NOAA FISHERIES

Alaska Fisheries Science Center

Assessment of Pacific cod in the eastern Bering Sea

Grant Thompson

November 14, 2017

Team and SSC comments

Team and SSC comments (1 of 13)

- 25 comments specific to this assessment were addressed either in the minutes of the June 2017 Subcommittee meeting or in the preliminary assessment
- Sub8 (6/17 minutes): *"Although the Subcommittee feels that it will not be possible to incorporate feature Sub2 ("Examine survey data from the northern Bering Sea") into this year's preliminary EBS assessment due to the fact that there is currently only a single year's worth of data in the modern NBS survey time series and the results from this year's NBS survey will likely not be ready for inclusion until after the preliminary assessment is due, it may be possible to include this feature as a non-model analysis in the final assessment."* (next slide)

Team and SSC comments (2 of 13)

- Sub8, continued: Non-model analyses of results from the NBS and Norton Sound surveys are presented in the "Data" section.
- Sub9 (6/17 minutes): *"Although the Subcommittee also feels that features BPT3 ("Continue to compare empirical weight at age with the traditional approach") and GT10 ("Include EBS survey strata 82 and 90 (NW corner of EBS) in the data") should not be included as non-model analyses in this year's preliminary EBS assessment, it may be appropriate to include them as non-model analyses in the final assessment...."* See comment SSC23 regarding empirical weight at age. Indices in the "standard" survey area and strata 82 and 90 are compared in the "Data" section.

Team and SSC comments (3 of 13)

- BPT7 (9/17 minutes): *"The Team was pleased with the work done on model averaging, but recommends to not use model averaging in the final 2017 Pacific cod assessment."* See comments SSC17, SSC19-SSC22, and SSC25. In brief, at its October meeting, the SSC advocated multiple times for inclusion of model averaging in this final assessment.
- BPT8 (9/17 minutes): *"The Team recommends considering only models 16.6 and 17.6 for the final Pacific cod assessment."* See comments SSC17 and SSC19.

Team and SSC comments (4 of 13)

- BPT9 (9/17 minutes): *"The Team would like to better understand the effects of the individual changes bridging from Model 16.6 to Model 17.6 and recommends that the analyst present a bridging analysis at the November meeting."* See comment SSC22.
- BPT10 (9/17 minutes): *"The Team leaves it up to the analyst to determine the best order of changes/elements to investigate, and will be happy with a linear analysis of sequentially adding in elements…."* See comment SSC22.

Team and SSC comments (5 of 13)

- SSC16 (10/17 minutes): *"The SSC supported the Plan Team's recommendation to use the lognormal prior distribution from this review, and further recommended removing all estimates from the prior that contained an appreciable amount of the data that is currently used in the stock assessment model, and would therefore be included in the likelihood function."* The prior distribution for the natural mortality rate has been revised along the lines suggested, and is described in the "Description of Alternative Models" section.

Team and SSC comments (6 of 13)

- SSC17 (10/17 minutes): *"The SSC disagreed with the Plan Team recommendations to bring forward only models 16.6 and 17.6, and not use model averaging for 2017."* Models 16.6 and 17.6 are not the only models brought forward (see also comments SSC19, SSC21, and SSC26); model averaging is the subject of Appendix 2.5.
- SSC18 (10/17 minutes): *"Drop models 17.4 and 17.5 from the set under consideration."* Models 17.4 and 17.5 are not included.

Team and SSC comments (7 of 13)

- SSC19 (10/17 minutes): *"Perform further diagnostics and evaluation on models 16.6, 17.1-17.3, and 17.6 in order to determine whether all five may be candidates for inclusion in a model averaged result in December."* All of the requested models are included in this final assessment, along with a new model (Model 17.7; see comment SSC26). Many diagnostics that were not provided in the preliminary assessment are included. In order to allow the SSC complete flexibility in determining which models to include in the ensemble to be averaged, Appendix 2.5 includes results for every possible subset of models.

Team and SSC comments (8 of 13)

- SSC20 (10/17 minutes): *"The SSC encourages the author to consider a broader method for model weighting (perhaps subjective in nature) that includes model fit and also retrospective performance, model convergence behavior and general plausibility."* The approaches to model weighting described in Appendix 2.5 (except for the equal weighting approach) account for retrospective performance, model convergence behavior, and general plausibility.

Team and SSC comments (9 of 13)

- SSC21 (10/17 minutes): *"Bring forward for consideration in December one or more alternatives for model averaged results (based on models 16.6, 17.1-17.3 , and 17.6), which may include equal weighting, individual model averaged results using some other weighting developed per above, and a distribution fit to the model results (similar to the preliminary approach)."* Appendix 2.5 provides a total of 504 alternatives (each) for model-averaged 2018 ABC, 2018 OFL, 2019 ABC, and 2019 OFL, based on the models listed above and also Model 17.7, along with all possible subsets of that set (see comments SSC19 and SSC26). Approaches include equal weighting and three weighting systems based on the response to comment SSC20. (continued on next slide)

Team and SSC comments (10 of 13)

- SSC21, continued: Sample means, medians, and standard deviations are provided for each alternative and approach, which can be used to fit two-parameter distributions, as in the preliminary assessment (see also comment SSC25).
- SSC22 (10/17 minutes): *"The SSC did not support the Plan Team's recommendation to provide further bridging analysis between models 16.6 and 17.6, but instead suggested a focus on model evaluation and diagnosis of 16.6, 17.1-17.3 and 17.6 for potential inclusion in a model-averaged approach in December."* See also comments BPT8, BPT9, and BPT10. Preliminary steps toward developing a bridging analysis are reported in the "Description of Alternative Models" section.

Team and SSC comments (11 of 13)

- SSC23 (10/17 minutes): *"Following on the December 2016 recommendation, continue exploration of the treatment of weight-at-age using both internally and externally estimated values, and the treatment of ageing bias in the stock assessment."* With respect to these two SSC recommendations, the Subcommittee recommended that: 1) the requested exploration of empirical weight at age should wait until the final assessment when more data would be available, and 2) the requested exploration of ageing bias does not have to be done this year at all. This year's preliminary and final assessments were prepared accordingly. The potential use of empirical weight at age is further addressed in this final assessment in the "Model Evaluation" section.

Team and SSC comments (12 of 13)

- SSC24 (10/17 minutes): *"Further, conduct an exploratory analysis of recent weight-at-age data for evidence of patterns resembling those seen for GOA Pacific cod."* An analysis of condition factor is provided in the "Data" section, and an analysis of weight at age is provided under "Model Evaluation."
- SSC25 (10/17 minutes): *"Clarify, with the joint Plan Teams, the preferred measure of central tendency (e.g., median or mean) for assessments reporting probabilistic results either via Bayesian posteriors or model-averaged distributions."* Because the assessment was prepared prior to the Team meeting, full sets of results for both the mean and median are presented in Appendix 2.5 (see also comment SSC21).

Team and SSC comments (13 of 13)

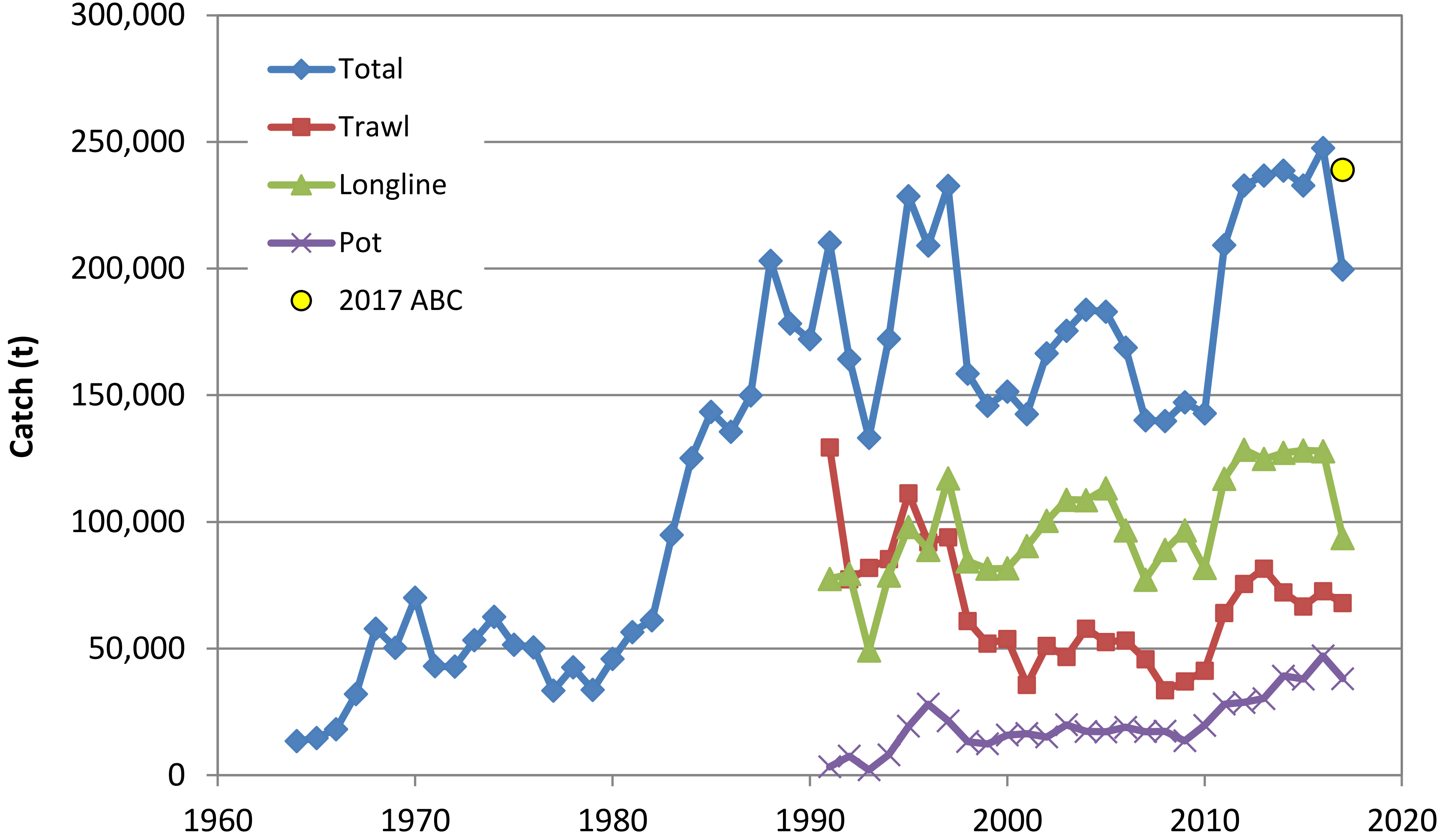
- SSC26 (10/17 minutes): *"For models where iterative reweighting is applied, if the initial input sample sizes have been derived based on a boot strapping approach or using the number of hauls, strongly consider tuning these inputs only in a downward direction in order to avoid placing implausibly high weights on certain data sets to the effective exclusion of others."* When reweighting was completed, there were only two instances of multipliers exceeding a value of 1.0: One multiplier in Model 17.3 had a value of 1.0237, and one multiplier in Model 17.6 had a value of 1.5903. Because that single multiplier in Model 17.6 was well above 1.0, an additional model (17.7) was developed in order to address the SSC's recommendation.

Data highlights

Economic performance report (Appendix 2.2)

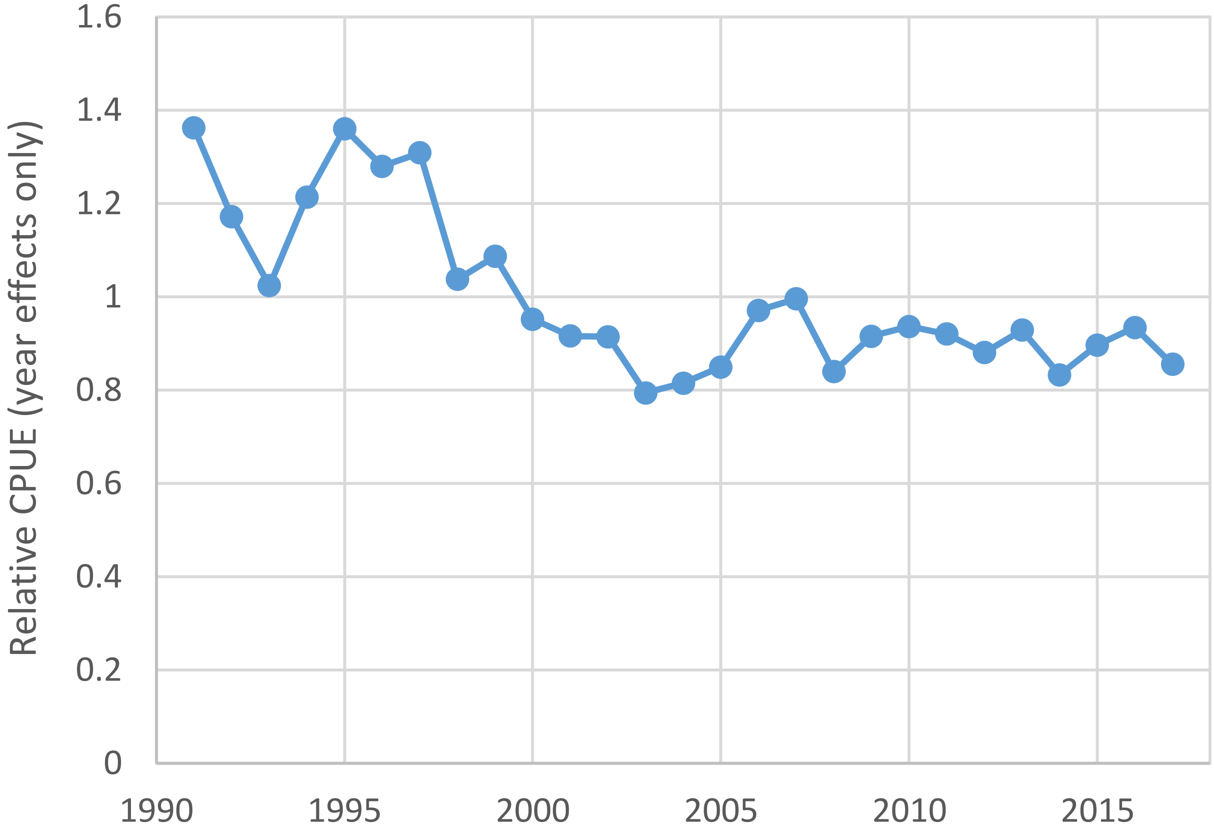
	Avg 07-11	2012	2013	2014	2015	2016
Total catch K mt	182.7	251	250.2	249.3	242	260.8
Retained catch K mt	179.8	246.5	243.5	244.4	238.9	257.5
Vessels #	189	175	175	156	149	162
CP H&L share of BSAI catch	53%	52%	50%	50%	54%	49%
CP trawl share of BSAI catch	17%	15%	18%	14%	15%	14%
Shoreside retained catch K mt	51.0	75.2	71.1	79.0	68.3	85.9
Shoreside catcher vessels #	131	121	125	109	100	110
CV pot gear share of BSAI catch	9%	11%	11%	14%	12%	15%
CV trawl share of BSAI catch	18%	20%	18%	17%	16%	18%
Shoreside ex-vessel value M $	$36.6	$49.0	$37.0	$44.7	$34.1	$44.6
Shoreside ex-vessel price lb $	$0.326	$0.323	$0.244	$0.274	$0.248	$0.264
Shoreside fixed gear ex-vessel price premium	$0.06	$0.03	$0.01	$0.03	$0.03	$0.03

Catch history (2017 data are incomplete)



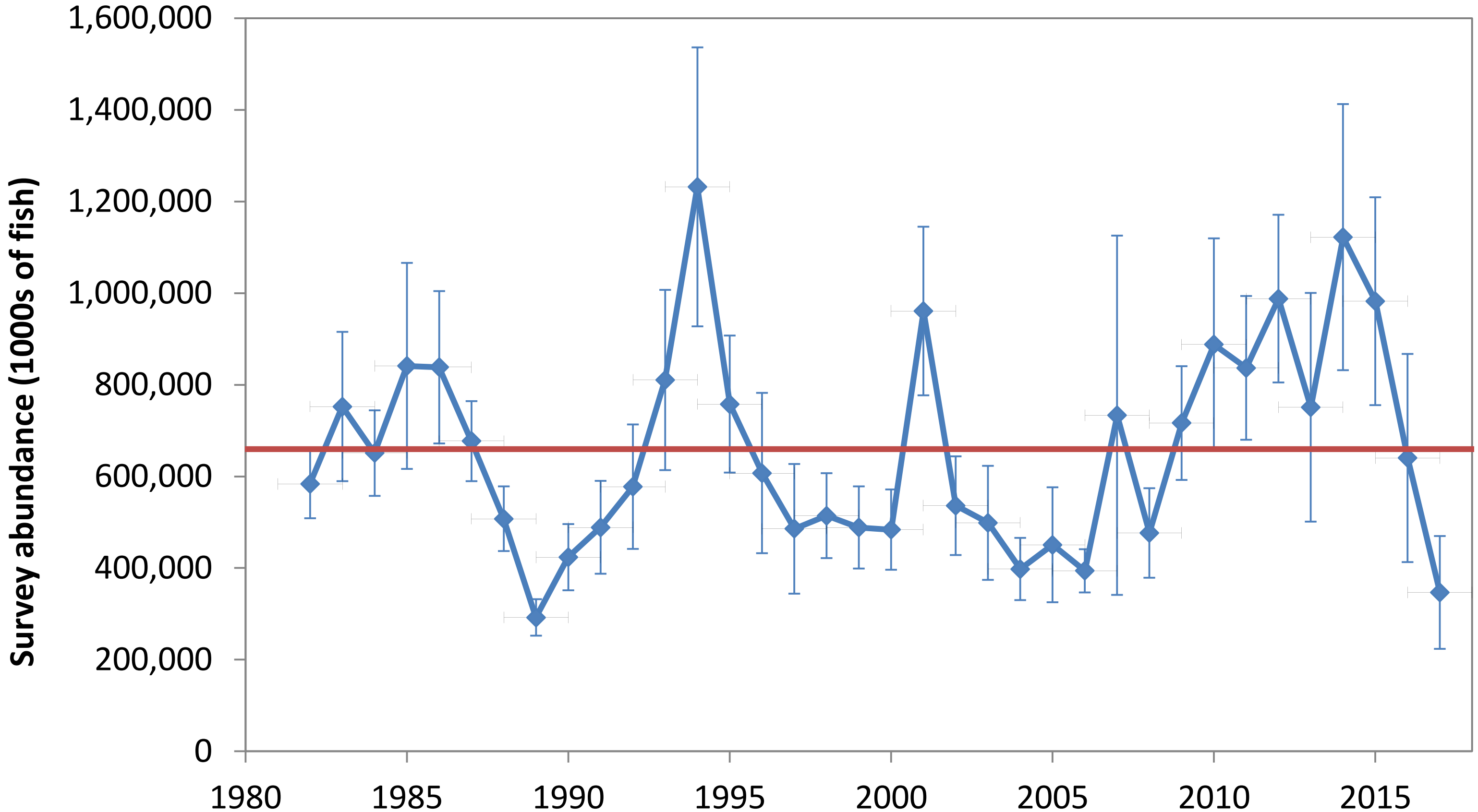
Longline fishery CPUE

- Year effect down 8%

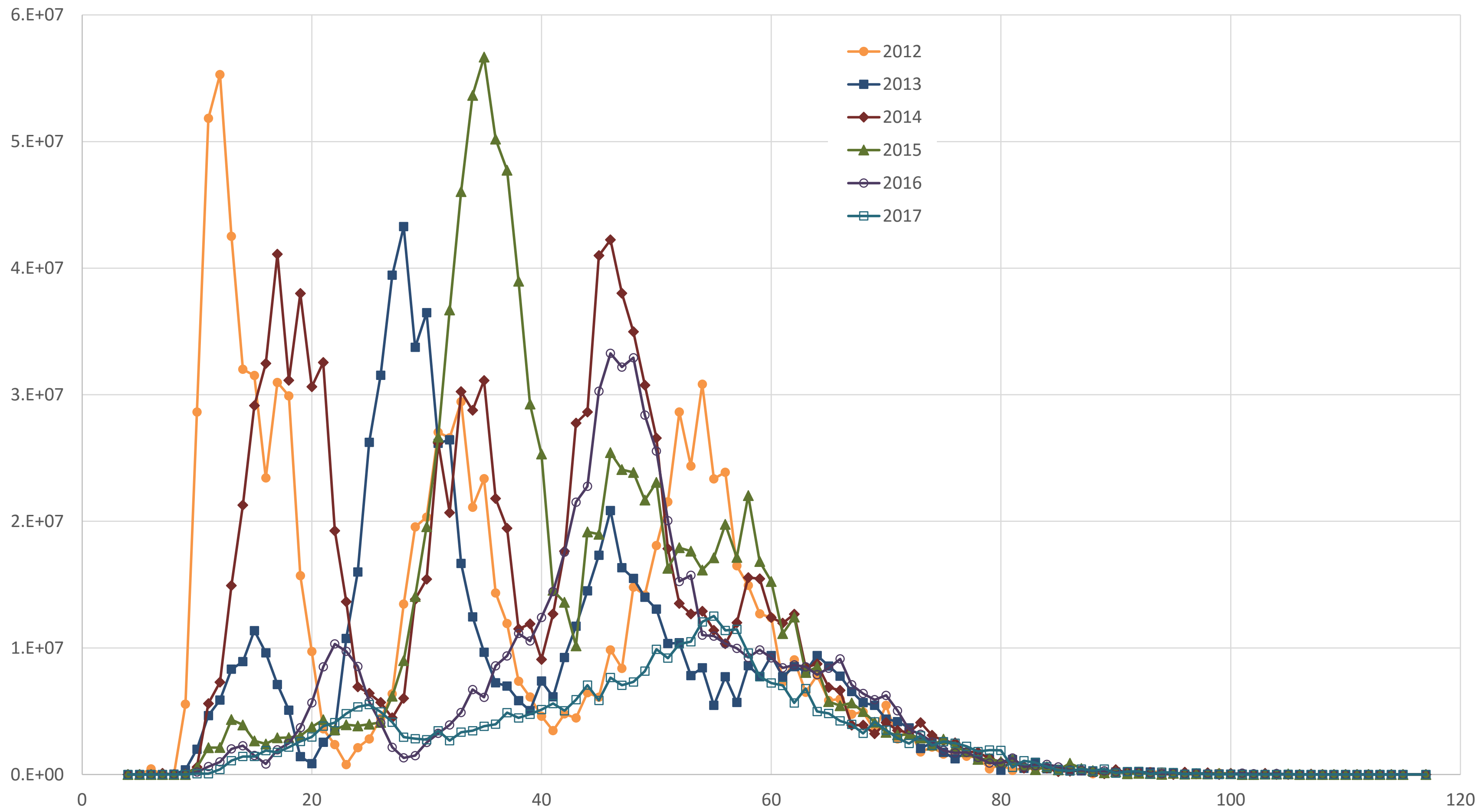


EBS shelf trawl survey abundance (numbers)

