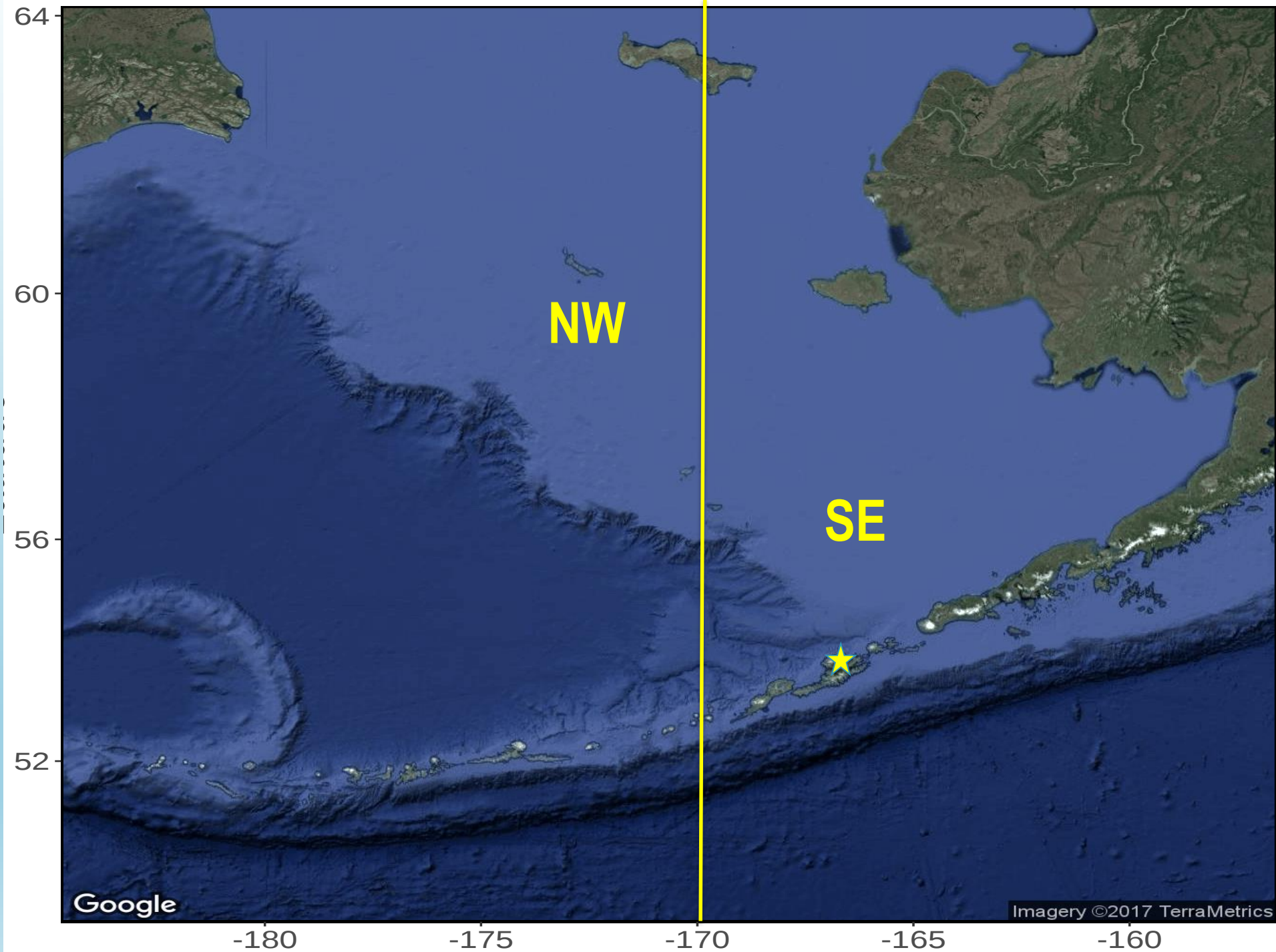




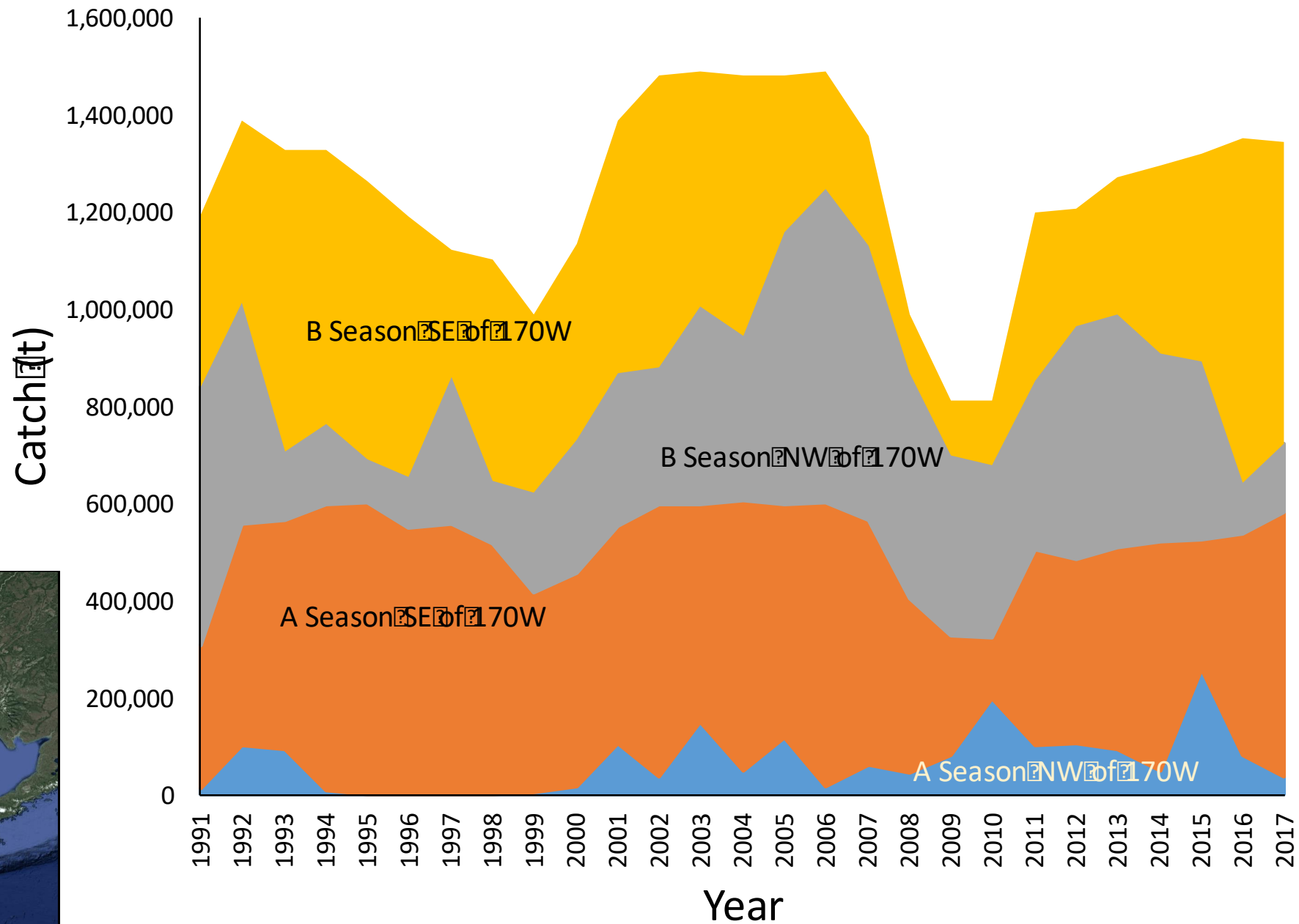
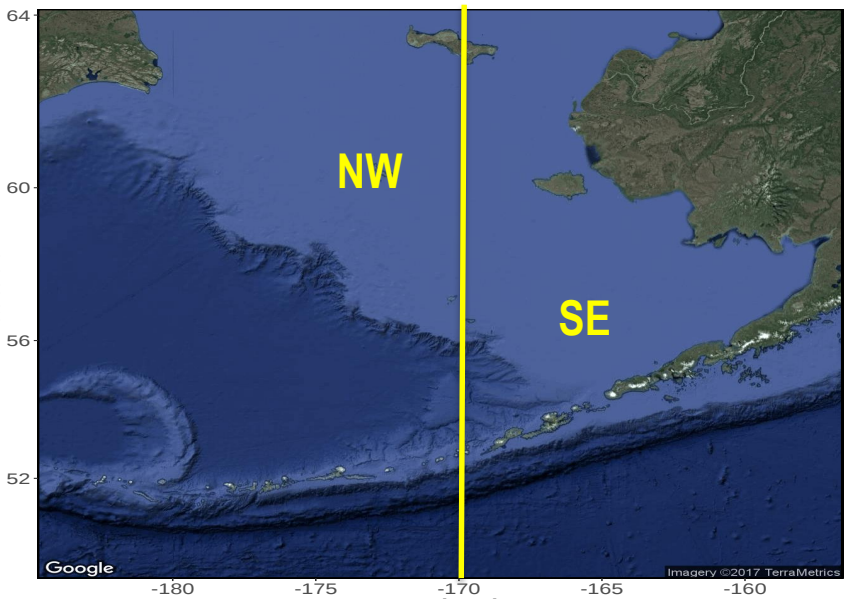
NOAA
FISHERIES

Eastern Bering Sea pollock

Jim Ianelli, Stan Kotwicki,
Taina Honkalehto, and Kirstin Holsman
Alaska Fisheries Science Center
NMFS/NOAA



Fishery catches



Fishery catches

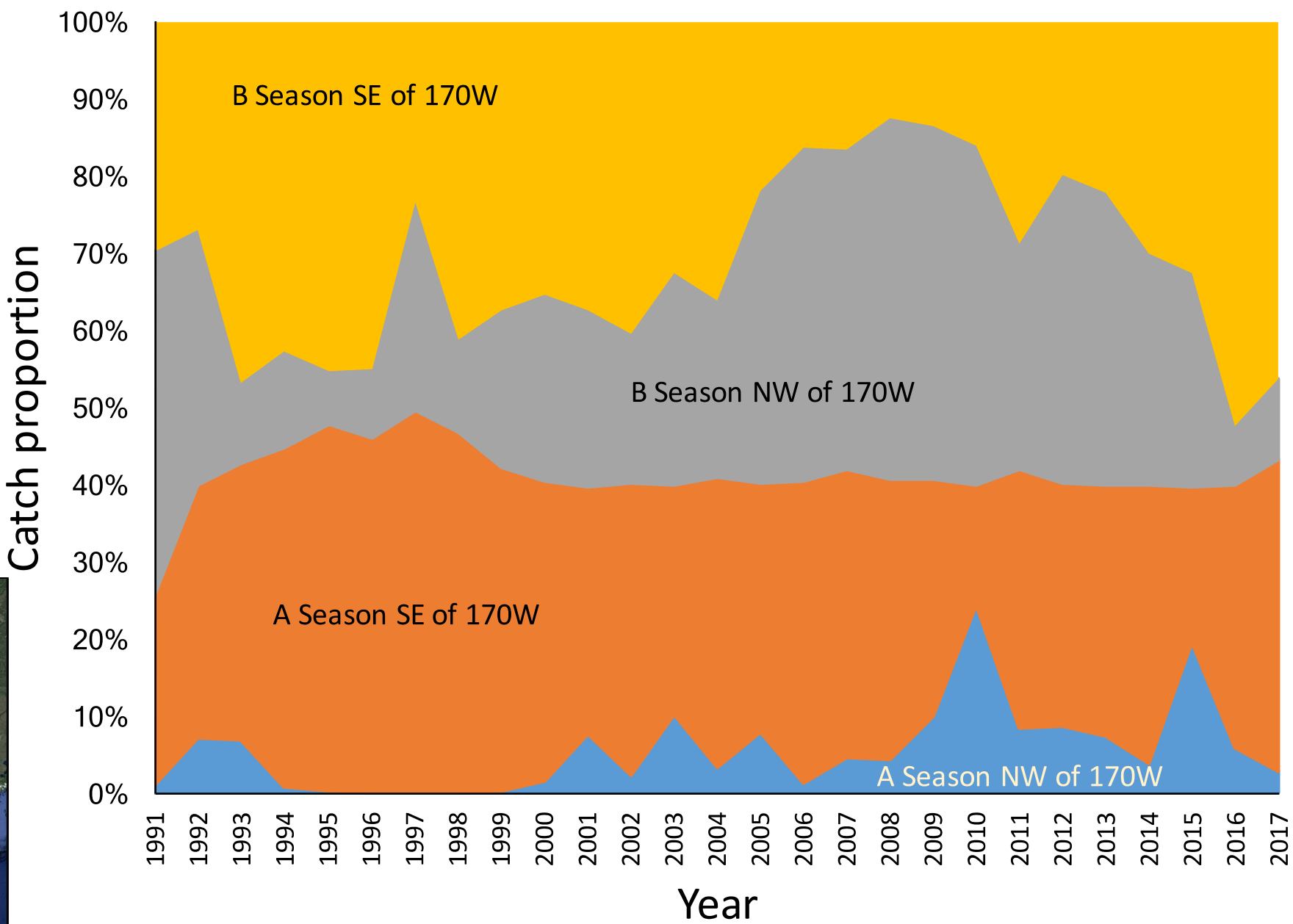
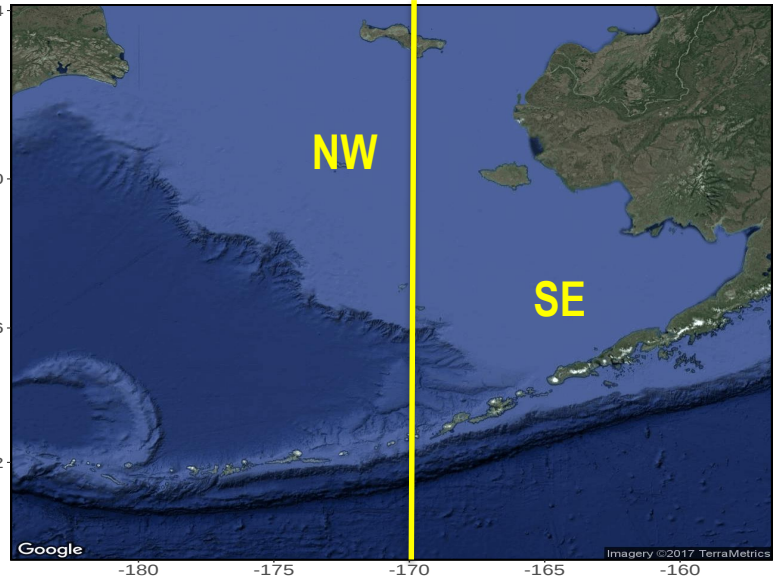


Table 6: BSAI pollock catch and ex-vessel data showing the total and retained catch (in kt), the number of vessels for all sectors and for trawl catcher vessels including ex-vessel value (million US\$), price (US\$ per pound), and catcher vessel shares. Years covered include the 2005-2007 average, the 2008-2010 average, and annual from 2011-2016.

	Avg 05-07	Avg 08-10	2011	2012	2013	2014	2015	2016
All Sectors								
Catch kt	1,444	872	1,200	1,206	1,274	1,300	1,323	1,355
Retained Catch kt	1,427	866	1,195	1,200	1,267	1,285	1,314	1,346
Vessels	110	121	118	122	121	121	120	121
Catcher Vessels (Trawl)								
Retained Catch kt	768.67	459	630	632	661	668	687	704
Ex-vessel Value M \$	\$213.60	\$183.80	\$229.40	\$241.30	\$218.70	\$226.50	\$227.40	\$209.40
Ex-vessel Price/lb \$	\$0.13	\$0.18	\$0.16	\$0.17	\$0.15	\$0.16	\$0.15	\$0.14
CV ret. catch share	53.90%	53.00%	52.70%	52.70%	52.20%	52.00%	52.30%	52.30%
Vessels	89	89	86	90	87	87	87	88

Source: NMFS Alaska Region Blend and Catch-accounting System estimates; and ADF&G Commercial Operators Annual Reports (COAR). Data compiled and provided by the Alaska Fisheries Information Network (AKFIN).

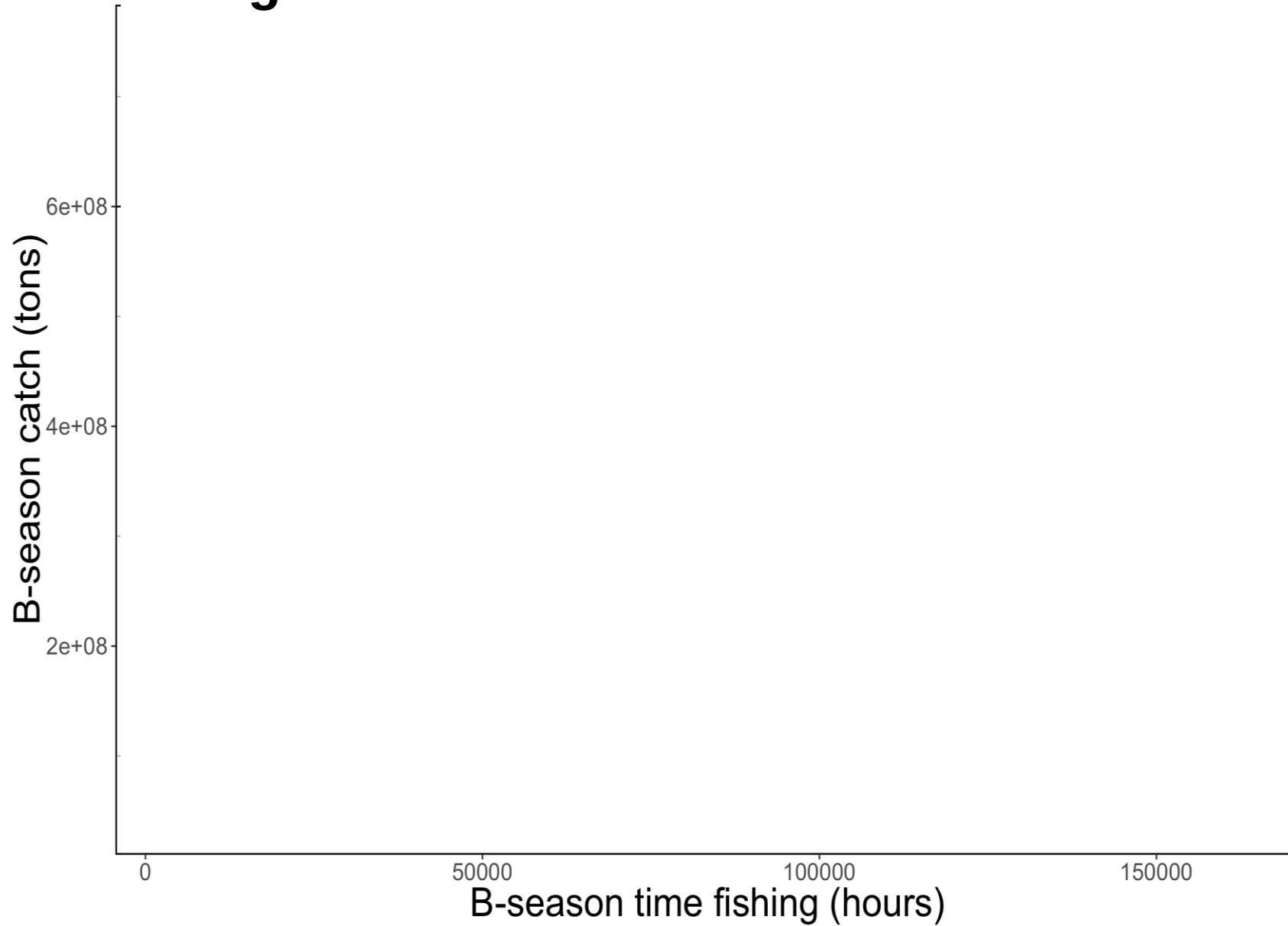
Table 7: BSAI pollock first-wholesale market data including production (kt), value (million US\$), price (US\$ per pound) for all products and then separately for other categories (head and gut, fillet, surimi, and roe production). Years covered include the 2005-2007 average, the 2008-2010 average, and annual from 2011-2016.

	Avg 05-07	Avg 08-10	2011	2012	2013	2014	2015	2016
	BSAI							
All Products Volume kt	498.25	355.99	483.11	472.72	506.84	525.54	520.94	534.89
All Products Value M\$	\$1,246.4	\$1,133.4	\$1,351.1	\$1,381.0	\$1,242.1	\$1,301.2	\$1,272.5	\$1,351.5
All Products Price lb \$	\$1.13	\$1.44	\$1.27	\$1.33	\$1.11	\$1.12	\$1.11	\$1.15
Fillets Volume kt	162.70	113.90	161.22	146.55	170.87	175.78	167.01	161.29
Fillets Price lb \$	\$1.24	\$1.73	\$1.55	\$1.55	\$1.44	\$1.37	\$1.35	\$1.41
Fillets Value share	36%	38%	41%	36%	44%	41%	39%	37%
Surimi Volume kt	173.05	100.99	141.00	157.15	161.66	171.33	187.74	190.82
Surimi Price lb \$	\$0.96	\$1.63	\$1.28	\$1.43	\$1.00	\$1.10	\$1.14	\$1.19
Surimi Value share	29%	32%	29%	36%	29%	32%	37%	37%
Roe Volume kt	27.03	17.63	18.03	16.48	13.91	20.60	18.75	14.26
Roe Price lb \$	\$4.84	\$4.14	\$3.63	\$4.32	\$3.33	\$2.92	\$2.29	\$2.84
Roe Value share	23%	14%	11%	11%	8%	10%	7%	7%
At-sea price premium (\$/lb)	\$0.30	\$0.32	\$0.20	\$0.25	\$0.13	\$0.15	\$0.25	\$0.25

Source: NMFS Alaska Region Blend and Catch-accounting System estimates; NMFS Alaska Region At-sea Production Reports; and ADF&G Commercial Operators Annual Reports (COAR). Data compiled and provided by the Alaska Fisheries Information Network (AKFIN).

