Assessment of Pacific cod in the Eastern Bering Sea

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Alaska Fisheries Science Center

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Team and SSC comments

Comments on assessments in general (1 of 4)

- JPT1: "The Teams recommended that authors continue to fill out the risk tables for full assessments." *Response*: A risk table is included in the "Risk Table" subsection of the "Harvest Recommendations" section.
- JPT2: "The Teams recommended that adjustment of ABC in response to levels of concern should be left to the discretion of the author, the Team(s), and/or the SSC, but should not be mandated by the inclusion of a >1 level in any particular category." *Response*: One category (environmental/ecosystem) is assigned a level of 2 in this assessment (the other categories are all level 1), but an ABC adjustment is not recommended.
- SSC1: "The SSC requests that the GPTs, as time allows, update the risk tables for the 2020 full assessments, as the SSC found this exercise to be very helpful." *Response*: See response to Comment JPT1.

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Comments on assessments in general (2 of 4)

- SSC2: “The SSC recommends dropping the overall risk scores in the tables.” *Response*: The overall risk column has been omitted.
- SSC3: “The SSC requests that the table explanations be included in all the assessments which include a risk table for completeness.” *Response*: The table explanations are included here.
- SSC4: “The SSC discussed whether increased risk or uncertainty was relative to previous assessments of the same stock, or relative to other stocks. Both are relevant and elaboration by the authors or GPTs as to what the elevated risk refers to is encouraged.” *Response*: Uncertainty is evaluated relative to both previous assessments of EBS Pacific cod and assessments of other stocks. The evaluation with respect to previous assessments is undertaken primarily monitor between-year consistency, but the risk determinations themselves are based primarily on the evaluation relative to assessments of other stocks.

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Comments on assessments in general (3 of 4)

- JPT3: Referring to the analyses described by Bryan et al. (2020), "The Teams recommend that, to the extent practicable, authors consider these analyses, or analyses like them, for incorporation in the risk table." *Response*: The analysis of Bryan et al. was considered.
- SSC13: "The SSC recommends that standardized documentation (both format and content) will be very helpful to the authors, Plan Teams and SSC.... However, the SSC cautions against standardized model fitting (e.g., a single error distribution, set of covariates), other than as a starting point.... It is more important for each species to have a statistically rigorous model selection process resulting in good model fit and diagnostics than the simplicity of fitting the same approach to all species...." *Response*: The standardized documentation introduced in the preliminary assessment (Appendix 2.1) is retained here. Time since the October SSC meeting was insufficient to explore alternative VAST specifications, although this could be undertaken in the future.

Comments on assessments in general (4 of 4)

- SSC14: "The SSC received a summary of the work done by Meaghan Bryan (NOAA-AFSC) and Grant Thompson (NOAA-AFSC) to inform the Joint Plan Team regarding the effects of missing survey data on groundfish stock assessments. The SSC notes that missing data are expected due to the biennial nature of the GOA and AI surveys, and that the planned or unplanned nature of missing data does not inherently imply bias in the stock assessment. The SSC supports the JPT's recommendation for authors to explicitly consider the survey loss analyses (or analyses like them) in developing their risk tables for this year, but does not suggest a standardized approach for all species, noting important differences in the behavior of individual assessments." *Response*: See response to Comment JPT3.

Comments specific to this assessment (1 of 8)

- BPT10: “The Team recommends that the ESR and/or ESP provide an index of movement (e.g., using the standard EBS bottom trawl survey stations, evaluate the proportion of Pacific cod biomass over time in the northernmost survey stations that are located between 59°N and 60°N in years 1982-2019) to validate the movement indices in this model. This would be needed in November if these models move forward, or if not, should be included in the ESP for Pacific cod in 2021.” *Response*: This assessment includes a draft Ecosystem and Socioeconomic Profile (ESP) for the first time (Appendix 2.2), which provides some information on potential movement covariates. In particular, sea ice indicators are shown to be highly correlated with the northings in the center of gravity output from VAST. See also Comment SSC22.

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Comments specific to this assessment (2 of 8)

- BPT11: "The Team recommends the author run the model ensemble averaging approach using models 19.12a., 20.4, 19.12e, 19.12, 19.15, and using last year's ensemble averaging methodology (without the exponential weighting as per the SSC recommendations from 2019)." *Response*: All of the Team's requested models except 19.12e are included here (see Comment SSC19). Last year's ensemble averaging methodology is retained, except that the arithmetic mean is used instead of exponential weighting. See also Comment SSC25.
- SSC15: "The SSC does think there is value in looking back at previously accepted models to consider what advice they would provide under current conditions." *Response*: Two of the models in Ensemble B feature potentially dome-shaped survey selectivity, which was a regular feature of EBS Pacific cod assessment models prior to 2016.

Comments specific to this assessment (3 of 8)

- SSC16: “The use of the Dirichlet-multinomial distribution was discussed because the sample size parameter was quite large, potentially allowing the sample size to represent more samples than hauls. The author did not think this was causing any convergence issues, but the SSC recommends that the authors explore this and potentially constrain that parameter.” *Response*: There may have been some miscommunication during the SSC meeting, because one of the features of the Dirichlet-multinomial is that it *does not* allow the effective sample size to exceed the input sample size (here, number of hauls). All of the models presented here passed a “jitter” test (see “Convergence Behavior” subsection in the “Analytic Approach” section), indicating that convergence was not an issue, even though the log of the Dirichlet-multinomial parameter was invariably estimated to be near the upper bound (=10.0) in the case of size composition data (but not age composition data).

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Comments specific to this assessment (4 of 8)

- SSC17: “The SSC was very interested to see the exploration of spatial models with movement.... However, the SSC notes that this is a fairly large modeling innovation that needs further review.... The structure of the underlying linear model for age-dependent movement across a certain subset of ages needs further justification.... The SSC would like to have clear evidence of spawning occurring in the NBS.... Fully vetting all of the models for these ensembles may be better suited for the upcoming CIE review in 2021....” *Response*: Further investigation of movement models will be proposed as a topic for the 2021 CIE review. Regarding the desire for clear evidence of spawning in the NBS, the sizecomp data from the 2019 NBS survey show a very pronounced peak in the size range corresponding to 1-year-old fish (Figure 2.9b). Unless there was a very substantial migration of age 0 fish (in 2018) or early age 1 fish (in 2019) from the EBS to the NBS, the most likely explanation for this pronounced size mode is successful spawning in the NBS.

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Comments specific to this assessment (5 of 8)

- SSC18: “The SSC supports the BSAI-GPT recommendation of using the set of models that do not have a catchability prior.” *Response*: None of the models included here feature a catchability prior.
- SSC19: “The SSC supports the models that the BSAI-GPT selected for inclusion in the ensemble, but not 19.12e because the SSC would like to see additional exploration of hypotheses about movement and spatial dynamics and how these are handled by the model. This reduces the model ensemble to four models. These models are 19.12a, 19.12, 20.4, and 19.15.... This selection of models eliminates all four of the two-area models. If it were desired to have a fifth model in the ensemble or for consideration on its own, a simpler model that was previously used for management (e.g., 16.6i) might be a useful addition.” *Response*: The four models requested by the SSC are included here, and Model 19.12e is not. Model 16.6i is also not included.

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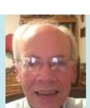
Comments specific to this assessment (6 of 8)

- SSC20: "The SSC suggests that spatial models that apportion movement and recruitment to sub-areas be considered research models..., including explorations of the relationships of the environmental covariates used, and other hypotheses about movement such as natal homing. The SSC suggests that if environmental covariates are to be used in the future, they should be sufficiently constrained by informative priors penalizing estimates toward no effect, such that only when there is strong evidence of their relationship will movement be substantially altered." *Response*: This comment will be forwarded for the 2021 CIE review.
- SSC21: "The SSC notes that the use of time-varying catchability in the NBS may be diluting the information content from that small set of surveys. It may be possible to include movement in a simple way by mirroring the NBS with the EBS catchability inversely (e.g., NBS $Q = 1 -$ EBS Q)." *Response*: SS currently lacks the capability to implement this suggestion, although it is under consideration for inclusion in the future.



Comments specific to this assessment (7 of 8)

- SSC22: "The BSAI-GPT recommended examining survey catches at the northern stations in the EBS survey over time as a potential index of movement. In addition to the BSAI-GPT request, there are some outputs of VAST that might be useful including the index of area occupied and the center of gravity estimates." *Response*: See Comment BPT10.
- SSC23: "The SSC recommends trying to obtain some fishery size and age composition samples in the NBS to verify that selectivities for both areas are similar." *Response*: It is likely that size composition data from the fishery in the NBS will become available in time for use next year. The assumption that NBS fishery selectivity mirrors EBS fishery selectivity was used in this year's preliminary assessment only because NBS fishery size composition data were unavailable.

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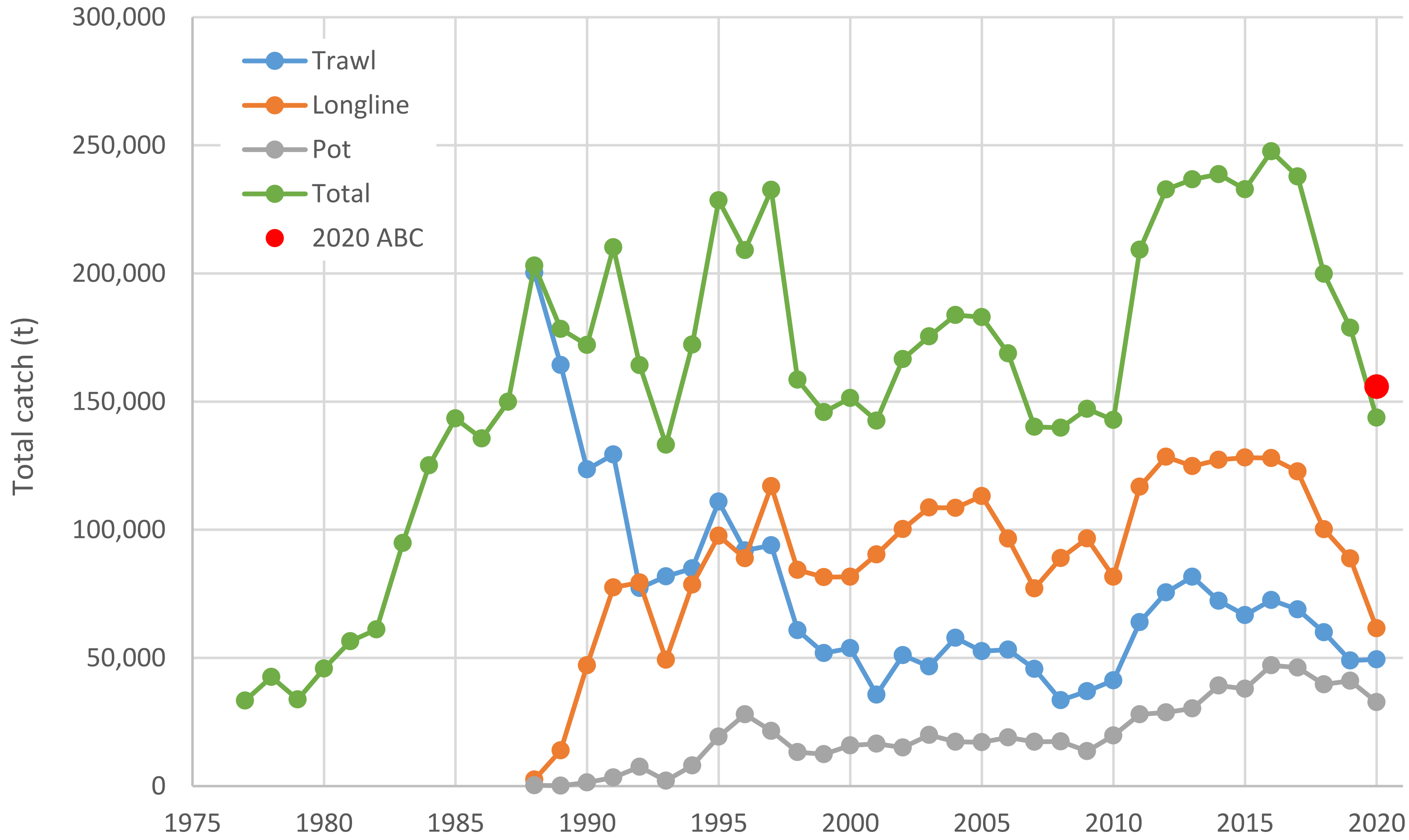
Comments specific to this assessment (8 of 8)

- SSC24: "Finally, the cross-conditional decision analysis (CCDA) is interesting and the SSC really appreciates the work done to identify viable alternative methods for weighting ensemble models, and the comparison to machine learning. This is a novel effort to address model weighting which is one of the most controversial aspects of ensemble modeling. However, it was noted that CCDA is a new, computationally-intensive method that might be too difficult for use due to time limitations ... in the current assessment cycle. The SSC recommends that this methodology be reviewed at the upcoming CIE review." *Response*: The CCDA approach will be proposed as a topic for the 2021 CIE review.
- SSC25: "The SSC affirms that the authors should use last year's ensemble averaging methodology (without the exponential weighting...)." *Response*: See Comment BPT11.