- 46% drop from 2016 to 2017 is biggest in history

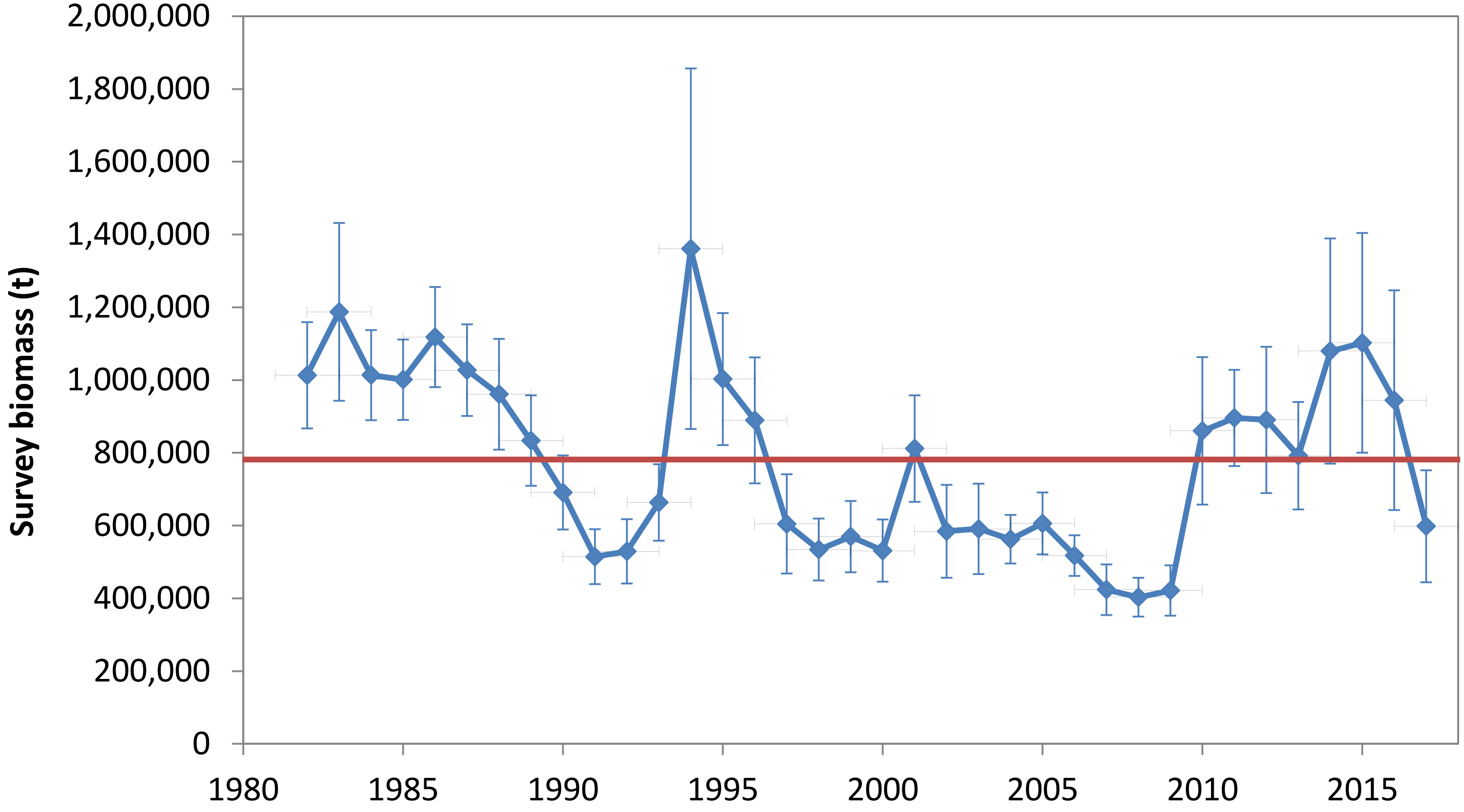


Recent EBS shelf survey length compositions



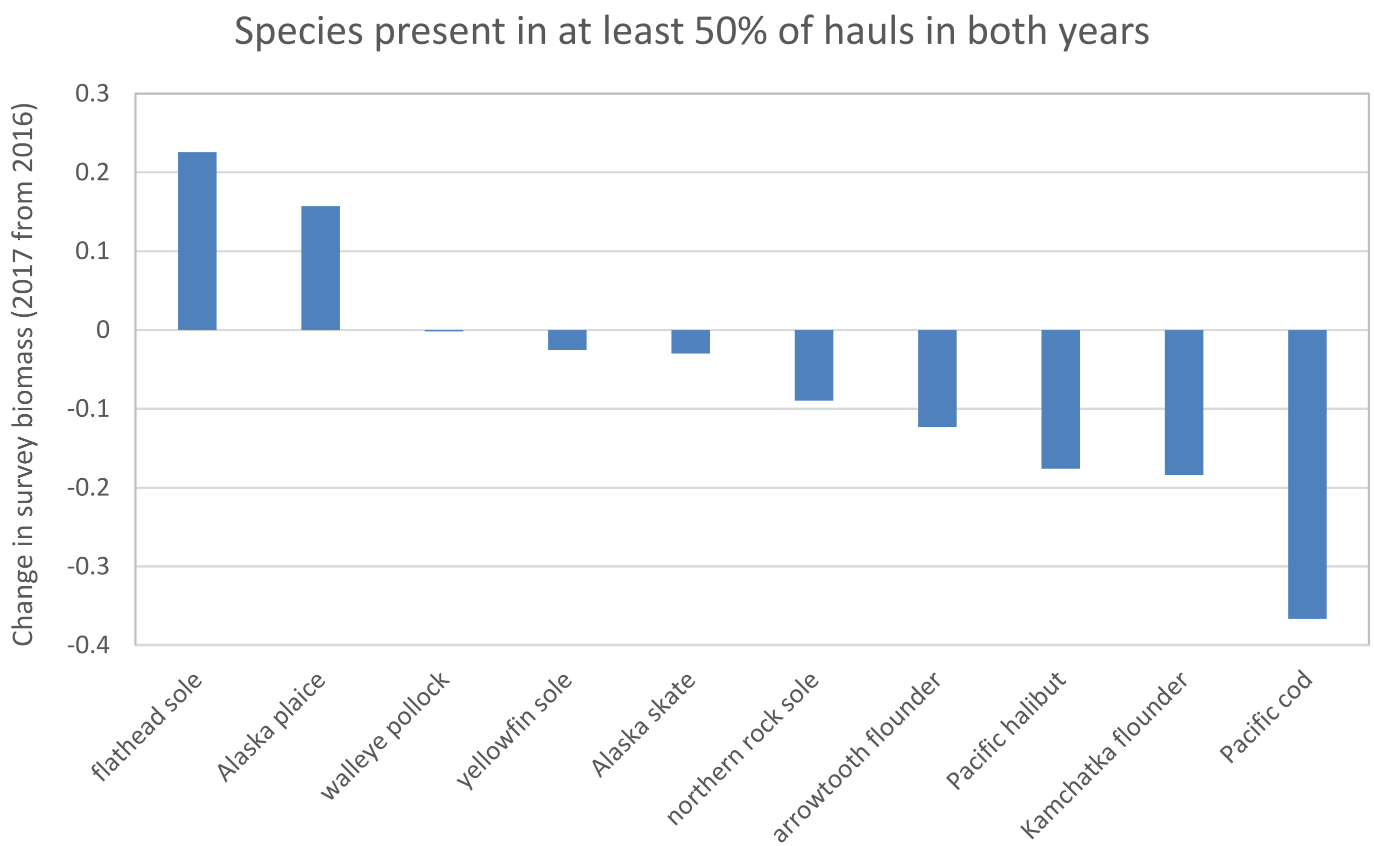
EBS shelf survey biomass (1 of 2)

- 37% drop from 2016 to 2017 is biggest in history



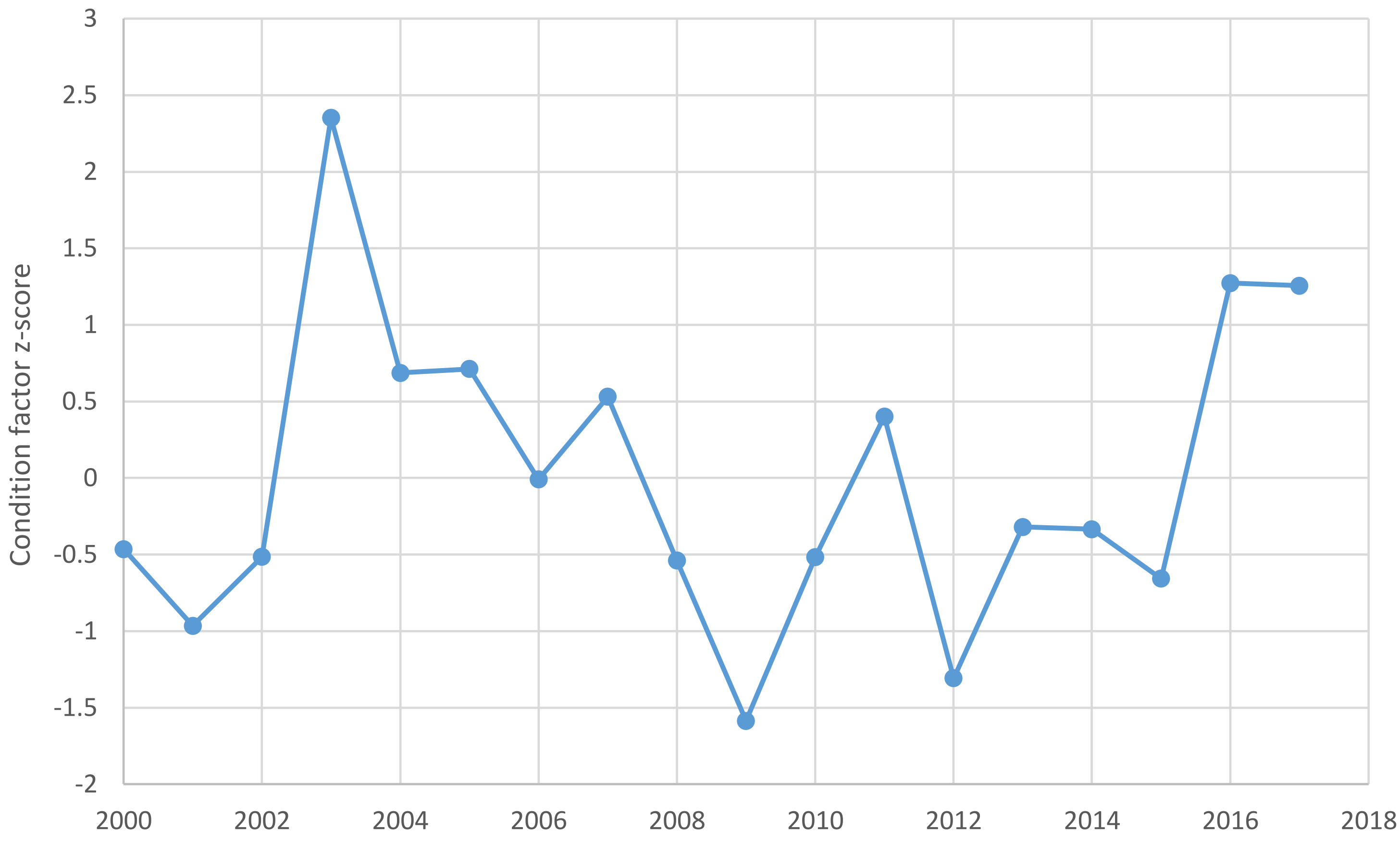
EBS shelf survey biomass (2 of 2)

- Does not appear to be result of across-the-board year effect



Condition factor from EBS survey data (1 of 3)

- Annual z-scores: 2 positives following 7 negatives in 8 years



Condition factor from EBS survey data (2 of 3)

- Z-scores by age (1-10) and year (2000-2016)

Year	1	2	3	4	5	6	7	8	9	10	Mean
2000	-1.64	-0.90	0.34	0.08	0.01	0.12	-1.39	-1.49	-0.13	-0.60	-0.44
2001	0.28	0.46	-0.40	-0.48	-0.72	-0.28	-0.62	-0.49	-1.03	-1.26	-0.94
2002	0.24	-0.51	-1.70	-1.49	-0.28	0.33	1.00	0.46	1.27	-0.12	-0.40
2003	0.71	1.40	1.79	0.55	2.30	2.61	2.08	2.15	0.57	0.54	2.47
2004	0.92	-0.03	-0.04	-1.11	0.40	1.51	1.23	0.47	1.43	2.56	0.84
2005	0.51	-1.27	0.01	-1.06	-0.68	-0.13	1.19	1.09	1.30	1.85	0.72
2006	-0.58	-0.13	-1.22	-0.90	-1.02	-0.84	0.51	0.79	0.66	0.59	0.10
2007	-0.33	0.13	-0.24	0.41	0.78	1.10	0.26	0.53	1.55	-0.03	0.52
2008	-0.61	-0.56	0.08	0.93	0.74	0.01	-0.32	-0.78	-0.61	-0.28	-0.54
2009	-0.95	-1.13	-0.50	0.42	0.76	-0.69	-0.75	-1.59	-1.45	-0.46	-1.59
2010	-1.10	0.04	0.79	1.47	-0.39	-1.14	-0.16	0.70	-0.32	-1.40	-0.43
2011	0.11	0.15	1.18	1.98	1.43	0.20	-0.45	0.66	-0.34	-0.16	0.42
2012	-0.26	-0.91	-1.68	0.44	-1.38	-1.30	-1.64	-0.60	-0.95	0.17	-1.21
2013	-0.88	-0.83	0.02	-0.38	0.07	-0.12	0.25	0.31	-0.29	-0.18	-0.24
2014	0.24	0.67	0.41	0.83	-0.13	-0.19	-1.00	-1.01	-1.57	-0.35	-0.20
2015	0.64	0.78	-0.45	-1.25	-1.58	-1.11	-0.54	-0.85	0.35	-0.97	-0.54
2016	2.70	2.63	1.62	-0.45	-0.33	-0.06	0.37	-0.34	-0.43	0.08	1.45

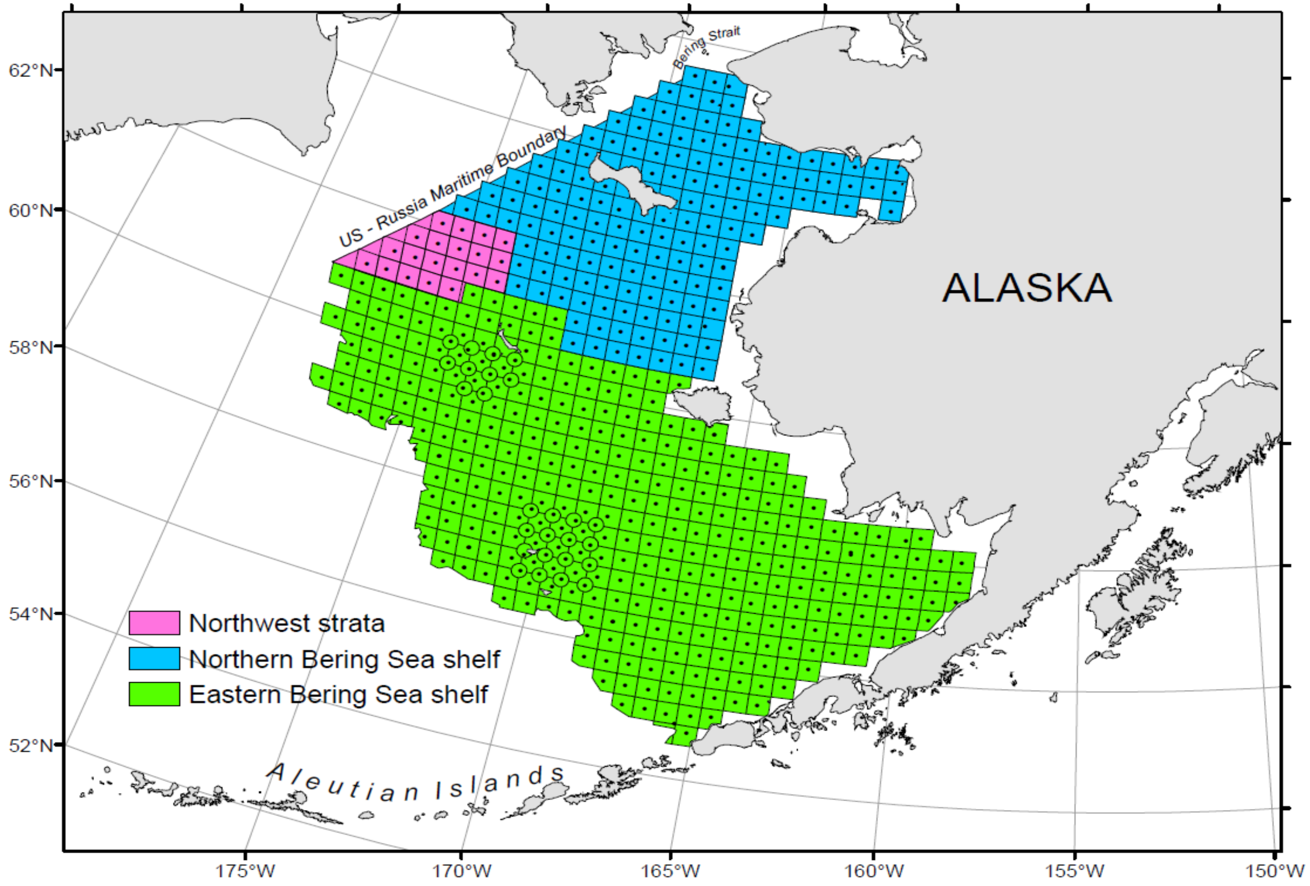
Condition factor from EBS survey data (3 of 3)

- 5 recent strong year classes highlighted

Year	1	2	3	4	5	6	7	8	9	10
2006	-0.58	-0.13	-1.22	-0.90	-1.02	-0.84	0.51	0.79	0.66	0.59
2007	-0.33	0.13	-0.24	0.41	0.78	1.10	0.26	0.53	1.55	-0.03
2008	-0.61	-0.56	0.08	0.93	0.74	0.01	-0.32	-0.78	-0.61	-0.28
2009	-0.95	-1.13	-0.50	0.42	0.76	-0.69	-0.75	-1.59	-1.45	-0.46
2010	-1.10	0.04	0.79	1.47	-0.39	-1.14	-0.16	0.70	-0.32	-1.40
2011	0.11	0.15	1.18	1.98	1.43	0.20	-0.45	0.66	-0.34	-0.16
2012	-0.26	-0.91	-1.68	0.44	-1.38	-1.30	-1.64	-0.60	-0.95	0.17
2013	-0.88	-0.83	0.02	-0.38	0.07	-0.12	0.25	0.31	-0.29	-0.18
2014	0.24	0.67	0.41	0.83	-0.13	-0.19	-1.00	-1.01	-1.57	-0.35
2015	0.64	0.78	-0.45	-1.25	-1.58	-1.11	-0.54	-0.85	0.35	-0.97
2016	2.70	2.63	1.62	-0.45	-0.33	-0.06	0.37	-0.34	-0.43	0.08

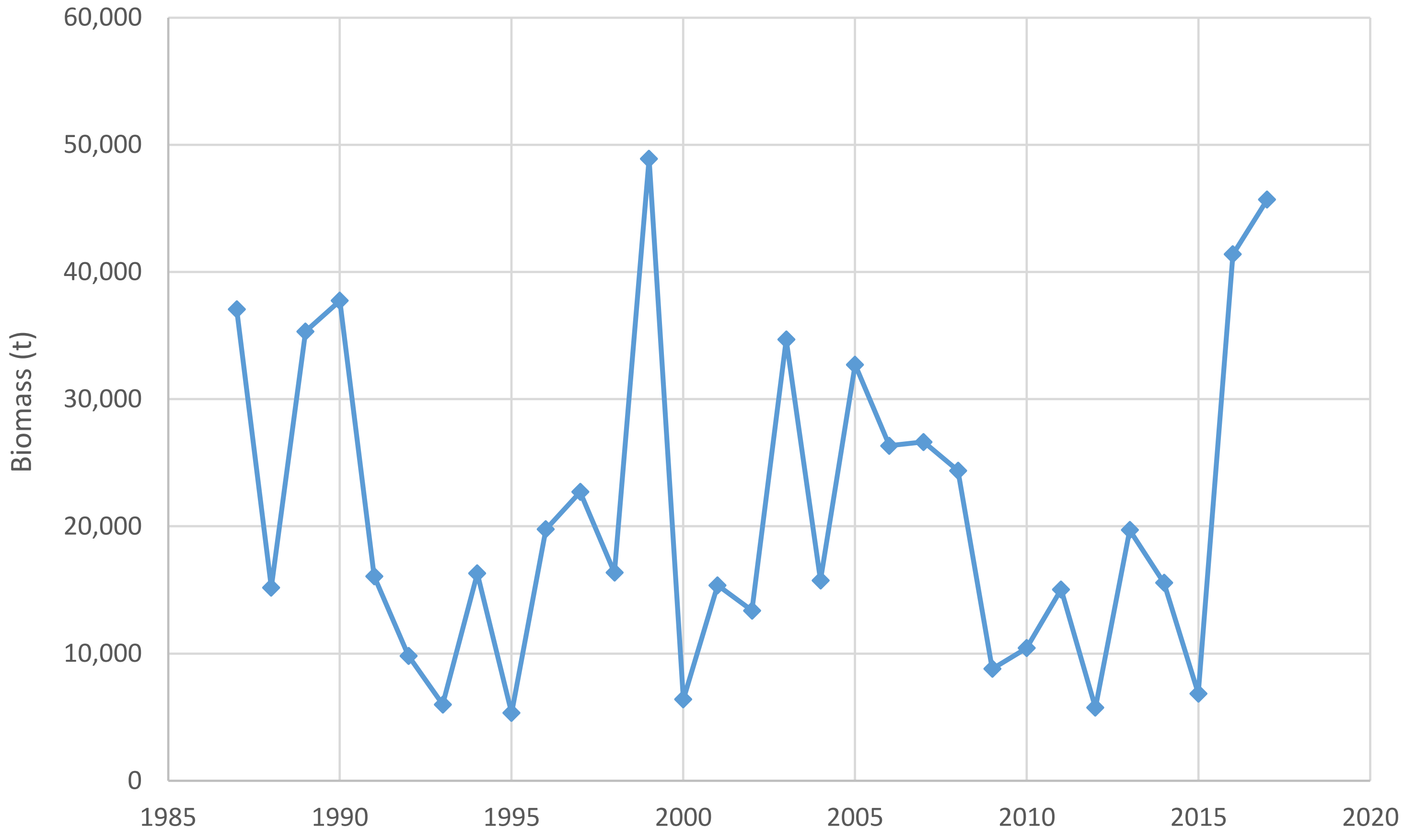
EBS, strata 82/90, an NBS trawl survey areas