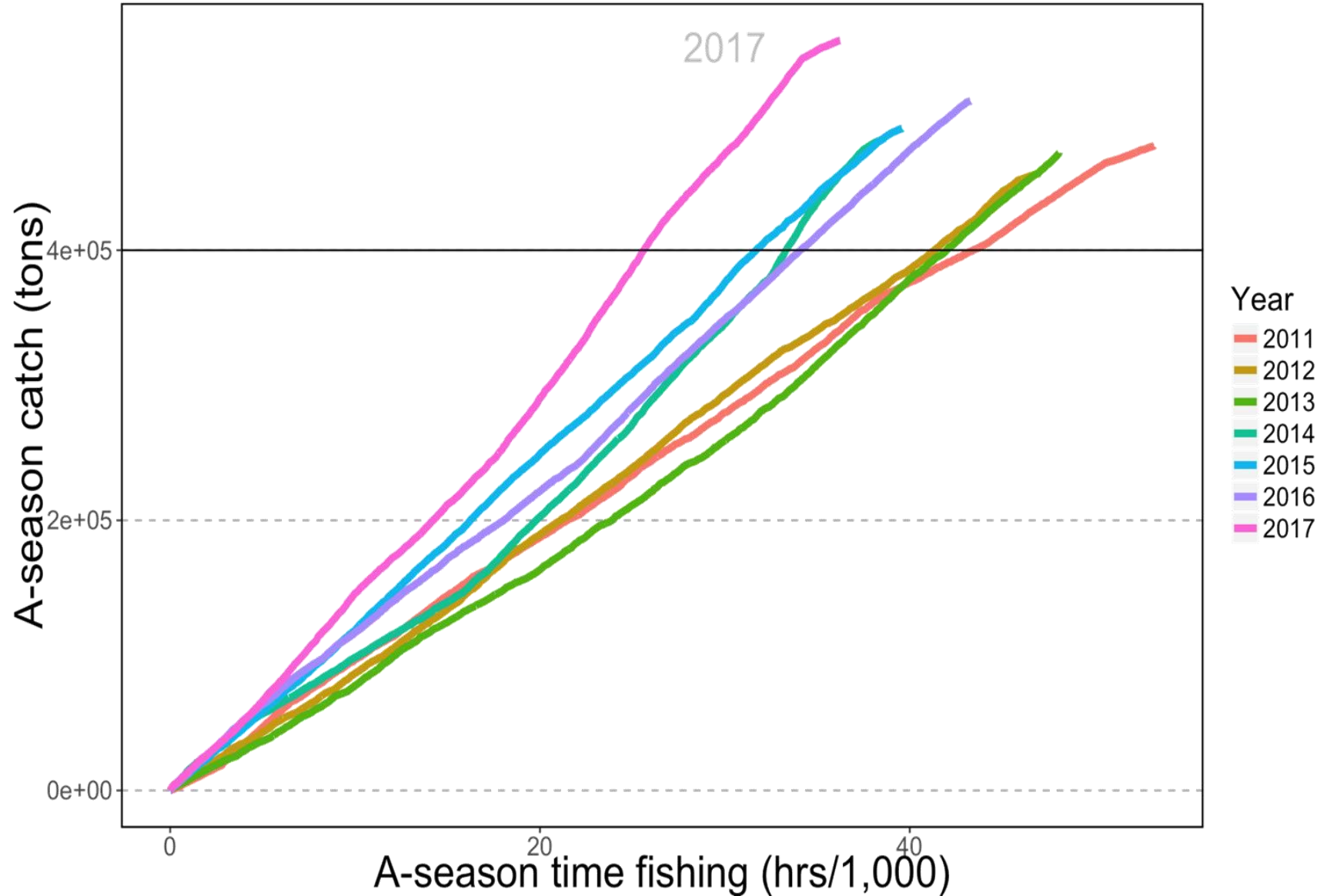
Fishing conditions

B-season



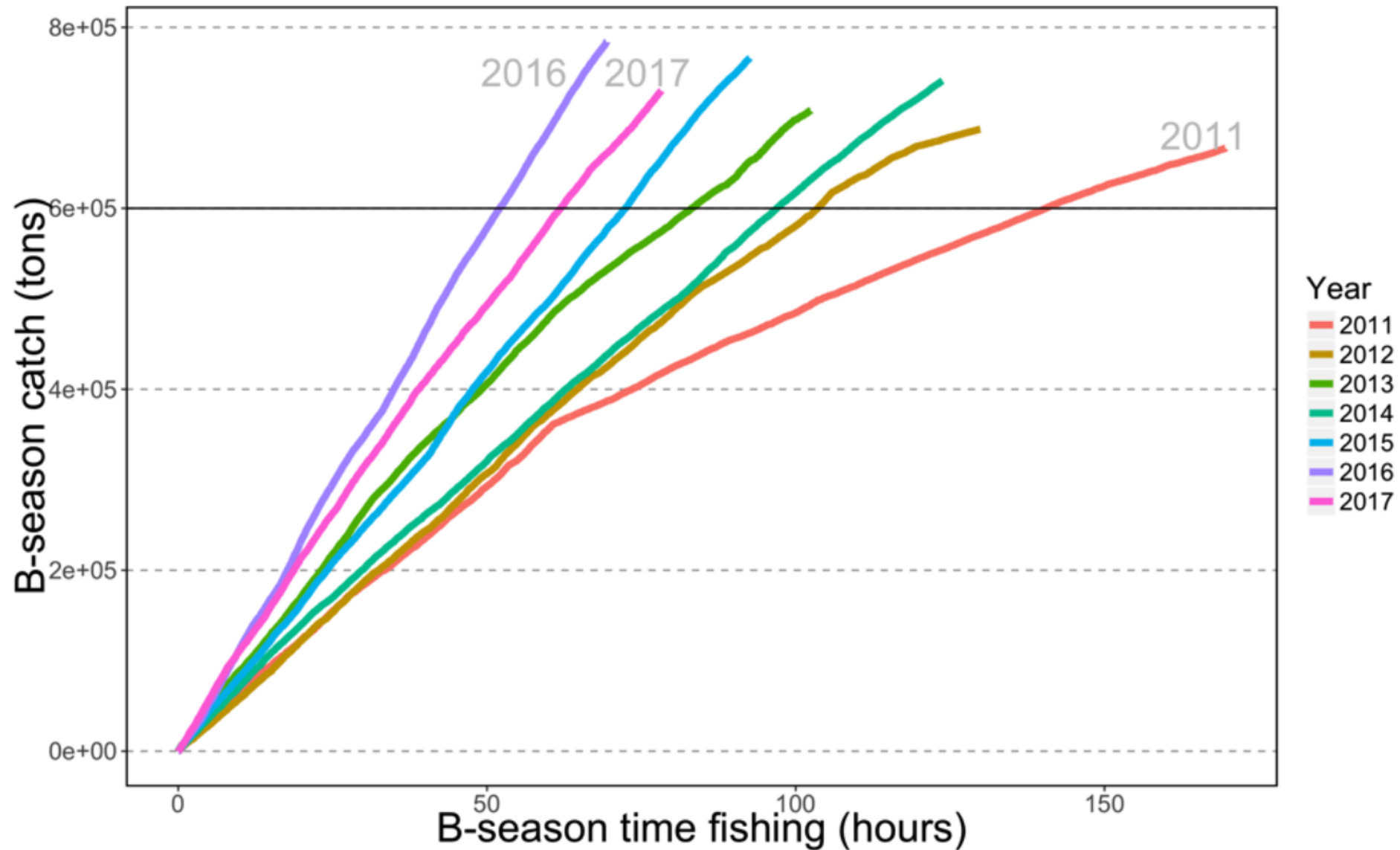
Fishing conditions

A-season



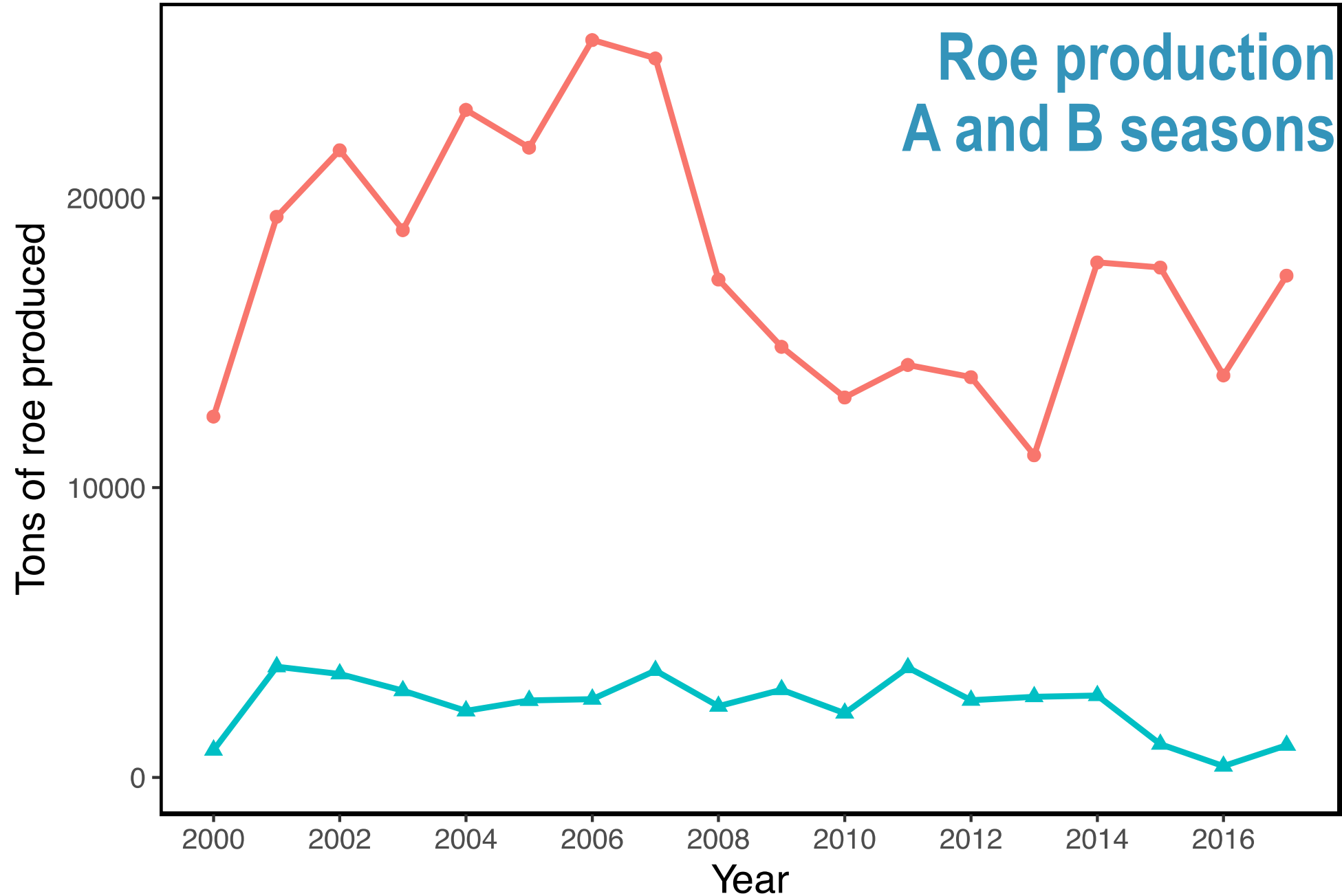
Fishing conditions

B-season...updated



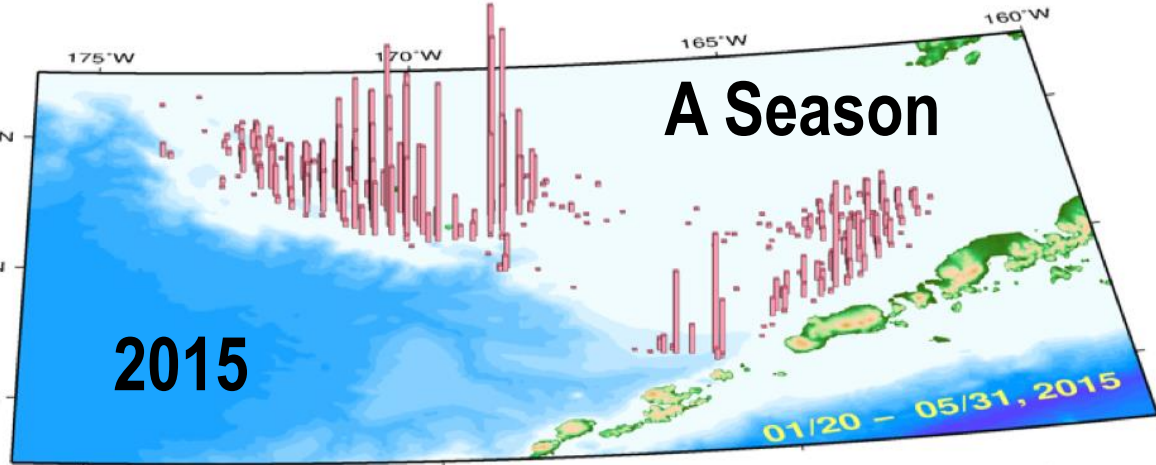
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Roe production A and B seasons

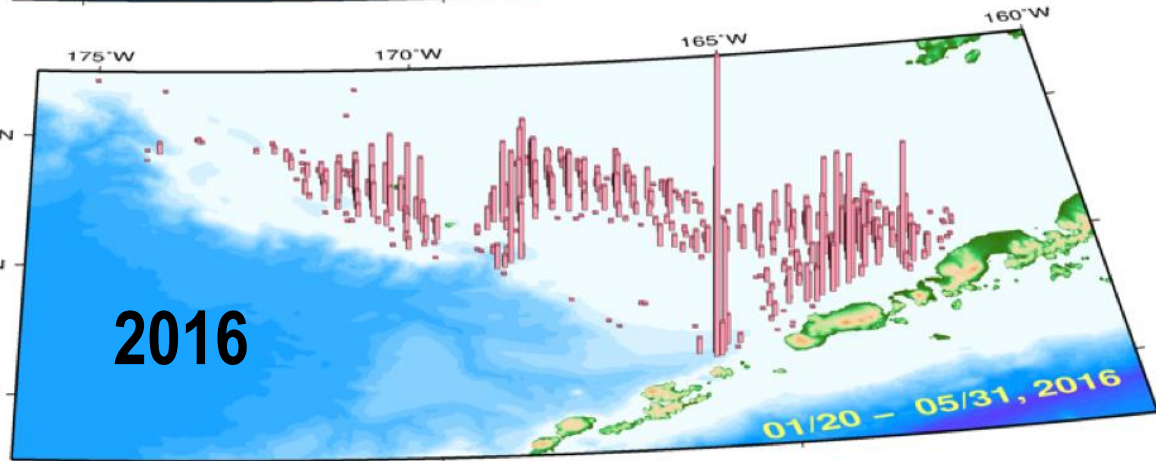


A Season

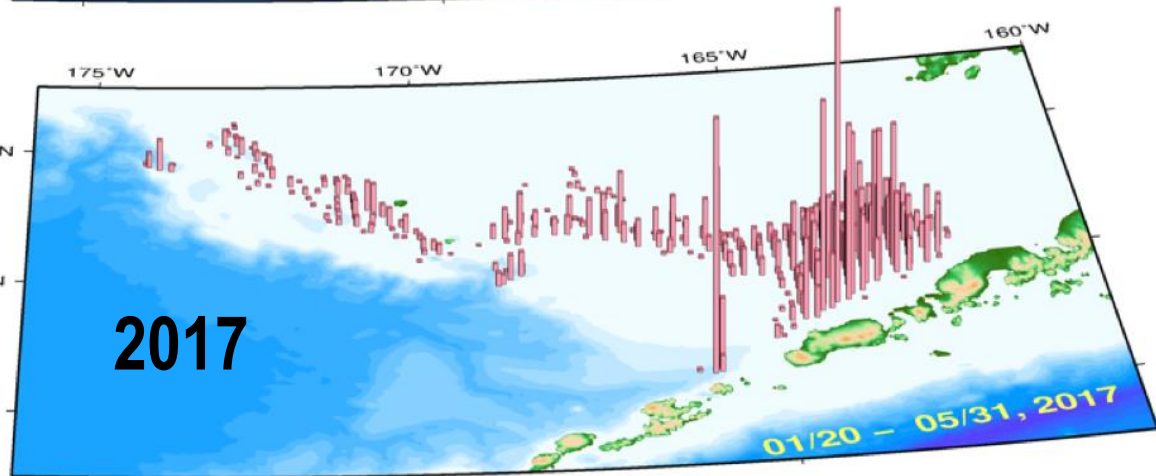
2015



2016



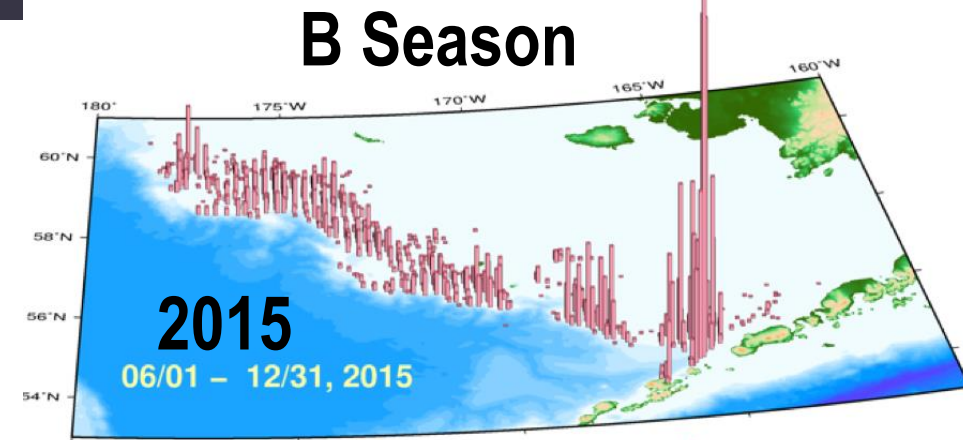
2017



B Season

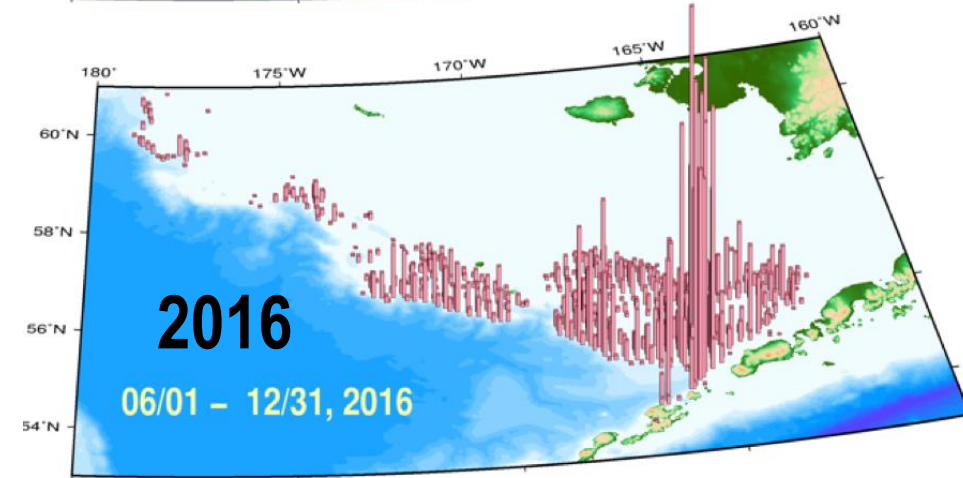
2015

06/01 - 12/31, 2015



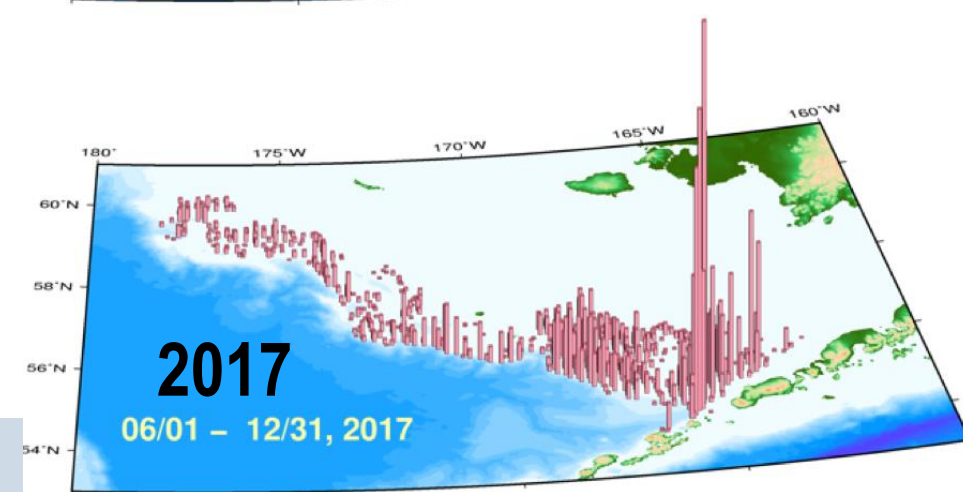
2016

06/01 - 12/31, 2016



2017

06/01 - 12/31, 2017



Fishery data from scientific observers



~300,000 lengths

~30,000 wts

~3,000
ages

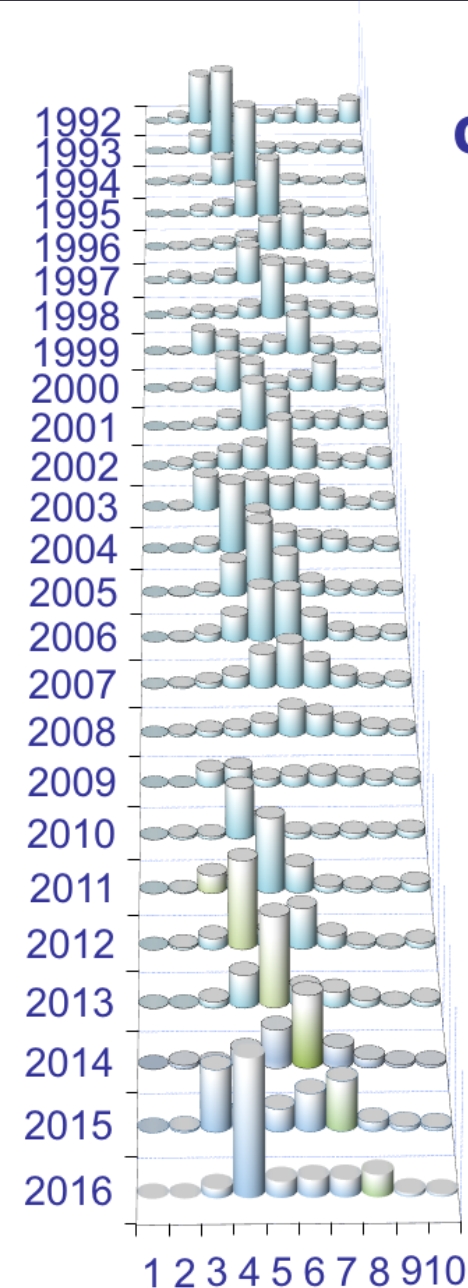


NOAA FISHERIES

Fishery weight-at-age

Year													15
	3	4	5	6	7	8	9	10	11	12	13	14	
1991	0.286	0.476	0.604	0.728	0.839	0.873	1.014	1.127	1.129	1.251	1.240	1.308	1.249
1992	0.394	0.462	0.647	0.701	0.812	0.982	1.031	1.210	1.226	1.272	1.199	1.340	1.430
1993	0.497	0.610	0.650	0.754	0.904	1.039	1.211	1.232	1.391	1.538	1.610	1.646	1.584
1994	0.405	0.651	0.728	0.747	0.707	1.057	1.395	1.347	1.347	1.391	1.394	1.301	1.341
1995	0.377	0.498	0.735	0.840	0.856	0.986	1.220	1.315	1.388	1.477	1.390	1.297	1.341
1996	0.323	0.427	0.679	0.794	0.949	0.953	1.020	1.096	1.362	1.500	1.520	1.710	1.598
1997	0.315	0.471	0.559	0.747	0.893	1.072	1.091	1.243	1.346	1.443	1.668	1.423	1.383
1998	0.368	0.589	0.627	0.621	0.775	1.029	1.169	1.253	1.327	1.452	1.414	1.523	1.537
1999	0.405	0.507	0.643	0.701	0.728	0.891	1.037	1.250	1.248	1.431	1.429	1.444	1.236
2000	0.353	0.526	0.629	0.731	0.782	0.806	0.966	1.007	1.242	1.321	1.453	1.165	1.466
2001	0.327	0.503	0.669	0.788	0.958	0.987	1.063	1.115	1.314	1.435	1.563	1.433	1.467
2002	0.386	0.509	0.666	0.795	0.910	1.029	1.104	1.095	1.288	1.448	1.597	1.343	1.683
2003	0.489	0.547	0.649	0.767	0.862	0.953	1.081	1.200	1.200	1.206	1.362	1.377	1.699
2004	0.409	0.583	0.640	0.758	0.889	0.924	1.035	1.162	1.110	1.160	1.333	1.281	1.213
2005	0.346	0.508	0.642	0.741	0.882	0.954	1.062	1.096	1.225	1.276	1.251	1.174	1.373
2006	0.305	0.447	0.606	0.755	0.853	0.952	1.065	1.114	1.219	1.234	1.282	1.399	1.462
2007	0.346	0.506	0.641	0.781	0.962	1.098	1.182	1.275	1.304	1.477	1.500	1.738	1.520
2008	0.330	0.520	0.652	0.774	0.903	1.049	1.119	1.282	1.421	1.524	1.553	1.921	1.660
2009	0.340	0.526	0.704	0.879	1.002	1.125	1.399	1.490	1.563	1.614	1.814	1.996	2.230
2010	0.383	0.489	0.664	0.915	1.119	1.261	1.371	1.587	1.659	1.924	1.923	2.079	2.316
2011	0.290	0.509	0.665	0.808	0.976	1.225	1.346	1.518	1.585	1.621	2.176	1.754	2.287
2012	0.270	0.410	0.643	0.824	0.974	1.172	1.306	1.519	1.614	1.644	1.717	2.040	2.086
2013	0.289	0.442	0.564	0.782	1.131	1.284	1.426	1.692	1.834	1.806	1.960	2.187	2.207
2014	0.316	0.455	0.617	0.751	0.894	1.154	1.310	1.370	1.692	1.815	1.733	1.658	2.236
2015	0.403	0.463	0.571	0.690	0.786	0.887	1.145	1.201	1.378	1.892	1.452	1.603	2.627
2016	0.407	0.531	0.557	0.648	0.732	0.801	0.943	1.047	1.201	1.486	1.541	1.870	1.638
2017	0.369	0.565	0.707	0.756	0.849	0.980	1.094	1.269	1.448	1.594	1.758	1.870	1.935
2018	0.395	0.496	0.696	0.837	0.882	0.969	1.093	1.199	1.365	1.536	1.673	1.830	1.935
2019	0.395	0.523	0.627	0.826	0.963	1.002	1.082	1.198	1.296	1.454	1.616	1.746	1.895

