Assessment of Pacific cod in the eastern Bering Sea

NOAA FISHERIES
Alaska Fisheries Science Center

Grant Thompson and Jim Thorson

November 13, 2019

Team and SSC comments

Comments overview

- 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

Comments on assessments in general

- SSC1: "The SSC requests that all authors fill out the risk table in 2019, and that the PTs provide comment on the author's results in any cases where a reduction to the ABC may be warranted (concern levels 2-4). The author and PT do not have to recommend a specific ABC reduction, but should provide a complete evaluation to allow for the SSC to come up with a recommendation if they should choose not to do so." *Response*: The risk table is included here (see "Risk Table" subsection in the "Harvest Recommendations" section). No specific ABC reduction is recommended, but a complete evaluation is provided in order to allow the SSC to come up with a reduction if it chooses to do so.
- SSC12: "The SSC recommends the authors complete the risk table and note important concerns or issues associated with completing the table." *Response*: As noted in response to SSC1, the risk table is included here. Some concerns and issues associated with completing the table are noted in the subsection where the table appears.

Comments specific to this assessment (1 of 11)

- BPT3: "...a model-based survey time-series be developed that can predict combined abundance of the expanded EBS survey area and the Northern Bering Sea survey area for all years.... Validate the predictions using various methods as well as consistency with observations from other external surveys (e.g., BASIS)." *Response*: As reported in the preliminary assessment, a model-based survey time series for the combined EBS and Northern Bering Sea (NBS) areas, based on the vector autoregressive spatio-temporal (VAST) method developed by Thorson et al. (2015), has been developed. It was used in two of the models presented in the preliminary assessment, and is used in all nine of the new models presented here. While validation of the estimates using comparison for consistency with *other surveys* has not yet been attempted, comparison of the estimates with those obtained under the traditional design-based approach was provided in Figure 2.1.1 and Tables 2.1.1 and 2.1.2 from the preliminary assessment and in Tables 2.8 and 2.9 here.

Comments specific to this assessment (2 of 11)

- BPT5: "...Pacific cod fishery catches and Pacific cod survey data in Russia be researched and summarized." *Response*: A small amount of data on Russian catches of Pacific cod from the Western Bering Sea is reported in a text table in the "Fishery" section.
- BPT8: "...the author considers bringing forward an ensemble of models to capture structural uncertainty with a justifiable weighting as well as a "null" approach with equal weights...." *Response*: An ensemble of models is included here, with results reported for both weighted and unweighted averages.
- BPT9: "...the authors coordinate with Council staff to augment the fishery information section of the assessment for next year. Council staff will be providing a cod allocation review in 2019 and will work with the author to provide pertinent summary sections over the summer." *Response*: The requested augmentation will be included once it has been provided by Council staff.

Comments specific to this assessment (3 of 11)

- BPT11: “The Team recommends that the authors break out the NBS VAST vs empirical in November. (Show separate indices for EBS and NBS using VAST and design-based estimators, along with the combined estimates).” *Response*: Separate EBS and NBS estimates, along with combined EBS and NBS estimates, are provided for the design-based method in Table 2.8 and for the VAST method in Table 2.9.
- BPT12: “The Team recommends that the simple and complex versions of models associated with the 3 developed hypotheses should move forward.” *Response*: See responses to comments SSC13 and SSC15.
- BPT13: “The Team recommends that, if possible, the authors leave out areas of the NBS (for 2017-2019) for cross-validation of VAST models 19.3 and 19.4 and areas of the EBS. Specifically leaving out the northern portion could be valuable, dependent on the time available.” *Response*: Sufficient time was not available to complete the requested exercise. See also response to comment SSC16.

Comments specific to this assessment (4 of 11)

- BPT14: “The Team recommends that the 6 19.X models be brought forward in November and the author choose an ensemble if time allows along with appropriate weighting.” *Response*: Regarding the six models in the 19.x series presented in September, see responses to comments SSC13 and SSC15. An ensemble is chosen here, with appropriate weighting.
- BPT15: “The Team recommends that, if time does not allow, bring back six 19.X models and an equal weighting average may be attempted by the Team during the Plan Team meeting with the set or a subset of the available models (using code developed for SS ensemble averaging developed by Allan Hicks).” *Response*: An option for equal weighting of the models in the proposed ensemble is presented here.

Comments specific to this assessment (5 of 11)

- BPT16: "The Team recommends that the author provide measures of uncertainty for all models so that it would be possible to select ensemble elements and integrate them into a single assessment model."
  Response: Measures of uncertainty associated with all parameter estimates and with some key derived quantities such as spawning biomass, relative spawning biomass, ABC, and OFL are provided for all models as well as for the ensemble (both weighted and unweighted averages).
- BPT17: "The Team recommends that [the authors] present retrospective estimates of specific parameters that show retrospective patterns."
  Response: The retrospective behaviors of the estimates of all time-invariant parameters is summarized in Table 2.23a, and the retrospective behavior of the four time-invariant parameters with the highest median correlation with respect to retrospective "peels" is detailed in Table 2.23b.

Comments specific to this assessment (6 of 11)

- BPT18: “The Team recommends continuing investigation of the CCDA model averaging method, realizing it is unlikely to be implemented this year. The Team is very enthusiastic about this approach. The Team will discuss with the author whether additional input would be useful in further testing and developing the method.” *Response*: Investigation of model averaging by cross-conditional decision analysis will continue, although, as anticipated, it was not possible to implement the method this year.

Comments specific to this assessment (7 of 11)

- SSC13: “The SSC generally supports the PT recommendations to bring forward the six models and hypothesis testing framework for PT and SSC evaluation in November/December. However, the SSC requests that the PT strongly consider not carrying forward hypothesis 1 given many indicators are certainly pointing to strong interaction between the NBS and EBS....” *Response*: This request consists of two parts, which could be viewed as inconsistent. The first is to “bring forward” the models presented in the preliminary assessment, including those associated with Hypothesis 1 (in which the NBS survey data are ignored). The second involves “not carrying forward” the models associated with Hypothesis 1. In an attempt to reconcile these parts, models associated with Hypothesis 1 are included in the ensemble but given very little weight (see Table 2.22 and Figure 2.14).

Comments specific to this assessment (8 of 11)

- SSC14: "The GPT suggested that Mohn's rho may not be a useful statistic given the different hypotheses and data. The SSC disagrees with this statement because one of the main reasons retrospective analysis is conducted is to identify model misspecification, of which ignoring population closure is an important one. Thus, the SSC is concerned about the high values of Mohn's rho in some of the proposed set of models." *Response*: Both the Team and the SSC requested that the six models from the preliminary assessment be included in the final assessment (see comments BPT12, BPT14, and SSC13), but five of those models were associated with extremely high values of ρ, which would appear to render them unacceptable to the SSC. The only new model from the preliminary assessment that was not associated with an extremely high value of ρ was one of the models associated with Hypothesis 1, which, given comment SSC13, would appear to render it unacceptable to the SSC. See also response to comment SSC15.

Comments specific to this assessment (9 of 11)

- SSC15: "The SSC suggests that the 'simple model' should only compare the three biological hypotheses with the accepted model (but with the VAST estimated indices) and allow the 'complex models' to incorporate the additional structural and statistical changes of interest. Thus, at the authors' discretion, models that are similar to 16.6i from last year that use the VAST indices testing the three biological hypotheses could be substituted for models 19.1, 19.3, 19.5 and would be preferable to the SSC. However, if time constraints only permit fewer models, a model that only examines hypothesis 2 (combined EBS and NBS) that is the same as model 16.6i with the VAST estimates would be satisfactory as well." *Response*: The 3 new requested models are included here. They were not substituted for the "simple" models, however, in an attempt to satisfy the various requests for inclusion of those models (see comments BPT12, BPT14, SSC13, and SSC14). Nevertheless, with comment SSC14 also in mind, one or two adjustments to both the "simple" and "complex" models were made in order to keep ρ within acceptable levels.

Comments specific to this assessment (10 of 11)

- SSC16: "The GPT suggested that cross validating the VAST results by selectively removing different strata from the data and considering the results would be a useful exercise to test the model's ability to fill in missing data would be a useful exercise. The SSC agrees with this recommendation, but we do suggest that this may not be in the purview of the assessment author, but better suited for the survey analysis team." *Response*: In light of this recommendation (with time limitations also a factor), comment BPT13 will be left for the survey analysis team to address.

Comments specific to this assessment (11 of 11)

- SSC17: [The senior author] “requested that the SSC affirm their general statements on how the EBS Pacific cod should proceed in terms of modeling guidelines, including such things as avoiding ‘complexity creep’ and the SSC reiterates their recommendations which spanned between 2013 and the present.” *Response*: As a minor clarification, the senior author did not “request that the SSC affirm” the model evaluation criteria; rather, he asked, “Should last year’s model evaluation criteria ... be modified and, if so, how?” Given the SSC’s response, last year’s four model evaluation criteria are retained here (although not given equal emphasis), along with five others (see Table 2.22 and Figure 2.14).
- SSC18: “Finally, the SSC remains concerned about doing ensemble ‘on the fly’ during the Plan Team. Time allowing, the SSC requests the authors bring forward an ensemble set for the PT to evaluate. However, should the PT do an ensemble analysis, the SSC recommends they use the standardized code that the Plan Team discussed to work from.” *Response*: An ensemble is brought forward here.

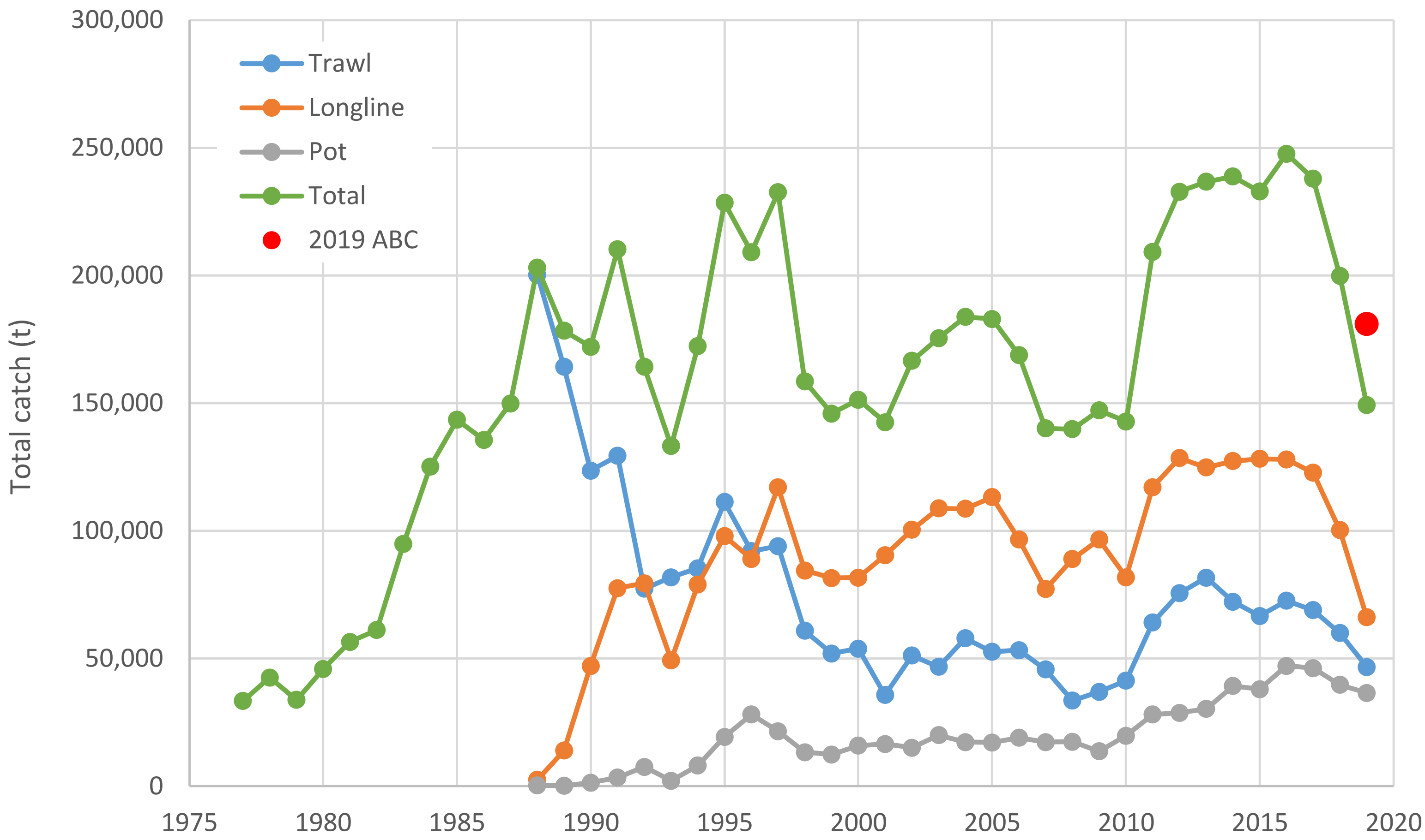
Data highlights

Economic performance report (Appendix 2.2)

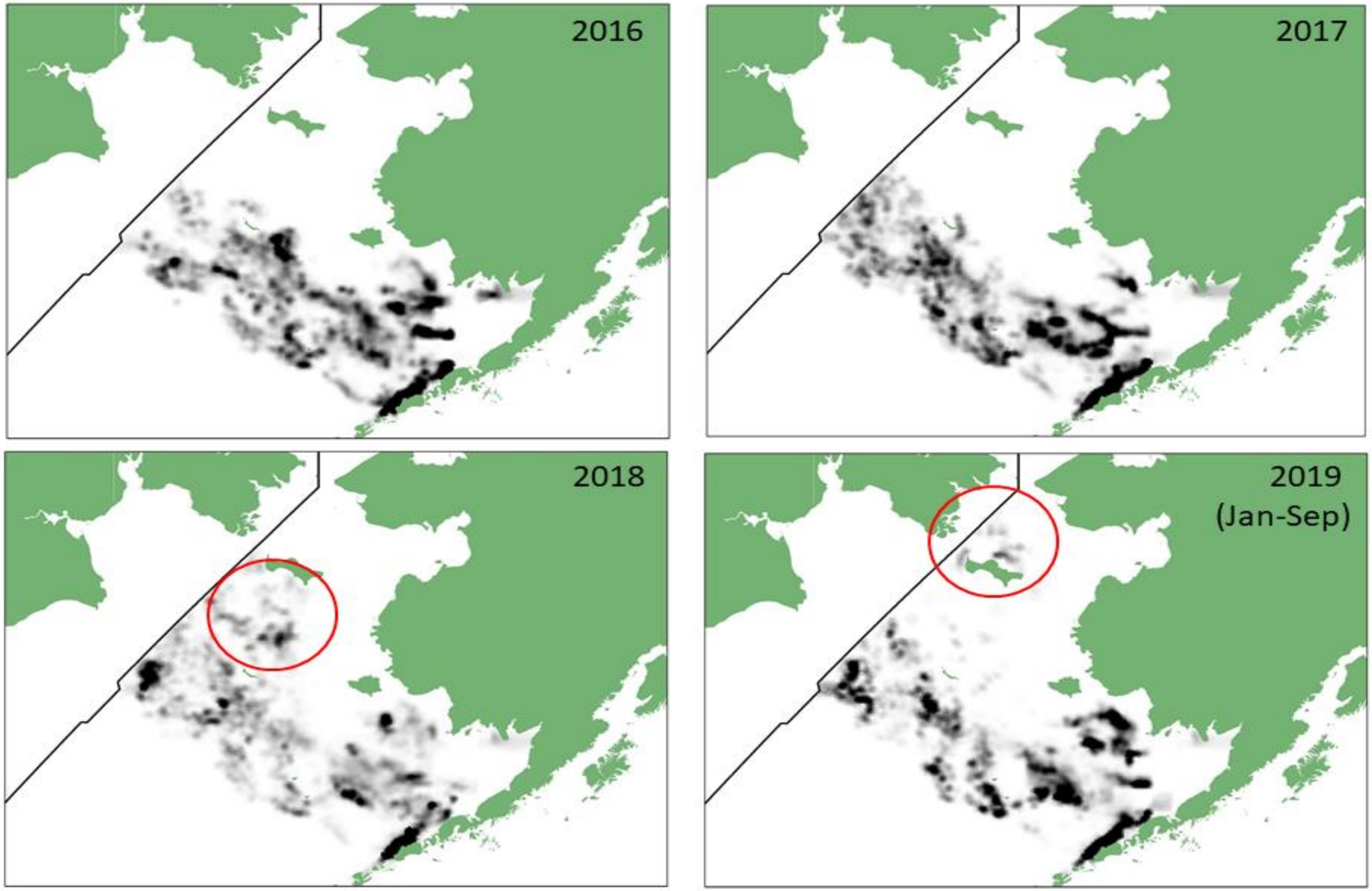
	Avg 09-13	2014	2015	2016	2017	2018
Total catch K mt	213.82	249.3	242.1	260.9	253.1	220.3
Retained catch K mt	209.8	244.5	239.0	257.7	250.1	218.0
Vessels #	171.2	156	149	162	170	190
CP H&L share of BSAI catch	53%	50%	54%	49%	50%	46%
CP trawl share of BSAI catch	16%	14%	15%	14%	13%	14%
Shoreside retained catch K mt	60.1	79.1	68.4	86.0	88.0	82.5
Shoreside catcher vessels #	117.2	109	100	110	125	141
CV pot gear share of BSAI catch	10%	14%	13%	15%	17%	19%
CV trawl share of BSAI catch	18%	17%	16%	18%	18%	18%
Shoreside ex-vessel value M $	$33.1	$44.8	$34.1	$44.6	$54.1	$65.1
Shoreside ex-vessel price lb $	$0.250	$0.274	$0.248	$0.264	$0.316	$0.399
Shoreside fixed gear ex-vessel price premium	$0.05	$0.03	$0.03	$0.03	$0.04	$0.03

Total catch

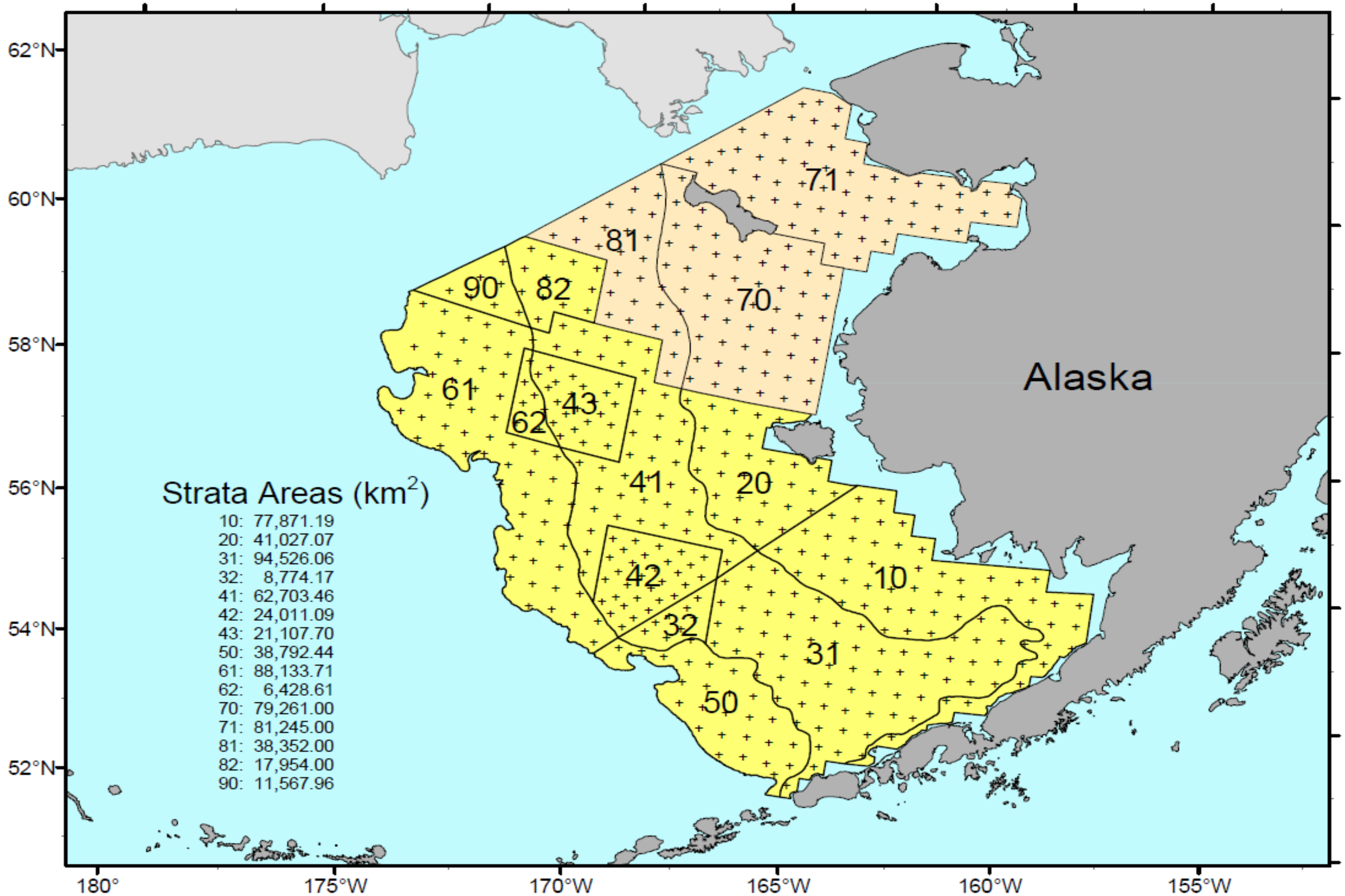
- 2019 current through October 27



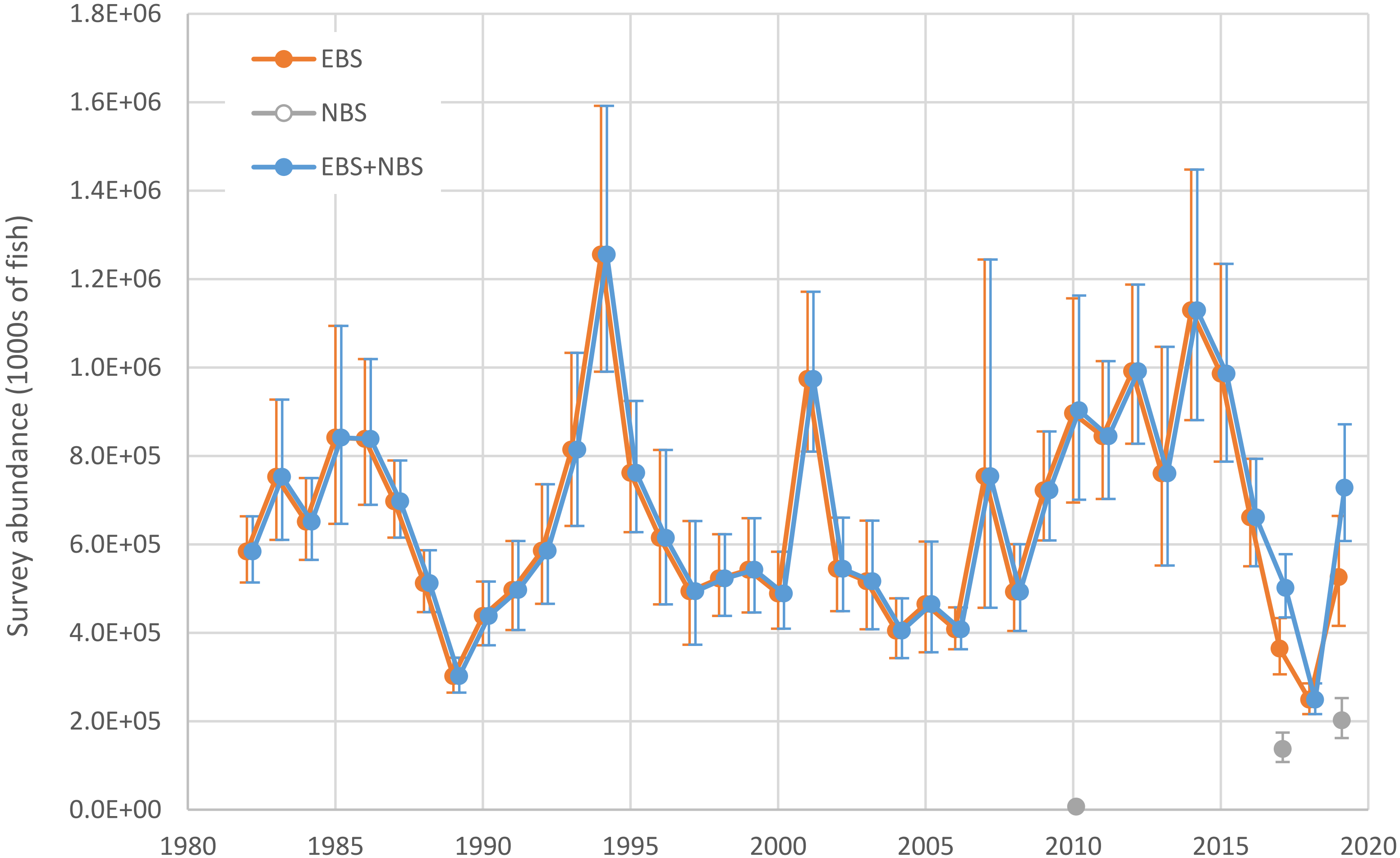
Spatial distribution of observed catch 2016-19



