Assessment of Pacific cod in the eastern Bering Sea

NOAA FISHERIES
Alaska Fisheries Science Center

Grant Thompson and Jim Thorson

December 2, 2019

Team and SSC comments

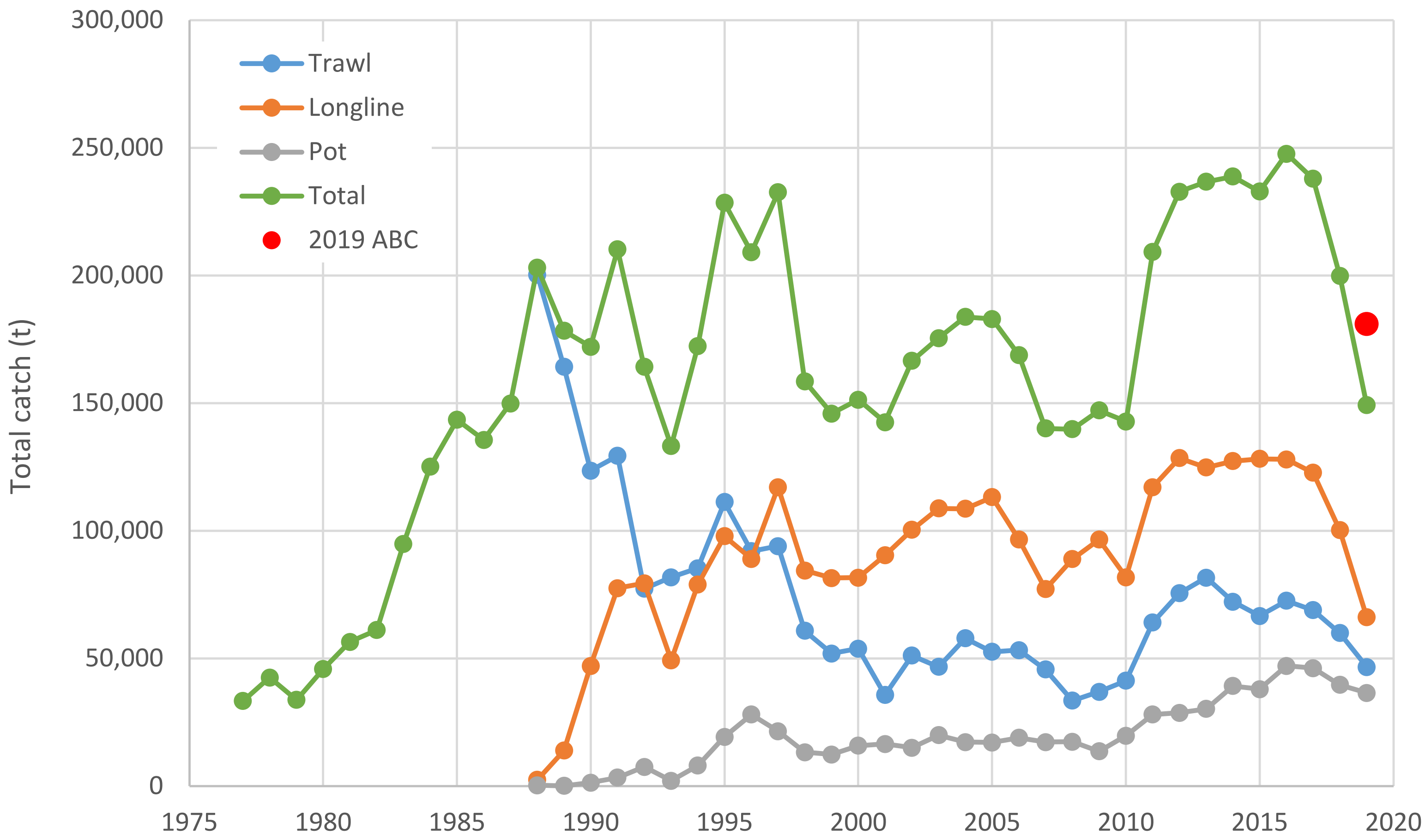
Comments overview (see chapter for details)

- Total of 36 comments this year (4 more than last year)!
  - 18 from Team
    - 10 comments from last year were addressed in preliminary draft
      - Albeit 4 only partially
    - Responses to the partially addressed comments expanded here
    - 8 new Team comments from September
  - 18 from SSC
    - 11 comments from last year were addressed in preliminary draft
      - Albeit 1 only partially
    - Response to the partially addressed comment expanded here
    - 7 new SSC comments from October

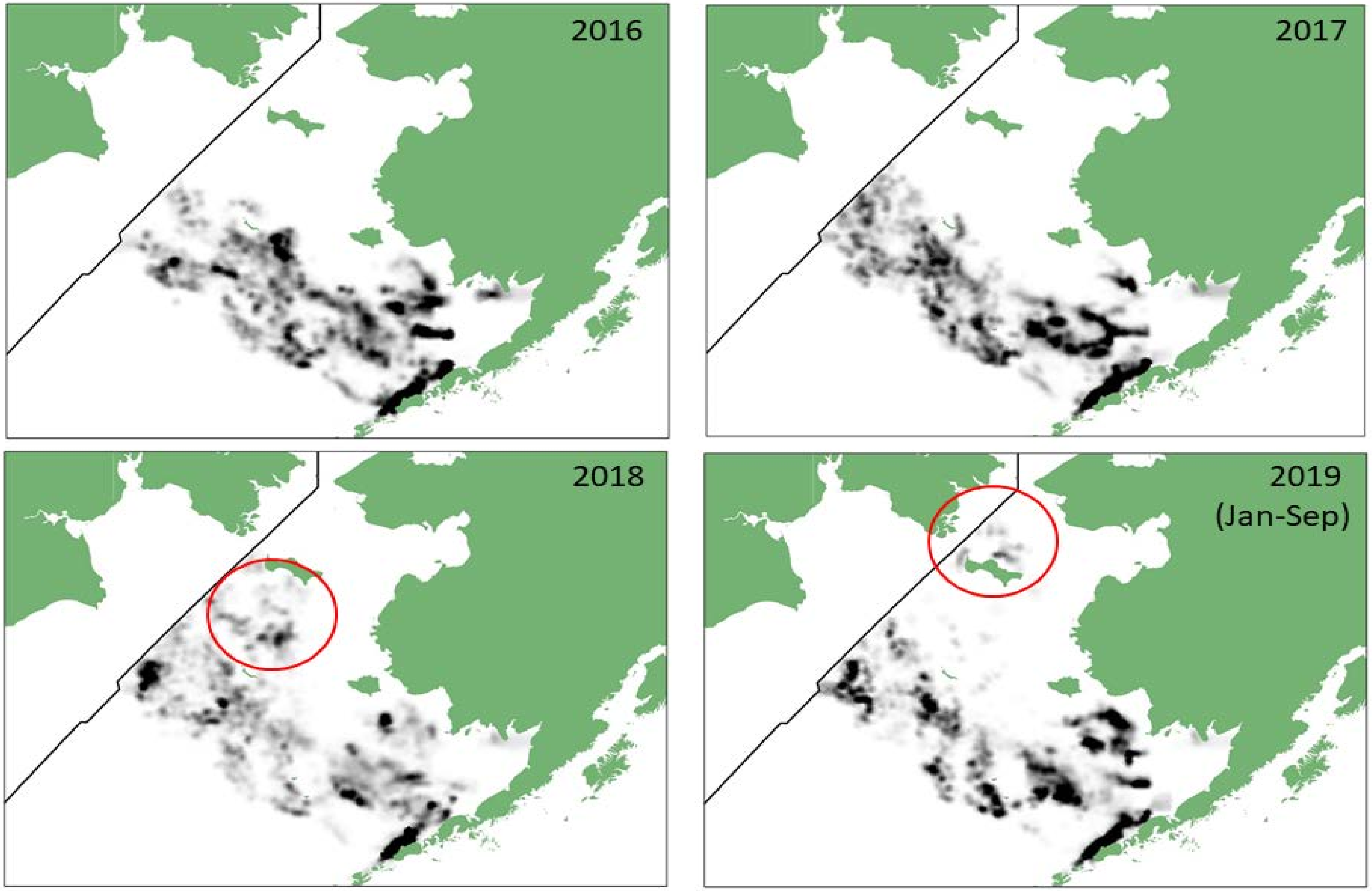
Data highlights

Total catch

- 2019 current through October 27

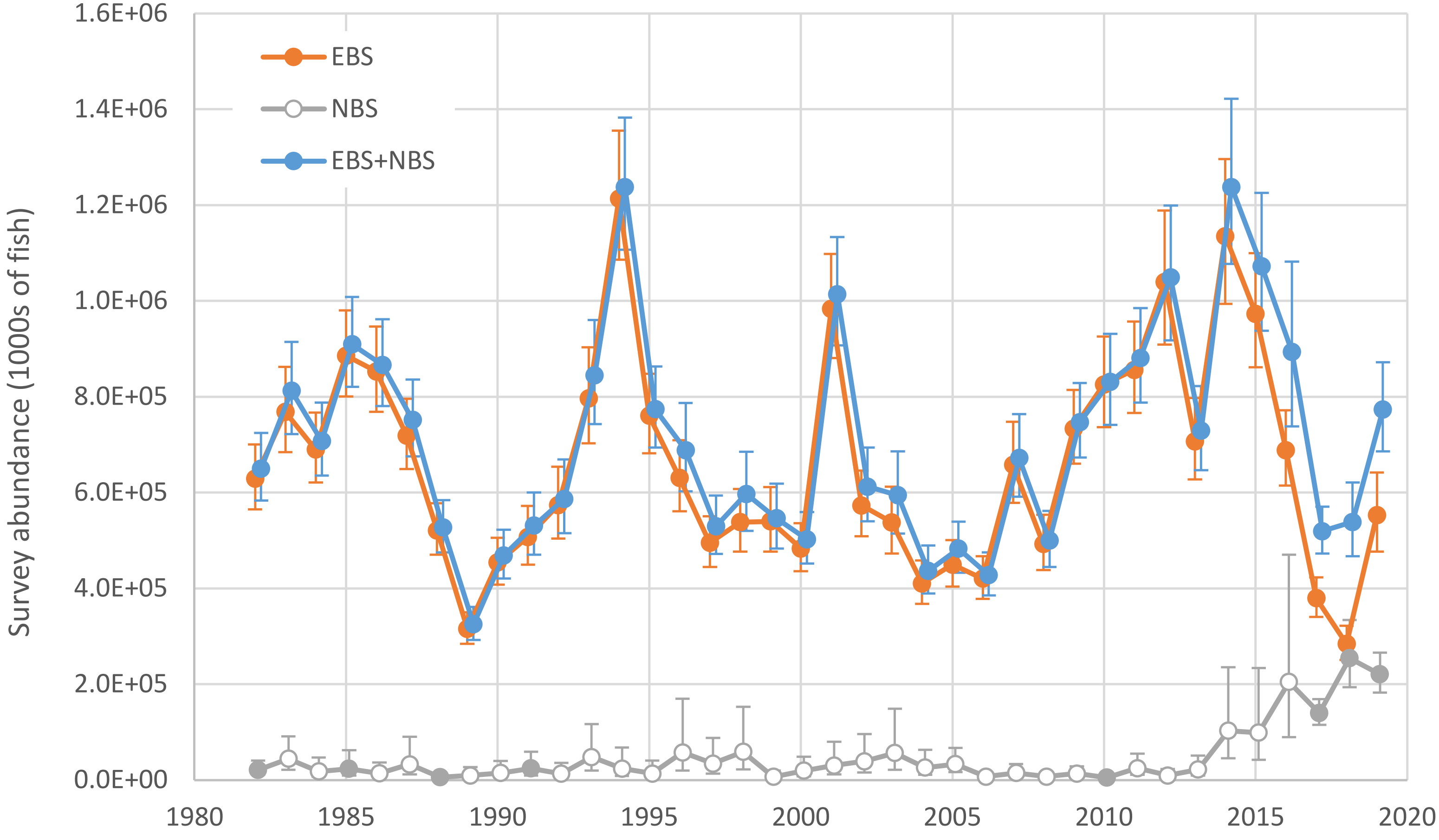


Spatial distribution of observed catch 2016-19

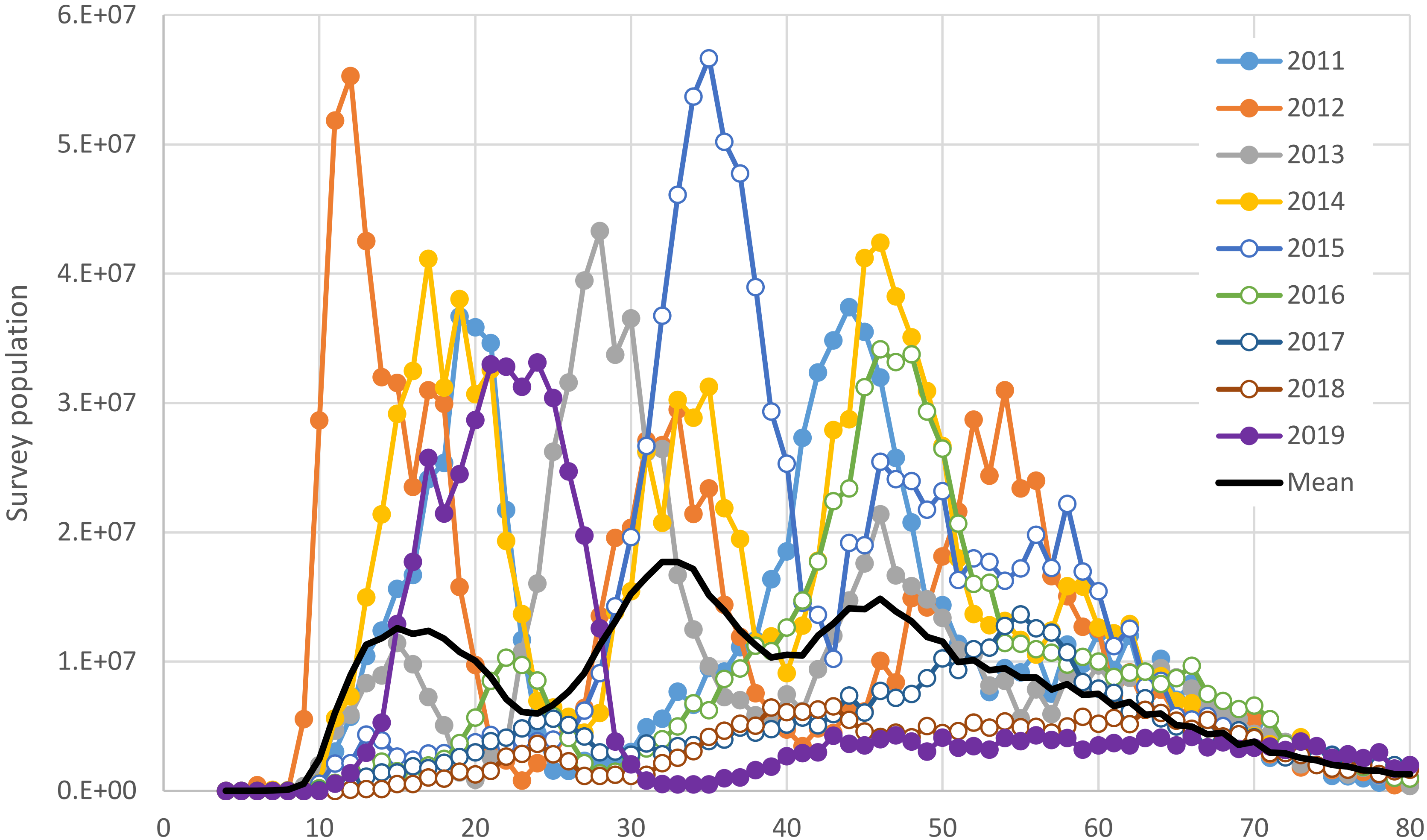


Trawl survey abundance (VAST)

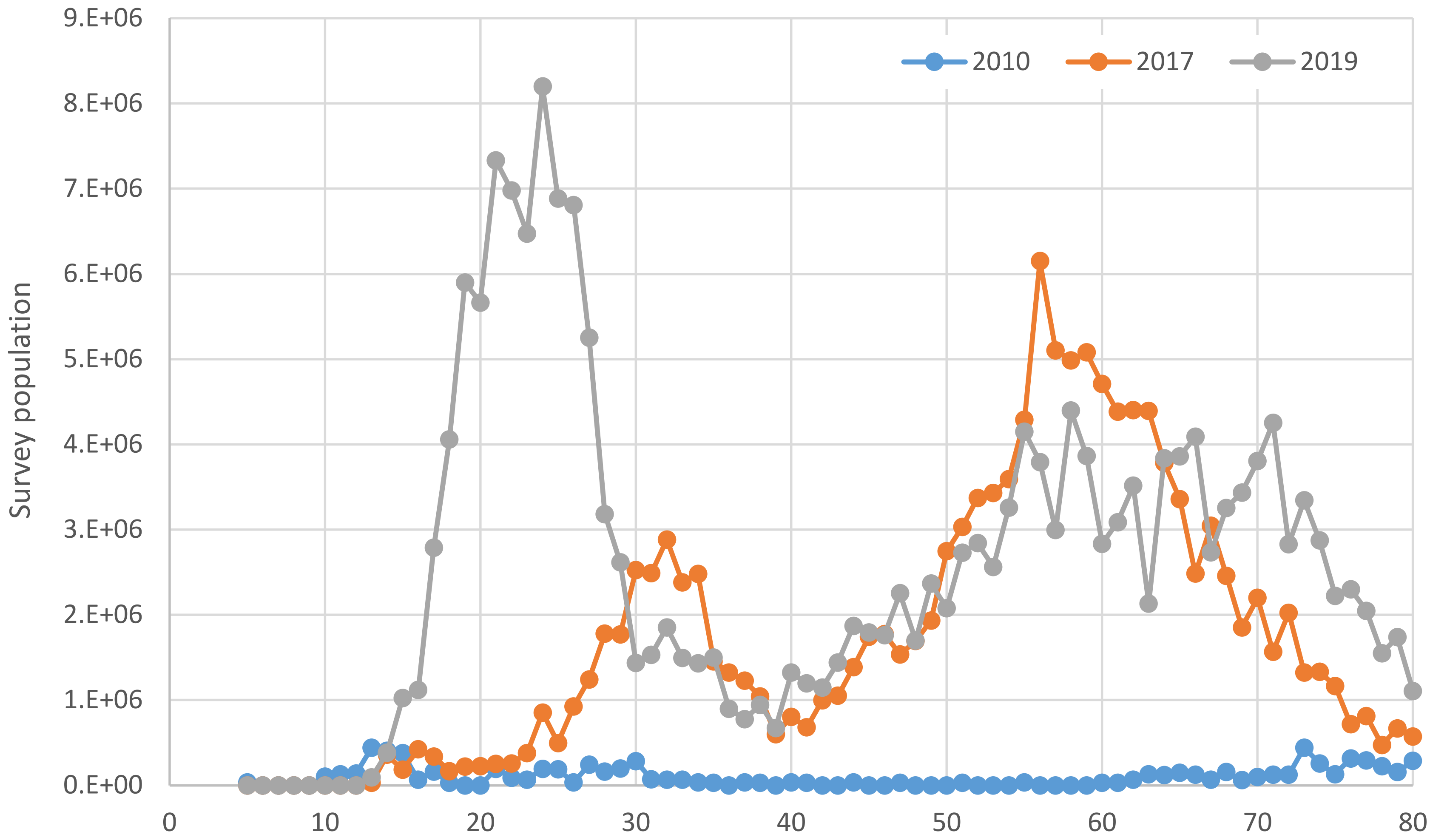
- Cold pool = true, bias correction = true