- “Northwest strata” = strata 82 and 90



Strata 82 and 90 biomass

- 2017 estimate up 10% from 2016

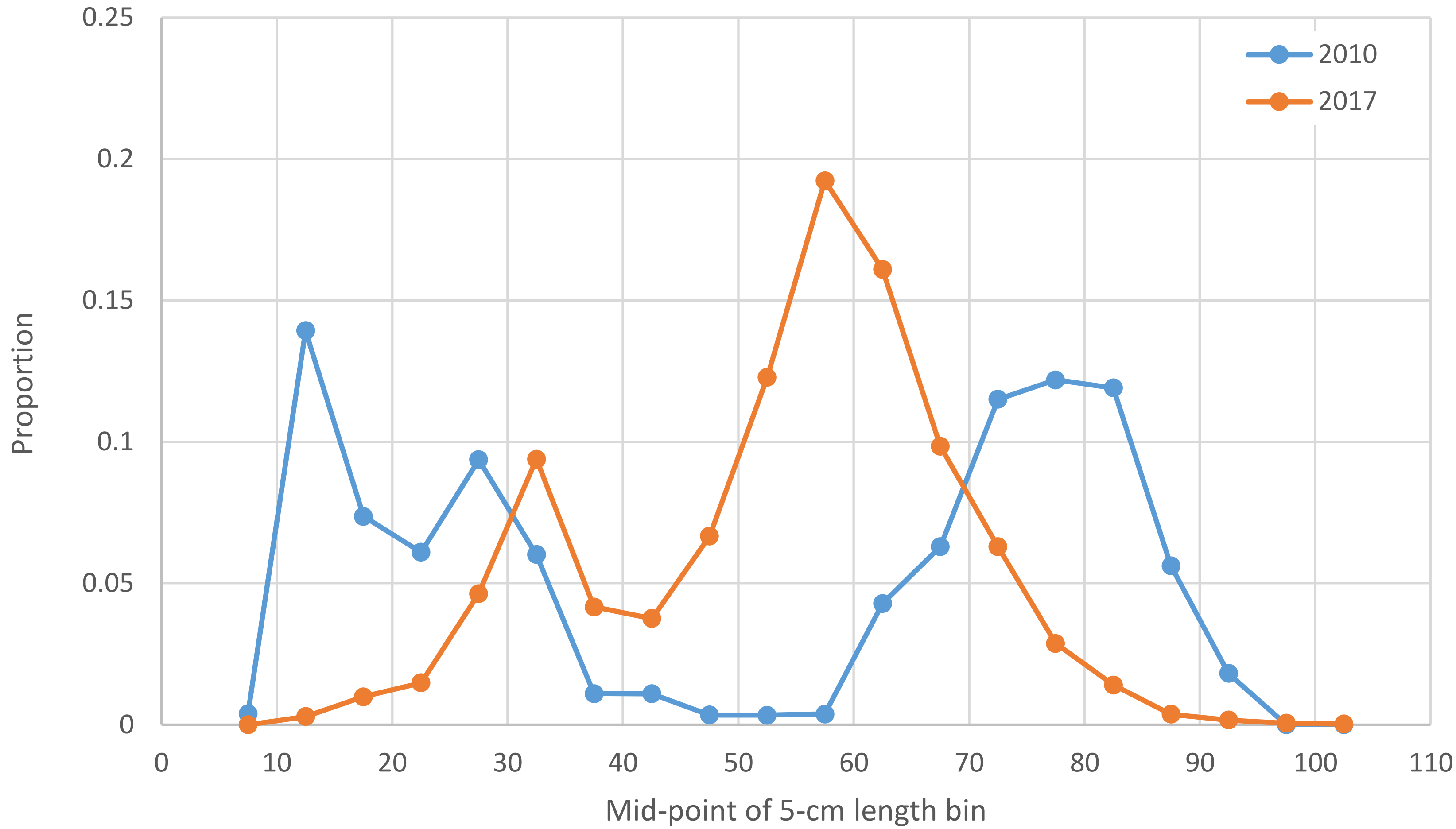


NBS survey indices

- Relative change in biomass (2010-2017): +907%
  - 2017 NBS biomass = 83% of EBS biomass change
- Relative change in abundance (2010-2017): +1421%

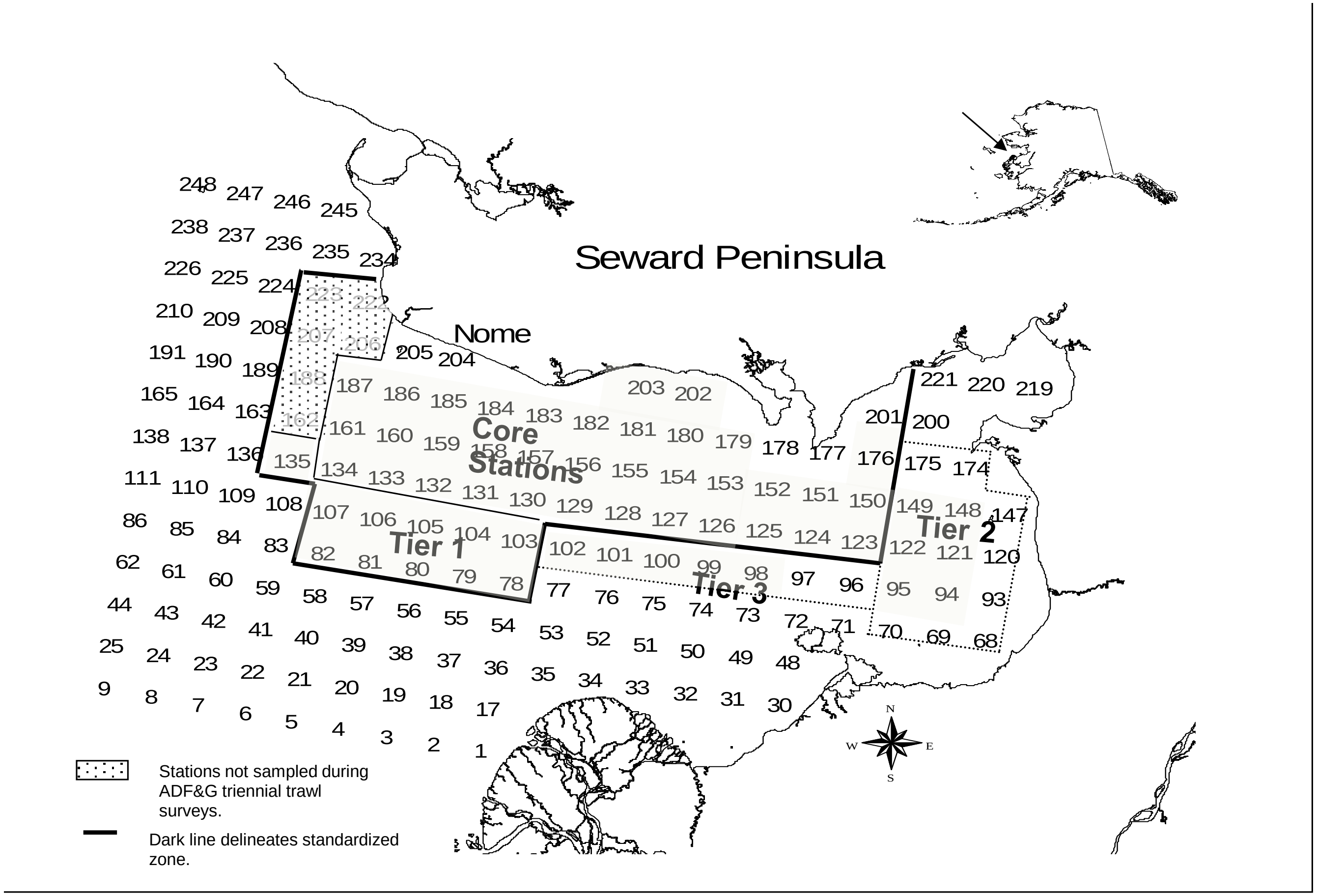
	Biomass			
Year	Estimate	CV	L95%CI	U95%CI
2010	28,425	0.23	15,520	41,330
2017	286,310	0.13	211,479	361,140
	Abundance			
Year	Estimate	CV	L95%CI	U95%CI
2010	8,881,464	0.20	5,402,268	12,360,661
2017	135,064,549	0.13	100,794,138	169,334,960

NBS survey sizecomps



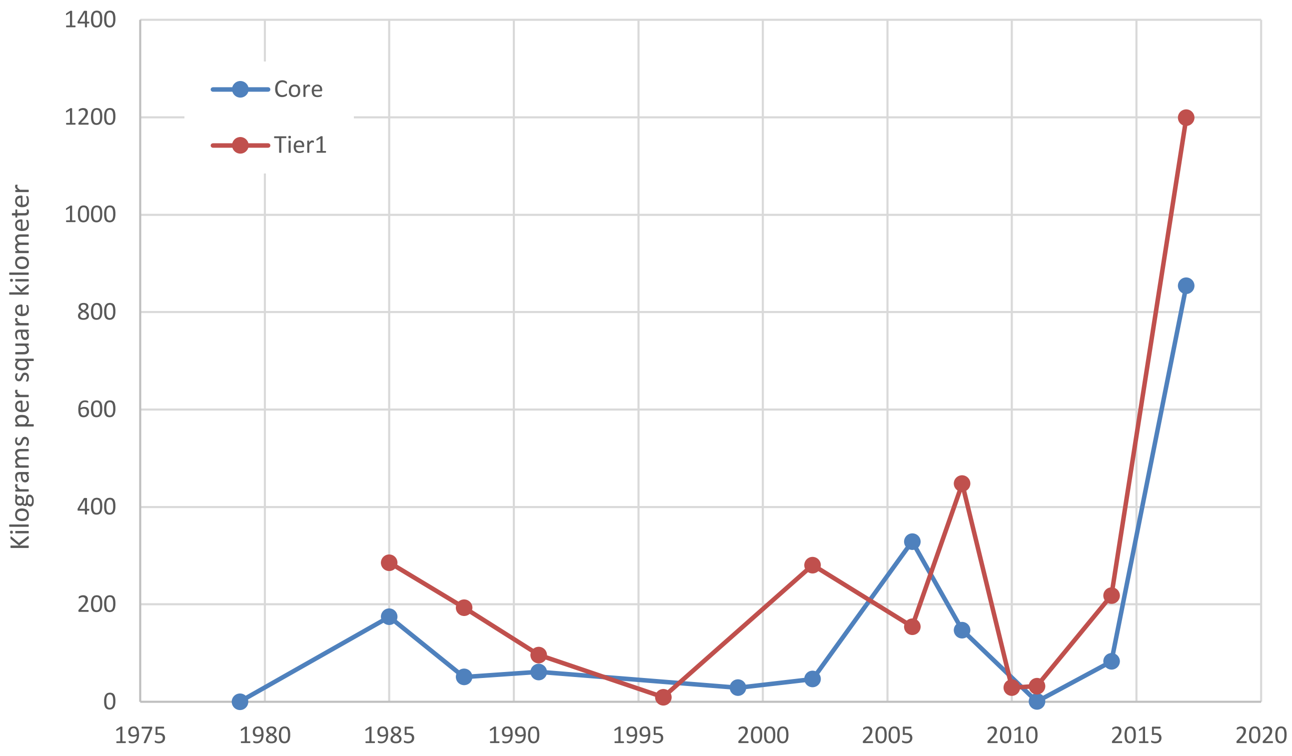
Norton Sound survey areas

- Only areas surveyed consistently are Core and Tier1



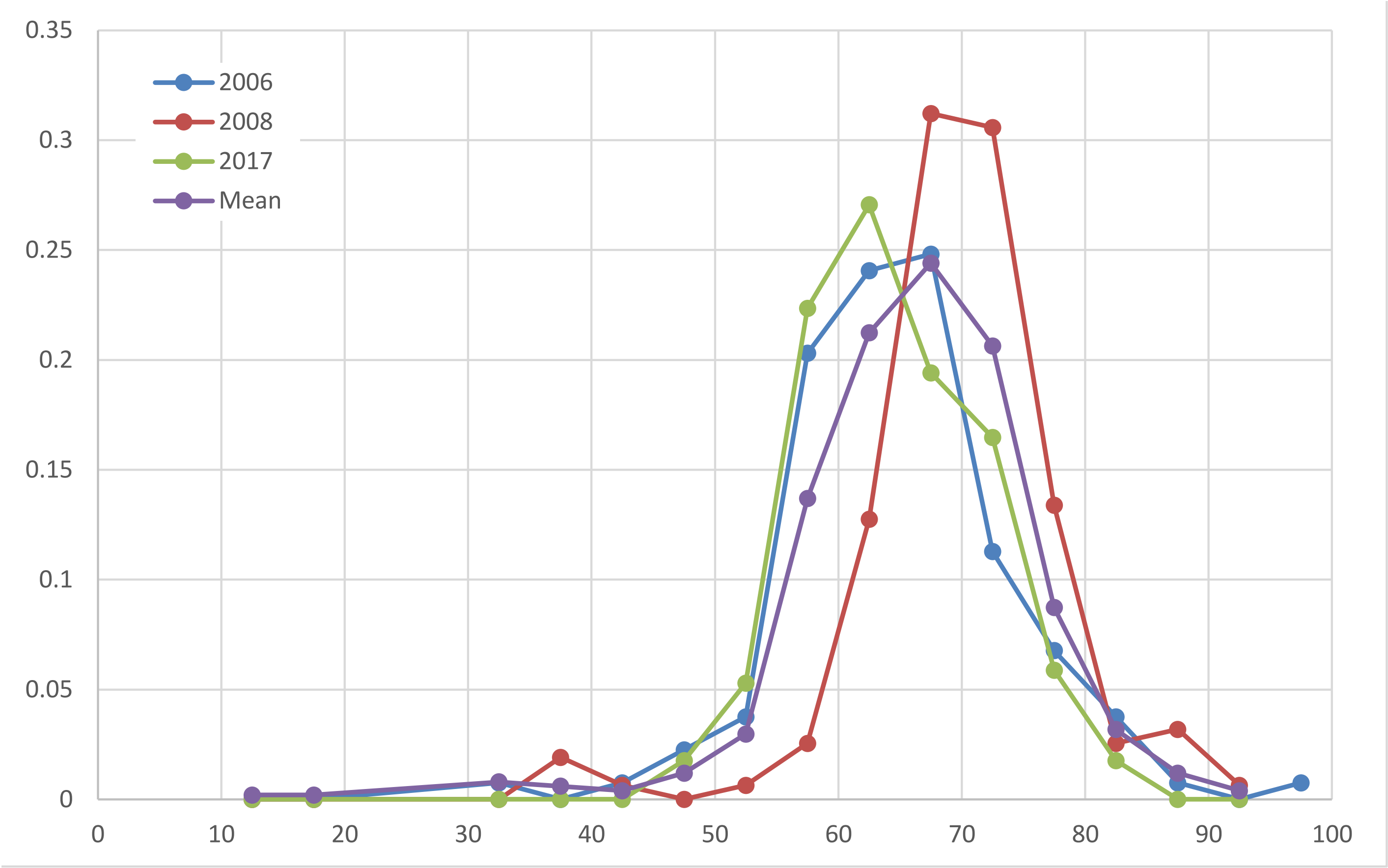
Norton Sound survey CPUE

- Core area up 933% from 2014; Tier1 area up 450%
- Compare to EBS shelf survey mean CPUE = 1648 kg/km^2



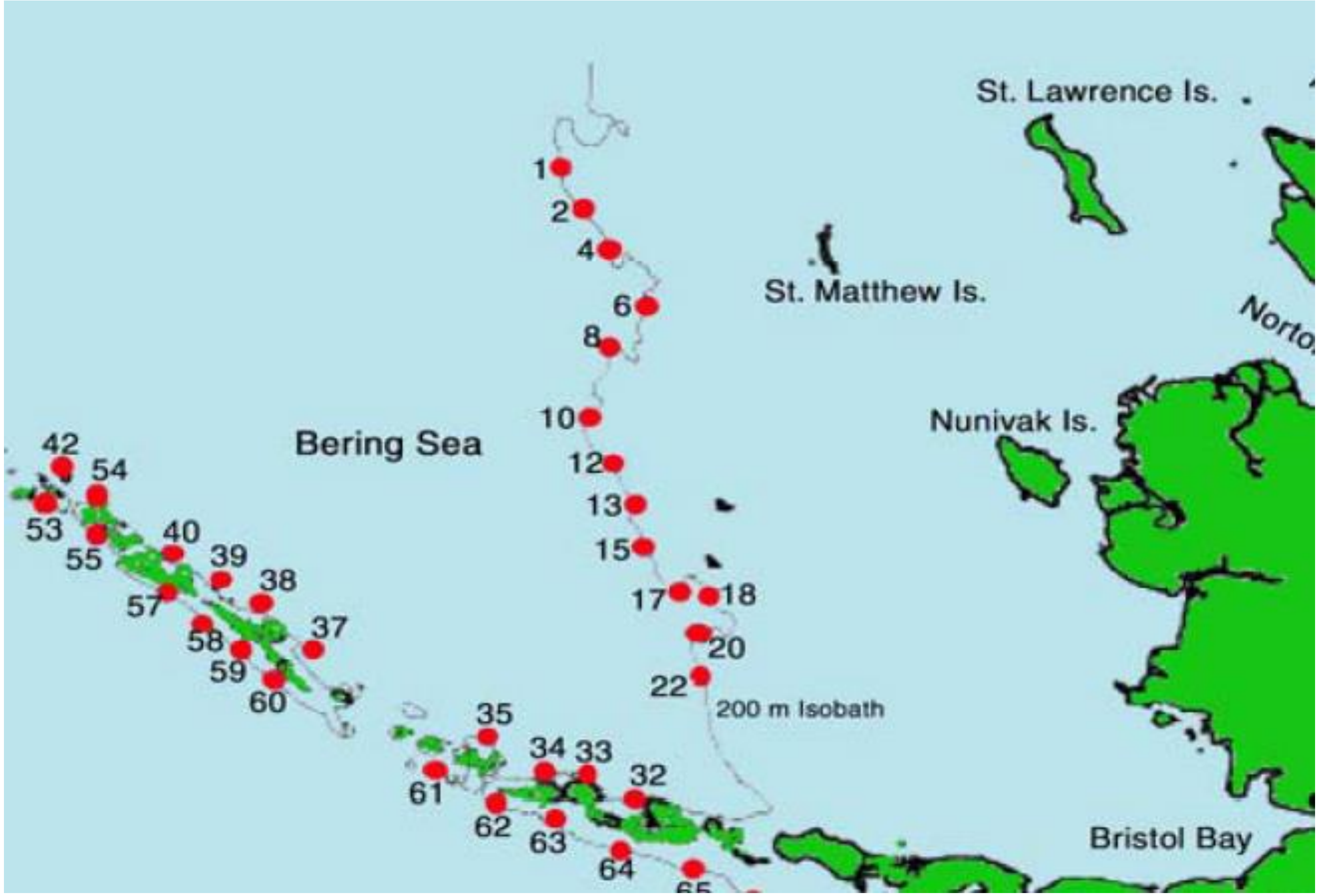
Norton Sound survey sizecomps

- Only 3 years with n>100



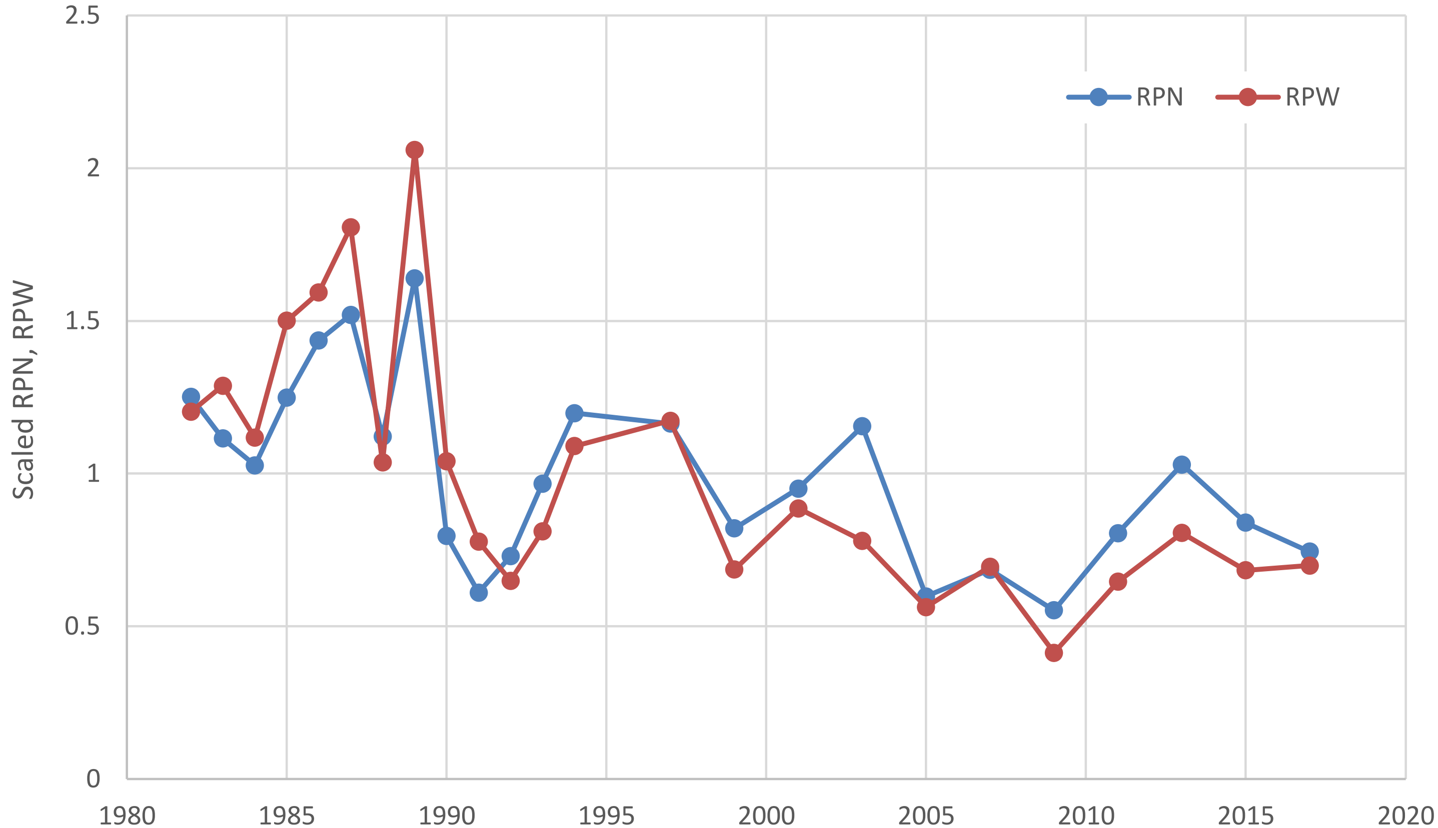
NMFS longline survey stations in the EBS