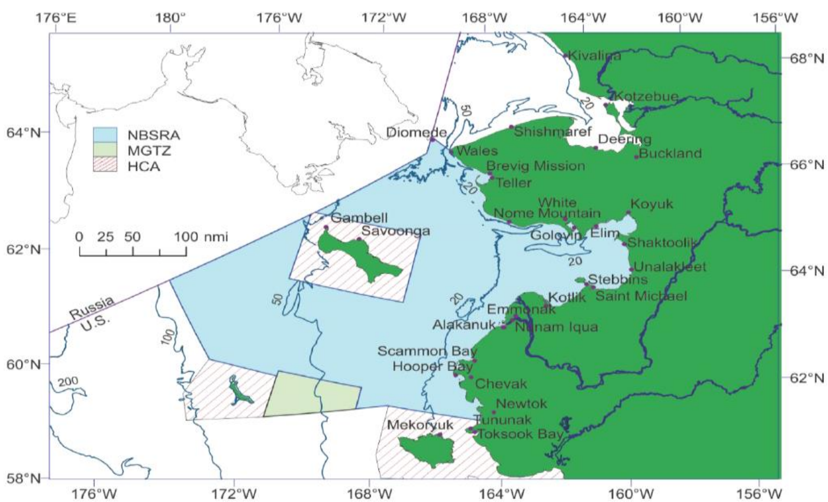
Data

Catch time series, 1977-2020 (by gear)

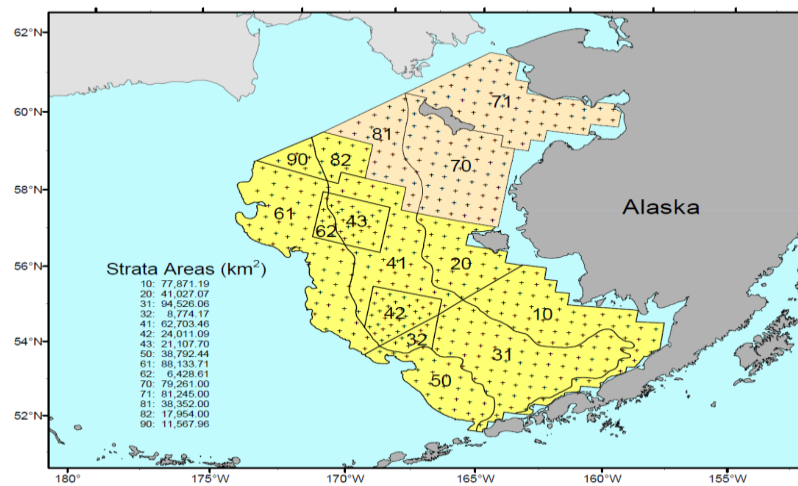


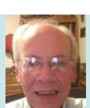
Comparing the NBSRA and NBS survey area

Northern Bering Sea Research Area

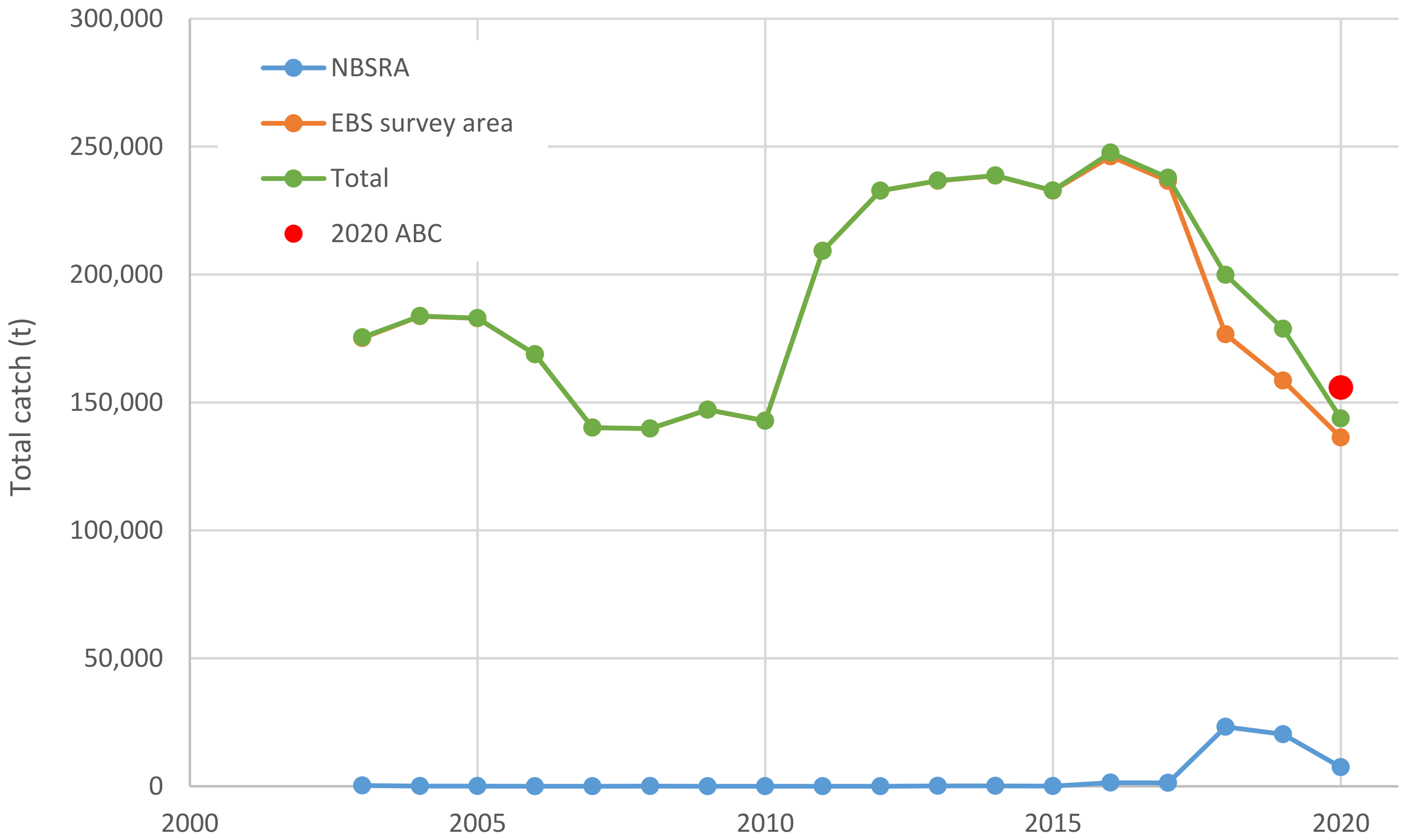


Bering Sea shelf survey areas

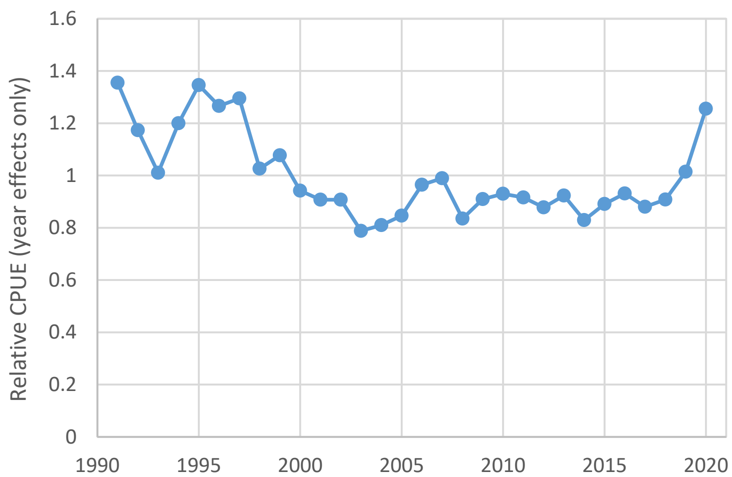


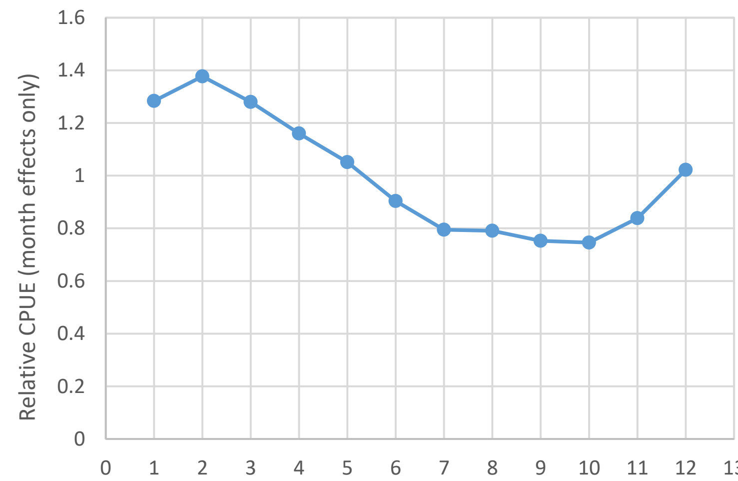


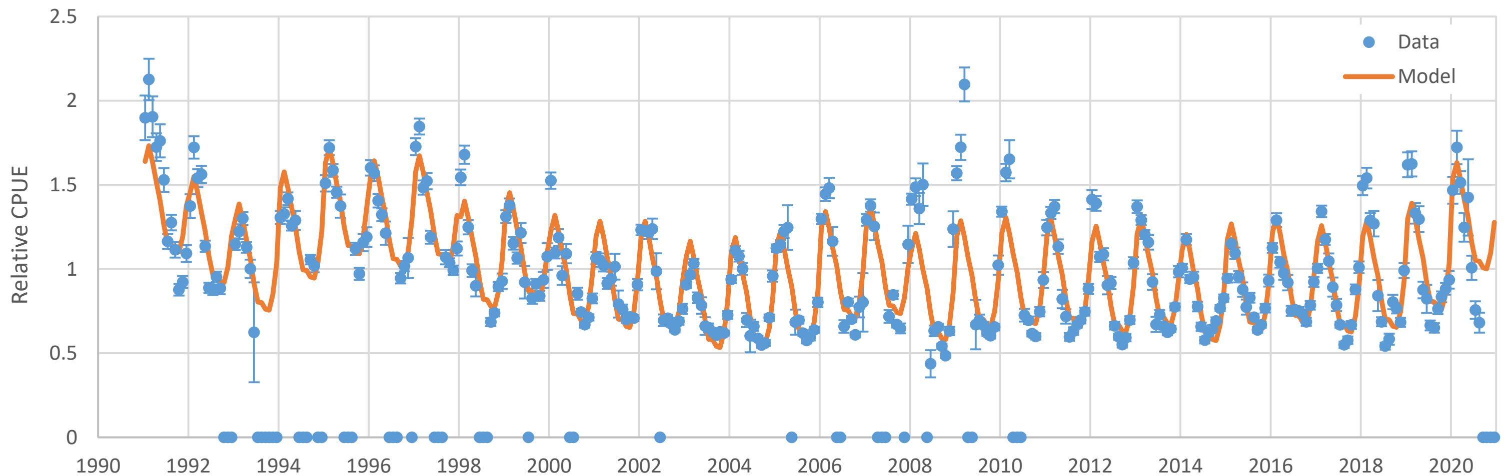
Catch time series, 2003-2020 (by area)