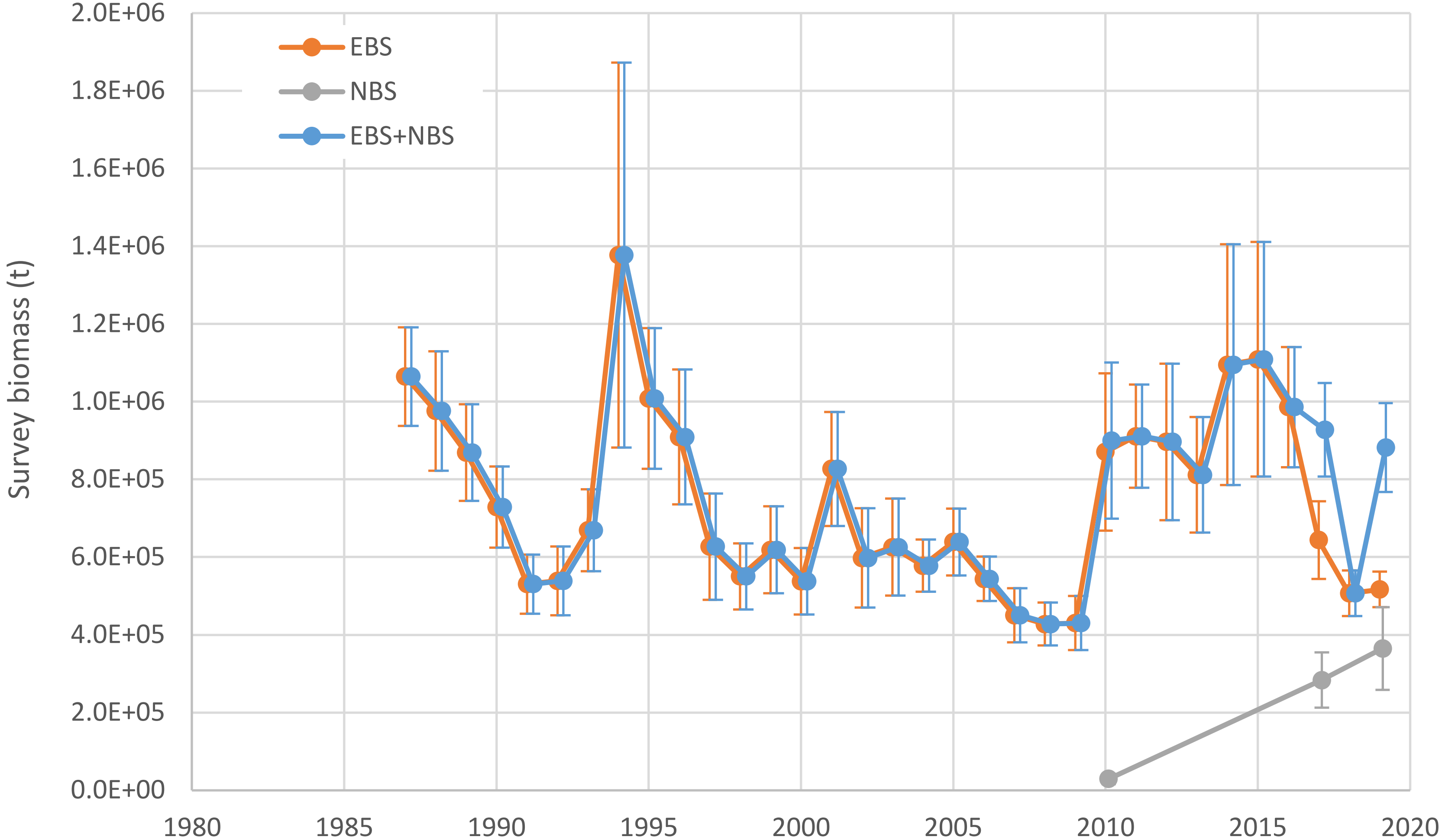
Recent survey sizecomps, to 80 cm (EBS)



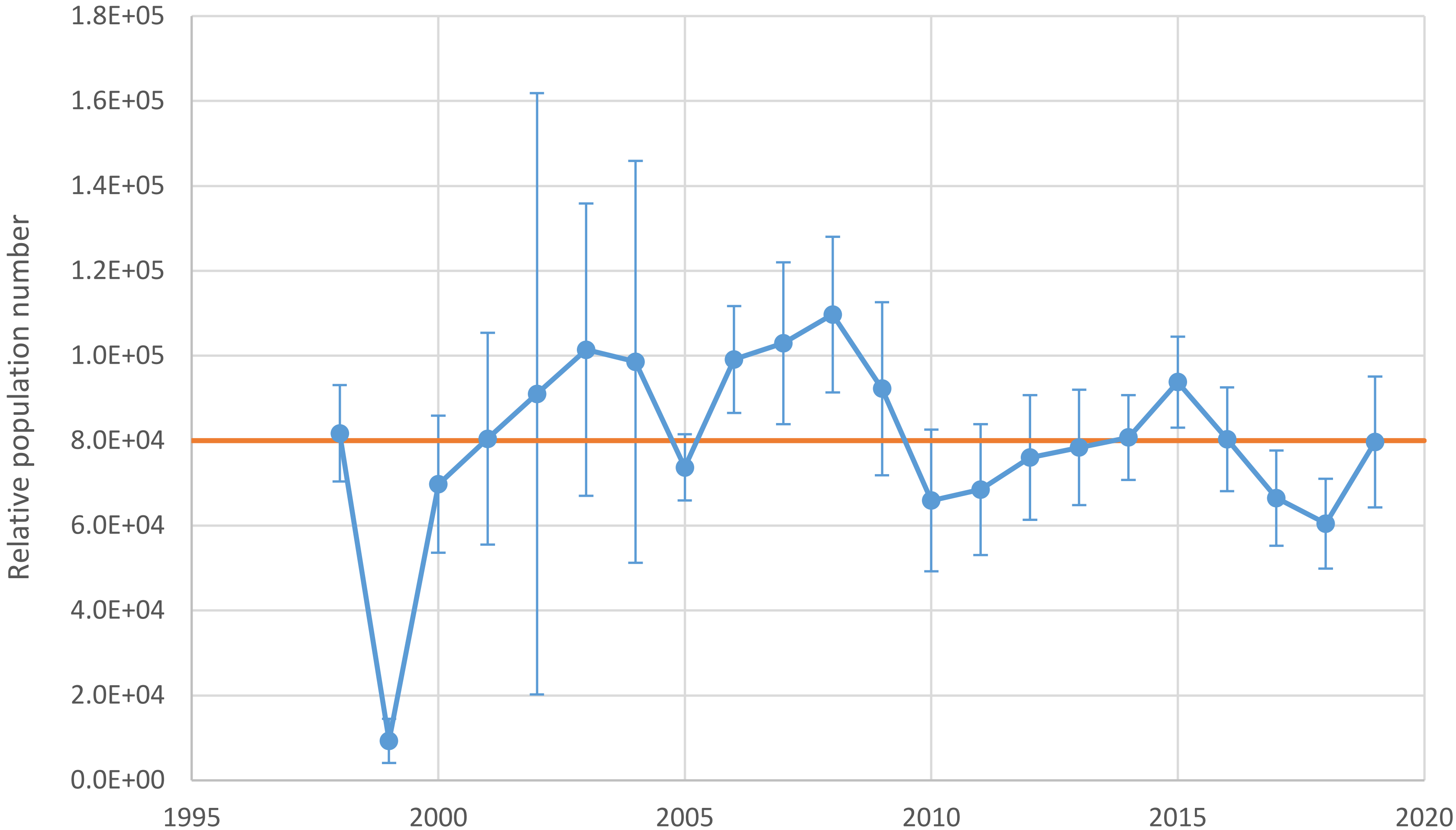
Recent survey sizecomps, to 80 cm (NBS)



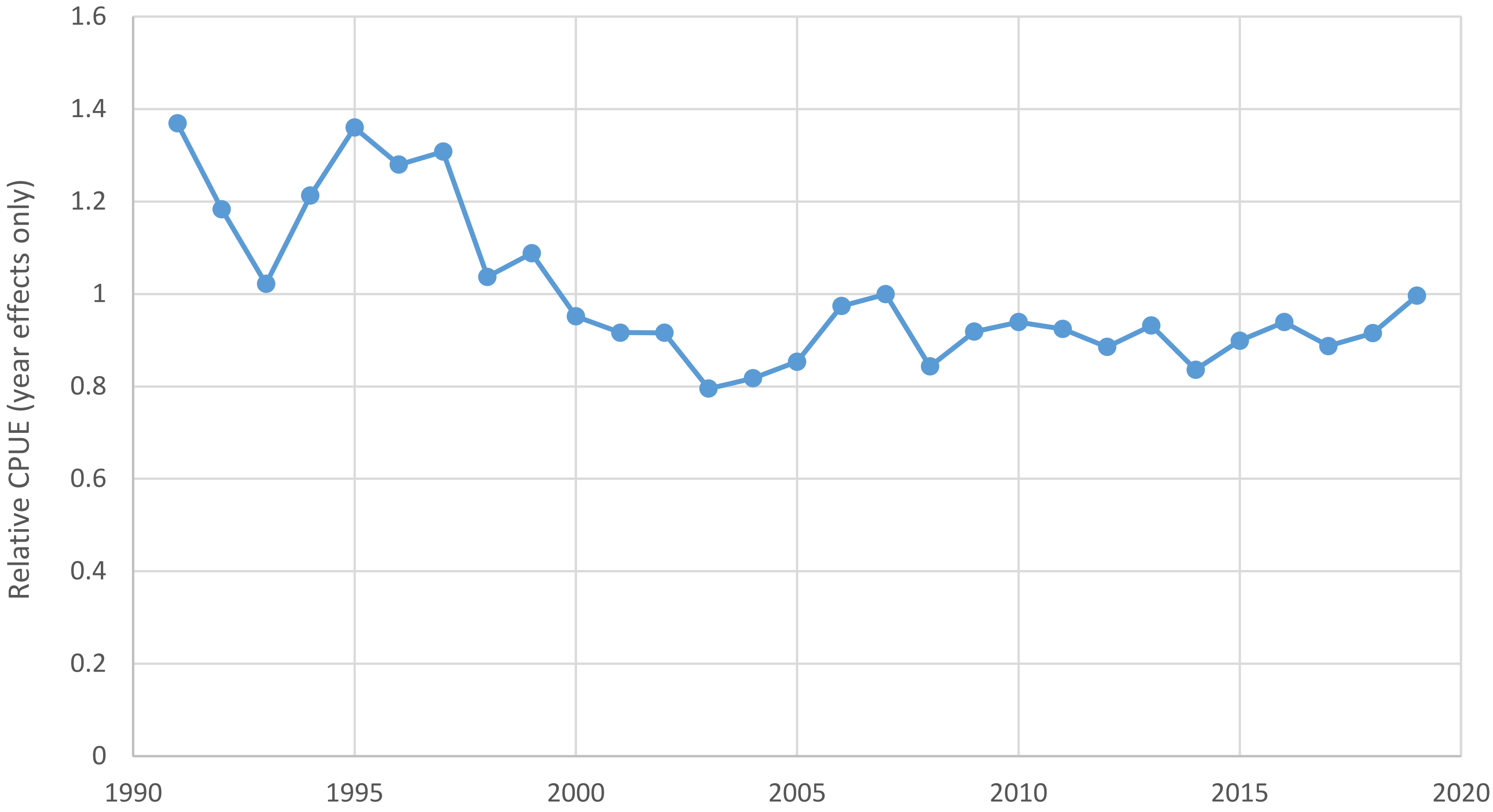
Other indices: survey biomass (design-based)



Other indices: IPHC longline survey



Other indices: longline fishery CPUE



Model structures

Base model

- Model 16.6i was adopted by the SSC last year as the new base model
- Its main structural features are as follow:
  - One fishery, one gear type, one season per year
  - 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 over time except for recruitment and F
  - Internal estimation of all natural mortality, fishing mortality, length-at-age (including ageing bias), recruitment (conditional on Beverton-Holt recruitment steepness fixed at 1.0), catchability, and selectivity parameters
- The only difference between Model 16.6i and Model 16.6 is the inclusion in Model 16.6i of data from the NBS survey, which were incorporated by simple summation with the EBS survey data

Factorial design of new models in Sept/Oct

- Factor 1: the Team's and SSC's three hypotheses
  1. Pacific cod in the NBS are insignificant to the managed stock, so the assessment should include data from the EBS only
  2. Pacific cod in the EBS and NBS comprise a single stock, and the EBS and NBS surveys can be modeled in combination
  3. Pacific cod in the EBS and NBS comprise a single stock, but the EBS and NBS surveys should be modeled separately
- Factor 2: two levels of model complexity (see next 3 slides for details)
  1. "Simple" = modified from first set of changes listed in SSC3
  2. "Complex" = modified from both sets of changes listed in SSC3

Changes from base model in Sept/Oct (1 of 2)

- The first (“Simple”) set of structural changes was as follows:
  - Recalibrate input sample sizes for comp data (hauls, mean=300)
  - Include the available fishery age composition data
  - Use age-based, double-normal selectivity, potentially dome-shaped for the fishery but forced asymptotic for the survey
  - Tune the input standard deviation of log-scale recruitment deviations (σ_R) appropriately
  - Use size-based maturity

Changes from base model in Sept/Oct (2 of 2)

- The second ("Complex") set of structural changes was as follows:
  - Recalibrate input sample sizes for comp data (hauls, raw)
  - Reweight compositional data internally using Dirichlet-multinomial
  - Use size-based double-normal selectivity rather than age-based, still forced asymptotic for the survey
  - Allow ageing bias at ages 1 and 20 to differ pre-2008 and post-2007
  - Allow yearly variation in survey selectivity (two parameters)
  - Allow yearly random variation in survey catchability
  - Allow yearly random variation in fishery selectivity (three parameters)
  - Allow yearly random variation in mean length at age 1.5

Resulting set of models in Sept/Oct

Hypothesis	Structure	Model
2: EBS+NBS	Basic	M16.6i
1: EBS only	Simple	M19.1
	Complex	M19.2
2: EBS and NBS combined	Simple	M19.3
	Complex	M19.4
3: EBS and NBS separated	Simple	M19.5
	Complex	M19.6

- Both the Team and SSC requested that Models 16.6i and 19.1-19.6 be included in this year's final assessment

But then...

- The SSC also requested three other new models (see comment SSC15), bringing the total of requested models to ten
- However, this set of models was rendered problematic by some of the Team and SSC comments from the September 2019 and October 2019 meetings, respectively:
  - SSC asked that the Team strongly consider not carrying forward Hypothesis 1, so M19.1 and M19.2 would be "out"
  - Unlike the Team, the SSC felt that retrospective bias should be among the model evaluation criteria, so M19.2-M19.6 would be "out"
  - Lots of support by both Team and SSC for use of VAST, but only M19.3 and M19.4 used VAST, so developing VAST-based analogues of M19.1, M19.2, M19.5, and M19.6 would bring the total to 14
    - These might well have all the same problems as the originals

A slightly different direction

- Rather than produce a large number of models that would seem to have very little chance of being either adopted or given substantial weight in an ensemble, attention was turned instead to investigating the issue of the large retrospective biases exhibited by M19.2-M19.6
- Results suggested that the retrospective biases of at least some of the new models might be reduced to acceptable levels by making the following changes to the simple and complex models:
  - For both the simple and complex models, eliminate the fishery agecomps that were added as part of the first set of structural changes (no base model since 1992 has included fishery agecomps)
  - For the complex models, reduce the average input N of the *fishery* sizecomps so that it equals the average input N of the *survey* sizecomps (standard practice for all base models since 2007)

Resulting set of models for Nov/Dec

Hypothesis	Structure	Preliminary	Final	Changes (from preliminary to final)
2: EBS+NBS	Basic	M16.6i	M16.6i	none
1: EBS only	Basic	n/a	M19.7	n/a
	Simple	M19.1	M19.8	fishery: no agecomps
	Complex	M19.2	M19.9	fishery: no agecomps, downweighted sizecomps
2: EBS and NBS combined	Basic	n/a	M19.10	n/a
	Simple	M19.3	M19.11	fishery: no agecomps
	Complex	M19.4	M19.12	fishery: no agecomps, downweighted sizecomps
3: EBS and NBS separated	Basic	n/a	M19.13	n/a
	Simple	M19.5	M19.14	fishery: no agecomps
	Complex	M19.6	M19.15	fishery: no agecomps, downweighted sizecomps

- Adopted after consulting with Team/SSC co-chairs and rapporteurs
- Models 19.7-19.15 all use VAST survey estimates; M16.6i does not

Results

Objective function values, parameter counts

Objective function values

Component	M16.6i	M19.7	M19.8	M19.9	M19.10	M19.11	M19.12	M19.13	M19.14	M19.15
Equil. catch	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00
Survey indices	-26.44	43.84	39.26	-88.78	43.14	34.73	-87.65	237.94	201.86	-95.89
Sizecomps	1573.25	1570.48	1451.03	794.33	1582.04	1444.40	814.26	1825.66	1968.74	938.24
Agecomps	278.62	255.80	262.76	227.09	267.66	269.91	251.33	330.75	388.35	268.15
Recruitment	-4.02	-2.11	-1.10	1.52	-2.62	-2.35	-0.41	-2.24	-7.22	-1.87
Initial recruitment	10.40	8.68	3.57	4.76	10.03	4.15	5.36	11.60	5.10	4.91
"Softbounds"	0.01	0.01	0.00	0.01	0.01	0.01	0.02	0.01	0.00	0.02
Parameter devs	n/a	n/a	n/a	99.27	n/a	n/a	97.79	n/a	n/a	121.51
Total	1831.81	1876.70	1755.52	1038.20	1900.26	1750.84	1080.68	2403.73	2556.83	1235.08

Parameter counts

Parameter type	M16.6i	M19.7	M19.8	M19.9	M19.10	M19.11	M19.12	M19.13	M19.14	M19.15
True parameters	18	18	20	24	18	20	24	21	23	29
Parameter devs	62	62	62	305	62	62	305	62	62	343
Total	80	80	82	329	80	82	329	83	85	372

Fit to survey index: RMSSR

EBS+NBS (design-based)

Hypothesis:	2
Model:	M16.6i
RMSSR:	1.789

EBS only (VAST)

Hypothesis:	Hypothesis 1			Hypothesis 3		
Model:	M19.7	M19.8	M19.9	M19.13	M19.14	M19.15
RMSSR:	2.825	2.782	1.000	2.880	2.833	1.001

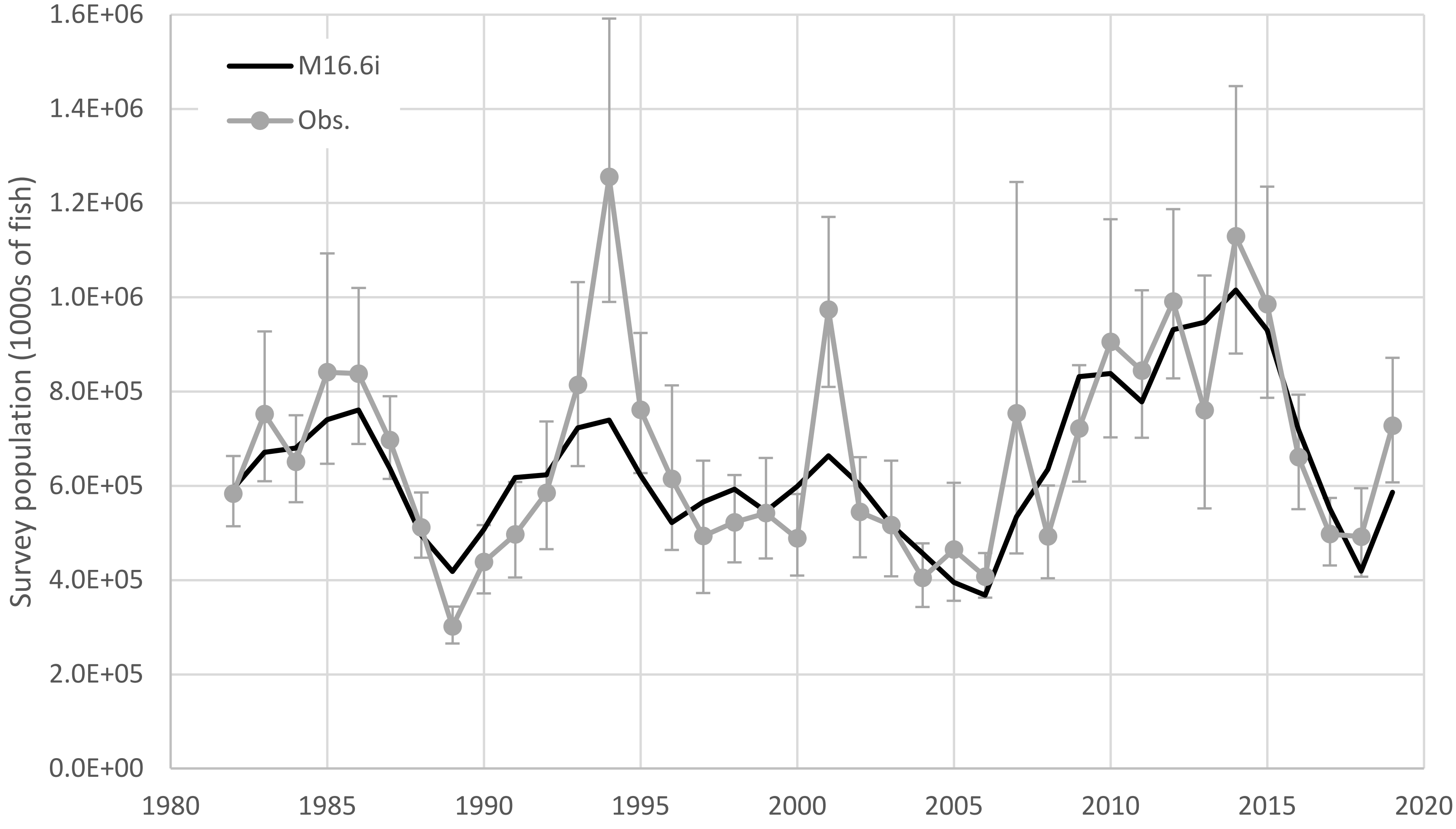
EBS+NBS (VAST)