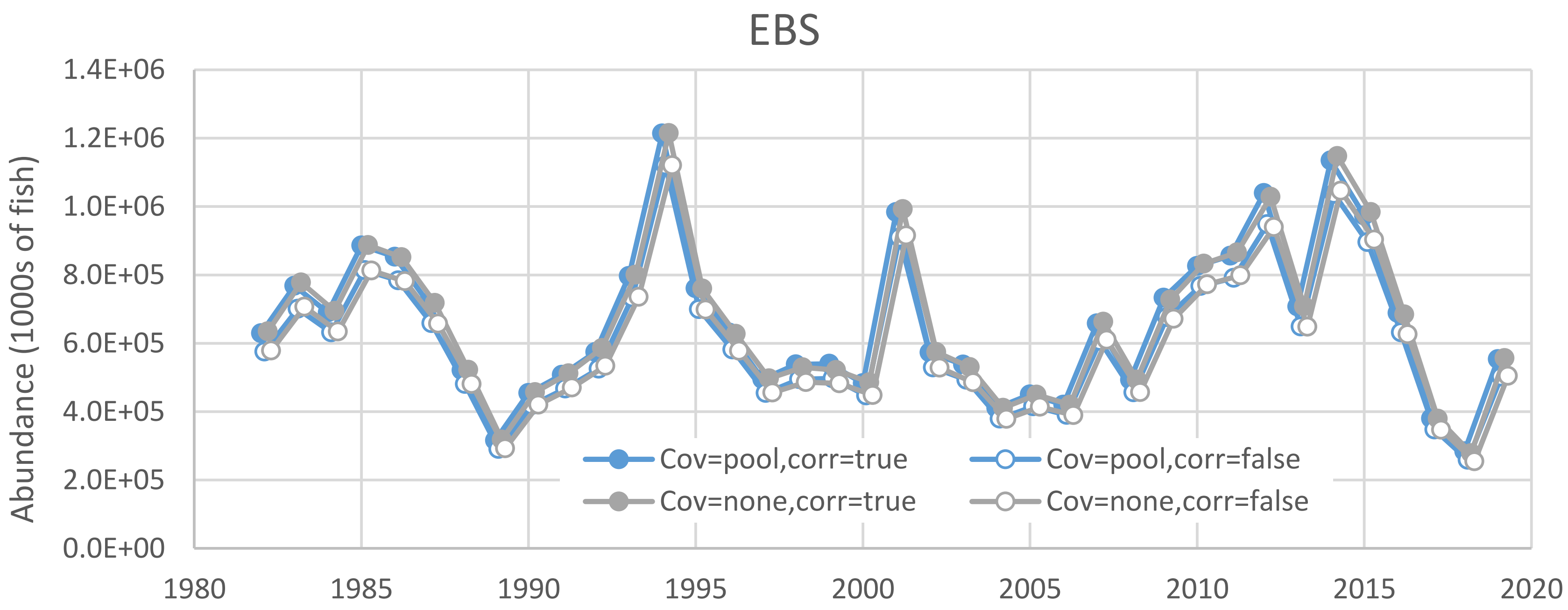
Map of bottom trawl survey areas



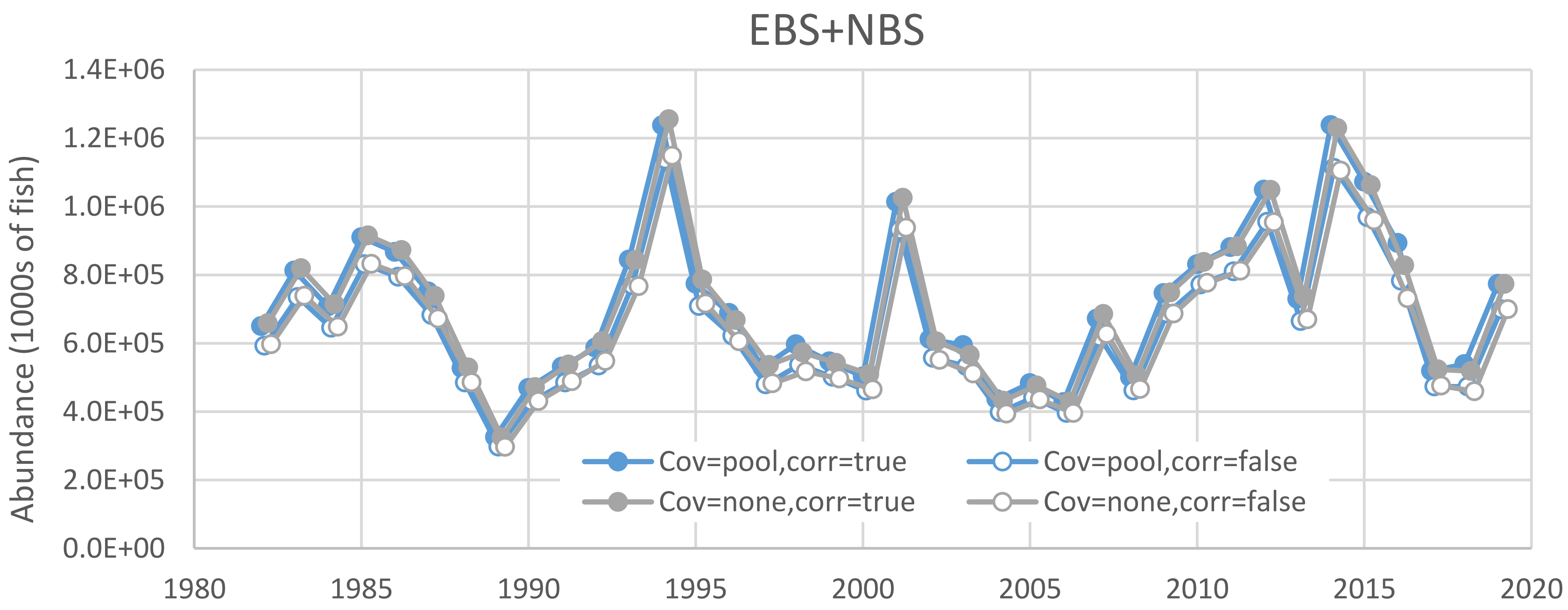
Trawl survey abundance (design-based)



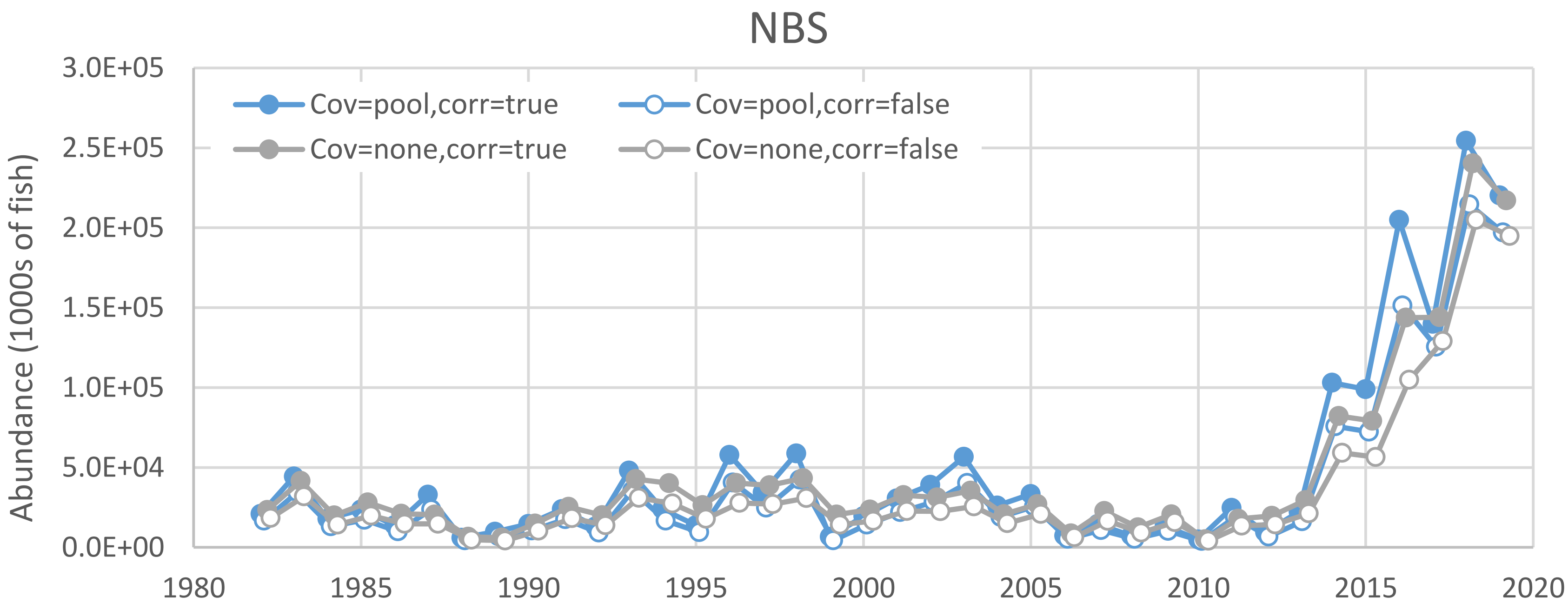
Trawl survey abundance (VAST, 1 of 4)



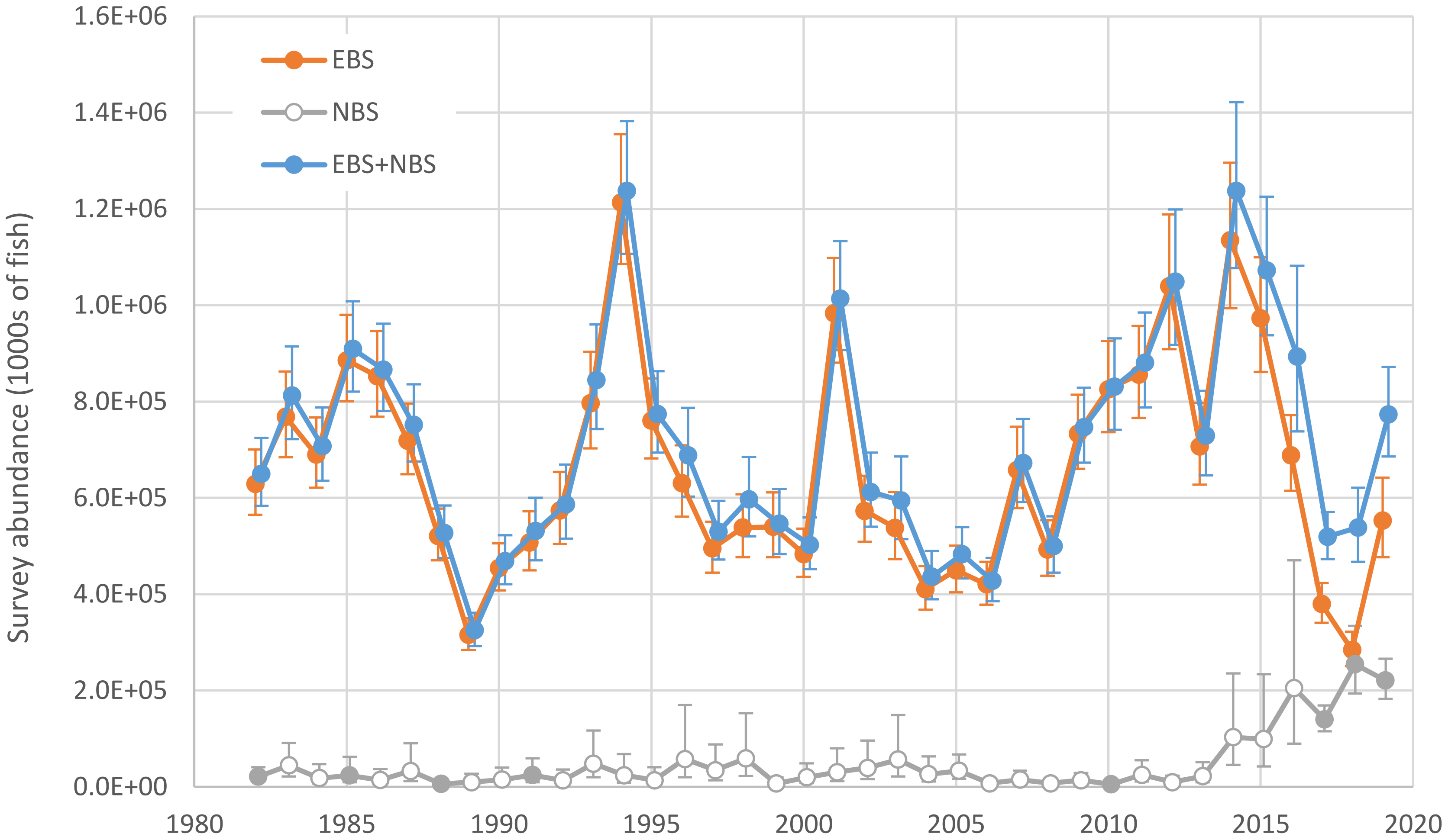
Trawl survey abundance (VAST, 2 of 4)



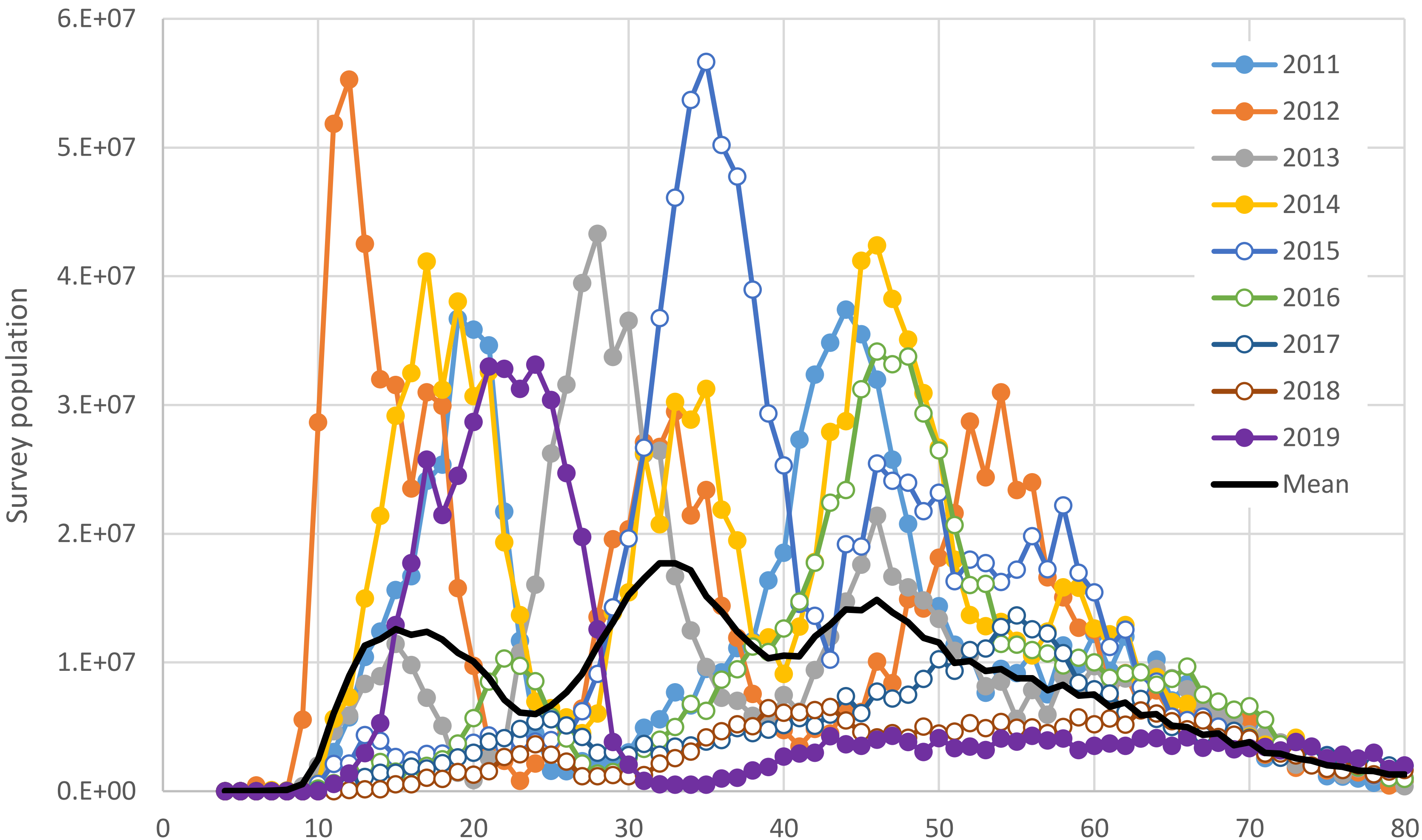
Trawl survey abundance (VAST, 3 of 4)



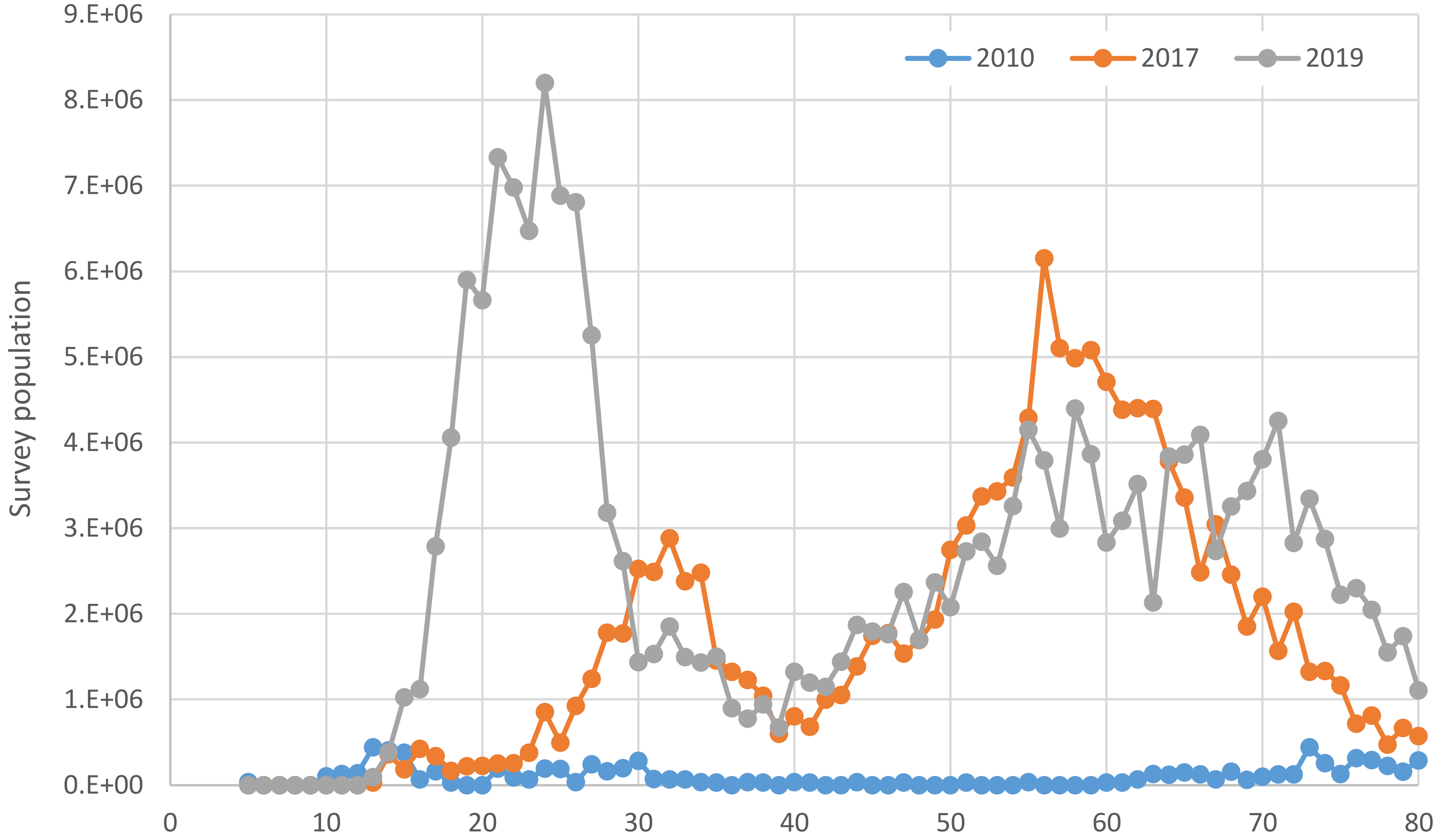
Trawl survey abundance (VAST, 4 of 4)



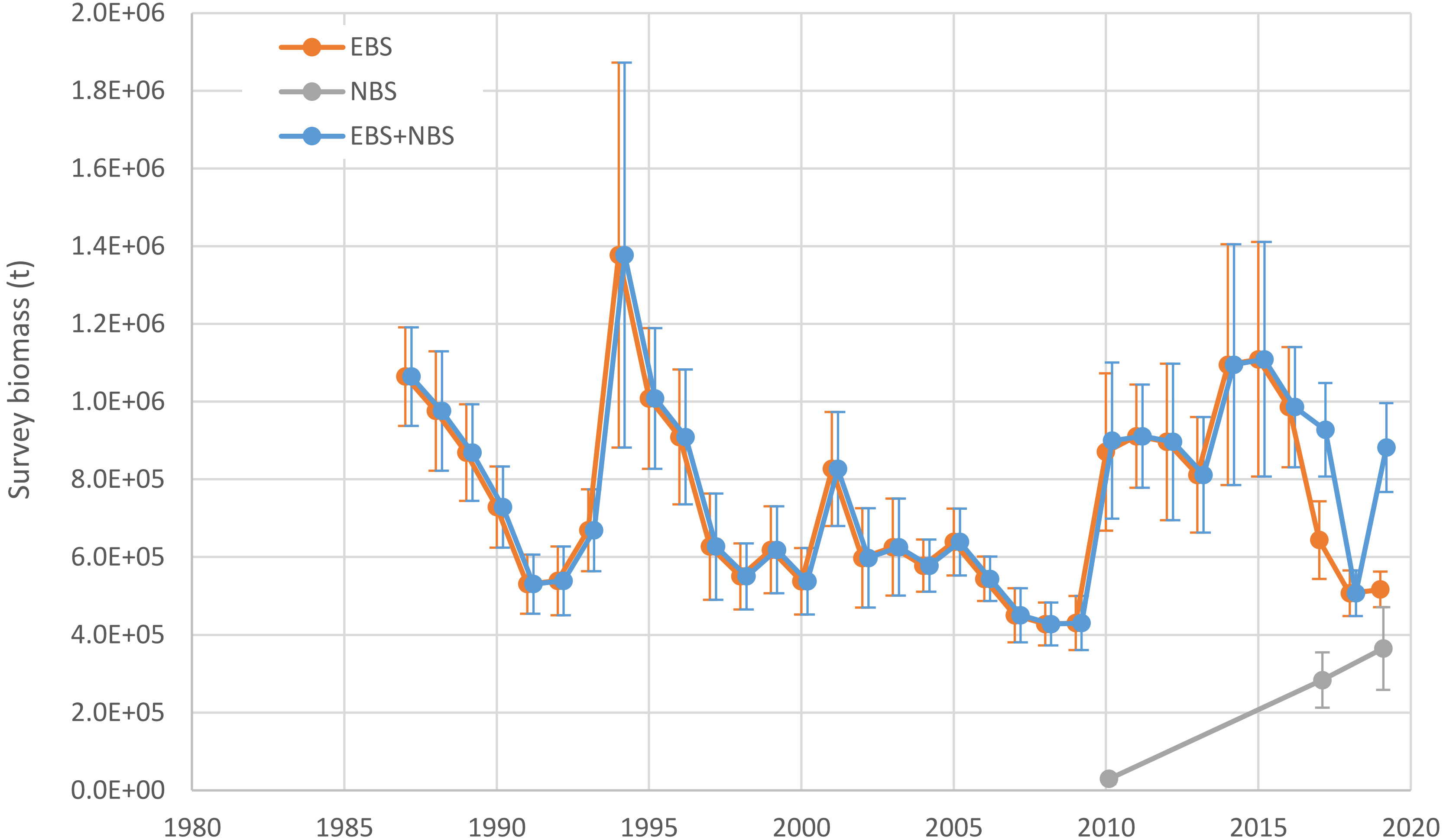
Recent survey sizecomps, to 80 cm (EBS)



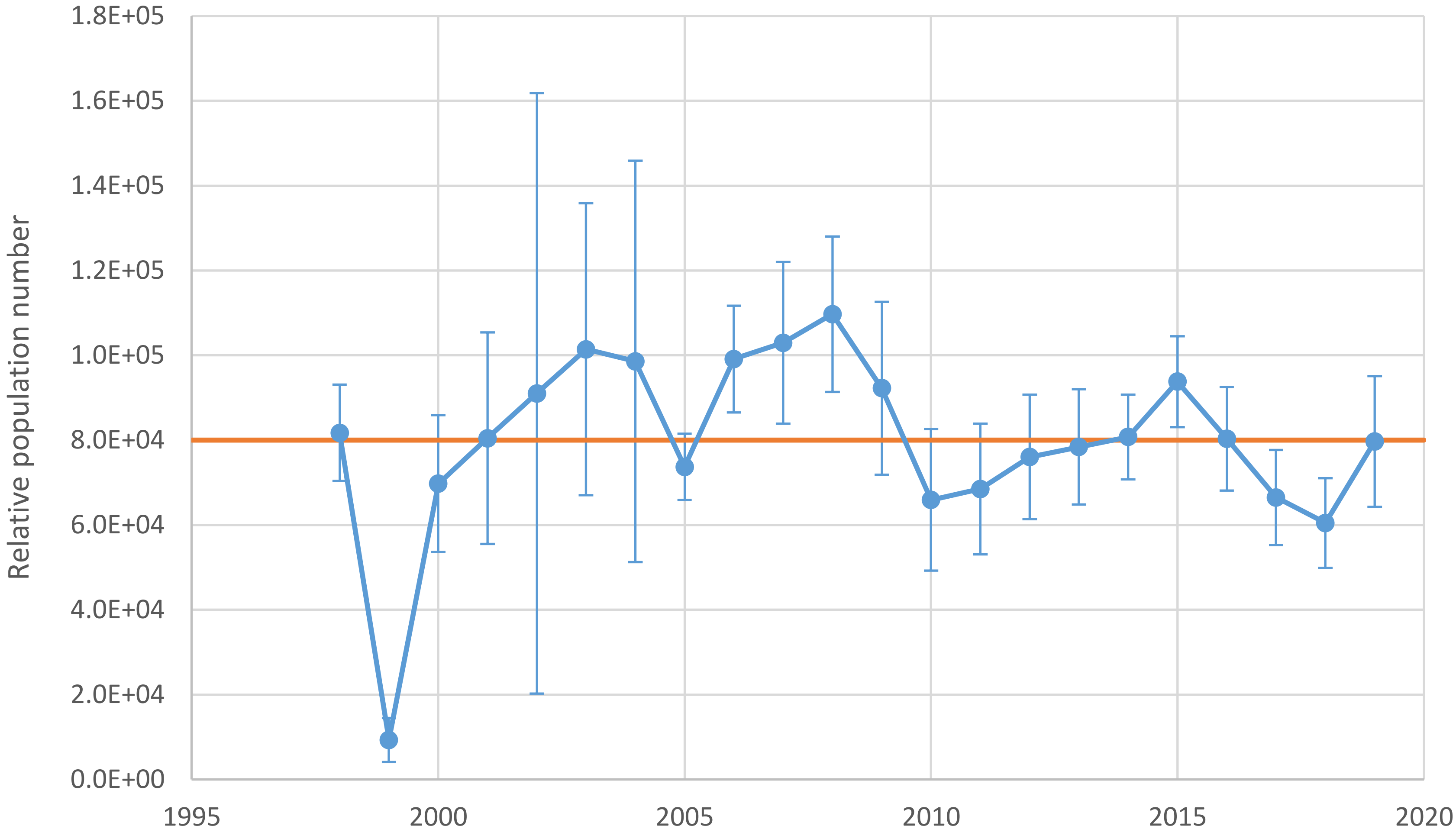
Recent survey sizecomps, to 80 cm (NBS)



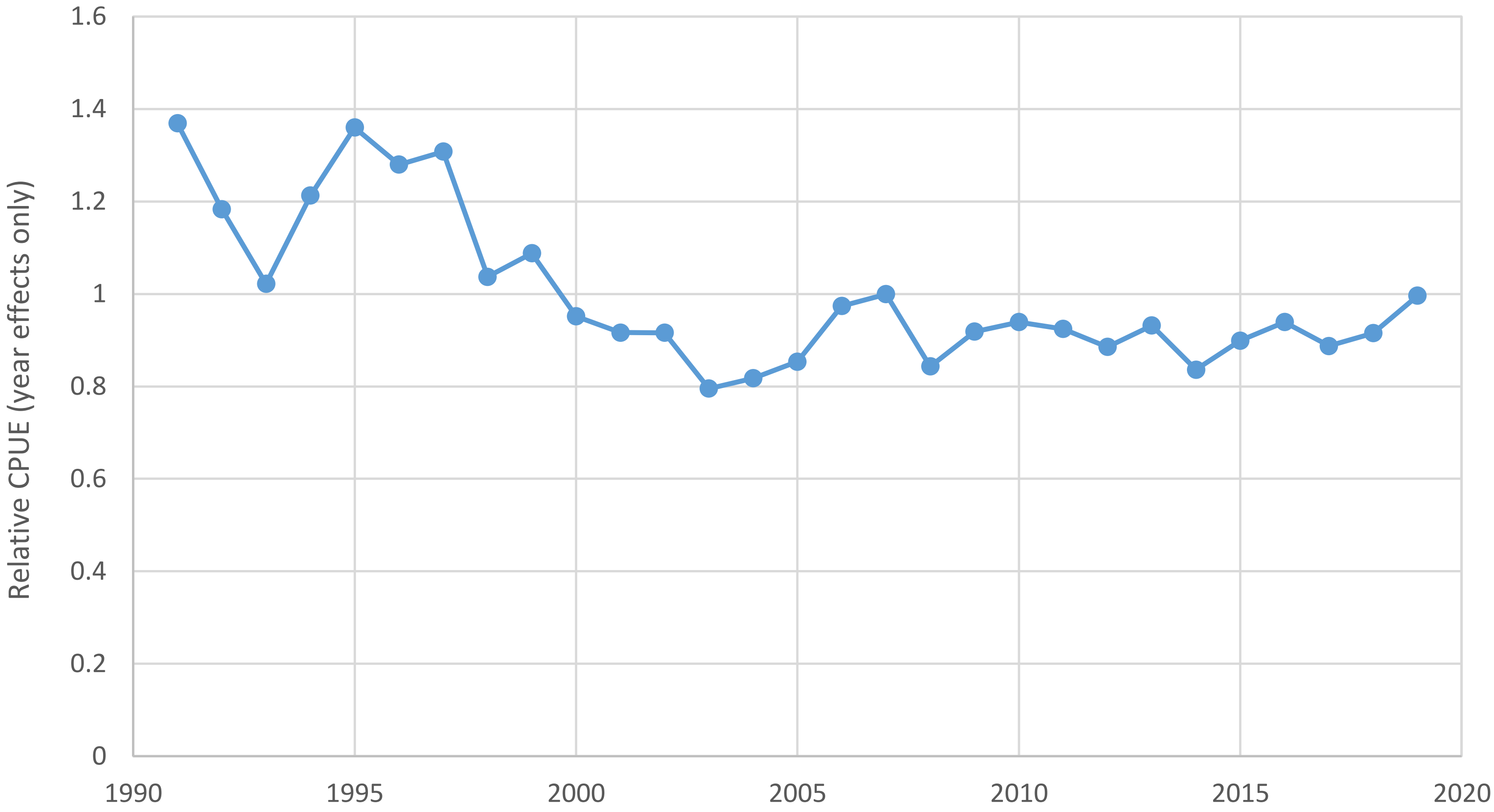
Other indices: survey biomass (design-based)



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 models in September

- 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 September (1 of 3)

- The first (smaller) set of structural changes was as follows:
  - Set input sample size for compositional data equal to the number of hauls, rescaled to an average of 300 for each component (Model 16.6i sets input sample size equal to the number of *observations*, rescaled to an average of 300 for each component).
  - Include the available fishery age composition data (Model 16.6i ignores those data).
  - Use age-based, double-normal selectivity, potentially dome-shaped for the fishery but forced asymptotic for the survey (Model 16.6i uses age-based, logistic selectivity for both fleets).
  - Tune the input standard deviation of log-scale recruitment deviations (σ_R) to match the square root of the variance of the estimates plus the sum of the estimates' variances (Methot and Taylor 2011; Model 16.6i estimates σ_R internally).
  - Use size-based maturity (Model 16.6i uses age-based maturity).