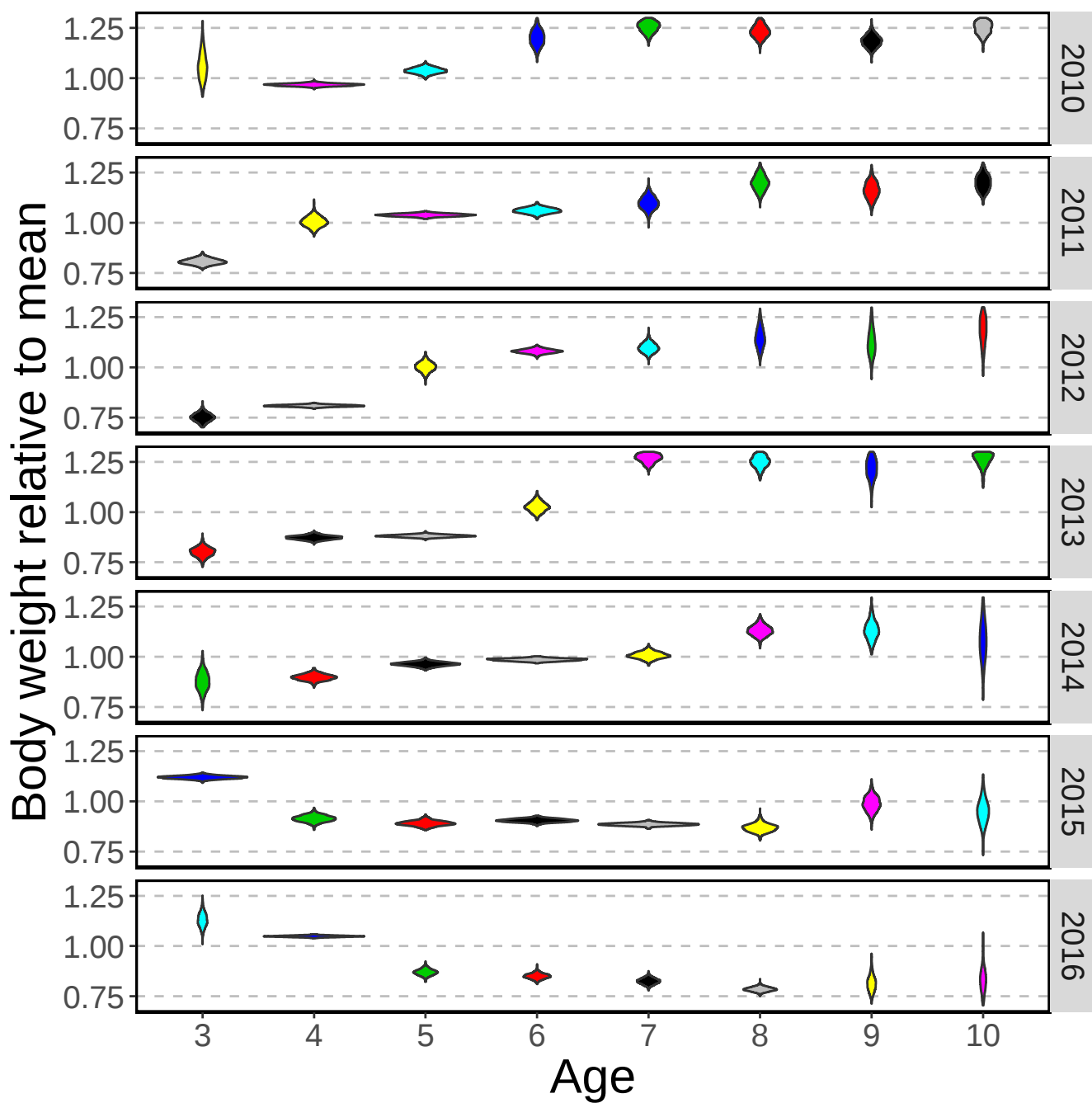
Fishery catch-at-age

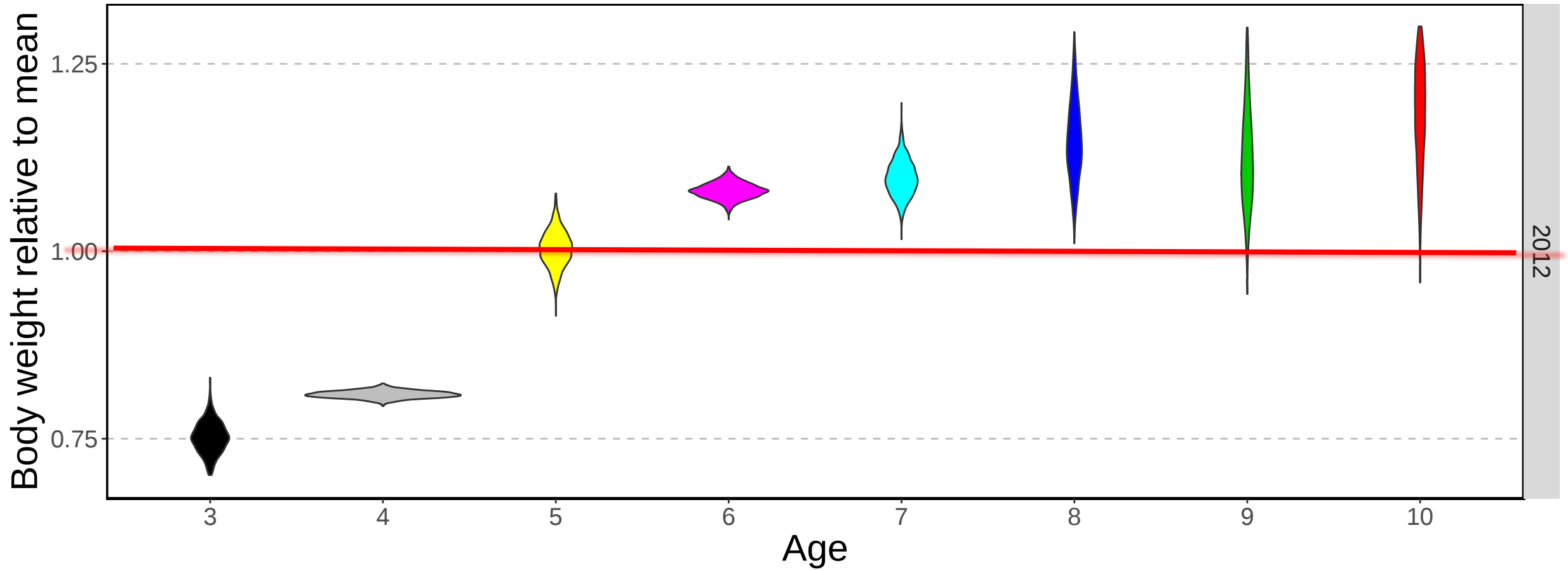


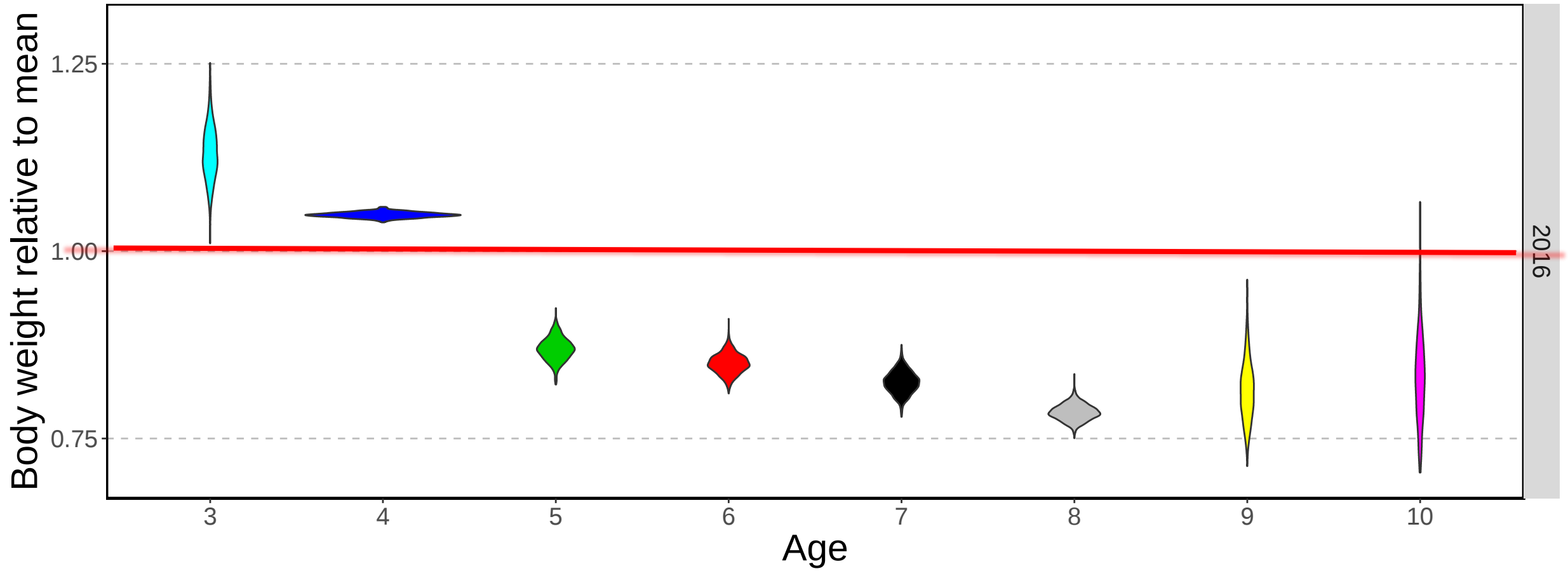
NOAA FISHERIES

Age

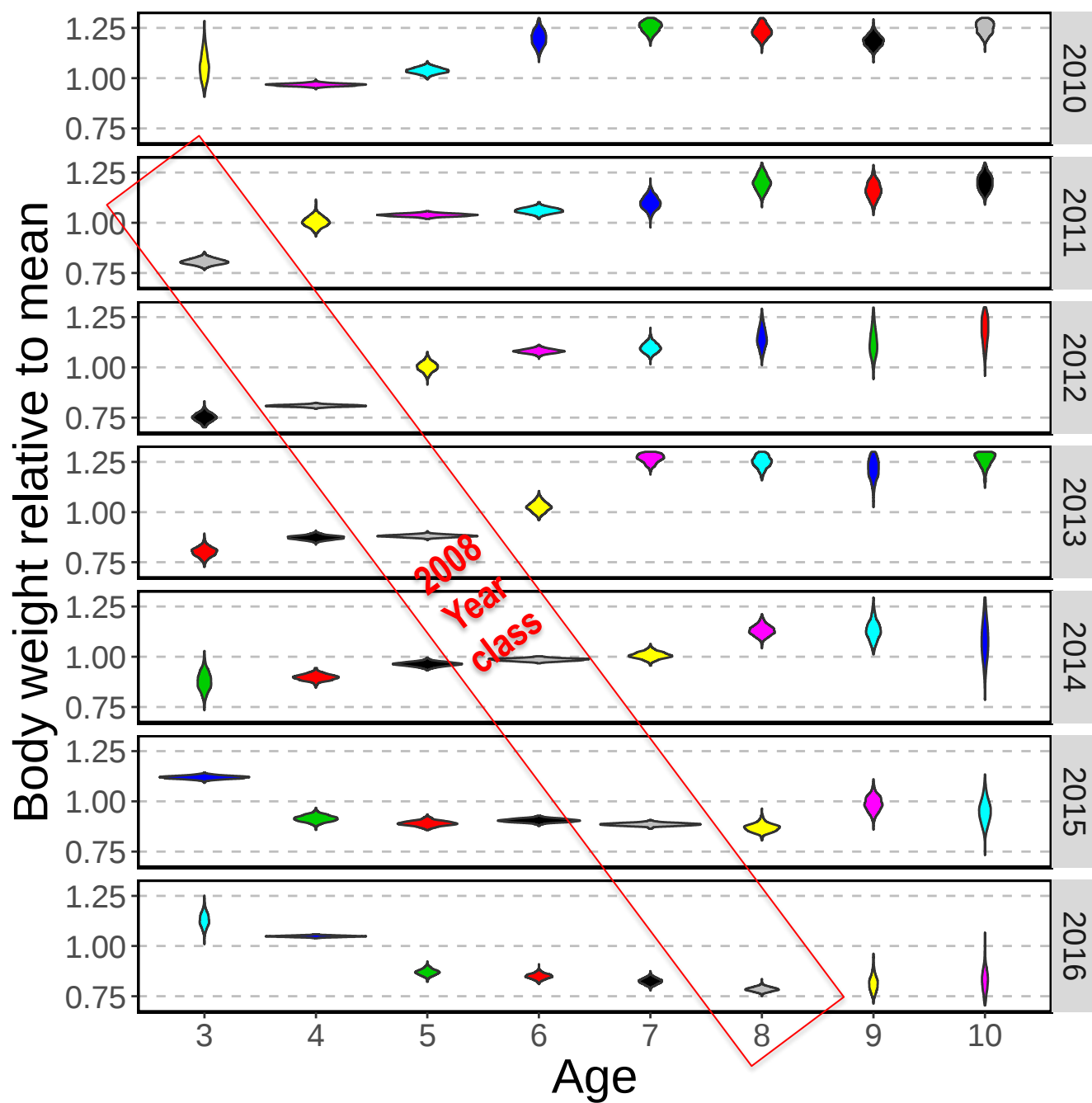
Average weight at age **anomalies**







Average weight at age anomalies

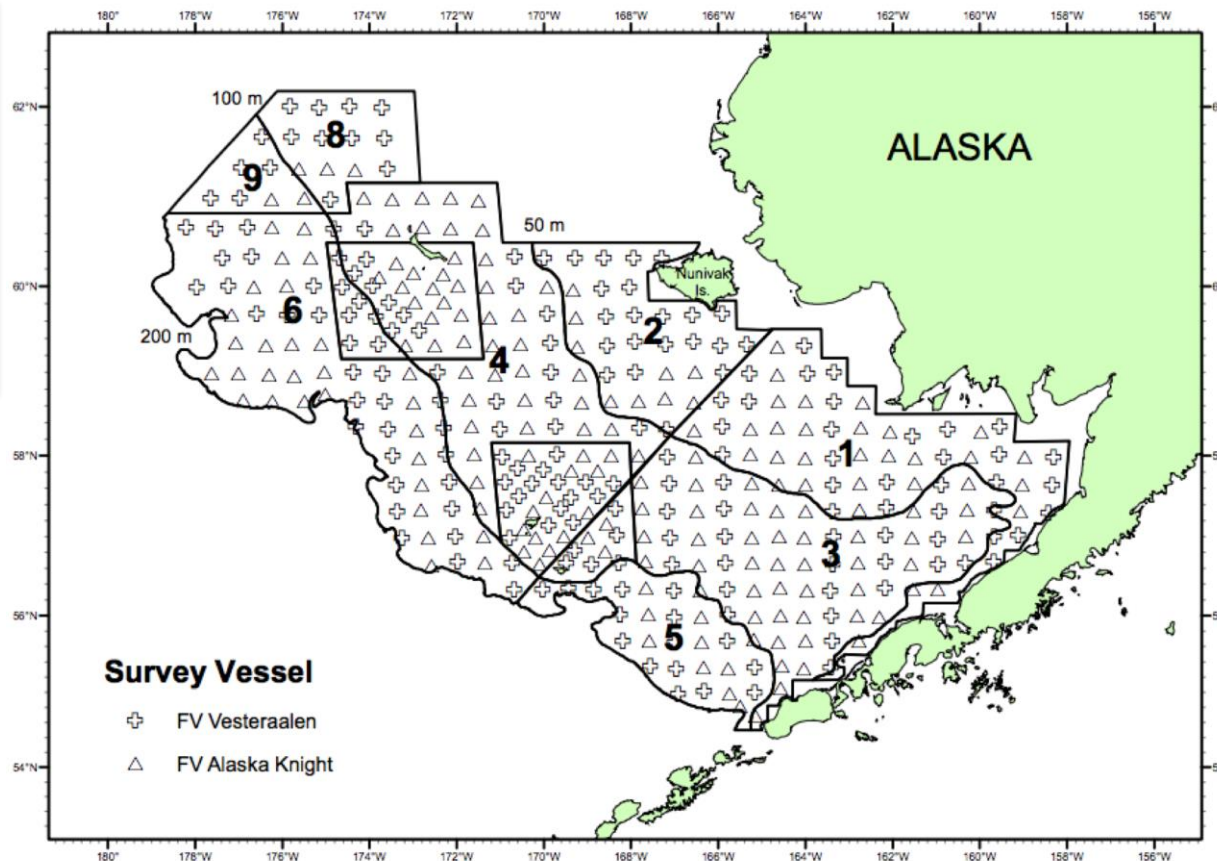
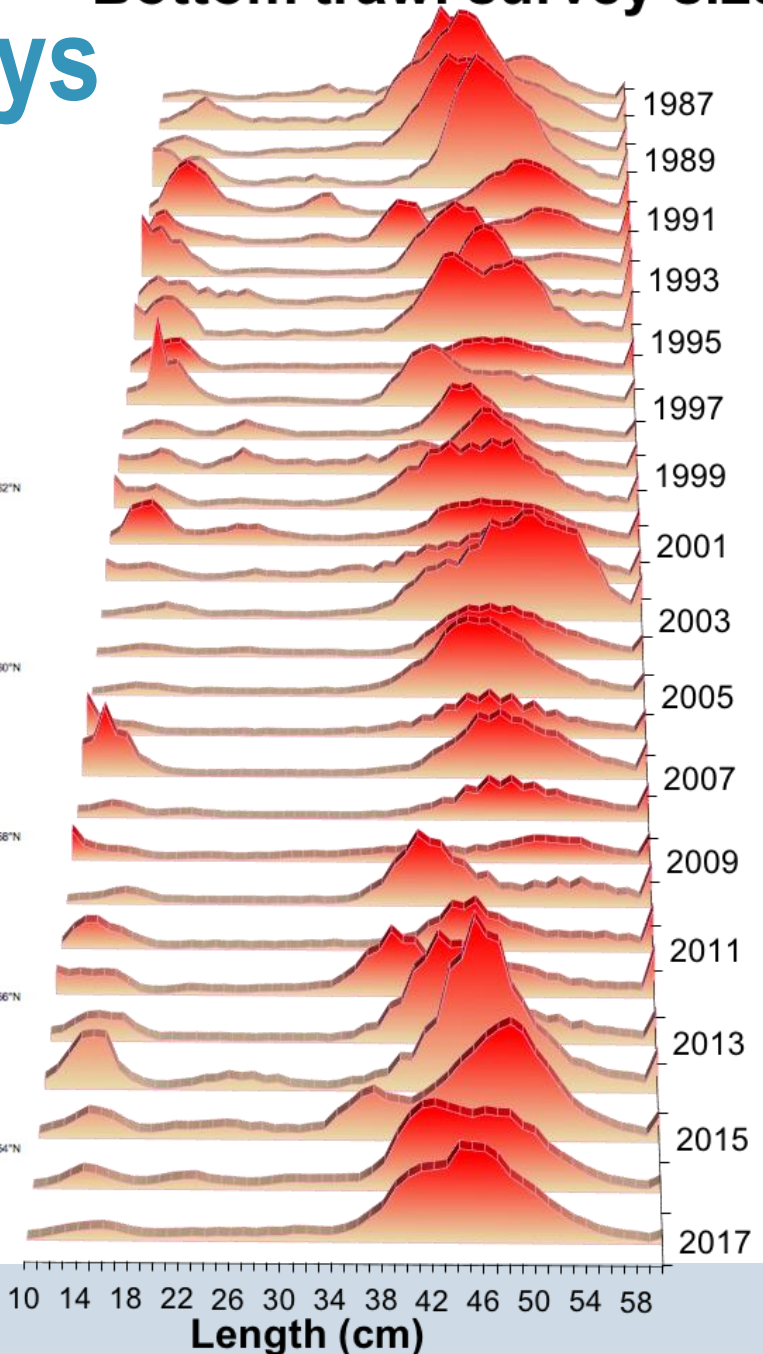


Procedure for fishery weight-age estimation (near term projections)

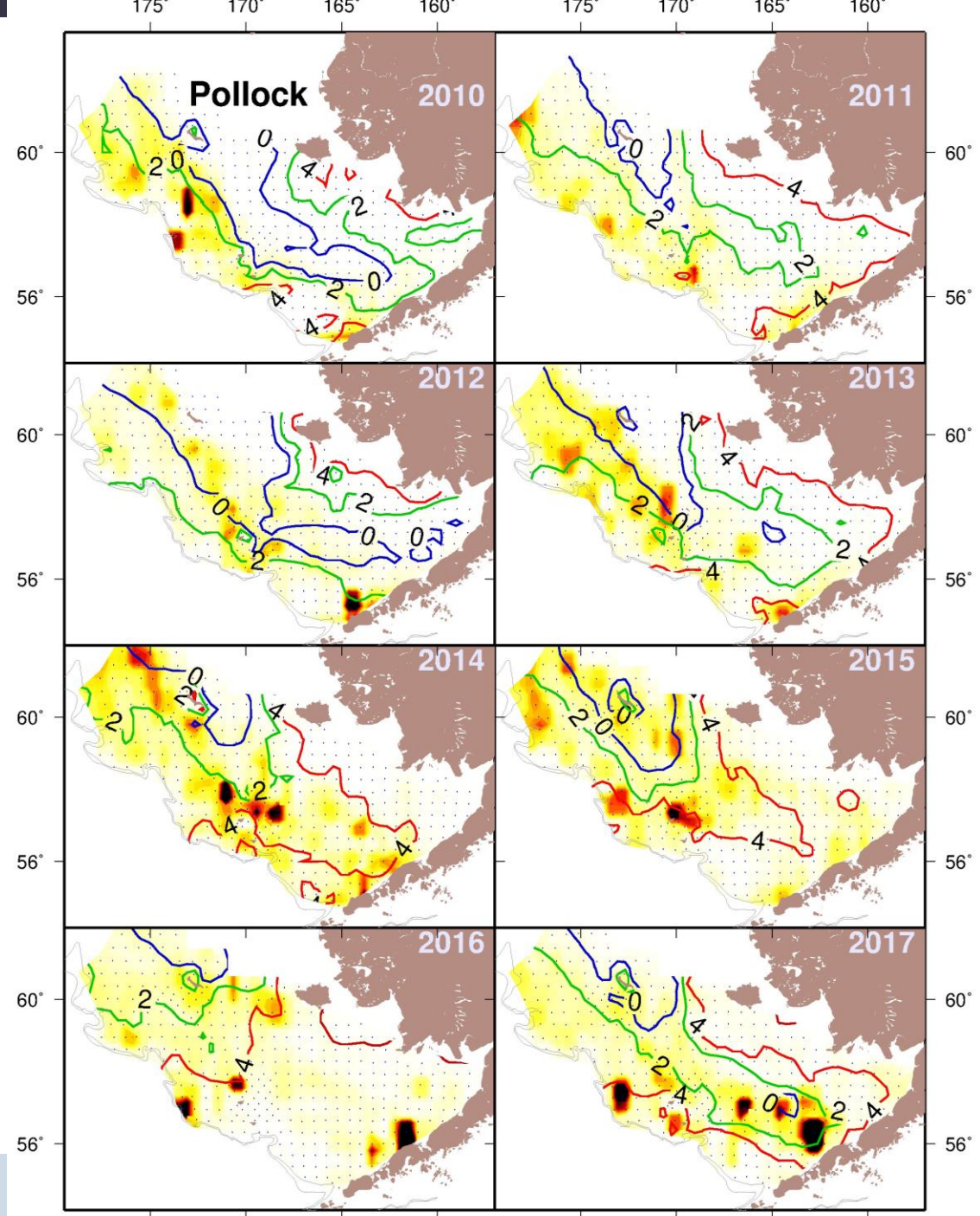
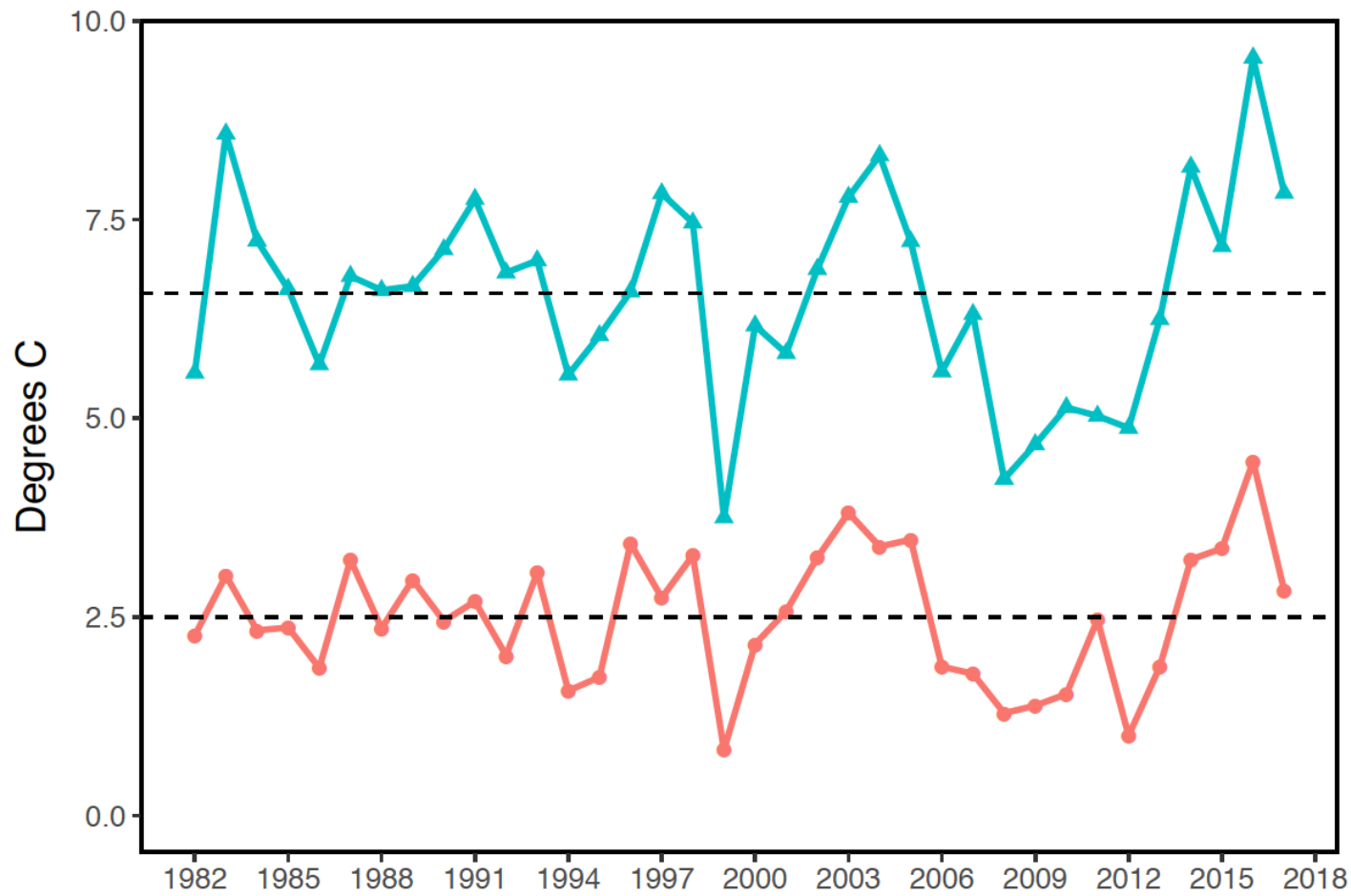
1. Run separate random effects model
 - Observation errors specified (available from bootstraps)
 - **Estimate the process error variances:**
 - Year and cohort effects
2. Use same estimation procedure in full assessment model
 - Year and cohort effects **treated as fixed effects because:**
 - Variances available from step 1

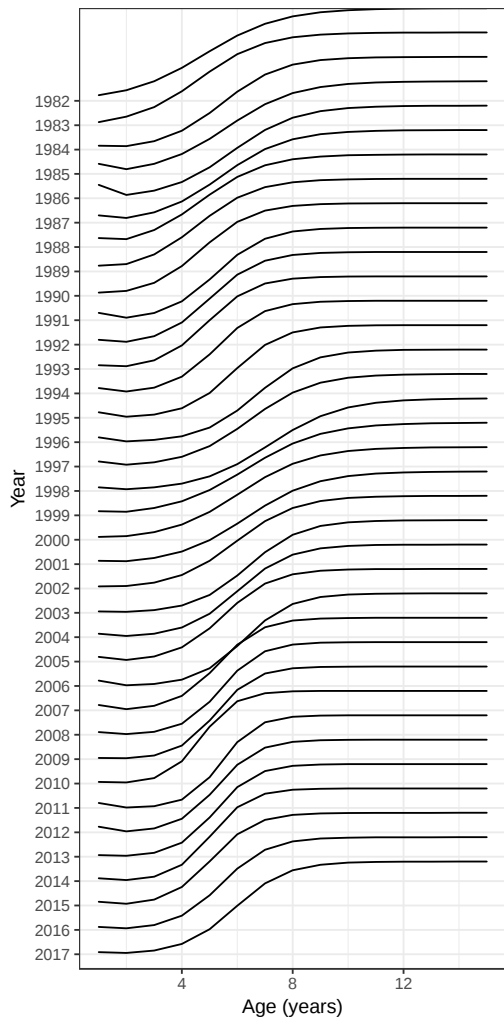
Scientific research surveys

Independent from fishery data—
designed sampling

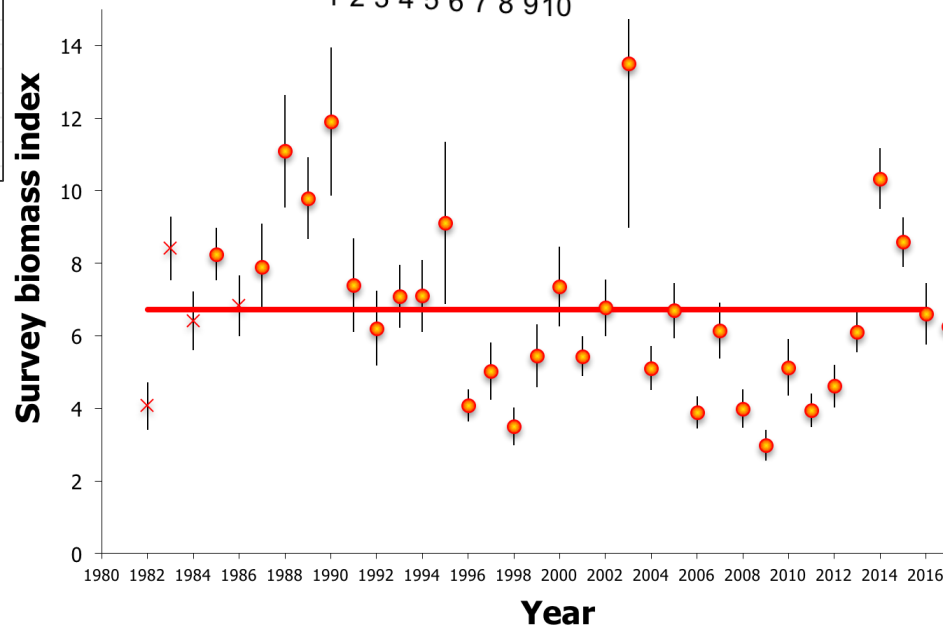
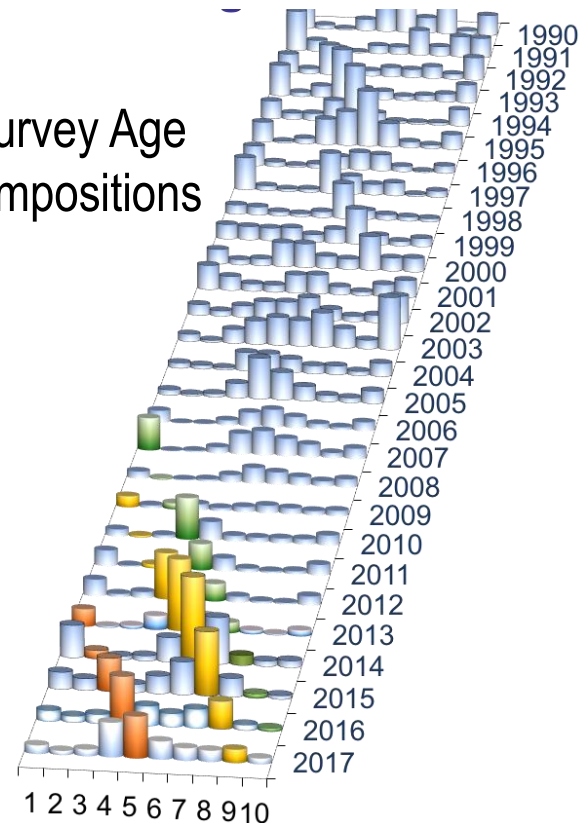


Pollock density and environment

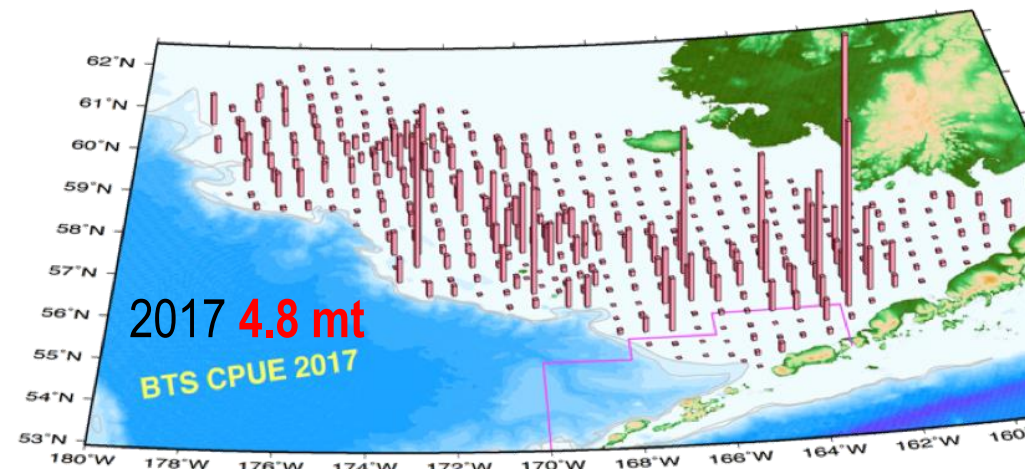
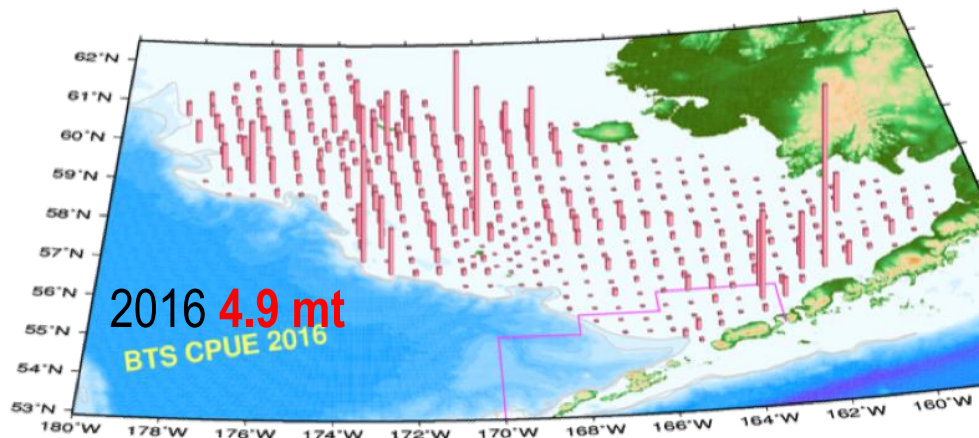
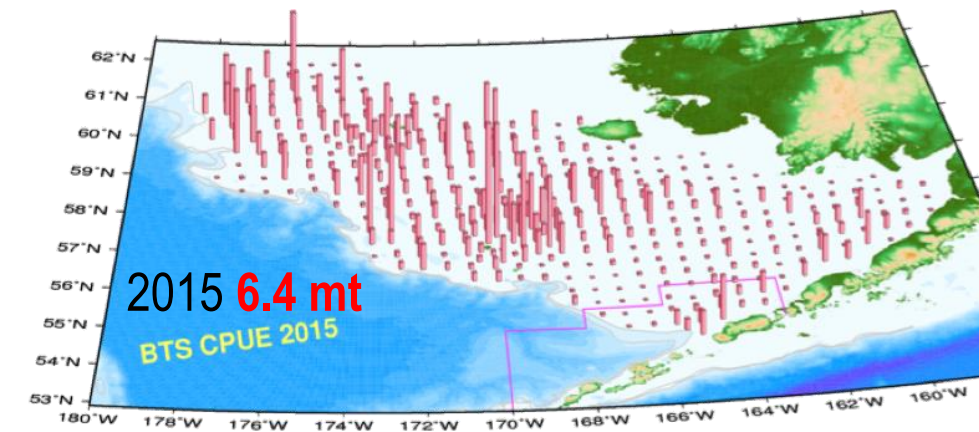