- Alternating years in EBS and AI

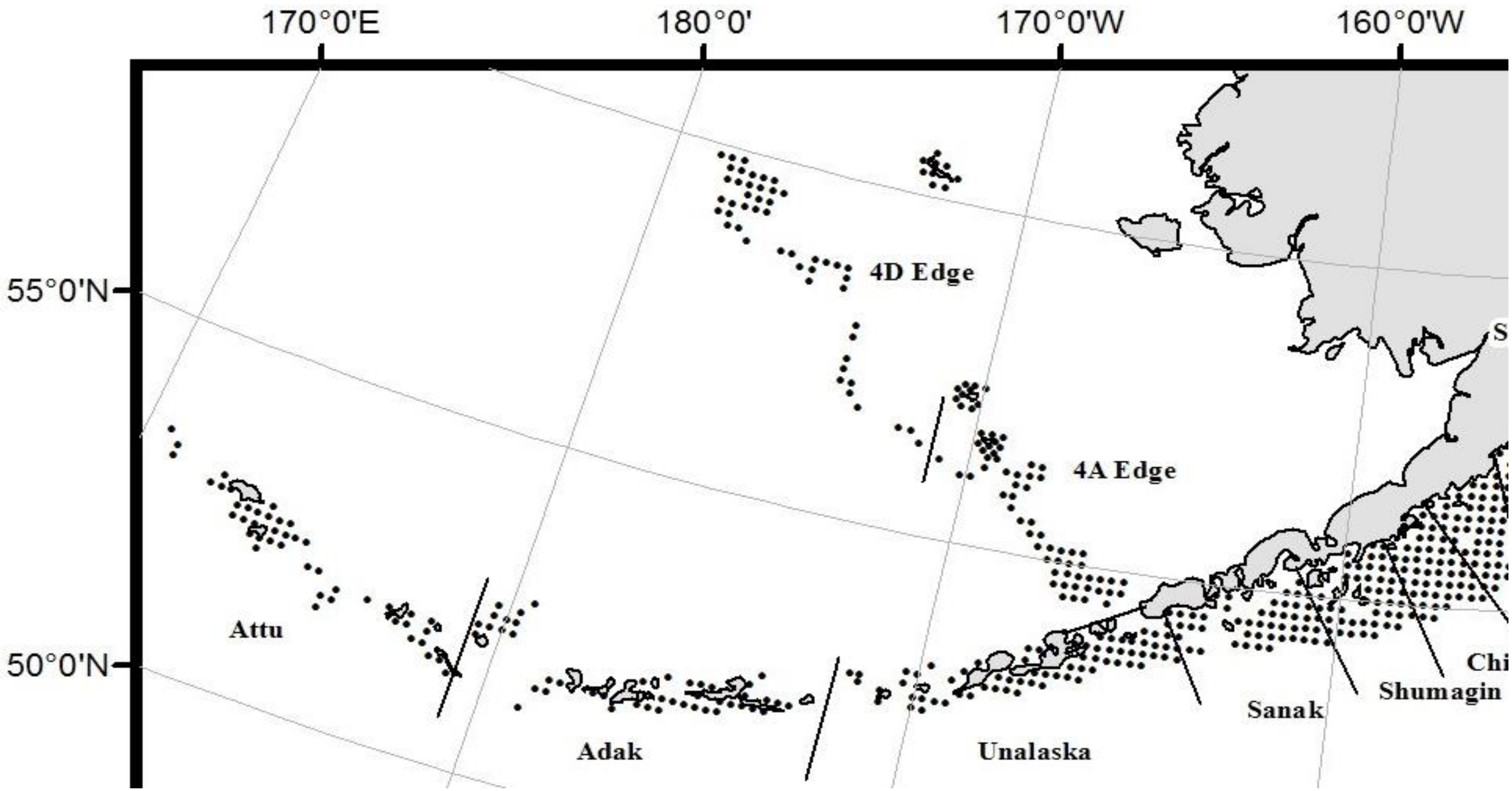


NMFS longline survey index

- RPN down 11%, RPW up 2%

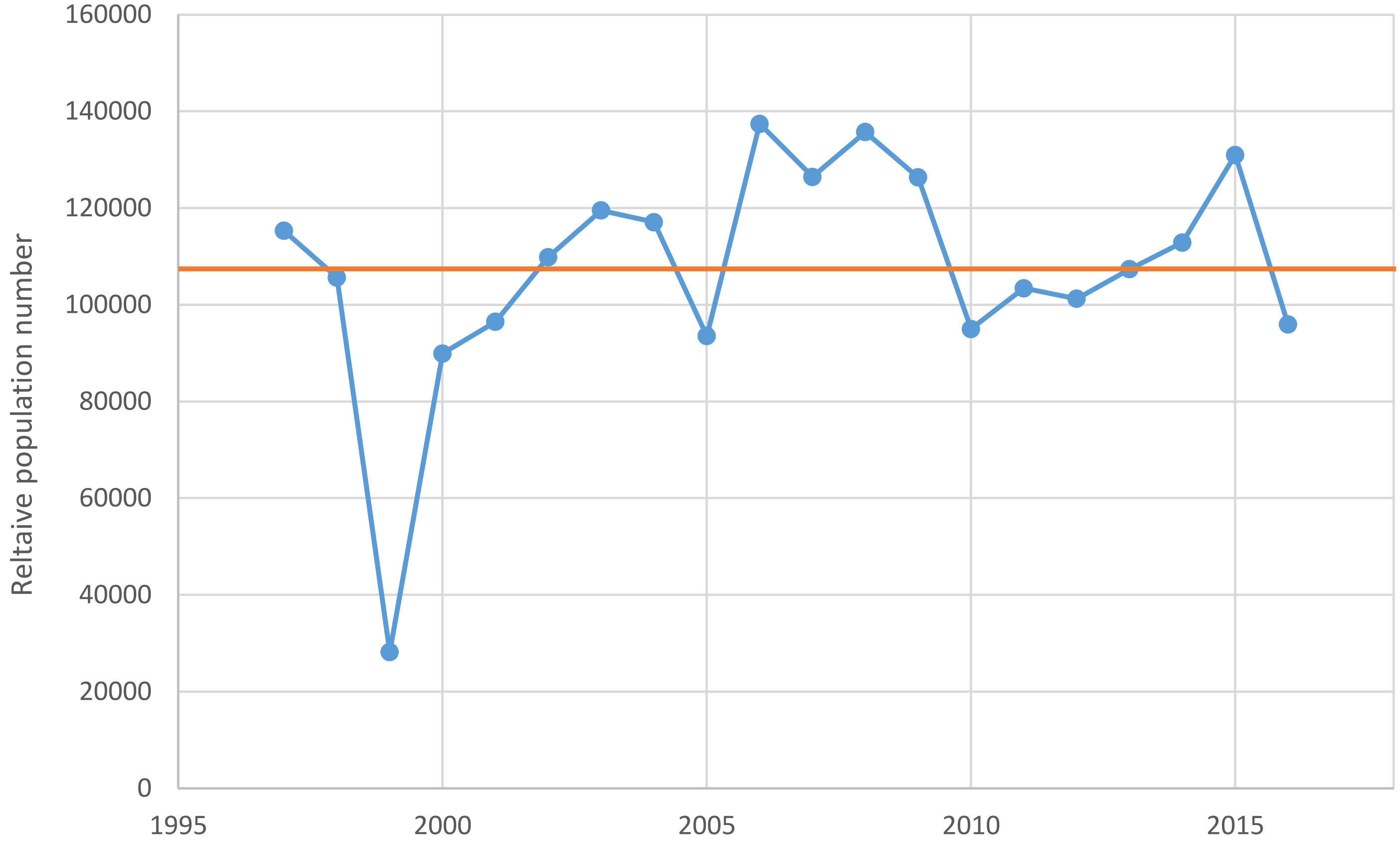


IPHC longline survey stations in the EBS



IPHC longline survey index

- 2016 RPN down 27% from 2015



Model structures

List of models (1 of 4)

- Model 16.6 (current base model):
  - One fishery, one gear type, one season per year
  - Input sample sizes average 300, with season×gear catch-weighted sizecomps
  - Logistic age-based selectivity for both the fishery and survey
  - External estimation of time-varying weight-at-length parameters and the standard deviations of ageing error at ages 1 and 20
  - All parameters constant except recruitment and fishing mortality
  - Internal estimation of all natural mortality, fishing mortality, length-at-age (including ageing bias), recruitment (conditional on steepness fixed at 1.0), catchability, and selectivity parameters

List of models (2 of 4)

- Model 17.1: Same as Model 16.6, except:
  - Adjust timing of the fishery and survey in SS
  - Switch to haul-based input sample size and week×gear×area catch-weighted sizecomps
  - Do not use old (poorly sampled) fishery agecomps, but do add new fishery agecomps
  - Develop a prior distribution for natural mortality based on previous estimates
  - Switch to age-based, flat-topped, double normal selectivity
  - Allow randomly time-varying selectivity for the fishery and survey, with σs fixed at the restricted MLEs

List of models (3 of 4)

- Model 17.2: Same as Model 17.1, except:
  - Use harmonic mean weighting of composition data
  - Allow randomly time-varying selectivity for the fishery but not the survey
- Model 17.3: Same as Model 17.1, except:
  - Use harmonic mean weighting of composition data
  - Estimate "extra" survey index standard error internally

List of models (4 of 4)

- Model 17.6: Same as Model 17.1, except:
  - Use harmonic mean weighting of composition data
  - Allow randomly time-varying length at age 1.5, with σ fixed at the restricted MLE
  - Allow randomly time-varying trawl survey catchability
- Model 17.7: Same as Model 17.6, except:
  - All sizecomp and agecomp multipliers capped at 1.0

“Pre-bridging” analysis (1 of 2)

- Features added to Model 16.6 1 at a time (not cumulatively)

Sorted in order of increasing average difference in spawning biomass ("ADSB")	
Feature	ADSB
Prior distribution for natural mortality	0.0067
Flat-topped, time-invariant, double normal selectivity	0.0146
Random time variability in length at age 1.5	0.0178
Random time variability in survey catchability	0.0444
New fishery agecomps	0.0474
Gear/week/area-catch-weighted sizecomp data	0.0605
Double normal selectivity with variability in survey selparm P1	0.0699
Double normal selectivity with variability in survey selparm P3	0.1080
Double normal selectivity with variability in fishery selparm P3	0.1091
Double normal selectivity with variability in fishery selparm P1	0.1818
Haul-based sample sizes with harmonic mean reweighting	0.2420
Haul-based sample sizes without reweighting	0.3705

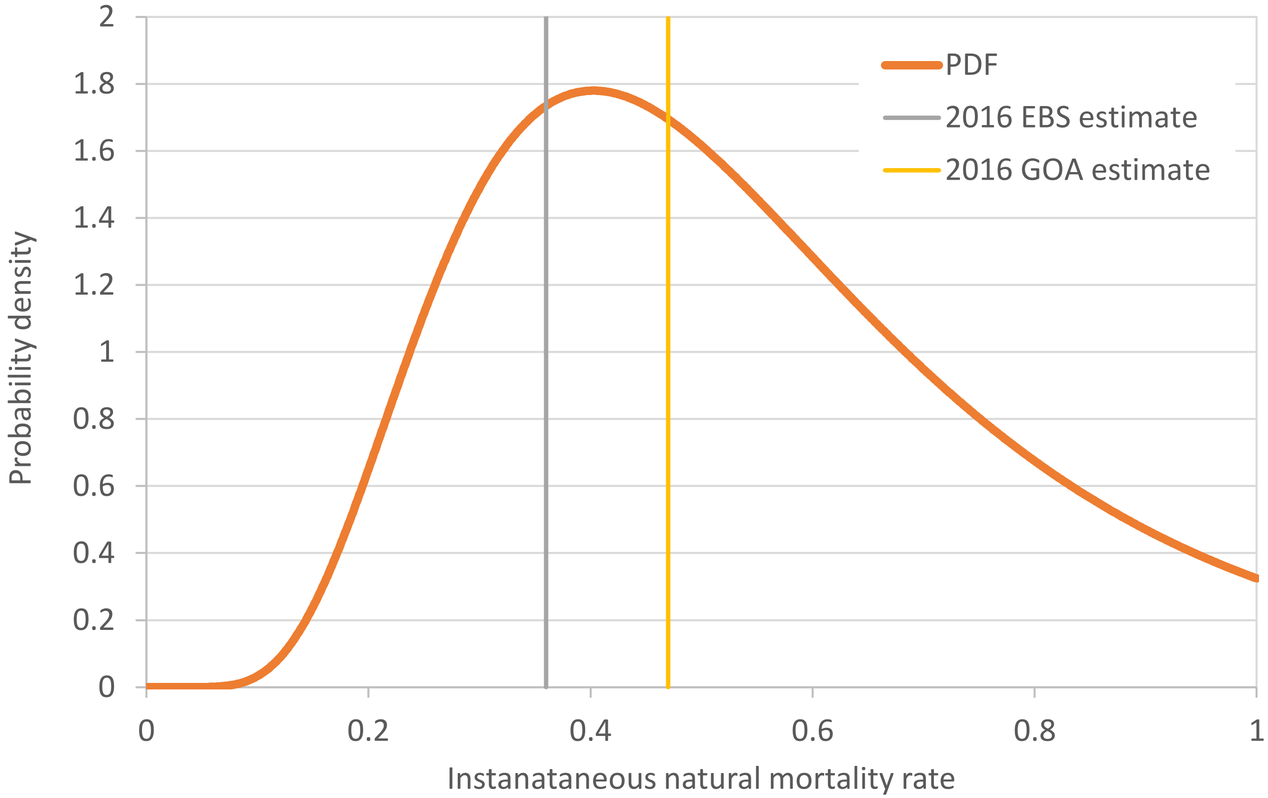
“Pre-bridging” analysis (2 of 2)

- Top 1 and bottom 4 features same as on previous slide

Sorted in order of increasing change in 2016 spawning biomass ("ΔSB16")	
Feature	ΔSB16
Random time variability in survey catchability	0.0101
Prior distribution for natural mortality	0.0114
Flat-topped, time-invariant, double normal selectivity	0.0126
Random time variability in length at age 1.5	0.0272
Double normal selectivity with variability in survey selparm P3	0.0379
Gear/week/area-catch-weighted sizecomp data	0.0414
New fishery agecomps	0.0587
Double normal selectivity with variability in fishery selparm P3	0.0967
Double normal selectivity with variability in fishery selparm P1	0.1142
Haul-based sample sizes with harmonic mean reweighting	0.2016
Double normal selectivity with variability in survey selparm P1	0.2116
Haul-based sample sizes without reweighting	0.5197

Prior distribution for natural mortality

- Estimated from previous estimates of *M* in various Pcod stocks, excluding those that involve overlapping data



Results

Objective function values, parameter counts

Component	M16.6	M17.1	M17.2	M17.3	M17.6	M17.7
Catch	0.00	0.00	0.00	0.00	0.00	0.00
Equilibrium catch	0.00	0.12	0.02	0.07	0.05	0.06
Survey abundance index	-23.31	-9.30	-11.44	-40.39	-64.68	-64.61
Recruitment	5.14	12.34	3.93	-2.95	2.44	-0.82
Priors	0.00	0.44	0.17	0.41	0.45	0.48
"Softbounds"	0.01	0.00	0.00	0.00	0.00	0.00
Deviations	0.00	-240.88	-94.79	-267.46	-398.01	-401.84
Size composition (fishery)	376.60	1586.83	491.42	323.16	365.70	325.80
Size composition (survey)	1030.55	1119.77	1015.71	984.28	1017.45	670.06
Age composition (fishery)	0.00	440.15	40.17	31.75	37.78	37.78
Age composition (survey)	293.08	275.90	54.33	62.24	61.48	61.07
Total	1682.06	3185.37	1499.53	1091.11	1022.66	627.97

Parameter type	M16.6	M17.1	M17.2	M17.3	M17.6	M17.7
Free parameters	18	16	16	17	17	17
Parameters with priors	0	1	1	1	1	1
Constrained deviations	60	214	142	214	286	286
Total	78	231	159	232	304	304

Effective sample sizes: M16.6, M17.1, M17.2

				Model 16.6				
Type	Fleet	Yrs	N	Mult	N×Mult	Har	ΣNeff1	ΣNeff2
Size	Fish.	41	300	1.0000	300	582	12299	23850
Size	Surv.	36	300	1.0000	300	308	10798	11086
Age	Fish.	–	–	–	–	–	–	–
Age	Surv.	23	300	1.0000	300	61	6898	1395
				SEave	SEextra	RMSE		
Index	Surv.	36	336	0.1074	0	0.1886	12083	3921
						Ave:	10519	10063

				Model 17.1					Model 17.2				
Type	Fleet	Yrs	N	Mult	N×Mult	Har	ΣNeff1	ΣNeff2	Mult	N×Mult	Har	ΣNeff1	ΣNeff2
Size	Fish.	41	5522	1.0000	5522	1826	226402	74884	0.2425	1339	1365	54902	55964
Size	Surv.	36	336	1.0000	336	290	12083	10438	0.8480	285	284	10246	10217
Age	Fish.	4	11093	1.0000	11093	839	44373	3357	0.0836	927	844	3710	3375
Age	Surv.	23	343	1.0000	343	73	7891	1670	0.1155	40	40	911	915
				SEave	SEextra	RMSE			SEave	SEextra	RMSE		
Index	Surv.	36	336	0.1074	0	0.1968	12083	3601	0.1074	0	0.2072	12083	3247
						Ave:	60566	18790			Ave:	16371	14744

Effective sample sizes: M17.3, M17.6, M17.7

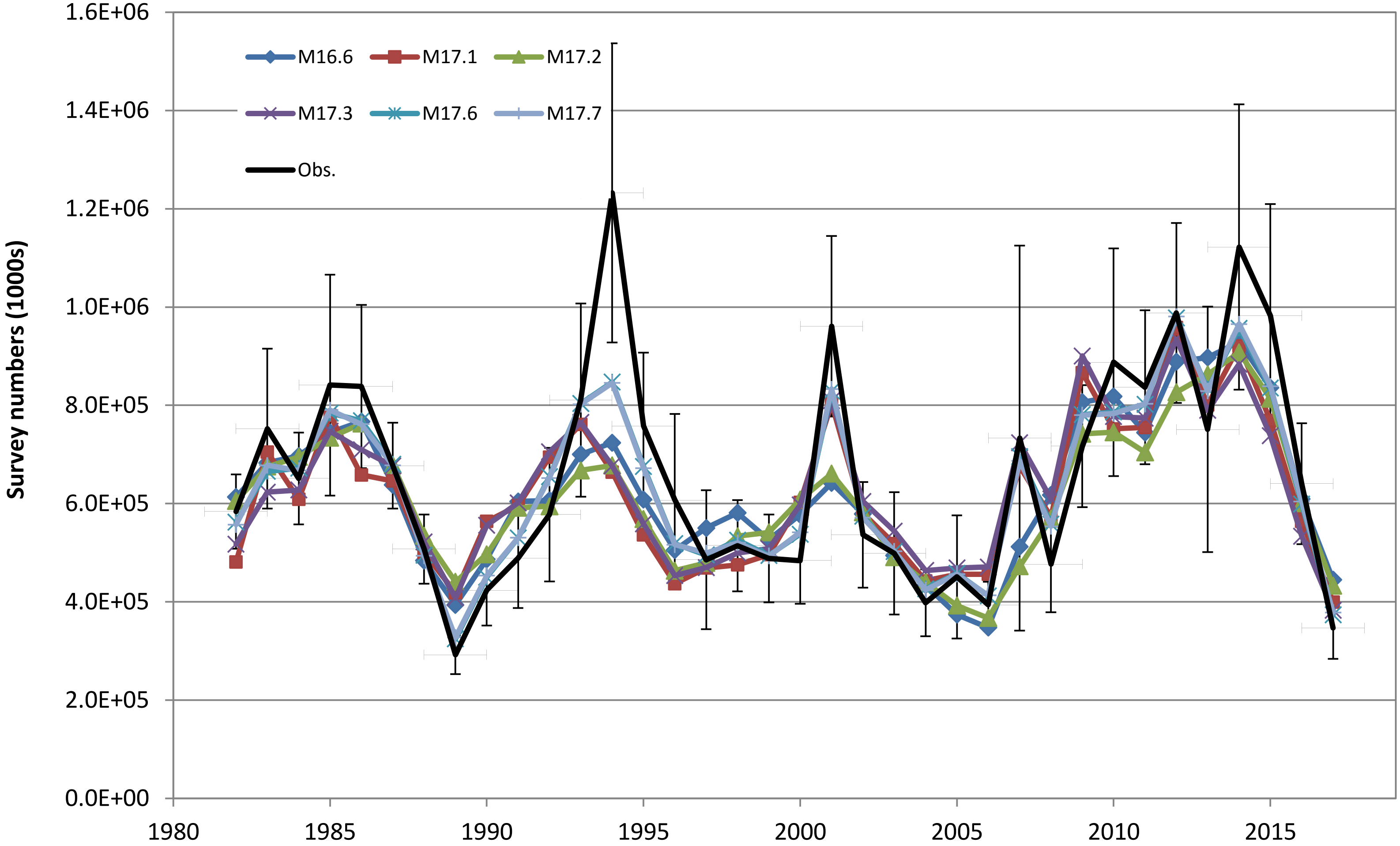
				Model 17.3				
Type	Fleet	Yrs	N	Mult	N×Mult	Har	ΣNeff1	ΣNeff2
Size	Fish.	41	5522	0.1525	842	827	34526	33901
Size	Surv.	36	336	1.0237	344	345	12369	12428
Age	Fish.	4	11093	0.0599	664	662	2658	2646
Age	Surv.	23	343	0.2561	88	89	2021	2054
				SEave	SEextra	RMSE		
Index	Surv.	36	336	0.1074	0.0944	0.1959	12083	12832
						Ave:	12732	12772

				Model 17.6					Model 17.7				
Type	Fleet	Yrs	N	Mult	N×Mult	Har	ΣNeff1	ΣNeff2	Mult	N×Mult	Har	ΣNeff1	ΣNeff2
Size	Fish.	41	5522	0.1611	890	846	36473	34686	0.1554	858	840	35183	34425
Size	Surv.	36	336	1.5903	534	536	19216	19290	1.0000	336	507	12083	18242
Age	Fish.	4	11093	0.0690	765	765	3062	3060	0.0736	816	841	3266	3363
Age	Surv.	23	343	0.2502	86	86	1974	1988	0.2499	86	86	1972	1972
				SEave	SEextra	RMSE			SEave	SEextra	RMSE		
Index	Surv.	36	336	0.1074	0	0.1075	12083	12062	0.1074	0	0.1071	12083	12145
						Ave:	14562	14217			Ave:	12917	14029

Management reference points

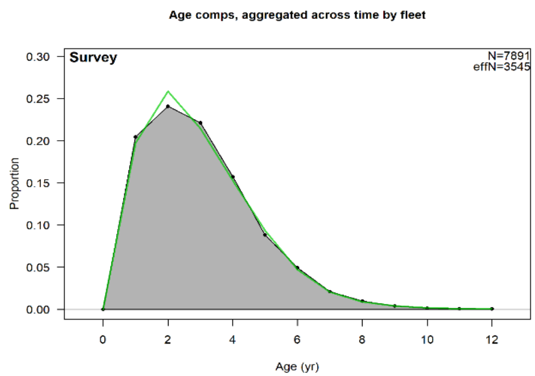
Quantity	M16.6	M17.1	M17.2	M17.3	M17.6	M17.7
B100%	593,000	644,000	548,000	622,000	633,000	644,000
B40%	237,000	258,000	219,000	249,000	253,000	258,000
B35%	207,000	226,000	192,000	218,000	221,000	225,000
B(2018)	264,000	173,000	217,000	146,000	142,000	145,000
B(2019)	248,000	200,000	211,000	179,000	177,000	181,000
B(2018)/B100%	0.45	0.27	0.40	0.24	0.22	0.23
B(2019)/B100%	0.42	0.31	0.39	0.29	0.28	0.28
F40%	0.31	0.25	0.32	0.26	0.26	0.26
F35%	0.38	0.31	0.38	0.31	0.32	0.31
maxFABC(2018)	0.31	0.16	0.31	0.15	0.14	0.14
maxFABC(2019)	0.31	0.19	0.30	0.18	0.18	0.18
maxABC(2018)	201,000	75,500	172,000	59,100	57,300	57,600
maxABC(2019)	170,000	92,400	148,000	79,900	79,200	80,300
FOFL(2018)	0.38	0.20	0.38	0.18	0.17	0.17
FOFL(2019)	0.38	0.23	0.37	0.22	0.22	0.21
OFL(2018)	238,000	89,600	202,000	70,300	68,400	68,700
OFL(2019)	201,000	109,000	173,000	94,500	93,900	95,100
Pr(maxABC(2018)>truOFL(2018))	0.03	0.11	0.05	0.21	0.14	0.17
Pr(maxABC(2019)>truOFL(2019))	0.09	0.12	0.23	0.22	0.13	0.15
Pr(B(2018)<B20%)	0.00	0.00	0.00	0.13	0.09	0.11
Pr(B(2019)<B20%)	0.00	0.00	0.00	0.00	0.00	0.00
Pr(B(2020)<B20%)	0.00	0.00	0.00	0.00	0.00	0.00
Pr(B(2021)<B20%)	0.00	0.00	0.00	0.00	0.00	0.00