Changes from base model in September (2 of 3)

- The second (larger) set of structural changes was as follows:
  - Set input sample size for compositional data equal to raw number of hauls rather (than rescaled to an average of 300)
  - Reweight compositional data internally using the Dirichlet-multinomial distribution (Thorson et al. 2017; see also Discussion)
  - Use size-based double-normal selectivity rather than age-based (but keeping the assumption of asymptotic survey selectivity)
  - Allow mean ageing bias at ages 1 and 20 to differ between the pre-2008 and post-2007 periods in order to compensate for an apparent change in ageing criteria (Beth Matta, AFSC, pers. comm., 6/27/19)
  - Allow yearly variation in survey selectivity (two parameters), with the input standard deviation of the deviations tuned to set the variance of the estimates plus the sum of the estimates’ variances equal to unity
  - (continued on next slide)

Changes from base model in September (3 of 3)

- The second (larger) set of structural changes (continued):
  - Allow yearly random variation in survey catchability, with the input standard deviation of the deviations tuned to set the variance of the estimates plus the sum of the estimates' variances equal to unity
  - Allow yearly random variation in mean length at age 1.5, with the input standard deviation of the deviations tuned to set the variance of the estimates plus the sum of the estimates' variances equal to unity, in order to address the significant amount of time-variability in growth documented by Puerta et al. (2019)
  - Allow yearly random variation in fishery selectivity (three parameters), with the input standard deviation of the deviations tuned to set the variance of the estimates plus the sum of the estimates' variances equal to unity

Resulting set of models in September

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 November

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 and SSC co-chairs and rapporteurs

Estimated parameters (1 of 3)

- 80 parameters were estimated inside SS for Model 16.6i:
  - instantaneous natural mortality rate (M)
  - 3 von Bertalanffy growth parameters, plus Richards growth parameter
  - standard deviation of length at ages 1 and 20
  - mean ageing bias at ages 1 and 20
  - log mean recruitment since the 1976-1977 regime shift
  - offset for log-scale mean recruits before the 1976-1977 regime shift
  - standard deviation of the log-scale recruitment deviations (σ_R)
  - initial (equilibrium) fishing mortality
  - log catchability for the trawl survey
  - deviations for log-scale initial (i.e., 1977) abundance, ages 1-20
  - log-scale recruitment deviations, 1977-2018
  - base values of both selectivity parameters for fishery and survey

Estimated parameters (2 of 3)

- The three new models with “basic” model structure (M19.7, M19.10, and M19.13) estimate the same set of parameters as the base model, except that:
  - M19.13 also estimates catchability and two selectivity parameters for the NBS bottom trawl survey
- The three new models with “simple” model structure (M19.8, M19.11, and M19.14) each estimate two parameters in addition to their respective “basic” counterparts:
  - Representing the more flexible form of the fishery selectivity curve
  - Note that the definitions of the selectivity parameters also differ between the “basic” and “simple” models, owing to the difference in functional form

Estimated parameters (3 of 3)

- The three new models with "complex" model structure (M19.9, M19.12, and M19.15) each estimate the same parameters as their respective "simple" counterparts, except that:
  - 2 additional ageing bias parameters are also estimated (to allow for the change in ageing criteria that occurred in 2008)
  - 1 fewer fishery selectivity parameter (top width) is estimated, as it always ended up being bound low and so was fixed at a low value
  - 3 parameters representing the Dirichlet weights are also estimated
  - an additional 247 constrained deviations for length at age 1.5, three fishery selectivity parameters, two survey selectivity parameters, and survey catchability are also estimated, except that:
    - an additional 40 constrained deviations for NBS survey catchability are also estimated for Model 19.15
    - but only 8 of those are fit to data (others are constrained $N(0,1)$)

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

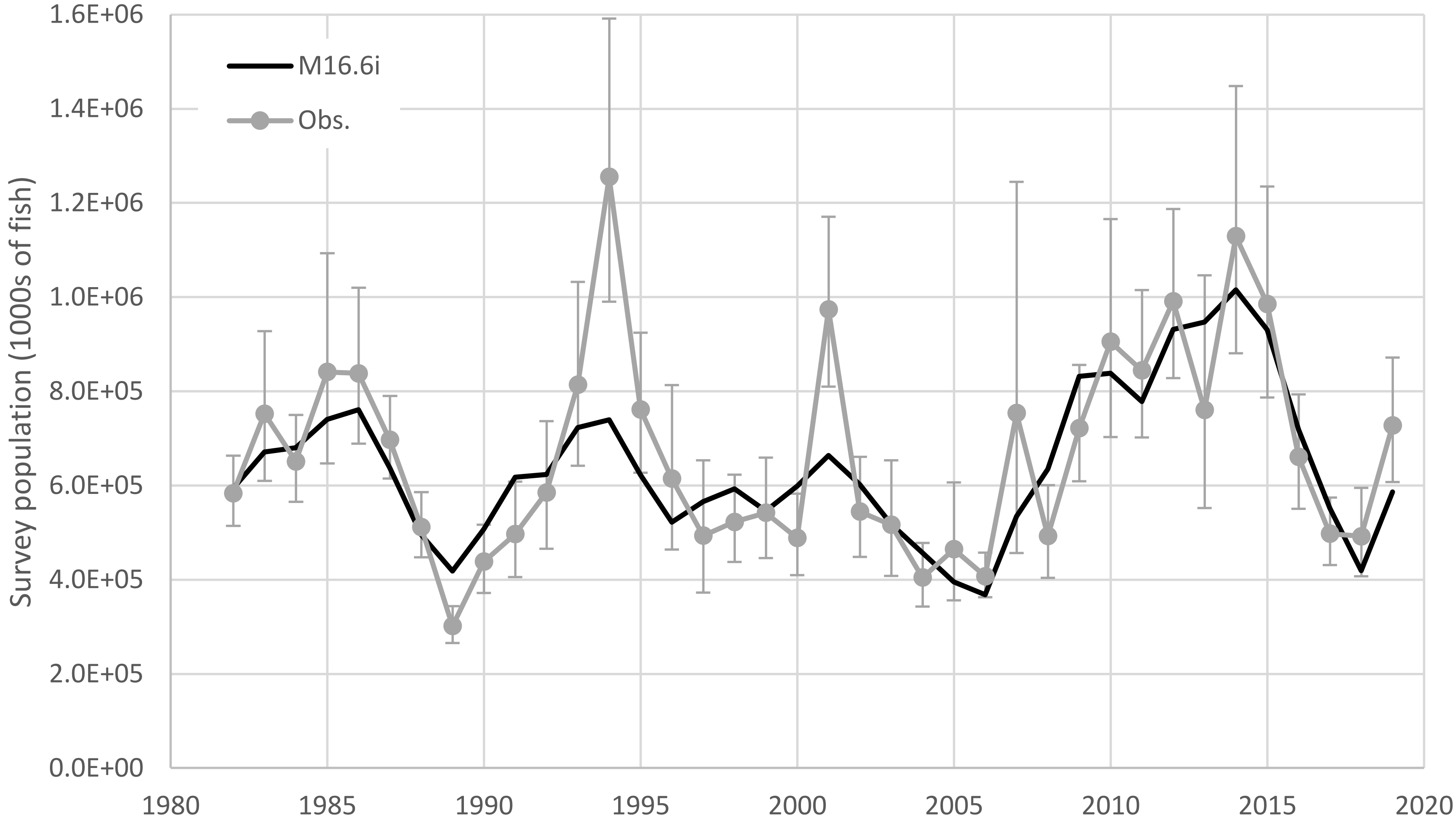
EBS+NBS (VAST)

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

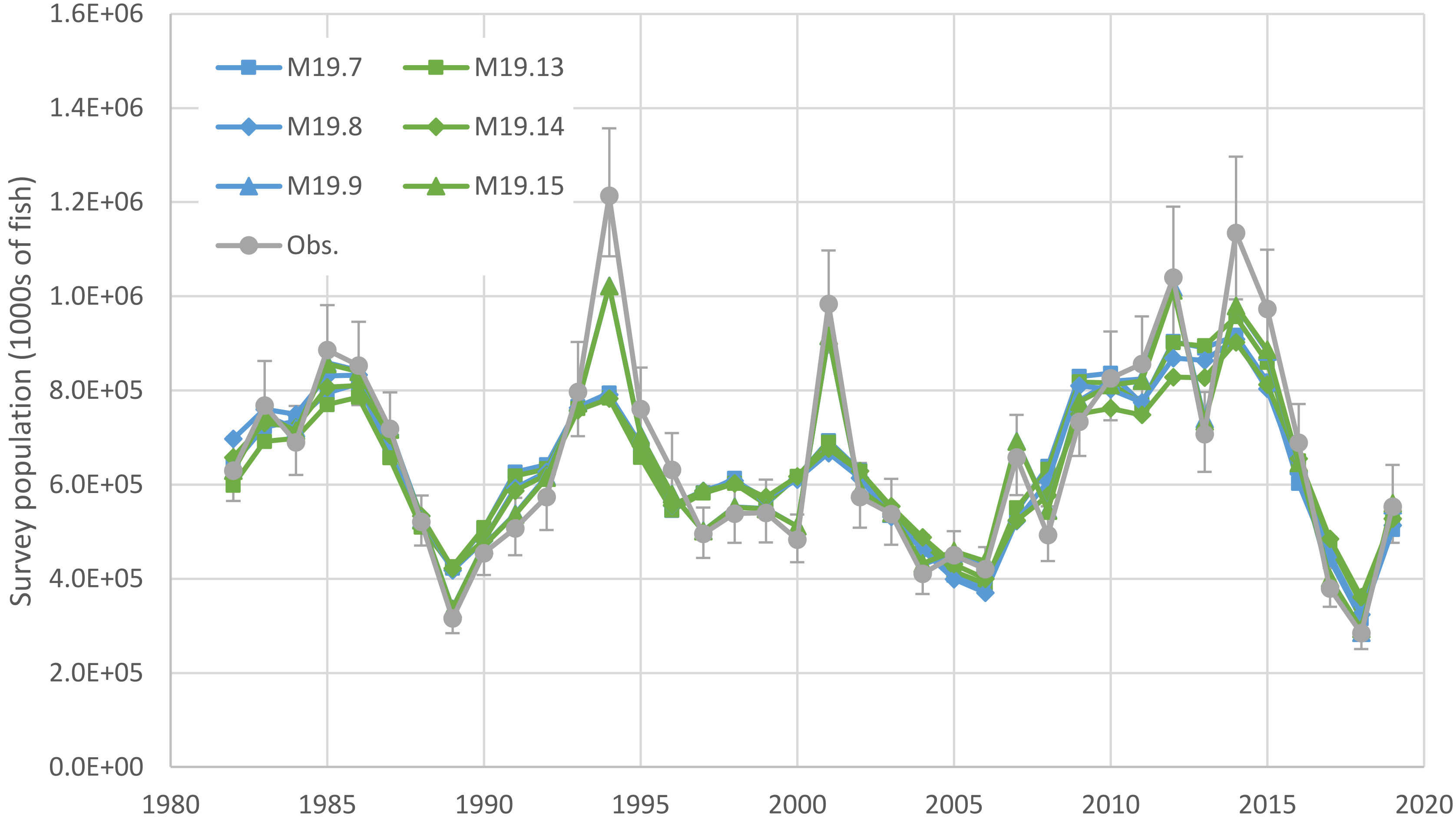
NBS only (VAST)

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

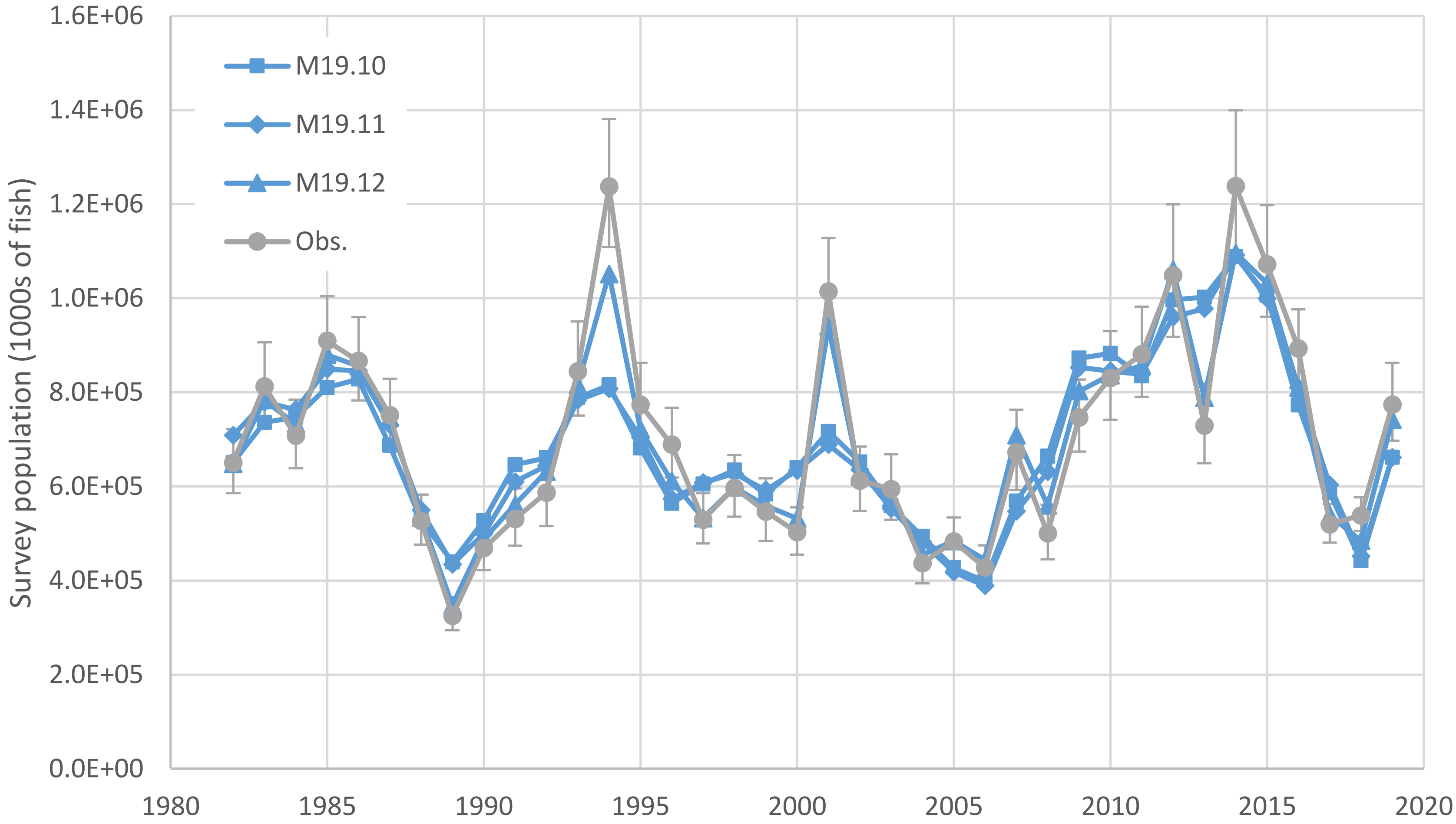
Fit to survey index: EBS+NBS, design-based



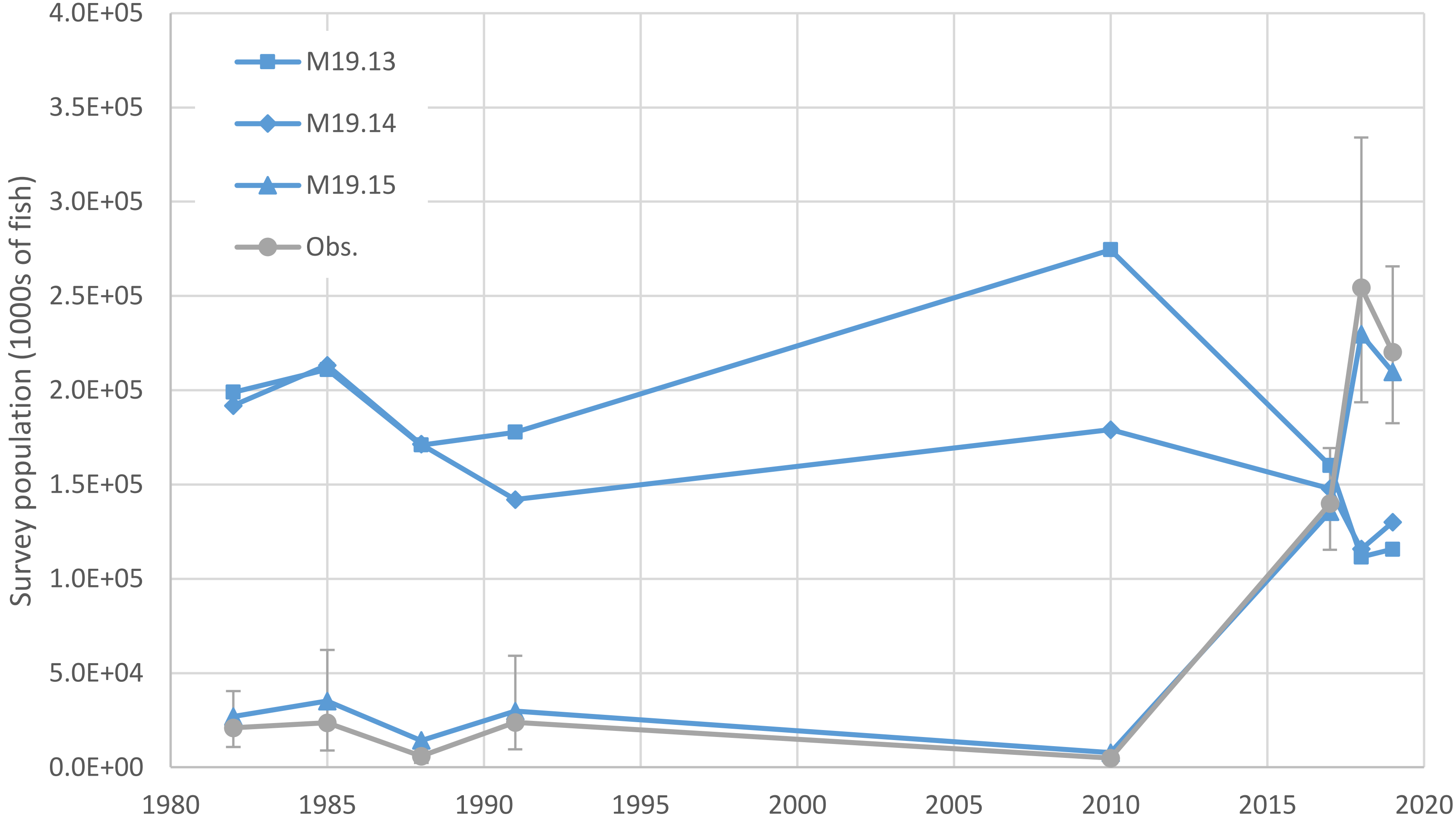
Fit to survey index: EBS only (VAST)



Fit to survey index: EBS+NBS (VAST)



Fit to survey index: NBS (VAST)

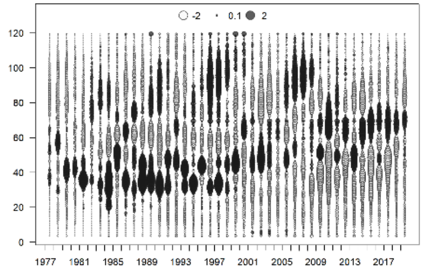


Fit to sizecomps and agecomps: effective *N*

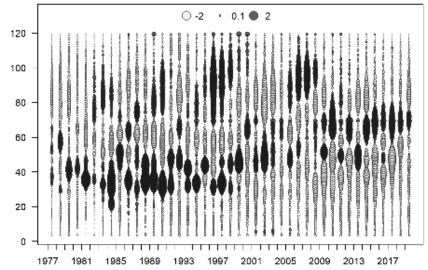
		Size composition data					Age composition data				
			McAllister-Ianelli		Thorson et al.			McAllister-Ianelli		Thorson et al.	
Model	Fleet	Nave	Neff	Ratio	Theta	Neff	Nave	Neff	Ratio	Theta	Neff
M16.6i	Fishery	300	581	1.937							
	EBS survey						300	60	0.199		
	EBS+NBS survey	300	282	0.940							
M19.7	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

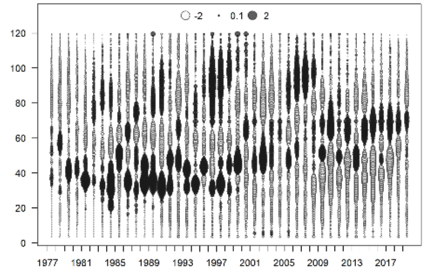
Model 16.6i



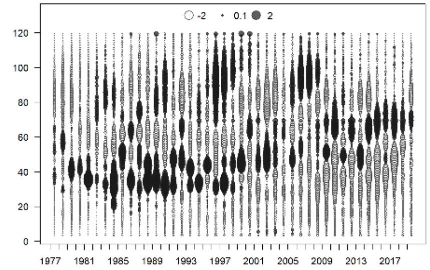
Model 19.7



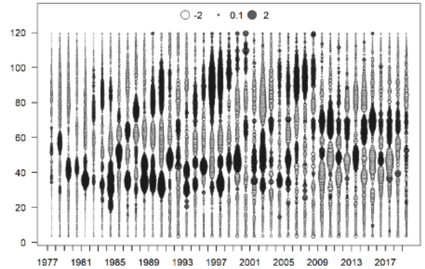
Model 19.10



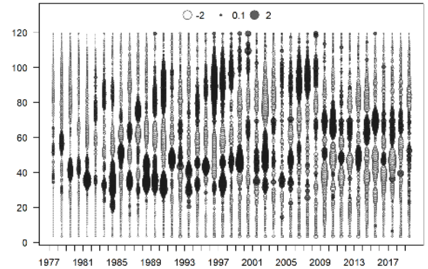
Model 19.13



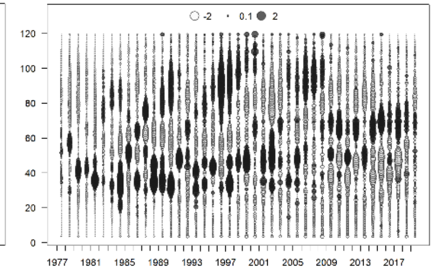
Model 19.8



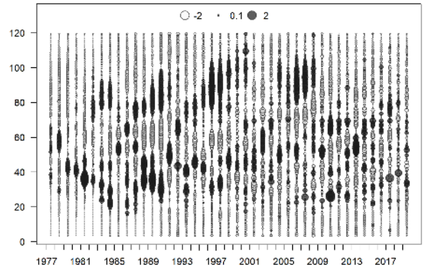
Model 19.11



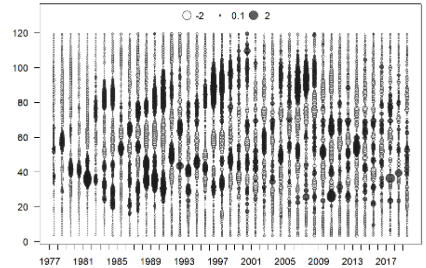
Model 19.14



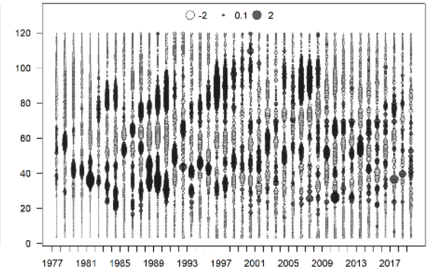
Model 19.9



Model 19.12

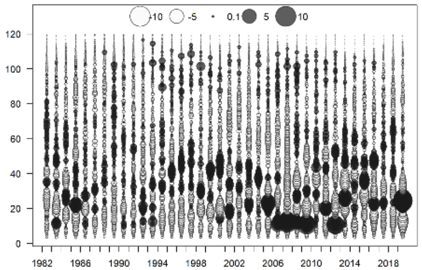


Model 19.15

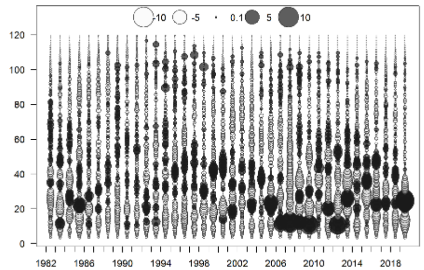


Fit to sizecomps: survey (EBS, EBS+NBS)