Hypothesis:	Hypothesis 2		
Model:	M19.10	M19.11	M19.12
RMSSR:	2.808	2.728	1.000

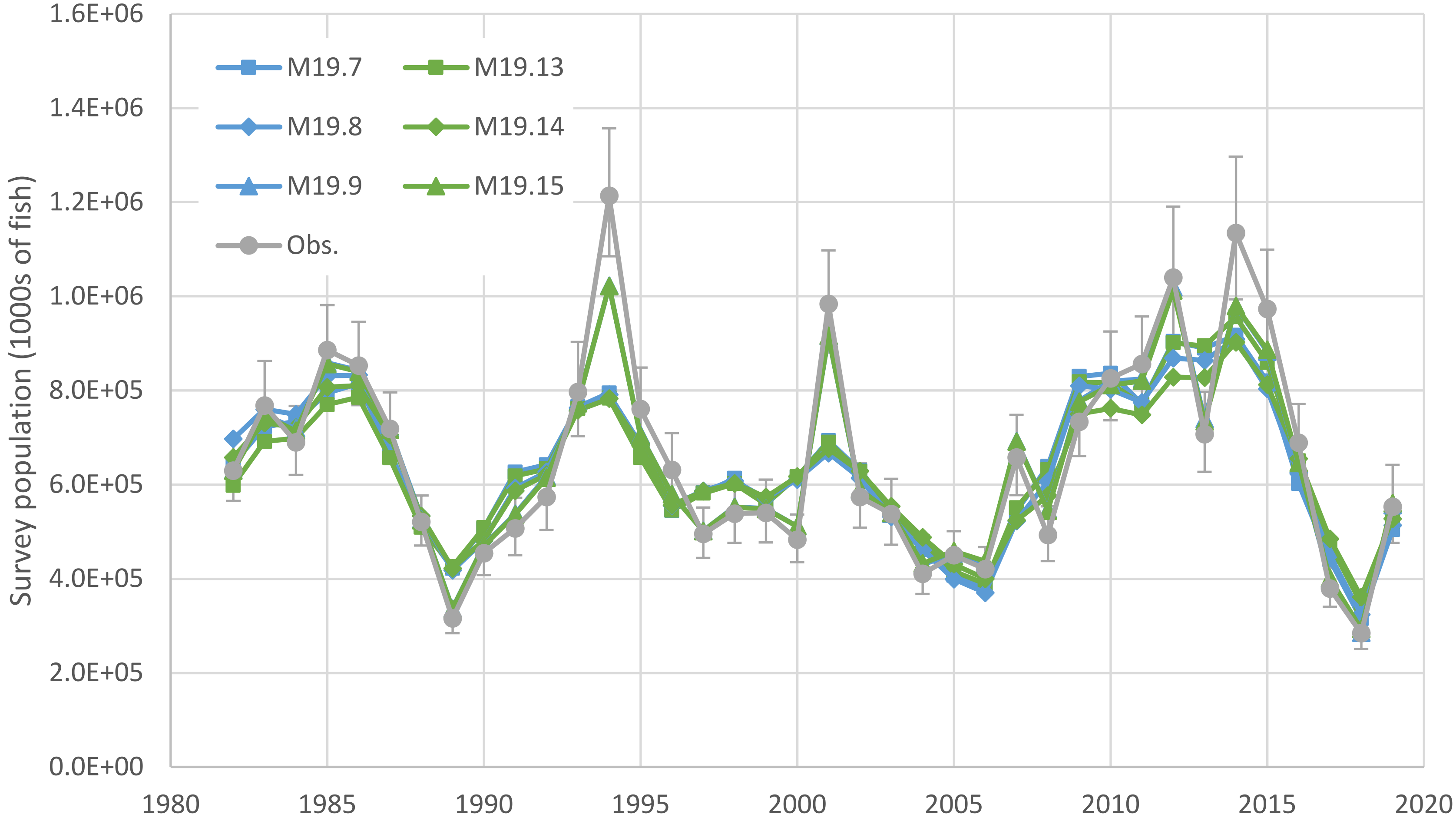
NBS only (VAST)

Hypothesis:	Hypothesis 3		
Model:	M19.13	M19.14	M19.15
RMSSR:	7.059	6.485	1.000

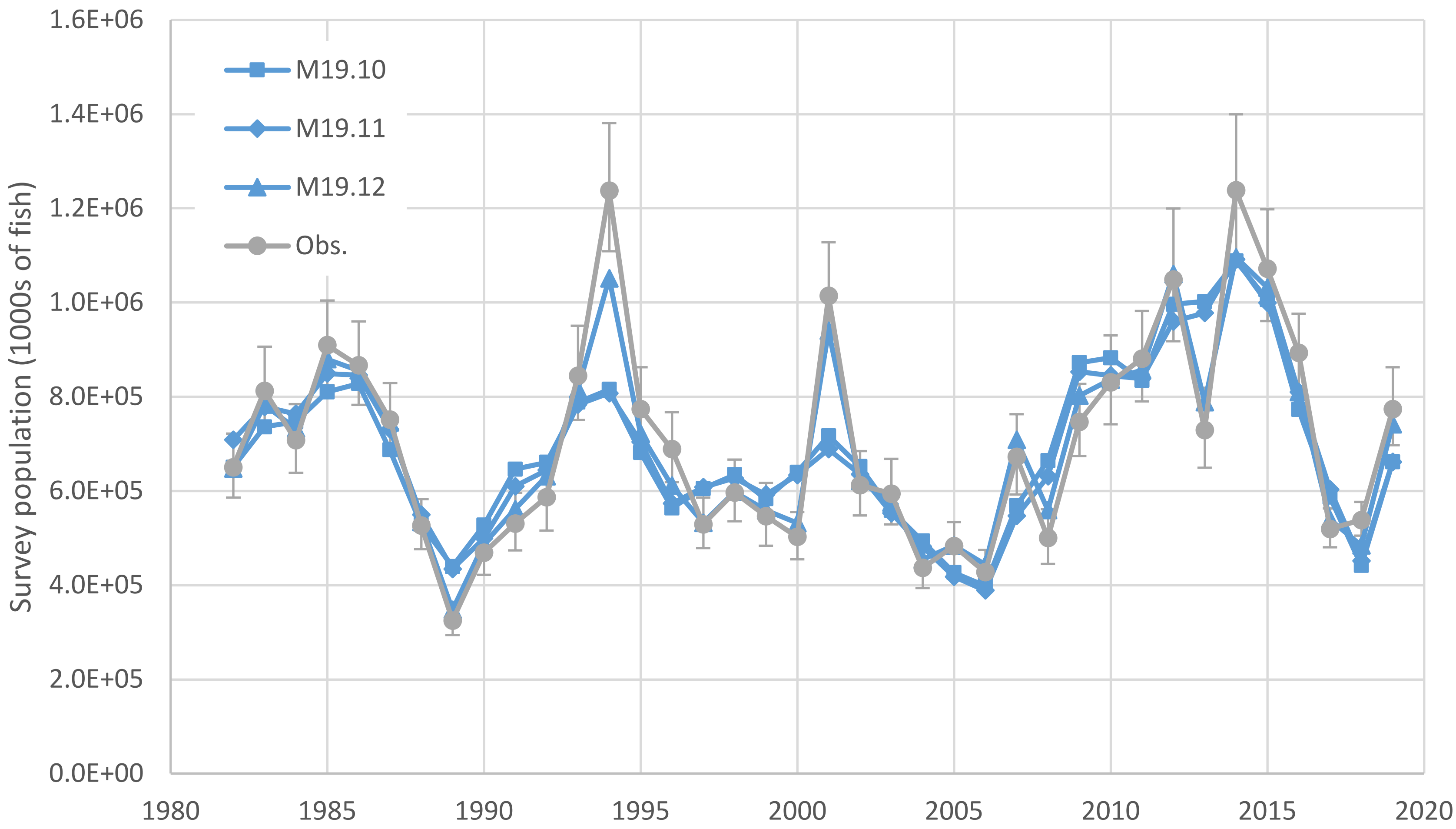
Fit to survey index: EBS+NBS, design-based



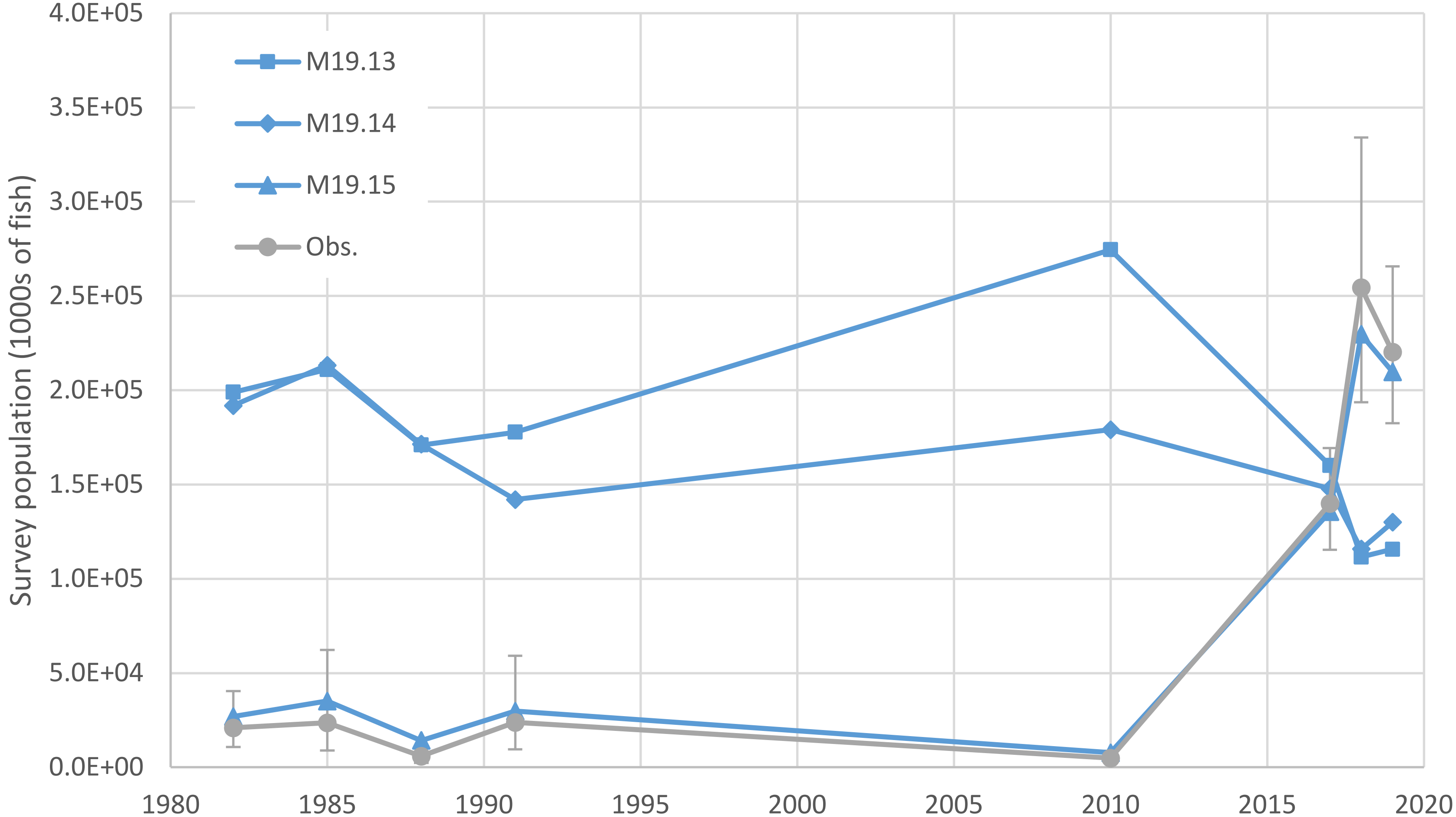
Fit to survey index: EBS only (VAST)



Fit to survey index: EBS+NBS (VAST)



Fit to survey index: NBS (VAST)

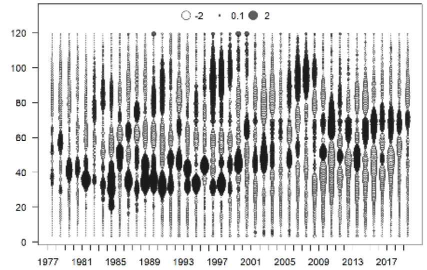


Fit to sizecomps and agecomps: effective *N*

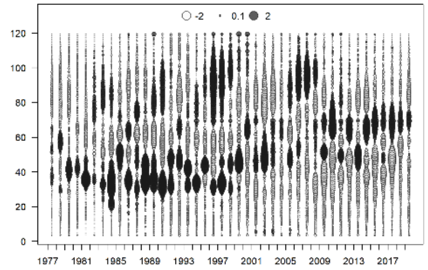
		Size composition data					Age composition data				
			McAllister-Ianelli		Thorson et al.			McAllister-Ianelli		Thorson et al.	
Model	Fleet	Nave	Neff	Ratio	Theta	Neff	Nave	Neff	Ratio	Theta	Neff
M16.6i	Fishery	300	581	1.937							
	EBS survey						300	60	0.199		
	EBS+NBS survey	300	282	0.940							
M19.7	Fishery	300	598	1.993							
	EBS survey	300	273	0.908			300	67	0.223		
M19.8	Fishery	300	626	2.086							
	EBS survey	300	278	0.927			300	71	0.236		
M19.9	Fishery	347	812	2.340	9.990	347					
	EBS survey	347	624	1.798	9.984	347	359	130	0.362	0.637	235
M19.10	Fishery	300	585	1.951							
	EBS+NBS survey	300	280	0.933			300	65	0.216		
M19.11	Fishery	300	610	2.035							
	EBS+NBS survey	300	285	0.949			300	68	0.226		
M19.12	Fishery	356	819	2.301	9.990	356					
	EBS+NBS survey	356	623	1.752	9.984	356	368	111	0.302	0.099	194
M19.13	Fishery	300	591	1.970							
	EBS survey	300	271	0.904			300	66	0.220		
	NBS survey	300	82	0.275			300	40	0.133		
M19.14	Fishery	300	610	2.034							
	EBS survey	300	270	0.901			300	63	0.210		
	NBS survey	300	99	0.331			300	47	0.157		
M19.15	Fishery	356	812	2.282	9.989	356					
	EBS survey	347	608	1.753	9.984	347	359	124	0.344	0.453	220
	NBS survey	85	110	1.297	9.696	84	85	35	0.417	0.073	44

Fit to sizecomps: fishery

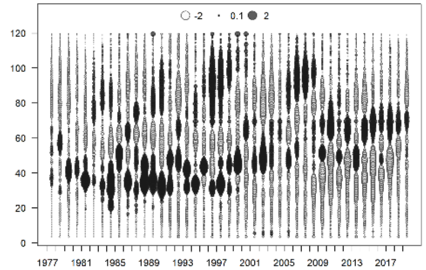
Model 16.6i



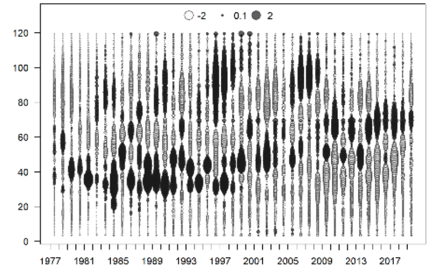
Model 19.7



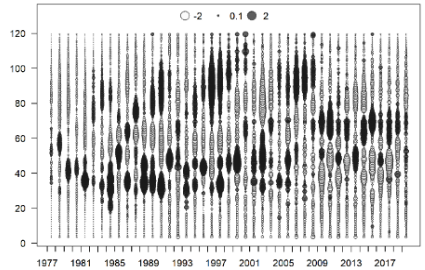
Model 19.10



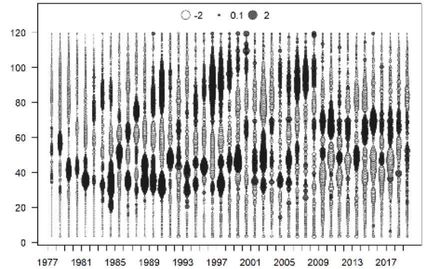
Model 19.13



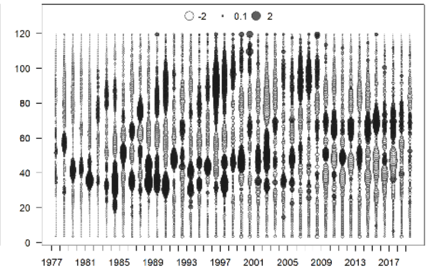
Model 19.8



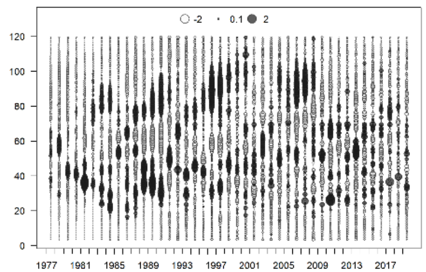
Model 19.11



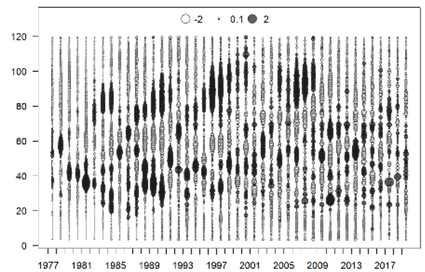
Model 19.14



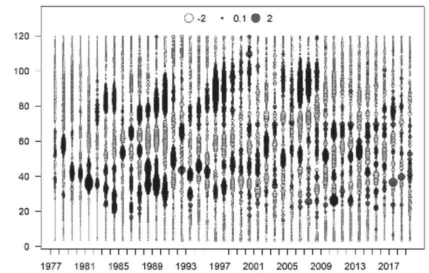
Model 19.9



Model 19.12

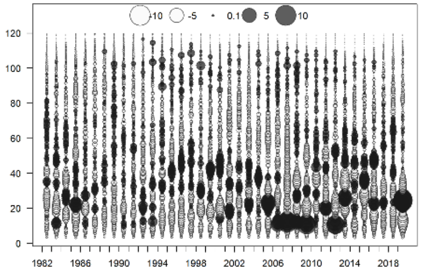


Model 19.15

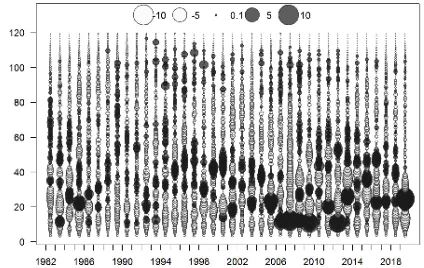


Fit to sizecomps: survey (EBS, EBS+NBS)