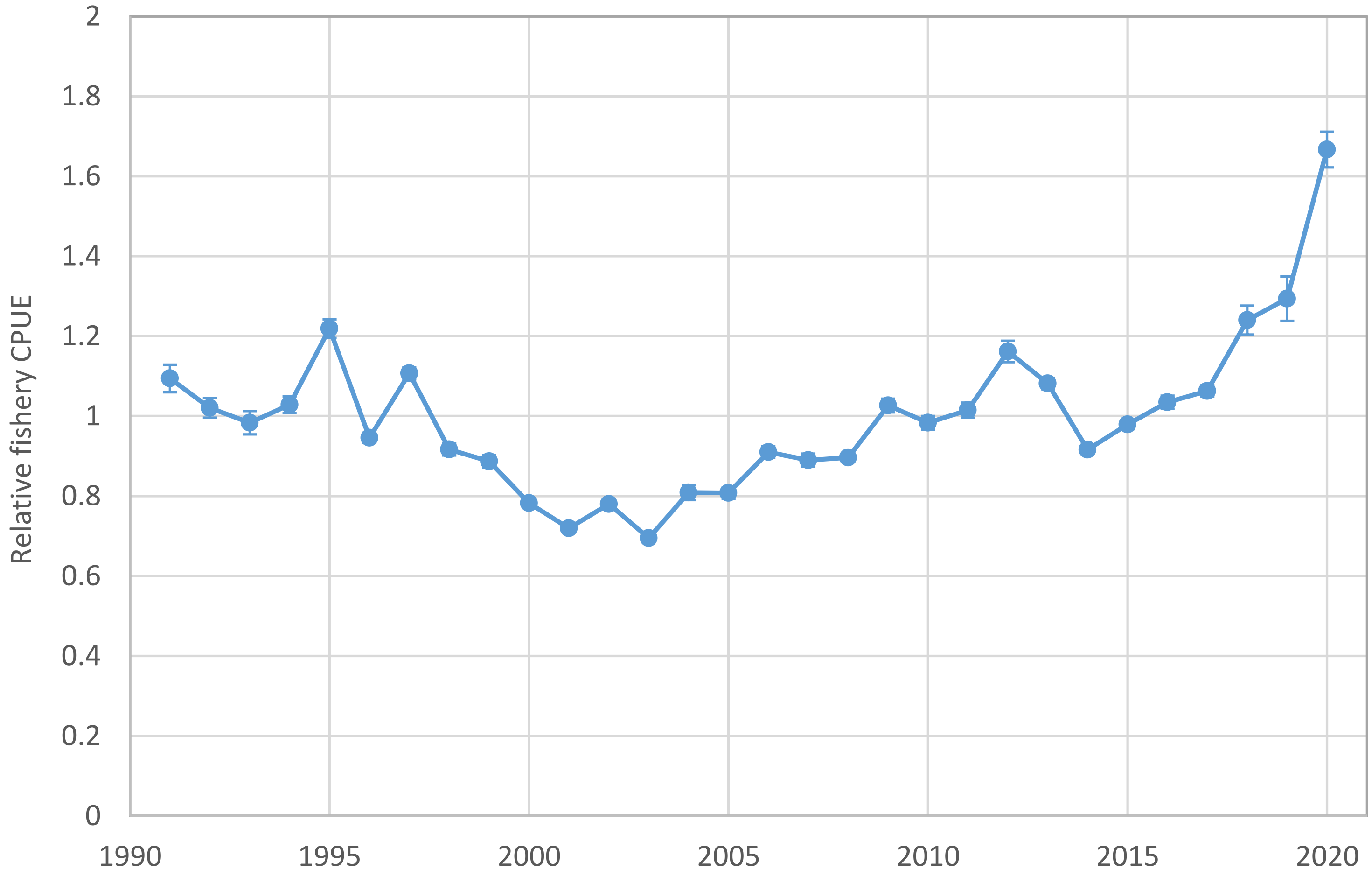
Longline fishery year-and-month CPUE



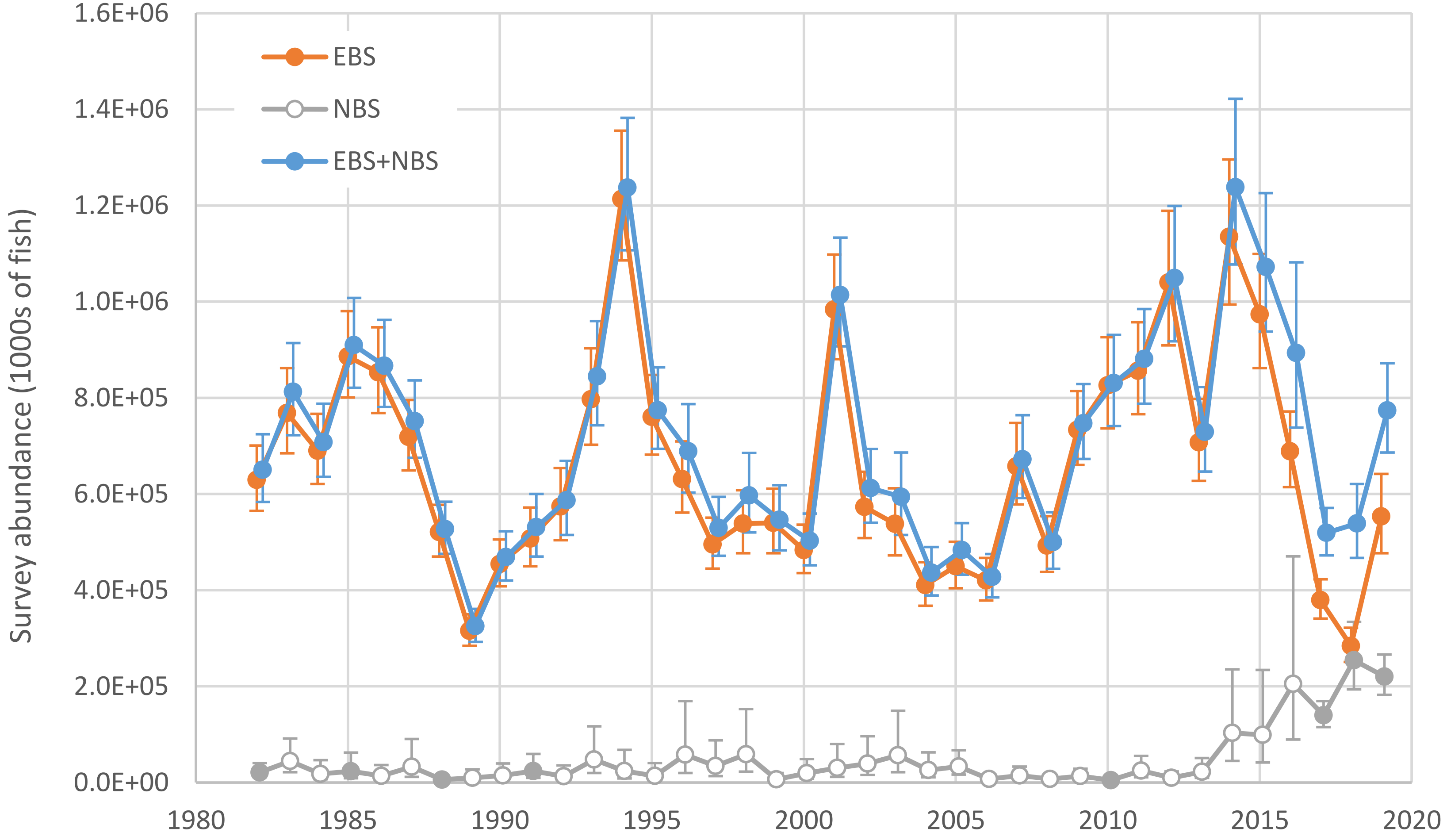




Catch-weighted, all-gear, annual mean CPUE

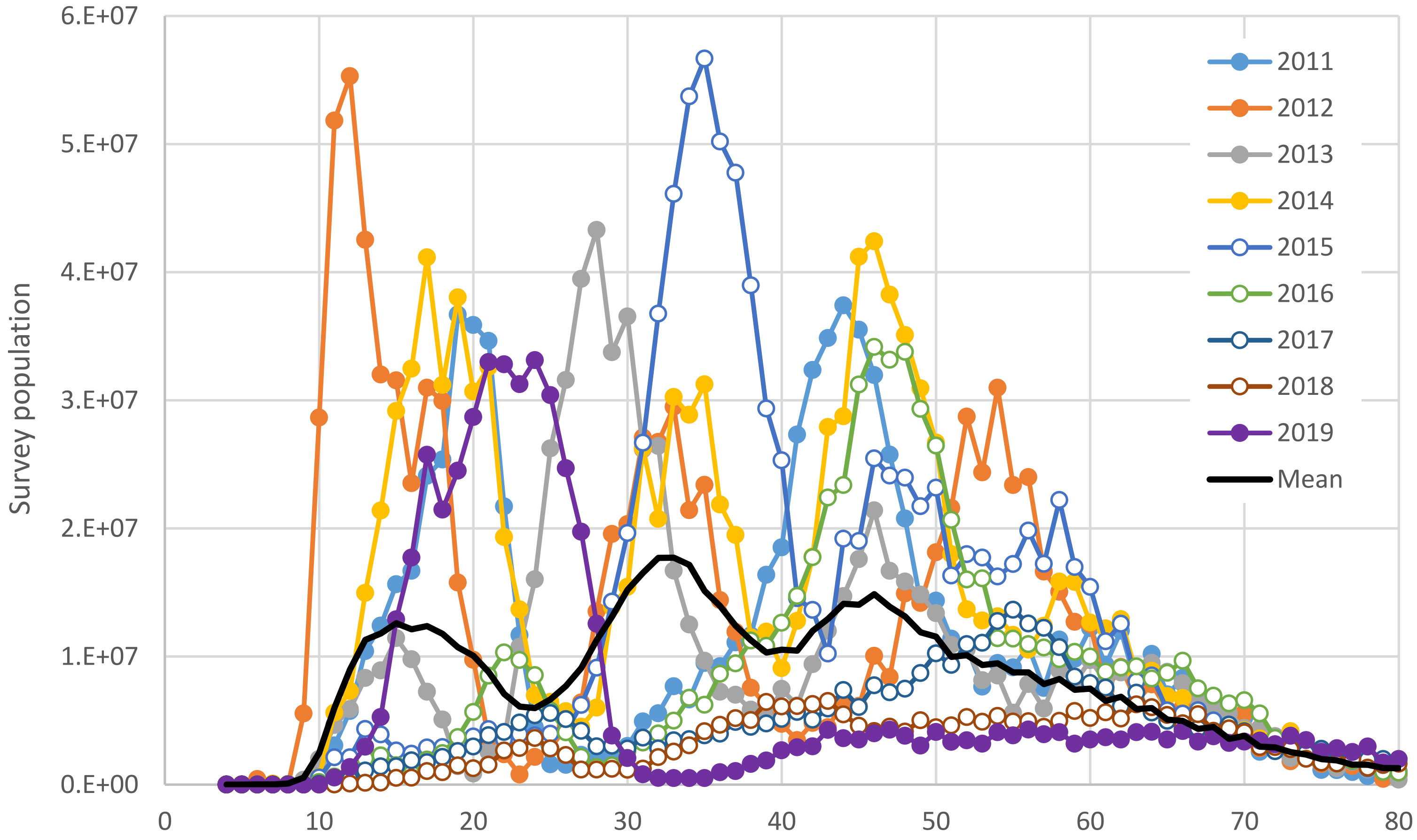


Survey abundance (VAST)



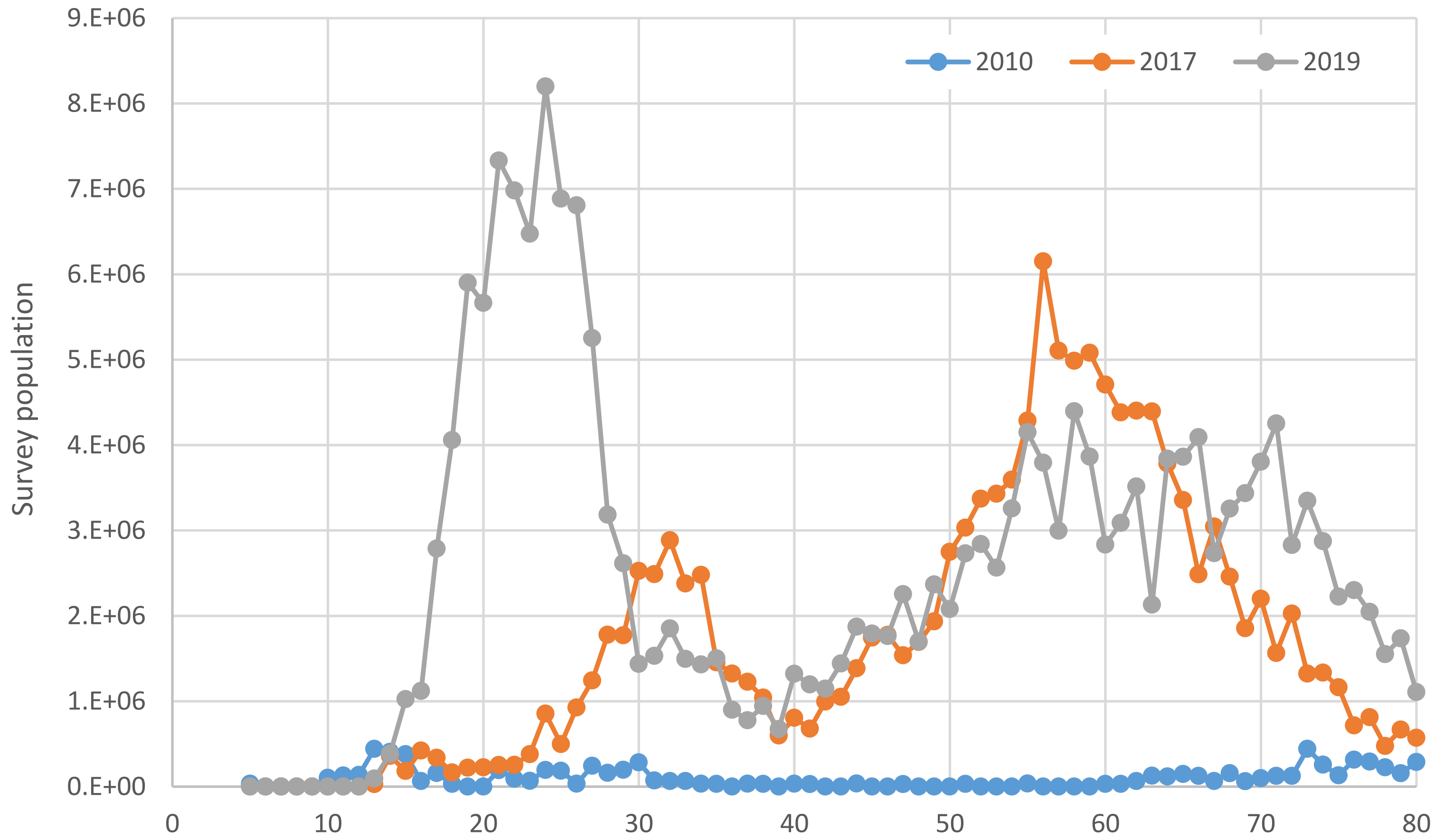
Recent survey sizecomps (EBS)

- 2011-14: strong age 1; 2015-18: weak age 1; 2019: strong age 1



Recent survey sizecomps (NBS)

- 2018 looks strong here, too (the result of NBS spawning?)