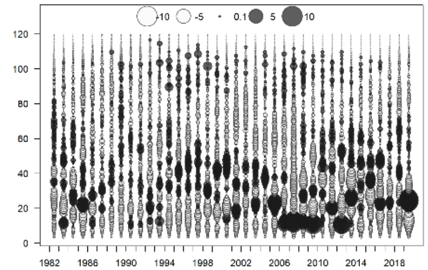
Model 16.6i



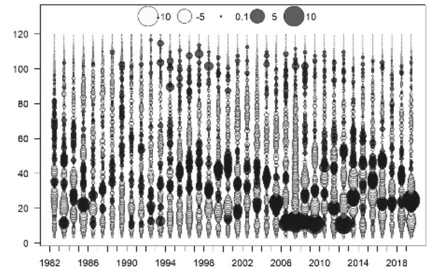
Model 19.7



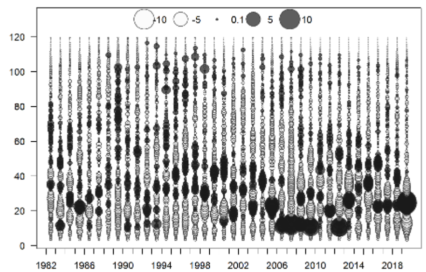
Model 19.10



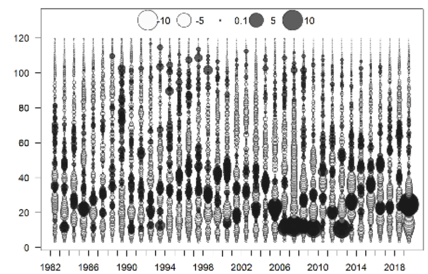
Model 19.13



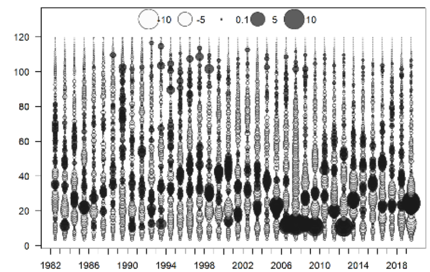
Model 19.8



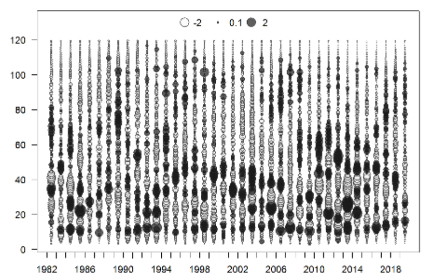
Model 19.11



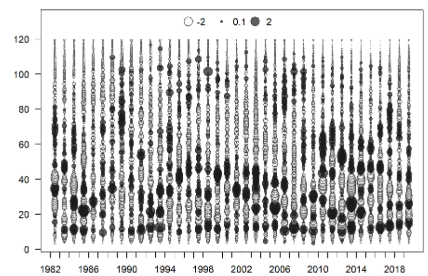
Model 19.14



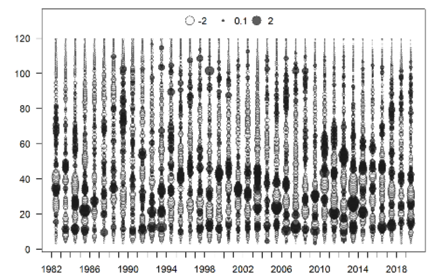
Model 19.9



Model 19.12

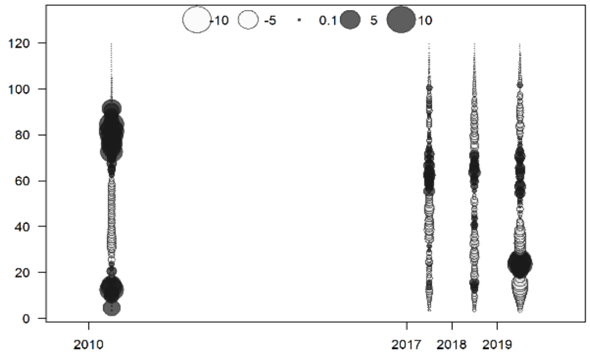


Model 19.15

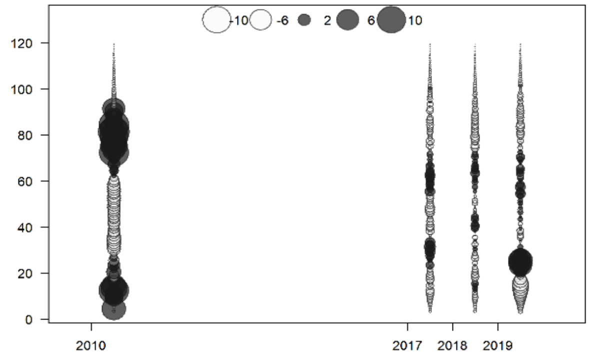


Fit to sizecomps: survey (NBS)

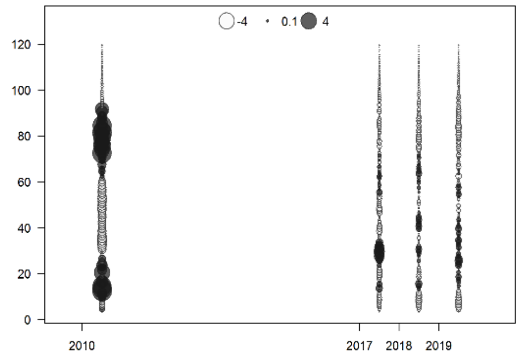
Model 19.13



Model 19.14

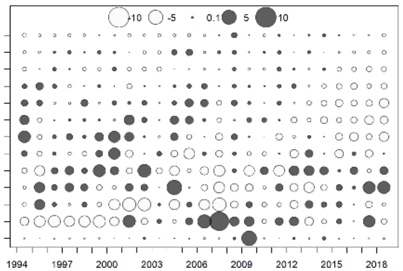


Model 19.15

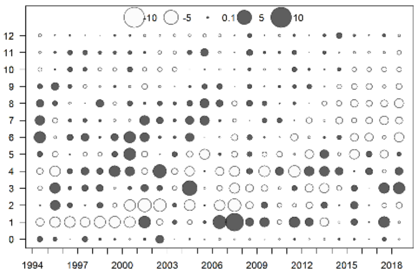


Fit to agecomps

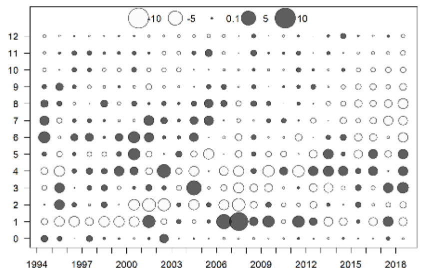
Model 16.6i



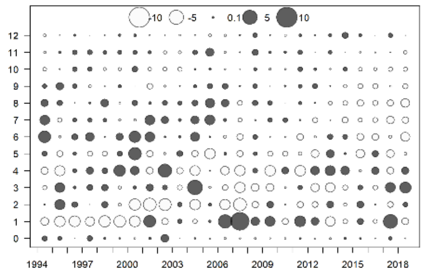
Model 19.7



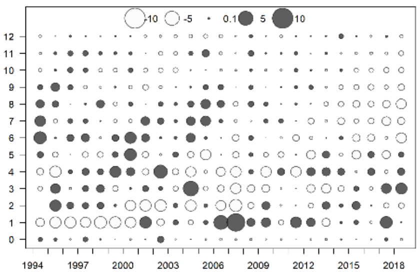
Model 19.10



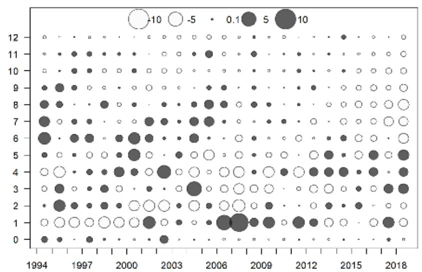
Model 19.13



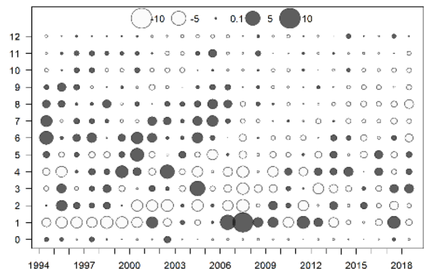
Model 19.8



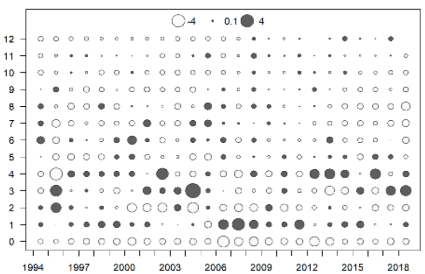
Model 19.11



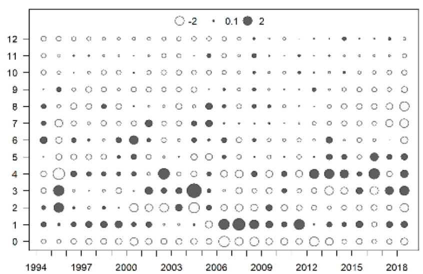
Model 19.14



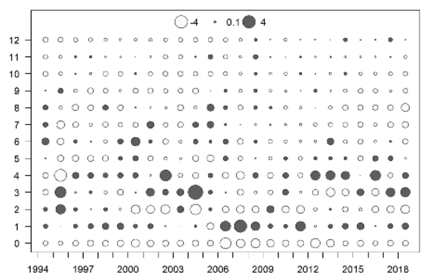
Model 19.9



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)

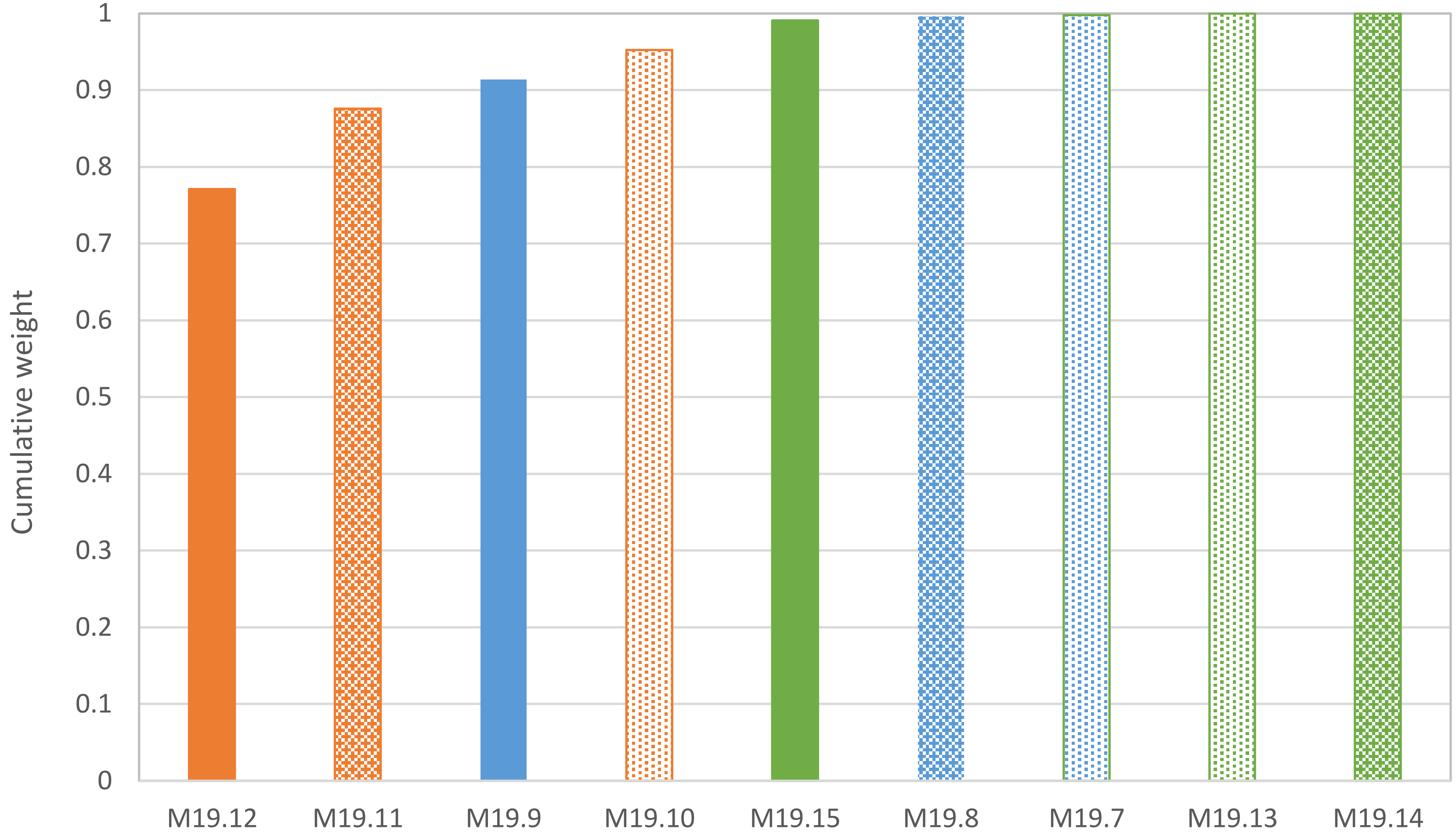
3. Given comment SSC13, all models associated with Hypothesis 1 were deemed implausible
4. All “basic” and “simple” models were deemed to have levels of complexity similar to that of other BSAI groundfish Tier 3 assessments
5. All “simple” and “complex” models were deemed to have appropriately estimated 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

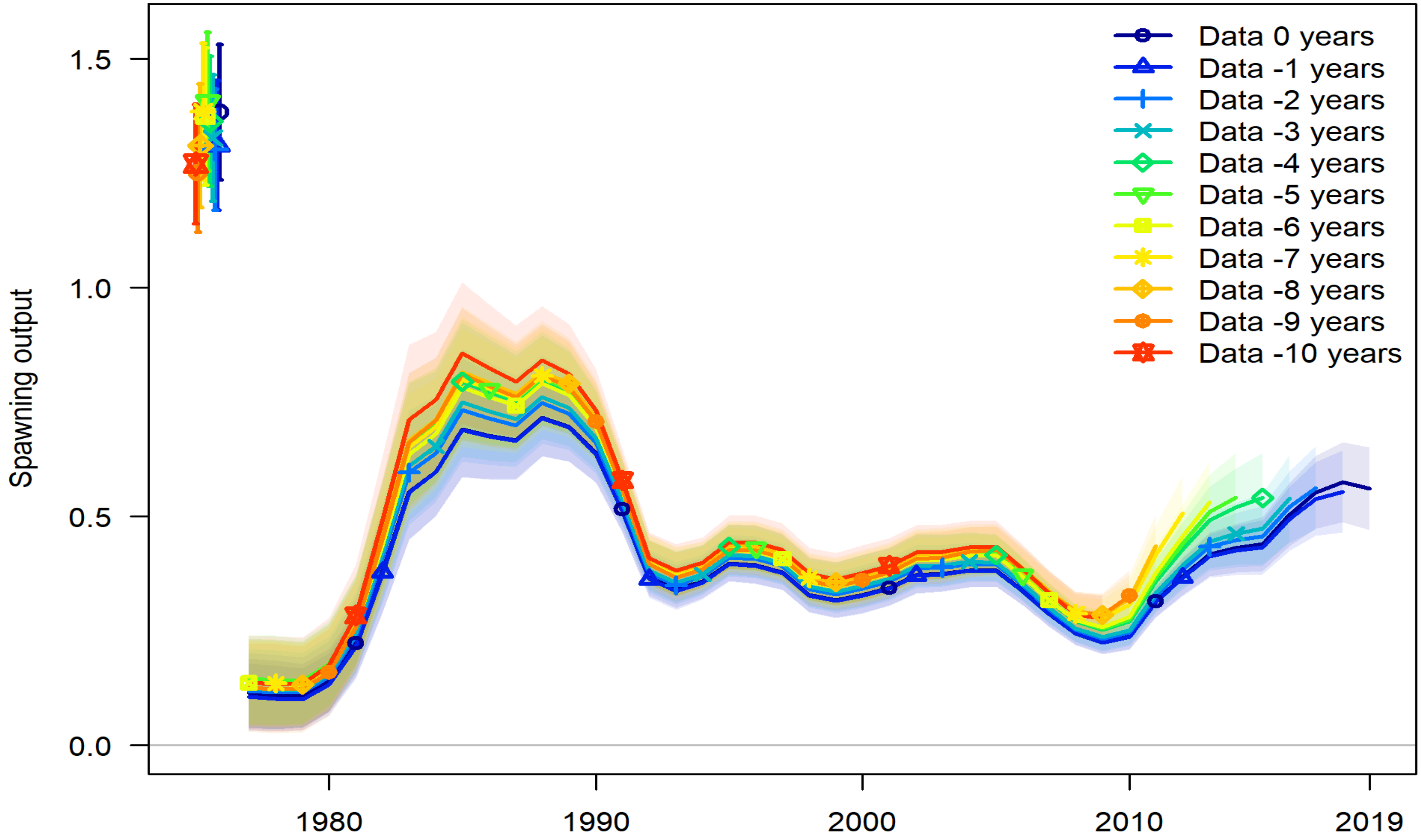
		Hypothesis 1			Hypothesis 2			Hypothesis 3		
		Basic	Simple	Complex	Basic	Simple	Complex	Basic	Simple	Complex
Criterion	Emphasis	M19.7	M19.8	M19.9	M19.10	M19.11	M19.12	M19.13	M19.14	M19.15
Plausible hypothesis	3	0	0	0	1	1	1	1	1	1
Plausible catchability	3	1	1	1	1	1	1	0	0	0
Acceptable retrospective bias	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

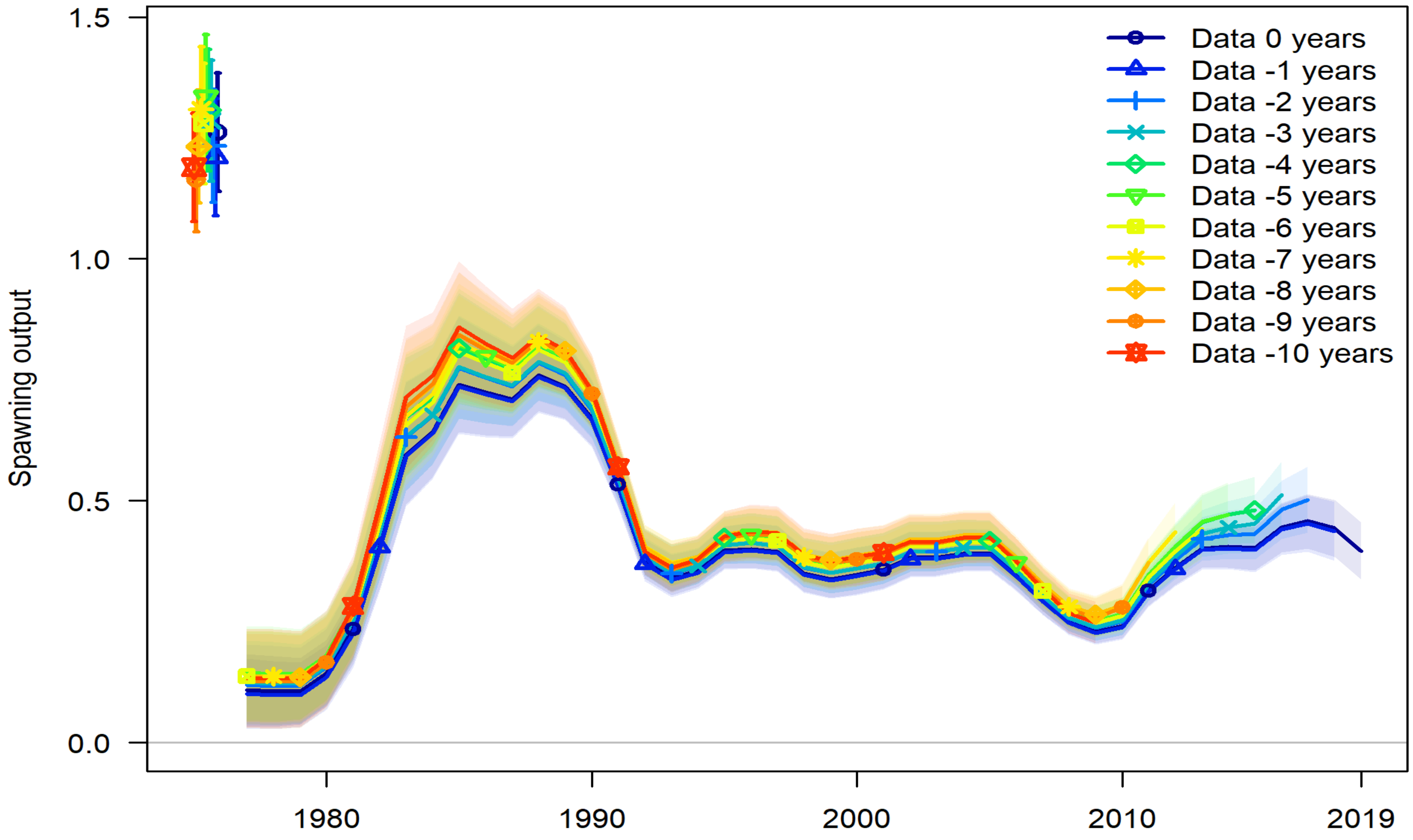
Cumulative model weight



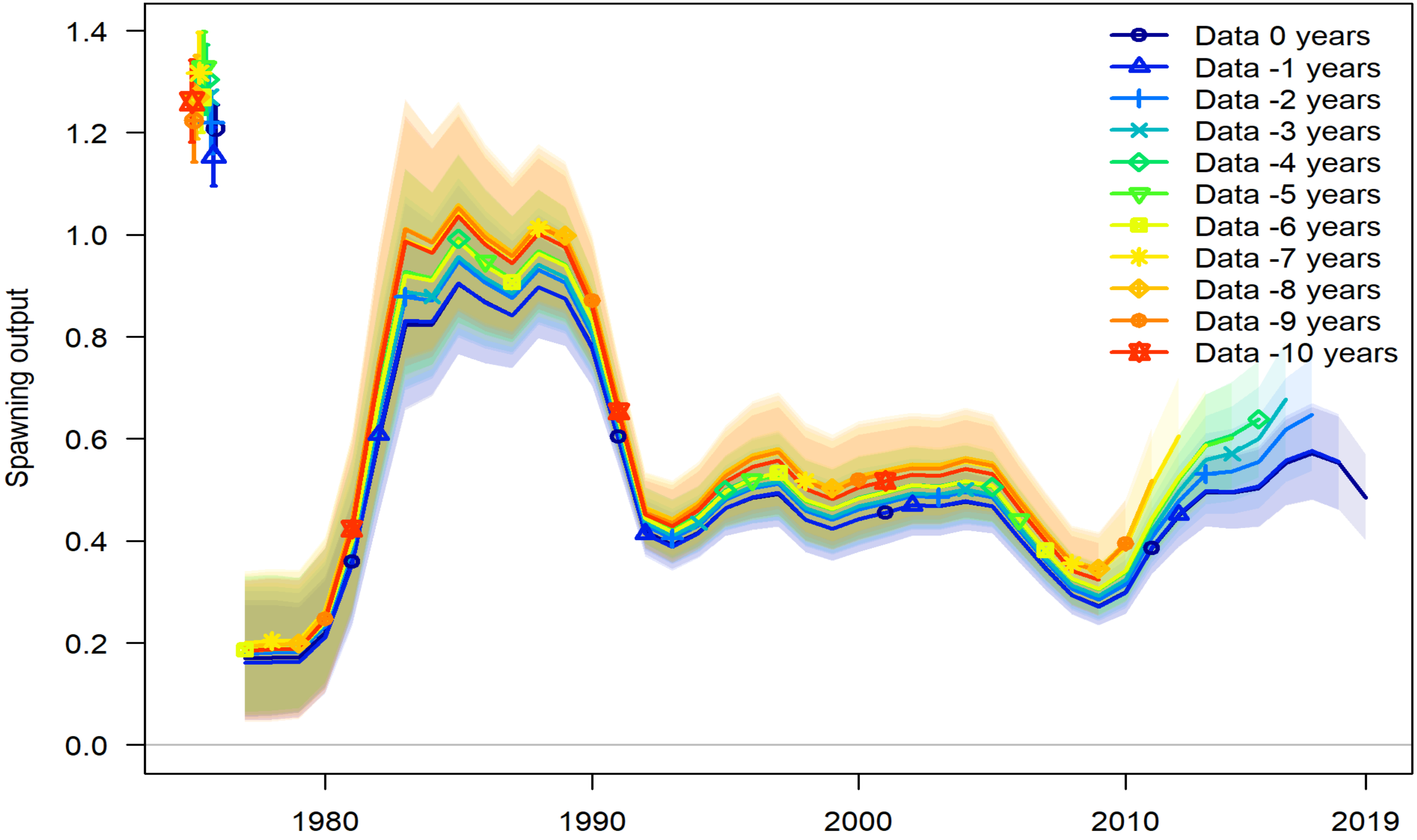
Retrospective analysis: Model 16.6i (ρ = 0.22)



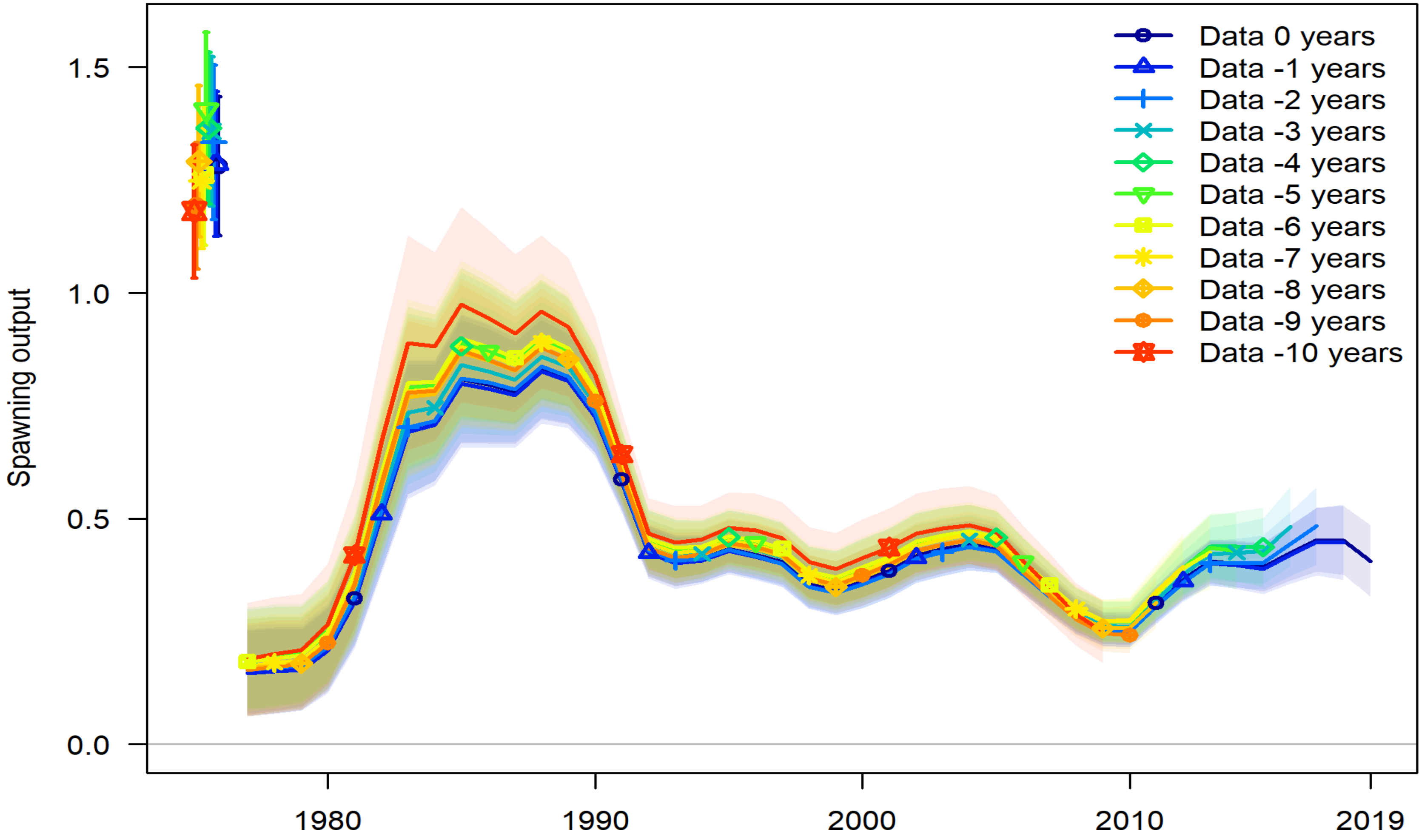
Retrospective analysis: Model 19.7 (ρ = 0.13)