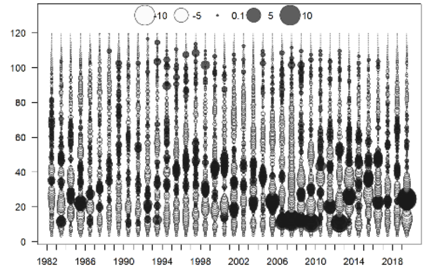
Model 16.6i



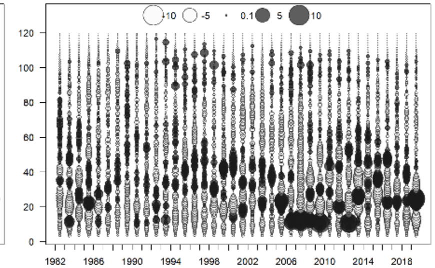
Model 19.7



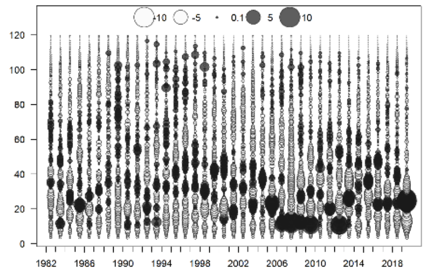
Model 19.10



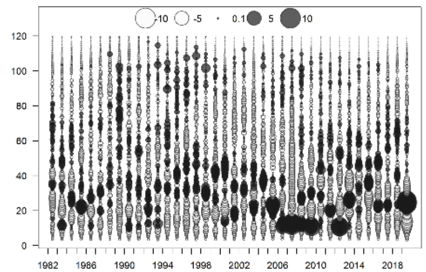
Model 19.13



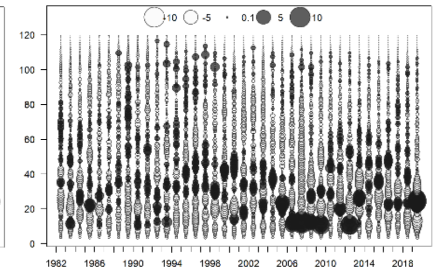
Model 19.8



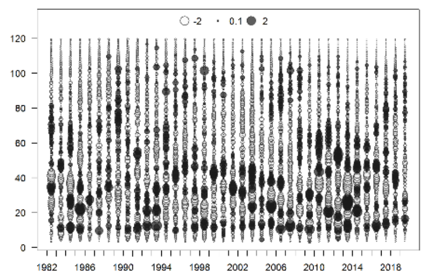
Model 19.11



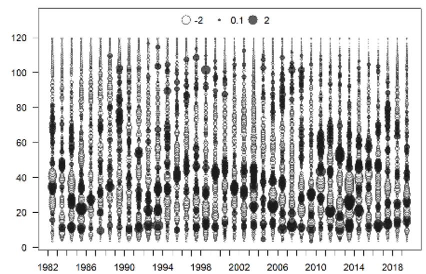
Model 19.14



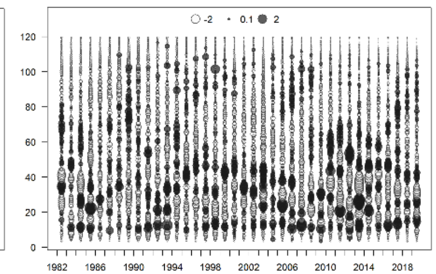
Model 19.9



Model 19.12

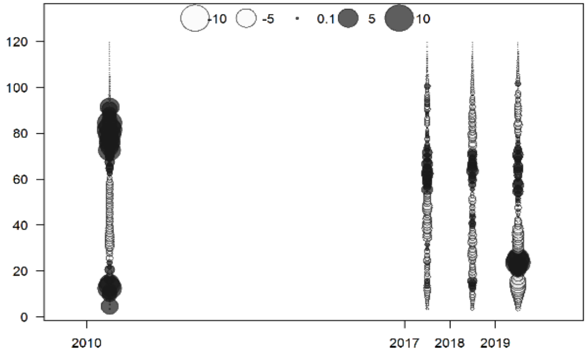


Model 19.15

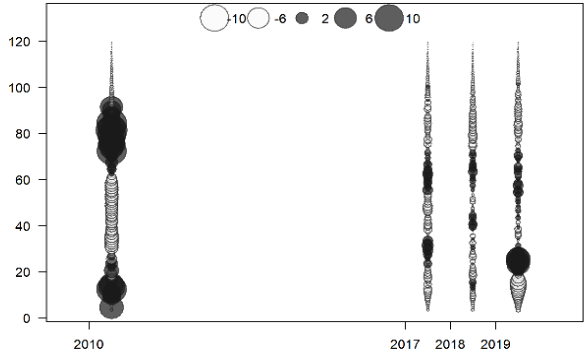


Fit to sizecomps: survey (NBS)

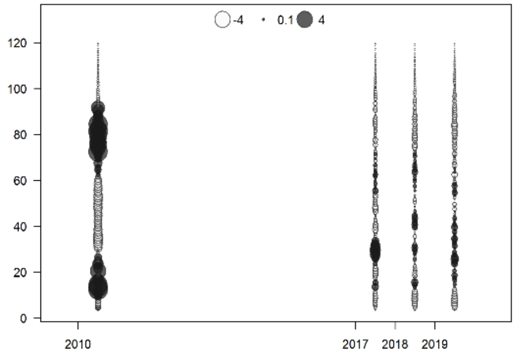
Model 19.13



Model 19.14

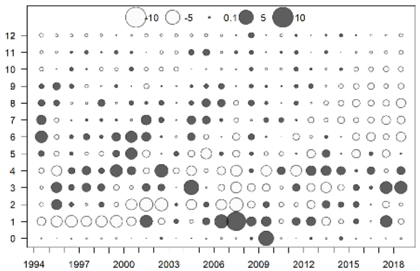


Model 19.15

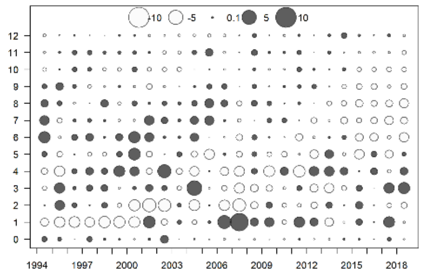


Fit to agecomps

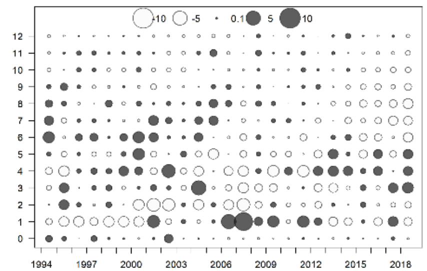
Model 16.6i



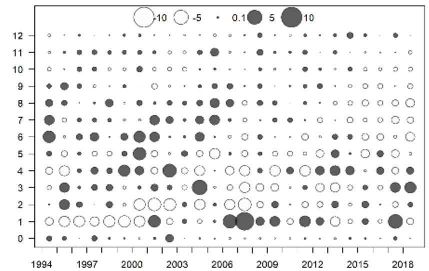
Model 19.7



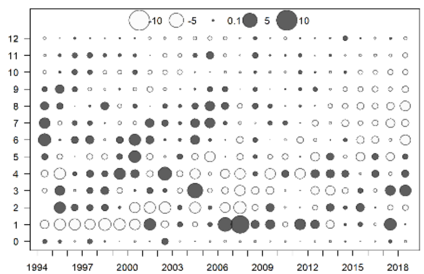
Model 19.10



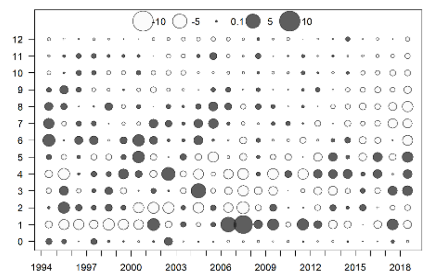
Model 19.13



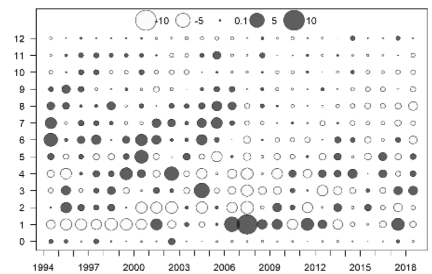
Model 19.8



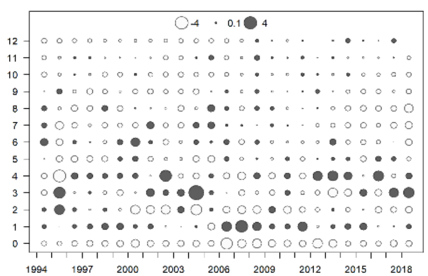
Model 19.11



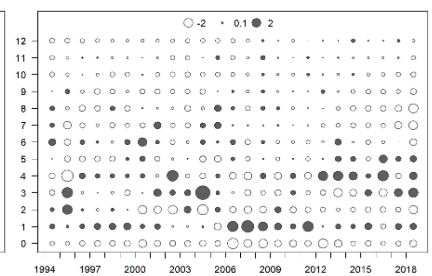
Model 19.14



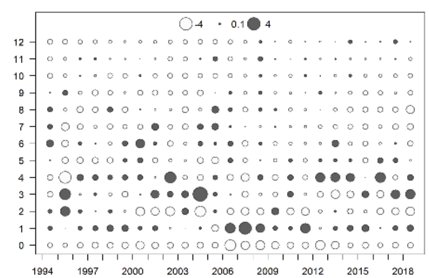
Model 19.9



Model 19.12



Model 19.15



Model evaluation criteria (SSC in green)

1. Are the catchability estimates plausible?
2. Is the retrospective bias within the acceptable range?
3. Is the associated “hypothesis” plausible?
4. Is the model complexity similar to that of other Tier 3 assessments?
5. Are input σs of “dev” vectors estimated appropriately?
6. Are fits to data consistent with variances specified for those data?
7. Are changes from the base model, if any, suitably incremental?
8. Is an objective criterion used to specify input N for comp data?
9. Is the apparent change in ageing criteria after 2007 addressed?

Scoring the criteria (1 of 2)

1. Mean catchability in 2017-2019 should not be much greater than 1.0

Hypothesis 1			Hypothesis 2		
M19.7	M19.8	M19.9	M19.10	M19.11	M19.12
1.05	0.88	0.94	1.14	0.95	1.07

Hypothesis 3								
M19.13			M19.14			M19.15		
EBS	NBS	EBS+NBS	EBS	NBS	EBS+NBS	EBS	NBS	EBS+NBS
1.18	0.41	1.59	0.98	0.56	1.54	0.91	1.21	2.12

2. Mohn's ρ should be within the acceptable range of Hurtado-Ferro et al.

Hypothesis	2	1			2			3		
Model	16.6i	19.7	19.8	19.9	19.10	19.11	19.12	19.13	19.14	19.15
M	0.33	0.35	0.42	0.36	0.33	0.40	0.35	0.32	0.41	0.36
Mohn's ρ	0.22	0.13	0.22	0.04	0.06	0.14	-0.06	0.20	1.51	0.11
ρmin	-0.20	-0.20	-0.23	-0.21	-0.20	-0.22	-0.20	-0.19	-0.23	-0.21
ρmax	0.27	0.28	0.31	0.28	0.27	0.30	0.27	0.26	0.31	0.28

Scoring the criteria (2 of 2)

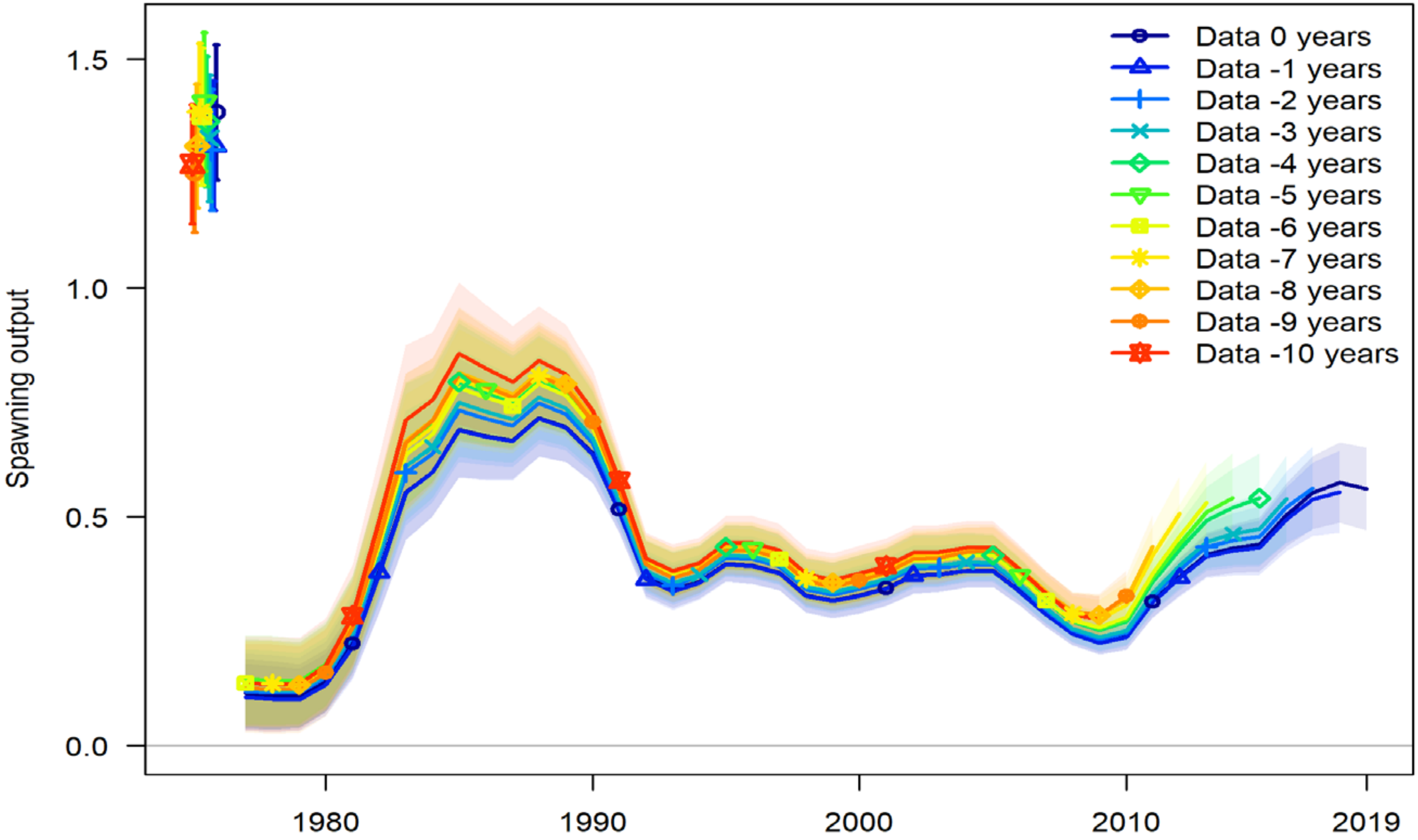
3. Given comment SSC13, all models associated with Hypothesis 1 were deemed implausible
4. All “basic” and “simple” models were deemed to have levels of complexity similar to that of other BSAI groundfish Tier 3 assessments
5. All “simple” and “complex” models were deemed to have appropriately estimated input standard deviations for their associated “dev” vectors
6. All “complex” models were deemed to exhibit fits to the data that were consistent with the variances specified for those data
7. All “basic” models were deemed to exhibit suitably incremental changes from the base model
8. All “complex” models were deemed to use an objective criterion to specify input sample sizes for compositional data
9. All “complex” models were deemed to have addressed the apparent change in ageing criteria

Choice of ensemble and model weights

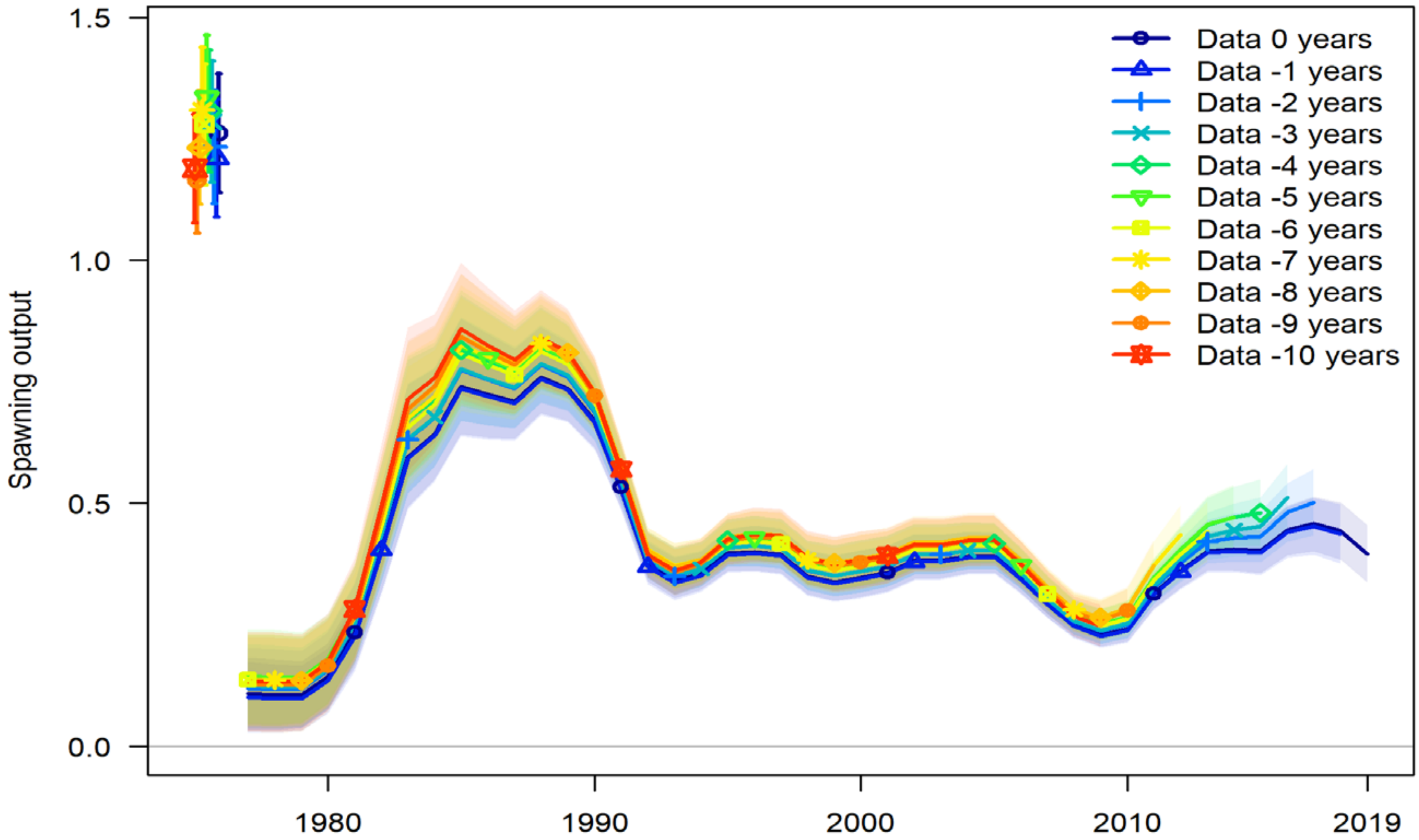
		Hypothesis 1			Hypothesis 2			Hypothesis 3		
		Basic	Simple	Complex	Basic	Simple	Complex	Basic	Simple	Complex
Criterion	Emphasis	M19.7	M19.8	M19.9	M19.10	M19.11	M19.12	M19.13	M19.14	M19.15
Plausible hypothesis	3	0	0	0	1	1	1	1	1	1
Plausible catchability	3	1	1	1	1	1	1	0	0	0
Acceptable retrospective bias	3	1	1	1	1	1	1	1	0	1
Comparable complexity	2	1	1	0	1	1	0	1	1	0
Dev sigmas estimated appropriately	2	0	1	1	0	1	1	0	1	1
Fits consistent with variances	2	0	0	1	0	0	1	0	0	1
Incremental changes	1	1	0	0	1	0	0	1	0	0
Objective criterion for sample sizes	1	0	0	1	0	0	1	0	0	1
Change in ageing criteria addressed	1	0	0	1	0	0	1	0	0	1
Exponential average emphasis:		0.0001	0.0003	0.0025	0.0025	0.0067	0.0498	0.0001	0.0000	0.0025
Model weight:		0.0019	0.0052	0.0384	0.0384	0.1044	0.7712	0.0019	0.0003	0.0384

- M16.6i not included in ensemble because:
  1. Does not account for changes in NBS sampling design or gaps
  2. “Team expressed many caveats,” with 7 “significant concerns”
  3. Results are close to those of M19.10, so double-counting
  4. Inclusion would spoil the 3×3 factorial design of the ensemble