Survey Age compositions

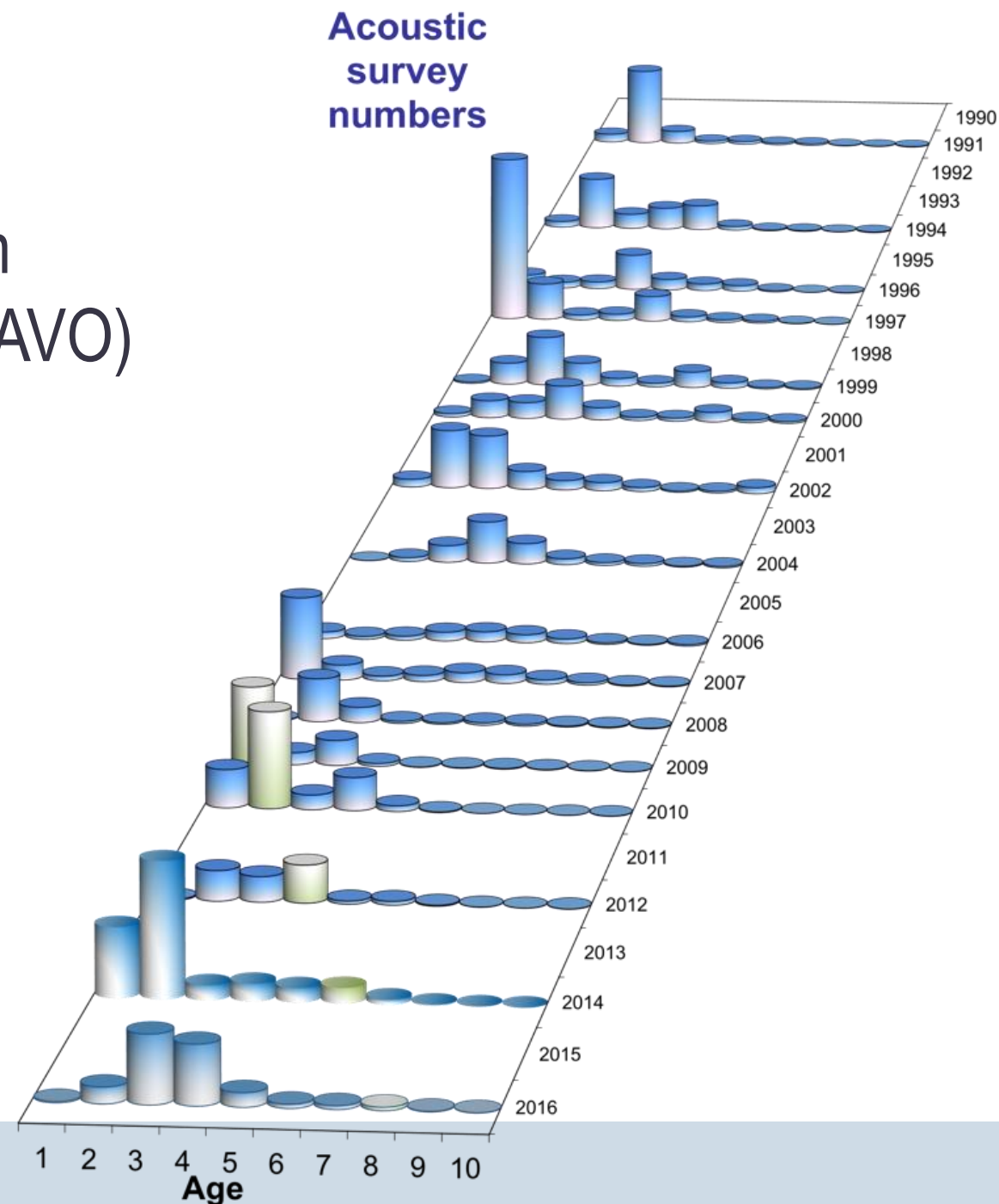


Bottom-trawl surveys



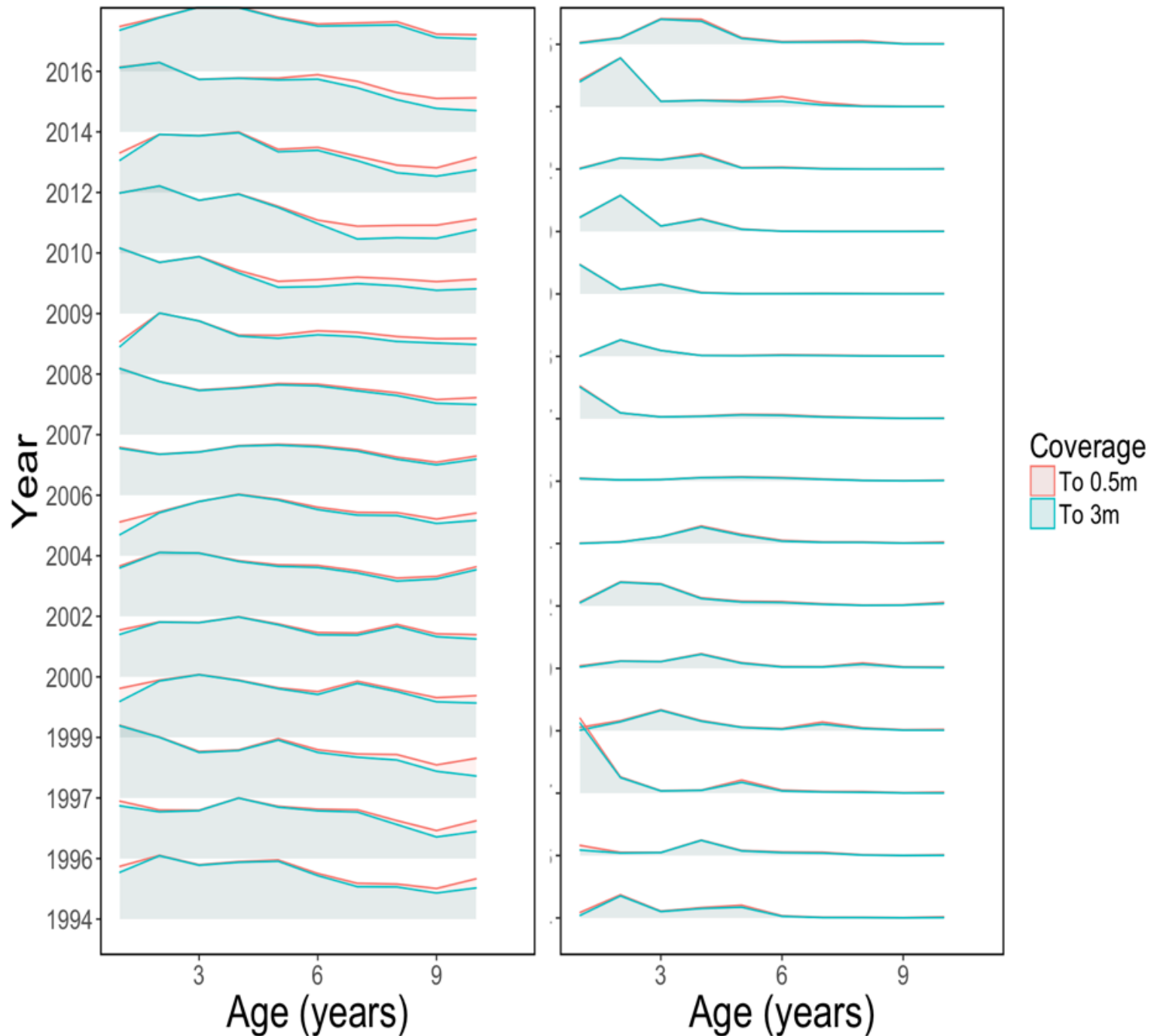
New data

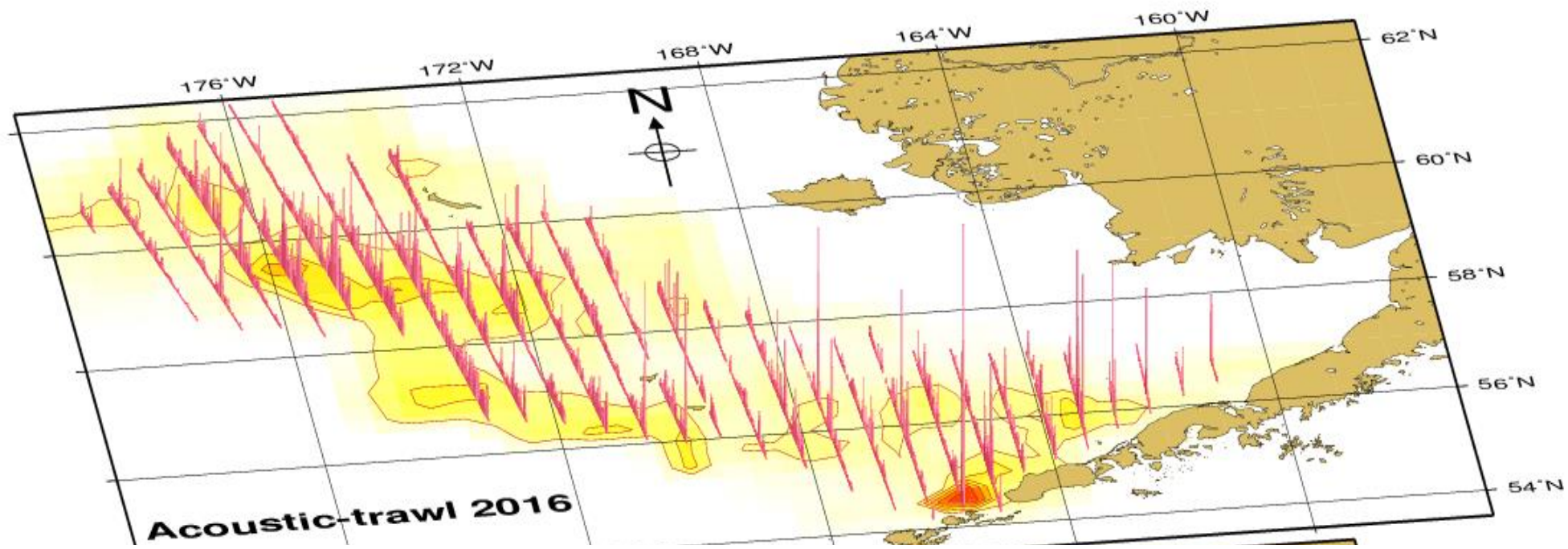
Updated acoustics to 0.5m from bottom
Acoustics from vessels of opportunity (AVO)
Fishery and bottom trawl survey



Acoustic trawl survey age compositions

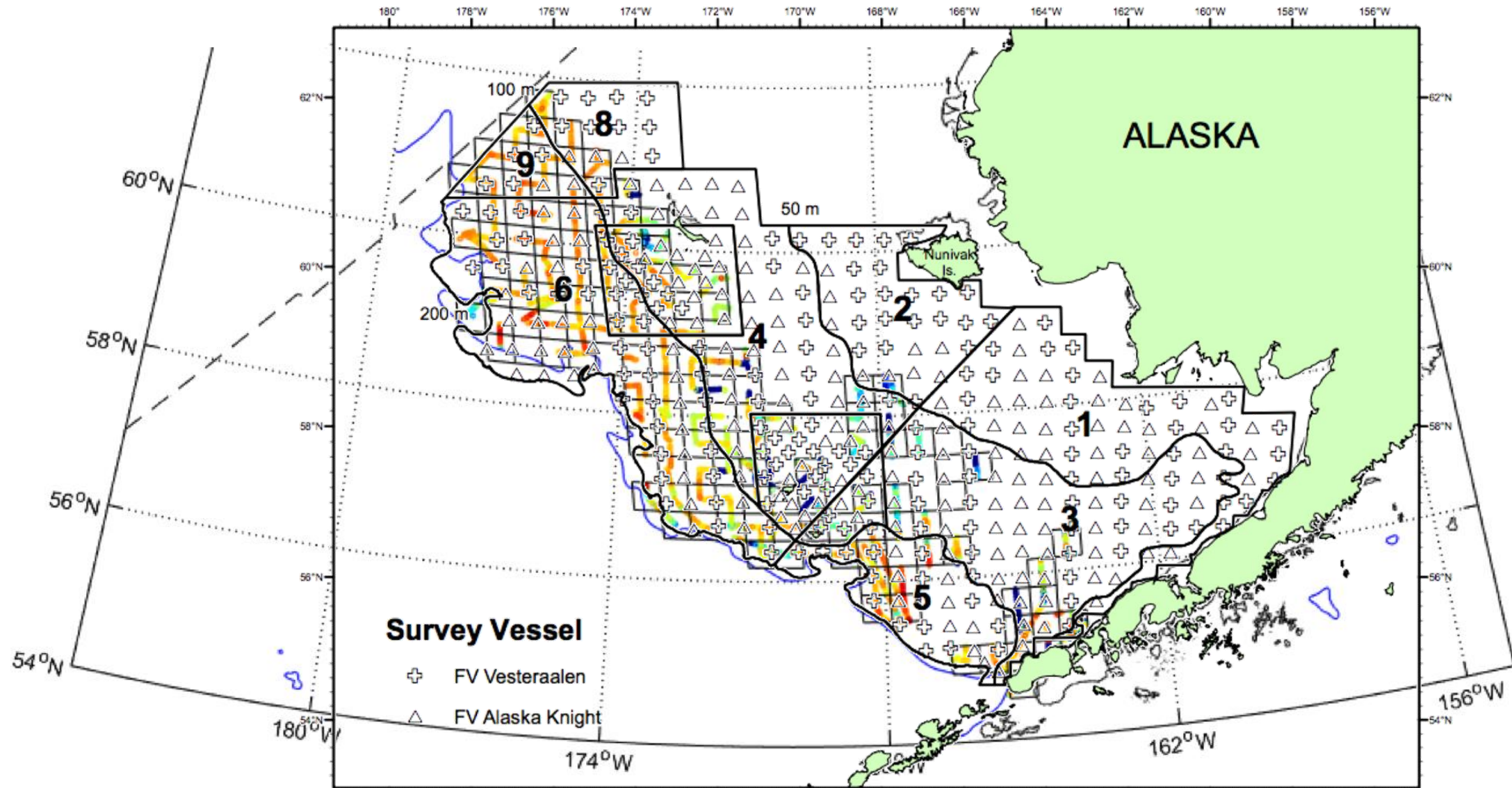
Change w/ bottom
layer added

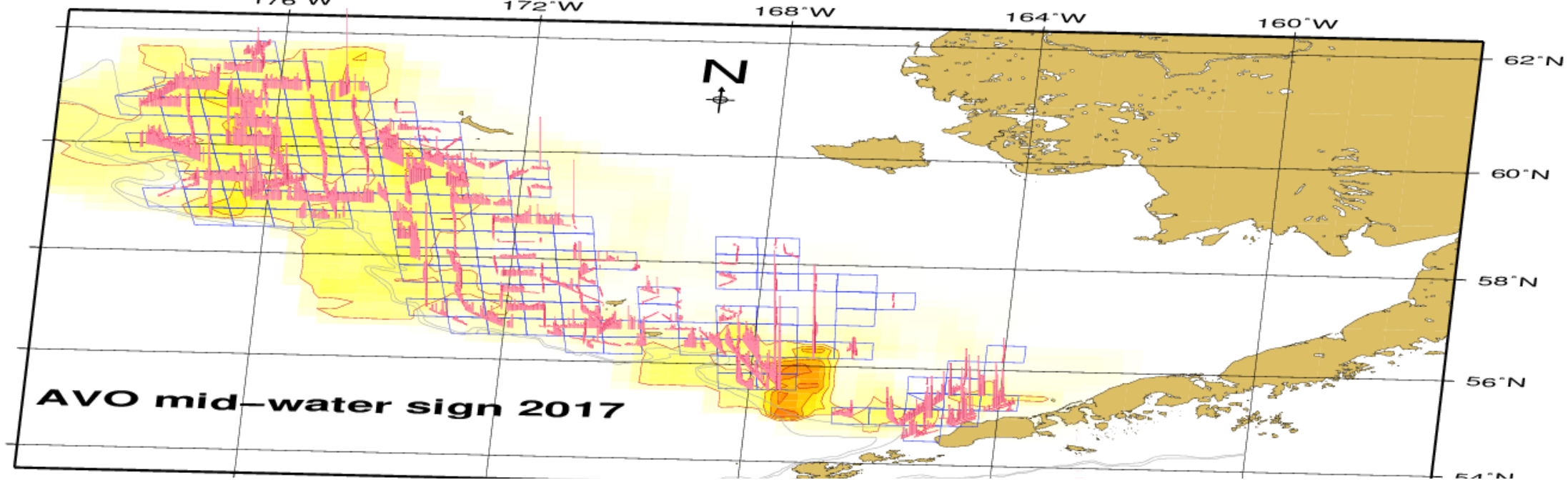


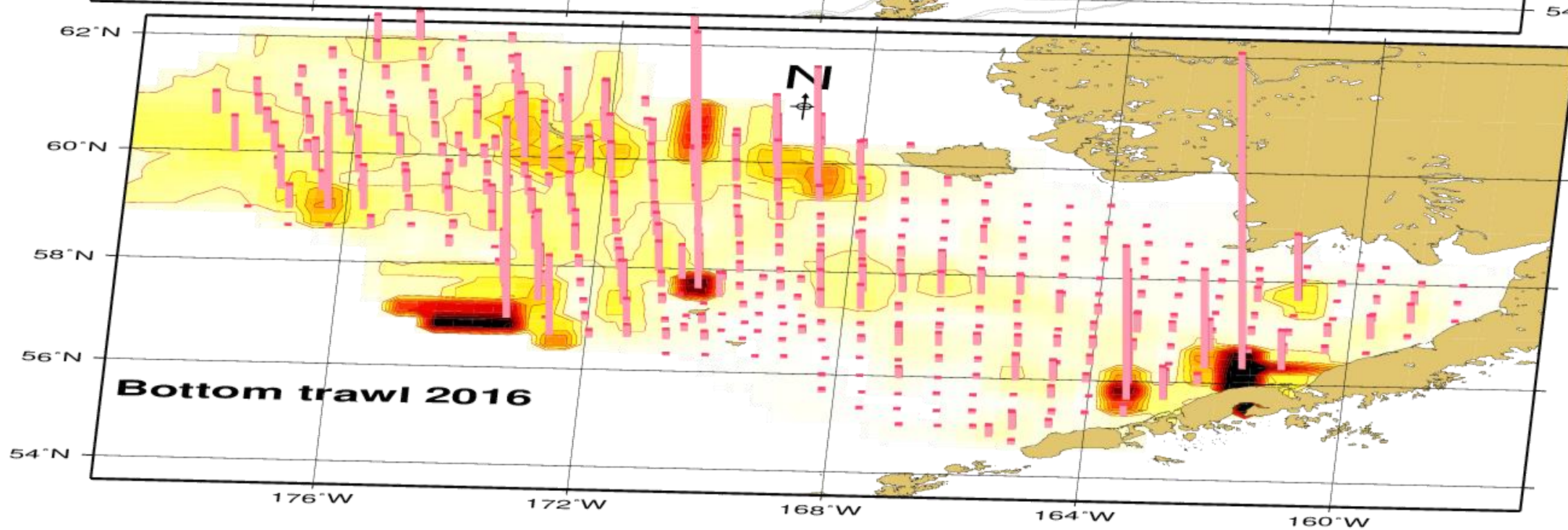
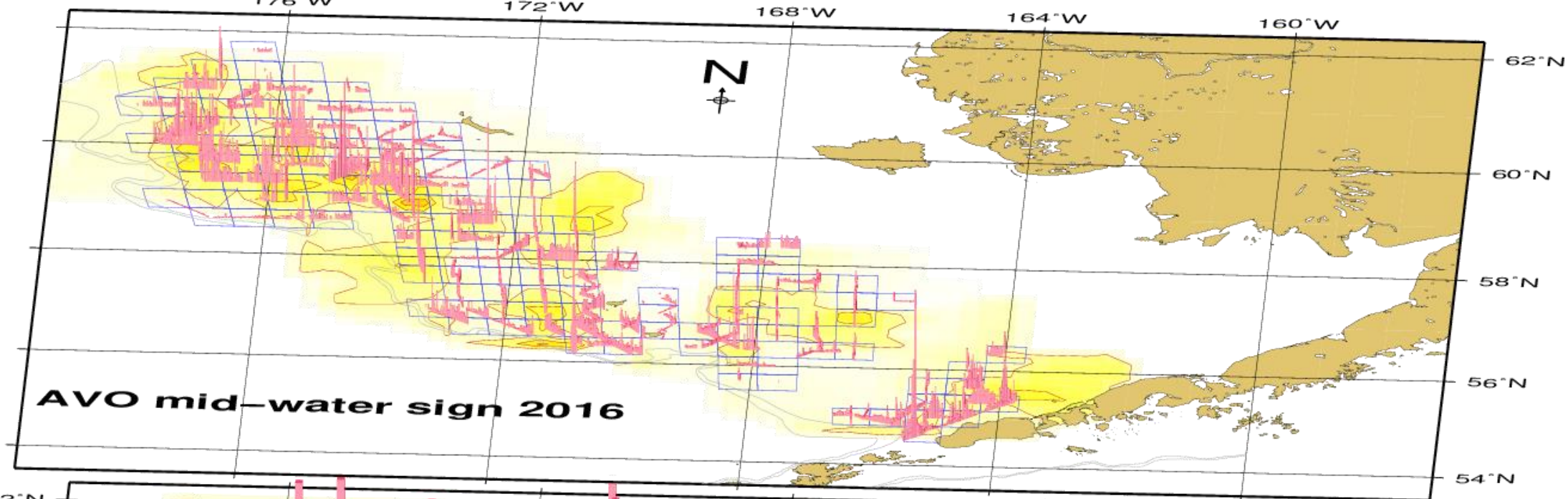