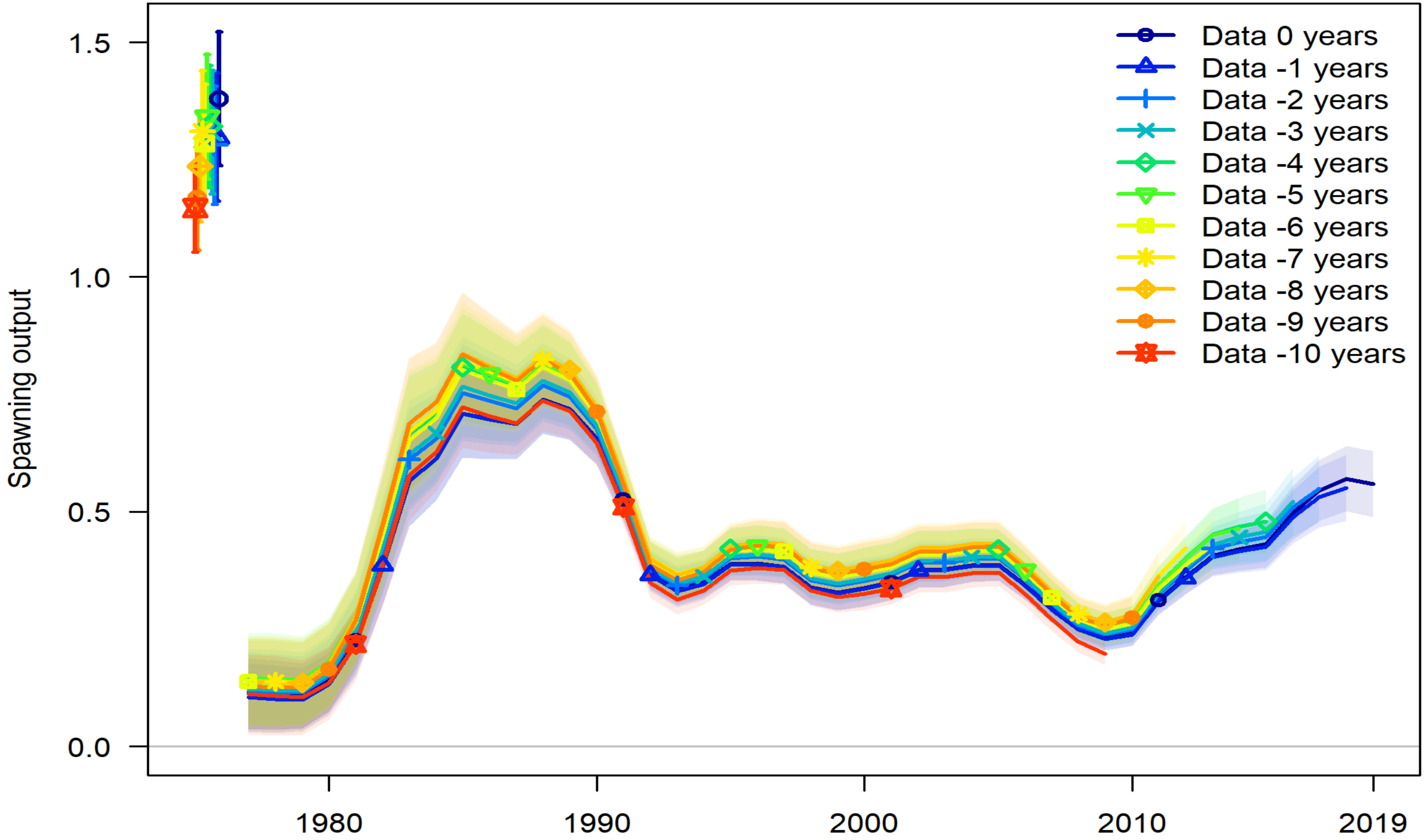
Retrospective analysis: Model 19.8 (ρ = 0.22)



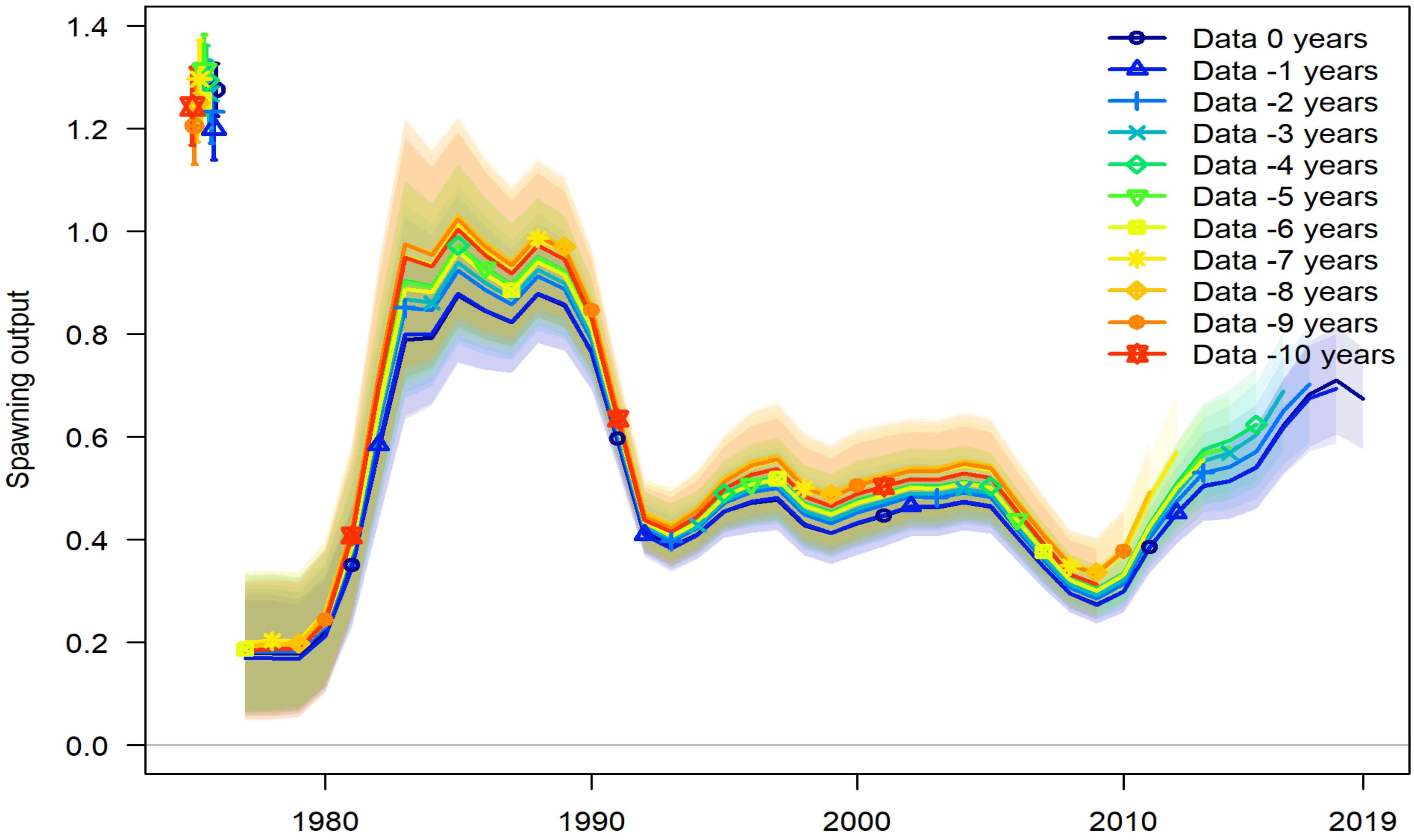
Retrospective analysis: Model 19.9 (ρ = 0.04)



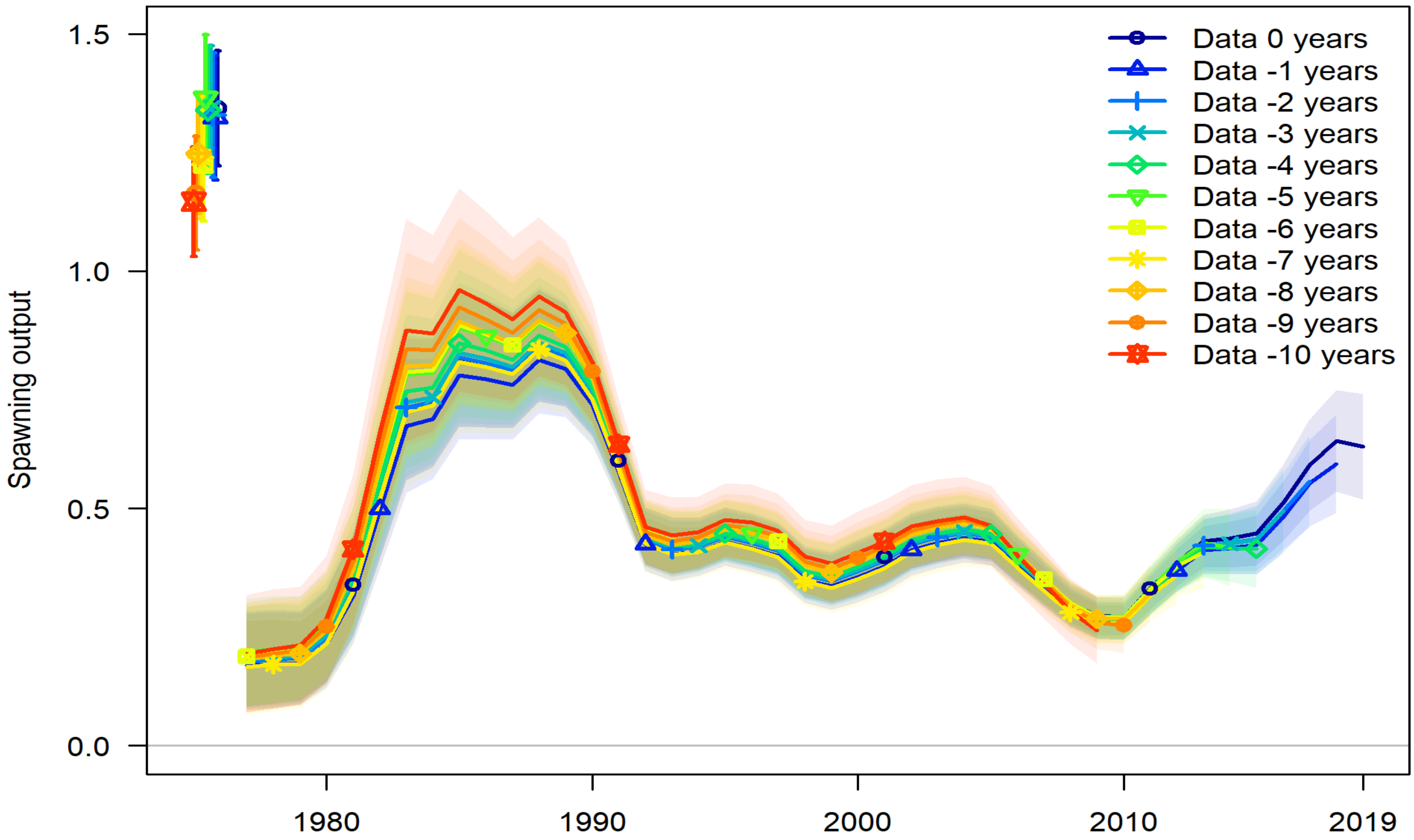
Retrospective analysis: Model 19.10 (ρ = 0.06)



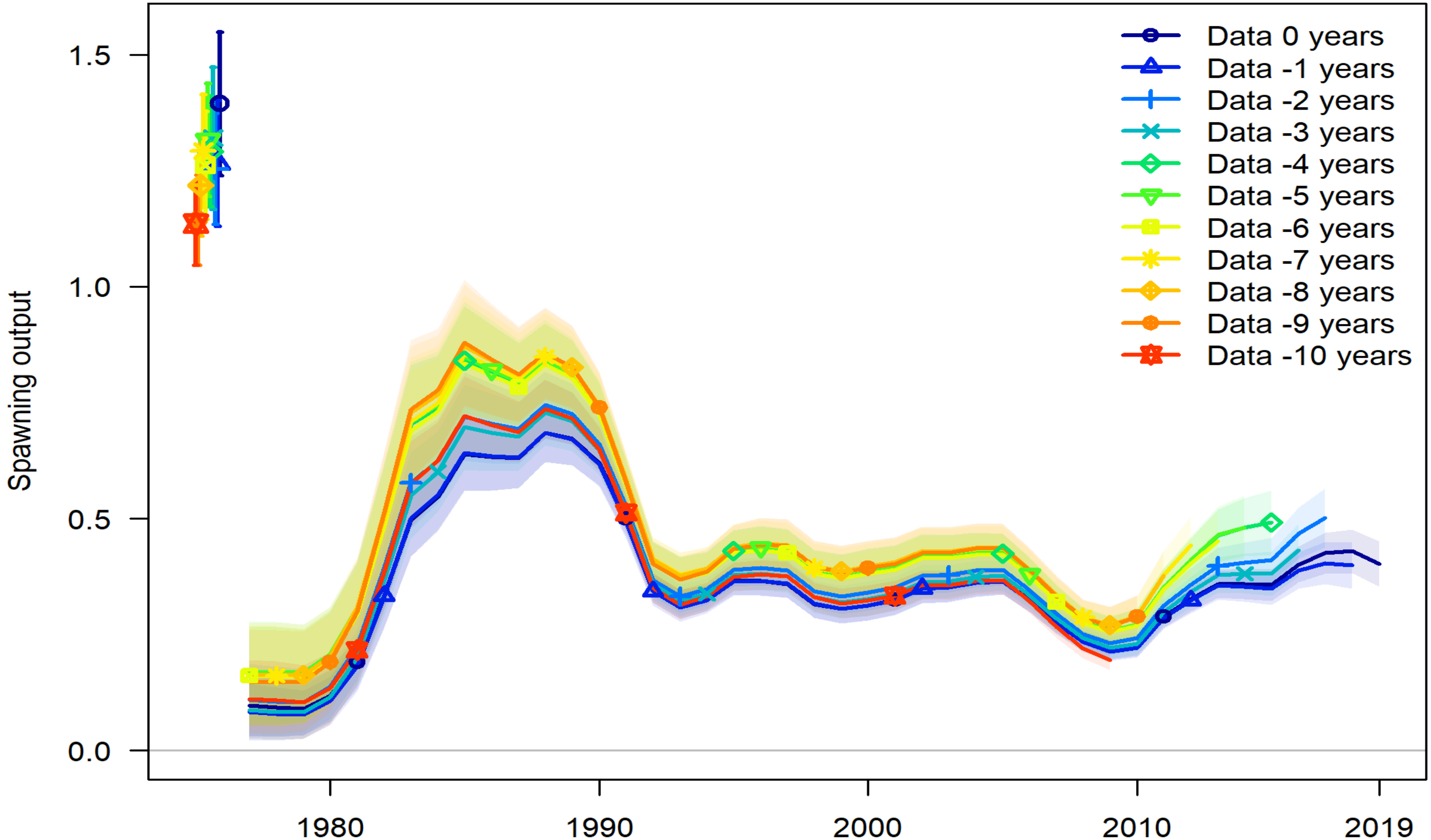
Retrospective analysis: Model 19.11 ($\rho = 0.14$)



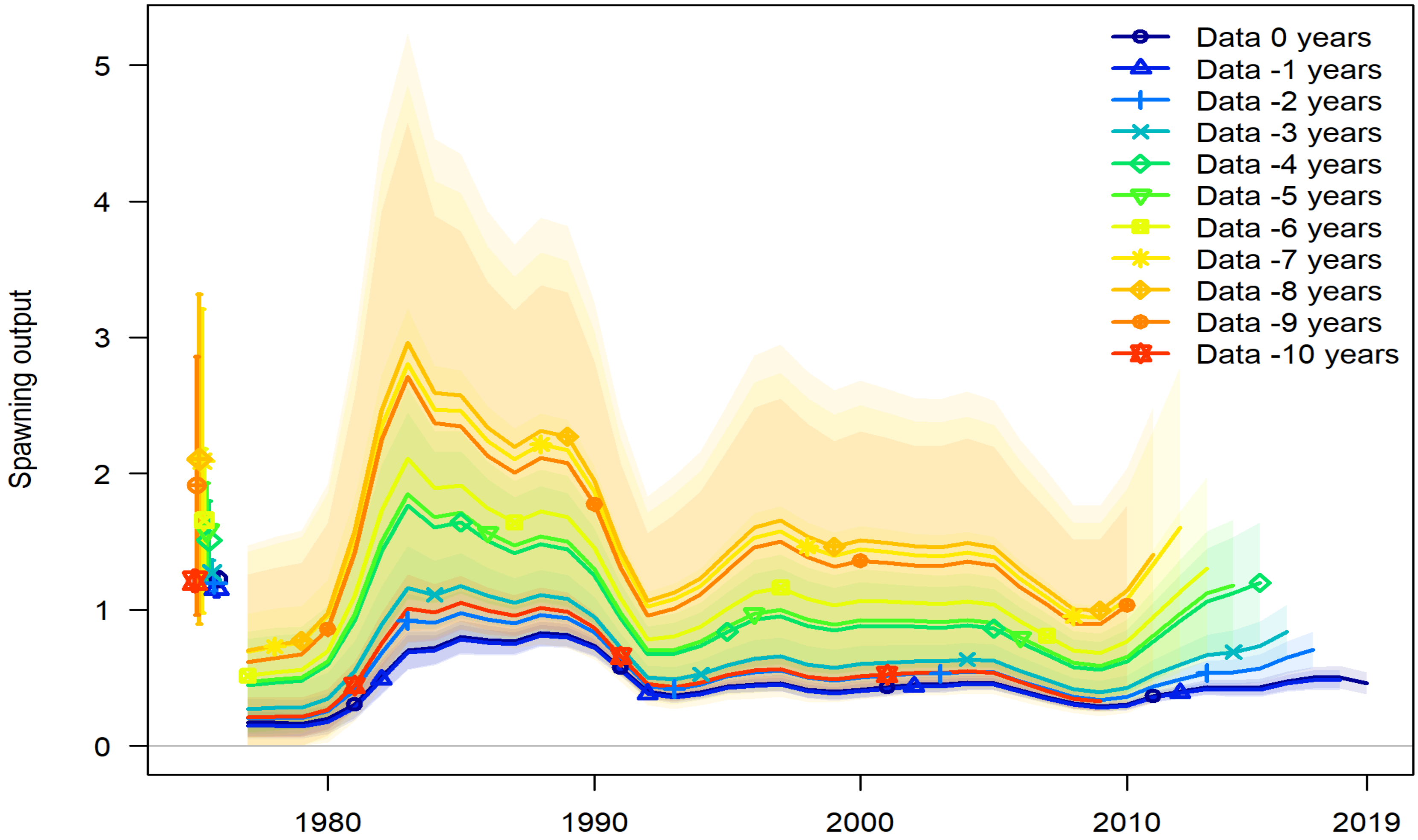
Retrospective analysis: Model 19.12 (ρ = -0.06)



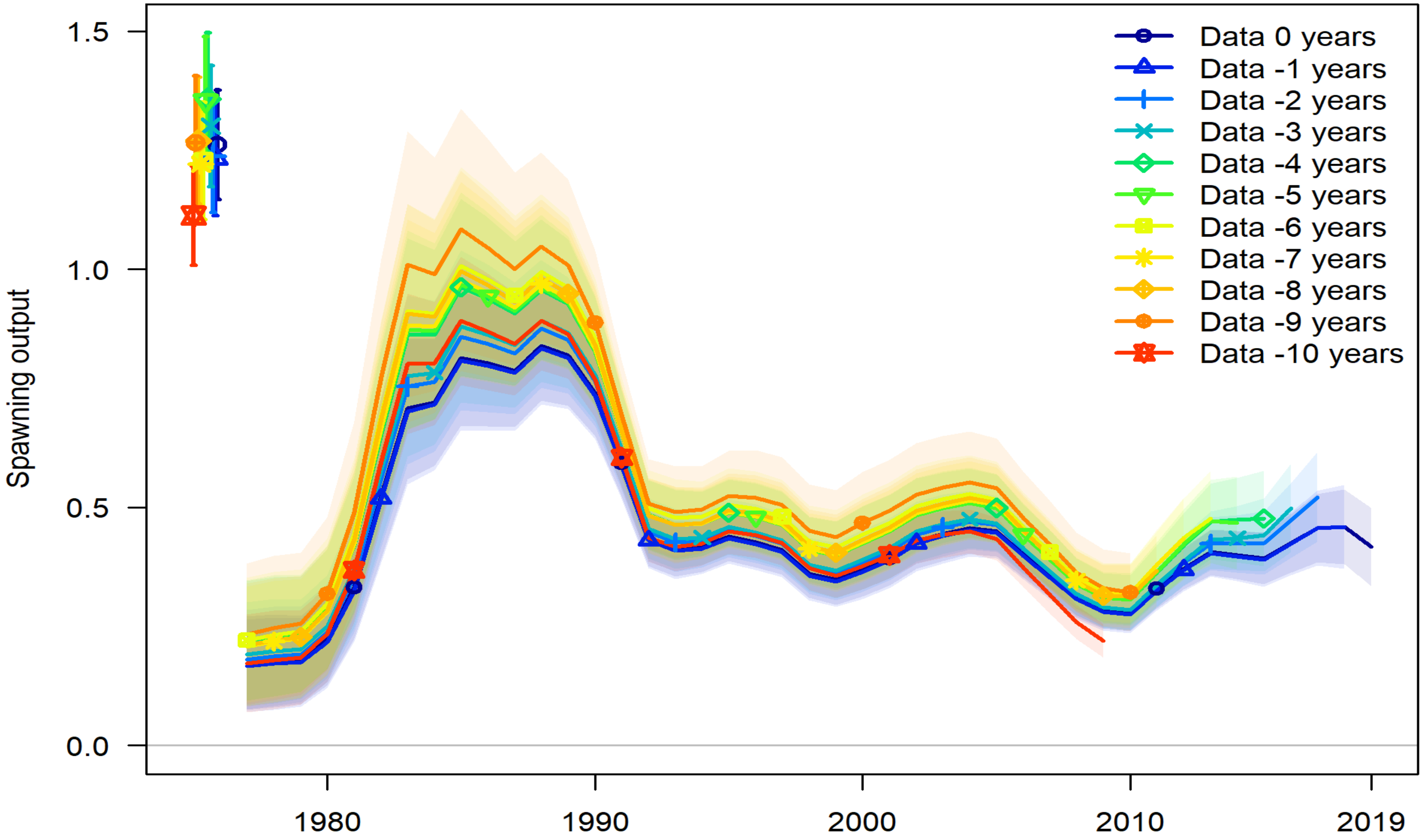
Retrospective analysis: Model 19.13 ($\rho = 0.20$)



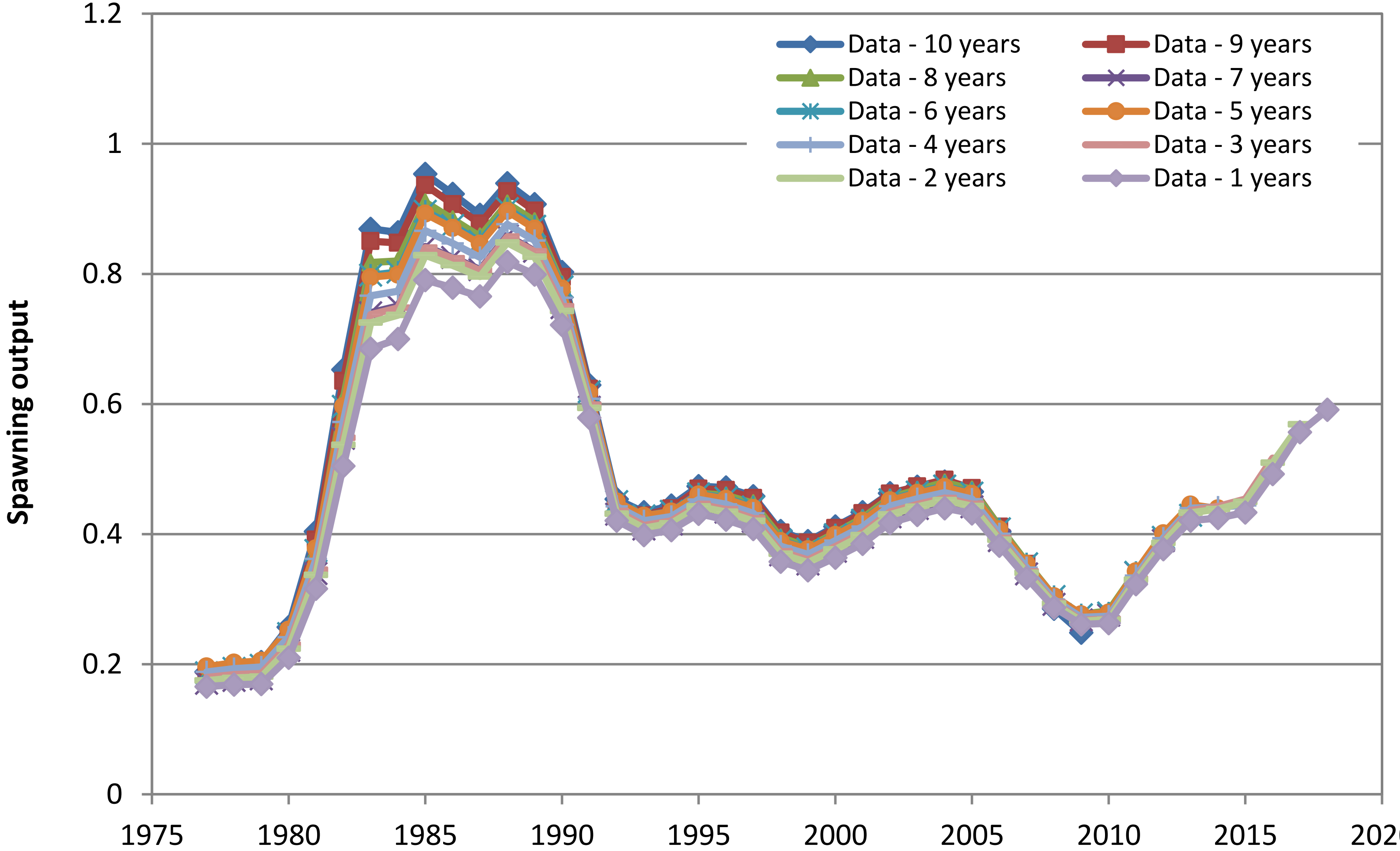
Retrospective analysis: Model 19.14 ($\rho = 1.51$)