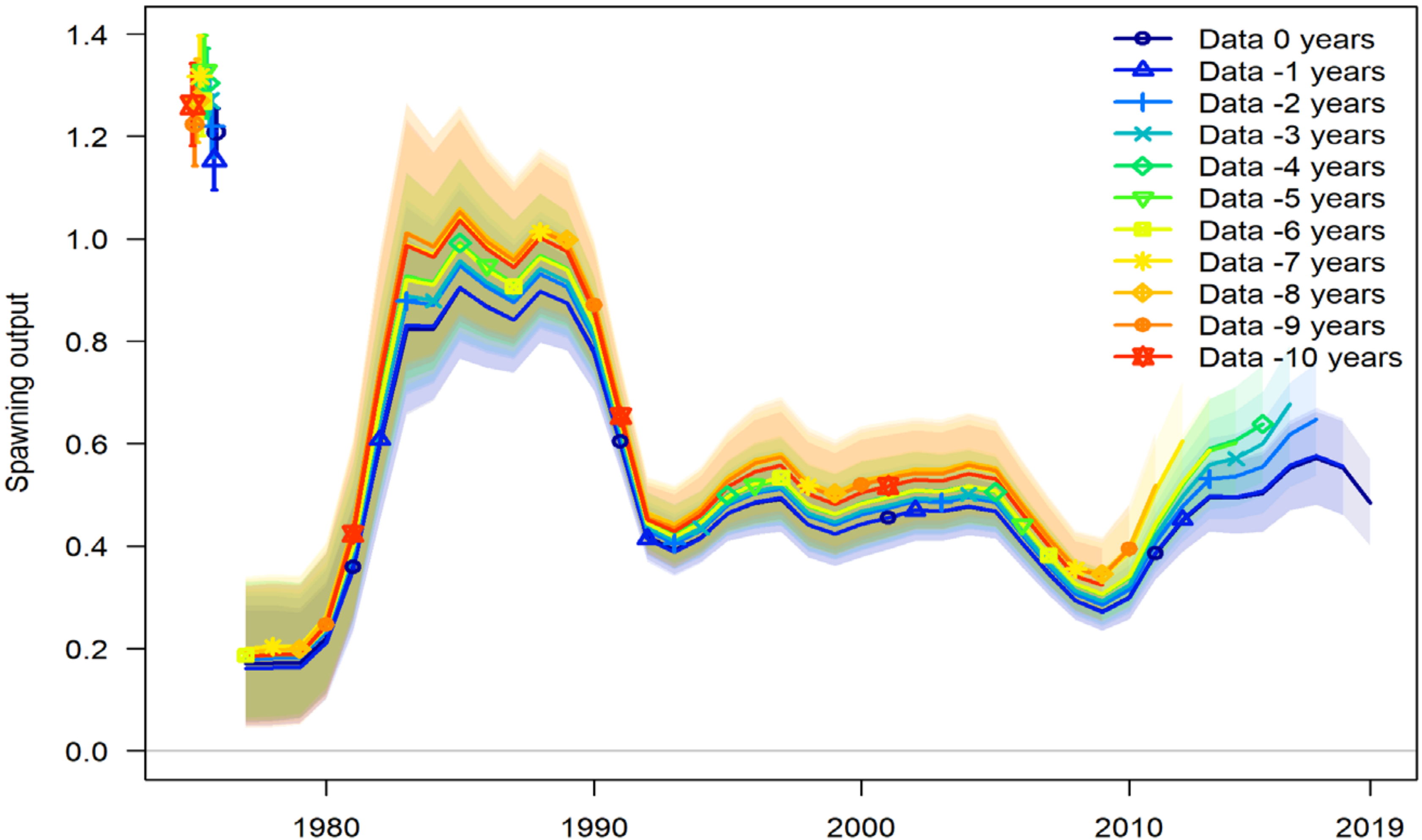
Retrospective analysis: Model 16.6i ($\rho = 0.22$)



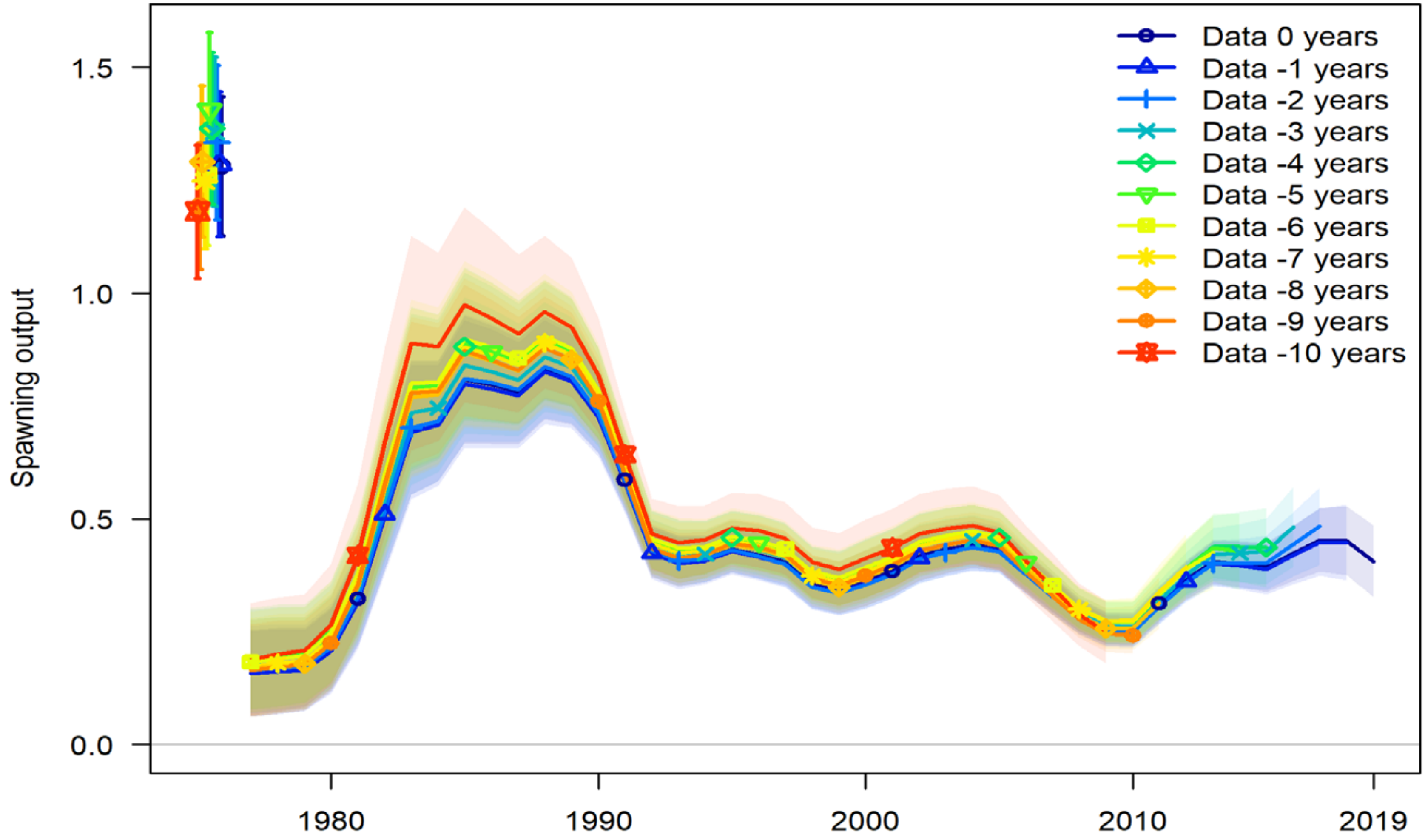
Retrospective analysis: Model 19.7 (ρ = 0.13)



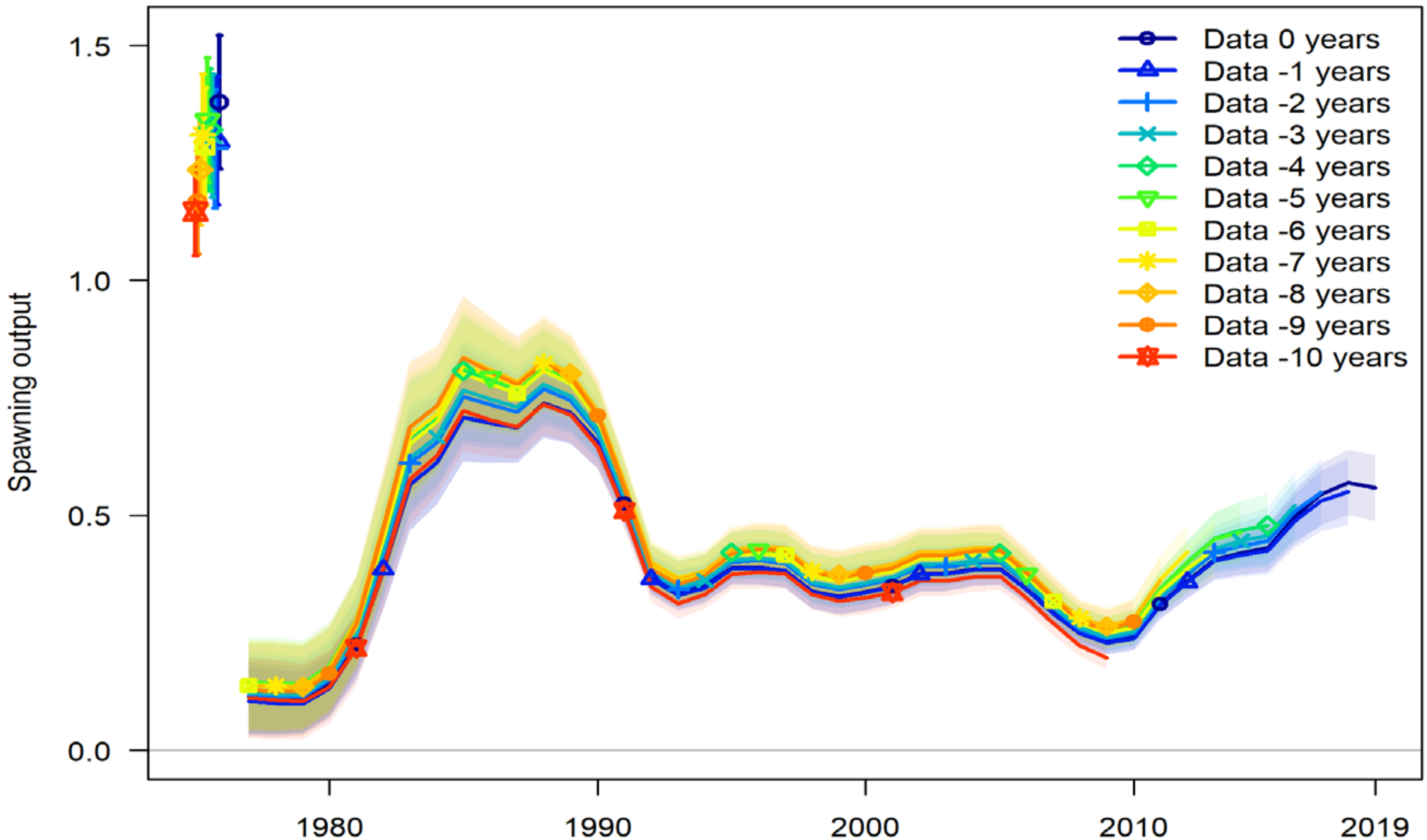
Retrospective analysis: Model 19.8 (ρ = 0.22)



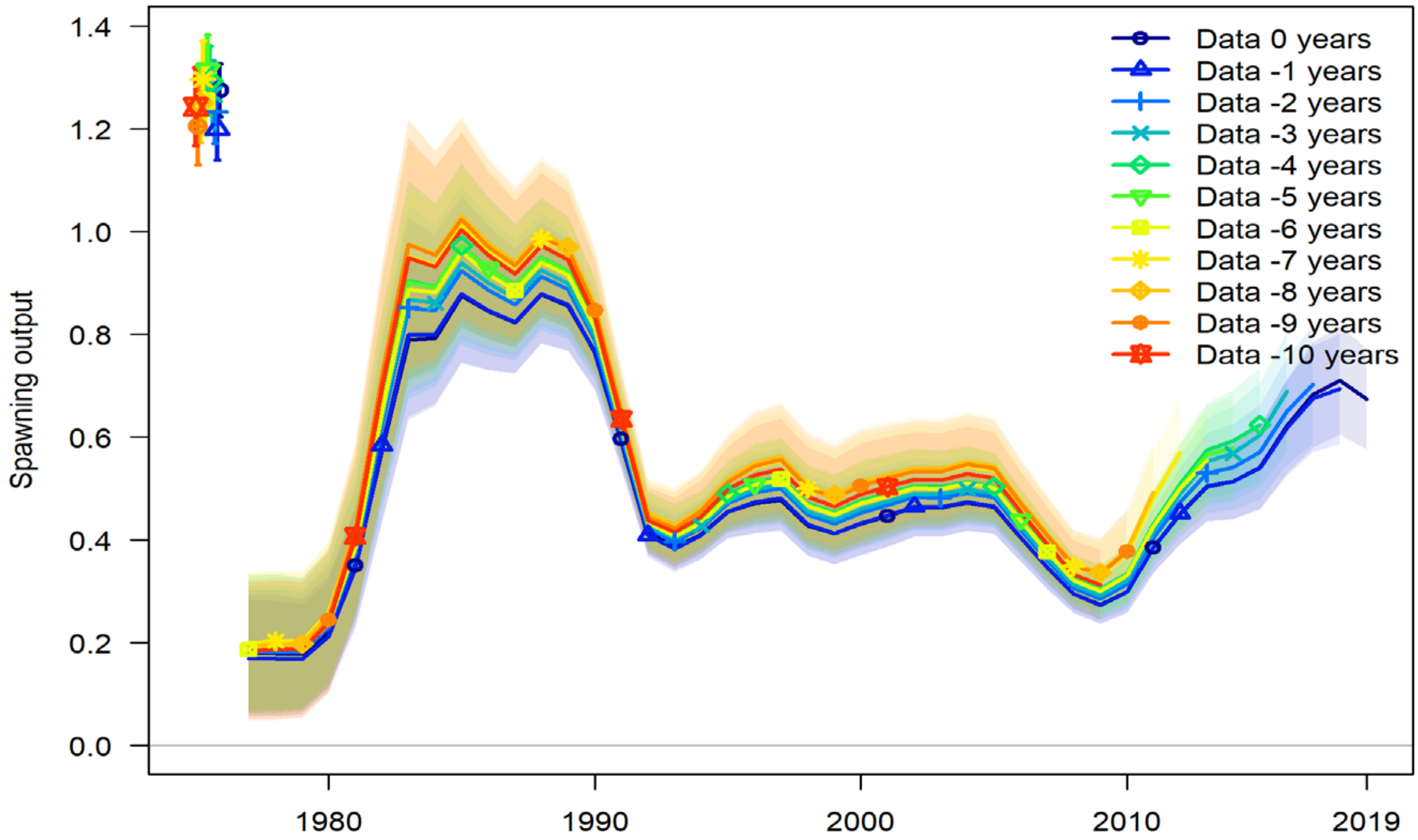
Retrospective analysis: Model 19.9 (ρ = 0.04)



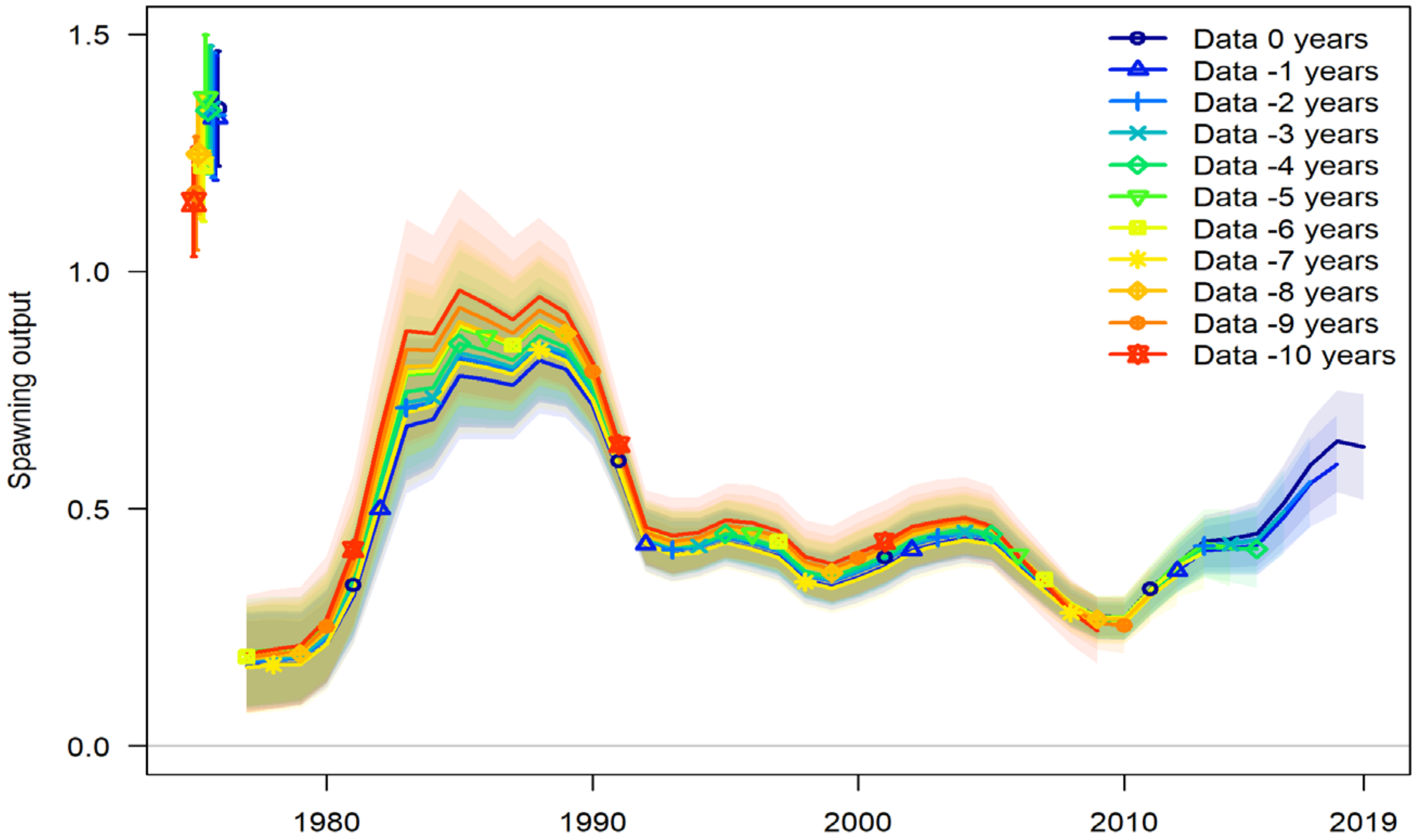
Retrospective analysis: Model 19.10 (ρ = 0.06)



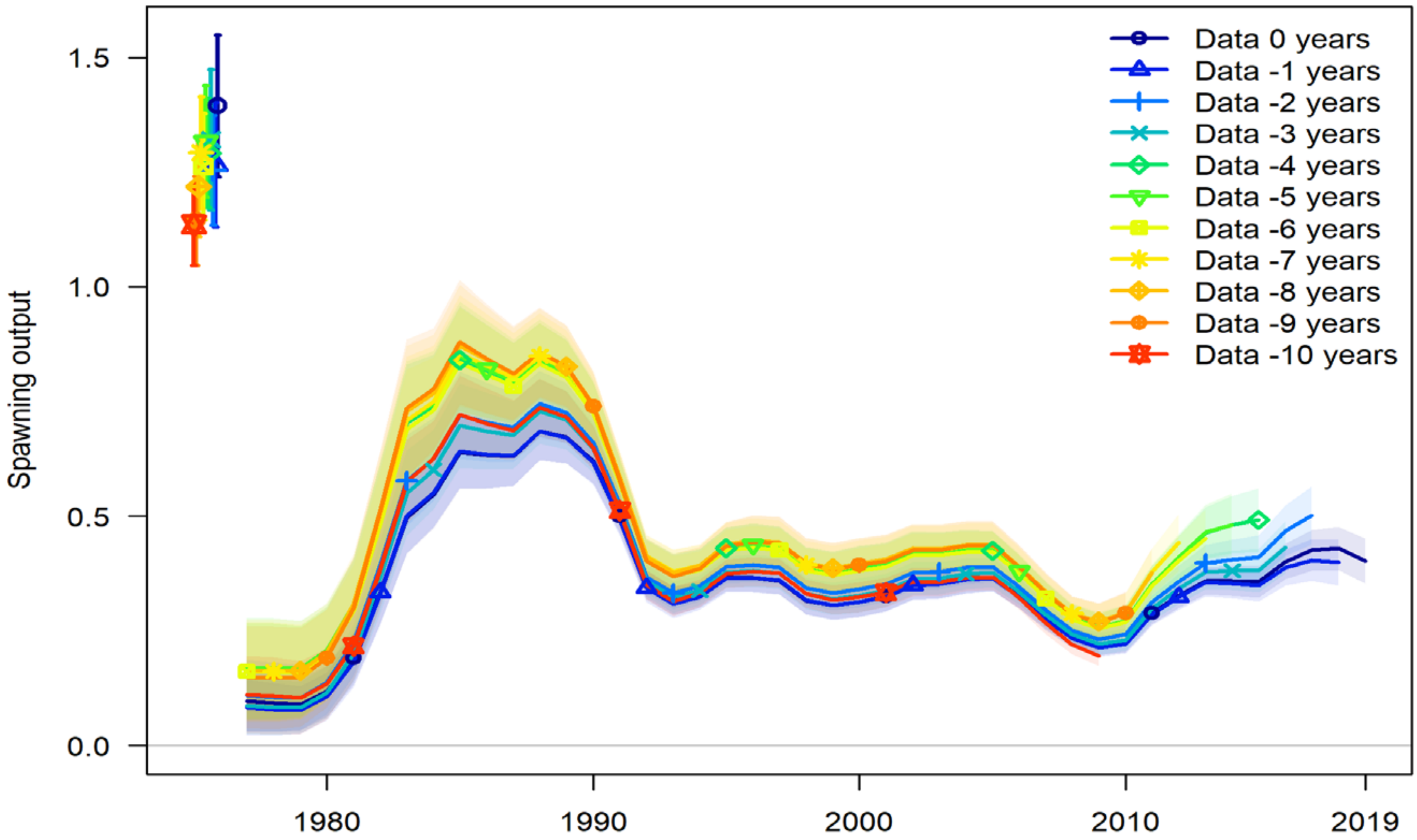
Retrospective analysis: Model 19.11 (ρ = 0.14)