**Comparing
2016
Surveys**

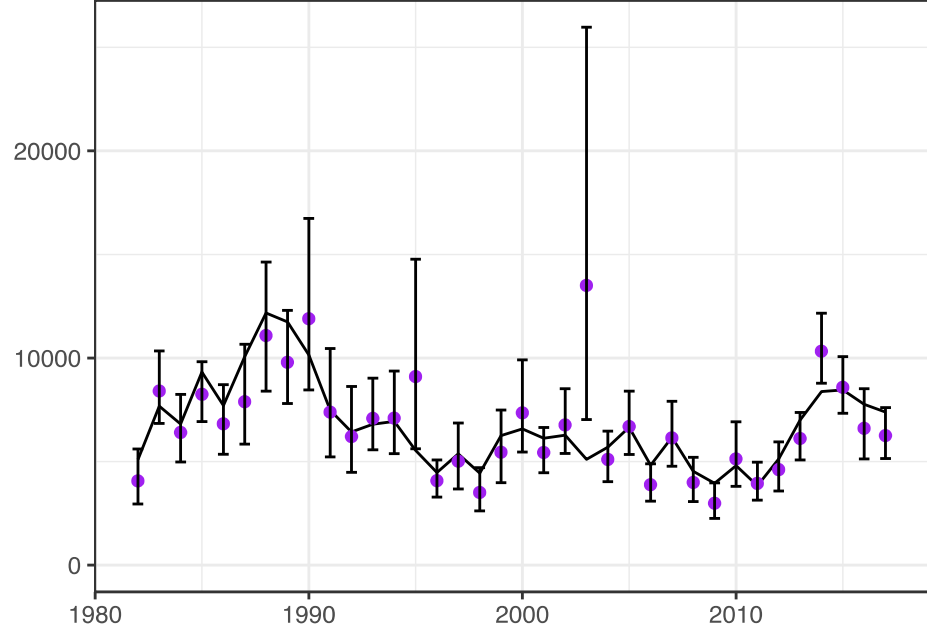
New Data in 2017—two years of AVO





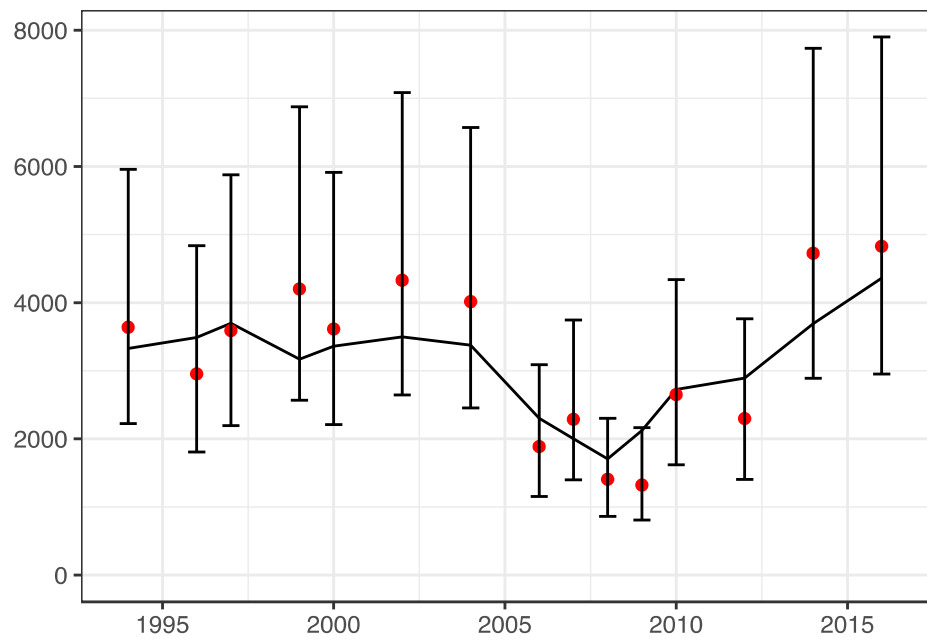


Bottom trawl survey biomass



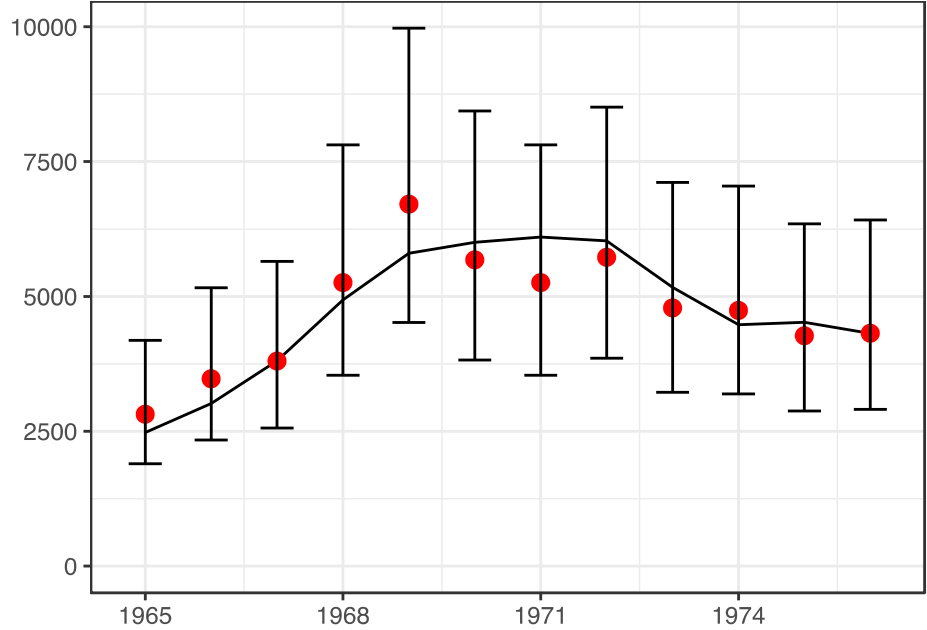
Year

Acoustic trawl survey biomass



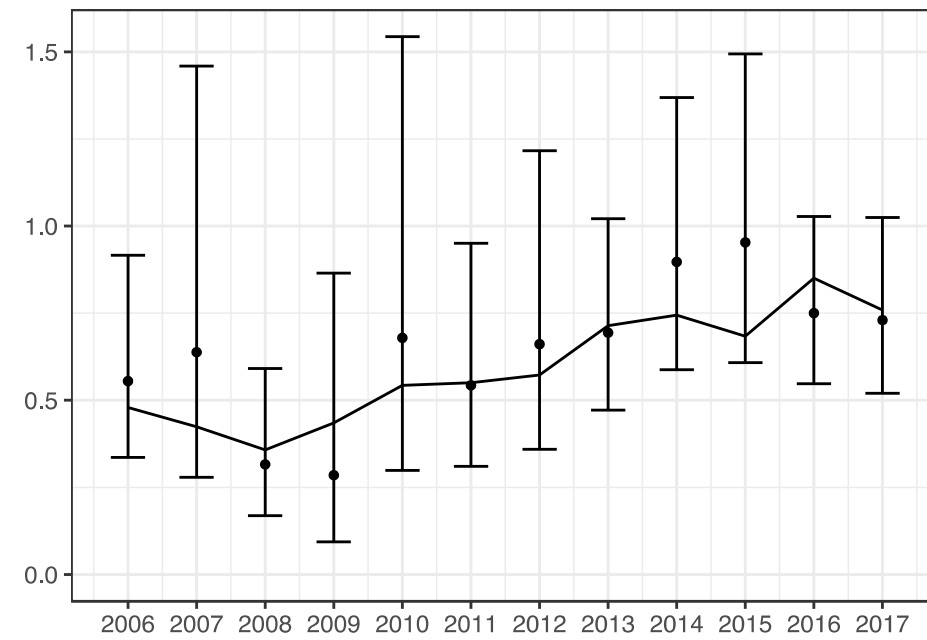
Year

Early trawl fishery CPUE

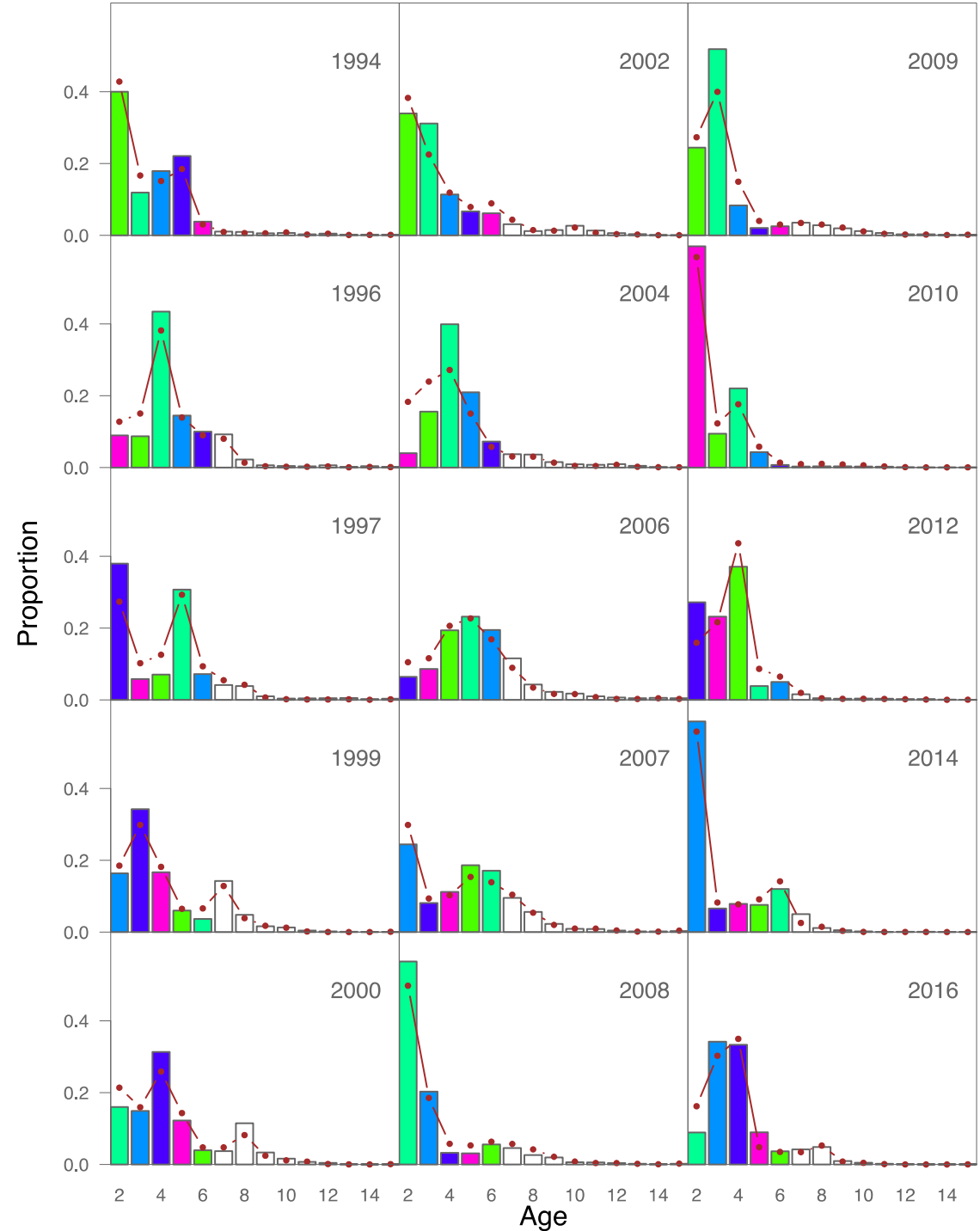
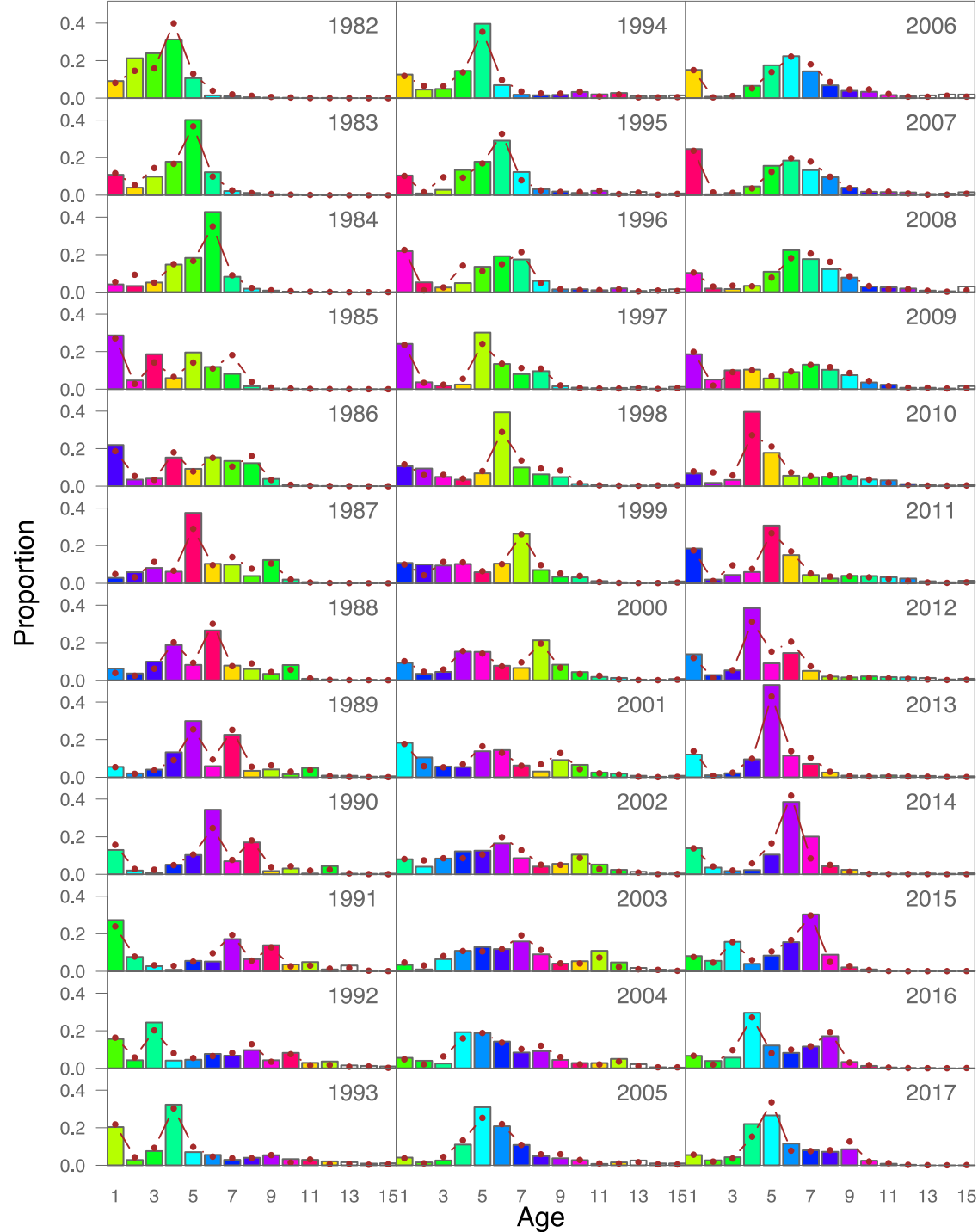


Year

Acoustic return (Sa from AVO)

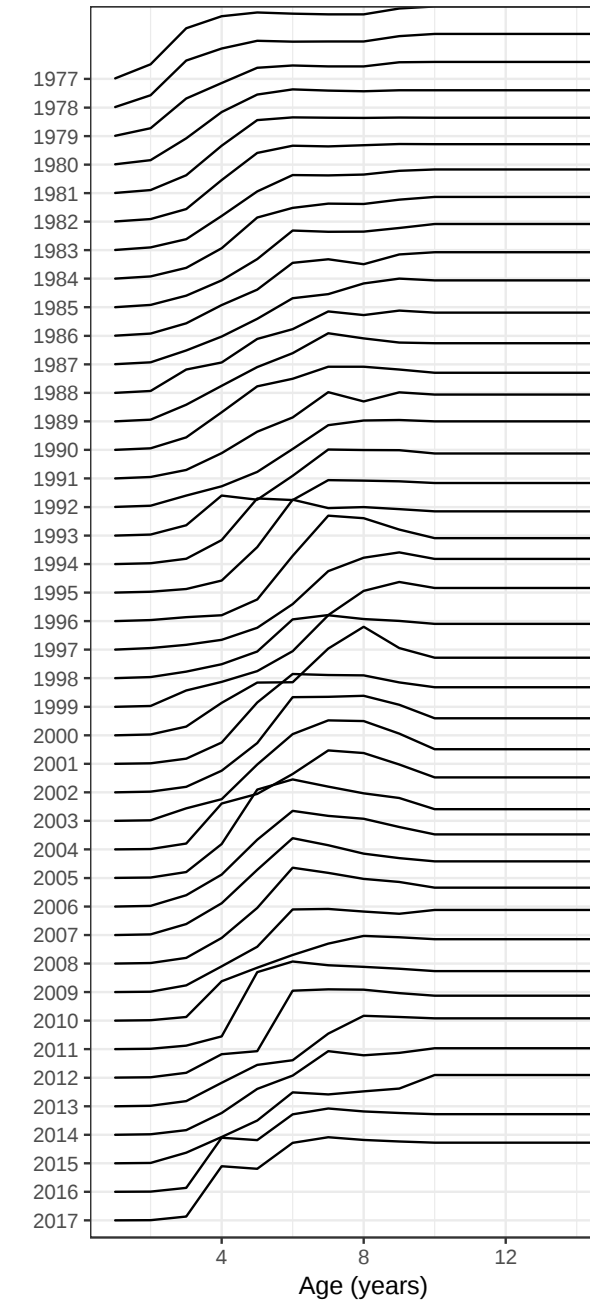
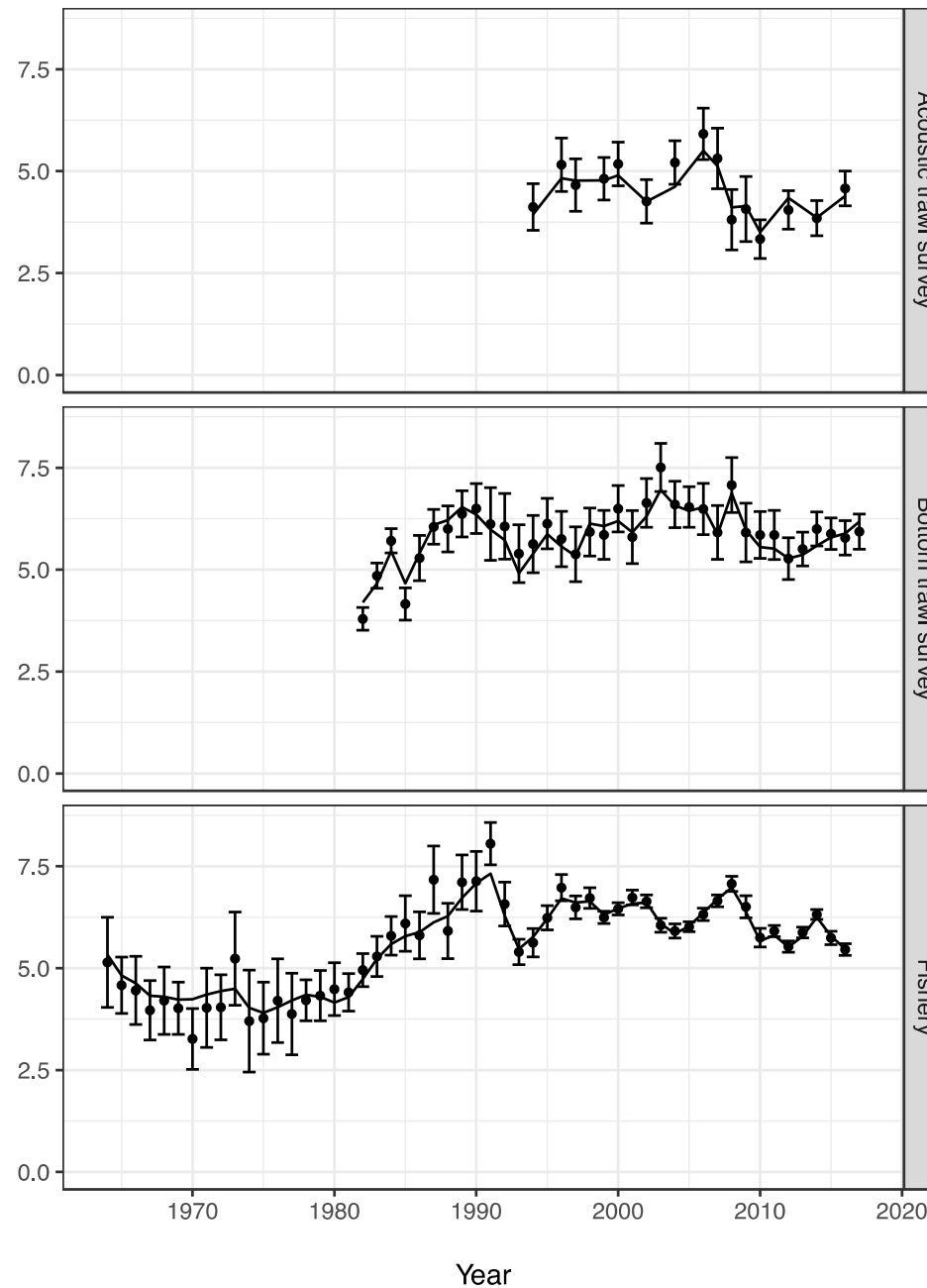
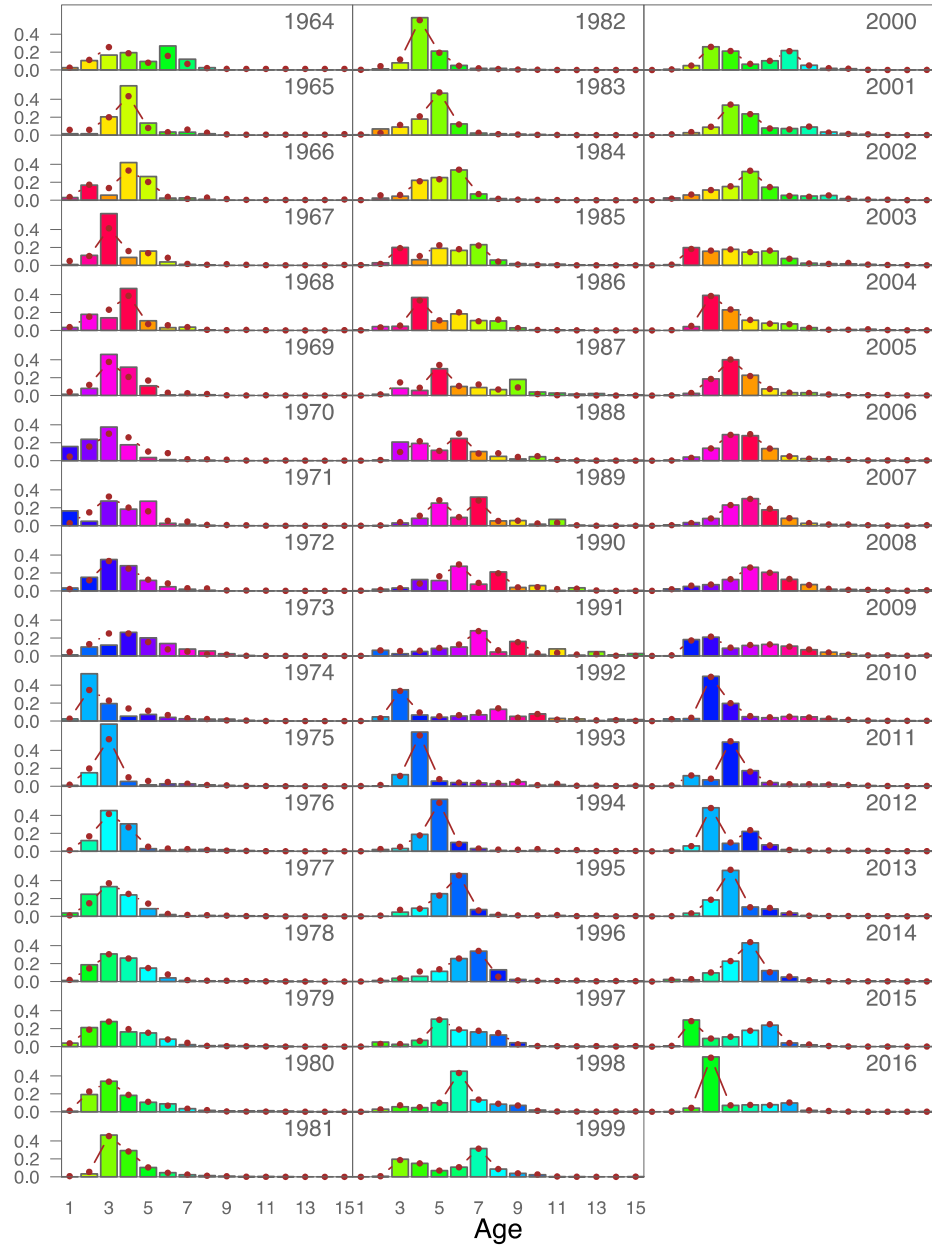


Year

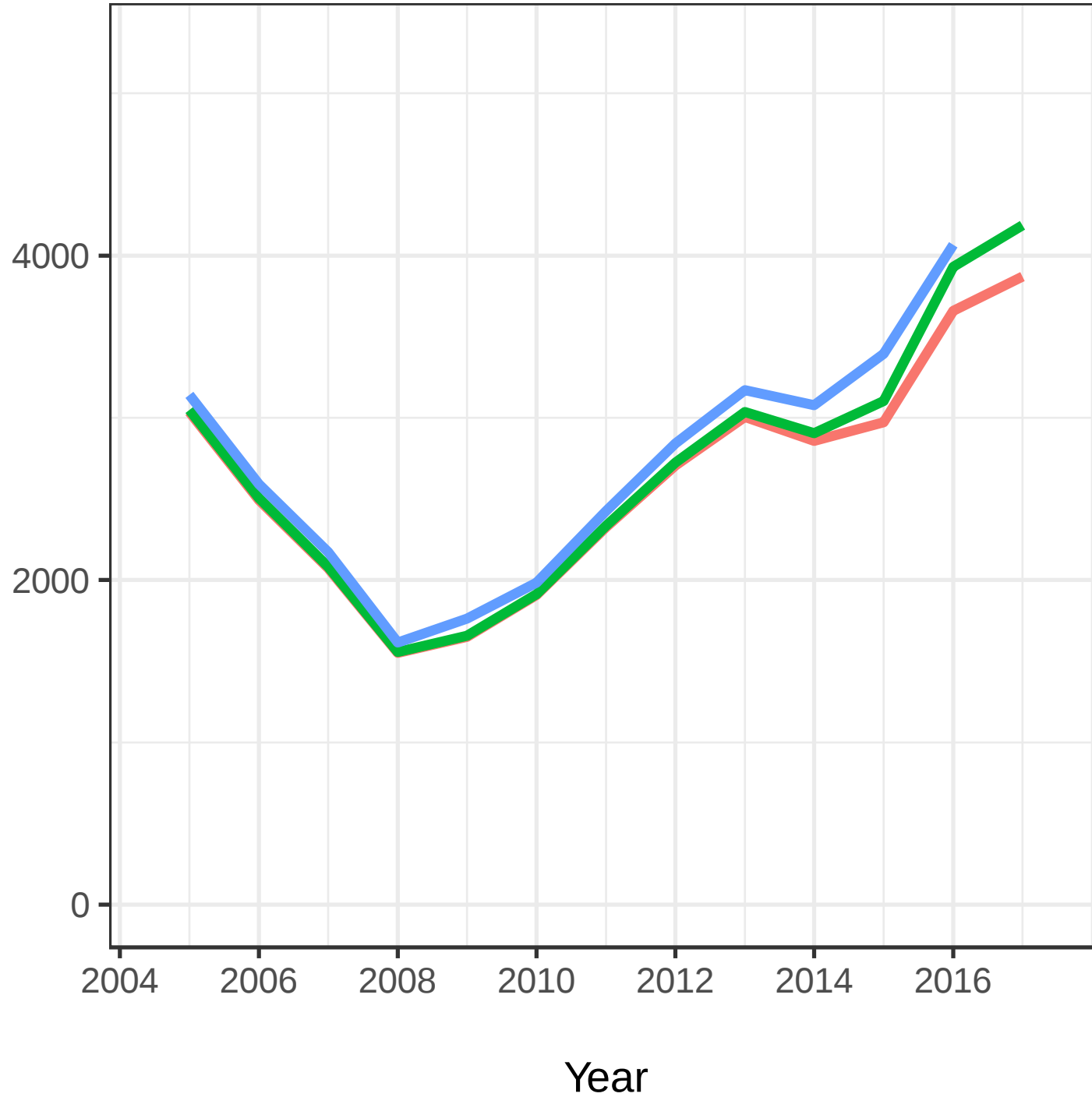


EBS pollock survey age composition data

(2017 Assessment)



Female spawning biomass (kt)

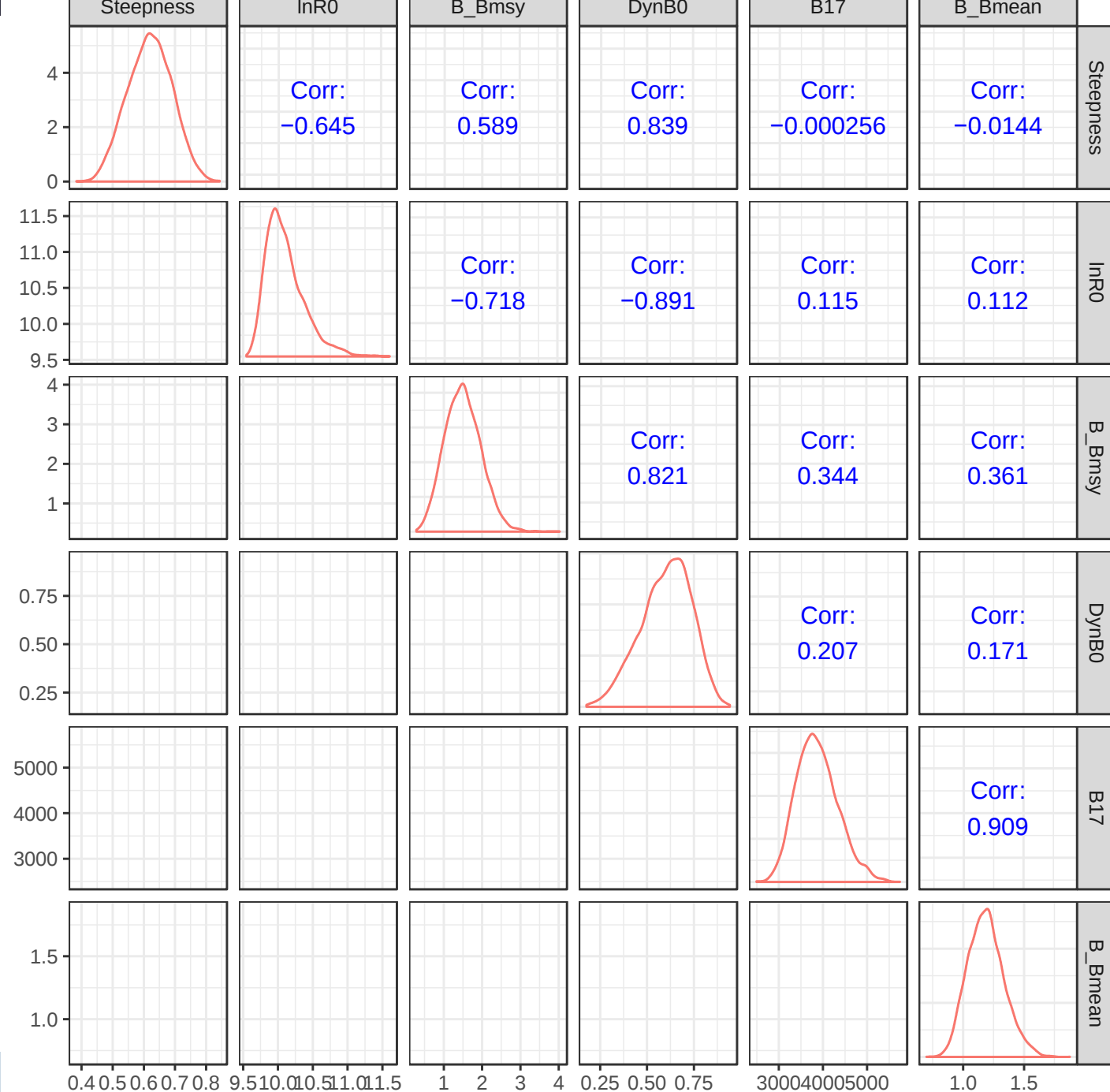


Model

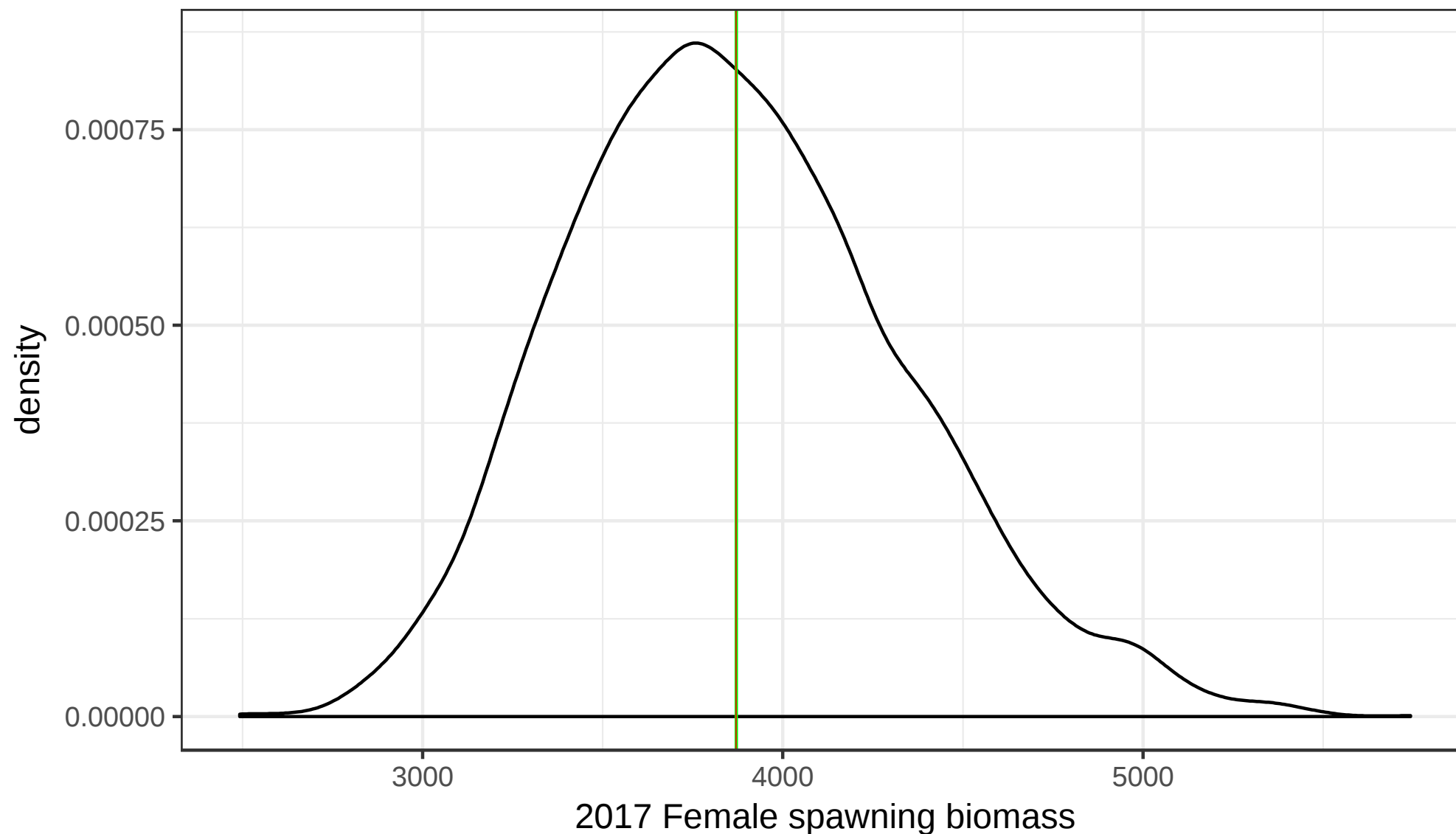
- 16.0a
(acoustics to 0.5m)
- Model 16.0
- Model 16.0
last year