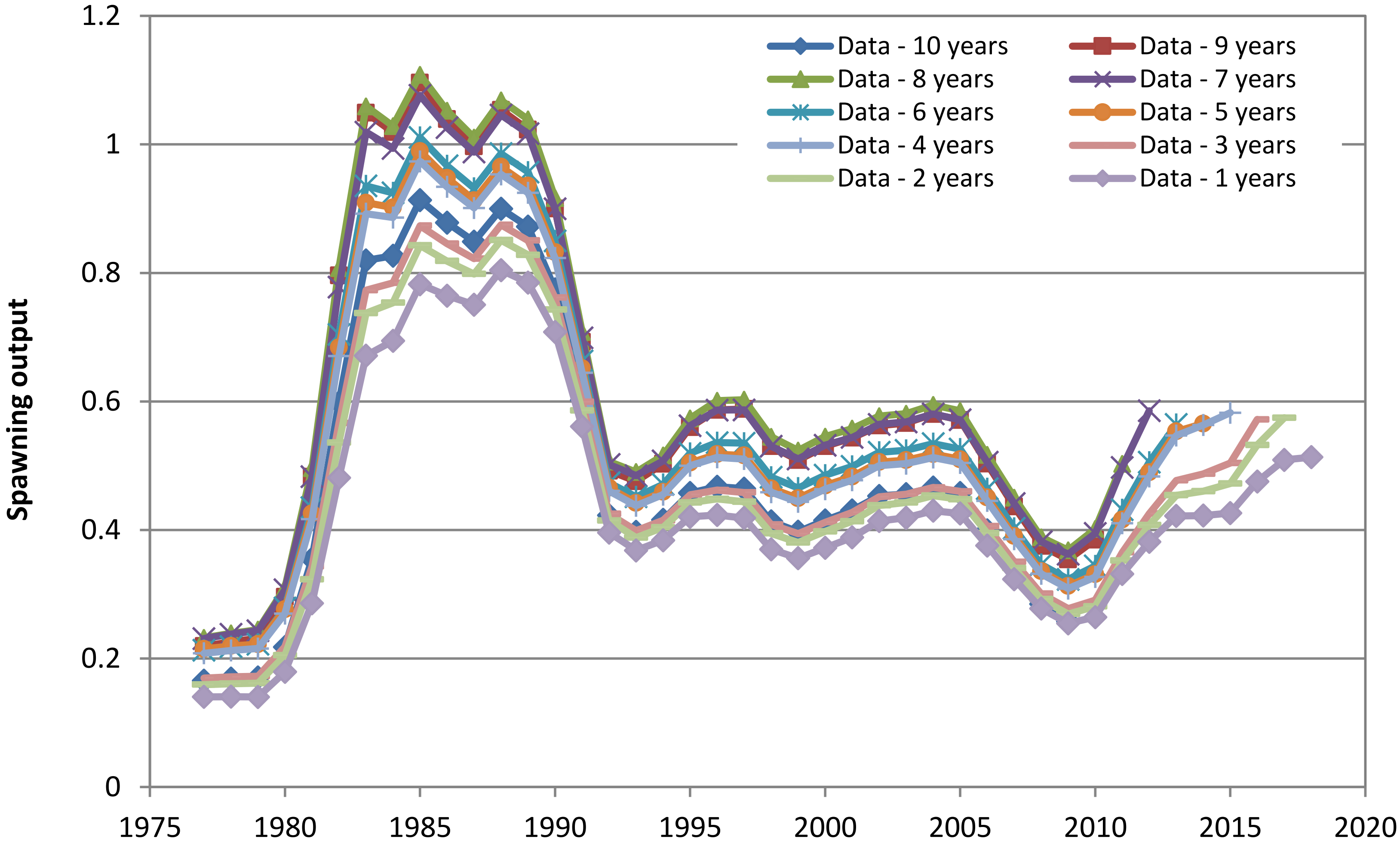
Retrospective analysis: Model 19.15 (ρ = 0.11)



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



Retrospective: ensemble unw. ave. (ρ = 0.27)



Retrospective analysis of parameters

	H2	Hypothesis 1			Hypothesis 2			Hypothesis 3		
	Basic	Basic	Smpl	Cplx	Basic	Smpl	Cplx	Basic	Smpl	Cplx
Parameter	16.6i	19.7	19.8	19.9	19.10	19.11	19.12	19.13	19.14	19.15
Mean ageing bias at age 1[a]	0.365	0.773	0.686	0.168	0.595	0.789	0.077	0.874	0.636	0.420
Mean ageing bias at age 20[a]	0.916	0.915	0.977	0.810	0.682	0.986	0.878	0.965	0.973	0.830
Mean bias at age 1 (2008+)				0.499			0.356			0.960
Mean bias at age 20 (2008+)				0.624			0.612			0.776
Pre-1977 fishing mortality rate	0.529	0.562	0.740	0.464	0.056	0.680	0.050	0.491	0.671	0.428
Asymptotic length	0.871	0.875	0.942	0.052	0.326	0.902	0.351	0.703	0.701	0.043
Mean length at age 1.5	0.777	0.798	0.728	0.903	0.277	0.706	0.898	0.739	0.666	0.900
ln(EBS survey catchability)[b]	0.968	0.964	0.953	0.863	0.235	0.943	0.864	0.677	0.695	0.742
ln(NBS survey catchability)								0.117	0.670	0.792
Natural mortality rate	0.920	0.861	0.876	0.958	0.489	0.909	0.933	0.840	0.686	0.914
Richards growth coefficient	0.669	0.719	0.646	0.772	0.577	0.494	0.802	0.257	0.338	0.818
SD(length at age 20)	0.890	0.890	0.933	0.908	0.492	0.936	0.955	0.879	0.933	0.892
SD(length at age 1)	0.839	0.864	0.830	0.898	0.327	0.808	0.896	0.804	0.783	0.862
ln(mean post-1976 recruitment)	0.938	0.930	0.932	0.886	0.253	0.917	0.833	0.682	0.684	0.756
ln(pre-1977 recruitment offset)	0.606	0.755	0.851	0.663	0.435	0.466	0.735	0.698	0.570	0.669
SD(log-scale recruitment)	0.890	0.933			0.634			0.826		
Brody growth coefficient	0.849	0.871	0.881	0.292	0.560	0.790	0.497	0.647	0.548	0.261

- Table 2.23b shows peel-specific values of the parameters with the 4 highest correlations in the above (mean ageing bias at 20+, SD(length at age 20+, natural mortality, EBS (or EBS+NBS) survey catchability)

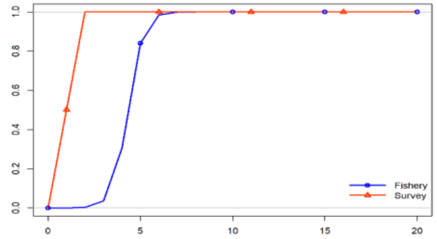
Common time-invariant parameters

- Table 2.24a (p. 93)

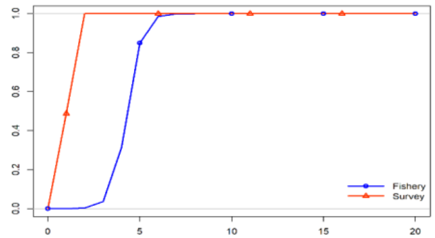
Hypothesis:	2:EBS+NBS		1: EBS only						2: EBS and NBS combined						3: EBS and NBS separated						Ensemble (19.x series)			
Structure:	Basic		Basic		Simple		Complex		Basic		Simple		Complex		Basic		Simple		Complex					
Model:	M16.6i		M19.7		M19.8		M19.9		M19.10		M19.11		M19.12		M19.13		M19.14		M19.15		Weighted		Unweighted	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
Natural mortality rate	0.33	0.01	0.35	0.01	0.42	0.02	0.36	0.01	0.33	0.01	0.40	0.02	0.35	0.01	0.32	0.01	0.40	0.02	0.36	0.01	0.35	0.01	0.37	0.02
Mean length at age 1.5	16.83	0.10	16.75	0.09	16.91	0.10	15.41	0.54	16.85	0.09	16.95	0.10	14.90	0.41	17.01	0.10	17.15	0.10	14.87	0.41	15.23	0.50	16.31	0.41
Asymptotic length	101.3	1.94	100.9	1.88	103.9	2.16	117.9	3.92	100.4	1.85	103.1	2.05	117.3	3.65	99.9	1.78	102.5	1.87	116.3	3.54	115.0	4.11	106.9	3.62
Brody growth coefficient	0.20	0.01	0.20	0.01	0.19	0.01	0.11	0.01	0.20	0.01	0.19	0.01	0.11	0.01	0.21	0.01	0.21	0.01	0.11	0.01	0.12	0.02	0.17	0.02
Richards growth coefficient	1.00	0.05	0.99	0.05	1.01	0.05	1.46	0.04	0.99	0.05	1.01	0.05	1.47	0.04	0.92	0.05	0.91	0.05	1.44	0.04	1.39	0.08	1.13	0.09
SD(length at age 1)	3.66	0.06	3.63	0.06	3.69	0.06	3.43	0.07	3.67	0.06	3.70	0.06	3.51	0.07	3.74	0.06	3.84	0.07	3.48	0.07	3.53	0.07	3.63	0.08
SD(length at age 20)	9.07	0.27	9.20	0.27	9.13	0.28	10.31	0.45	9.11	0.27	9.01	0.28	9.86	0.41	8.93	0.26	8.33	0.28	9.94	0.41	9.76	0.41	9.31	0.38
Mean ageing bias at age 1[a]	0.33	0.01	0.34	0.01	0.32	0.02	0.35	0.01	0.33	0.01	0.32	0.02	0.34	0.02	0.35	0.01	0.33	0.02	0.35	0.01	0.33	0.02	0.34	0.01
Mean ageing bias at age 20[a]	0.03	0.14	0.17	0.14	0.21	0.15	0.83	0.20	0.18	0.14	0.23	0.15	0.91	0.22	-0.16	0.13	-0.13	0.15	0.82	0.20	0.79	0.24	0.34	0.21
Mean bias at age 1 (2008+)							0.01	0.02					0.02	0.02					0.00	0.02	0.02	0.02	0.01	0.02
Mean bias at age 20 (2008+)							-1.85	0.33					-1.72	0.32					-1.94	0.35	-1.73	0.34	-1.84	0.20
ln(mean post-1976 recruitment)	12.96	0.09	13.05	0.09	13.56	0.14	13.15	0.10	12.97	0.09	13.49	0.13	13.10	0.10	12.82	0.08	13.35	0.13	13.15	0.10	13.14	0.12	13.18	0.13
SD(log-scale recruitment)	0.65	0.07	0.66	0.06	0.69	_	0.72	_	0.66	0.07	0.67	_	0.69	_	0.68	0.07	0.62	_	0.68	_	0.69	_	0.67	_
ln(pre-1977 recruitment offset)	-1.19	0.20	-1.17	0.20	-0.98	0.24	-0.97	0.21	-1.19	0.20	-0.98	0.23	-0.95	0.19	-1.23	0.19	-0.99	0.21	-0.93	0.20	-0.96	0.20	-1.04	0.21
Pre-1977 fishing mortality rate	0.18	0.07	0.20	0.08	0.16	0.06	0.15	0.05	0.18	0.07	0.15	0.05	0.13	0.04	0.21	0.09	0.16	0.05	0.14	0.05	0.14	0.05	0.16	0.06
ln(EBS survey catchability)[b]	0.06	0.06	0.05	0.05	-0.13	0.07	-0.02	0.07	0.13	0.05	-0.05	0.07	0.03	0.07	0.16	0.04	-0.02	0.06	-0.03	0.07	0.02	0.07	0.01	0.07
ln(NBS survey catchability)															-0.88	0.08	-0.57	0.17	-1.53	0.27	-1.49	0.26	-0.99	0.30

Selectivity: “basic” and “simple” models

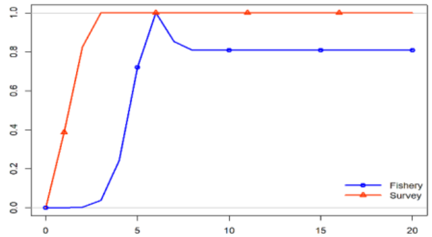
Model 16.6i



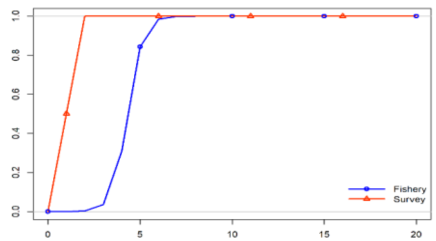
Model 19.7



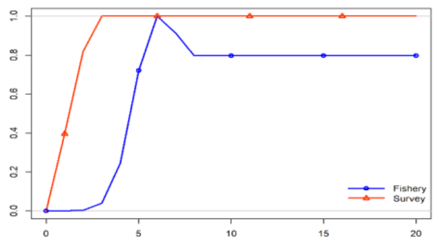
Model 19.8



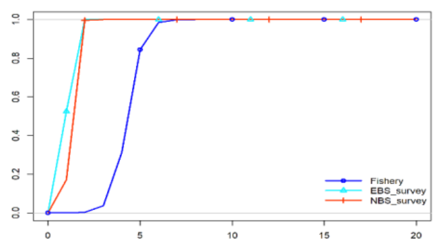
Model 19.10



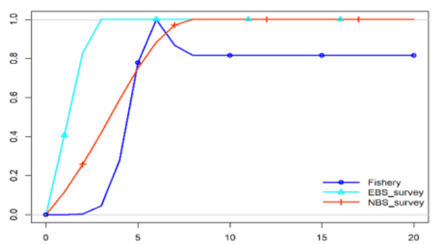
Model 19.11



Model 19.13

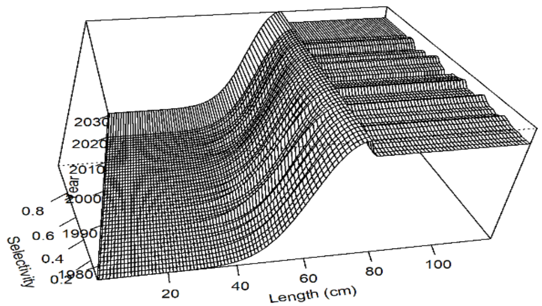


Model 19.14

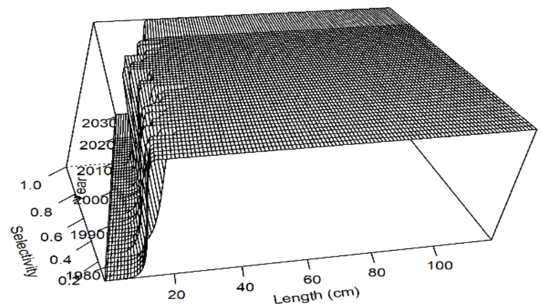


Selectivity: “complex” models

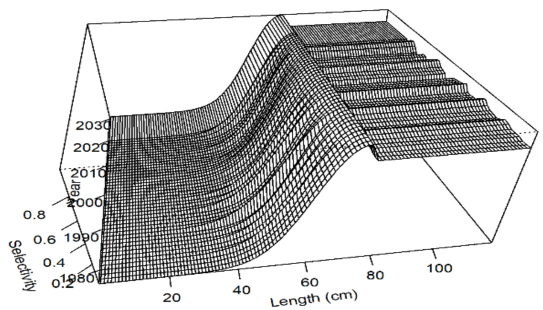
Model 19.9 (fishery)



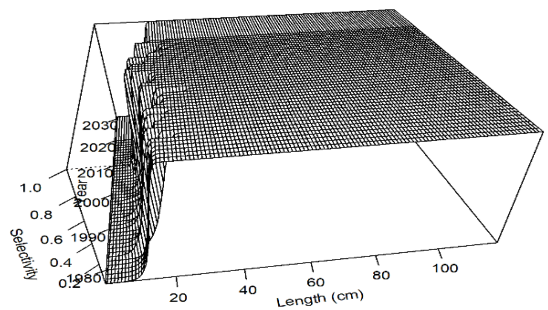
Model 19.9 (EBS survey)



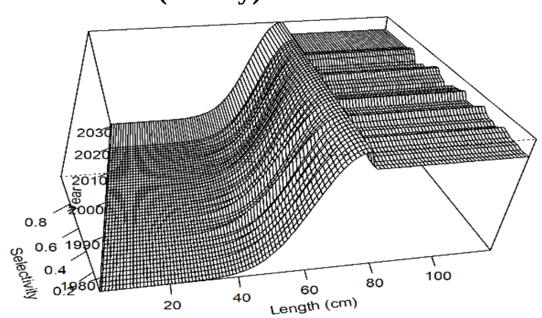
Model 19.12 (fishery)



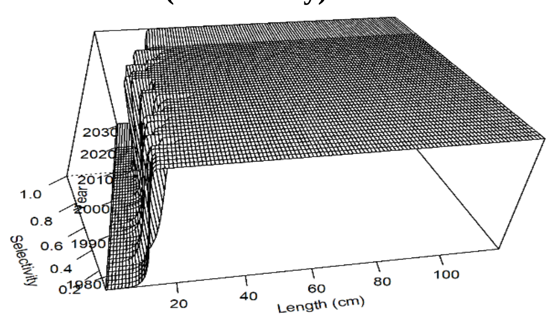
Model 19.12 (EBS+NBS survey)



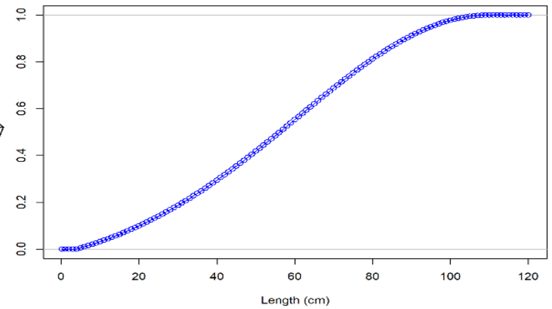
Model 19.15 (fishery)



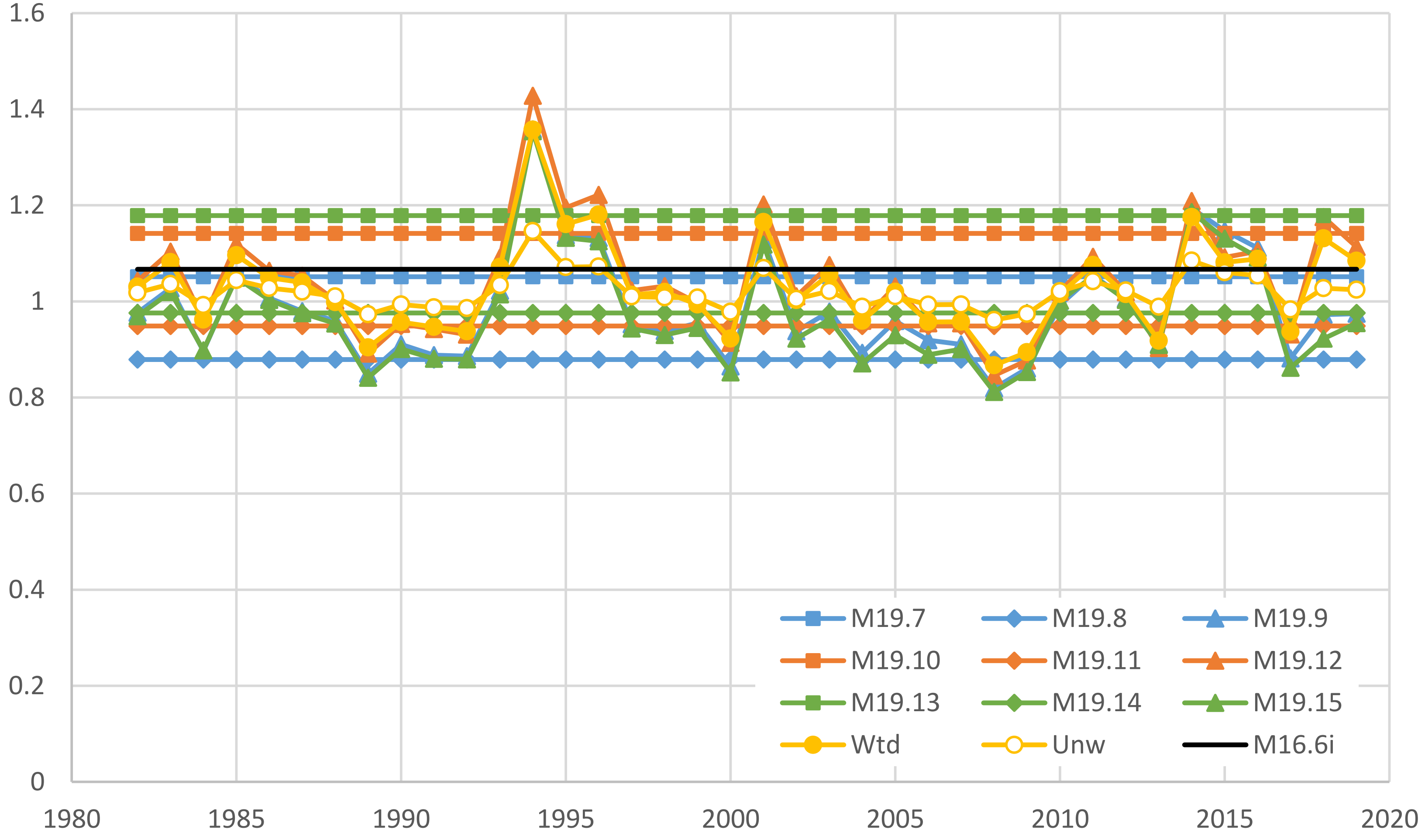
Model 19.15 (EBS survey)



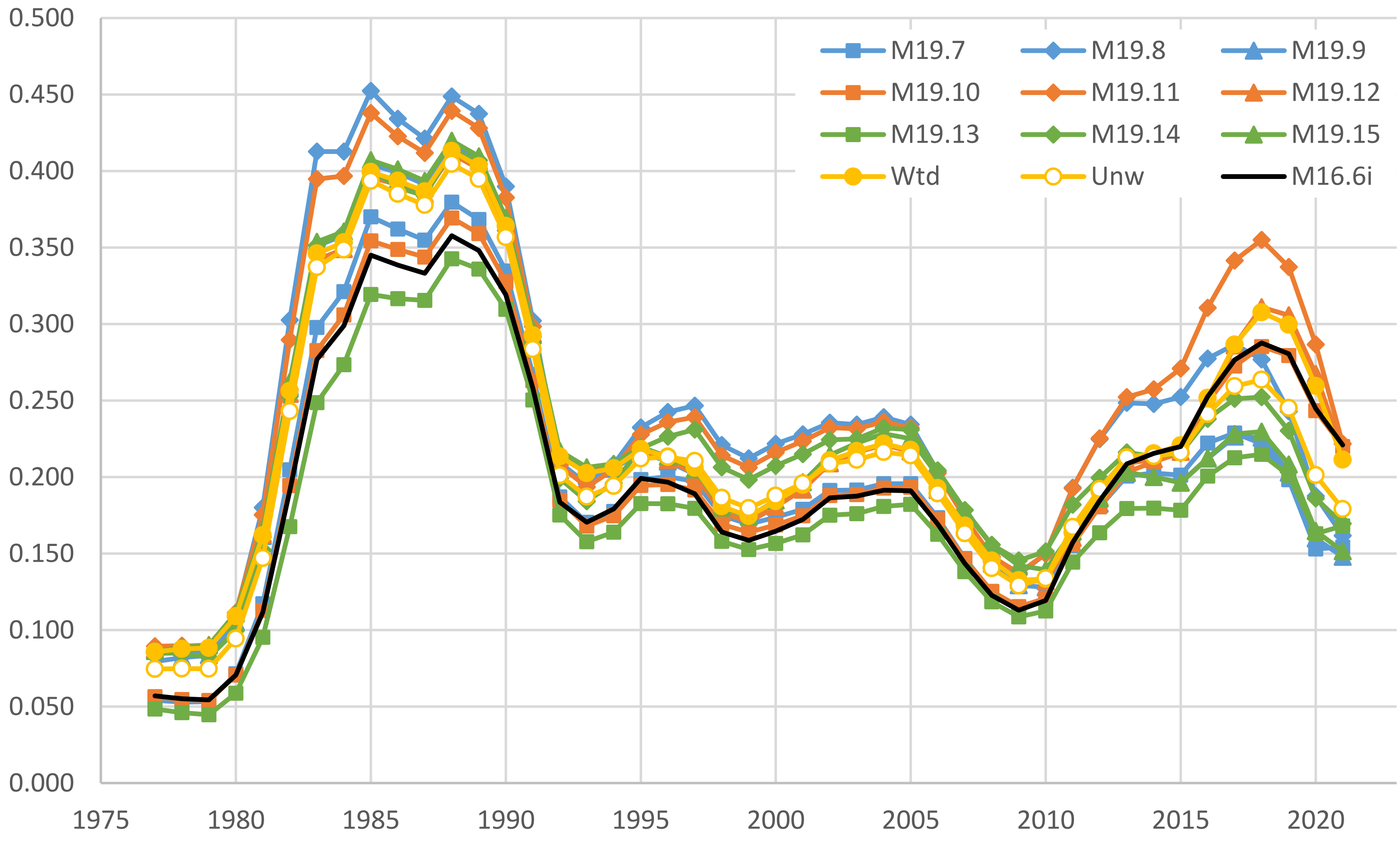
Model 19.15 (NBS survey)



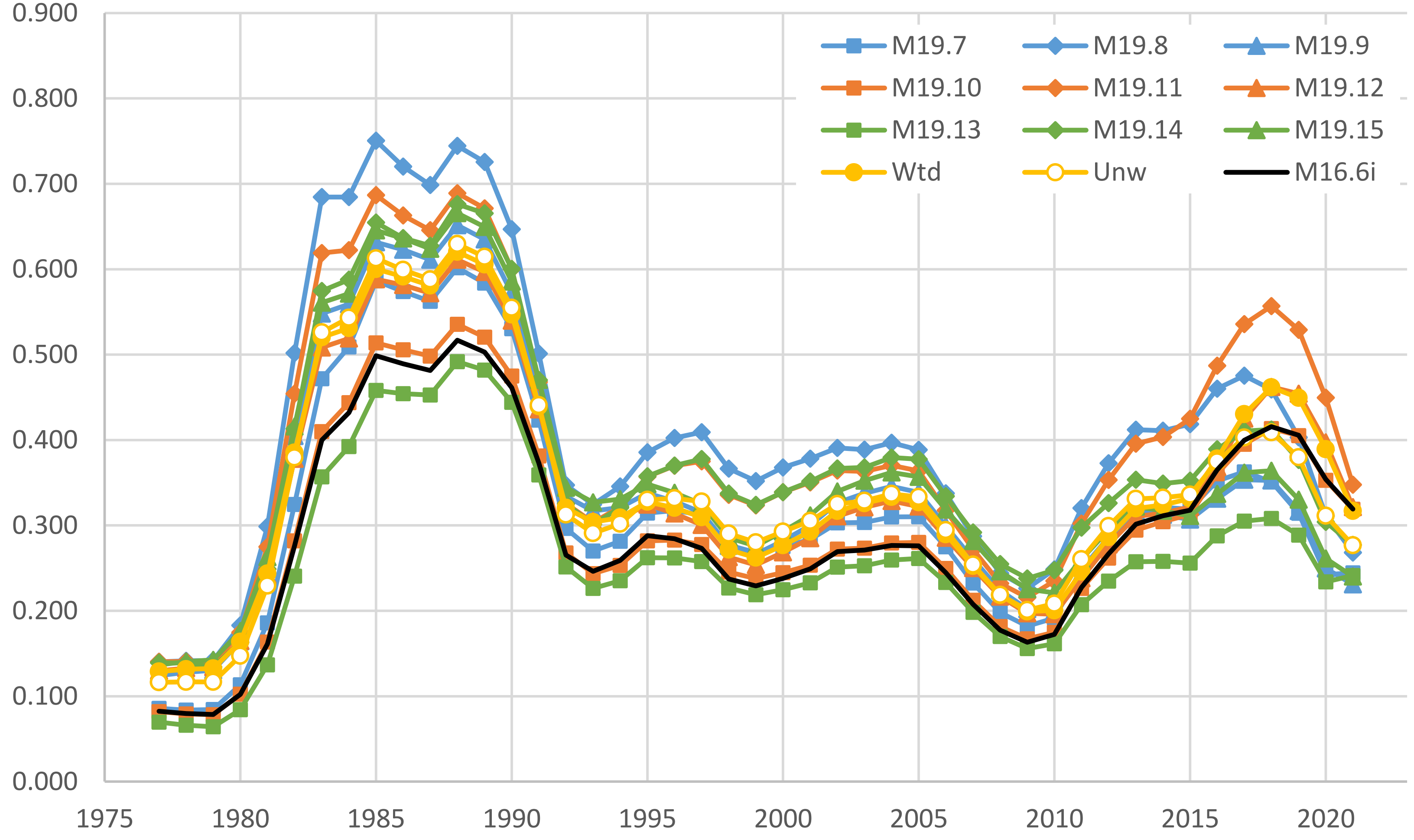
EBS (or EBS+NBS) catchability



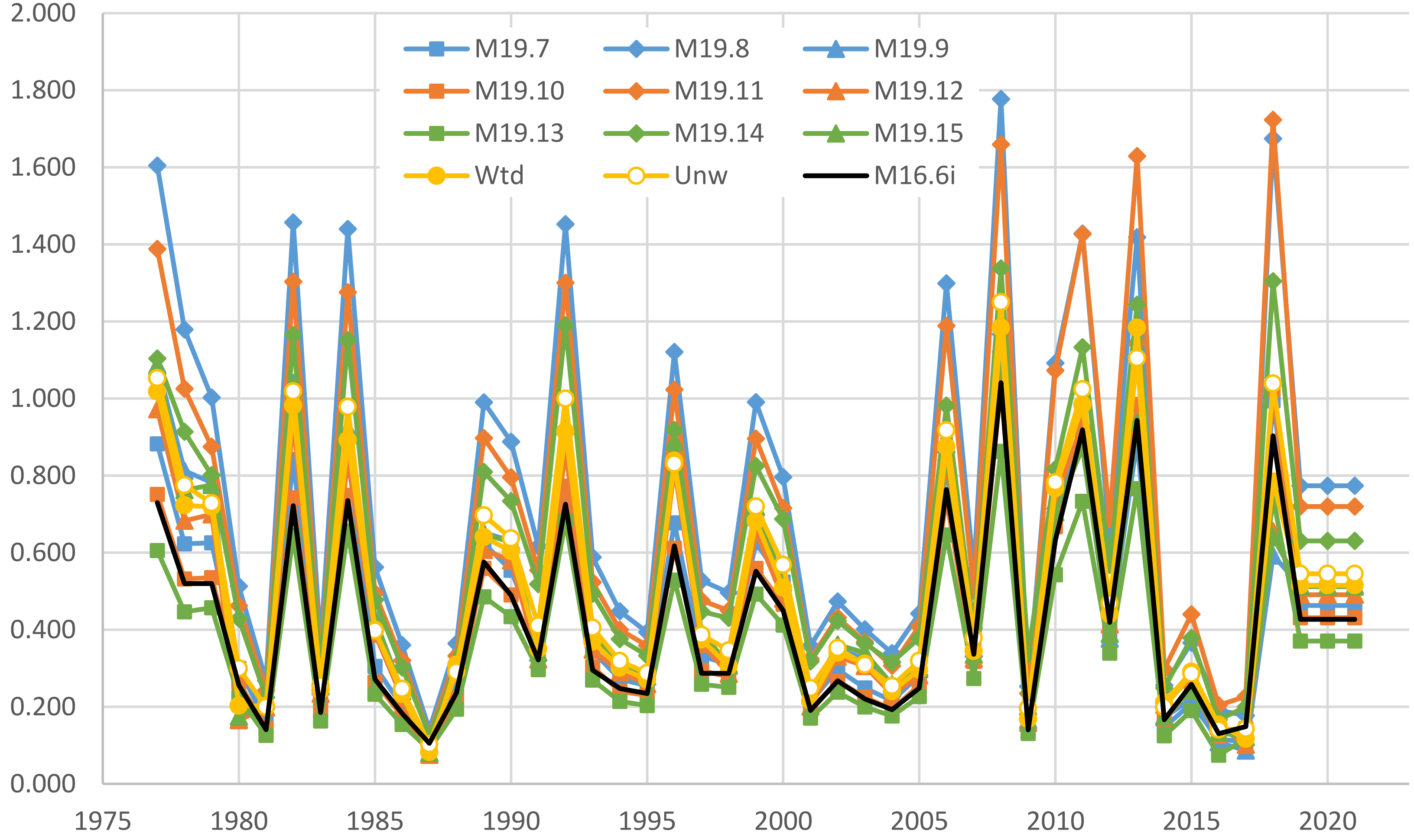
Female spawning biomass (millions of t)