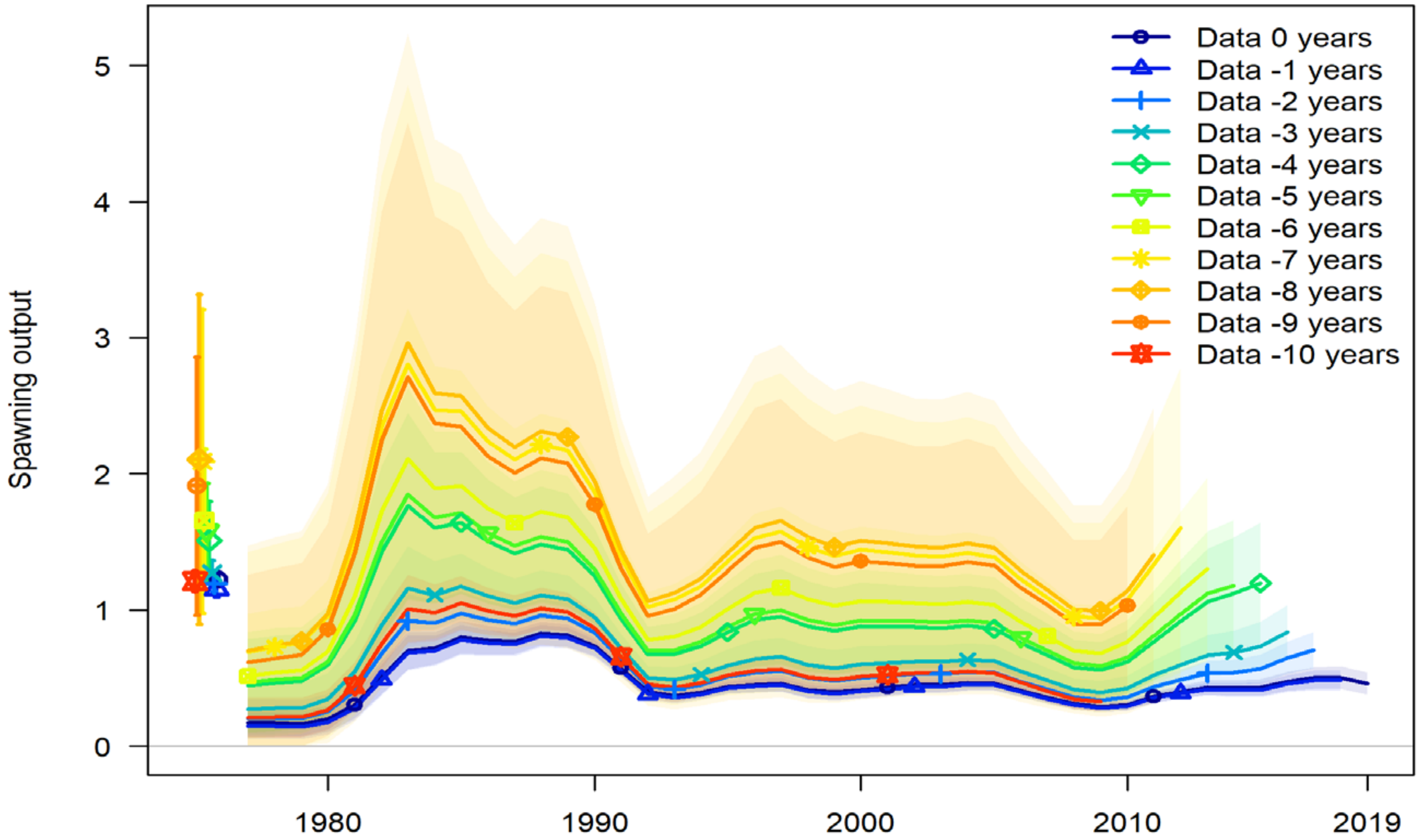
Retrospective analysis: Model 19.12 (ρ = -0.06)



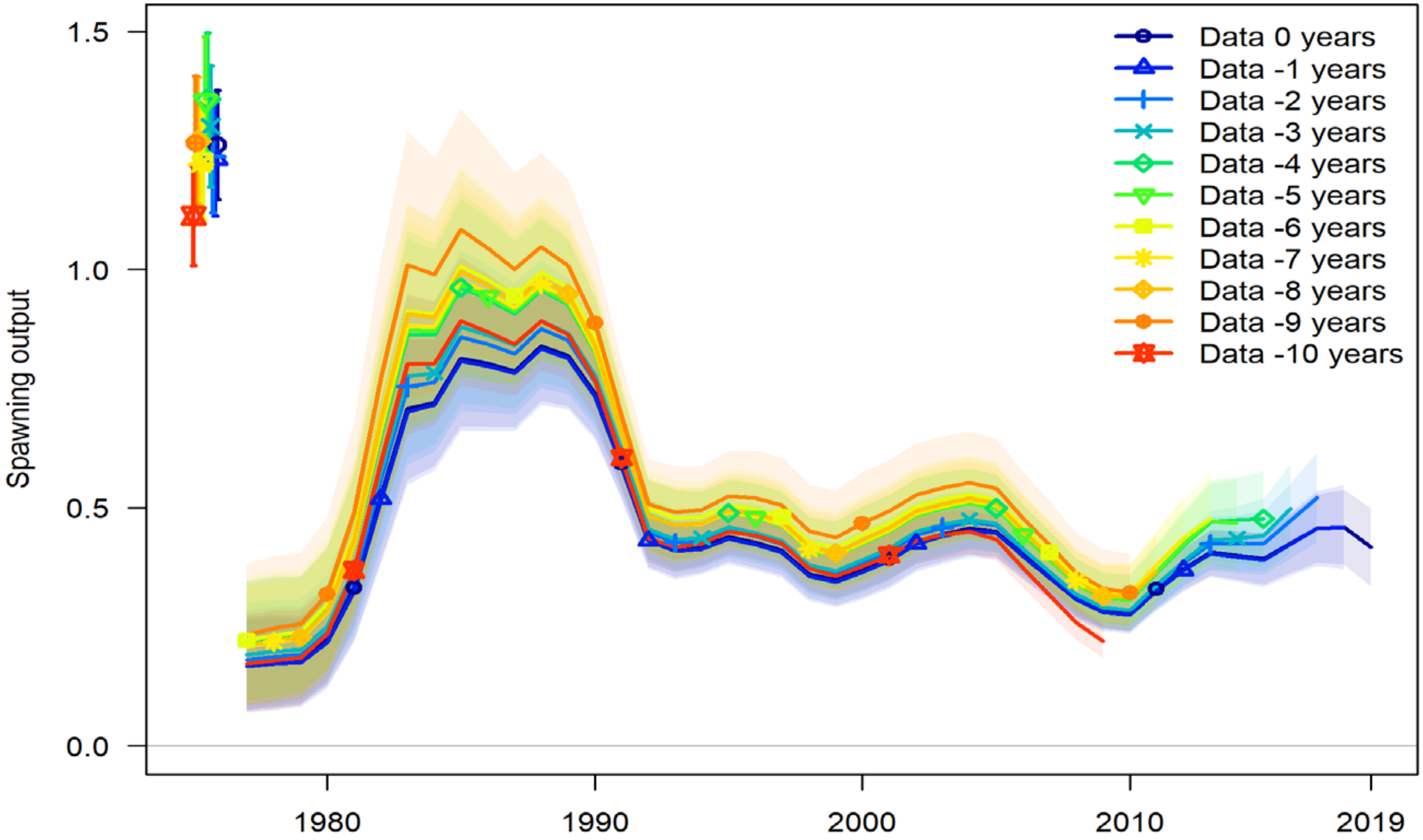
Retrospective analysis: Model 19.13 (ρ = 0.20)



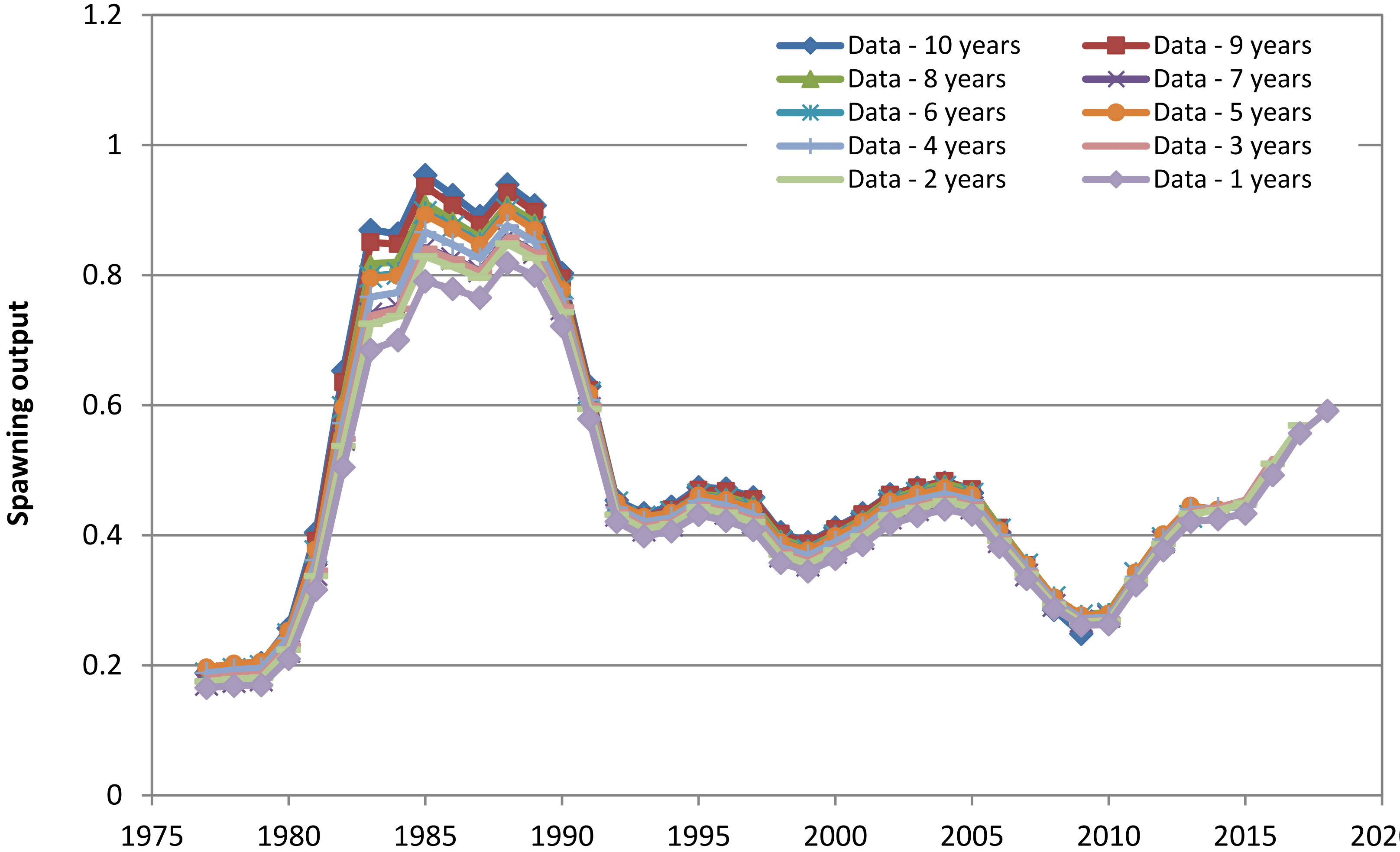
Retrospective analysis: Model 19.14 (ρ = 1.51)



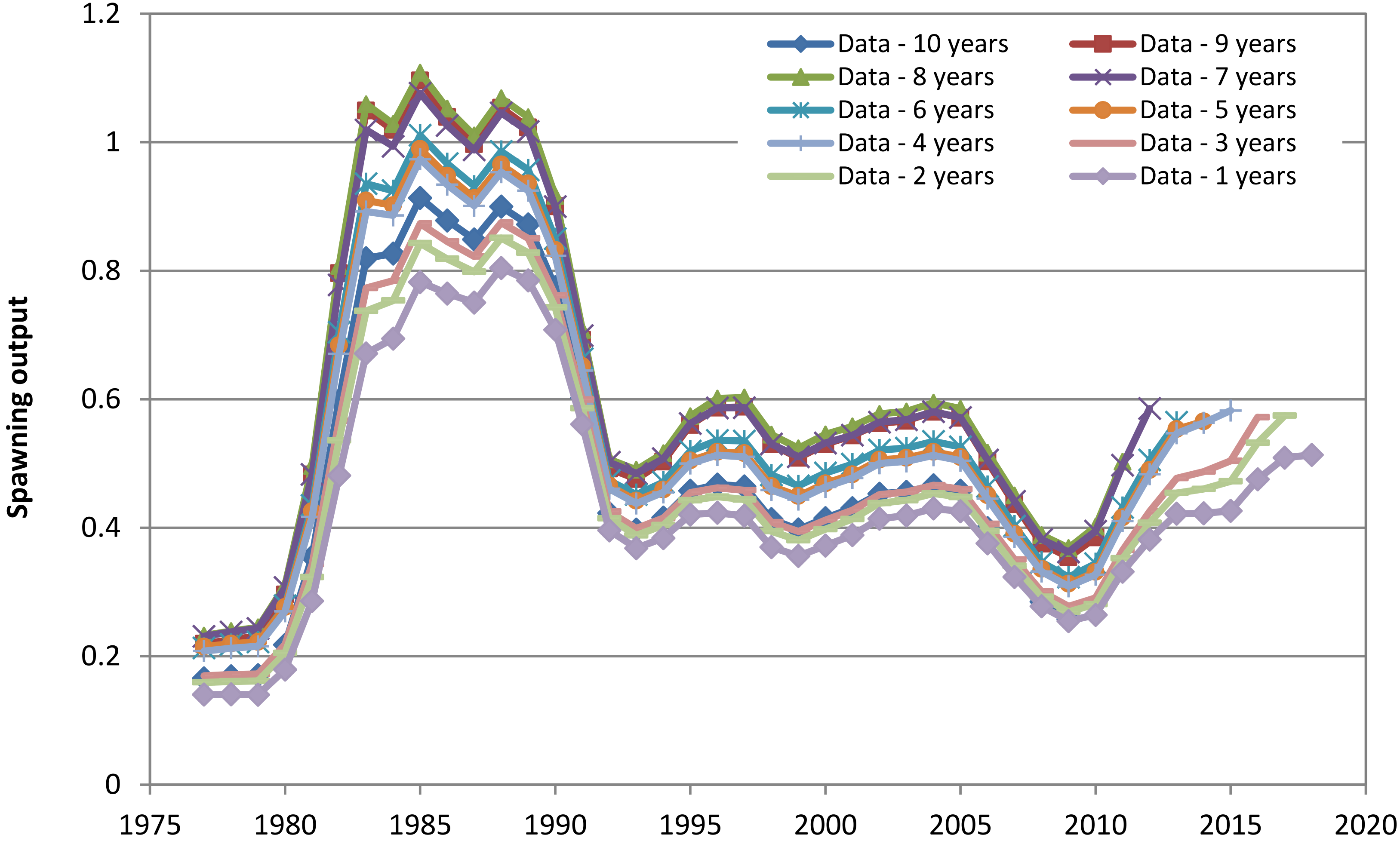
Retrospective analysis: Model 19.15 (ρ = 0.11)



Retrospective: ensemble wtd. ave. (ρ = -0.02)

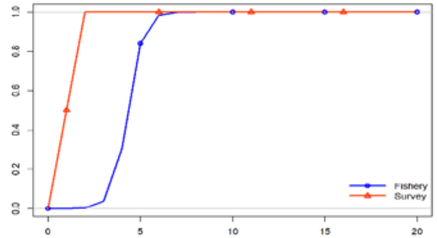


Retrospective: ensemble unw. ave. ($\rho = 0.27$)

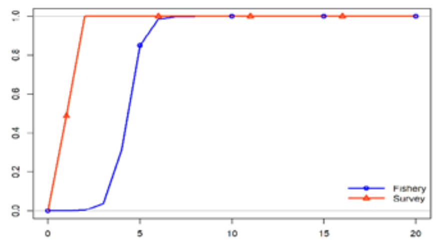


Selectivity: “basic” and “simple” models

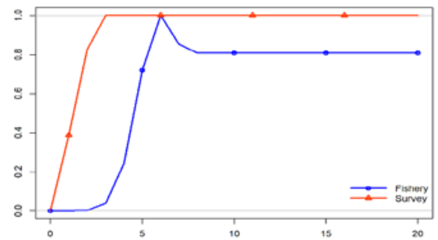
Model 16.6i



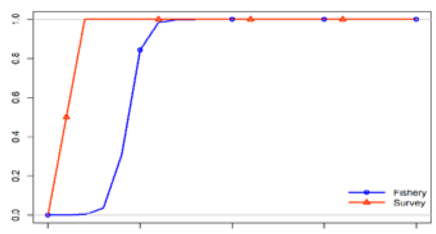
Model 19.7



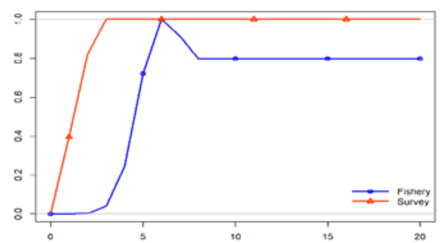
Model 19.8



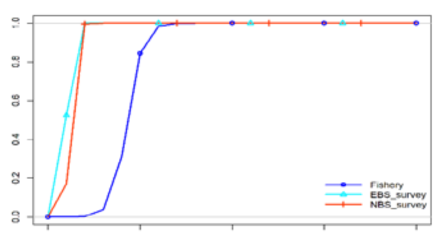
Model 19.10



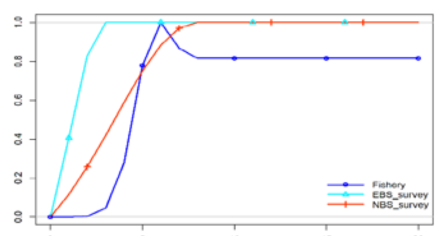
Model 19.11



Model 19.13

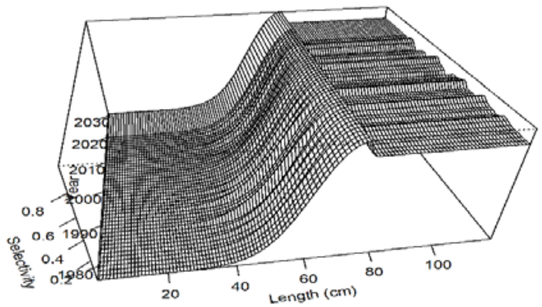


Model 19.14

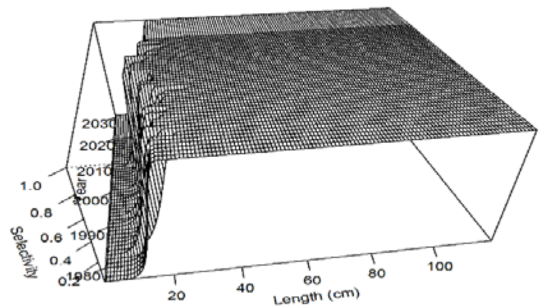


Selectivity: “complex” models

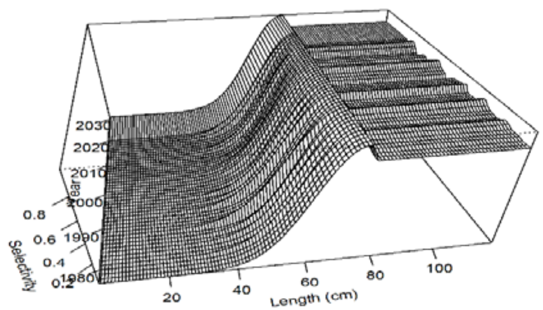
Model 19.9 (fishery)



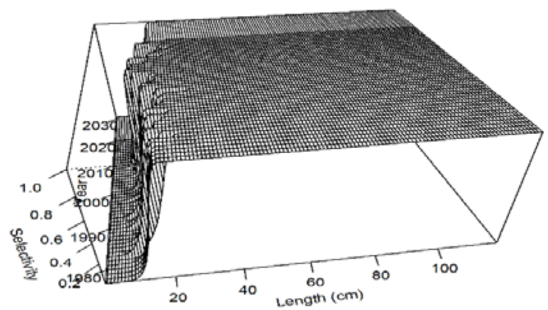
Model 19.9 (EBS survey)