Fit to survey abundance index

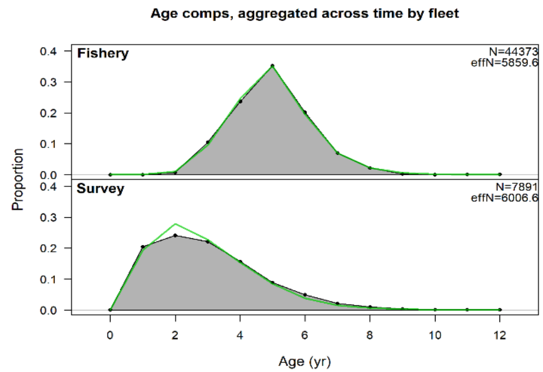


Time-aggregated agecomp fits

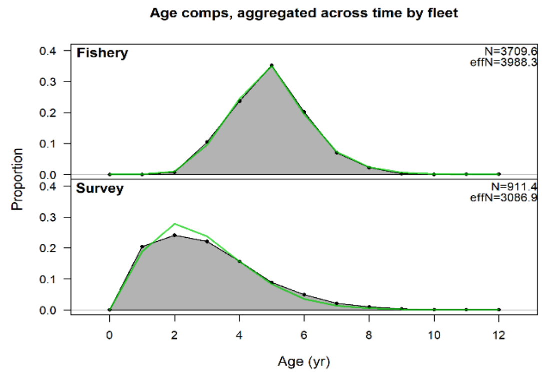
Model 16.6



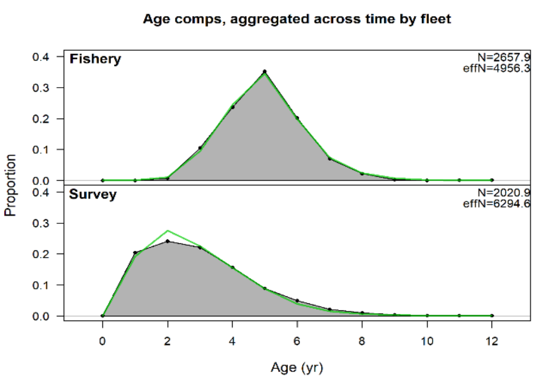
Model 17.1



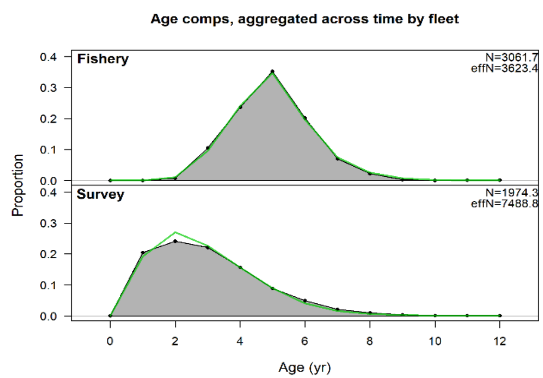
Model 17.2



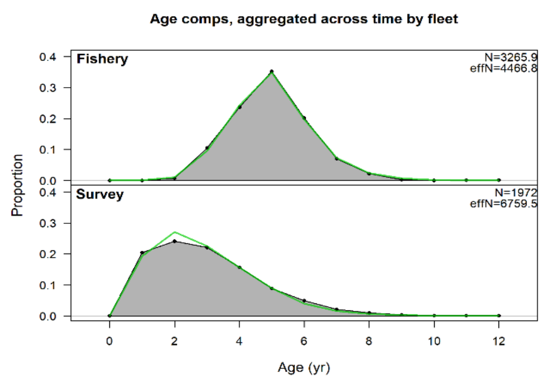
Model 17.3



Model 17.6

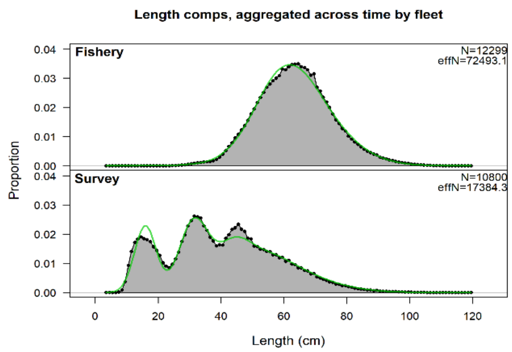


Model 17.7

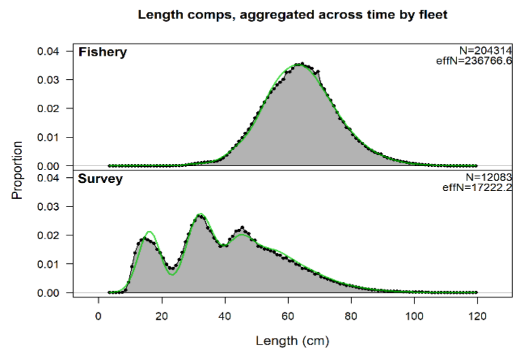


Time-aggregated sizecomp fits

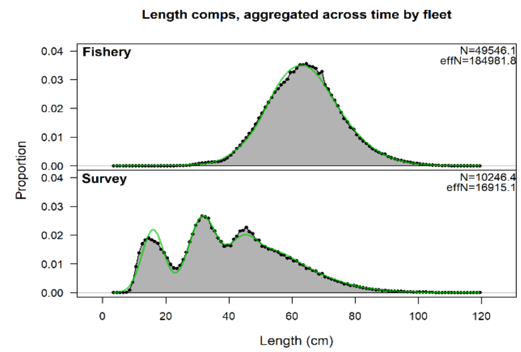
Model 16.6



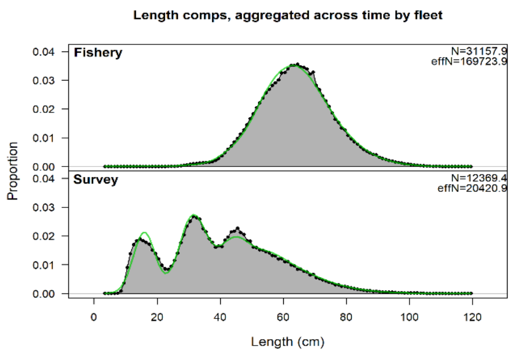
Model 17.1



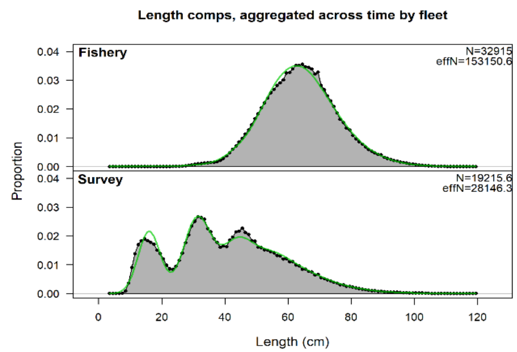
Model 17.2



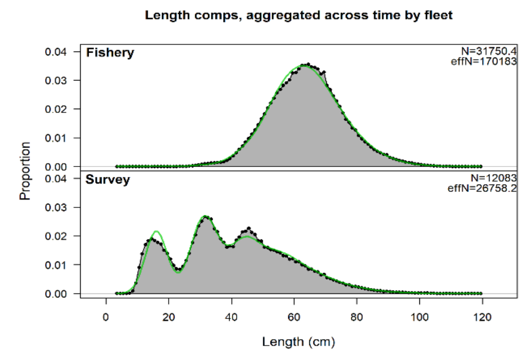
Model 17.3



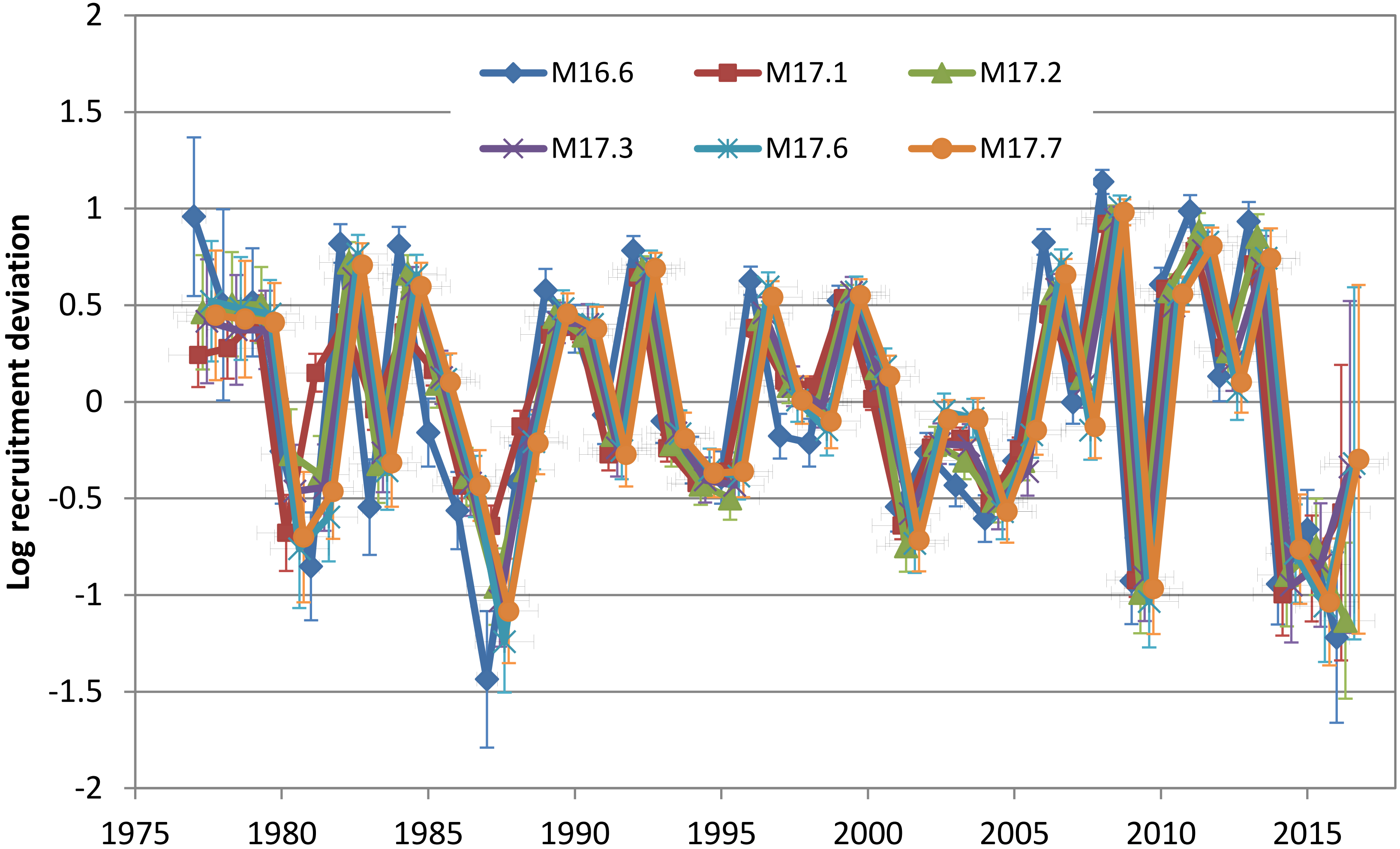
Model 17.6



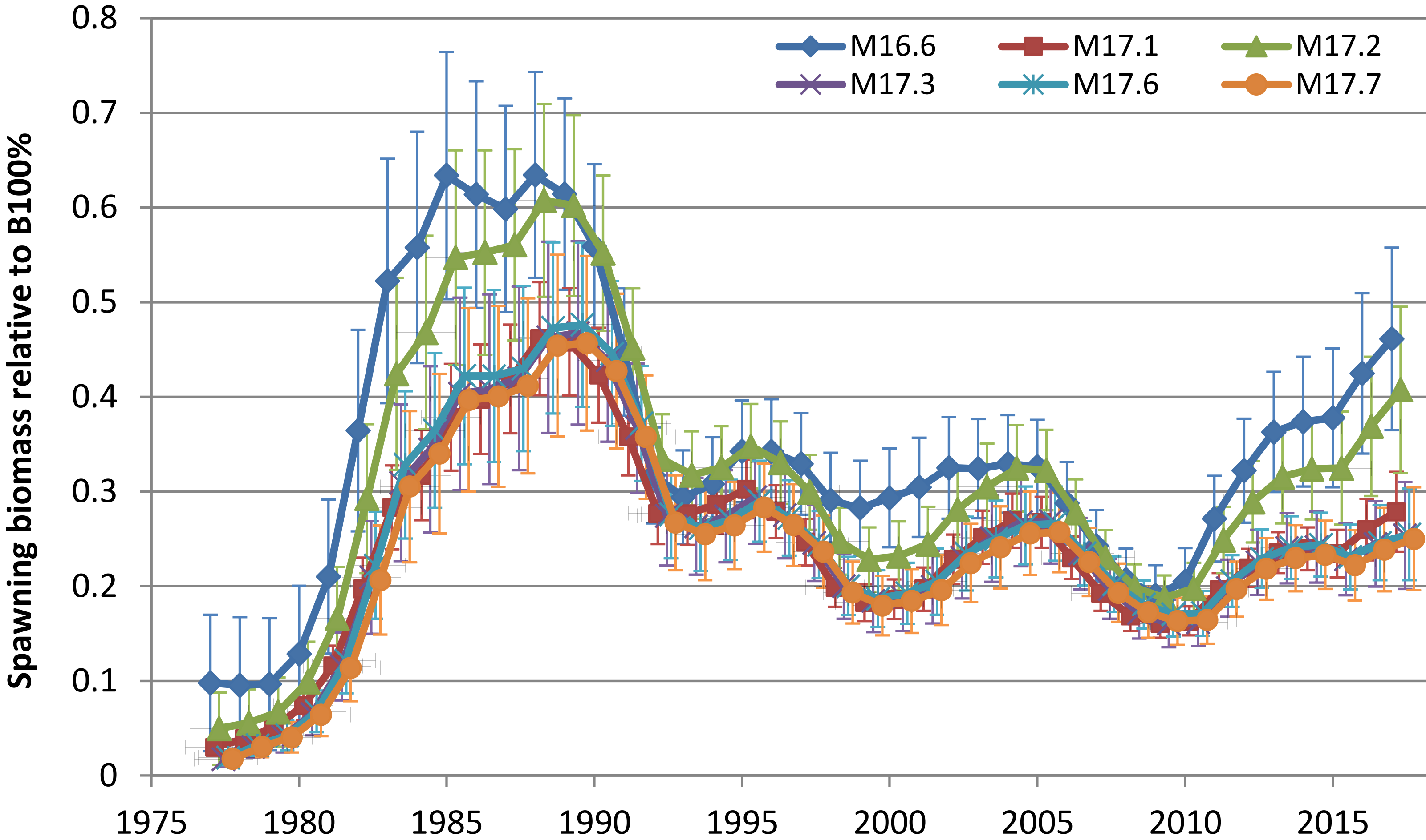
Model 17.7



Age 0 recruitment deviations

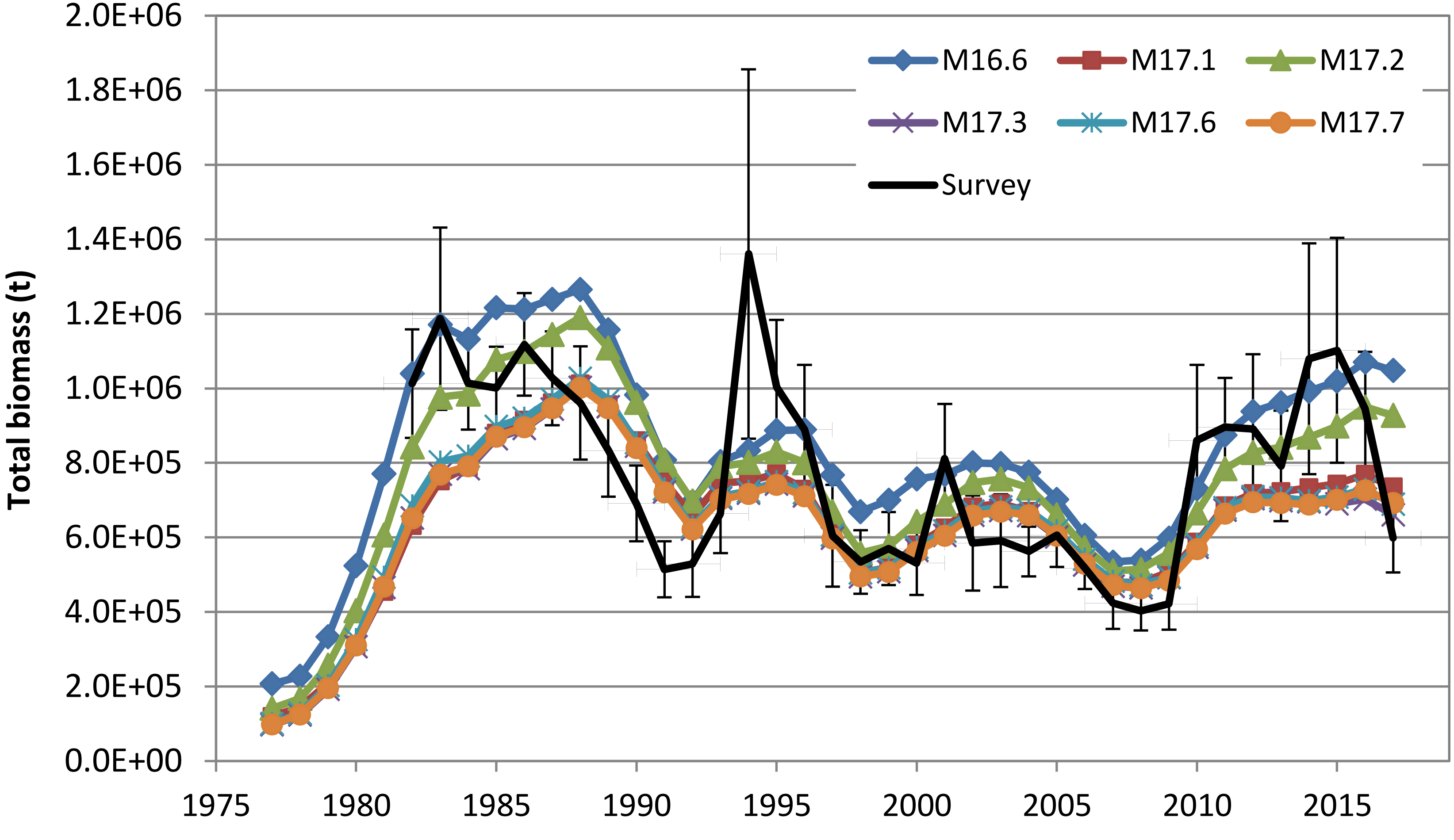


Depletion



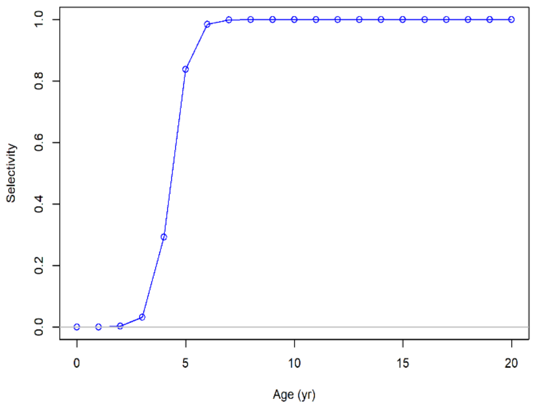
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Spawning biomass relative to B100%
1975
1980
1985
1990
1995
2000
2005
2010
2015
M16.6
M17.1
M17.2
M17.3
M17.6
M17.7

Total biomass (and survey biomass)