MCMC posterior

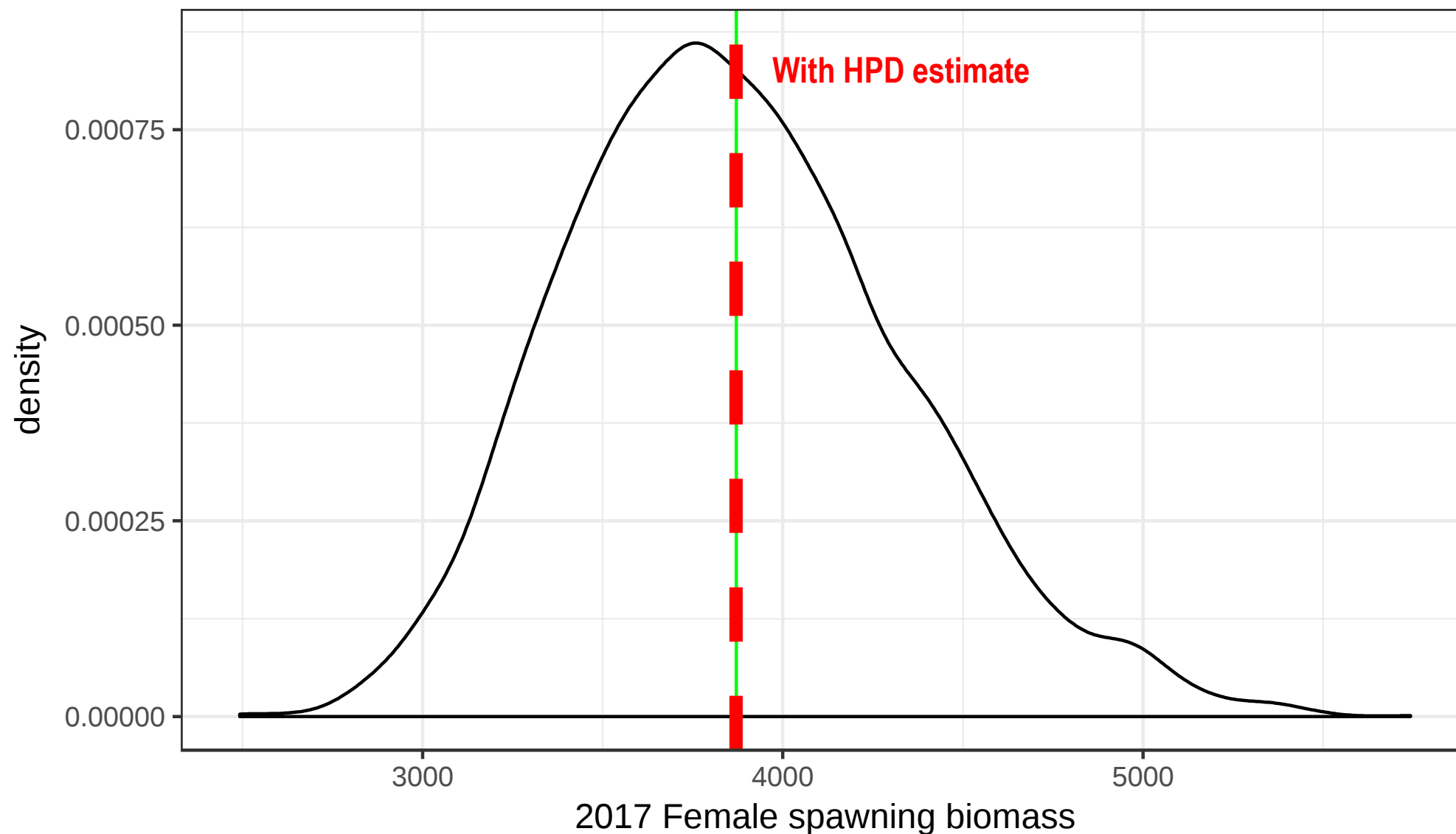
- Added to draft
- Consistent with asymptotic approximations

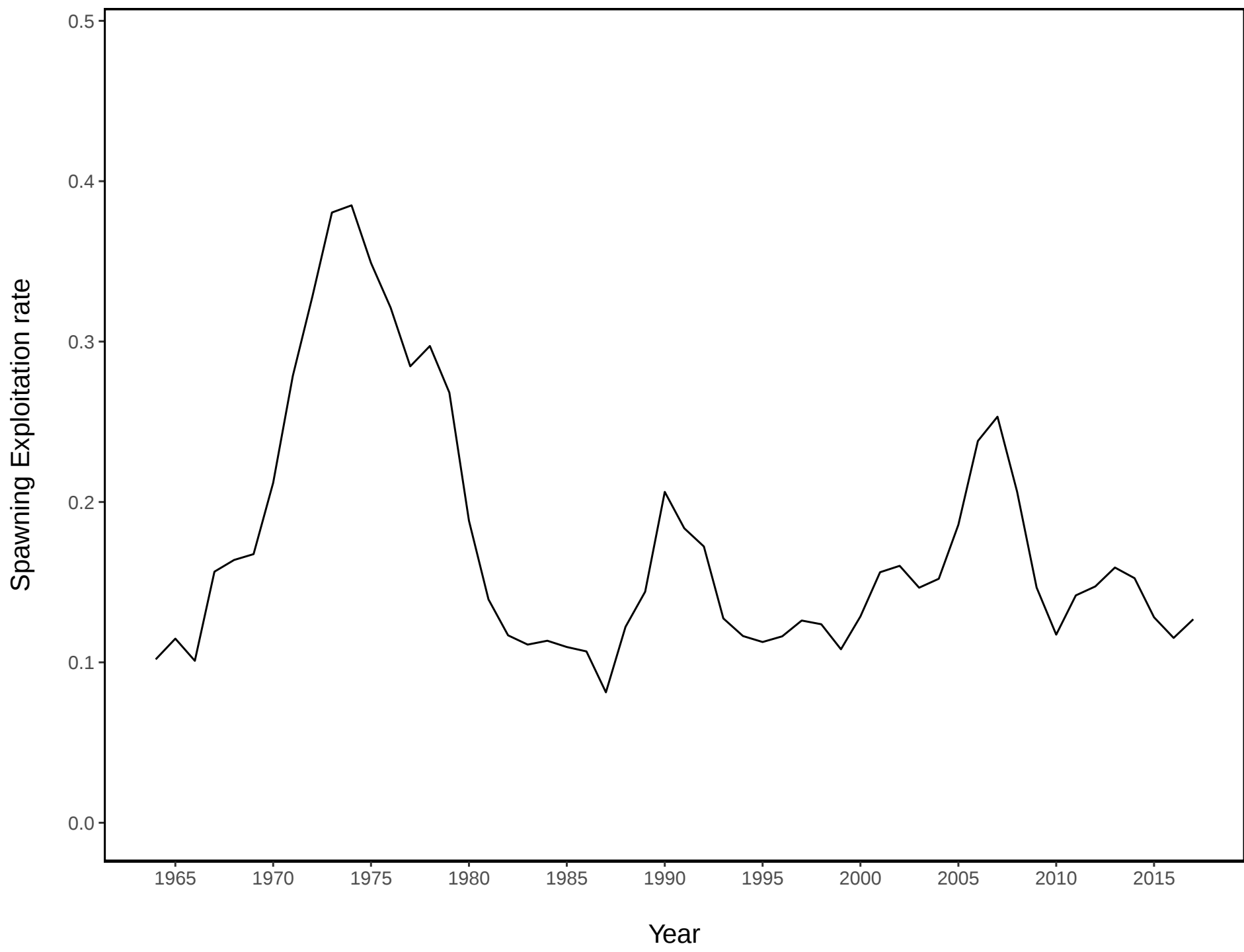


Posterior marginal distribution

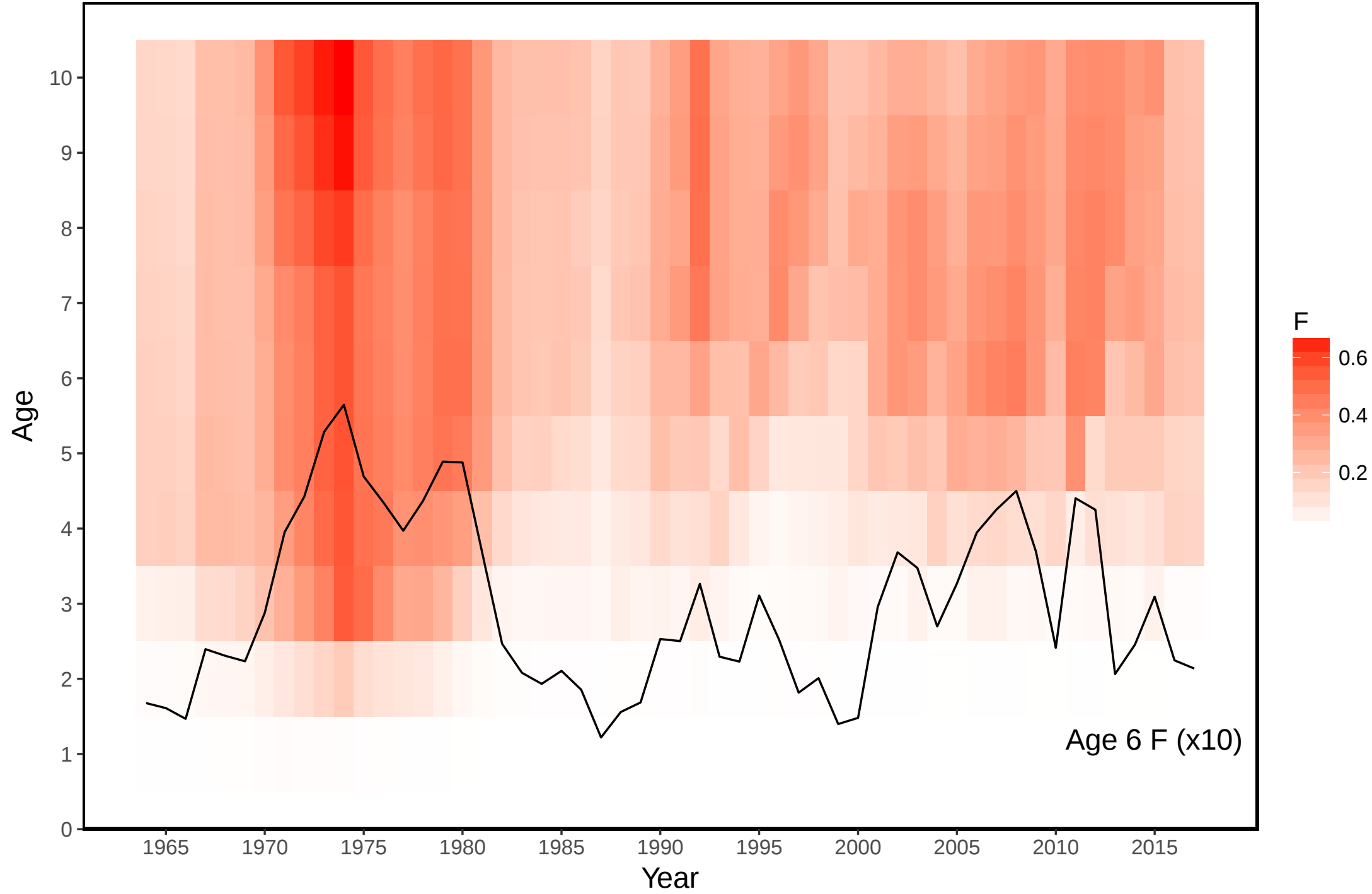


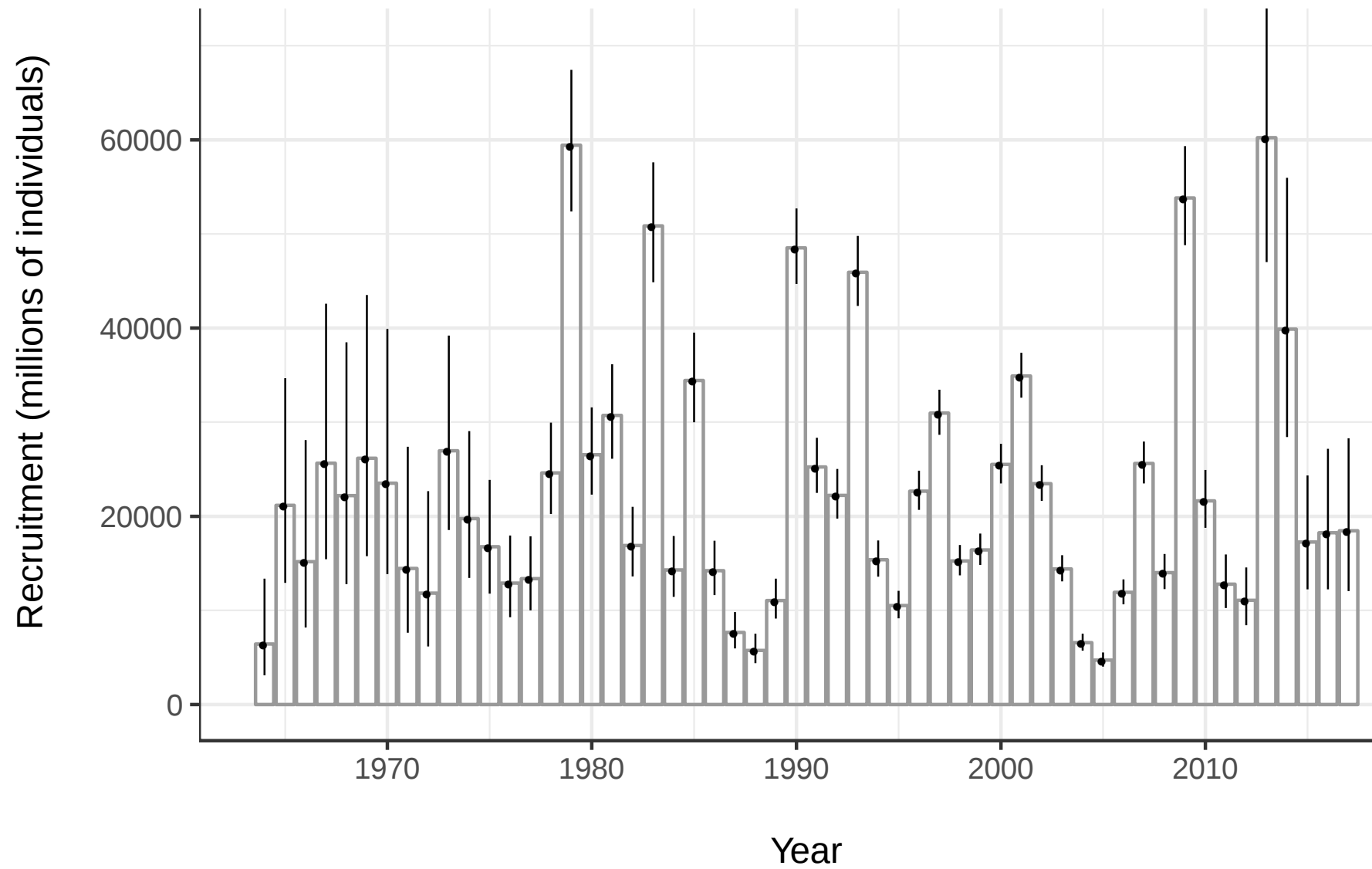
Posterior marginal distribution



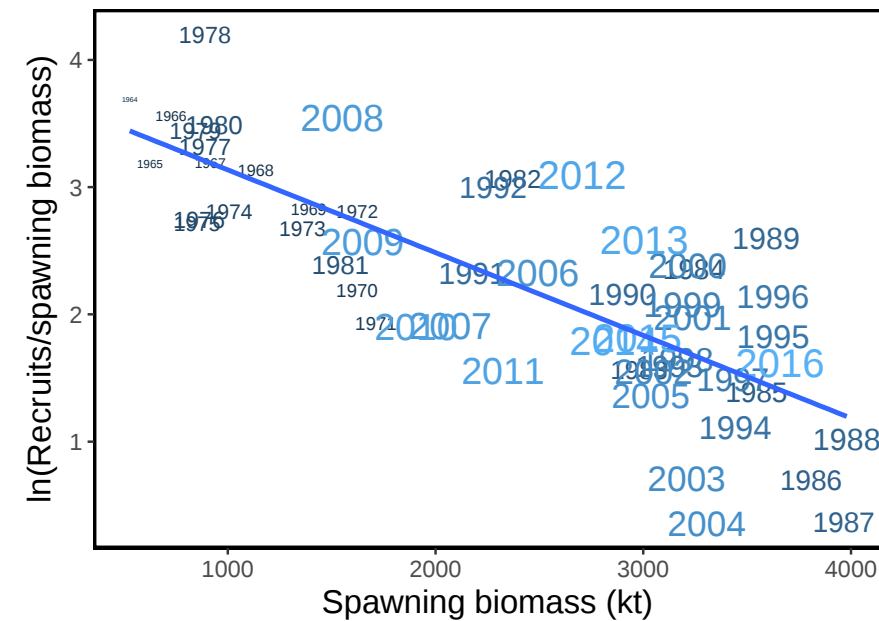
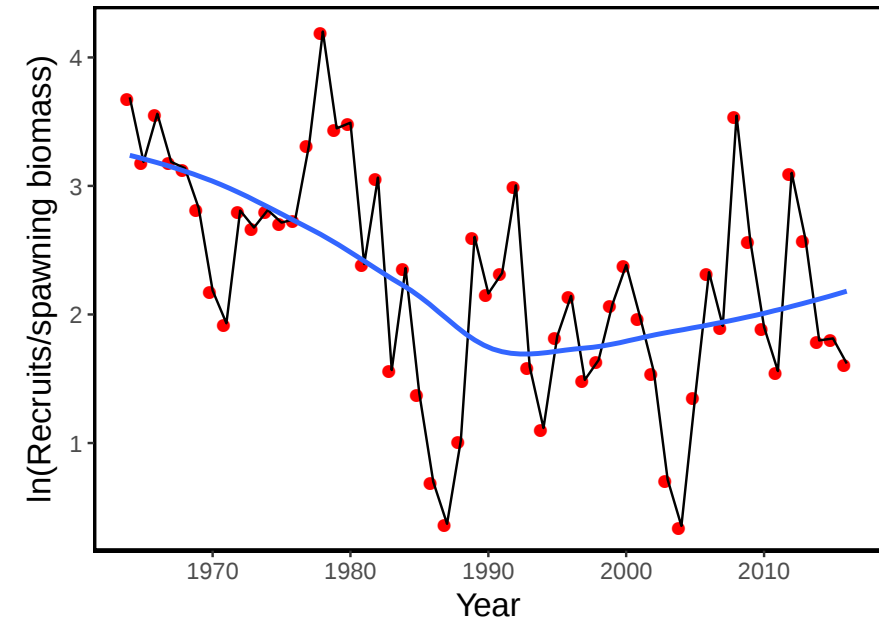
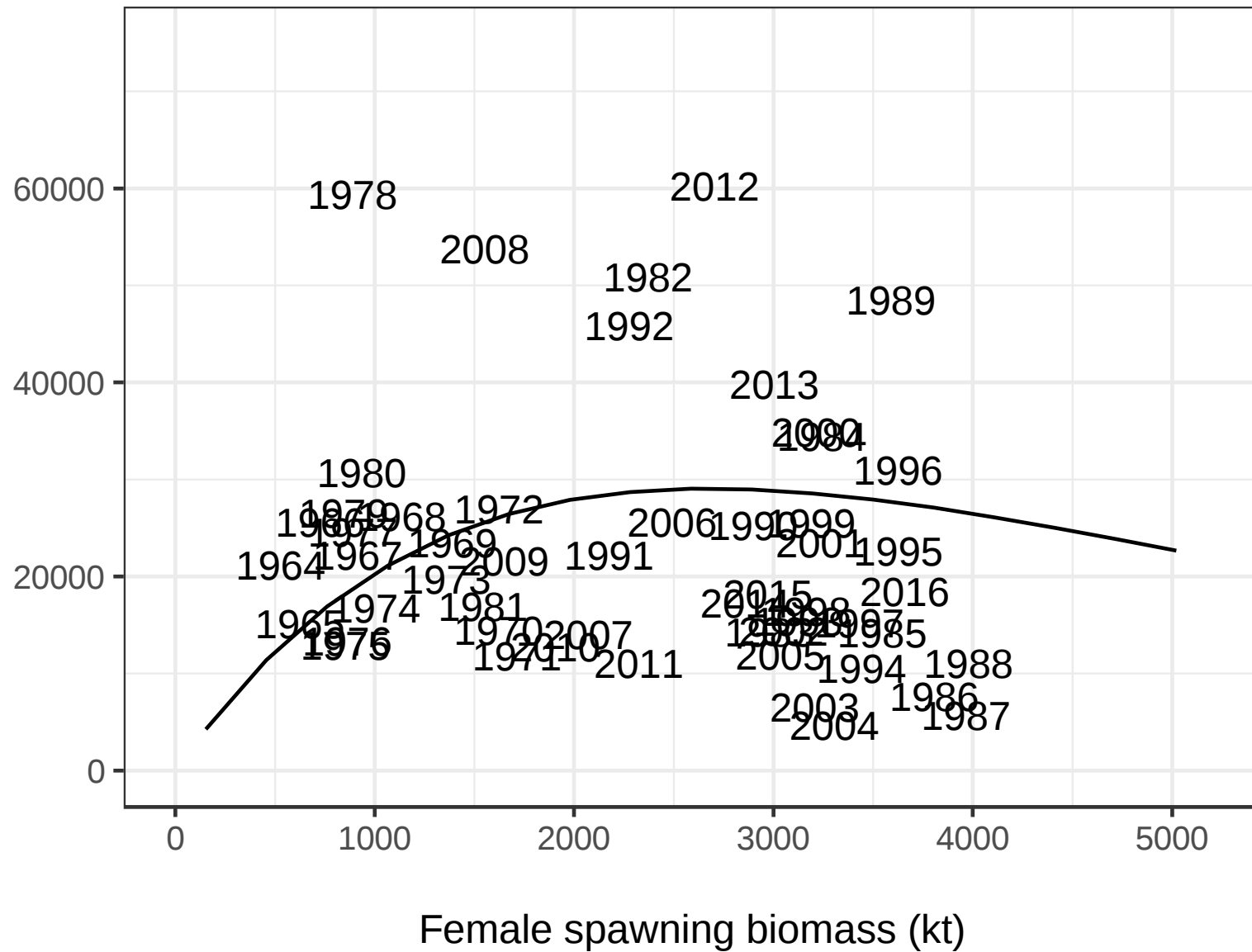


NOAA FISHERIES

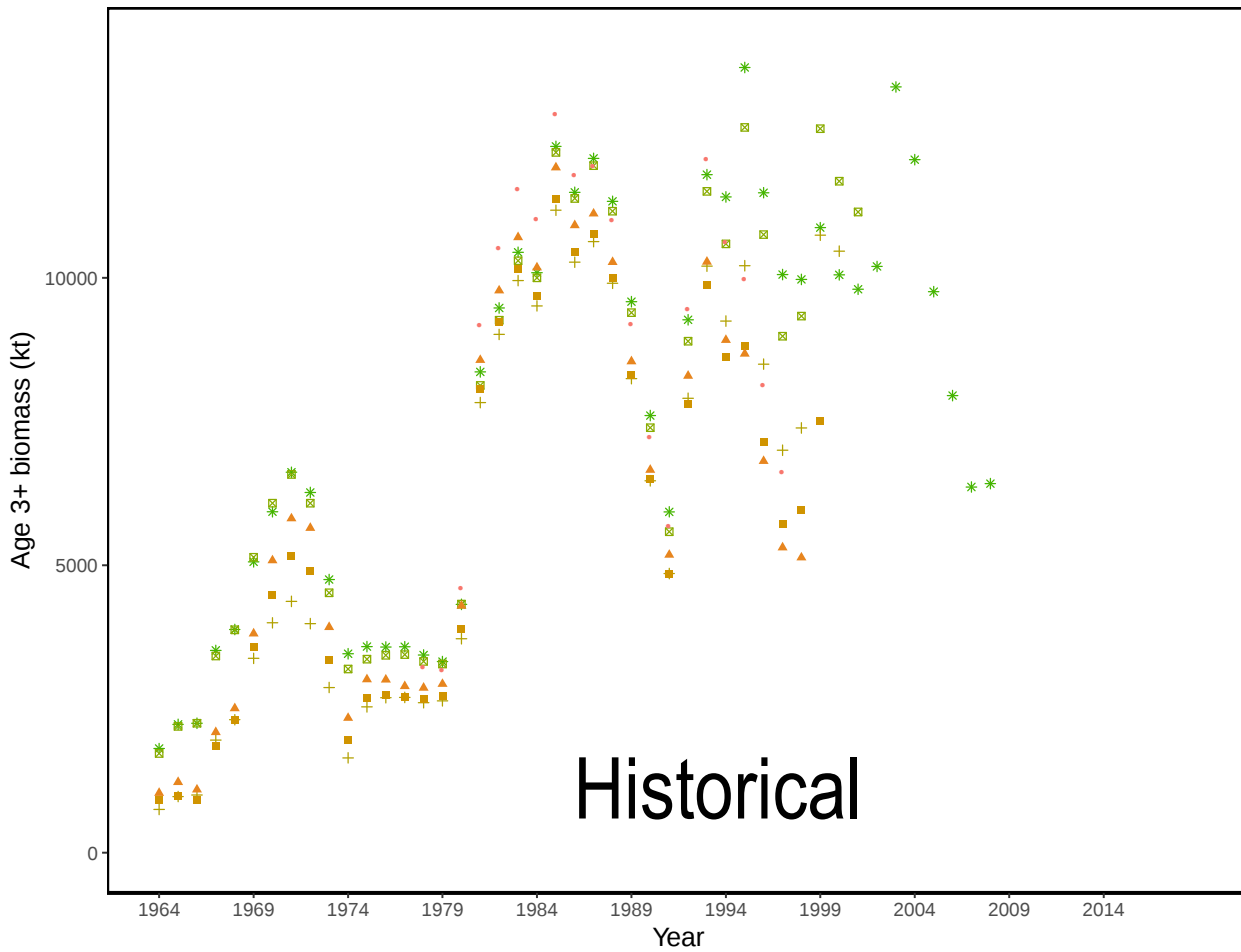




Recruits (age 1, millions)

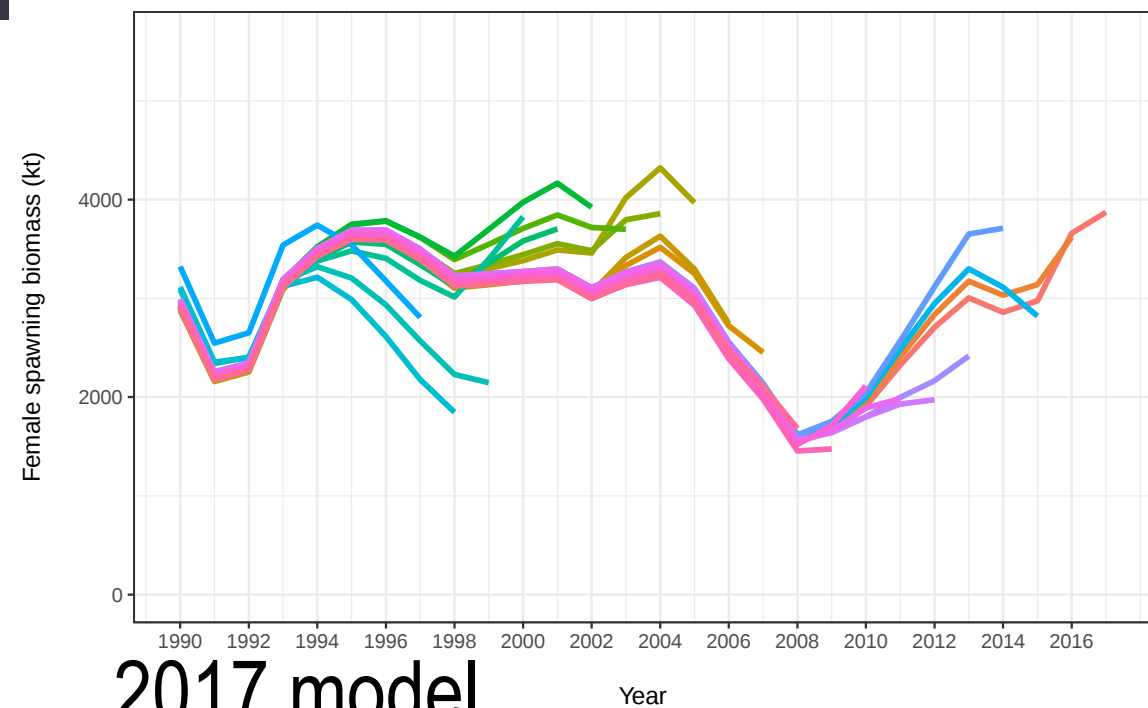


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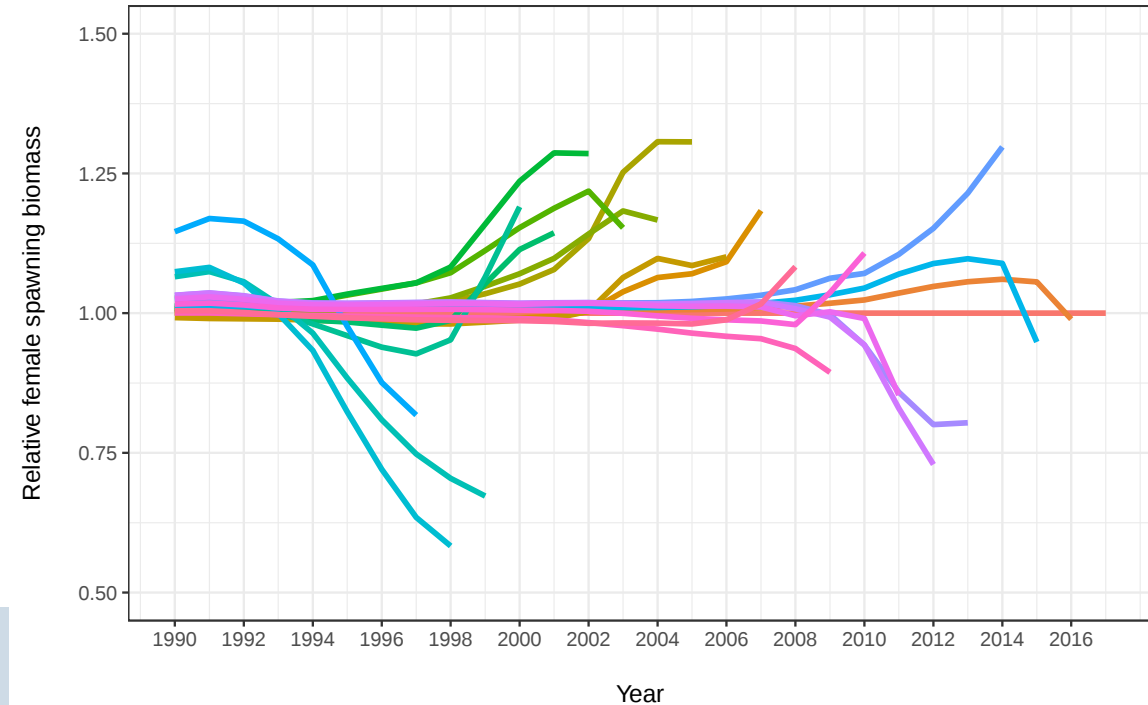