Models

Overview of models

- A pair of 2x2 factorial designs
  - Ensemble A (requested by SSC; previewed in September)
    - Factor A1: Allow *Q* to vary?
    - Factor A2: Combine EBS and NBS surveys?
  - Ensemble B (prompted by industry review and comments)
    - Factor B1: Use fishery CPUE?
    - Factor B2: Allow domed survey selectivity?
- AB = union of A (blue) and B (yellow); base model = intersection (green)

Factor A1: Allow *Q* to vary?	no		yes		(yes)		
Factor A2: Combine surveys?	no	yes	no	yes			
Factor B1: Use fishery CPUE?	(no)			no		yes	
Factor B2: Allow domed selex?				no	yes	no	yes
Model:	20.4	19.12a	19.15	19.12	20.8	20.9	20.10

Base model (1 of 5)

- Sexes combined
- One season per year
- Natural mortality (constant across age and time) freely estimated
- Mean length at age follows a Richards growth function:
  - Base value of length at age 1.5 freely estimated
    - With constrained annual deviations on the log scale
  - Von Bertalanffy (Brody) growth coefficient freely estimated
  - Asymptotic length freely estimated
  - Richards growth coefficient freely estimated
- SD of L_at_A varies linearly with L_at_A, parameters freely estimated
- Weight at length varies annually, estimated outside the model
- Maturity at length (constant across time) estimated outside the model

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Base model (2 of 5)

- Mean ageing error varies with age, freely estimated within each block:
  - 1977-2007
  - 2008-present
- Recruitment is independent of stock size:
  - Mean freely estimated within each block:
    - Pre-1977
    - 1977-present
  - With constrained annual deviations on the log scale

Base model (3 of 5)

- One survey, covering the EBS and NBS combined
  - Base value of log catchability freely estimated
    - With constrained annual deviations
  - Size-based, double-normal selectivity, with parameters as follow:
    - Base value of first size with selectivity=1 freely estimated
      - With constrained annual deviations on the log scale
    - Logit of size range with selectivity=1 fixed at 10.0
    - Base value of log of SD for 1st normal pdf freely estimated
      - With constrained annual deviations
    - Log of SD for 2nd normal pdf fixed at 10.0
    - Logit of selectivity at minimum size fixed at -10.0
    - Logit of selectivity at maximum size fixed at 10.0

Base model (4 of 5)

- One fishery, covering the EBS and NBS combined
  - Size-based, double-normal selectivity, with parameters as follow:
    - First size with selectivity=1 freely estimated
    - Logit of size range with selectivity=1 freely estimated
    - Base value of log of SD for 1st normal pdf freely estimated
      - With constrained annual deviations
    - Log of standard deviation for 2nd normal pdf freely estimated
    - Logit of selectivity at minimum size fixed at -10.0
    - Base value of logit of selectivity at maximum size freely estimated
      - With constrained annual deviations

Base model (5 of 5)

- Input sample sizes ($Nsamp$) for compositional data range between zero and an initial number ($Ninit$) according to the formula $Nsamp = (1 + \exp(ln\theta)\, Ninit)/(1 + \exp(ln\theta))$, where $ln\theta$ is a time-invariant parameter (the "Dirichlet-multinomial" parameter, estimated in natural log space, so that $Nsamp$ approaches 0 as $ln\theta$ approaches $-\infty$, $Nsamp$=(1+$Ninit$)/2 when $ln\theta$=0, and $Nsamp$ approaches $Ninit$ as $ln\theta$ approaches $+\infty$), freely estimated for each of the compositional data types (fishery size composition data, survey size composition data, and survey age composition data), where:
  - For survey compositional data, $Ninit$ is the number of sampled hauls
  - For fishery compositional data, $Ninit$ is equal to the number of sampled hauls rescaled so that the average $Ninit$ for the fishery is equal to the average $Ninit$ for the survey (so that, on average, fishery data are emphasized equally with survey data)

Alternative models (1 of 2)

- Differences between 19.12 and the other Ensemble A models:
- Models 20.4 and 19.15 include 5 additional true parameters:
  - Base log catchability in the NBS survey
  - Two parameters for the NBS survey selectivity:
    - First size with selectivity=1
    - Log standard deviation for 1st normal pdf
  - Two Dirichlet-multinomial parameters for the NBS survey:
    - One for size composition
    - One for age composition
- Models 20.4 and 19.12a lack annual devs for survey $\ln(Q)$.
- Model 19.15 includes a set of annual devs for NBS survey $\ln(Q)$.

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Alternative models (2 of 2)

- Differences between 19.12 and the other Ensemble B models:
- Models 20.9 and 20.10 include a base value for fishery $\ln(Q)$, and, potentially, annual devs for fishery $\ln(Q)$
- Models 20.8 and 20.10 include 3 additional survey selectivity parameters:
  - Logit of size range with selectivity=1
  - Log of standard deviation for 2^{nd} normal pdf
  - Logit of selectivity at maximum size

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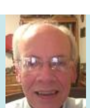
Results

Goodness of fit: abundance indices (1 of 2)

- Root-mean-squared-standardized-residual (RMSSR)

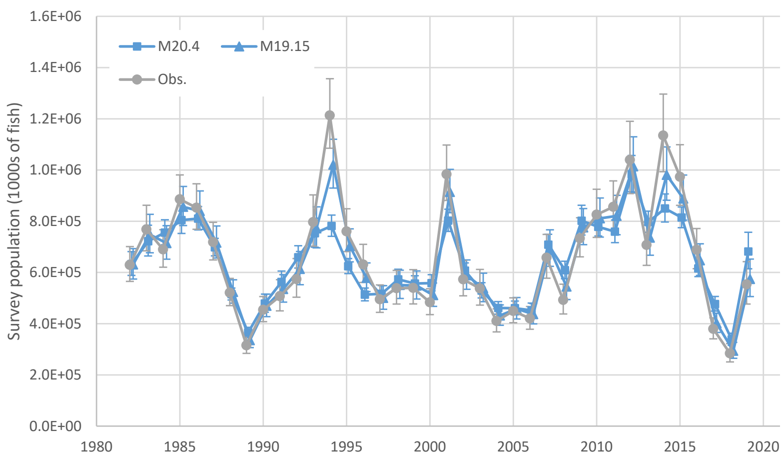
Index:	EBS		NBS	
Model:	M20.4	M19.15	M20.4	M19.15
RMSSR:	2.448	1.001	6.516	1.000

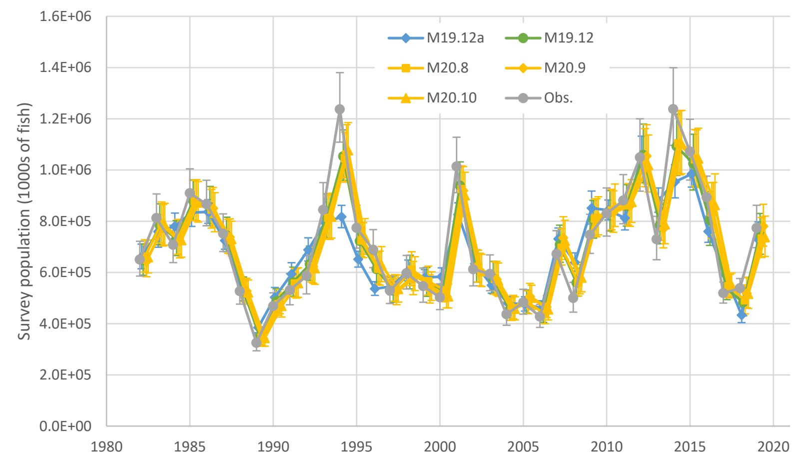
Index:	EBS+NBS					Fishery	
Model:	M19.12a	M19.12	M20.8	M20.9	M20.9	M20.9	M20.9
RMSSR:	2.319	0.999	1.000	0.999	1.000	0.992	0.659

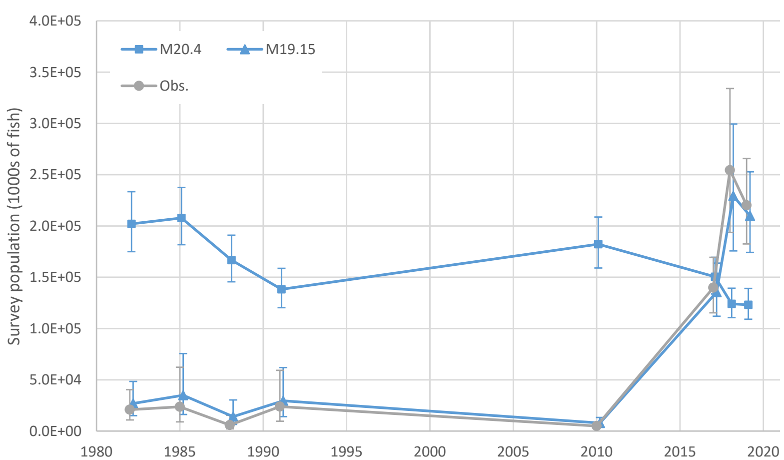


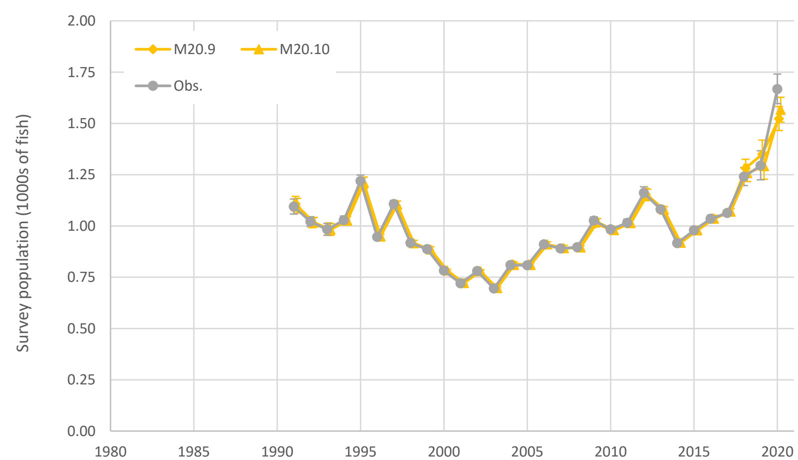
Goodness of fit: abundance indices (2 of 2)

- Top left: EBS; top right: EBS+NBS; bottom left: NBS; bottom right: fishery









Goodness of fit: size and age composition

- Size composition

	Fleet:	Fishery						
	Model:	M20.4	M19.12a	M19.15	M19.12	M20.8	M20.9	M20.10
	Nave:	356	356	356	356	356	356	356
McAllister-Ianelli	Neff:	820	824	823	820	816	795	835
	Ratio:	2.305	2.316	2.313	2.306	2.295	2.236	2.346
Thorson et al.	ln(θ):	9.989	9.989	9.989	9.989	9.989	9.988	9.989
	Neff:	356	356	356	356	356	356	356
	Ratio:	1.000	1.000	1.000	1.000	1.000	1.000	1.000