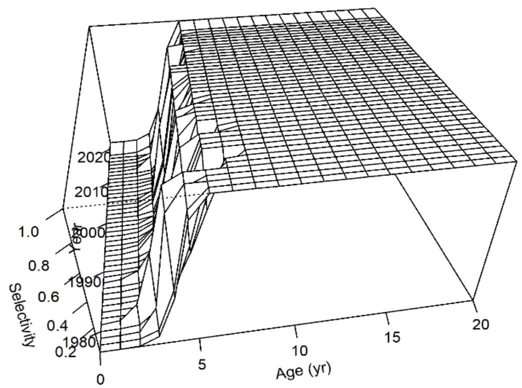


Fishery selectivity

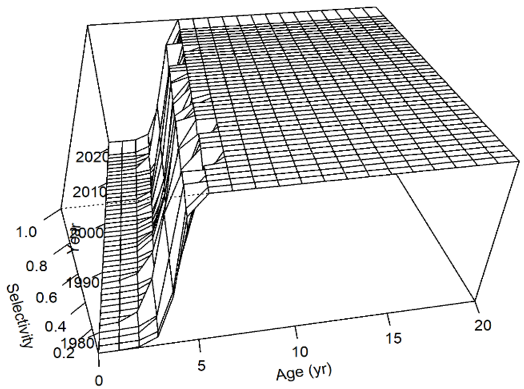
Model 16.6



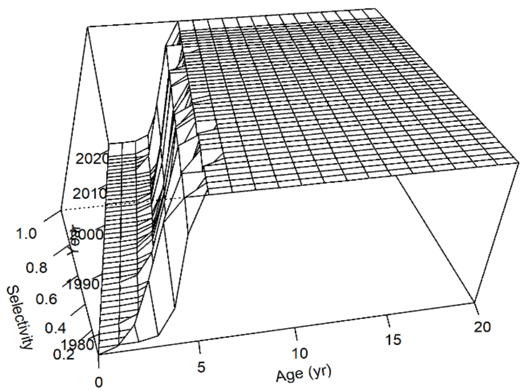
Model 17.1



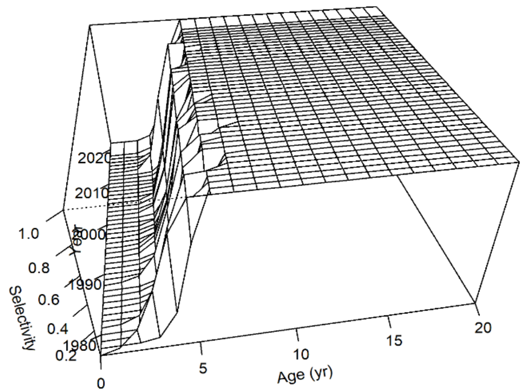
Model 17.2



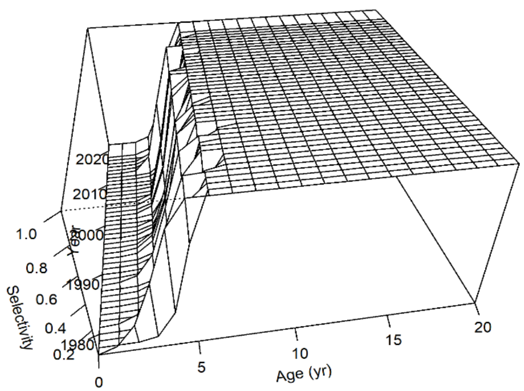
Model 17.3



Model 17.6

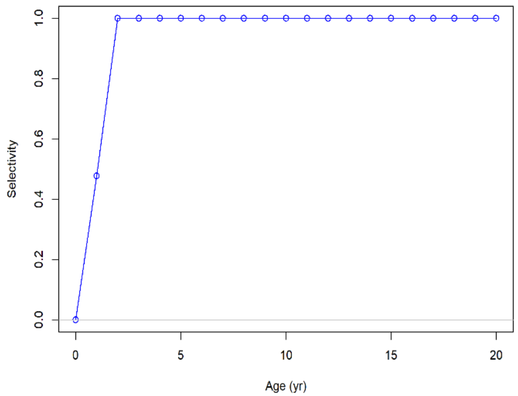


Model 17.7

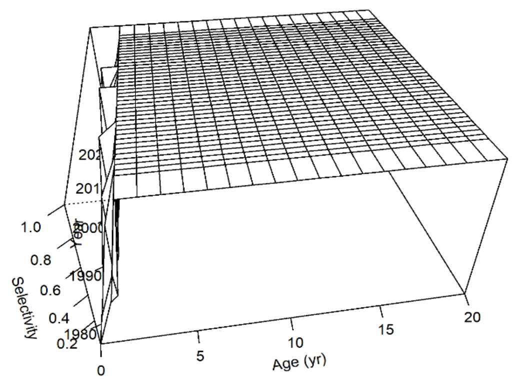


Survey selectivity

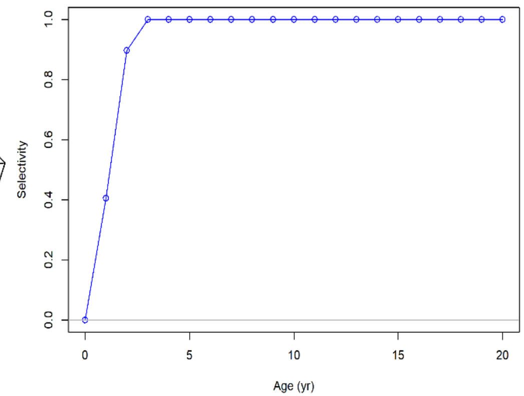
Model 16.6



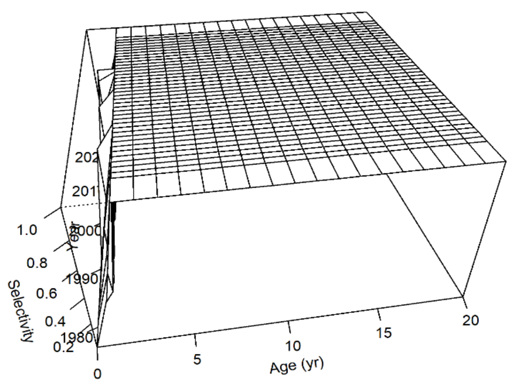
Model 17.1



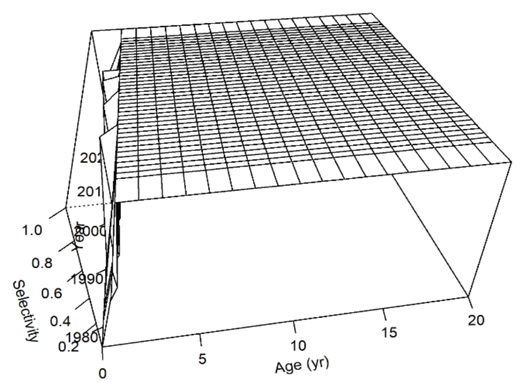
Model 17.2



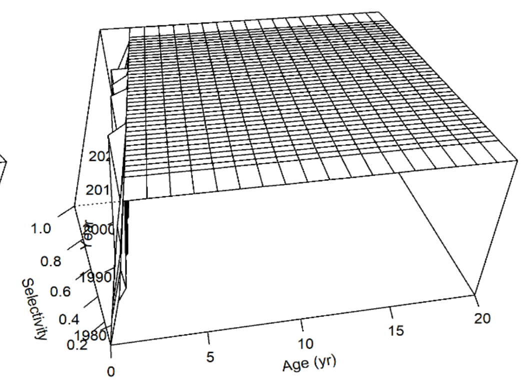
Model 17.3



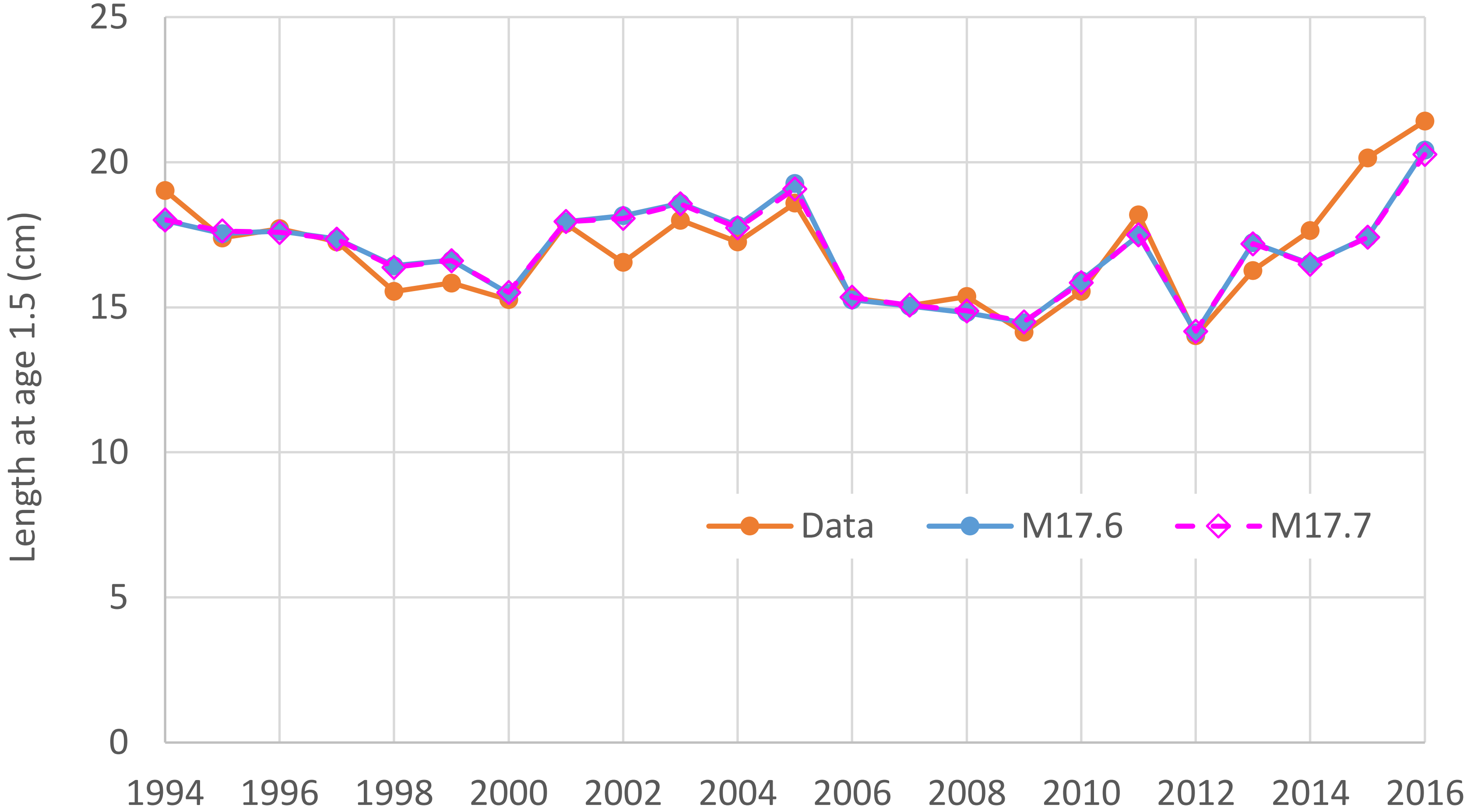
Model 17.6



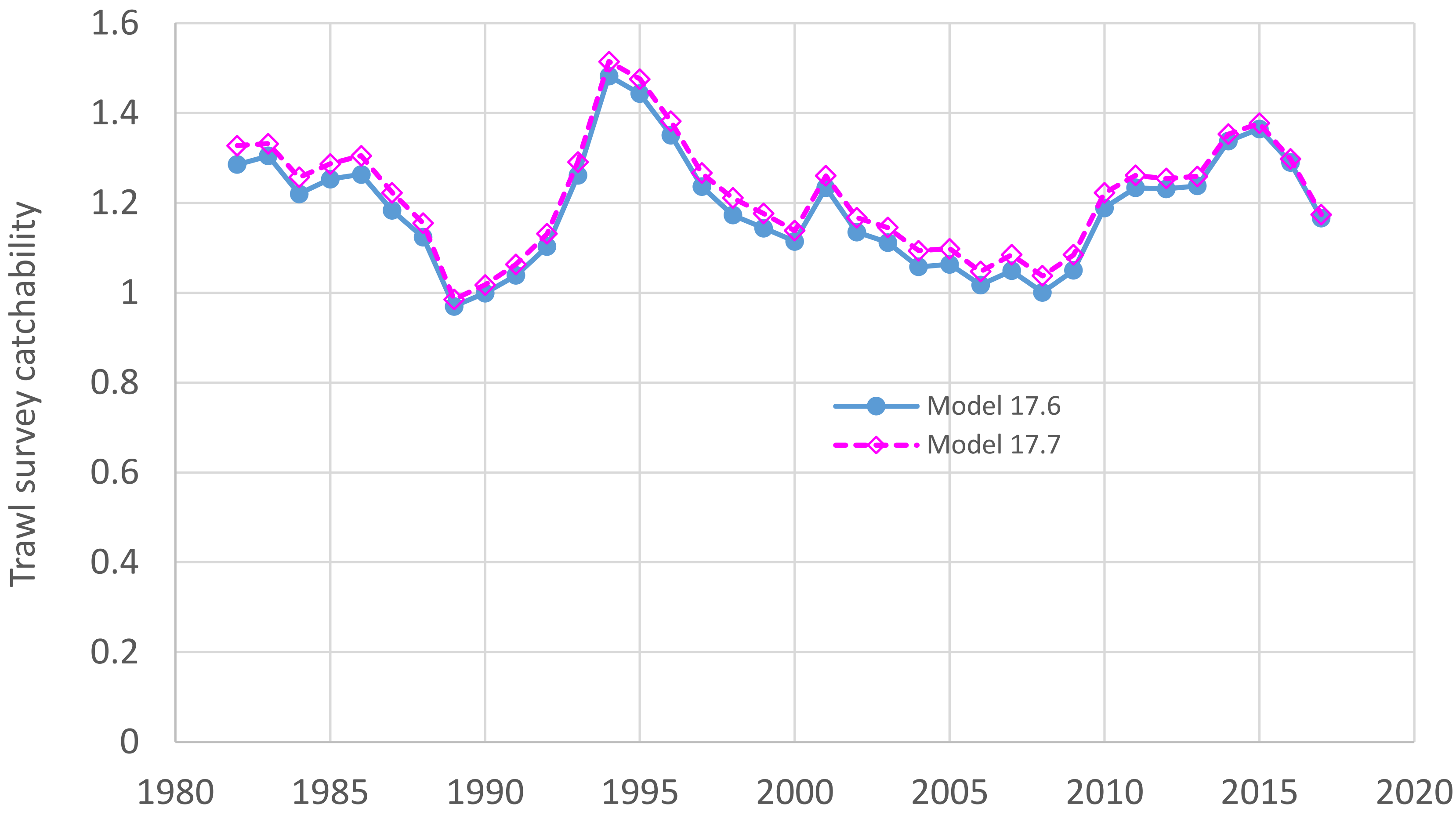
Model 17.7



Time varying length at age 1.5 (M17.6, M17.7)

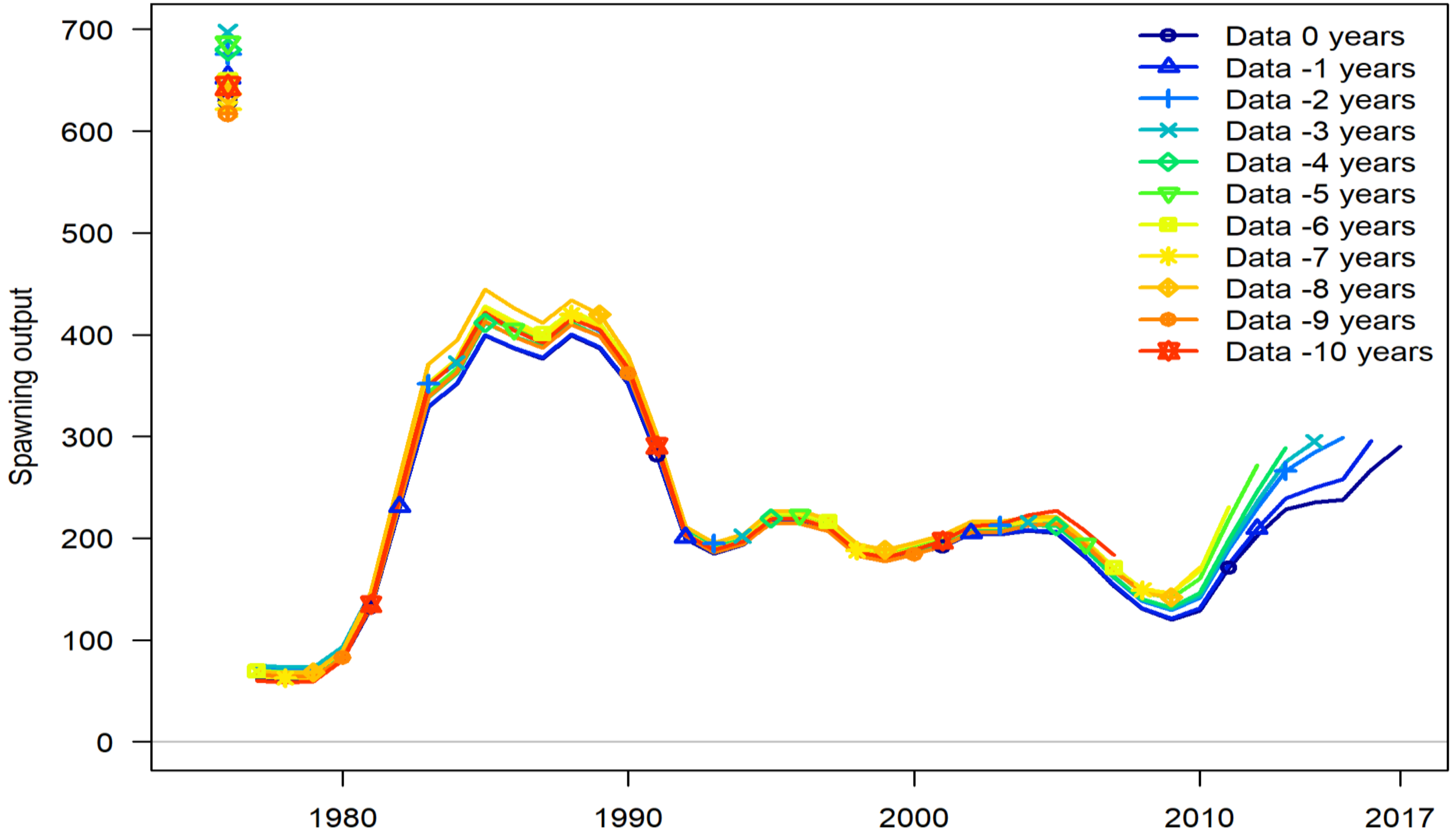


Time-varying catchability (M17.6, M17.7)