Historical

Retrospective patterns

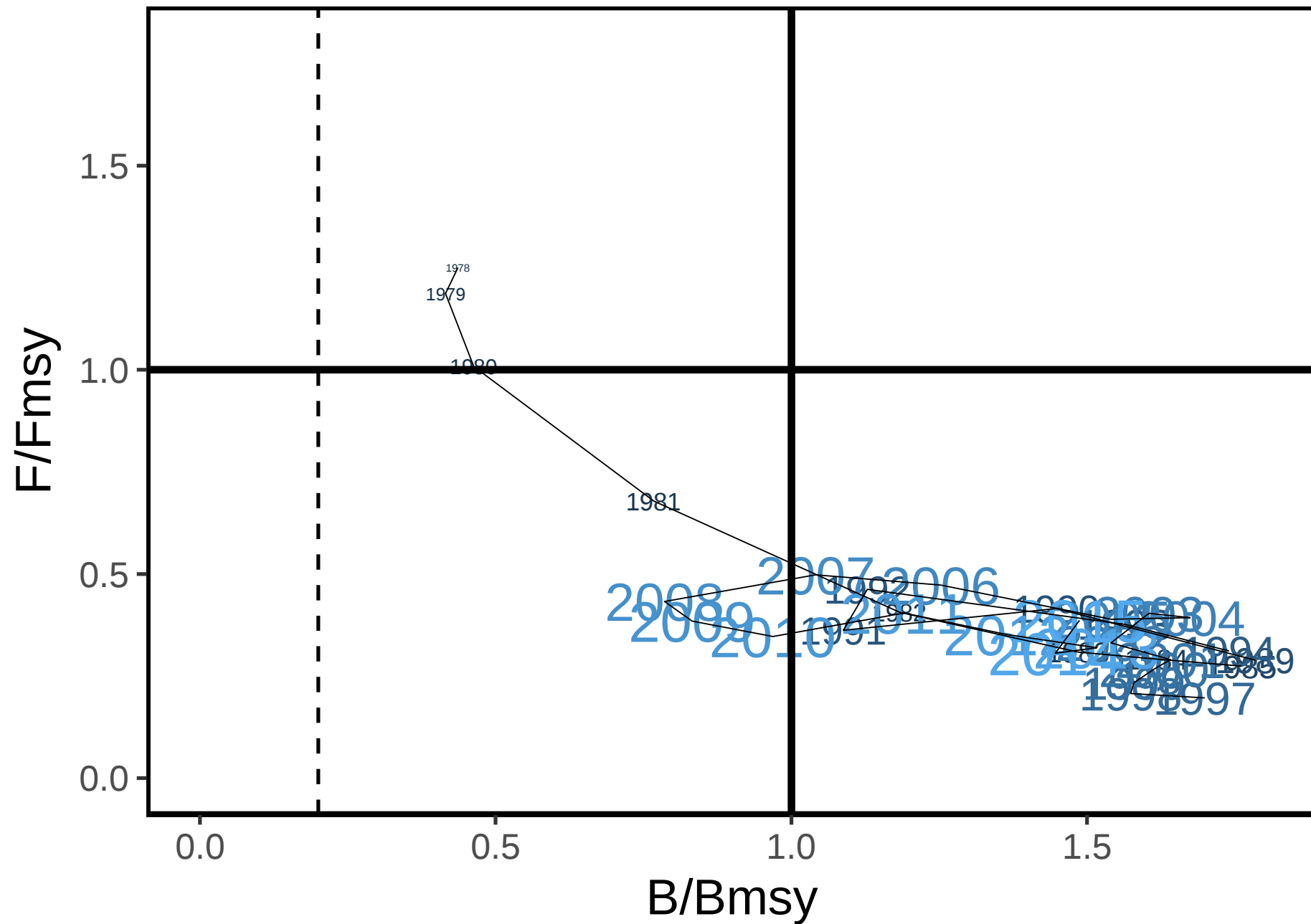


2017 model

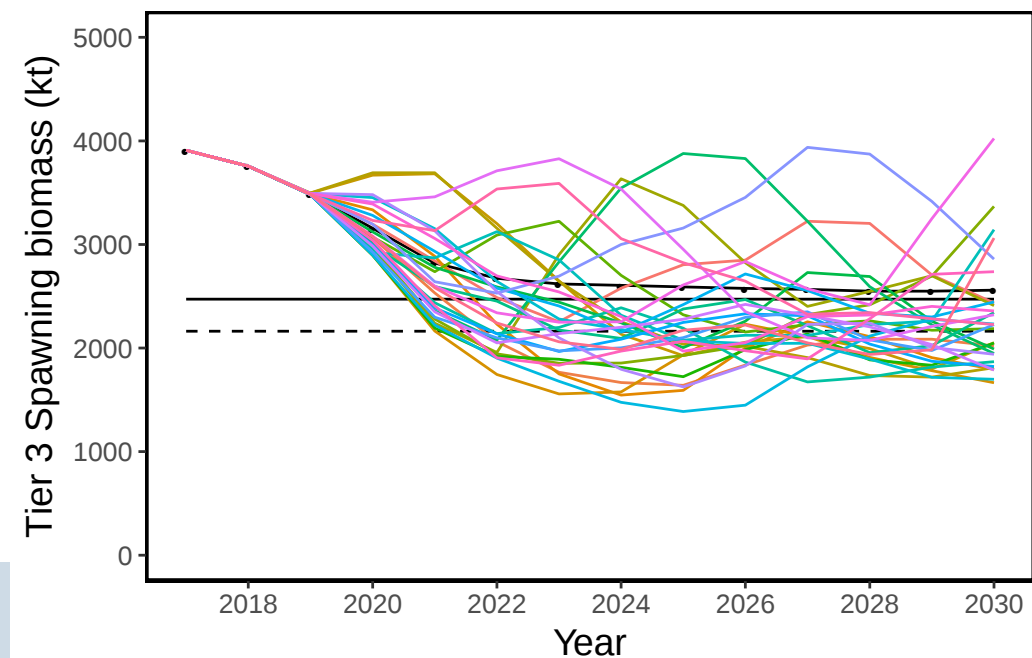
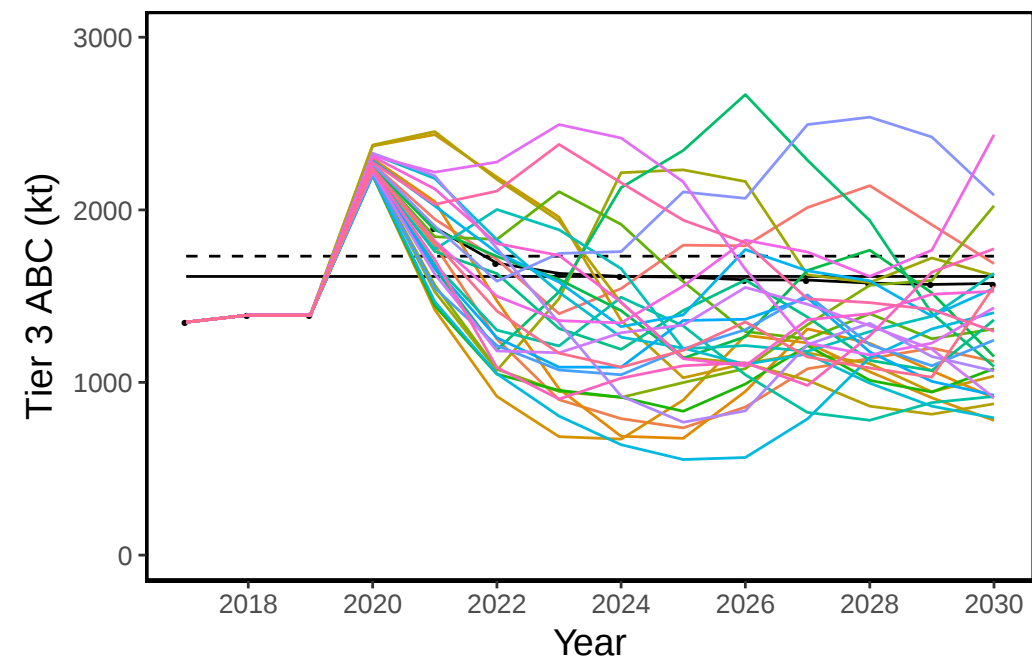


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Relative trend



Quantity	As estimated or <i>recommended</i> <i>this</i> year for:	
	2018	2019
M (natural mortality rate, ages 3+)	0.3	0.3
Tier	1a	1a
Projected total (age 3+) biomass (t)	10,967,000 t	10,119,000 t
Projected female spawning biomass (t)	3,679,000 t	3,365,000 t
B_0	5,394,000 t	5,394,000 t
B_{msy}	2,043,000 t	2,043,000 t
F_{OFL}	0.622	0.622
$maxF_{ABC}$	0.466	0.466
F_{ABC}	0.336	0.336
OFL	4,797,000 t	4,592,000 t
$maxABC$	3,598,000 t	3,445,000 t
ABC	2,592,000 t	2,467,000 t
Status	2016	2017
Overfishing	No	n/a
Overfished	n/a	No
Approaching overfished	n/a	No



High ABC and OFL...but as always caveats...

- **Shift in distribution?**
 - Ecosystem survey in Northern Bering Sea this summer found increases in pollock
- **Relatively few one-year-old pollock** in 2017 trawl survey
- Relatively few old fish in survey (not unexpected)
- Future catches near current levels will require more effort
 - Biomass expected to decline, quite quickly
 - Even higher salmon bycatch?

Figure added and text edit (page 25)

8. Finally, given the same estimated aggregate fishing effort in 2017, the estimated stock trend is downwards except at low catch levels (a replacement yield of 590 kt is the amount that would maintain the spawning stock constant). Furthermore, the ability to catch the same amount as in 2017 through to 2020 will require about 35% more effort with a decline in spawning biomass of about 28% compared to the current level (based on expected average recruitment).
8. Finally, given the same estimated aggregate fishing effort in 2017, the estimated stock trend is downwards except at low catch levels (a replacement yield of 560 kt is the amount that would maintain the spawning stock constant). Furthermore, the ability to catch the same amount as in 2017 through to 2021 will require about 25% more effort with a decline in spawning biomass of about 20% compared to the current level (based on expected average recruitment; Fig. 41).

**New
Figure (41)
to support
last bullet
point...**

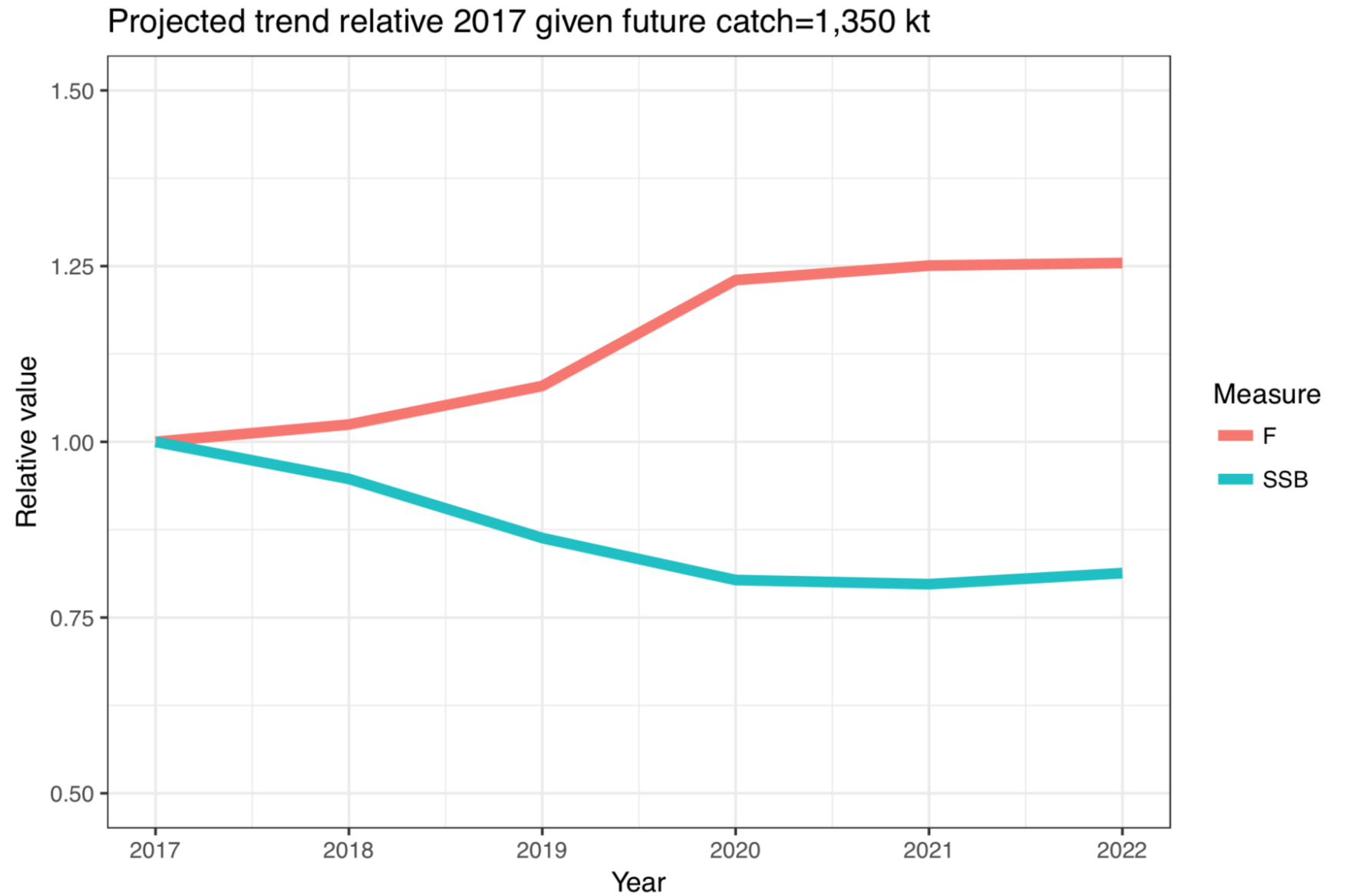
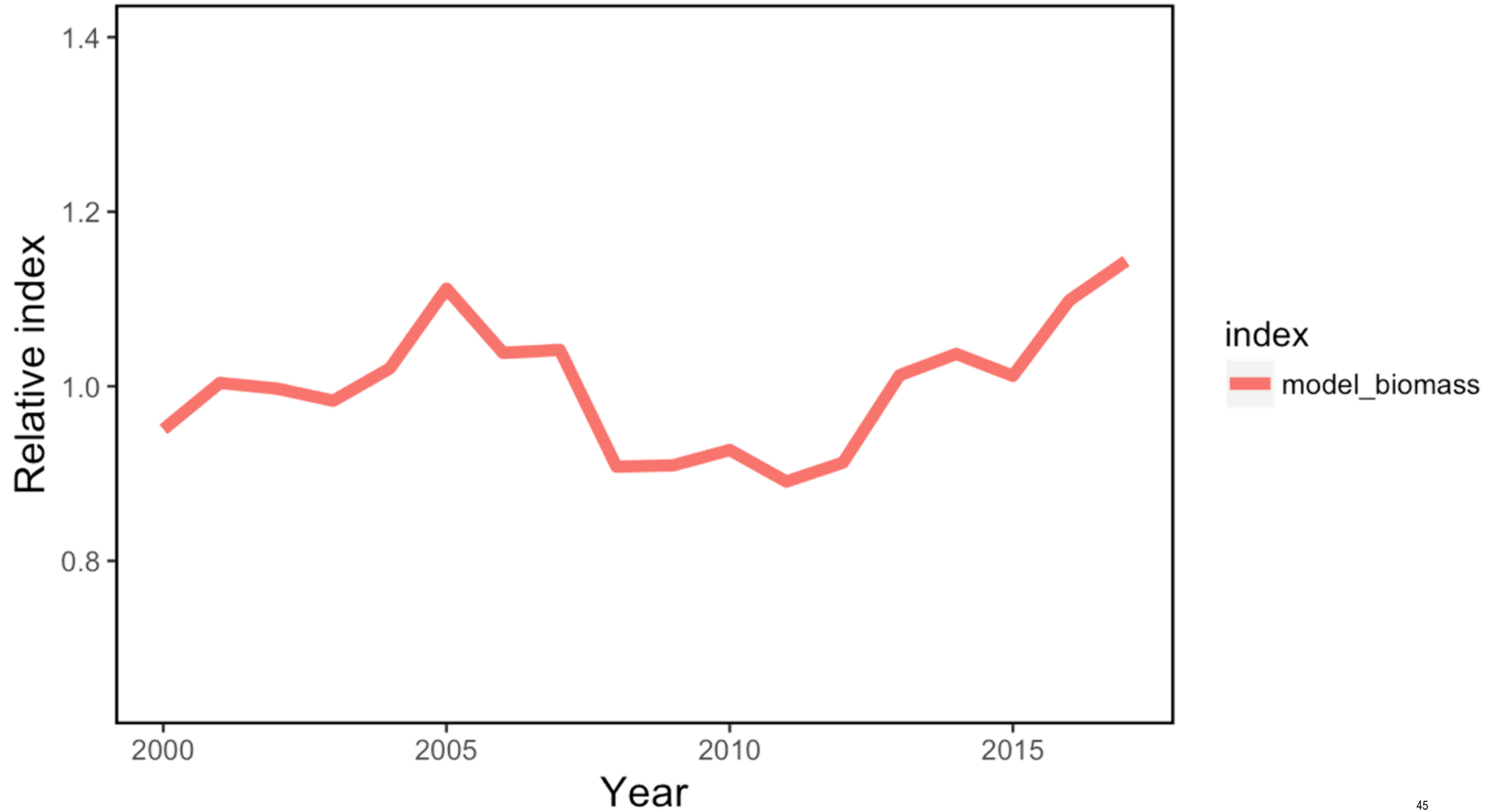
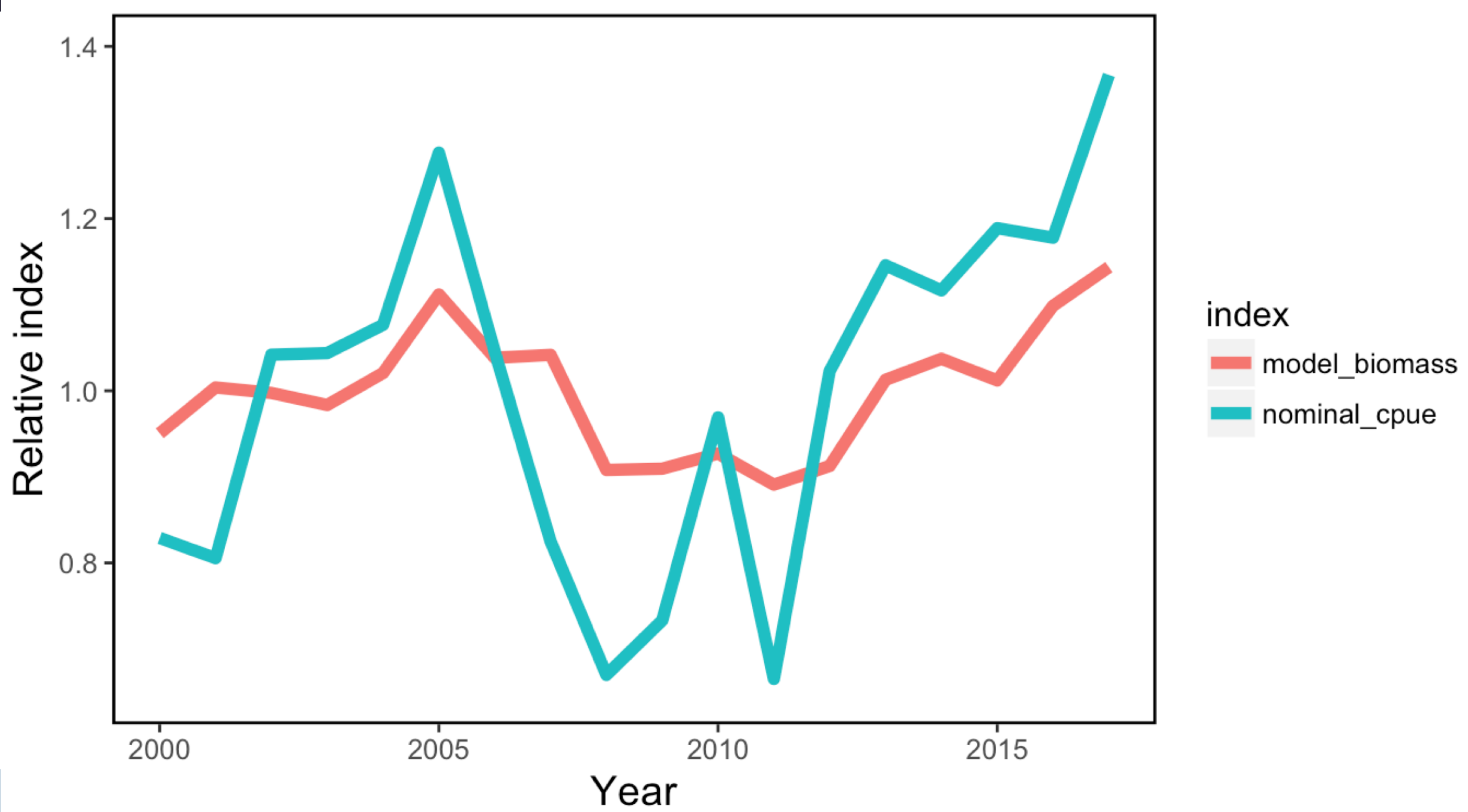
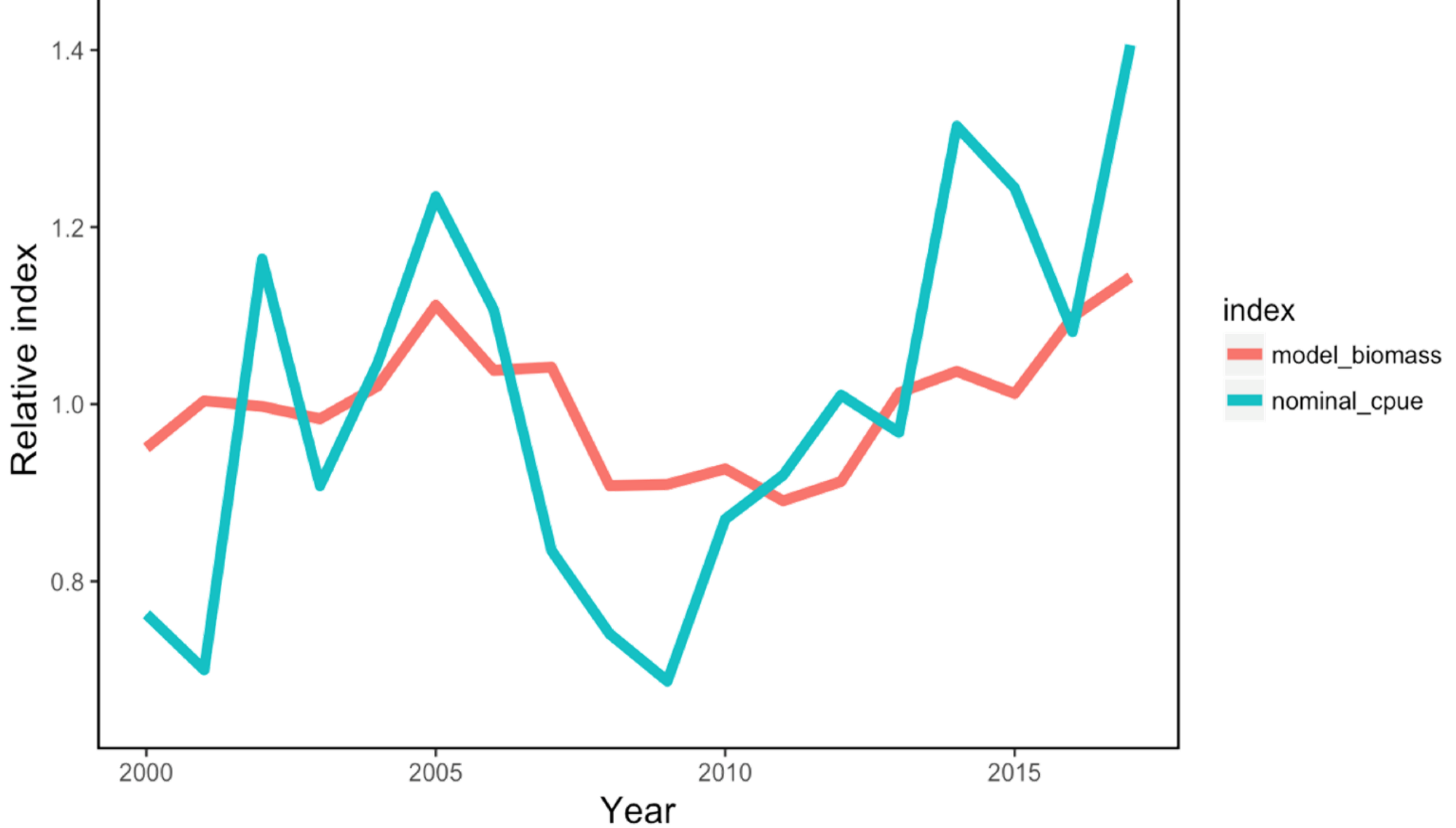


Figure 41: Projected fishing mortality and spawning biomass relative to 2017 values under constant catch of 1.35 million t







Other research

- Genetics sampling
- Further work on weight-at-age treatment
- Testing alternative stock assessment software (SAM, CASAL, SS)
- Multi-species modeling/prediction under climate change

ACLIM

Alaska Climate-change Integrated Modeling Project

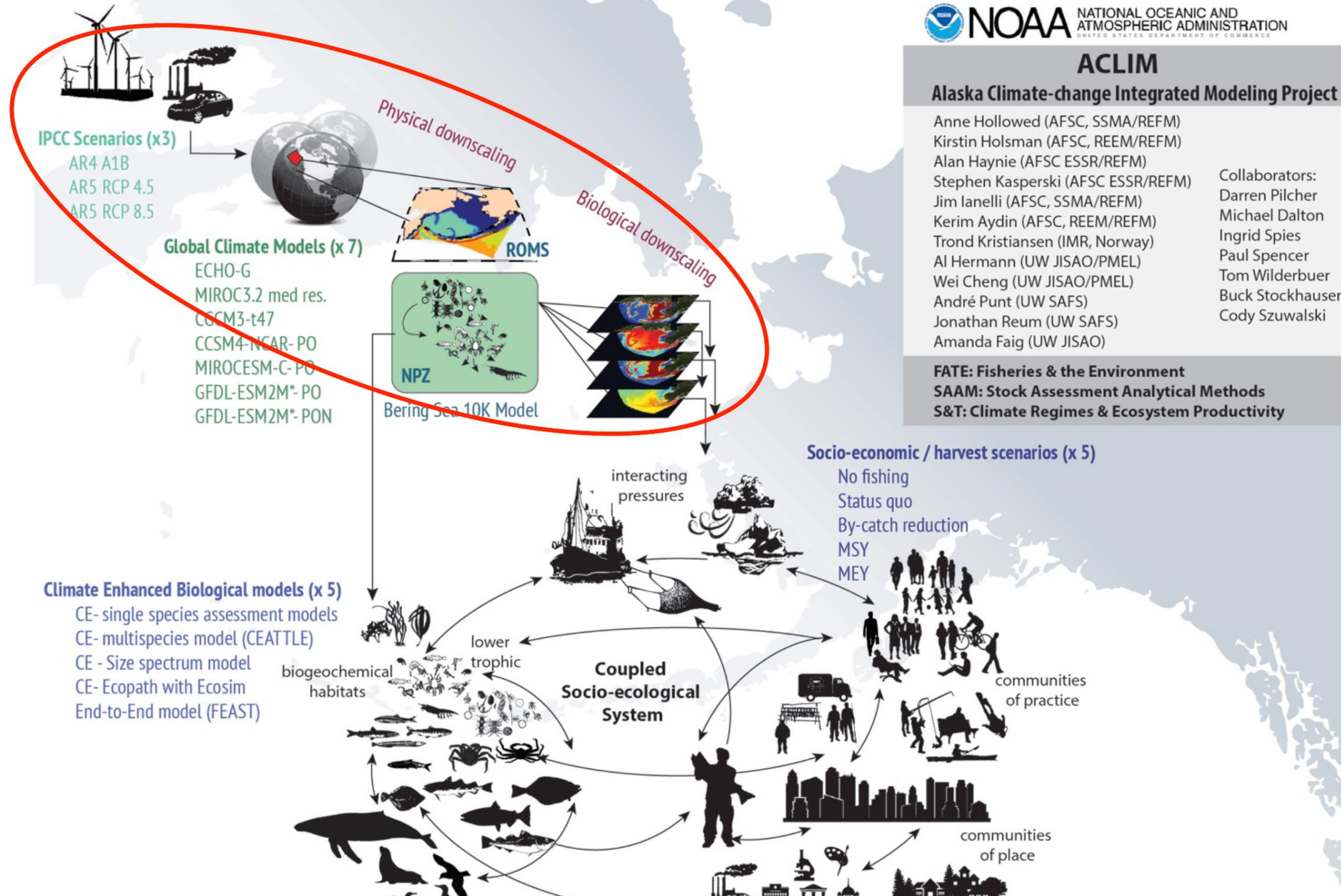
Anne Hollowed (AFSC, SSMA/REFM)
Kirstin Holsman (AFSC, REEM/REFM)
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Stephen Kasperski (AFSC ESSR/REFM)
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Collaborators:
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Buck Stockhauser
Cody Szuwalski

FATE: Fisheries & the Environment

SAAM: Stock Assessment Analytical Methods

S&T: Climate Regimes & Ecosystem Productivity



2017 Multi-species Stock Assessment for walleye pollock, Pacific cod, and arrowtooth flounder in the Eastern Bering Sea

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November 2017

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Executive Summary

This is a three species stock assessment for walleye pollock (*Gadus chalcogrammus*), Pacific cod (*Gadus macrocephalus*) and arrowtooth flounder (*Atheresthes stomias*), from the Eastern Bering Sea (EBS), Alaska updated from Holsman et al.(2016). Results are presented from models estimated and projected without trophic interactions (single-species mode, SSM) and with trophic interactions (multi-species mode, MSM).