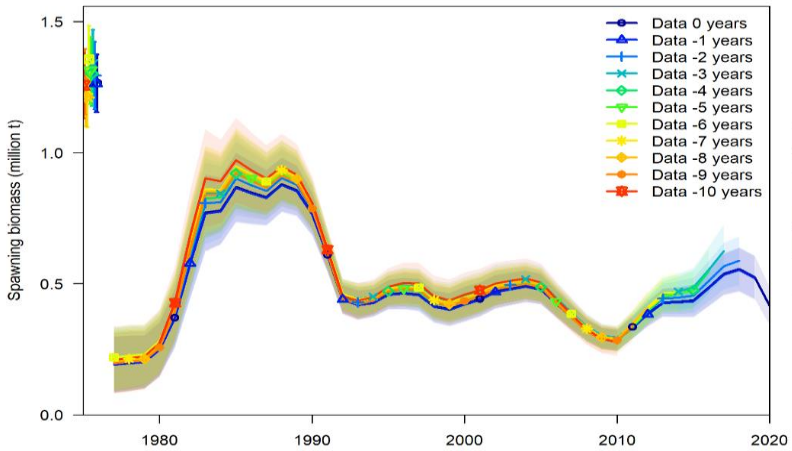
	Fleet:	EBS survey		NBS survey		EBS+NBS survey				
	Model:	M20.4	M19.15	M20.4	M19.15	M19.12a	M19.12	M20.8	M20.9	M20.10
	Nave:	347	347	96	96	356	356	356	356	356
McAllister-Ianelli	Neff:	584	607	84	85	596	621	630	601	599
	Ratio:	1.683	1.750	0.873	0.880	1.676	1.746	1.772	1.690	1.683
Thorson et al.	ln(θ):	9.984	9.984	9.117	9.236	9.983	9.984	9.985	9.982	9.986
	Neff:	347	347	96	96	356	356	356	356	356
	Ratio:	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

- Age composition

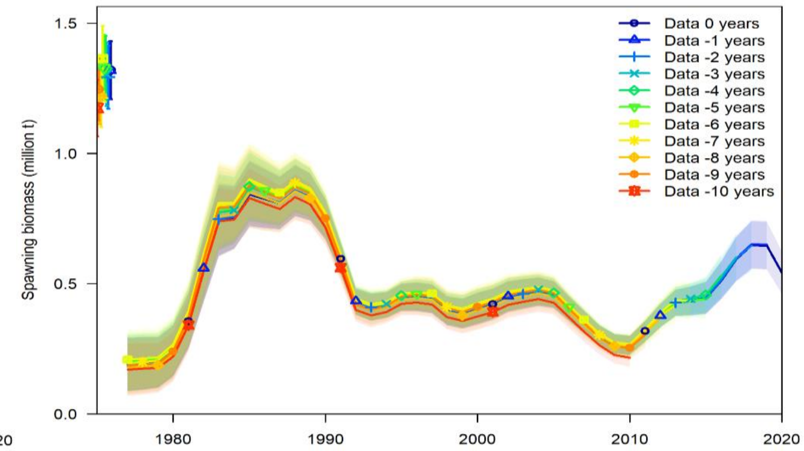
	Fleet:	EBS survey		NBS survey		EBS+NBS survey				
	Model:	M20.4	M19.15	M20.4	M19.15	M19.12a	M19.12	M20.8	M20.9	M20.10
	Nave:	360	360	85	85	373	373	373	373	373
McAllister-Ianelli	Neff:	119	125	23	24	106	113	109	91	85
	Ratio:	0.332	0.349	0.278	0.284	0.284	0.303	0.292	0.244	0.229
Thorson et al.	ln(θ):	0.253	0.363	-0.367	-0.314	-0.044	0.045	-0.211	-0.547	-0.922
	Neff:	203	212	35	36	183	191	167	137	107
	Ratio:	0.564	0.591	0.416	0.429	0.490	0.513	0.449	0.368	0.287

Retrospective analysis: Ensemble A models

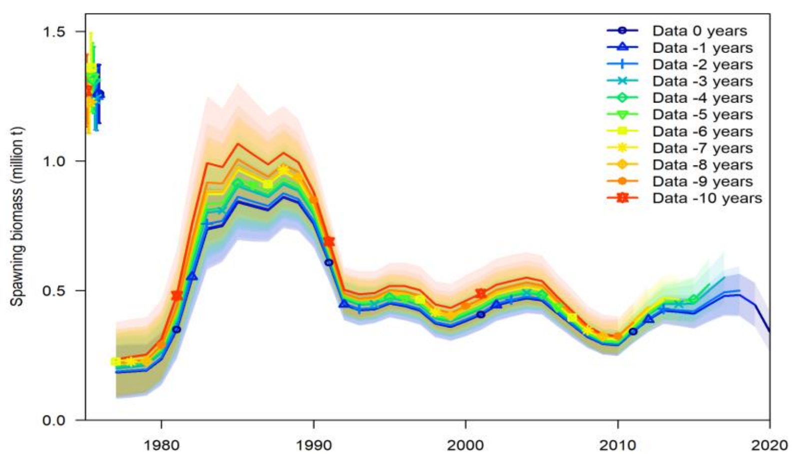
Model 20.4 (ρ = 0.0601)



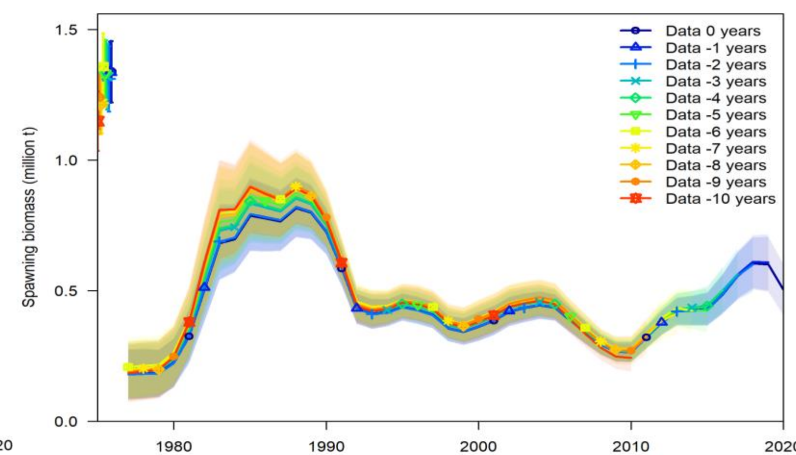
Model 19.12a (ρ = -0.0211)



Model 19.15 (ρ = 0.1046)

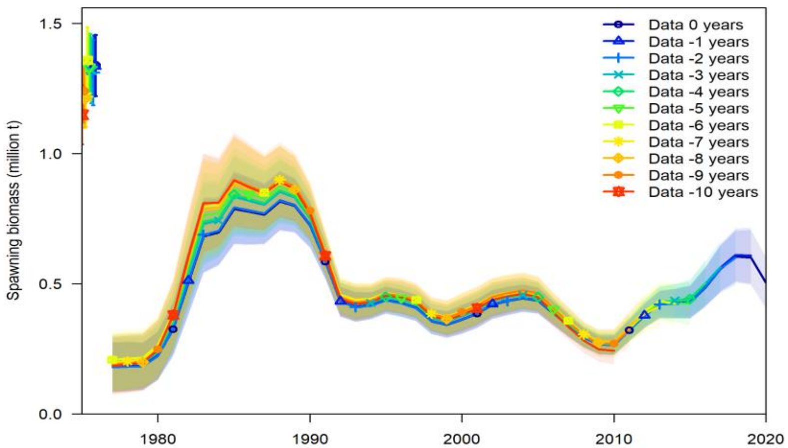


Model 19.12 (ρ = -0.0028)

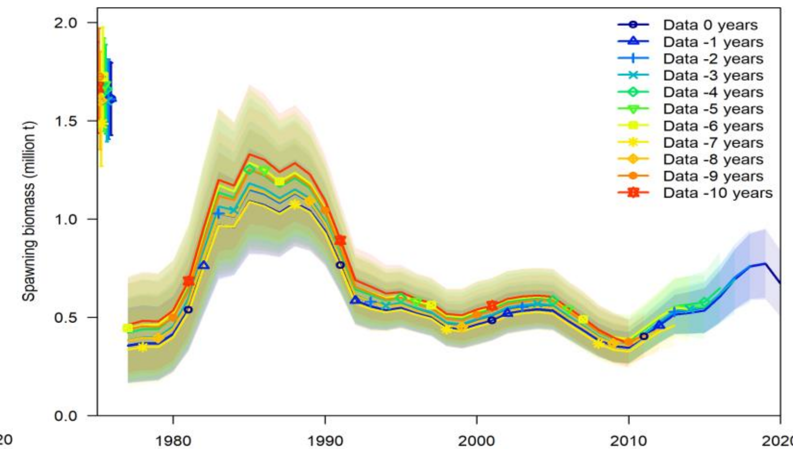


Retrospective analysis: Ensemble B models

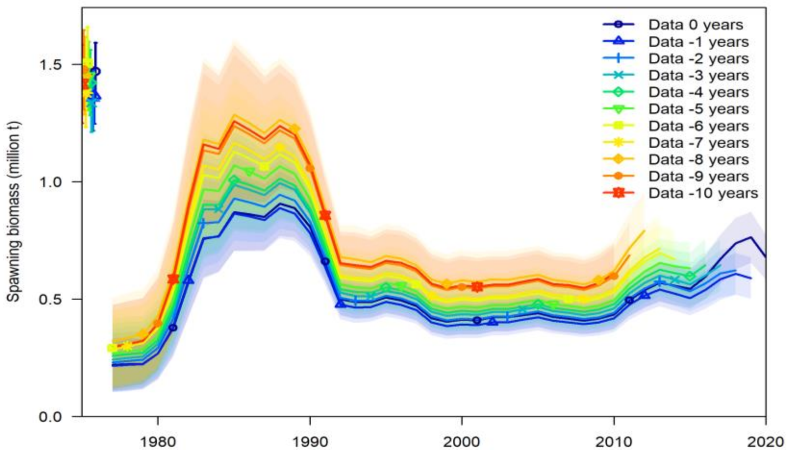
Model 19.12 (ρ = -0.0028)



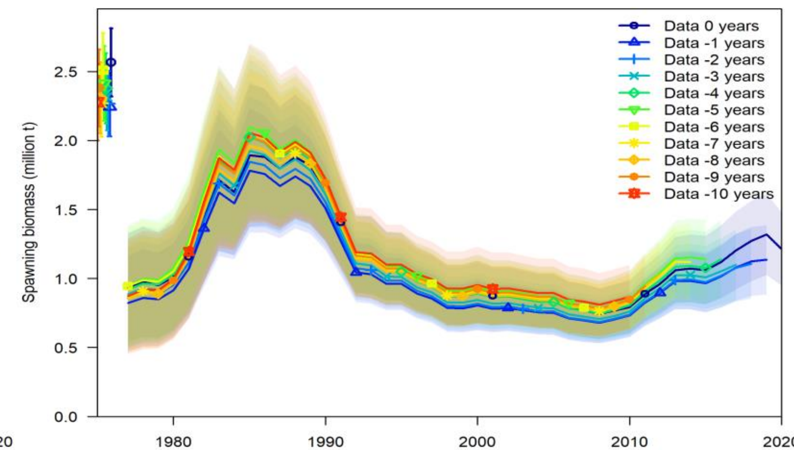
Model 20.8 (ρ = 0.0076)



Model 20.9 (ρ = 0.1533)



Model 20.10 (ρ = 0.0071)



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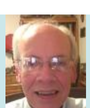
Team/SSC model weighting criteria/emphases

- Same criteria and emphases as last year:
  - Emphasis = 3
    - Plausible hypothesis
    - Plausible catchability
    - Acceptable retrospective bias
  - Emphasis = 2
    - Comparable complexity
    - Dev sigmas estimated appropriately
    - Fits consistent with variances
  - Emphasis = 1
    - Incremental changes
    - Objective criterion for sample sizes
    - Change in ageing criteria addressed



Evaluating the models w.r.t. criteria 1-3

1. Plausible hypothesis:
   - Hypothesis 1 is gone; all models are Hypothesis 2 or 3
2. Plausible catchability:

Year	20.4			19.15			EBS+NBS				
	EBS	NBS	Sum	EBS	NBS	Sum	19.12a	19.12	20.8	20.9	20.10
2017	0.894	0.430	1.324	0.838	0.441	1.279	0.986	0.952	1.023	0.771	1.084
2018	0.894	0.430	1.324	0.894	0.928	1.822	0.986	1.193	1.298	0.972	1.401
2019	0.894	0.430	1.324	0.906	0.884	1.790	0.986	1.113	1.278	0.900	1.456
Mean	0.894	0.430	1.324	0.879	0.751	1.630	0.986	1.086	1.199	0.881	1.314