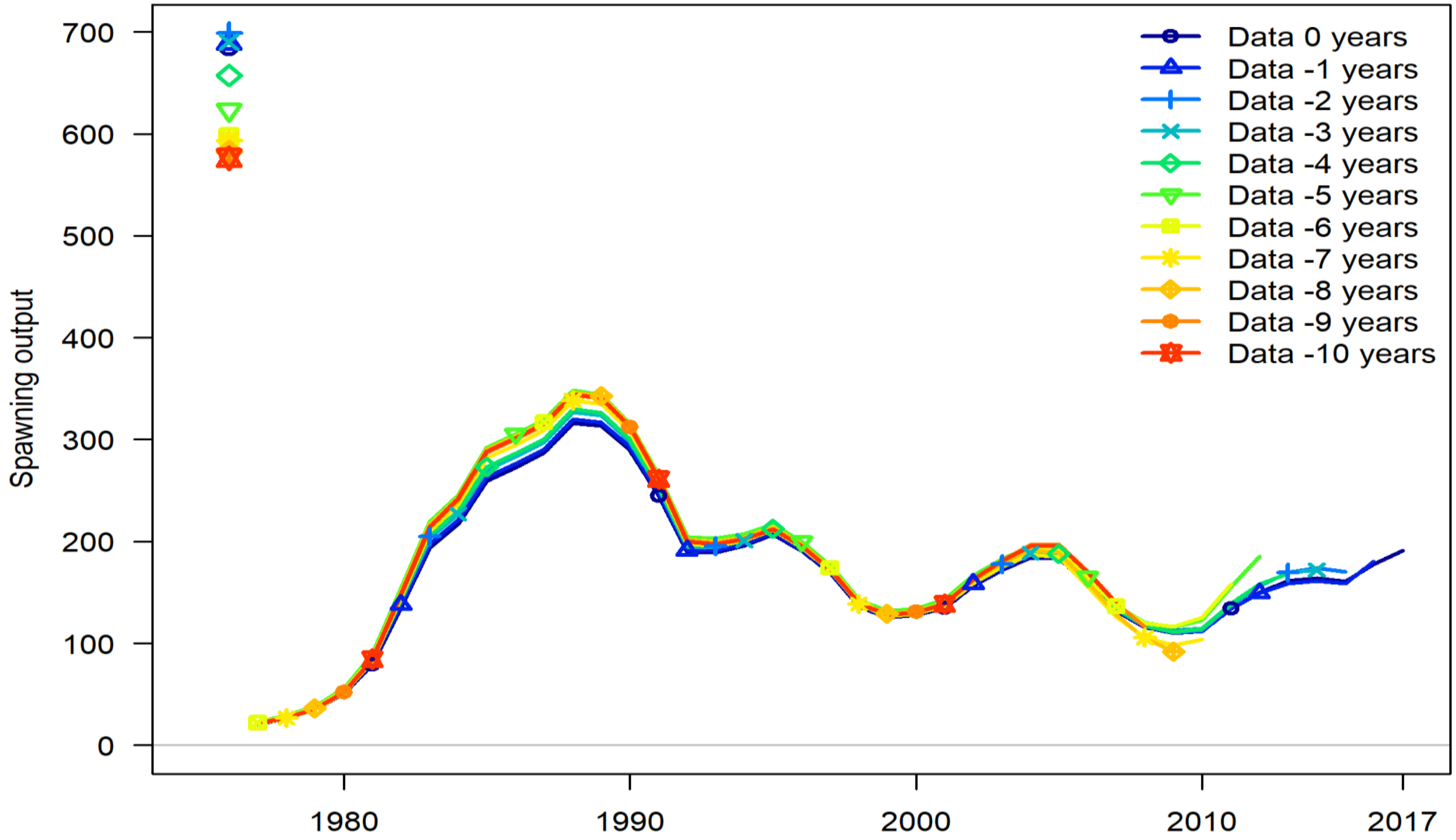
Retrospective: Model 16.6

- Mohn's rho = 0.243



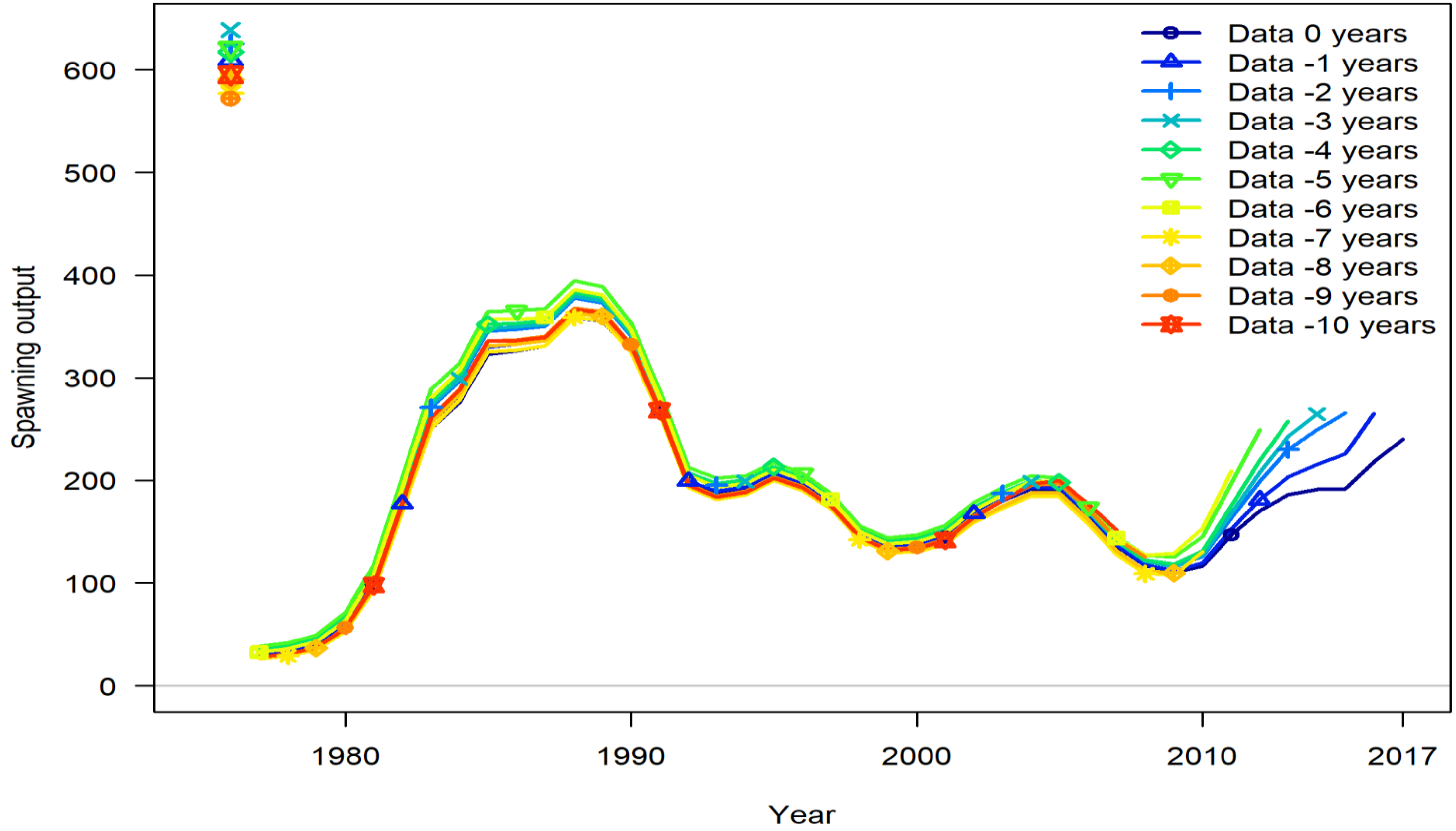
Retrospective: Model 17.1

- Mohn's rho = 0.040



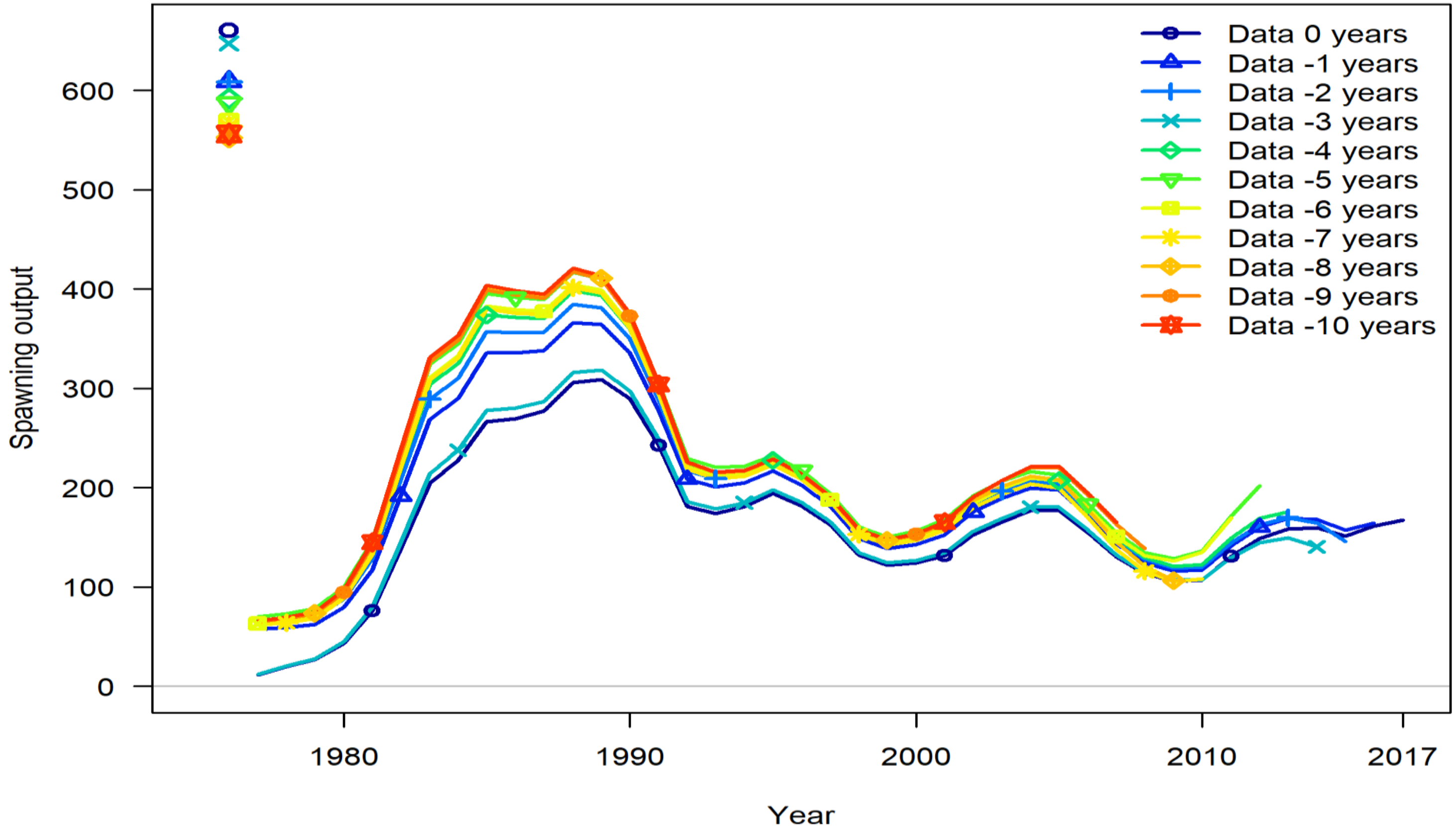
Retrospective: Model 17.2

- Mohn's rho = 0.255



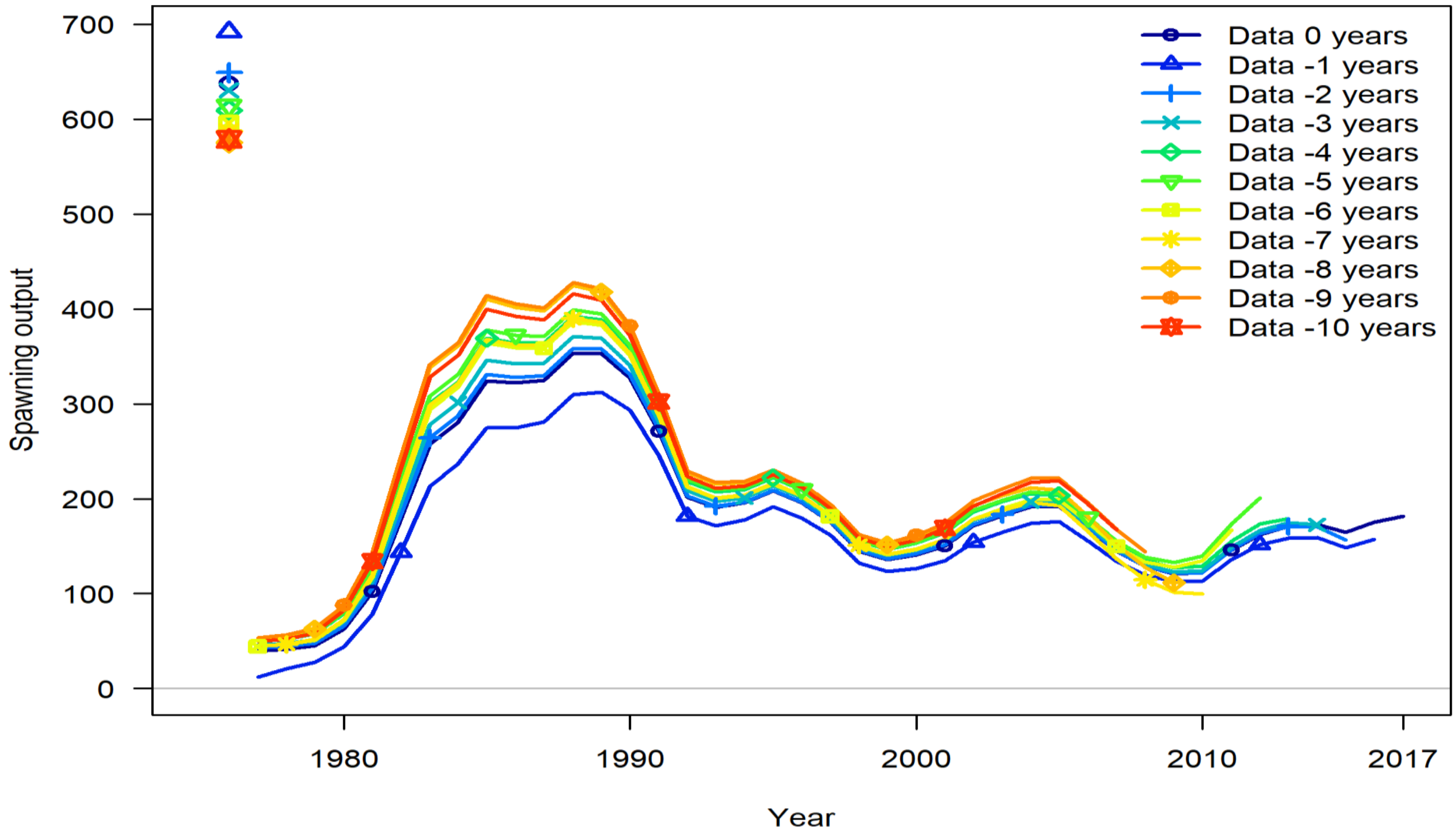
Retrospective: Model 17.3

- Mohn's rho = 0.113



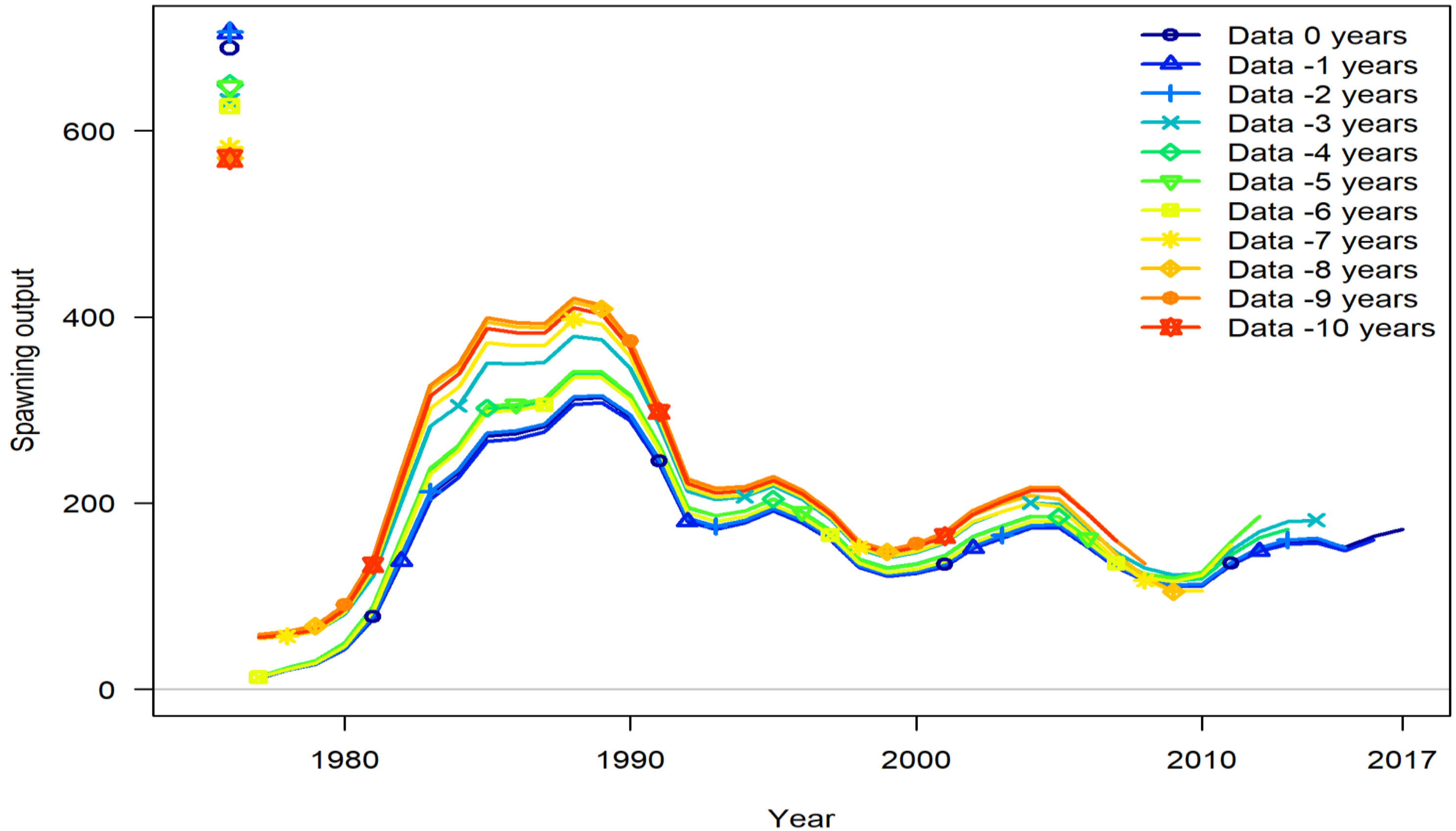
Retrospective: Model 17.6

- Mohn's rho = 0.028



Retrospective: Model 17.7

- Mohn's rho = 0.079



Mohn’s rho summary

- Acceptable range inferred from Hurtado-Ferro et al. (2015)

Model:	16.6	17.1	17.2	17.3	17.6	17.7
ρ:	0.243	0.040	0.255	0.113	0.028	0.079
M:	0.359	0.324	0.385	0.328	0.322	0.317
Min:	-0.206	-0.193	-0.215	-0.195	-0.193	-0.191
Max:	0.279	0.262	0.292	0.264	0.261	0.258

Final model and projections

Model weighting: September method

- Here are the output effective sample sizes again:

Type	Fleet	M16.6	M17.1	M17.2	M17.3	M17.6	M17.7
Sizecomp	Fishery	23,850	74,884	55,964	33,901	34,686	34,425
Sizecomp	Survey	11,086	10,438	10,217	12,428	19,290	18,242
Agecomp	Fishery		3,357	3,375	2,646	3,060	3,363
Agecomp	Survey	1,395	1,670	915	2,054	1,988	1,972
Index	Survey	3,921	3,601	3,247	12,832	12,062	12,145

- "Effective" number of parameters:

Model:	16.6	17.1	17.2	17.3	17.6	17.7
P_effective:	59	56	64	51	83	86

- Effective sample size per effective parameter:

Model:	16.6	17.1	17.2	17.3	17.6	17.7
Arithmetic:	170.56	335.53	230.37	250.44	171.29	163.13
Geometric:	104.51	123.43	88.20	153.49	104.50	101.46
Harmonic:	61.40	69.56	43.08	93.14	60.63	59.89

Model weighting: SSC adjustments (1 of 3)

- Retrospective performance: Adjustment = $\exp(-|\rho|)$

Model:	16.6	17.1	17.2	17.3	17.6	17.7
ρ:	0.243	0.040	0.255	0.113	0.028	0.079
Adjustment:	0.784	0.960	0.775	0.893	0.972	0.924

- Model convergence behavior: Adjustment = exp(–RMSE), where RMSE is measured in terms of ending biomass from each "jitter" run relative to ending biomass from best run

Model:	16.6	17.1	17.2	17.3	17.6	17.7
RMSE:	0.000	0.110	0.044	0.067	0.128	0.196
Adjustment:	1.000	0.895	0.957	0.935	0.880	0.822

Model weighting: SSC adjustments (2 of 3)

- General plausibility:
  - Adjustment #1 = exp(–max(0,*Finit*–*M*)), because no evidence of intensive fishery prior to 1977
  - Adjustment #2 = exp(–max(0,ln(*Q*))), because field studies do not indicate that *Q*>1 is likely

Model:	16.6	17.1	17.2	17.3	17.6	17.7
Finit :	0.180	1.029	0.470	1.632	1.674	1.697
M :	0.359	0.324	0.385	0.328	0.322	0.317
Adjustment:	1.000	0.494	0.918	0.271	0.259	0.252
ln(*Q*):	-0.074	0.177	0.023	0.196	0.169	0.193
Adjustment:	1.000	0.838	0.978	0.822	0.844	0.824
Total adj.:	1.000	0.414	0.897	0.223	0.218	0.207

Model weighting: SSC adjustments (3 of 3)

- Values of SSC adjustment factors:

Model:	16.6	17.1	17.2	17.3	17.6	17.7
Retrospective:	0.784	0.960	0.775	0.893	0.972	0.924
Convergence:	1.000	0.895	0.957	0.935	0.880	0.822
Plausibility:	1.000	0.414	0.897	0.223	0.218	0.207

- Final model weights (obtained by multiplying weights from September method by SSC adjustments, then rescaling):

Model:	16.6	17.1	17.2	17.3	17.6	17.7
Arithmetic:	0.2619	0.2337	0.3001	0.0914	0.0626	0.0503
Geometric:	0.3296	0.1766	0.2360	0.1150	0.0785	0.0642
Harmonic:	0.3447	0.1772	0.2052	0.1243	0.0811	0.0675

Qualitative considerations

- Does the given model address shortcomings that have been identified by the Team or SSC?
- Is the reduction in the maximum permissible ABC resulting from the given model roughly commensurate with the change in survey biomass observed between 2016 and 2017?
- Given that the cause of the decline in EBS survey biomass is unknown, but that one plausible hypothesis is that a substantial portion of the biomass simply moved to the NBS survey area while remaining part of the same spawning population as the fish in the EBS survey area, does the given model impose drastic reductions in ABC that have a significant probability of later being shown to have been unnecessary?

Choice of final model (1 of 4)

- Model weighting: The "best" model depends on whether the arithmetic, geometric, or harmonic mean of the model-specific output effective sample sizes values is chosen
  - If the arithmetic mean is chosen, then Model 17.2 is the best model by this criterion (with Model 16.6 as the second best model)
  - If either the geometric or harmonic mean is chosen, then Model 16.6 is the best model by this criterion (with Model 17.2 as the second best model)

Choice of final model (2 of 4)

- Inclusion of improvements: All of the models in the 17.x series address shortcomings that the Team or SSC has identified:
  - Team has recommended allowing time-varying fishery selectivity (comment BPT5)
  - SSC has recommended allowing for time varying selectivity in the survey and/or the fishery (comment SSC9)
  - SSC has recommended switching to haul-based initial sample sizes (comment SSC3)
  - SSC has recommended adoption of a prior distribution for *M* (comment SSC6, see also comment SSC16)
  - SSC has recommended including fishery age data in the model (comment SSC10)

Choice of final model (3 of 4)

- Match the change in ABC to the change in survey biomass:
  - Estimated biomass from the 2017 EBS shelf bottom trawl survey in the standard area was 37% less than in 2016
  - The percentage reductions in ABC for 2018 (relative to 2017) implied by this year's models are shown below:

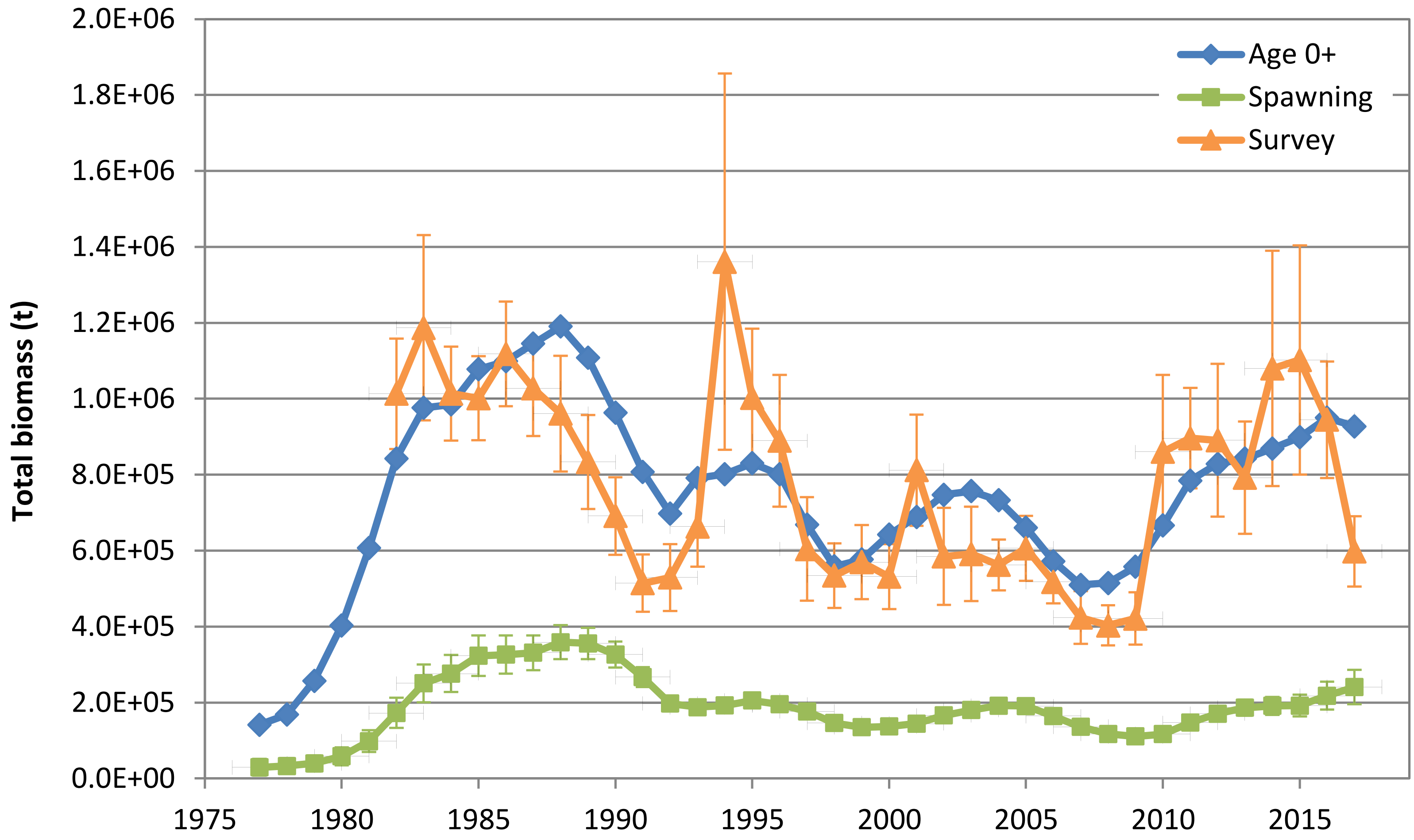
Model:	16.6	17.1	17.2	17.3	17.6	17.7
2018 ABC:	201,000	75,500	172,000	59,100	57,300	57,600
% change:	-16%	-68%	-28%	-75%	-76%	-76%

  - The reduction in ABC from 2017 to 2018 implied by Model 17.2 comes the closest to matching the change in survey biomass from 2016 to 2017

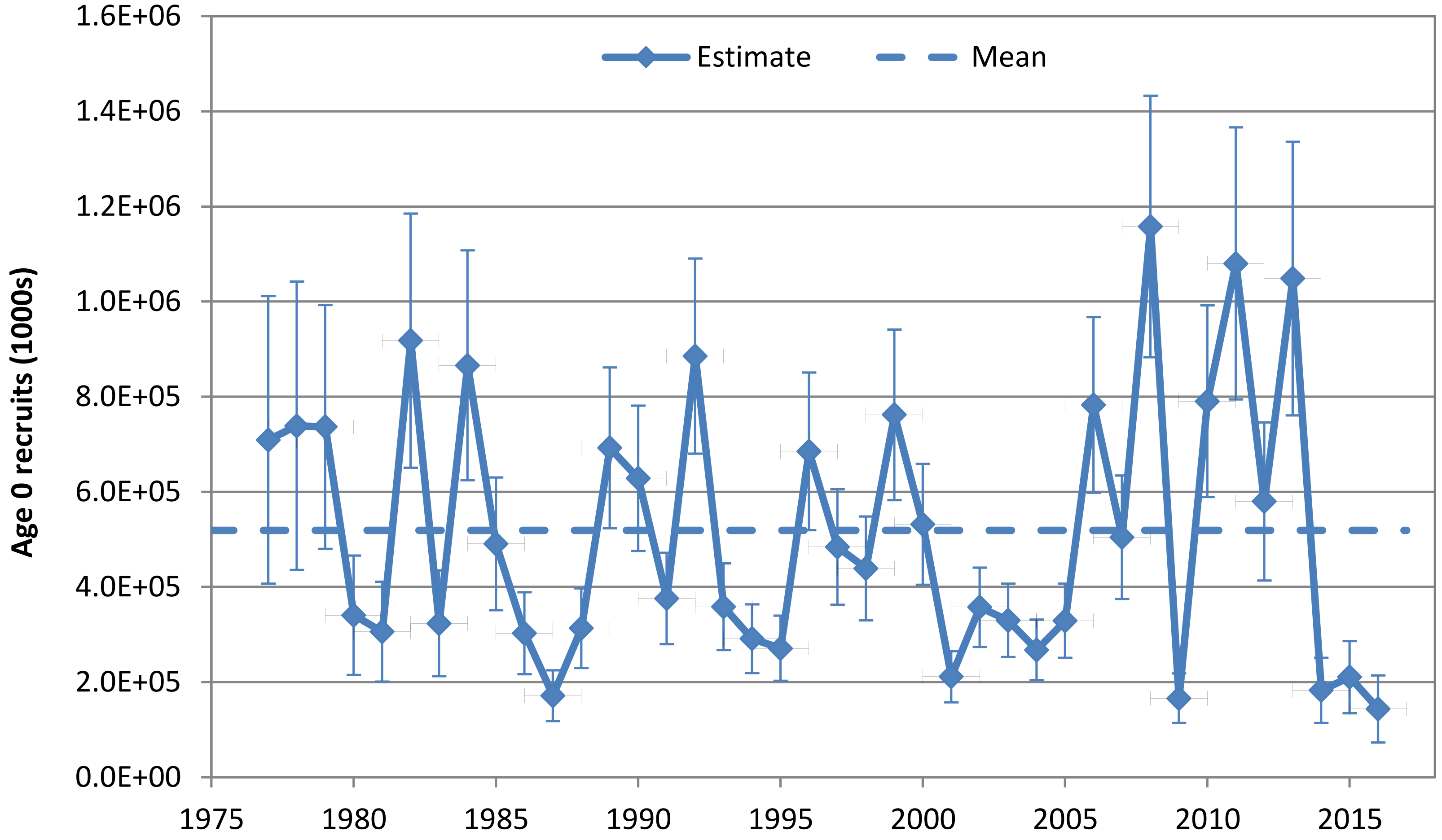
Choice of final model (4 of 4)

- Avoid drastic reductions that may prove unnecessary:
  - Models 16.6 and 17.2 are the only models that would not require drastic cuts in the ABC
  - It is possible, of course, that the other models are more accurate reflections of the true state of the stock, and if subsequent investigations reveal this to be the case, then drastic reductions in future ABCs would appear necessary
- Final choice: Model 17.2