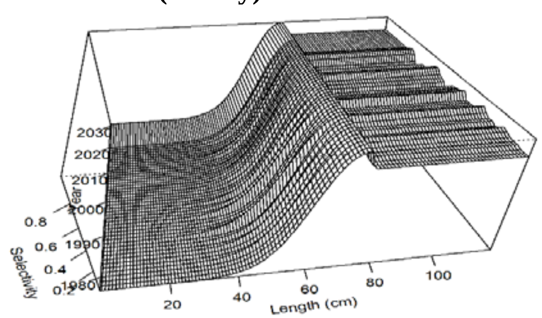
Model 19.12 (fishery)



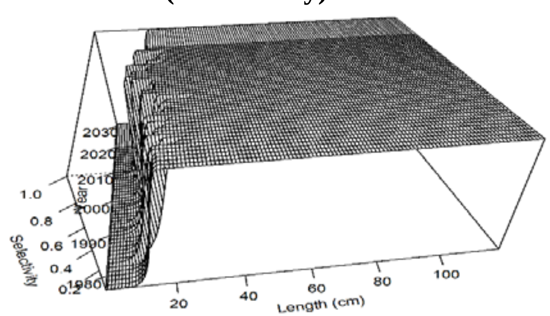
Model 19.12 (EBS+NBS survey)



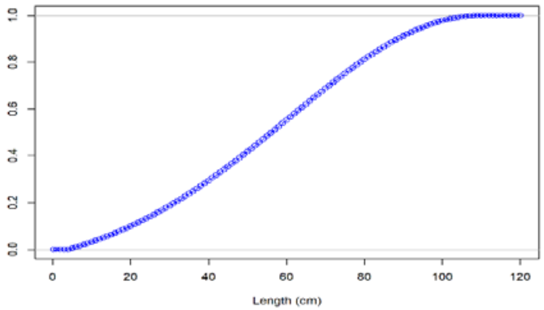
Model 19.15 (fishery)



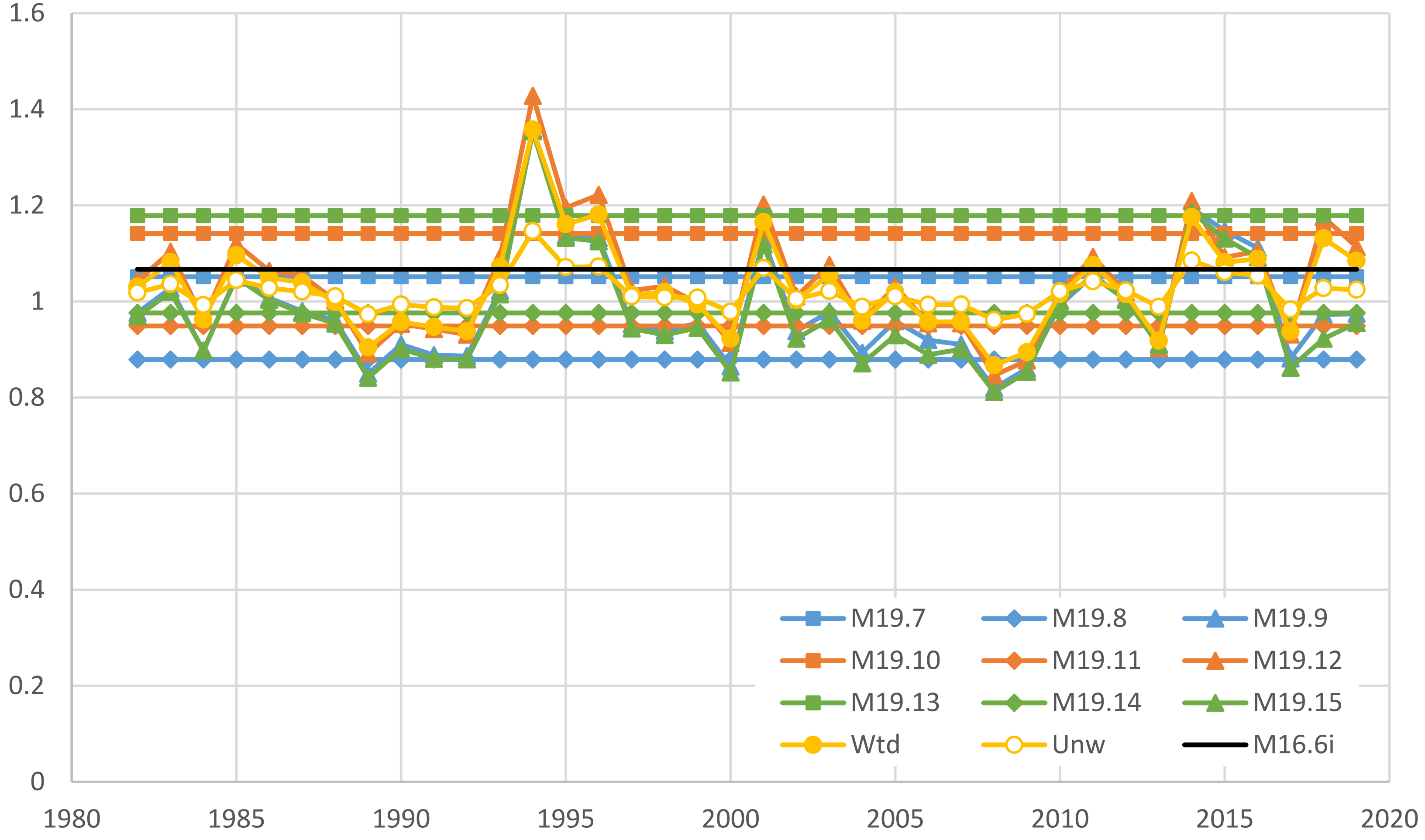
Model 19.15 (EBS survey)



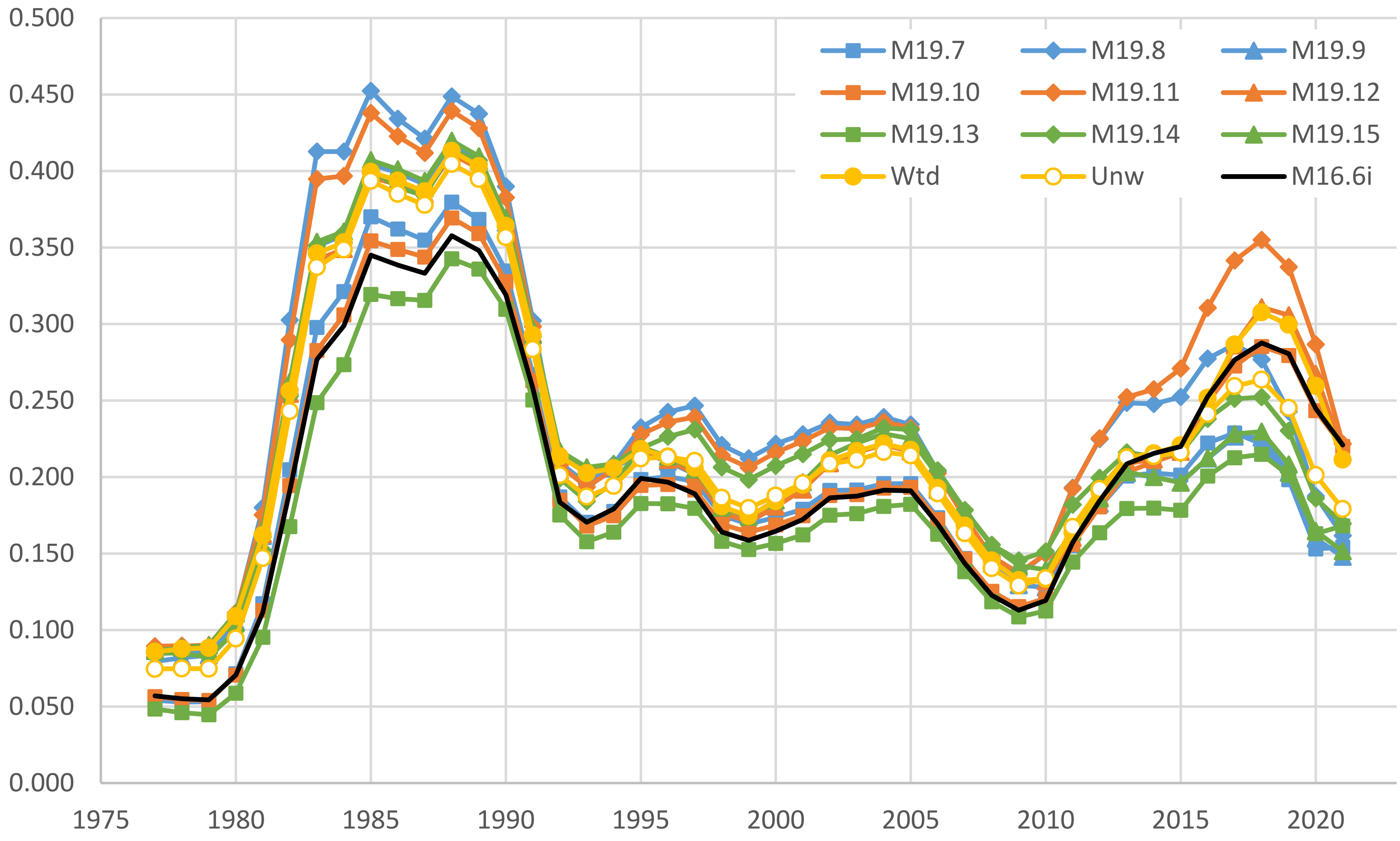
Model 19.15 (NBS survey)



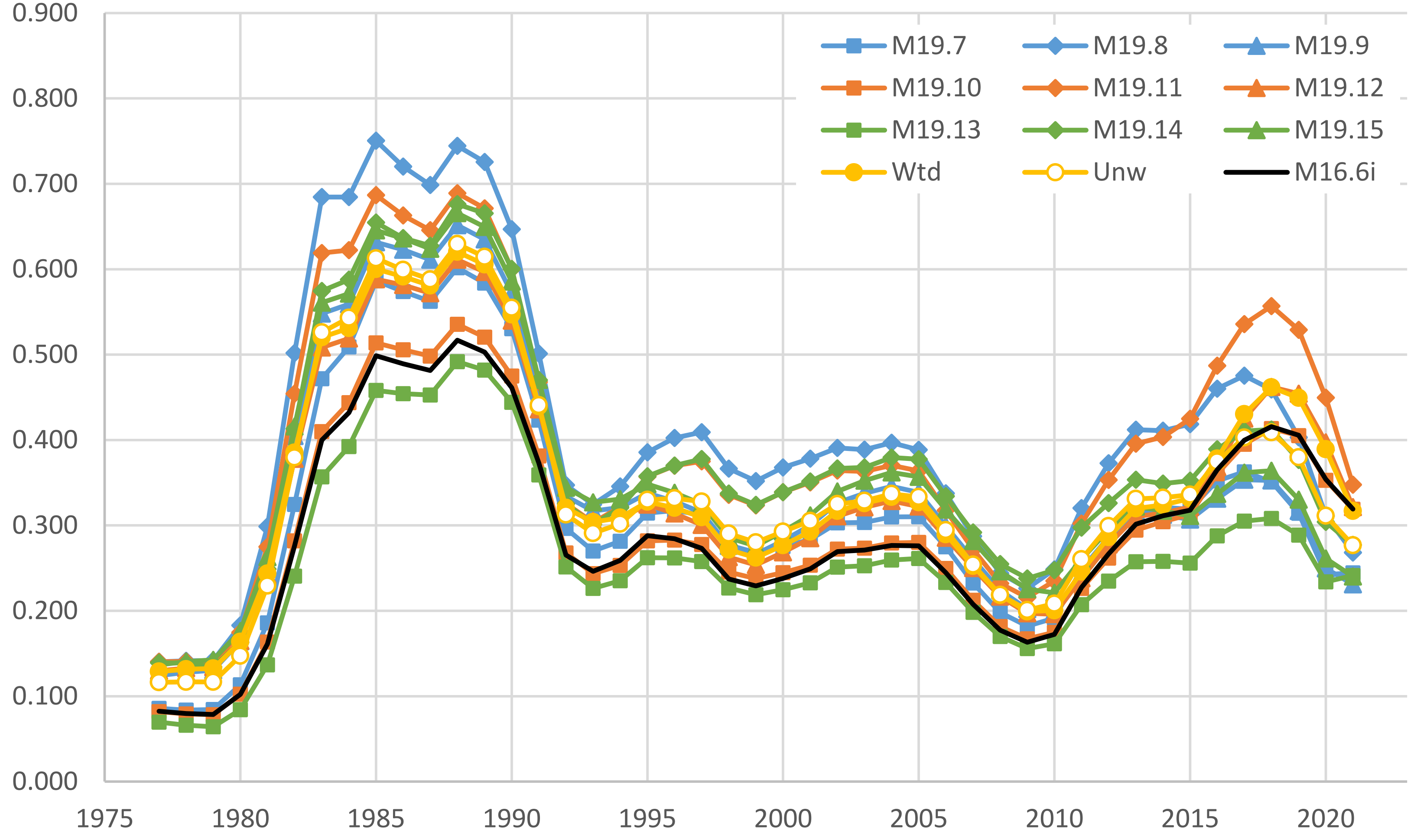
EBS (or EBS+NBS) catchability



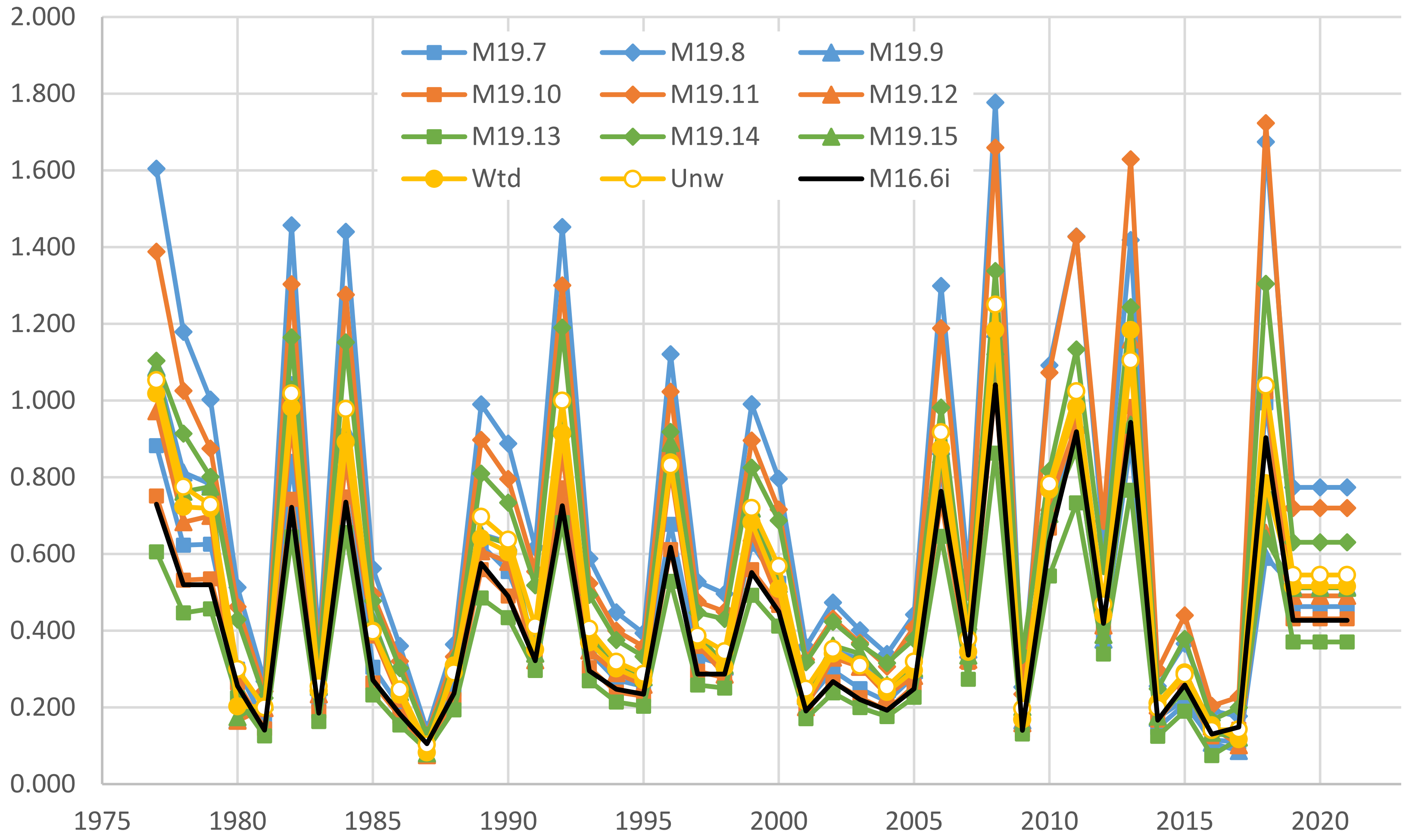
Female spawning biomass (millions of t)



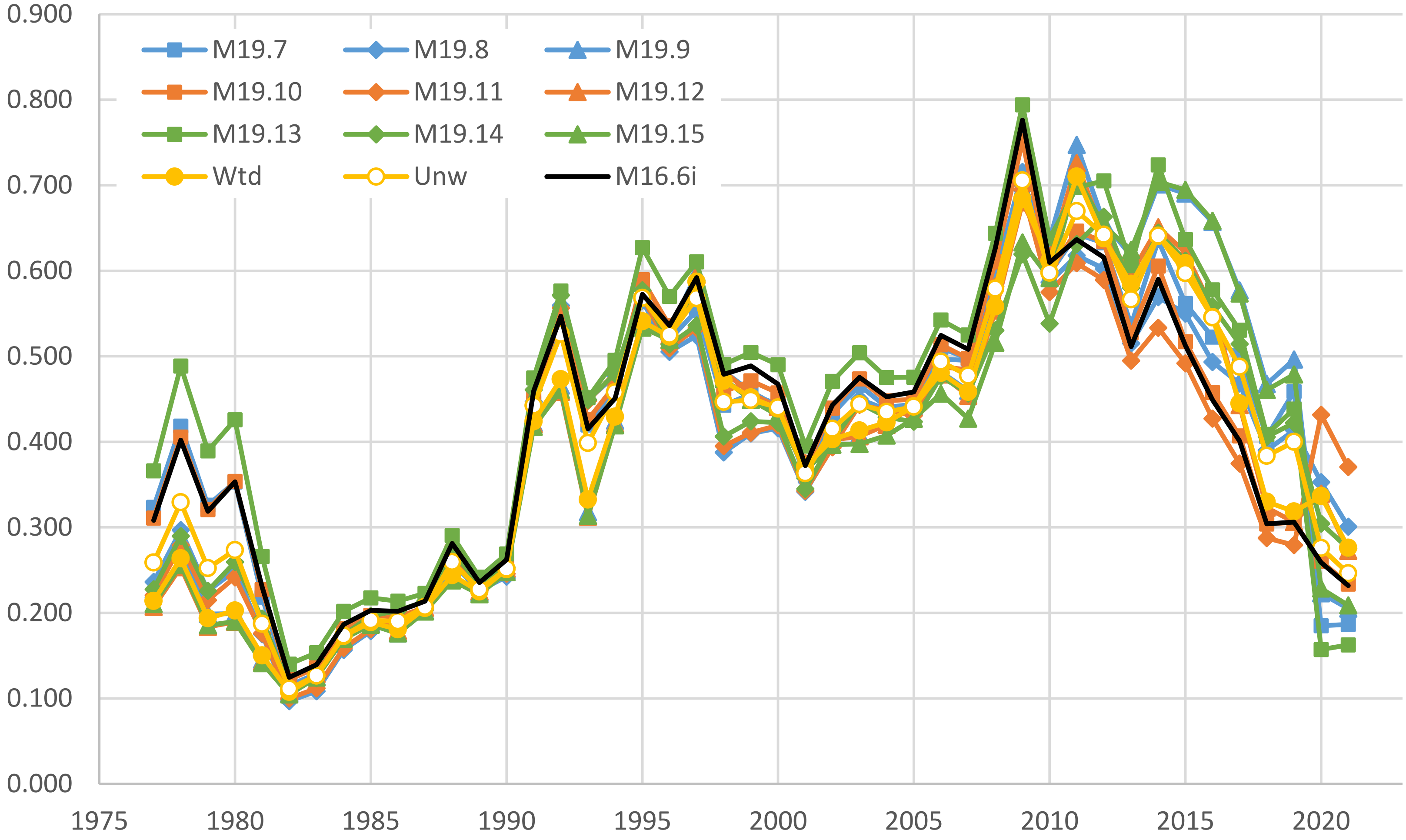
Spawning biomass relative to $B_{100\%}$