Definition	Equation	Definition	Equation
Predation mortality	$M2_{ij,y} = \sum_{pa} \left(\frac{N_{pa,y} \delta_{pa,y} \bar{S}_{pa,ij}}{(\sum_{ij} \bar{S}_{pa,ij} B_{ij,y}) + B_p^{other} (1 - \sum_{ij} (\bar{S}_{pa,ij}))} \right)$	T2.1 Recruitment	$N_{i,1,y} = R_{i,y} = R_{0,i} e^{\tau_{i,y}} \quad \tau_{i,y} \sim N(0, \sigma^2)$
Predator-ery suitability	$\bar{S}_{paij} = \frac{1}{n_y} \sum_y \left(\frac{\frac{O_{paij}}{B_{ij,y}}}{\sum_{ij} \left(\frac{O_{paij}}{B_{ij,y}} \right) + \frac{1 + \sum_{ij} O_{paij}}{B_p^{other}}} \right)$	Catch (numbers)	$C_{ij,y} = \frac{F_{ij,y}}{Z_{ij,y}} (1 - e^{-Z_{ij,y}}) N_{ij,y}$
Mean gravimetric diet proportion	$\bar{U}_{paij} = \frac{U_{paij}}{n_y}$	Total yield (kg)	$Y_{i,y} = \sum_j^{A_i} \left(\frac{F_{ij,y}}{Z_{ij,y}} (1 - e^{-Z_{ij,y}}) N_{ij,y} W_{ij,y} \right)$
Individual specific ration (kg kg ⁻¹ yr ⁻¹)	$\delta_{pa,y} = \hat{\varphi}_p \alpha_\delta W_{pa,y}^{(1+\beta_\delta)} f(T_y)_p$	Biomass at age (kg)	$B_{ij,y} = N_{ij,y} W_{ij,y}$
Temperature scaling	$f(T_y)_p = V^X e^{(X(1-V))}$	Spawning biomass at age (kg)	$SSB_{ij,y} = B_{ij,y} \rho_{ij}$
consumption algorithm	$V = (T_p^{cm} - T_y) / (T_p^{cm} - T_p^{co})$ $X = \left(Z^2 \left(1 + (1 + 40/Y)^{0.5} \right)^2 \right) / 400$ $Z = \ln(Q_p^c) (T_p^{cm} - T_p^{co})$ $Y = \ln(Q_p^c) (T_p^{cm} - T_p^{co} + 2)$	T2.3 Total mortality at age	$Z_{ij,y} = M1_{ij} + M2_{ij} + F_{ij}$
		T2.3 Total mortality at age	$F_{ij,y} = F_{0,i} e^{\epsilon_{i,y}} S_{ij}^f \quad \epsilon_{i,y} \sim N(0, \sigma_{F,i}^2)$
		T2.5 Weight at age (kg)	$W_{ij,y} = W_{\infty,ij} \left(1 - e^{(-K_i(1-d_{i,y})(j-t_{0,i}))} \right)^{\frac{1}{1-d_{i,y}}}$
		T2.5a	$d_{i,y} = e^{(\alpha_{d,i,y} + \alpha_{0,d,i} + \beta_{d,i} T_y)}$
		T2.5b	$W_{\infty,ij} = \left(\frac{H_i}{K_i} \right)^{1/(1-d_{i,y})}$
		T2.5c	$\hat{B}_{i,y}^s = \sum_j^{A_i} (N_{ij,y} e^{-0.5Z_{ij,y}} W_{ij,y} S_{ij}^s)$
		T2.5d	$\hat{B}_y^{eit} = \sum_j^{A_i} (N_{1j,y} e^{-0.5Z_{1j,y}} W_{1j,y} S_{1j}^{eit} q_{1,j}^{eit})$
			$\hat{O}_{ij,y}^f = \frac{C_{ij,y}}{\sum_j C_{ij,y}}$
			$\hat{O}_{ij,y}^s = \frac{N_{ij,y} e^{0.5(-Z_{ij,y}) S_{ij}^s}}{\sum_j (N_{ij,y} e^{0.5(-Z_{ij,y}) S_{ij}^s})}$
			$\hat{O}_{1j,y}^{eit} = \frac{N_{1j,y} e^{-0.5Z_{1j,y}} S_{1j}^{eit} q_{1,j}^{eit}}{\sum_j (N_{1j,y} e^{-0.5Z_{1j,y}} S_{1j}^{eit} q_{1,j}^{eit})}$
			$S_{ij}^s = \frac{1}{1 + e^{(-b_i^s j - a_i^s)}}$
			$S_{ij}^f = e^{\eta_{ij}} \quad j \leq A_{\eta,i}$
			$S_{ij}^f = e^{\eta_{ij} A_{\eta,i}} \quad j > A_{\eta,i}$
			$\omega_{ij} = \frac{e^{-j M_{fem}}}{e^{-j M_{fem}} + e^{-j M_{male}}}$
			$\rho_{ij} = \omega_{ij} \phi_{ij}$
			$W_{ij,y} = W_{ij,y}^{fem} \omega_{ij} + (1 - \omega_{ij}) W_{ij,y}^{male}$
			$M1_{ij} = M1_{ij}^{fem} \omega_{ij} + (1 - \omega_{ij}) M1_{ij,y}^{male}$

Table 4.	SSM	MSM
<i>Total survey biomass</i>		
Pollock	0.52	0.52
P. cod	0.81	0.82
Arrowtooth	0.66	0.65
<i>Survey age composition</i>		
Pollock	0.86	0.85
P. cod	0.89	0.88
Arrowtooth	0.54	0.56



Walleye pollock

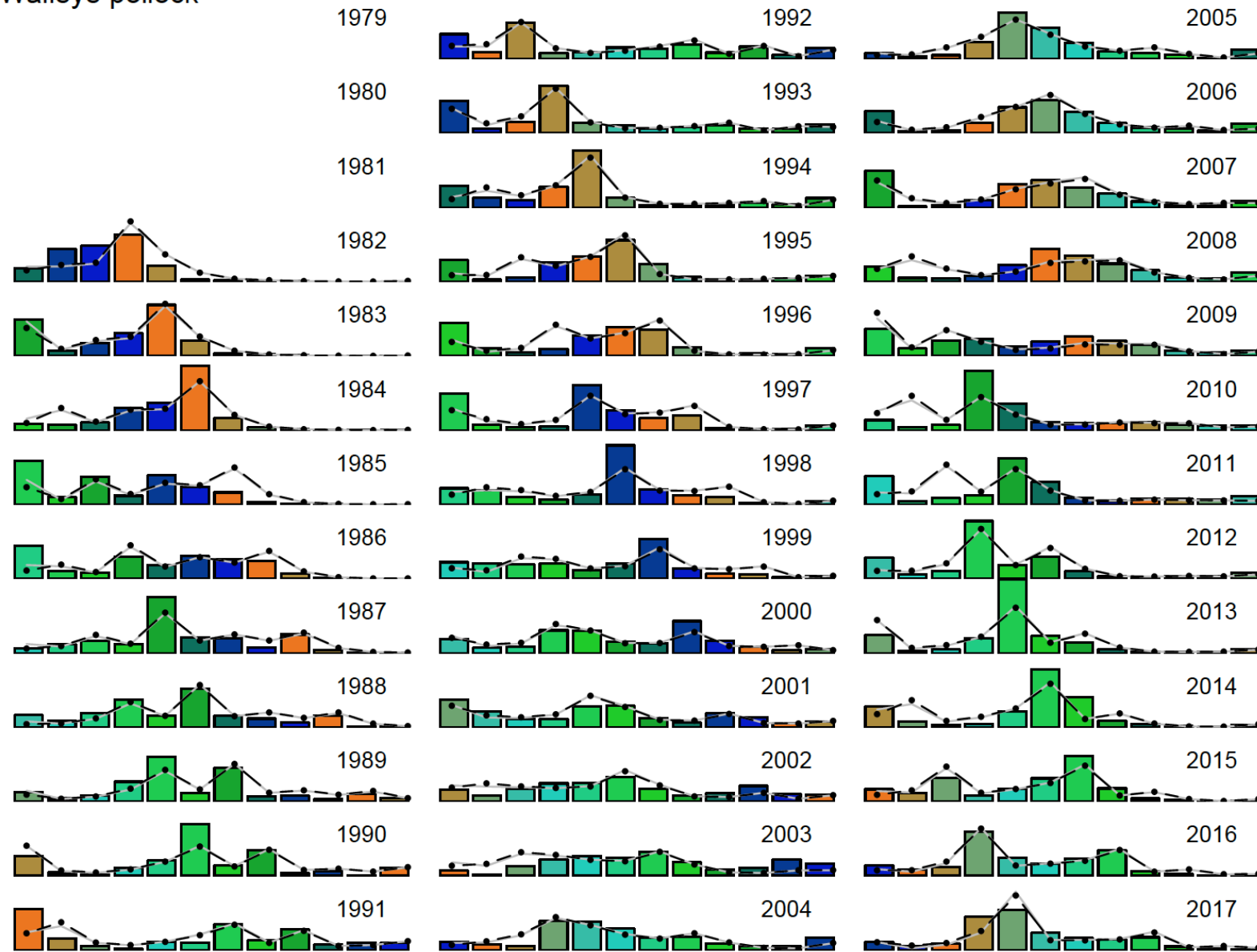


Figure 10: Survey age compositions for walleye pollock. Colored bars represent observed values, black and gray points represent single- and multi-species fits to the data, respectively.

Pacific cod

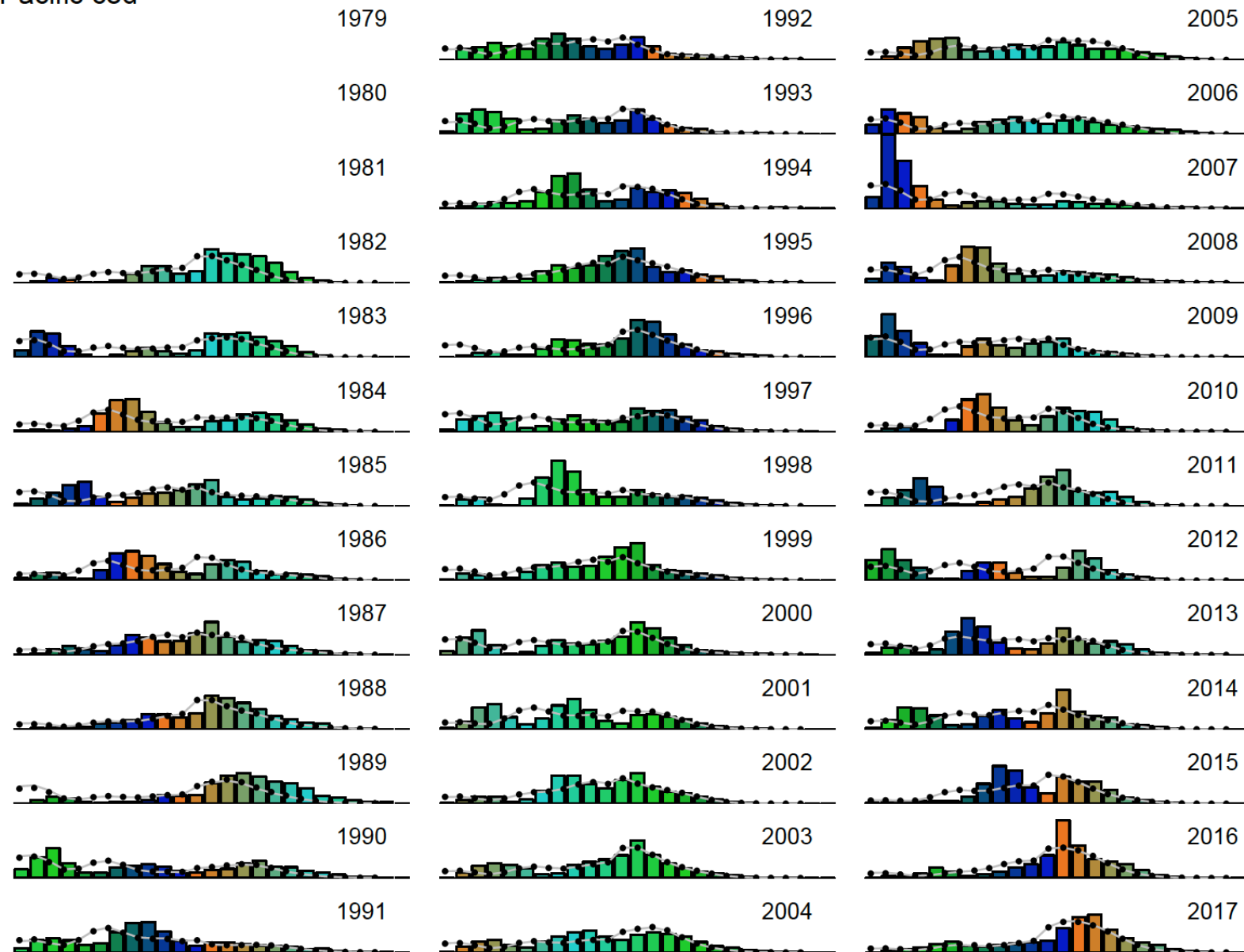
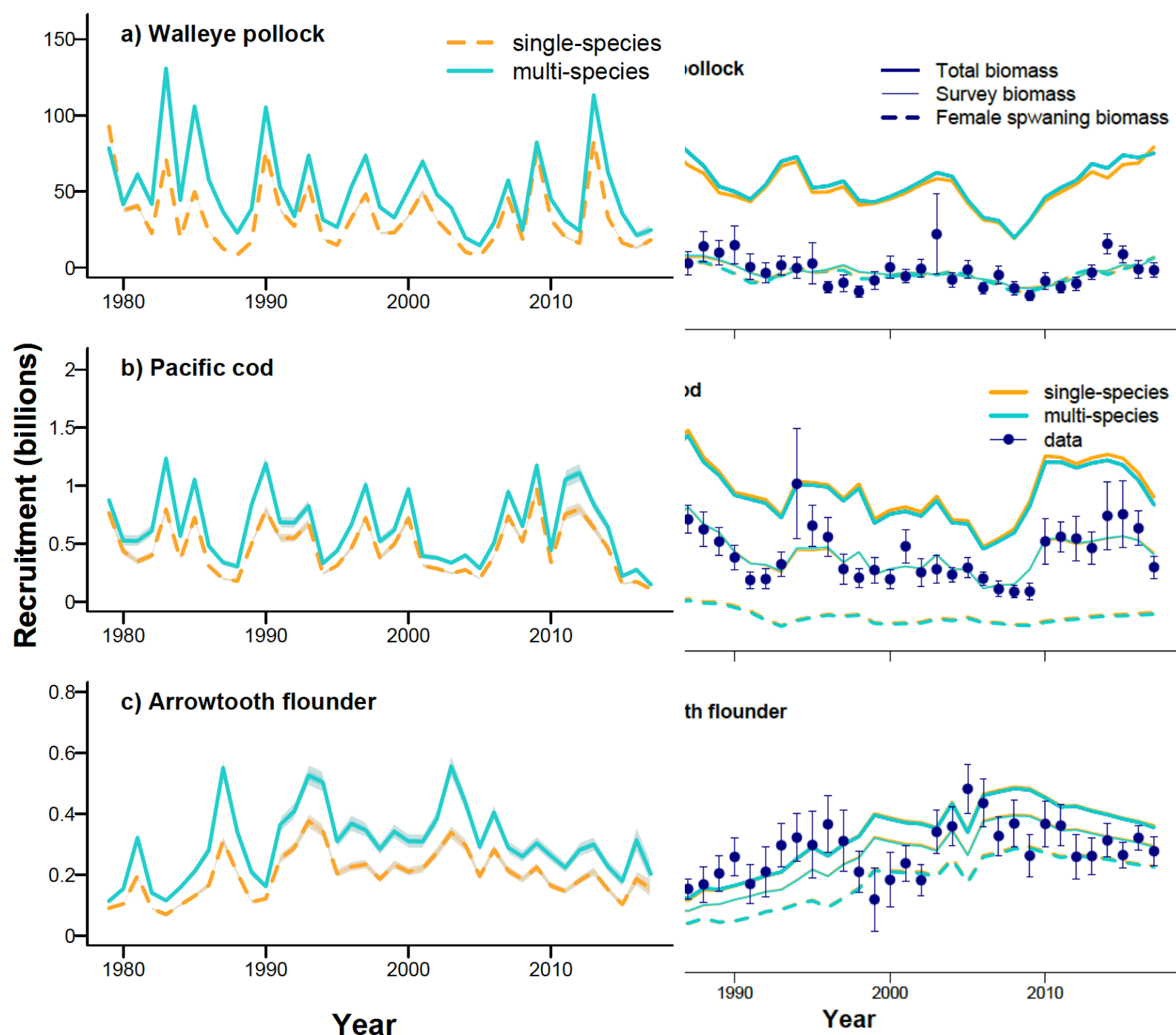
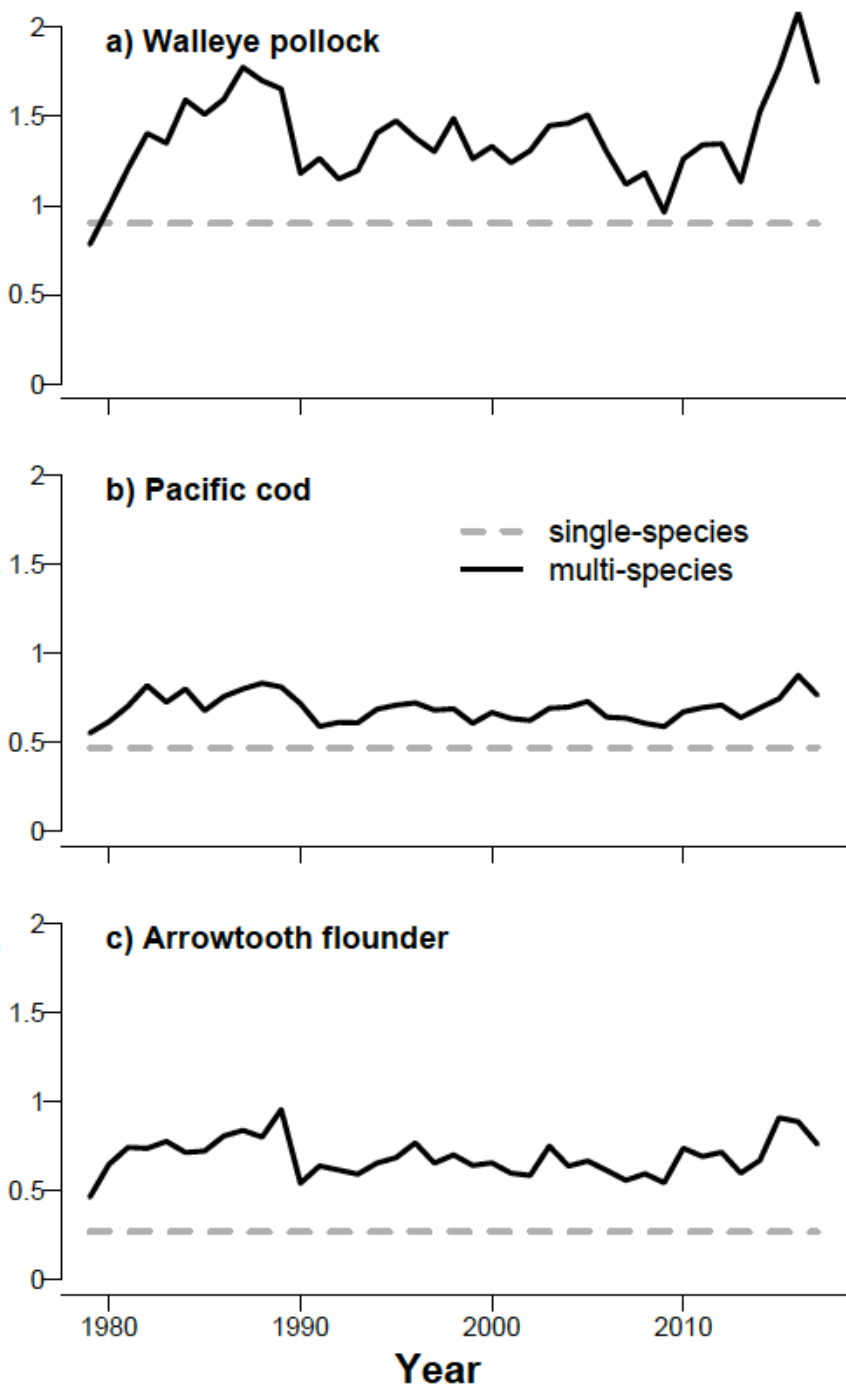
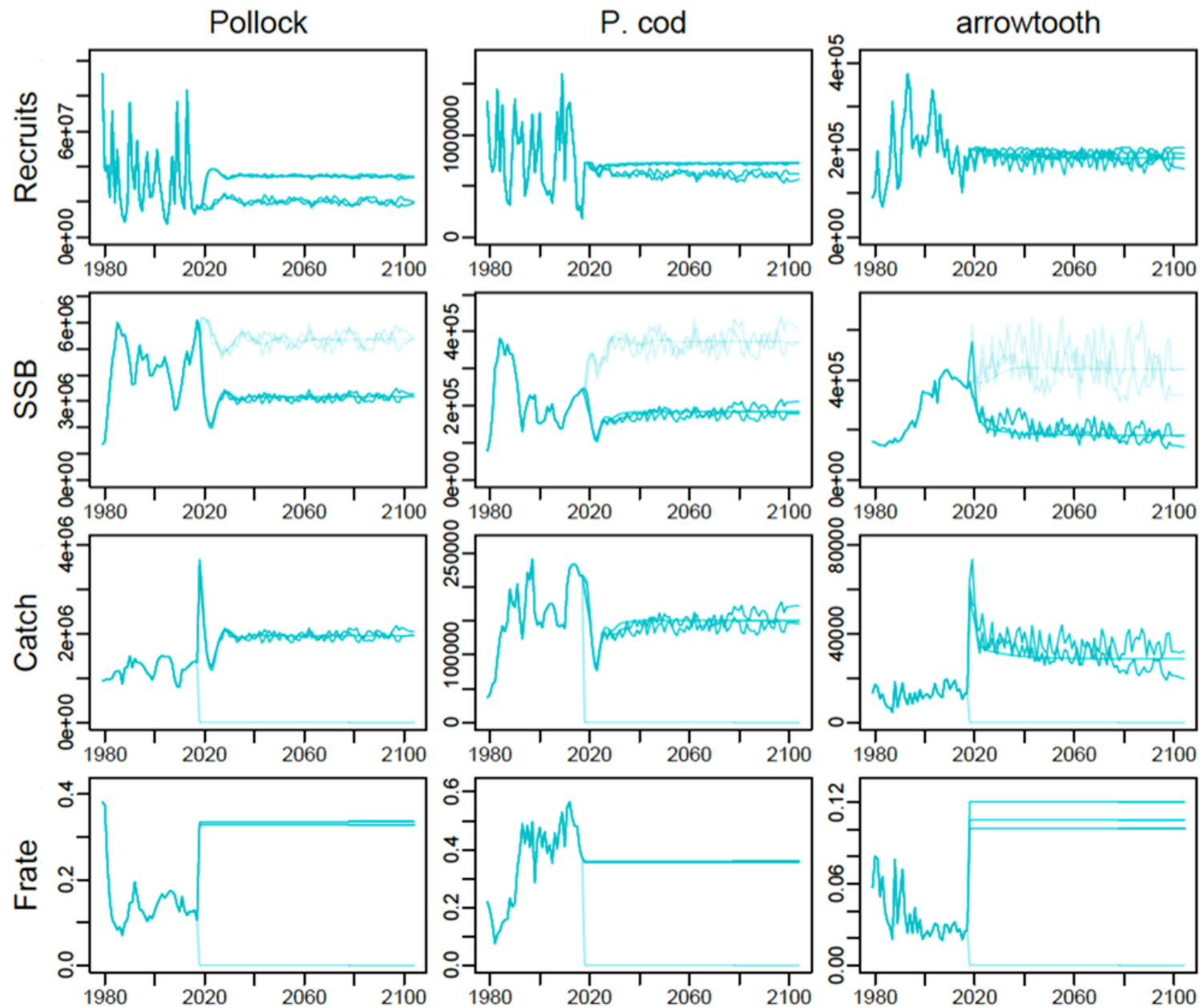


Figure 12: Survey length compositions for Pacific cod. Colored bars represent observed values, black and gray points represent single- and multi-species fits to the data, respectively.

Age 1 natural mortality (M1+M2)





As estimated or recommended this year (2017) for:

Multi-species supplement

Quantity	Walleye pollock		Pacific cod		Arrowtooth flounder	
	SSM	MSM	SSM	MSM	SSM	MSM
2017 M (age 1)	0.9	1.692	0.38	0.801	0.269	0.746
2017 Average 3+ M	0.3	0.311	0.38	0.38	0.226	0.227
Projected (age 3+) B_{2018} (t)	13,464,854	12,313,165	869,106	842,670	495,141	486,705
Projected $SSB_{2018}(t)$	5,831,610	5,852,470	231,702	226,771	395,277	391,310
*Projected $SSB_{0,target}(t)$	5,354,407	3,833,194	394,392	368,614	445,020	417,477
*Projected $SSB_{target}(t)$	3,173,340	3,101,376	197,965	190,330	178,019	167,000
**Target 2100 B/B_0	0.593	0.809	0.502	0.516	0.4	0.4
F_{target}	0.329	0.366	0.263	0.268	0.107	0.117
$F_{ABC,2018}$	0.161	0.168	0.202	0.202	0.053	0.055
ABC_{target}	3,657,230	3,978,190	185,006	184,317	55,944	59,904
ABC	1,954,180	2,034,666	147,374	144,210	28,695	29,398

* SSB is based on the projected SSB at 2100 (equilibrium)

** Target biomass ratios at year 2100 are based on F_{msy} proxy of $B/B_0=0.4$, given the constraint that $B/B_0 > 0.35$ for every projection year.



Pacific cod comparative BRPs

	2016 Assmnt	2016 CEATTLE- SSM	2016 CEATTLE- MSM	2017 Assmnt	2017 CEATTLE- SSM	2017 CEATTLE- MSM	
Projected total (age 0+) biomass (t)	1,110,000	1,313,105	1,308,217	807,000	869,106	842,670	CEATTLE is age 3 + biomass
<i>Change between years</i>				-27.3%	-33.8%	-35.6%	
2018 Projected female spawning biomass (t)	340,000	241,631	239,855	217,000	231,702	226,771	Maybe not comparable between CEATTLE and assmnt
<i>Change between years</i>				-36.2%	-4.1%	-5.5%	
B100%	620,000	435,039	415,105	548,000	394,392	368,614	
<i>Change between years</i>				-11.6%	-9.3%	-11.2%	
SSB40%	248000	174,503	166,030	219,000			
<i>Change between years</i>				-11.7%			
ABC	255,000	172,224	174,966	172,000	147,374	144,210	
<i>Change between years</i>				-32.5%	-14.4%	-17.6%	

Thanks!