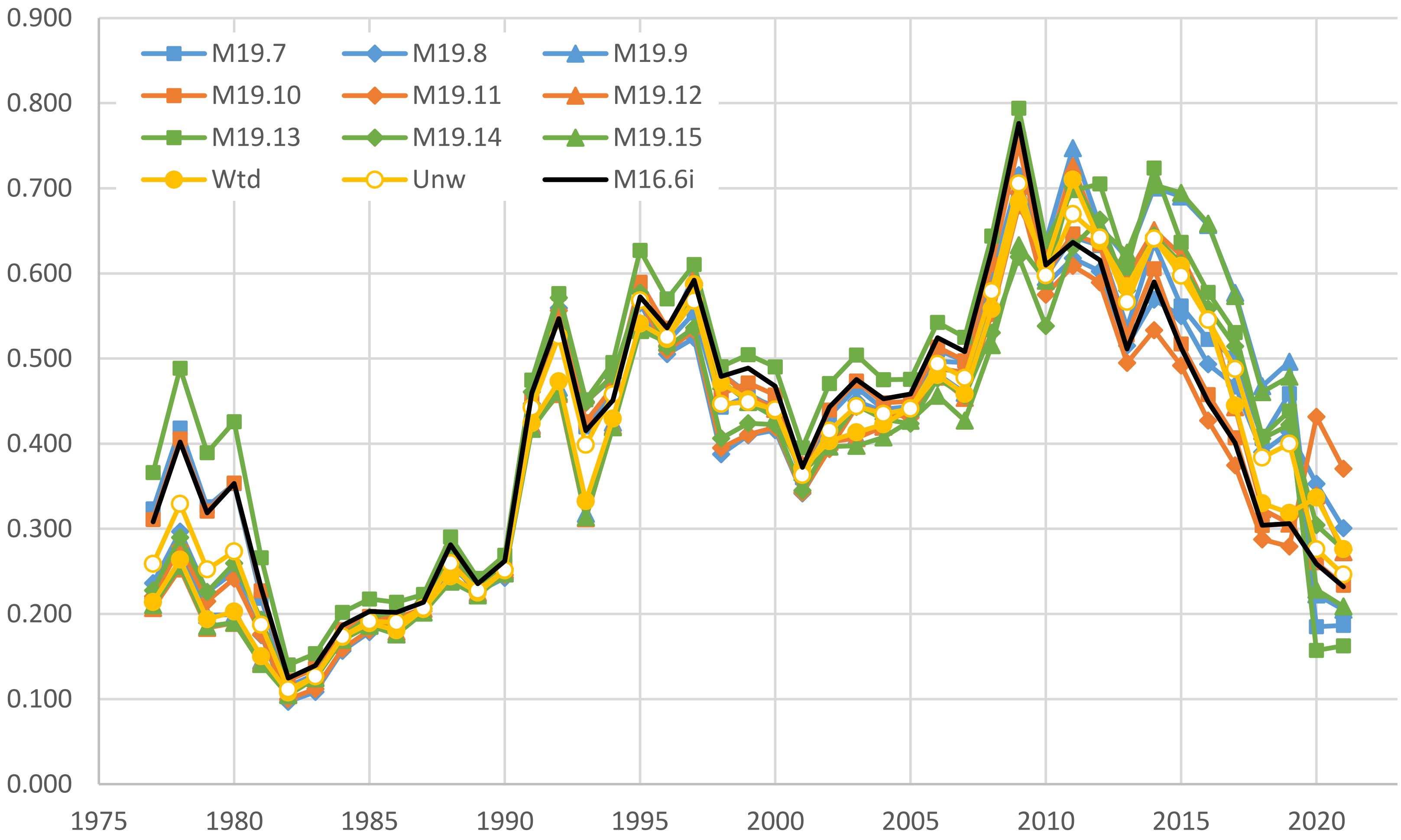
Spawning biomass relative to $B_{100\%}$



Age 0 recruitment (billions of fish)



Full-selection fishing mortality



Management reference points

	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

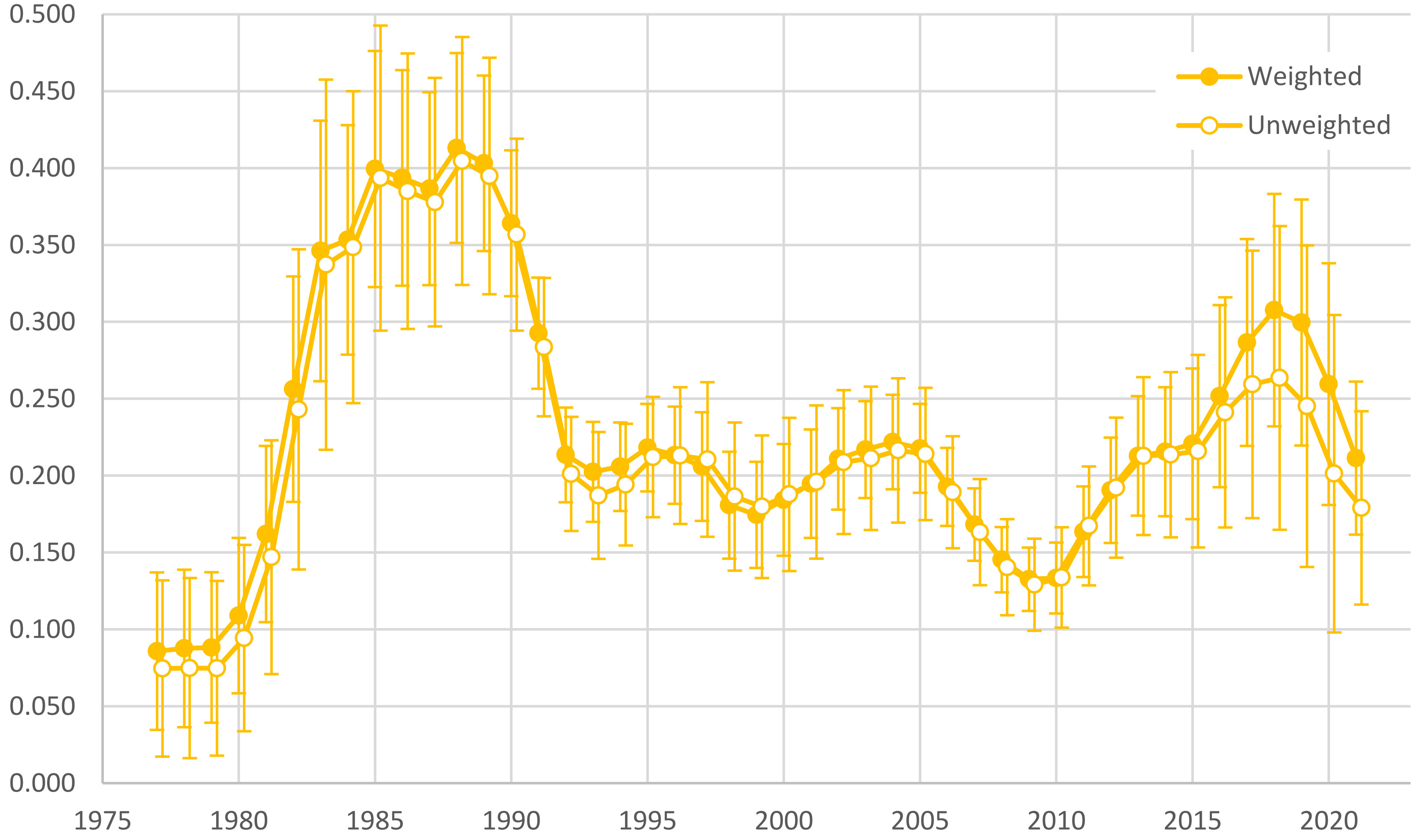
Choice of final model

- 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

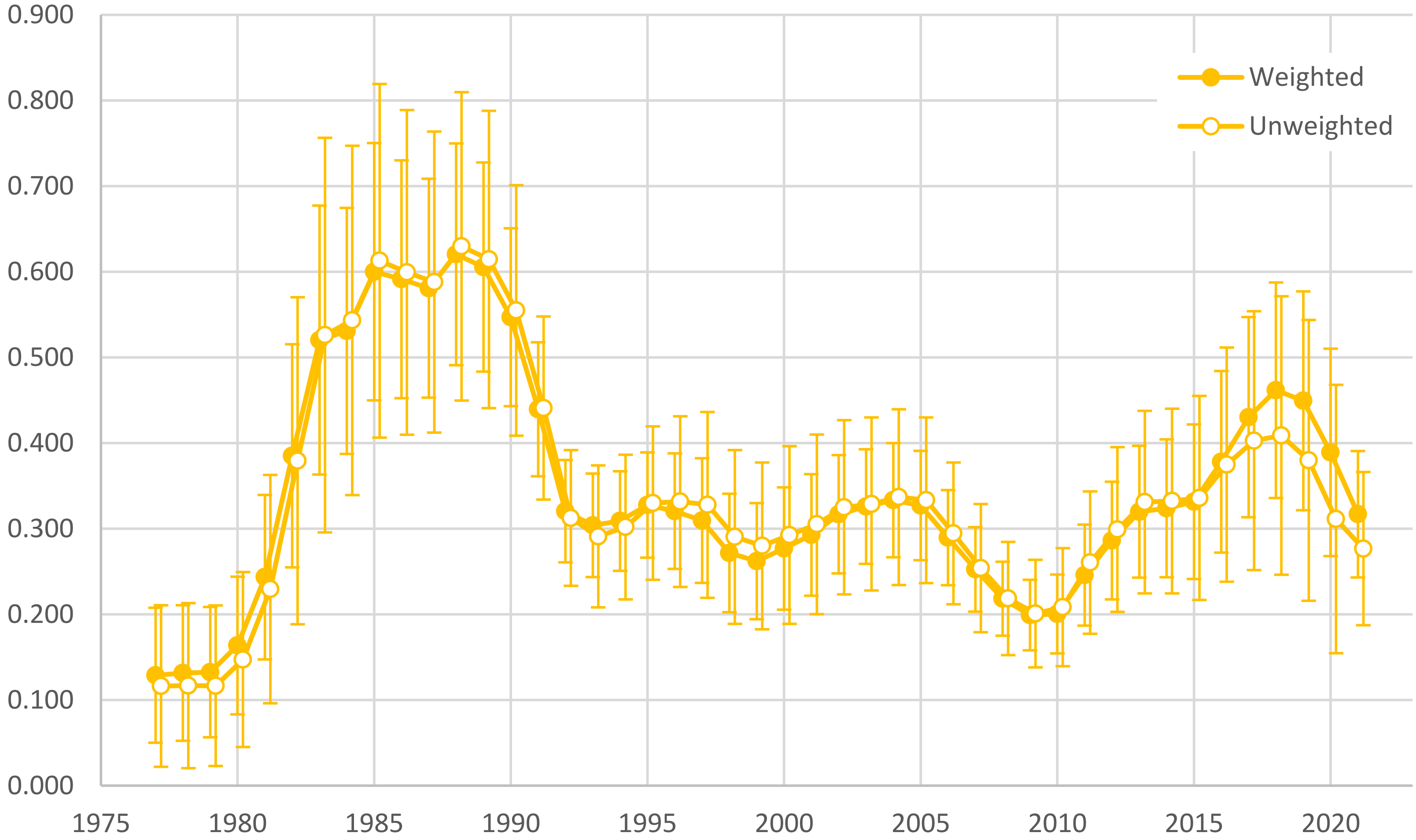
Model choice: a pragmatic consideration

- If the weighted average ensemble is chosen as the new base model, it will (probably?) have to 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)

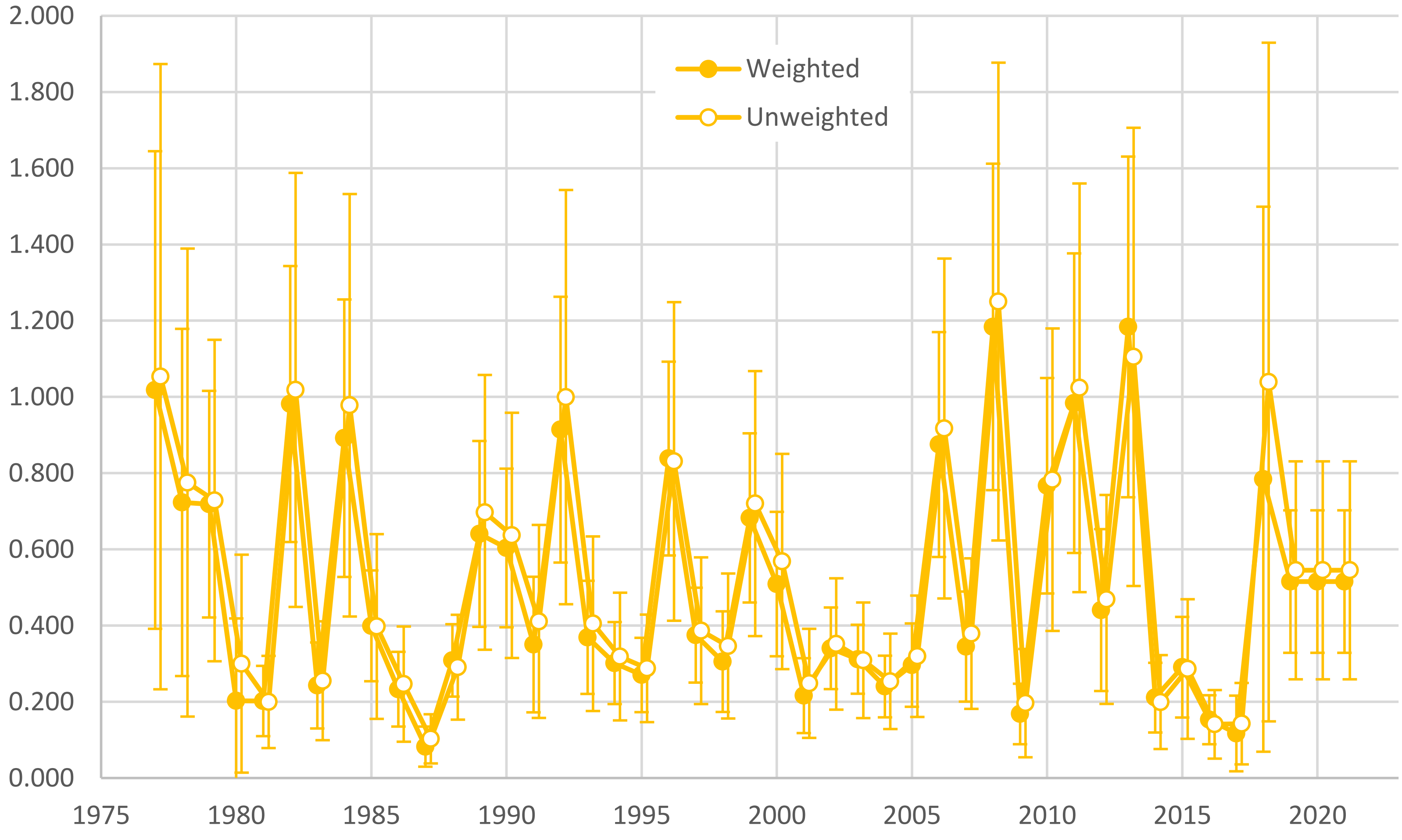
Female spawning biomass (millions of t)



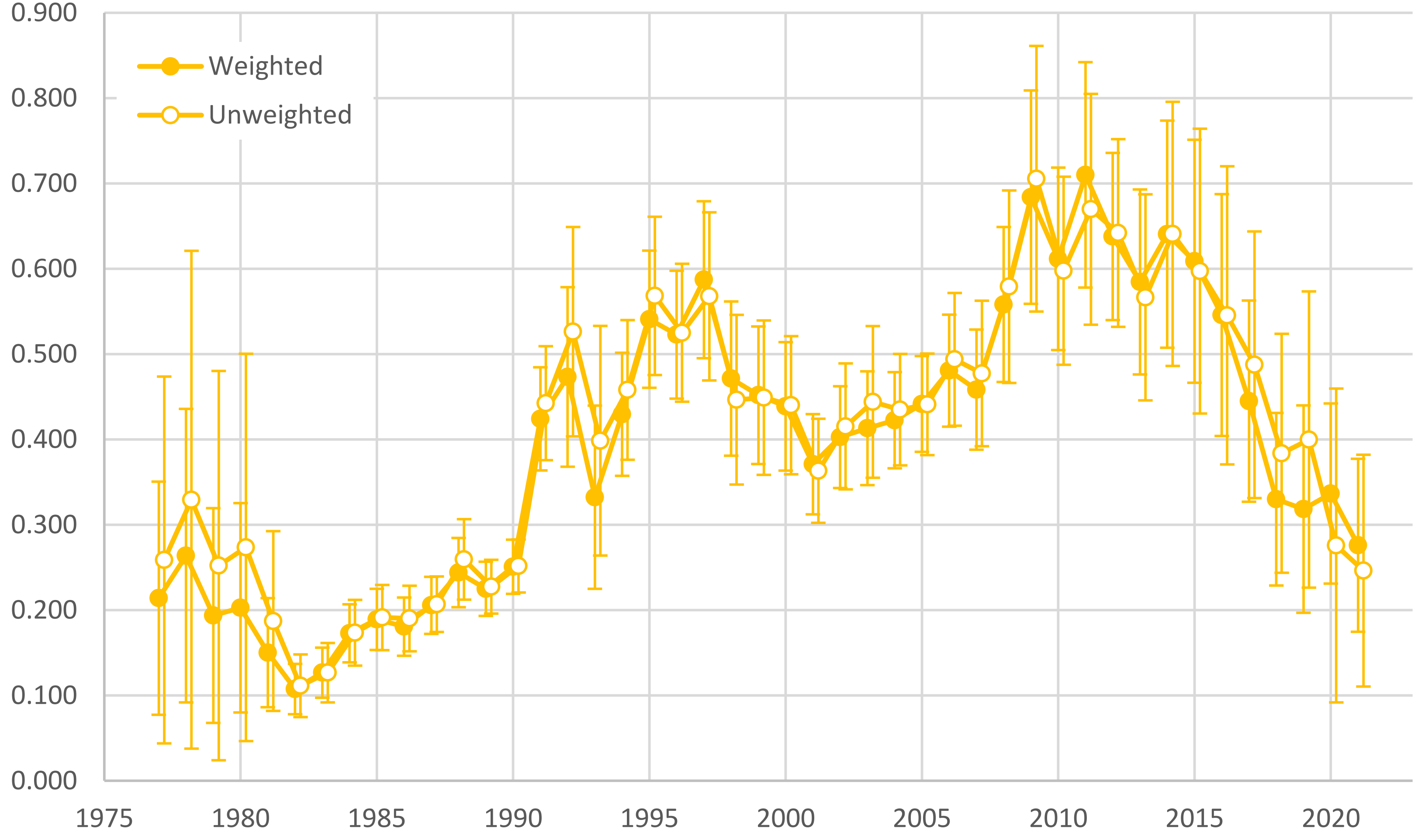
Spawning biomass relative to $B_{100\%}$



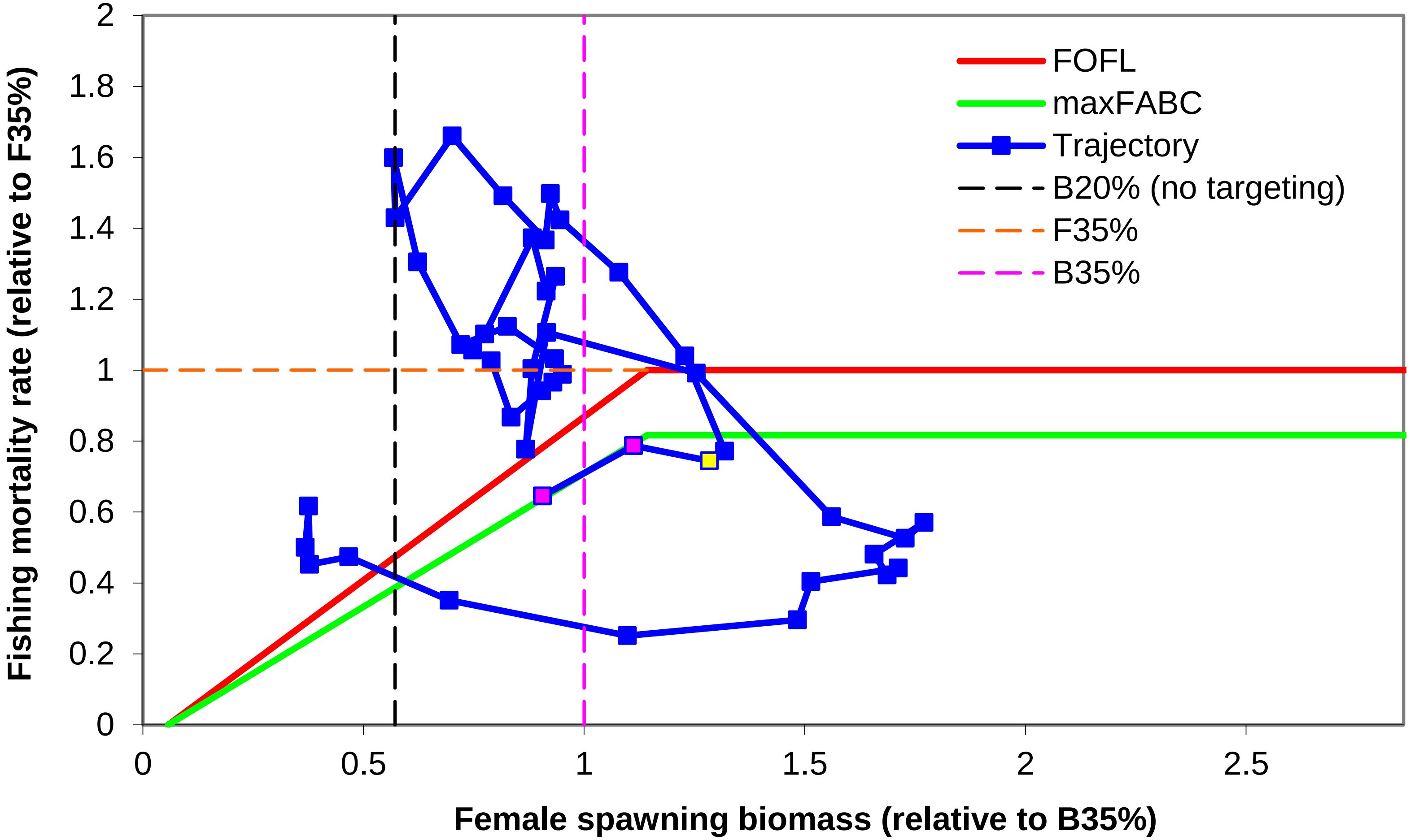
Age 0 recruitment (billions of fish)