3. Acceptable retrospective bias (based on Hurtado-Ferro et al. (2015)):

Allow Q to vary?	no		yes		(yes)		
Combine surveys?	no	yes	no	yes			
Use fishery CPUE?	(no)			no		yes	
Allow domed selex?				no	yes	no	yes
Quantity	20.4	19.12a	19.15	19.12	20.8	20.9	20.10
M	0.3713	0.3543	0.3615	0.3422	0.2944	0.3410	0.2124
Mohn's ρ	0.0601	-0.0211	0.1046	-0.0028	0.0076	0.1533	0.0071
ρmin	-0.2099	-0.2040	-0.2065	-0.1998	-0.1831	-0.1993	-0.1543
ρmax	0.2856	0.2772	0.2808	0.2711	0.2472	0.2705	0.2062

NOAA FISHERIES

Evaluating the models w.r.t. criteria 4-9

4. All models are substantially more complex than typical BSAI Tier 3
5. All models use the same approach for tuning σ terms as M19.12
6. All models with 0.99 < RMSSR < 1.01 for the index data (or that “tune out” $\ln(Q)$ devs) exhibit fits that are consistent with specified variances
7. All models have 0, 1, or 2 changes from M19.12, so are incremental
8. All models use Dirichlet-multinomial, so have objective weighting
9. All models estimate ageing bias separately for pre-2008 and post-2007

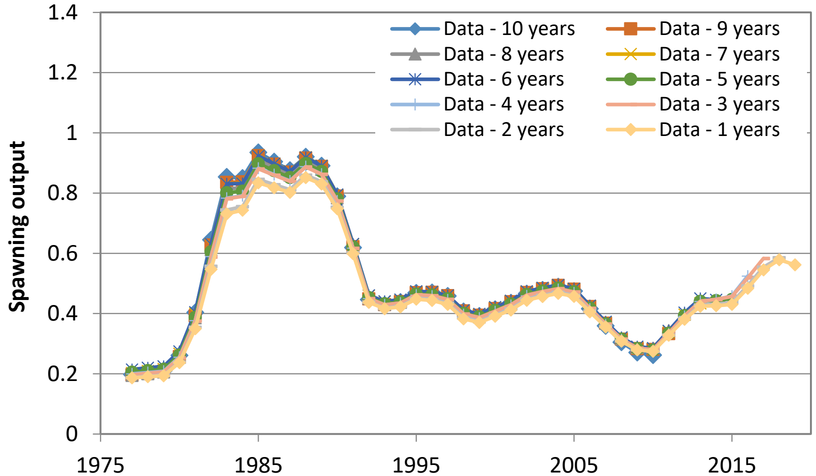
Computing the model weights

- Separate sets of weights computed for Ensemble A and Ensemble AB

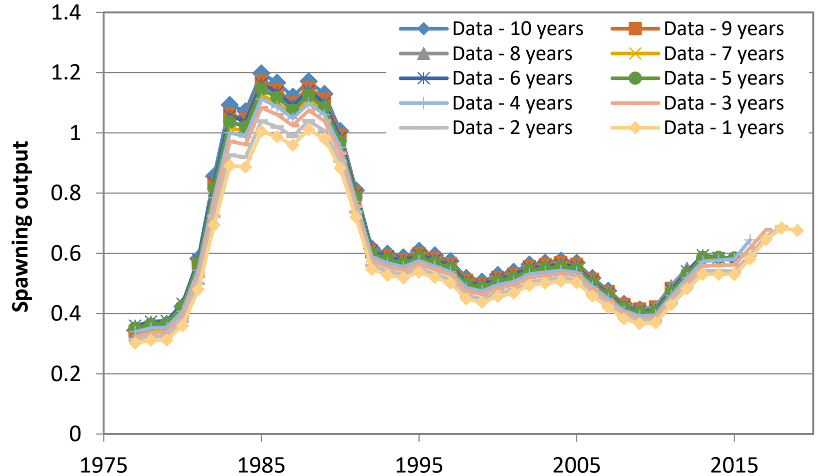
Factor A1: Allow *Q* to vary?		no		yes		(yes)		
Factor A2: Combine surveys?		no	yes	no	yes			
Factor B1: Use fishery CPUE?		(no)			no		yes	
Factor B2: Allow domed selex?					no	yes	no	yes
Criterion	Emph.	20.4	19.12a	19.15	19.12	20.8	20.9	20.10
Plausible hypothesis	3	1	1	1	1	1	1	1
Plausible catchability	3	0	1	0	1	1	1	0
Acceptable retrospective bias	3	1	1	1	1	1	1	1
Comparable complexity	2	0	0	0	0	0	0	0
Dev sigmas estimated appropriately	2	1	1	1	1	1	1	1
Fits consistent with variances	2	0	0	1	1	1	1	1
Incremental changes	1	1	1	1	1	1	1	1
Objective criterion for sample sizes	1	1	1	1	1	1	1	1
Change in ageing criteria addressed	1	1	1	1	1	1	1	1
Average emphasis:		0.6111	0.7778	0.7222	0.8889	0.8889	0.8889	0.7222
Model weight (Ensemble A):		0.2037	0.2593	0.2407	0.2963			
Model weight (Ensemble AB):		0.1111	0.1414	0.1313	0.1616	0.1616	0.1616	0.1313

Retrospective analysis: ensemble averages

Ensemble A (ρ = 0.0311)

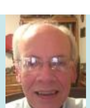


Ensemble AB (ρ = 0.0439)



Base values of non-selectivity parameters

A1: Allow Q to vary?	no				yes				(yes)									
A2: Combine surveys?	no		yes		no		yes											
B1: Use fishery CPUE?	(no)						no				yes							
B2: Allow domed selex?							no		yes		no		yes					
Model:	20.4		19.12a		19.15		19.12		20.8		20.9		20.10		Ensemble A		Ensemble AB	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
Natural mortality	0.371	0.012	0.354	0.011	0.362	0.013	0.342	0.013	0.294	0.017	0.341	0.013	0.212	0.016	0.356	0.016	0.325	0.051
Mean length at age 1.5	14.766	0.396	14.784	0.388	14.831	0.405	14.872	0.391	14.915	0.376	14.887	0.389	14.766	0.362	14.818	0.397	14.838	0.391
Asymptotic length	113.710	3.117	113.400	3.130	114.788	3.253	115.298	3.356	102.316	2.561	117.562	3.535	94.646	1.138	114.360	3.322	110.342	8.322
Brody growth coefficient	0.118	0.009	0.117	0.009	0.116	0.009	0.113	0.009	0.163	0.013	0.102	0.009	0.204	0.009	0.116	0.009	0.133	0.035
Richards growth coefficient	1.428	0.042	1.443	0.042	1.423	0.043	1.444	0.042	1.264	0.053	1.507	0.042	1.154	0.043	1.435	0.043	1.382	0.123
SD(length at age 1)	3.479	0.065	3.483	0.067	3.483	0.065	3.498	0.065	3.527	0.067	3.493	0.067	3.636	0.072	3.487	0.066	3.514	0.084
SD(length at age 20)	9.927	0.383	9.956	0.381	9.789	0.389	9.773	0.388	8.784	0.343	10.160	0.464	7.832	0.251	9.856	0.394	9.466	0.856
Mean ageing bias at age 1	0.349	0.015	0.338	0.017	0.347	0.015	0.336	0.017	0.331	0.018	0.339	0.019	0.333	0.022	0.342	0.017	0.338	0.019
Mean ageing bias at age 20	0.779	0.206	0.973	0.222	0.826	0.207	1.015	0.222	1.122	0.242	1.059	0.259	1.266	0.300	0.911	0.236	1.016	0.281
Mean bias at age 1 (2008+)	-0.010	0.024	0.011	0.024	-0.008	0.024	0.014	0.024	0.016	0.026	0.018	0.027	0.019	0.030	0.003	0.026	0.010	0.028
Mean bias at age 20 (2008+)	-1.635	0.324	-1.640	0.315	-1.831	0.346	-1.822	0.327	-1.929	0.355	-2.413	0.480	-2.231	0.467	-1.739	0.341	-1.943	0.468
ln(mean post-1976 recruits)	13.275	0.099	13.177	0.096	13.179	0.106	13.072	0.104	12.846	0.136	13.177	0.115	12.513	0.160	13.166	0.124	13.031	0.267
ln(pre-1977 recruits offset)	-0.890	0.205	-0.905	0.198	-0.899	0.199	-0.933	0.189	-0.607	0.187	-0.893	0.190	-0.272	0.136	-0.909	0.198	-0.774	0.292
Pre-1977 fishing mortality	0.125	0.039	0.122	0.037	0.130	0.041	0.128	0.039	0.071	0.019	0.115	0.040	0.041	0.012	0.126	0.039	0.104	0.047
ln(Fishery catchability)											-13.015	0.071	-13.618	0.107	n/a	n/a	-13.285	0.312
ln(EBS survey catchability)	-0.112	0.066			-0.058	0.070									-0.083	0.073	-0.083	0.073
ln(NBS survey catchability)	-0.844	0.107			-1.998	0.257									-1.469	0.610	-1.469	0.610
ln(XBS survey catchability)			-0.014	0.062			0.045	0.068	0.155	0.090	-0.087	0.077	0.274	0.120	0.017	0.071	0.069	0.151
ln(DM)_fishery_sizecomp	9.989	0.346	9.989	0.348	9.989	0.346	9.989	0.347	9.989	0.356	9.988	0.373	9.989	0.336	9.989	0.347	9.989	0.351
ln(DM)_EBS_surv_sizecomp	9.984	0.502			9.984	0.505									9.984	0.504	9.984	0.504
ln(DM)_NBS_surv_sizecomp	9.117	18.864			9.236	18.346									9.182	18.586	9.182	18.586
ln(DM)_XBS_surv_sizecomp			9.983	0.547			9.984	0.520	9.985	0.463	9.982	0.565	9.986	0.448	9.983	0.533	9.984	0.512
ln(DM)_EBS_surv_agecomp	0.253	0.242			0.363	0.260									0.313	0.258	0.313	0.258
ln(DM)_NBS_surv_agecomp	-0.367	0.362			-0.314	0.366									-0.338	0.365	-0.338	0.365
ln(DM)_XBS_surv_agecomp			-0.044	0.205			0.045	0.217	-0.211	0.200	-0.547	0.163	-0.922	0.143		0.216	-0.320	0.393



Base values of selectivity parameters

A1: Allow *Q* to vary?	no				yes				(yes)									
A2: Combine surveys?	no		yes		no		yes											
B1: Use fishery CPUE?	(no)						no				yes							
B2: Allow domed selex?							no		yes		no		yes					
	20.4		19.12a		19.15		19.12		20.8		20.9		20.10		Ensemble A		Ensemble AB	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
Fishery_Begin_top	75.012	0.038	74.983	0.044	75.012	0.039	75.013	0.045	71.840	0.760	75.956	0.033	67.473	0.490	75.005	0.044	73.658	2.744
Fishery_Logit(top)	-9.650	9.886	-9.745	7.227	-9.701	8.331	-9.742	7.450	-9.627	9.879	-9.939	1.889	-9.926	2.276	-9.714	8.161	-9.764	7.306
Fishery_Ln(SD1)	5.902	0.026	5.910	0.028	5.904	0.026	5.914	0.028	5.850	0.043	5.968	0.034	5.750	0.050	5.908	0.028	5.888	0.072
Fishery_Ln(SD2)	-9.952	1.488	-9.844	4.711	-9.932	2.094	-9.899	3.060	4.139	0.476	-8.651	12.381	4.669	0.120	-9.903	3.168	-5.518	8.430
Fishery_Logit(start)	-10	_	-10	_	-10	_	-10	_	-10	_	-10	_	-10	_	n/a	n/a	n/a	n/a
Fishery_Logit(end)	2.005	0.276	2.145	0.314	2.060	0.289	2.232	0.349	0.662	0.348	1.558	0.298	-0.544	0.247	2.122	0.324	1.445	0.985
EBSsrv_Begin_top	21.038	0.799			20.948	0.840									20.989	0.823	20.989	0.823
EBSsrv_Logit(top)	10	_			10	_									n/a	n/a	n/a	n/a
EBSsrv_Ln(SD1)	3.529	0.152			3.507	0.161									3.517	0.157	3.517	0.157
EBSsrv_Ln(SD2)	10	_			10	_									n/a	n/a	n/a	n/a
EBSsrv_Logit(start)	-10	_			-10	_									n/a	n/a	n/a	n/a
EBSsrv_Logit(end)	10	_			10	_									n/a	n/a	n/a	n/a
NBSsrv_Begin_top	79.998	0.073			79.997	0.099									79.997	0.088	79.997	0.088
NBSsrv_Logit(top)	10	_			10	_									n/a	n/a	n/a	n/a
NBSsrv_Ln(SD1)	7.923	0.167			7.908	0.163									7.915	0.165	7.915	0.165
NBSsrv_Ln(SD2)	10	_			10	_									n/a	n/a	n/a	n/a
NBSsrv_Logit(start)	-10	_			-10	_									n/a	n/a	n/a	n/a
NBSsrv_Logit(end)	10	_			10	_									n/a	n/a	n/a	n/a
XBSsrv_Begin_top			20.903	0.781			20.782	0.821	20.678	0.819	20.613	0.850	19.737	0.702	20.839	0.805	20.565	0.891
XBSsrv_Logit(top)			10	_			10	_	-1.346	0.221	10	_	-1.610	0.180	n/a	n/a	2.612	5.491
XBSsrv_Ln(SD1)			3.526	0.152			3.496	0.160	3.510	0.163	3.461	0.168	3.366	0.147	3.510	0.157	3.474	0.168
XBSsrv_Ln(SD2)			10	_			10	_	7.314	0.459	10	_	6.962	0.170	n/a	n/a	7.156	0.400
XBSsrv_Logit(start)			-10	_			-10	_	-10	_	-10	_	-10	_	n/a	n/a	n/a	n/a
XBSsrv_Logit(end)			10	_			10	_	-0.859	0.578	10	_	-2.664	0.364	n/a	n/a	-1.668	1.025