Age 0 recruitment (billions of fish)



Full-selection fishing mortality



Management reference points (Table 2.30)

Year	Hypothesis:	2	1 (EBS only)			2 (EBS and NBS combined)			3 (EBS and NBS separated)			Ensemble (19.x)	
Year	Quantity	M16.6i	M19.7	M19.8	M19.9	M19.10	M19.11	M19.12	M19.13	M19.14	M19.15	Wtd	Unw
n/a	B100%	691,900	630,950	602,845	640,400	689,780	637,650	672,795	696,950	611,630	630,700	666,506	645,967
n/a	B40%	276,760	252,380	241,138	256,160	275,912	255,060	269,118	278,780	244,652	252,280	266,602	258,387
n/a	B35%	242,165	220,833	210,996	224,140	241,423	223,178	235,478	243,933	214,071	220,745	233,277	226,089
n/a	F40%	0.30	0.32	0.46	0.36	0.30	0.43	0.34	0.28	0.41	0.36	0.35	0.36
n/a	F35%	0.36	0.39	0.57	0.44	0.36	0.53	0.41	0.34	0.50	0.44	0.43	0.44
2020	Female spawning biomass	244,813	153,001	187,569	159,841	243,403	286,638	267,333	162,925	186,003	164,727	259,509	201,271
2020	Relative spawning biomass	0.35	0.24	0.31	0.25	0.35	0.45	0.40	0.23	0.30	0.26	0.39	0.31
2020	Pr(B/B100%<0.2)	0.00	0.06	0.00	0.07	0.00	0.00	0.00	0.08	0.00	0.04	0.00	0.03
2020	maxFABC	0.26	0.19	0.35	0.22	0.26	0.43	0.34	0.16	0.30	0.23	0.34	0.28
2020	maxABC	125,431	58,057	108,529	67,127	125,009	201,257	160,789	54,138	99,642	70,089	155,873	104,960
2020	Catch	125,431	58,057	108,529	67,127	125,009	199,691	160,789	54,138	99,642	70,089	155,873	104,960
2020	FOFL	0.32	0.23	0.44	0.27	0.32	0.53	0.41	0.19	0.37	0.28	0.41	0.34
2020	OFL	149,545	69,846	130,680	80,820	149,039	239,837	191,386	64,987	119,390	84,245	185,650	125,581
2020	Pr(maxABC>truOFL)	0.22	0.22	0.23	0.26	0.17	0.07	0.09	0.20	0.23	0.27	0.16	0.47
2021	Female spawning biomass	220,884	154,188	161,736	147,900	220,007	222,277	216,255	168,136	169,558	151,479	211,410	179,060
2021	Relative spawning biomass	0.32	0.24	0.27	0.23	0.32	0.35	0.32	0.24	0.28	0.24	0.32	0.28
2021	Pr(B/B100%<0.2)	0.00	0.01	0.00	0.08	0.00	0.00	0.00	0.01	0.00	0.03	0.00	0.01
2021	maxFABC	0.23	0.19	0.30	0.20	0.23	0.37	0.27	0.16	0.28	0.21	0.28	0.25
2021	maxABC	95,283	53,705	76,738	56,445	94,551	127,409	105,046	52,651	78,630	58,585	102,975	78,196
2021	Catch	95,283	53,705	76,738	56,445	94,551	127,409	105,046	52,651	78,630	58,585	102,975	78,196
2021	FOFL	0.28	0.23	0.37	0.25	0.29	0.46	0.33	0.20	0.34	0.26	0.34	0.30
2021	OFL	113,925	64,631	92,873	68,065	113,057	152,858	125,734	63,192	94,509	70,566	123,331	93,943
2021	Pr(maxABC>truOFL)	0.23	0.21	0.23	0.31	0.17	0.20	0.24	0.22	0.23	0.27	0.27	0.43

- Ensemble values are equal to the weighted or unweighted means of the individual model point estimates, except for Pr(maxABC>truOFL), which is computed from the averaged distributions

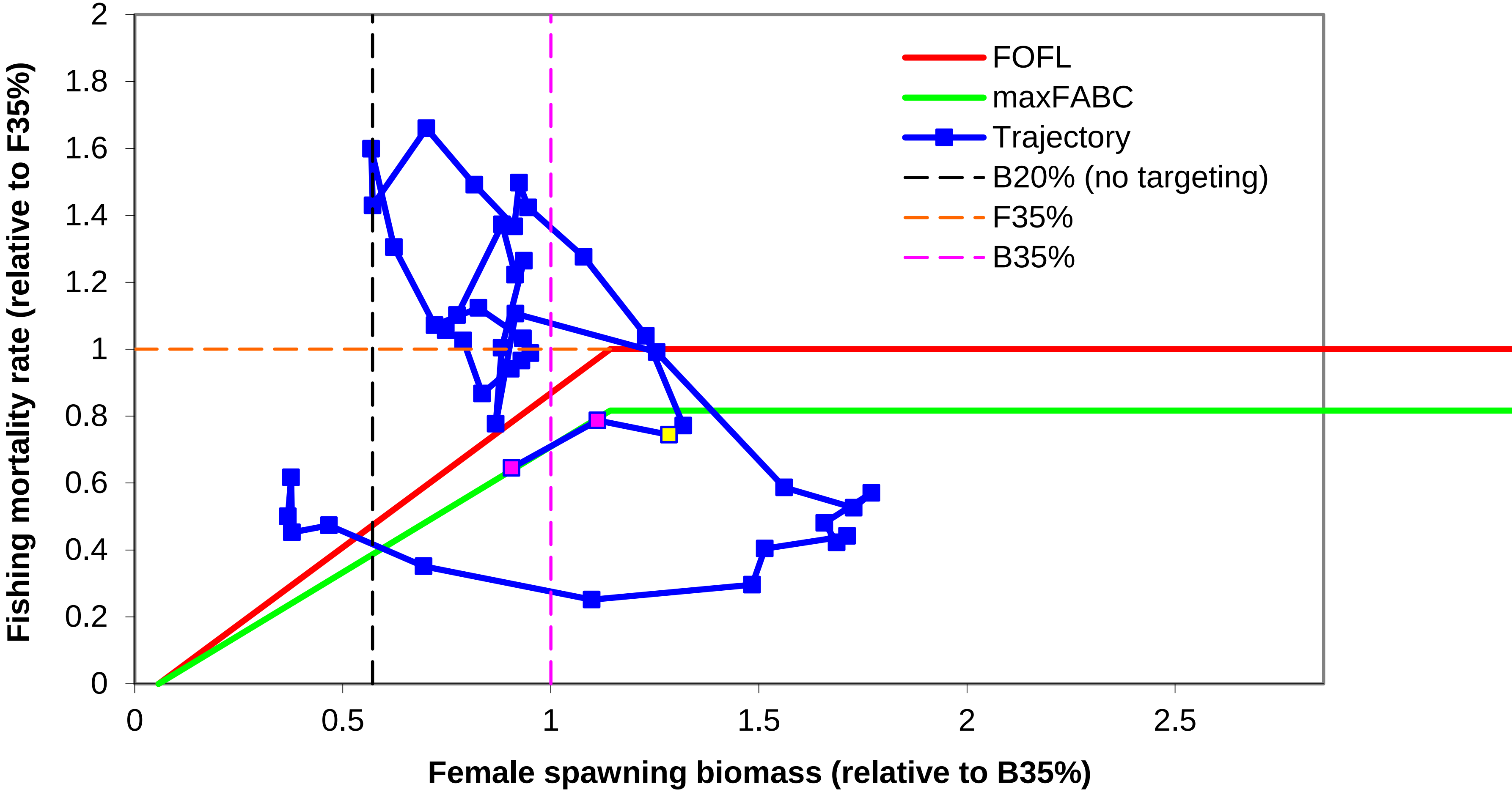
Choice of final model

- The weighted average ensemble is chosen as the final model
- Both the Team and SSC have encouraged adoption of an ensemble approach for this assessment for some time now, and the SSC has asked that the models associated with Hypothesis 1 be down-weighted, implying that the unweighted average would not be appropriate
- Nevertheless, because the Team has expressed interest in the unweighted average, values for that option are presented as well

Model choice: a pragmatic consideration

- If the weighted average ensemble is chosen as the new base model, the SAFE chapter guidelines require that it be re-run next year
- Doing so may be sufficiently time-consuming that it will be impossible to include any alternatives to the present ensemble in the next assessment
- Some options:
  - Model 19.12 would be another reasonable choice for the new base model, as it has the highest weight and gives results that are very similar to those of the weighted average ensemble
  - If Model 19.11 or 19.12 is chosen as the new base model, the weighted average ensemble maxABC could still be recommended as the ABC, because it is lower than maxABC for either of those models
  - SSC could change the base model in October (precedent in 2008)
  - AFSC could change the SAFE chapter guidelines

Phase plane: weighted average ensemble



Statistics of ABC and OFL distributions

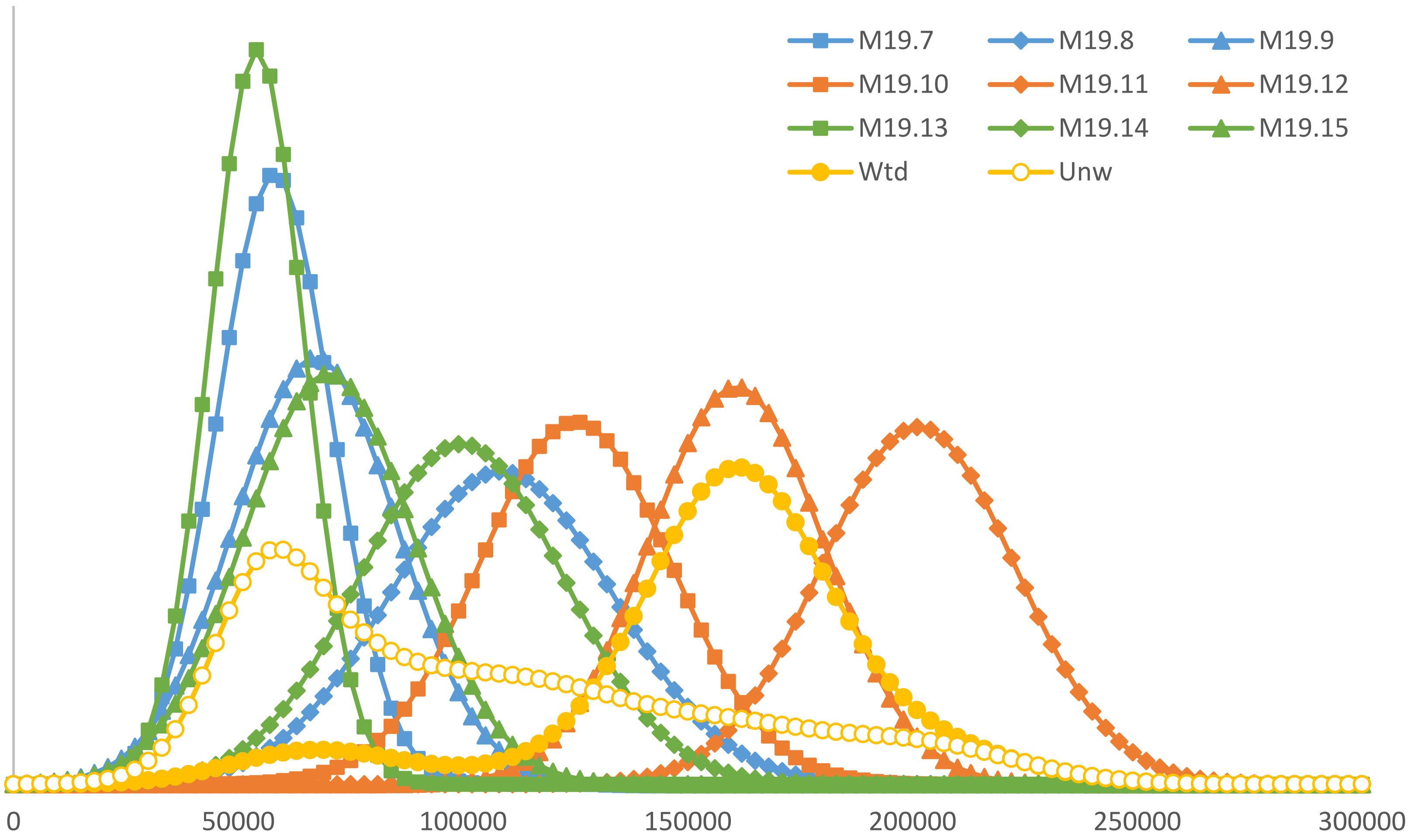
- Means and standard deviations:

			Hypothesis 1			Hypothesis 2			Hypothesis 3			Ensemble	
Year	Quantity	Statistic	M19.7	M19.8	M19.9	M19.10	M19.11	M19.12	M19.13	M19.14	M19.15	Wtd	Unw
2020	ABC	mean	58057	108529	67127	125009	201257	160789	54138	99642	70089	155873	104960
2020	ABC	sdev	12707	24817	18197	21423	21727	19533	10567	22815	18896	36014	51287
2020	OFL	mean	69846	130680	80820	149039	239837	191386	64987	119390	84245	185650	125581
2020	OFL	sdev	15200	29683	21759	25272	26132	23263	12625	27153	22551	42739	60867
2021	ABC	mean	53705	76738	56445	94551	127409	105046	52651	78630	58585	102975	78196
2021	ABC	sdev	7462	9565	13527	9117	25205	18420	6863	10293	10665	24157	28240
2021	OFL	mean	64631	92873	68065	113057	152858	125734	63192	94509	70566	123331	93943
2021	OFL	sdev	13300	22093	22898	19642	30036	29939	11549	21822	19146	34349	36847
2019	Bratio	mean	0.3142	0.4030	0.3168	0.4050	0.5289	0.4543	0.2887	0.3765	0.3302	0.4493	0.3797
2019	Bratio	sdev	0.0310	0.0373	0.0371	0.0371	0.0422	0.0464	0.0276	0.0368	0.0366	0.0639	0.0820

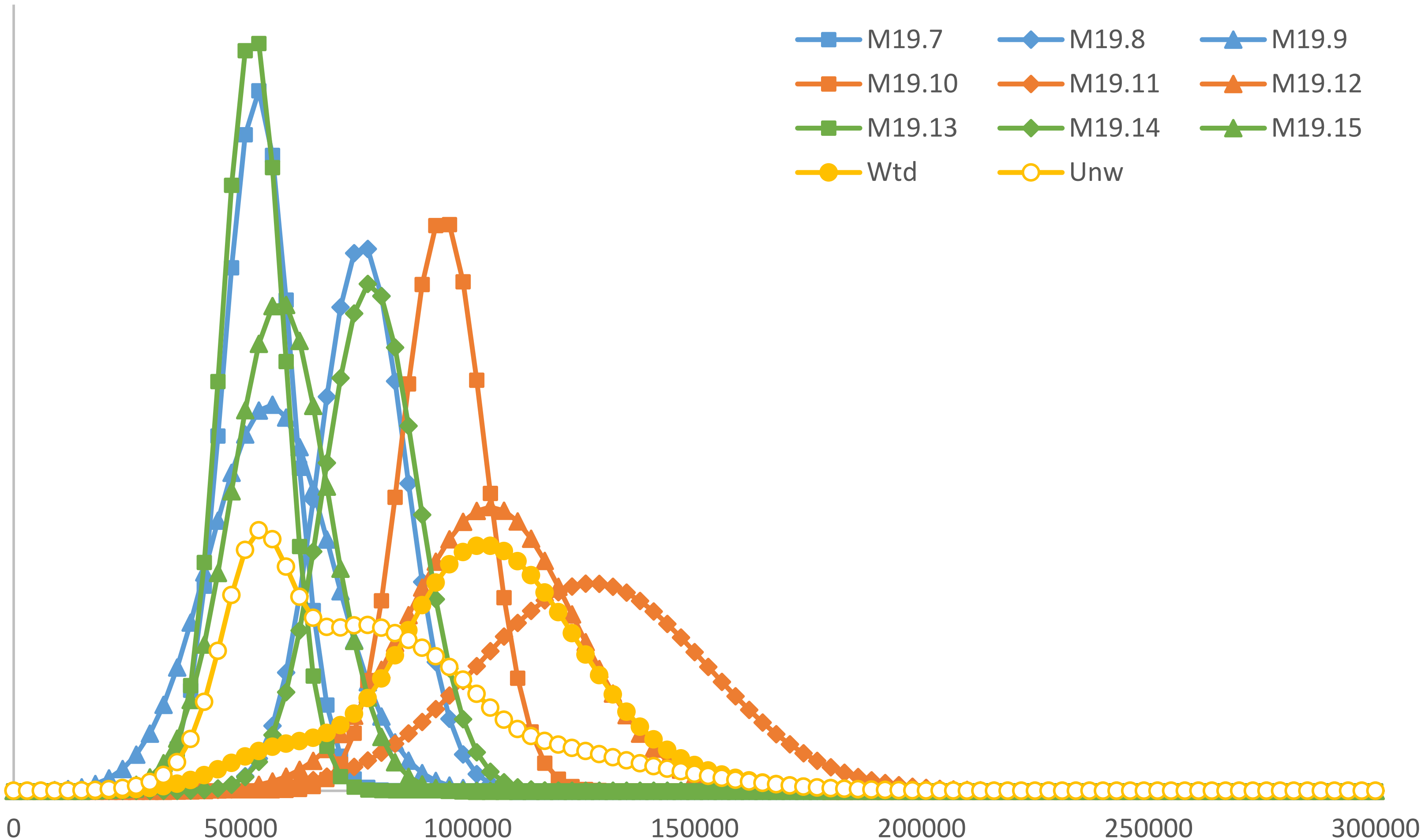
- Ensemble medians:

			Ensemble	
Year	Quantity	Statistic	Wtd	Unw
2020	ABC	median	160089	92537
2020	OFL	median	190547	111117
2021	ABC	median	103721	72996
2021	OFL	median	124182	87024

Constructing the 2020 ABC distribution



Constructing the 2021 ABC distribution



Risk table: environmental/ecosystem

- Summary of Appendix 2.6 (by Elizabeth Siddon):
  - Pacific cod continue to expand their range into the NBS
  - Condition factor is positive in both EBS and NBS
  - However, low abundances of euphausiids were observed in 2018 (MACE acoustic survey) and 2019 (RPA RZA)
  - Effects of cannibalism might be mediated by spatial mismatch between juvenile and adult cod
  - The 2019 gray whale unusual mortality event reflects poor 2018 NBS feeding conditions
  - Shearwater die-off events in 2019 could also reflect feeding conditions in the NBS in 2018
  - The abundance time series for Pacific cod and walleye pollock appear to decouple after 2010, suggesting a shift in drivers of survival
- Environmental/ecosystem considerations were rated as level 2

Risk table: three issues

1. The overall score of level 2 is due entirely to the identification of “some indicators showing adverse signals,” but it seems likely that, given sufficient effort, it would almost always be possible to identify one or more indicators showing adverse signals, and it is not obvious how this is to be reconciled with the SSC’s stated intent that “reductions from the maximum ABC are intended to be an infrequent action to respond to substantial unquantified risk” (SSC minutes, December 2018)
2. It seems odd that the *overall* level is set equal to the *highest* level, implying, for example, that {1,1,1,3} and {3,3,3,3} are equivalent
3. The SSC asked that the “additional” column consider “commercial as well as local/traditional knowledge,” but the risk table makes no mention of the latter

ABC recommendation

- Rather than having each assessment author determine the appropriate reduction in isolation, the SSC has volunteered to take responsibility for determining those reductions
- This seems a preferable course of action, as it should tend to increase consistency across assessments
- Therefore, no reduction is recommended here

Summary table

Quantity	As estimated or *specified last* year for: 2019	2020	As estimated or *recommended this* year for: 2020	2021
M (natural mortality rate)	0.34	0.34	0.35	0.35
Tier	3a	3b	3b	3b
Projected total (age 0+) biomass (t)	824,000	683,000	751,708	716,581
Projected female spawning biomass (t)	290,000	246,000	259,509	211,410
$B_{100\%}$	658,000	658,000	666,506	666,506
$B_{40\%}$	263,000	263,000	266,602	266,602
$B_{35\%}$	230,000	230,000	233,277	233,277
F_{OFL}	0.38	0.35	0.41	0.34
$maxF_{ABC}$	0.31	0.29	0.34	0.28
F_{ABC}	0.31	0.29	0.34	0.28
OFL (t)	216,000	164,000	185,650	123,331
maxABC (t)	181,000	137,000	155,873	102,975
ABC (t)	181,000	137,000	155,873	102,975
Status	As determined *last* year for: 2017	2018	As determined *this* year for: 2018	2019
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No