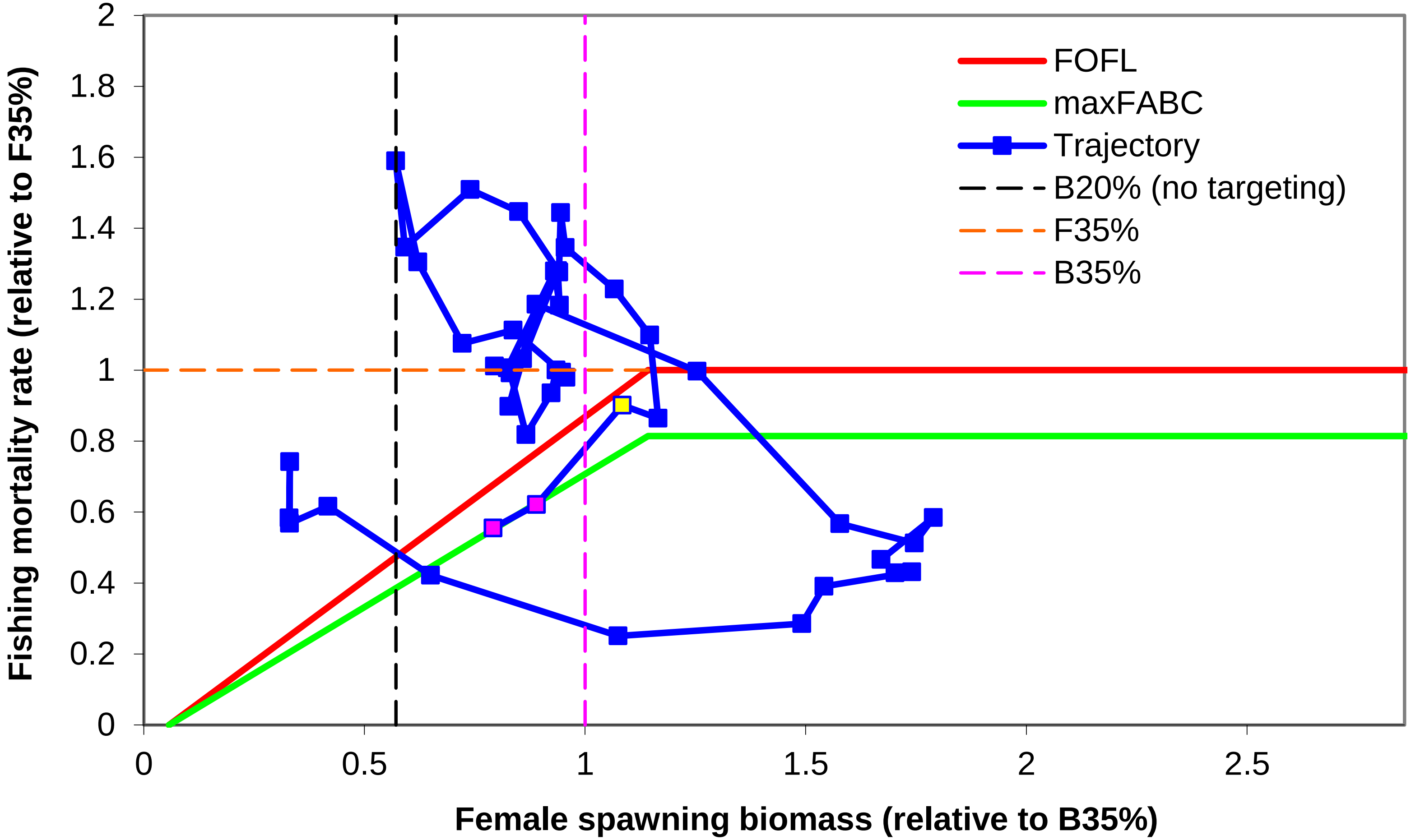
Full-selection fishing mortality



Phase plane: weighted average ensemble



Phase plane: unweighted average ensemble



Statistics of ABC and OFL distributions

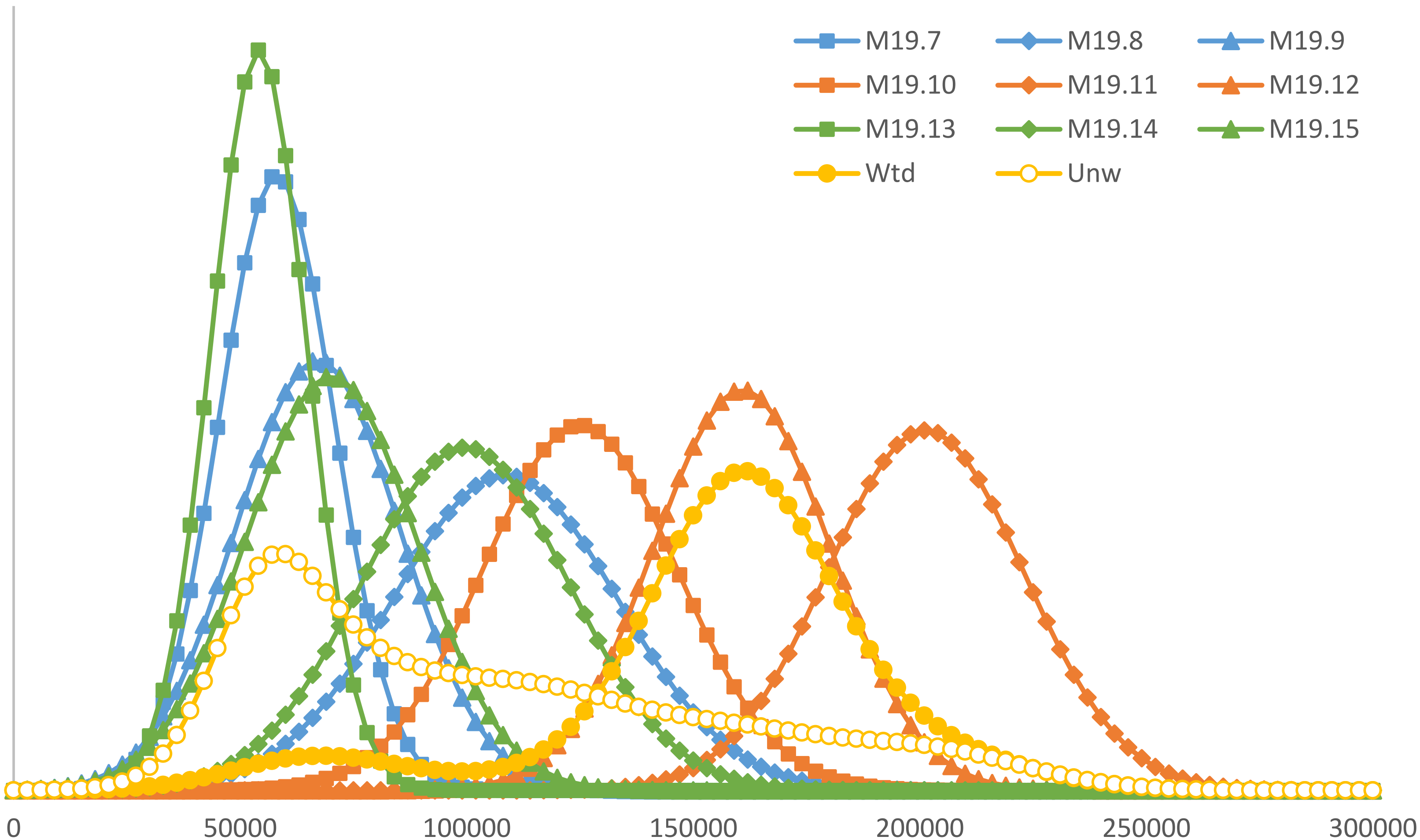
- Means and standard deviations:

			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

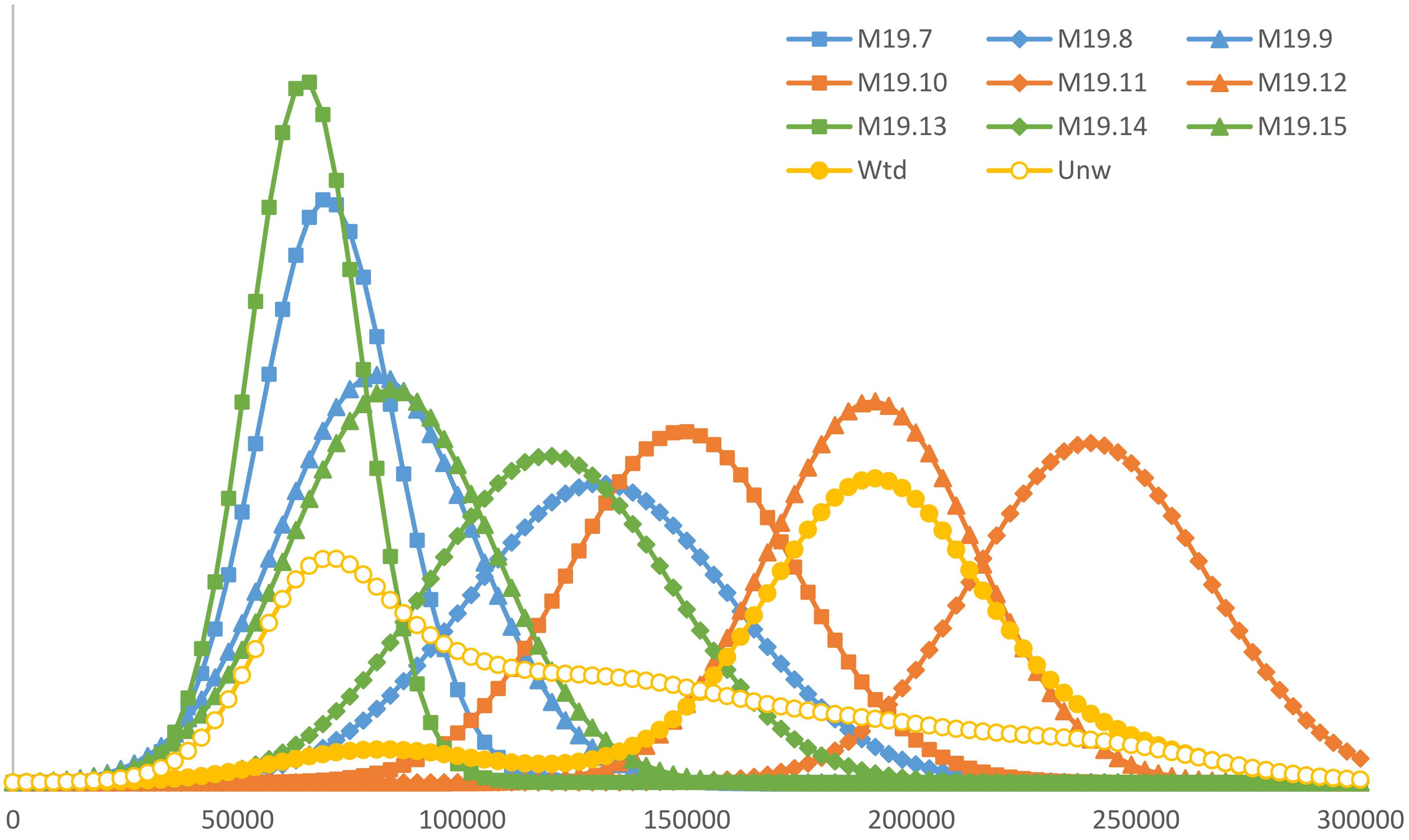
- Ensemble medians:

			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

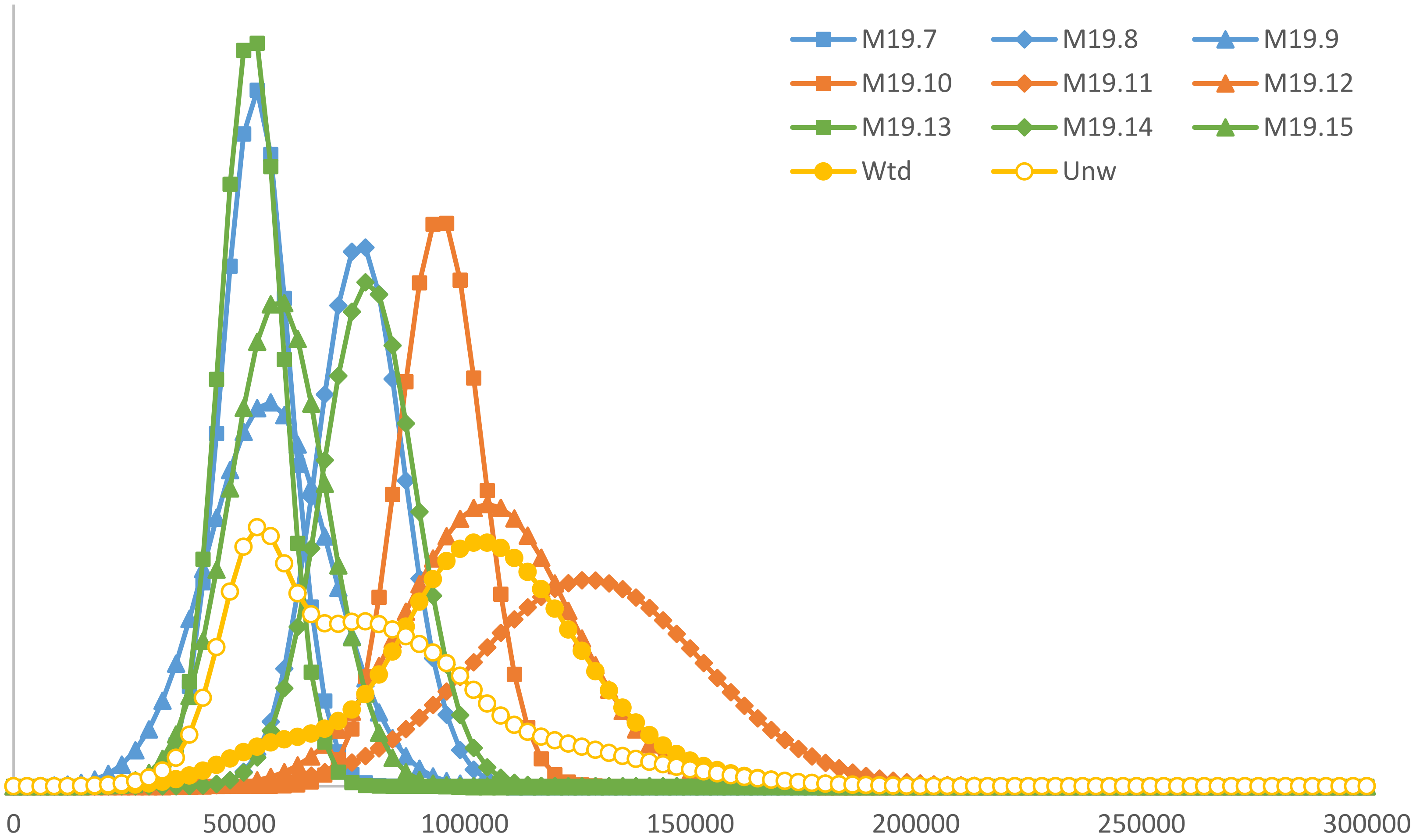
Constructing the 2020 ABC distribution



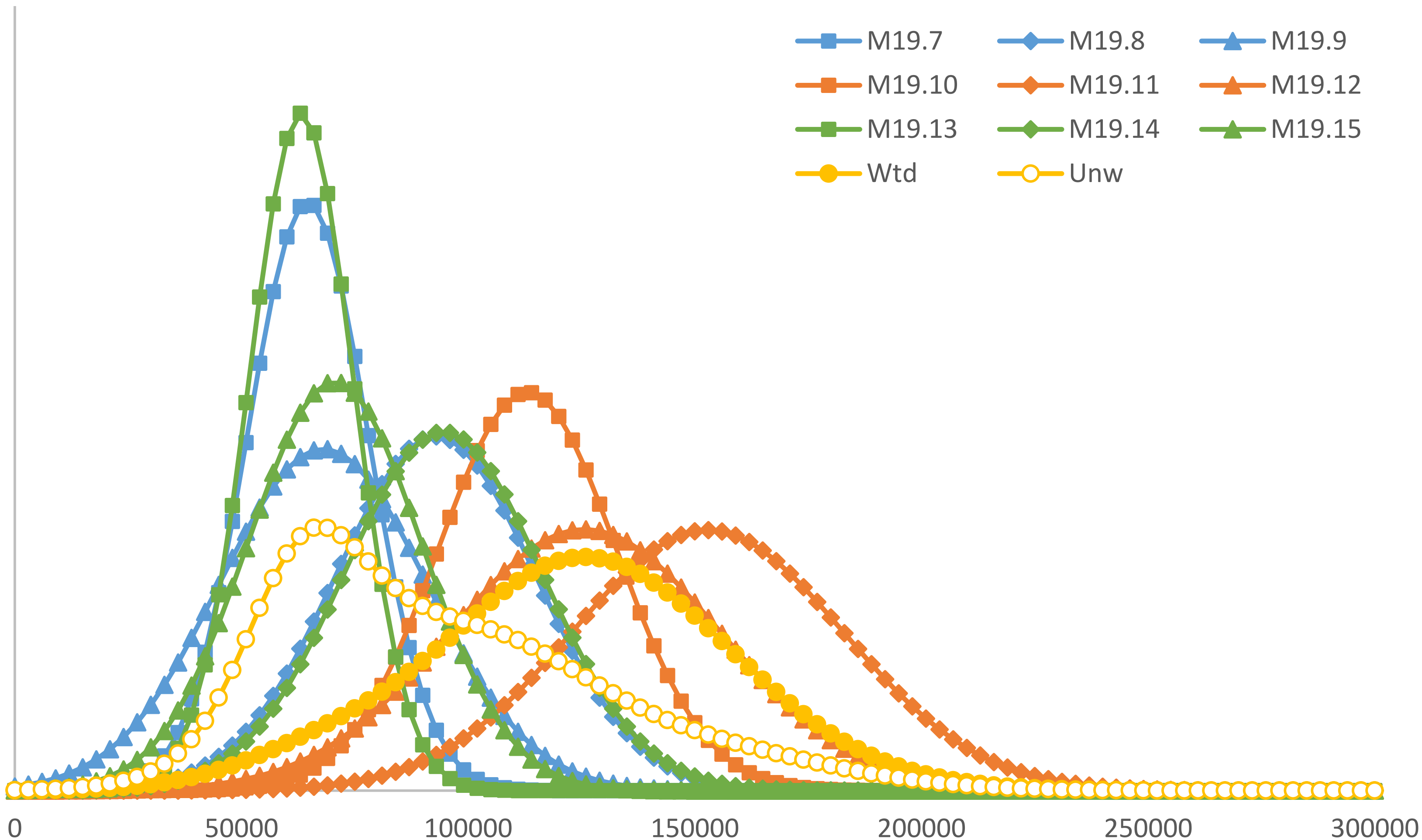
Constructing the 2020 OFL distribution



Constructing the 2021 ABC distribution



Constructing the 2021 OFL distribution



Risk table: assessment (1 of 2)

- Recent range expansion of the stock into the NBS has made assessment modeling more difficult
- On one hand, detailed investigation of multiple models gives some confidence that relevant uncertainties have been explored
- Use of an ensemble approach likewise gives some confidence that alternative explanations of the data are considered
- Moreover, an ensemble approach mitigates, at least to some extent, concerns that may exist regarding any individual model
- On the other hand, wide ranges of key quantities such as 2021 ABC (54,138 t to 201,257 t) tend to temper such confidence
- Retrospective behavior of nearly all models is within the acceptable range, but the fact that this was achieved, at least in part, by continuing to exclude the fishery age composition data is disappointing

Risk table: assessment (2 of 2)

- Ageing bias has long been suspected to exist, but this has been estimated within, and accounted for by, the assessment models for over a decade now, including (as of the present assessment) a change in the amount and direction of ageing bias during the time series
- This is a fairly data-rich assessment, with annual surveys covering a substantial portion of the stock's range and extensive observer coverage
- Assessment considerations were rated as level 1

Risk table: population dynamics (1 of 2)

- Looking at the EBS in isolation, survey biomass has been undergoing a pronounced decline since 2015
- However, when examined from the perspective of the combined EBS and NBS, the decline is much less dramatic
- Moreover, numerical abundance took a sharp upturn this year in both the EBS and NBS, due apparently to a strong 2018 year class
- On the other hand, nearshore temperatures were very high during this year's surveys, and it has been suggested that some of the 2018 cohort's apparent strength may actually represent a change in selectivity, as age 1 fish that would normally reside outside the survey areas in nearshore waters were forced to move into the survey areas
- This is corroborated to some extent by the "complex" models, which allow for time-varying selectivity, and which estimate lower relative values for the 2018 year class than the "basic" or "simple" models (although all models agree that 2018 is well above average)

Risk table: population dynamics (2 of 2)

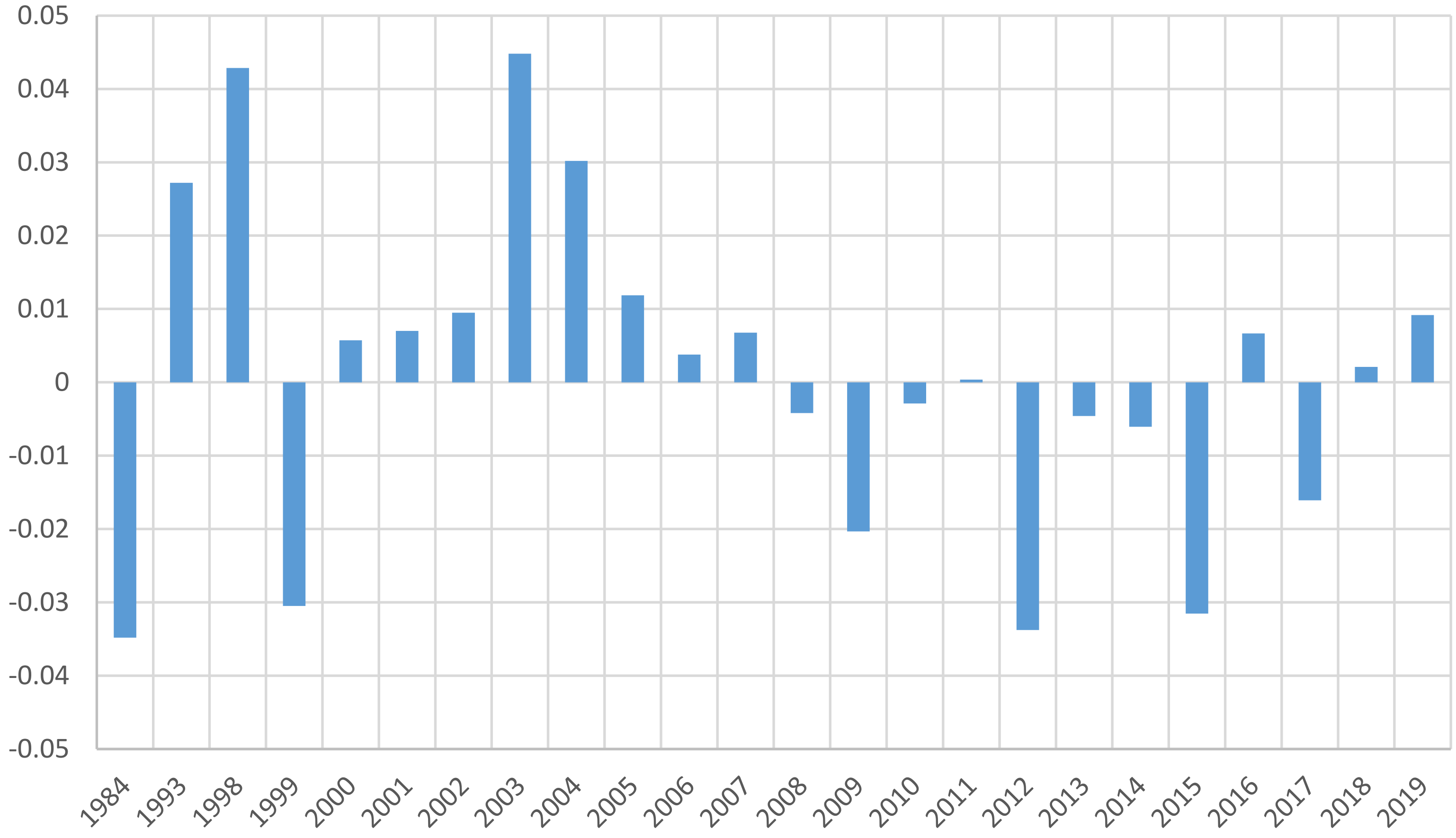
- Also of note is the string of four very poor year classes spawned in 2014-2017, two of which are among the three worst of all time
- However, these considerations are already incorporated into the assessment models and are also addressed by the harvest control rules
- Population dynamics considerations were rated as level 1

Risk table: environmental/ecosystem (1 of 3)

- 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 (see next 2 slides)
  - 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

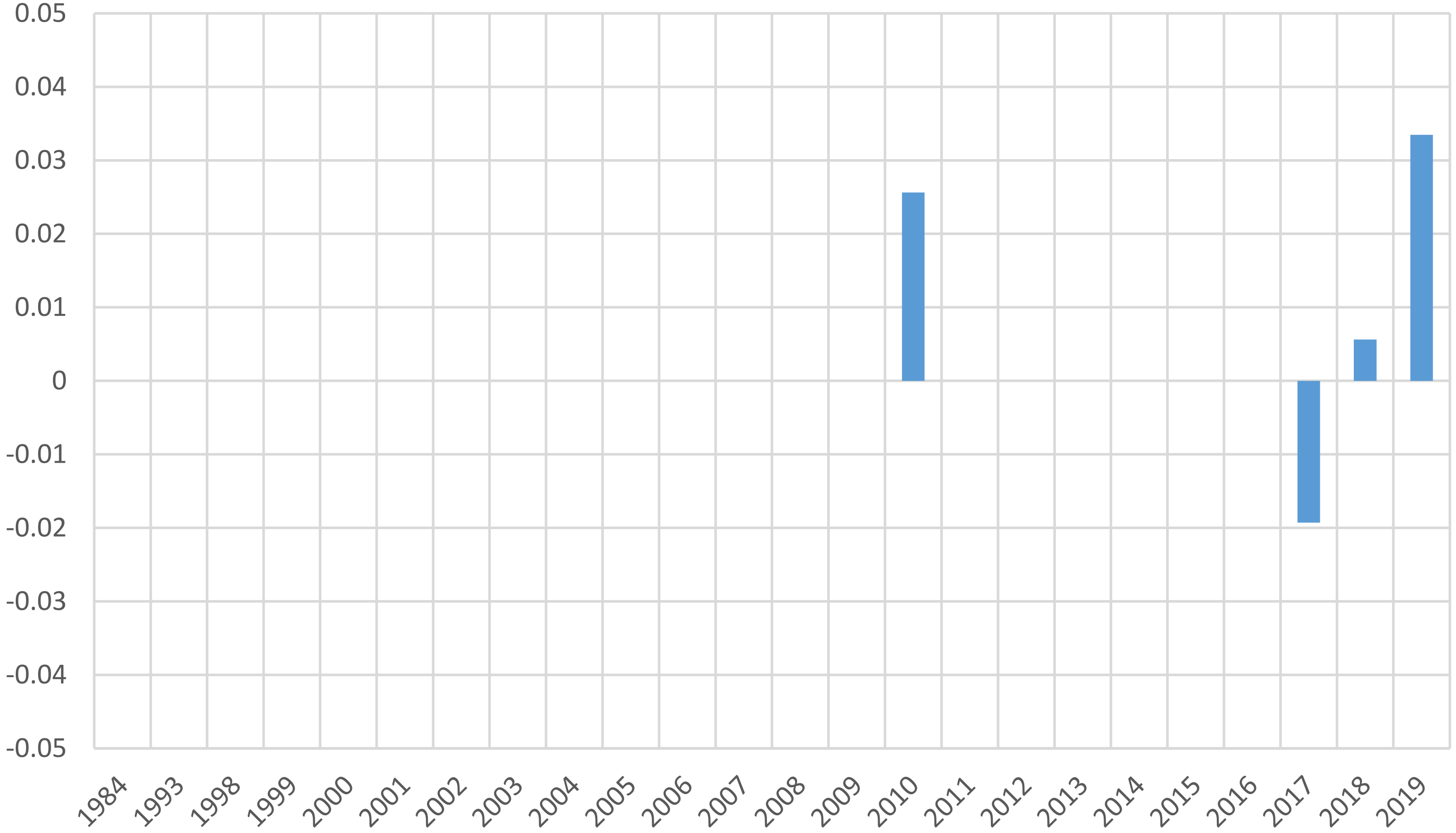
Risk table: environmental/ecosystem (2 of 3)

- EBS condition factor



Risk table: environmental/ecosystem (3 of 3)

- NBS condition factor



Risk table: fishery performance and summary

- Fishery performance considerations:
  - Mean longline fishery CPUE has increased for the last two years, and is now equal to the time series mean
  - Recent expansion of the fishery into the NBS is noteworthy, but not necessarily a concern
  - Fishery performance considerations were rated as level 1
- Summary:

Assessment-related considerations	*Population dynamics considerations*	*Environmental/ ecosystem considerations*	*Fishery Performance considerations*	*Overall score (highest of the individual scores)*
Level 1: Normal	Level 1: Normal	Level 2: Substantially increased concerns	Level 1: Normal	Level 2: Substantially increased concerns

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
- The recommended ABCs for 2020 and 2021 are 155,873 t (Tier 3b) and 102,975 t (Tier 3b), respectively, representing the maximum permissible levels under the ensemble weighted average

Summary table

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
	2019	2020	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:		As determined *this* year for:	
	2017	2018	2018	2019
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No