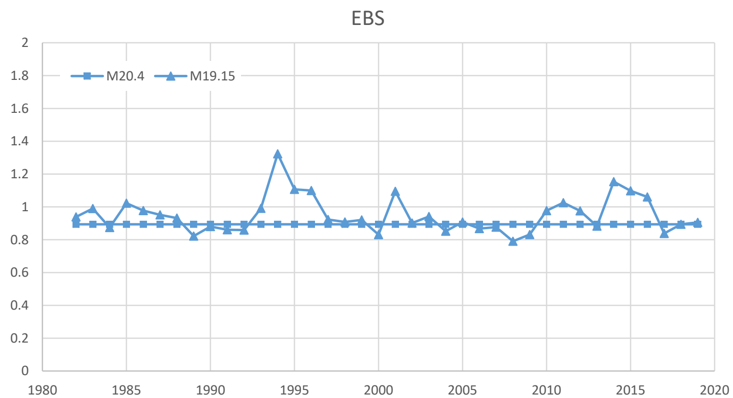
Sigmas for annual deviations (except ln(Q))

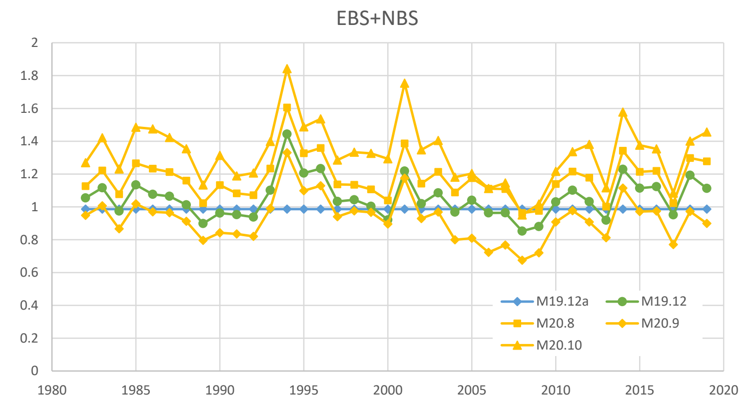
A1: Allow Q to vary?	no						yes					
A2: Combine surveys?	no			yes			no			yes		
	Model 20.4			Model 19.12a			Model 19.15			Model 19.12		
Parameter	var_dev	ave_var	sigma	var_dev	ave_var	sigma	var_dev	ave_var	sigma	var_dev	ave_var	sigma
ln(Recruits)	0.4498	0.0119	0.6827	0.4628	0.0126	0.6896	0.4408	0.0124	0.6733	0.4431	0.0130	0.6757
Length_at_1.5	0.8109	0.1911	0.1530	0.7986	0.1989	0.1478	0.8138	0.1865	0.1566	0.7911	0.1996	0.1486
Sel_fsh_lnSD1	0.6838	0.3150	0.1399	0.7041	0.2888	0.1558	0.6753	0.3211	0.1378	0.6971	0.2943	0.1533
Sel_fsh_logitEnd	0.2152	0.7815	0.7443	0.1763	0.8188	0.7539	0.2125	0.7846	0.7771	0.1517	0.8488	0.7641
Sel_EBS_srv_PeakStart	0.8499	0.1506	0.2090				0.8510	0.1483	0.2221			
Sel_EBS_srv_lnSD1	0.7320	0.2648	0.7744				0.7424	0.2576	0.8309			
Sel_XBS_srv_PeakStart				0.8423	0.1564	0.2041			0.2221	0.8471	0.1488	0.2191
Sel_XBS_srv_lnSD1				0.7285	0.2694	0.7711			0.8309	0.7366	0.2565	0.8300

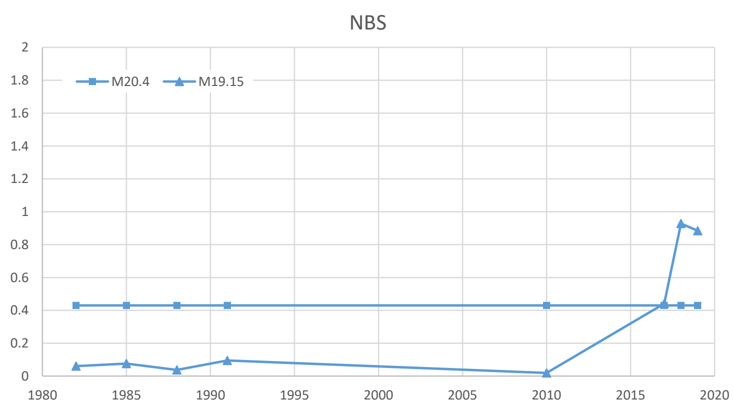
B1: Use fishery CPUE?	no						yes					
B2: Allow domed selex?	no			yes			no			yes		
	Model 19.12			Model 20.8			Model 20.9			Model 20.10		
Parameter	var_dev	ave_var	sigma	var_dev	ave_var	sigma	var_dev	ave_var	sigma	var_dev	ave_var	sigma
ln(Recruits)	(see above)			0.4470	0.0135	0.6787	0.4320	0.0142	0.6678	0.4252	0.0141	0.6630
Length_at_1.5				0.8017	0.1985	0.1424	0.7869	0.2133	0.1452	0.7928	0.2068	0.1360
Sel_fsh_lnSD1				0.7042	0.2957	0.1722	0.7844	0.2158	0.1932	0.7557	0.2442	0.2433
Sel_fsh_logitEnd				0.3473	0.6454	0.6106	0.6467	0.3561	1.5431	0.7956	0.2045	1.1177
Sel_XBS_srv_PeakStart				0.8419	0.1594	0.2129	0.8515	0.1497	0.2302	0.8438	0.1535	0.1826
Sel_XBS_srv_lnSD1				0.7147	0.2846	0.8049	0.7468	0.2551	0.8804	0.6548	0.3445	0.6427

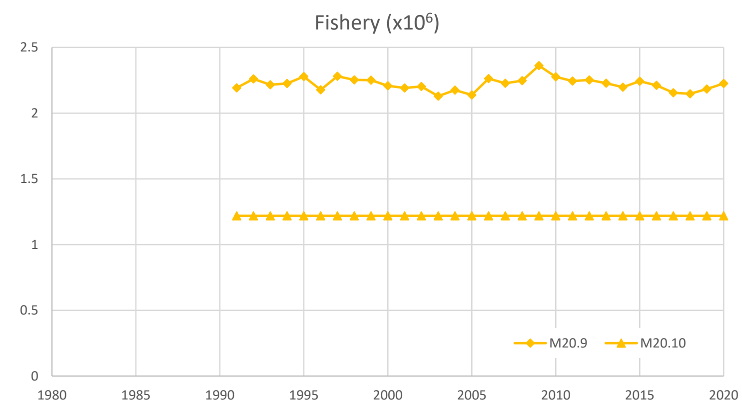
Sigmas for ln(Q) and back-transformed values

Index	19.15	19.12	20.8	20.9	20.10
EBS survey	0.0797				
NBS survey	0.5993				
EBS+NBS survey		0.0807	0.0785	0.0910	0.0889
Fishery CPUE				0.0188	0.0000