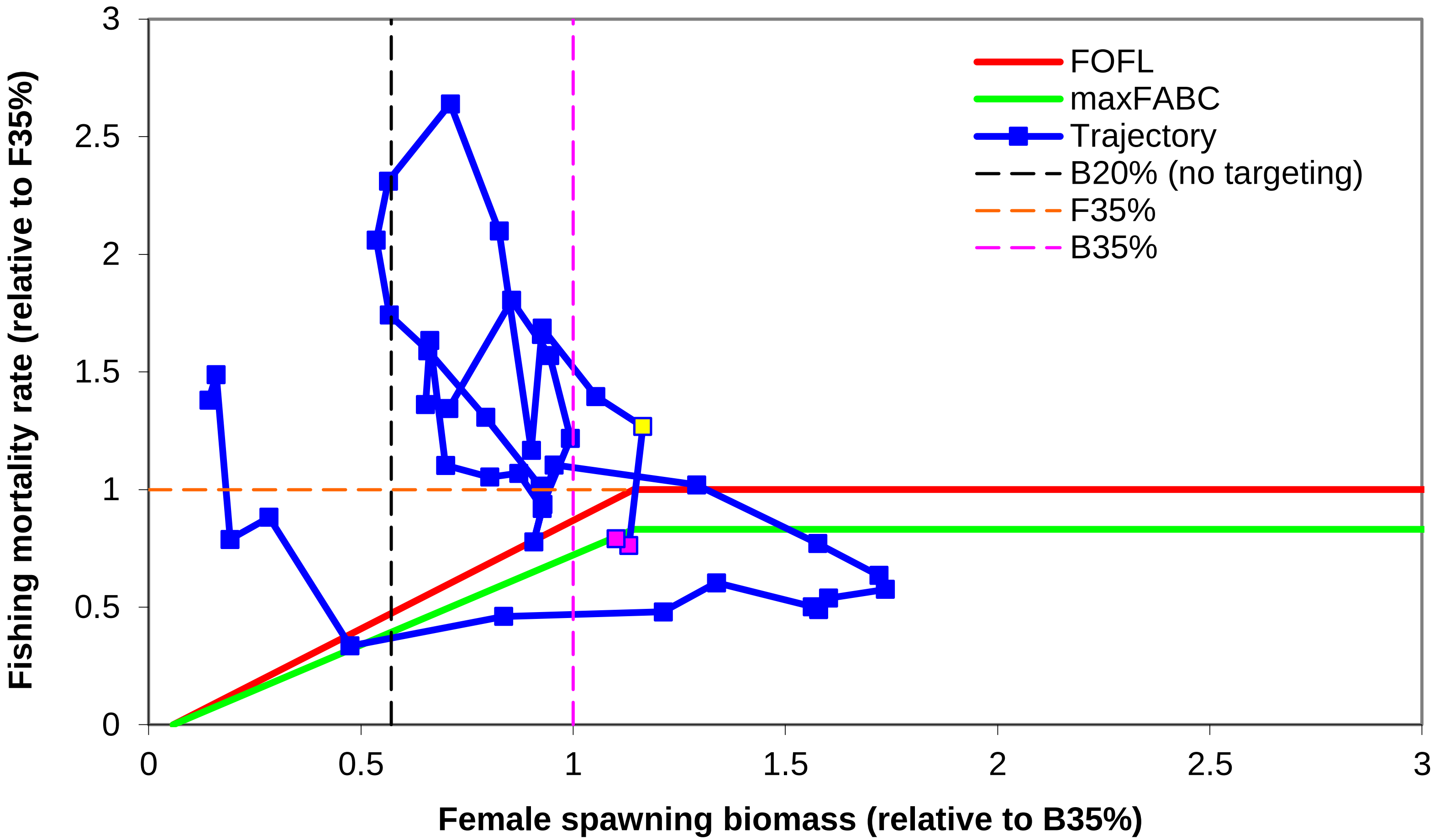
Model 17.2 biomass estimates



Model 17.2 age 0 recruitment estimates



Model 17.2 phase plane



Empirical weight at age considerations (1 of 2)

- Difficulties involved with switching to empirical weight at age:
  - Weight-at-age data exist for only 19 of the 36 years in the survey time series and only 4 of the 41 years in the fishery time series
  - Because the survey takes place during the summer, it is necessary to find a method for determining beginning-of-year weights at age from mid-year weights at age
  - All of the models estimate a positive ageing bias for the younger ages at least, a finding which was recently confirmed by Kastelle et al. (2017) on the basis of stable isotope analysis, meaning that the empirical weights at age are likely biased downward

Empirical weight at age considerations (2 of 2)

- Comparison of empirical and model weights for the fishery
- 79% of aged otoliths come from ages 4-6

Age	2013				2014				2015				2016			
	N	Sample	ALK-int.	M17.2	N	Sample	ALK-int.	M17.2	N	Sample	ALK-int.	M17.2	N	Sample	ALK-int.	M17.2
2	14	0.69	0.81	0.36	11	0.55	0.59	0.34	3	0.62	0.59	0.33	3	0.83	0.84	0.34
3	157	1.50	1.51	1.05	139	1.35	1.38	1.01	69	1.42	1.40	0.98	90	1.41	1.34	1.01
4	115	2.21	2.20	2.04	306	2.32	2.39	2.00	323	2.25	2.23	1.95	196	2.03	2.14	1.99
5	487	3.23	3.27	3.26	186	3.28	3.24	3.22	347	3.19	3.22	3.14	397	3.19	3.21	3.21
6	161	4.40	4.42	4.60	251	4.45	4.40	4.56	128	4.31	4.36	4.47	199	4.46	4.42	4.55
7	42	5.19	5.37	5.97	70	5.39	5.52	5.95	88	5.32	5.41	5.83	52	5.62	5.85	5.94
8	8	6.97	6.57	7.31	21	6.77	6.41	7.32	24	6.11	5.97	7.18	27	6.59	6.37	7.30
9	3	7.60	10.03	8.59	1	6.62		8.62	9	8.71	7.21	8.45				8.59
10				9.76	1	11.00	9.28	9.82				9.64	1	12.06	9.75	9.79
11				10.83				10.92	2	7.82	7.87	10.71				10.88
12	1	10.06	12.78	11.78	1	14.82	12.43	11.89	1	7.76	7.97	11.68				11.85

Time series of weights at age from Model 17.2

Year	1	2	3	4	5	6	7	8	9	10	11	12
1977	0.05	0.38	1.08	2.09	3.33	4.67	6.05	7.40	8.68	9.86	10.92	11.87
1978	0.04	0.35	1.04	2.09	3.38	4.83	6.32	7.79	9.20	10.51	11.69	12.76
1979	0.05	0.40	1.11	2.13	3.37	4.71	6.07	7.40	8.65	9.81	10.85	11.78
1980	0.05	0.37	1.06	2.06	3.27	4.60	5.96	7.29	8.55	9.72	10.77	11.71
1981	0.05	0.38	1.07	2.06	3.25	4.56	5.88	7.18	8.40	9.53	10.55	11.45
1982	0.06	0.41	1.14	2.18	3.43	4.77	6.14	7.47	8.72	9.86	10.90	11.82
1983	0.05	0.39	1.12	2.18	3.46	4.86	6.30	7.70	9.02	10.24	11.35	12.33
1984	0.07	0.43	1.13	2.07	3.15	4.30	5.45	6.55	7.57	8.50	9.34	10.08
1985	0.05	0.38	1.10	2.16	3.47	4.90	6.38	7.83	9.20	10.47	11.62	12.65
1986	0.04	0.36	1.07	2.14	3.46	4.93	6.45	7.95	9.38	10.70	11.91	12.99
1987	0.05	0.38	1.10	2.15	3.42	4.82	6.24	7.64	8.97	10.19	11.29	12.28
1988	0.04	0.37	1.10	2.21	3.57	5.09	6.66	8.21	9.69	11.06	12.31	13.43
1989	0.05	0.39	1.14	2.25	3.62	5.13	6.69	8.22	9.68	11.02	12.25	13.34
1990	0.05	0.41	1.16	2.24	3.54	4.95	6.40	7.81	9.14	10.37	11.48	12.47
1991	0.05	0.39	1.10	2.11	3.32	4.63	5.97	7.27	8.49	9.62	10.64	11.55
1992	0.05	0.37	1.04	2.02	3.20	4.49	5.81	7.10	8.31	9.43	10.44	11.35
1993	0.06	0.43	1.19	2.28	3.59	5.00	6.44	7.83	9.15	10.36	11.45	12.43
1994	0.05	0.39	1.09	2.11	3.35	4.69	6.07	7.41	8.68	9.85	10.91	11.86
1995	0.05	0.37	1.07	2.11	3.37	4.76	6.19	7.59	8.91	10.14	11.25	12.25
1996	0.06	0.44	1.17	2.18	3.36	4.62	5.89	7.11	8.25	9.30	10.24	11.07
1997	0.05	0.37	1.05	2.02	3.18	4.44	5.73	6.98	8.16	9.25	10.23	11.11
1998	0.05	0.38	1.05	2.01	3.16	4.41	5.68	6.91	8.07	9.14	10.10	10.96
1999	0.05	0.39	1.09	2.10	3.30	4.60	5.93	7.21	8.43	9.54	10.55	11.45
2000	0.06	0.41	1.15	2.21	3.47	4.85	6.24	7.60	8.88	10.06	11.12	12.07
2001	0.06	0.42	1.14	2.16	3.38	4.68	6.01	7.29	8.49	9.59	10.59	11.47
2002	0.05	0.39	1.11	2.13	3.36	4.69	6.06	7.38	8.63	9.78	10.82	11.75
2003	0.05	0.38	1.07	2.09	3.33	4.69	6.08	7.44	8.73	9.92	10.99	11.95
2004	0.05	0.40	1.11	2.12	3.34	4.65	5.99	7.29	8.51	9.64	10.66	11.56
2005	0.05	0.38	1.09	2.13	3.38	4.75	6.16	7.53	8.83	10.02	11.11	12.08
2006	0.05	0.39	1.10	2.12	3.36	4.70	6.07	7.41	8.67	9.83	10.88	11.82
2007	0.05	0.39	1.11	2.15	3.41	4.79	6.19	7.56	8.86	10.06	11.14	12.10
2008	0.06	0.42	1.14	2.15	3.35	4.65	5.96	7.22	8.41	9.51	10.49	11.36
2009	0.05	0.38	1.08	2.12	3.39	4.78	6.21	7.62	8.94	10.17	11.28	12.28
2010	0.05	0.39	1.09	2.10	3.31	4.63	5.98	7.29	8.53	9.67	10.70	11.62
2011	0.05	0.38	1.06	2.06	3.25	4.56	5.89	7.18	8.41	9.54	10.56	11.47
2012	0.05	0.39	1.08	2.06	3.22	4.47	5.74	6.97	8.13	9.20	10.16	11.01
2013	0.05	0.36	1.05	2.04	3.26	4.60	5.97	7.31	8.59	9.76	10.83	11.78
2014	0.04	0.34	1.01	2.00	3.22	4.56	5.95	7.32	8.62	9.82	10.92	11.89
2015	0.04	0.33	0.98	1.95	3.14	4.47	5.83	7.18	8.45	9.64	10.71	11.68
2016	0.04	0.34	1.01	1.99	3.21	4.55	5.94	7.30	8.59	9.79	10.88	11.85
2017	0.05	0.38	1.08	2.09	3.33	4.67	6.05	7.40	8.68	9.86	10.92	11.87

Model averaging

Stock Synthesis versus “Proj”

- Assessment authors are required to use the AFSC’s standard projection model (Proj) to do projections
- Therefore, projected ABCs and OFLs in the main text use Proj
- The only uncertainty used in Proj is uncertainty in future recruitment, which does not manifest itself significantly for the first couple of years or so
- However, the SSC wants model averaging to include the full uncertainty associated with each model
- Therefore, projected ABCs and OFLs in Appendix 2.5 are based on SS rather than Proj, meaning that results are slightly different from those shown in the main text

Distributions of 2018-2019 ABC and OFL

- Parameters of normal distributions, obtained from the Hessian approximation (these are the distributions that will be averaged using the weights described previously):

Quantity	Statistic	16.6	17.1	17.2	17.3	17.6	17.7
2018 ABC	Mean	214,025	82,395	185,835	64,324	65,464	65,379
2018 ABC	SD	24,473	15,640	24,532	19,096	16,848	18,520
2018 OFL	Mean	255,042	98,618	221,189	77,116	78,848	78,659
2018 OFL	SD	29,266	18,592	29,228	22,762	20,184	22,170
2019 ABC	Mean	172,137	98,163	151,408	84,652	89,824	90,593
2019 ABC	SD	15,614	12,146	25,754	17,255	15,303	16,887
2019 OFL	Mean	204,853	117,028	180,040	101,027	107,588	108,404
2019 OFL	SD	25,833	20,728	43,394	27,967	24,754	27,223

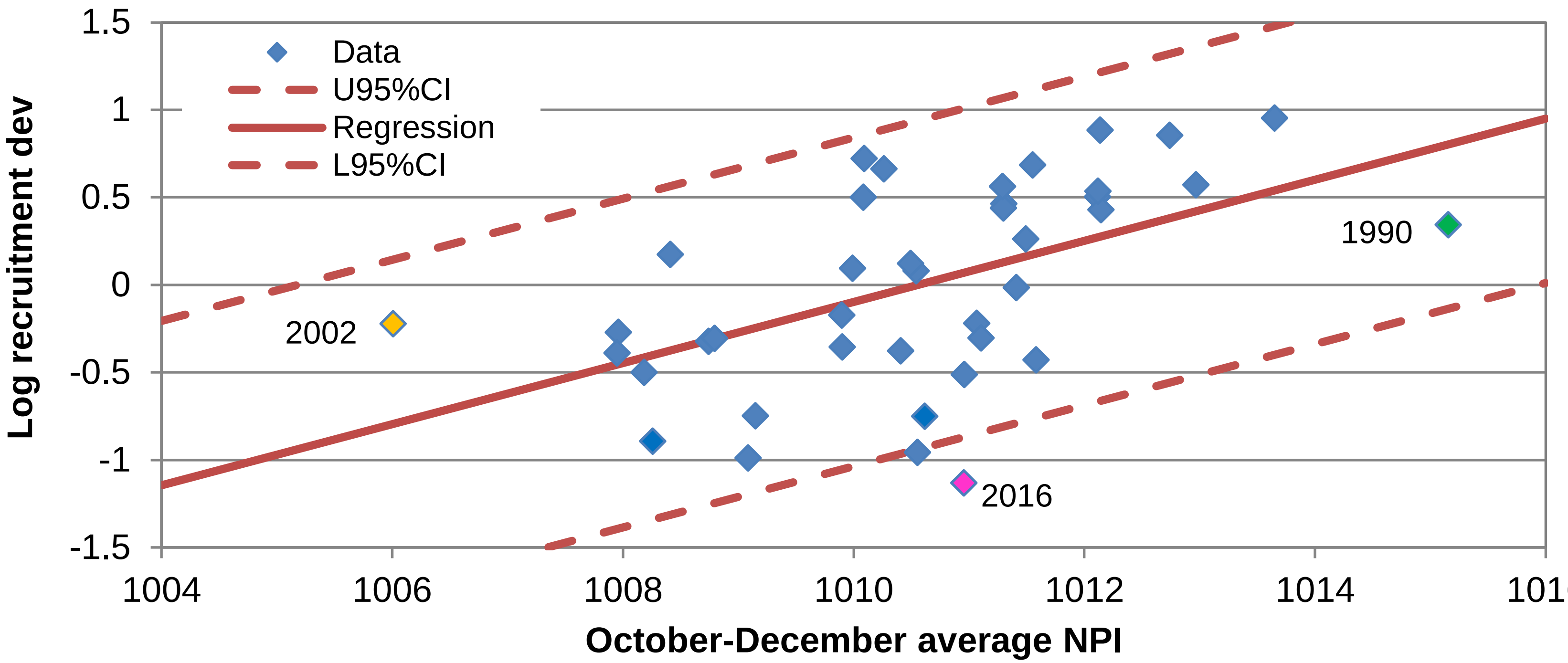
Alternatives

- Full factorial design of alternative model-averaged values:
  - Weighting approach: Include equal weighting approach along with the three sets of final weights listed above
  - Models to include: Because comment SSC19 suggests that the models to be averaged will be determined in December, include every possible non-empty subset
  - Measure of central tendency: Because the Joint Teams' response to comment SSC25 (regarding preferred measure of central tendency) was unknown when the assessment was prepared, include both the mean and median
- 4 weighting approaches x 63 possible subsets x 2 central tendencies = 504 alternatives included in Tables 2.5.2-2.5.5

Ecosystem considerations

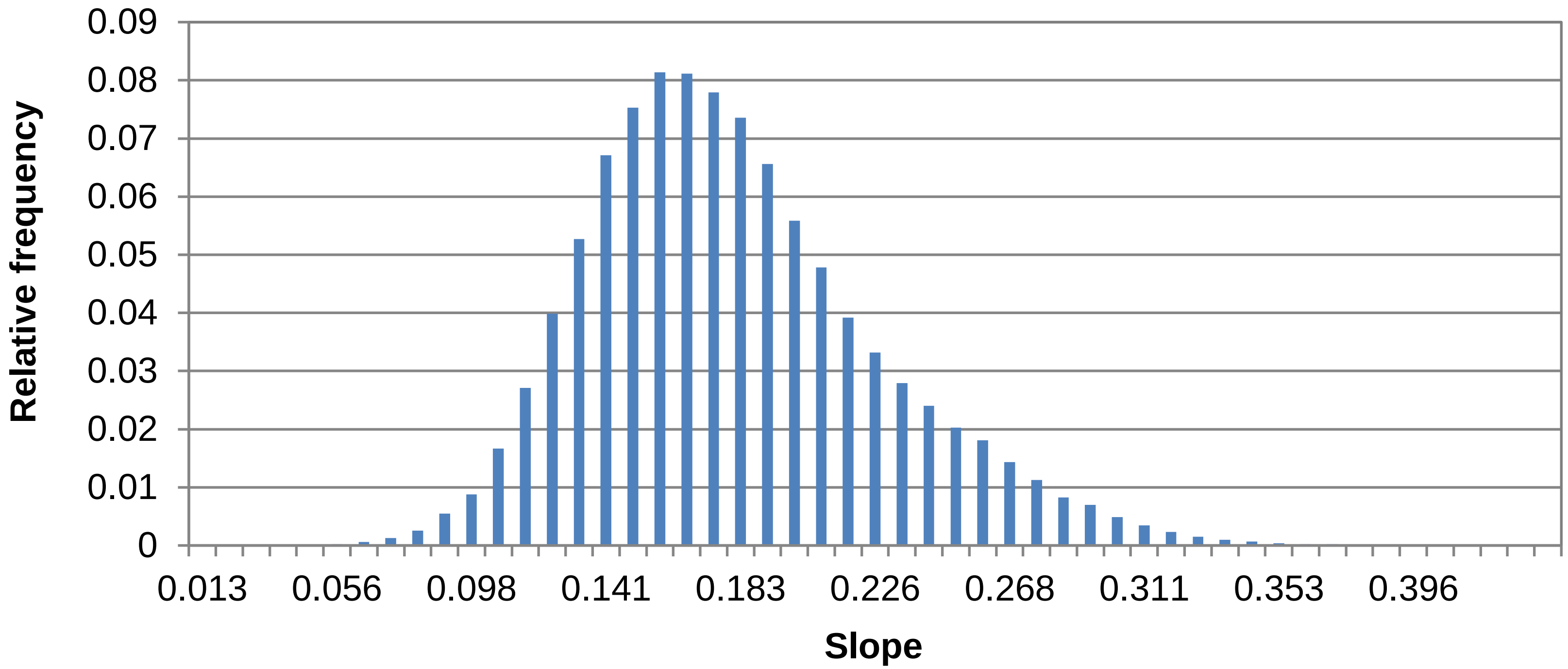
An environmental predictor of recruitment

- Recruitment varies directly with Oct-Dec average NPI
- Correlation = 0.53, R^2 = 0.28



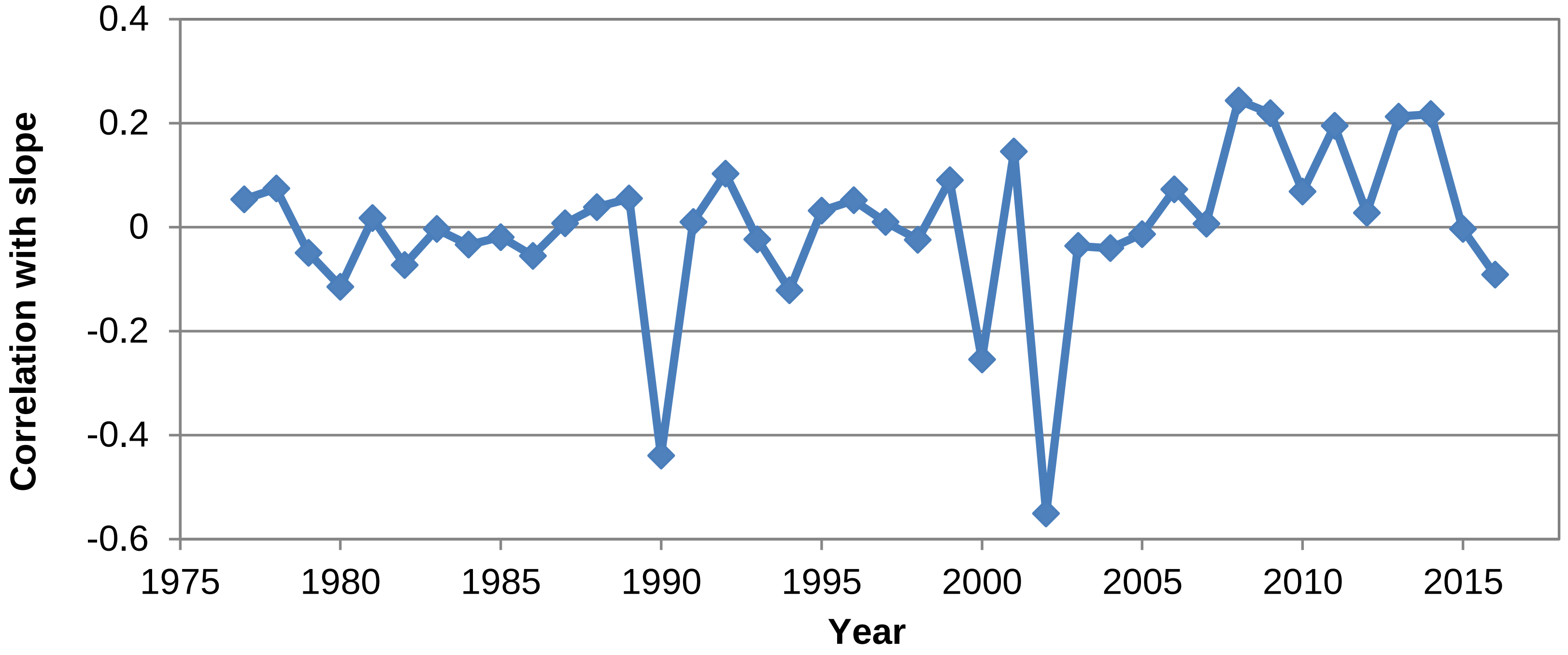
Cross validation (50% random samples)

- RMSE from *test* sets: 0.59 without NPI, 0.52 with NPI
- Distribution of slope estimates from *training* sets



Impact of individual years on slope estimate

- 1990 and 2002 have strongest impact on slope, and both of those are in the negative direction



Final recommendations

Executive Summary table

Quantity	As estimated or *specified last* year for: 2017	2018	As estimated or *recommended this* year for: 2018*	2019*
M (natural mortality rate)	0.36	0.36	0.38	0.38
Tier	3a	3a	3b	3b
Projected total (age 0+) biomass (t)	1,260,000	1,110,000	807,000	690,000
Projected female spawning biomass (t)	327,000	340,000	217,000	211,000
$B_{100\%}$	620,000	620,000	548,000	548,000
$B_{40\%}$	248,000	248,000	219,000	219,000
$B_{35\%}$	217,000	217,000	192,000	192,000
F_{OFL}	0.38	0.38	0.38	0.37
$maxF_{ABC}$	0.31	0.31	0.31	0.3
F_{ABC}	0.31	0.31	0.31	0.3
OFL (t)	284,000	302,000	202,000	173,000
maxABC (t)	239,000	255,000	172,000	148,000
ABC (t)	239,000	255,000	172,000	148,000
Status	As determined *last* year for: 2015	2016	As determined *this* year for: 2016	2017
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No