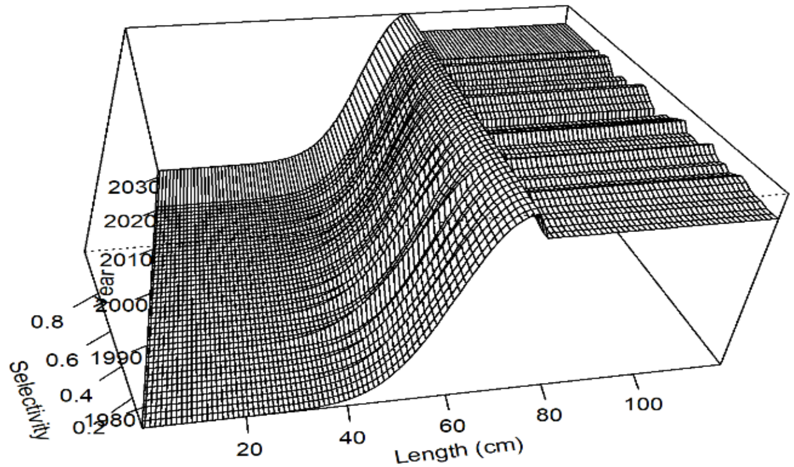




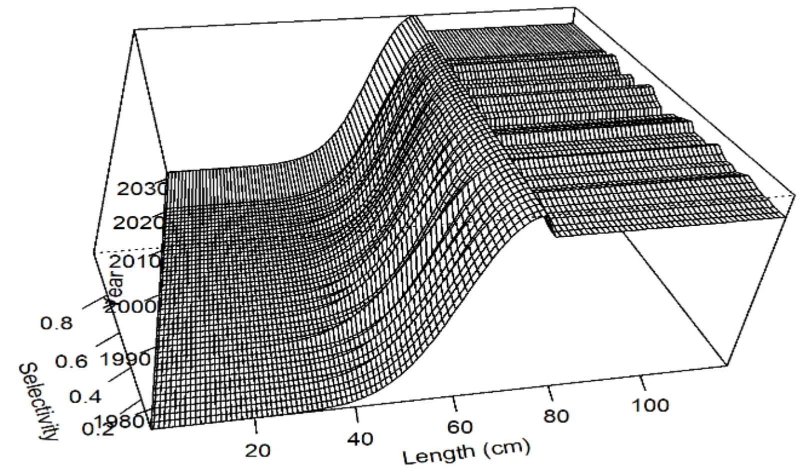


Fishery selectivity: Ensemble A models

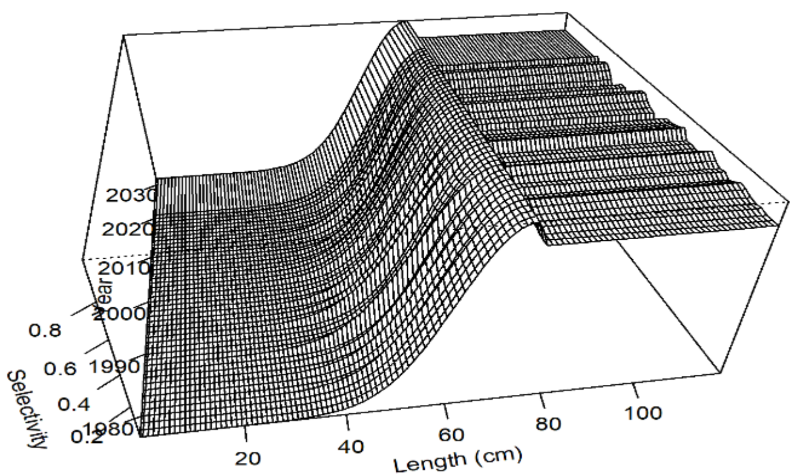
Model 20.4



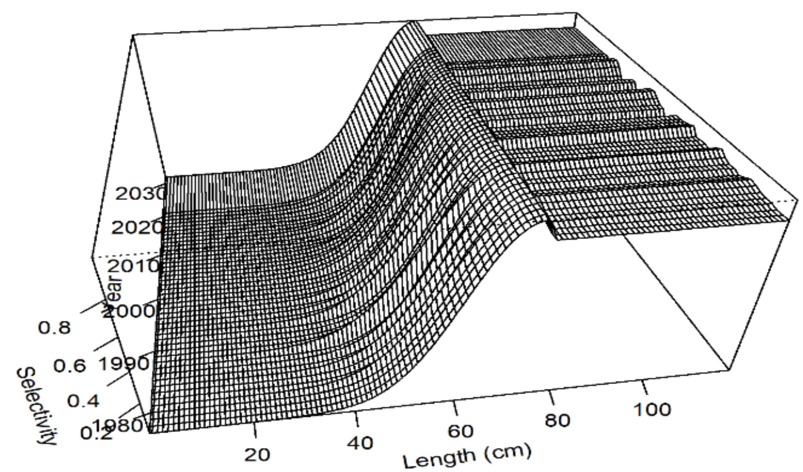
Model 19.12a



Model 19.15

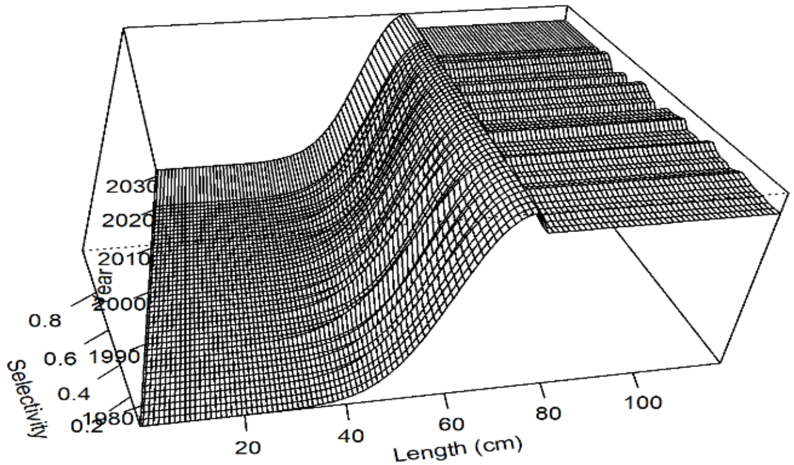


Model 19.12

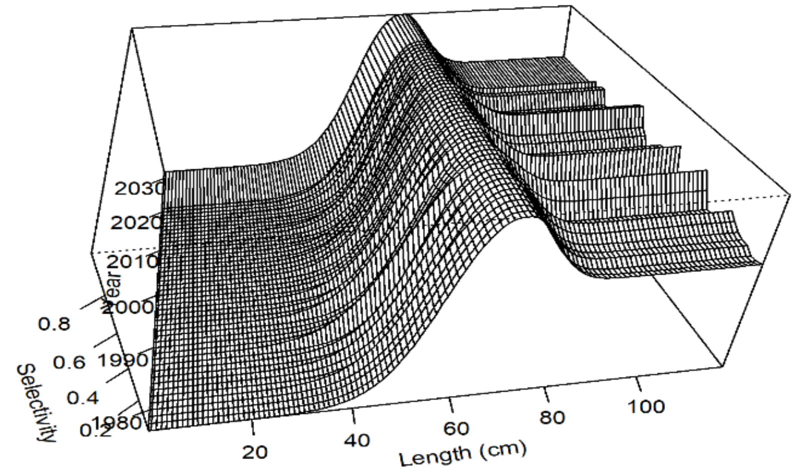


Fishery selectivity: Ensemble B models

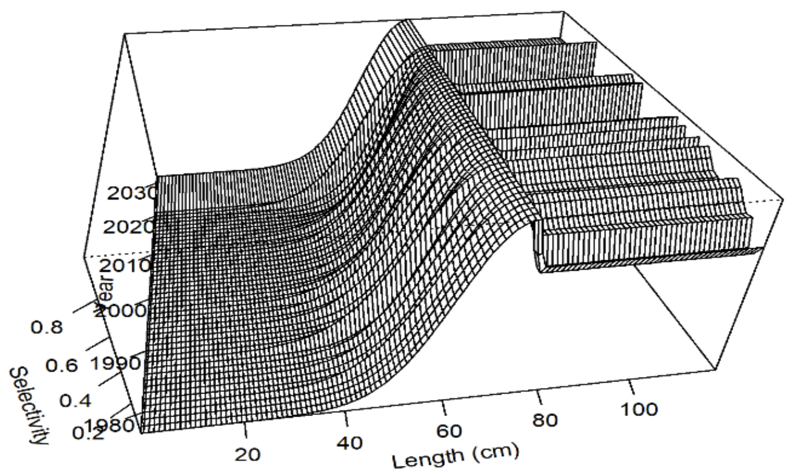
Model 19.12



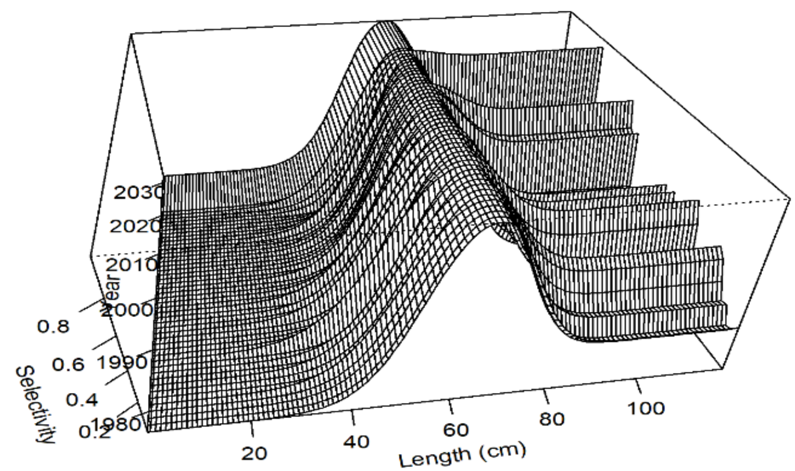
Model 20.8



Model 20.9

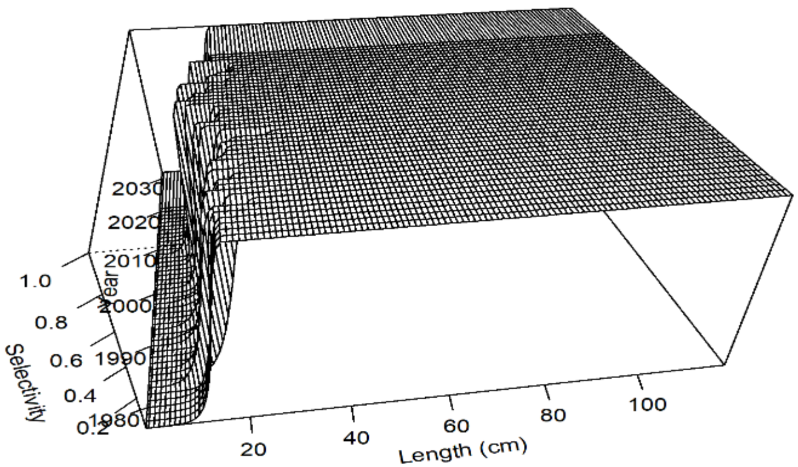


Model 20.10

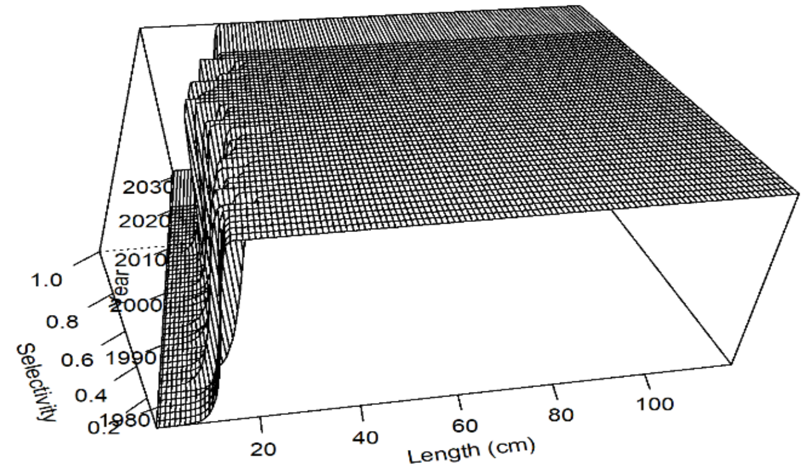


“Main” survey selectivity: Ensemble A

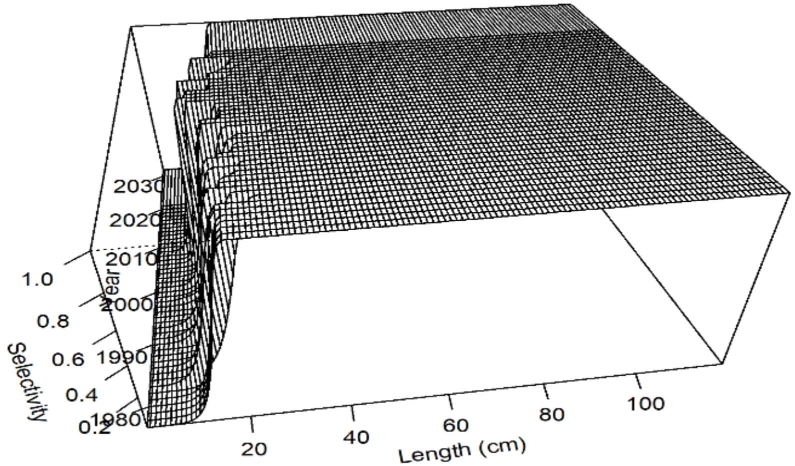
Model 20.4 (EBS only)



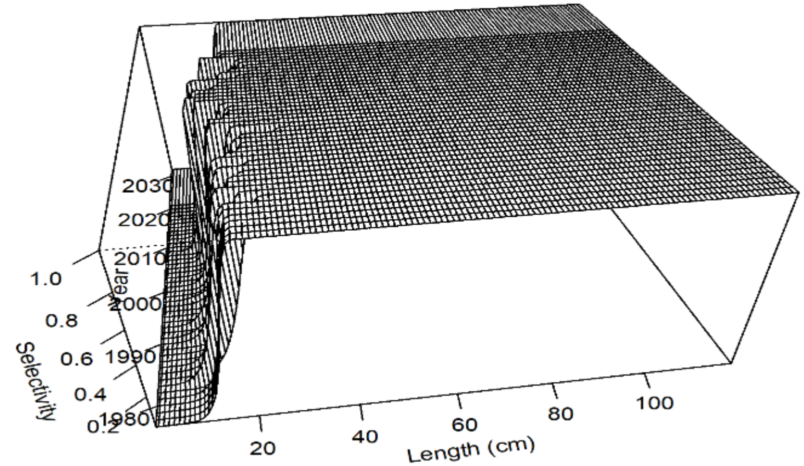
Model 19.12a (EBS+NBS)



Model 19.15 (EBS only)

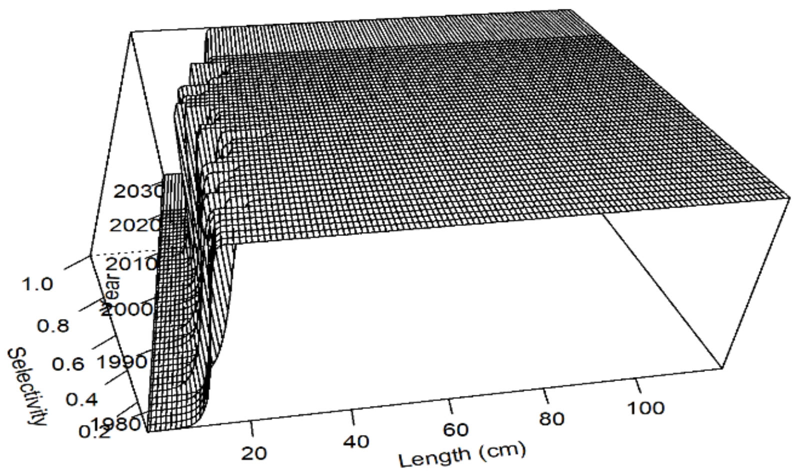


Model 19.12 (EBS+NBS)

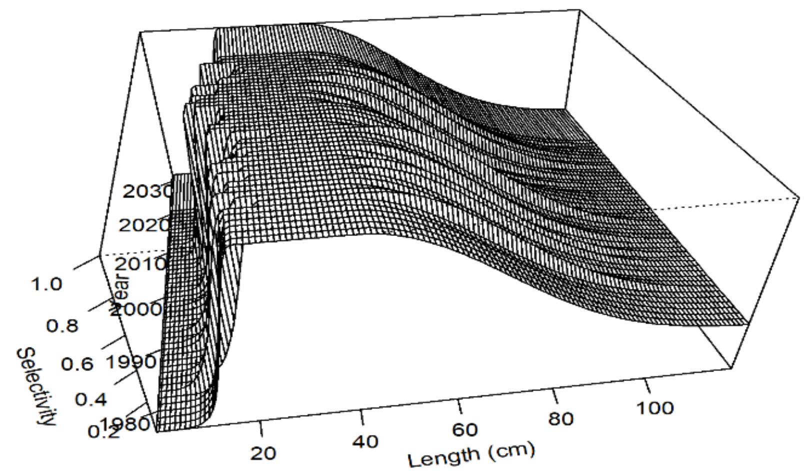


“Main” selectivity: Ensemble B

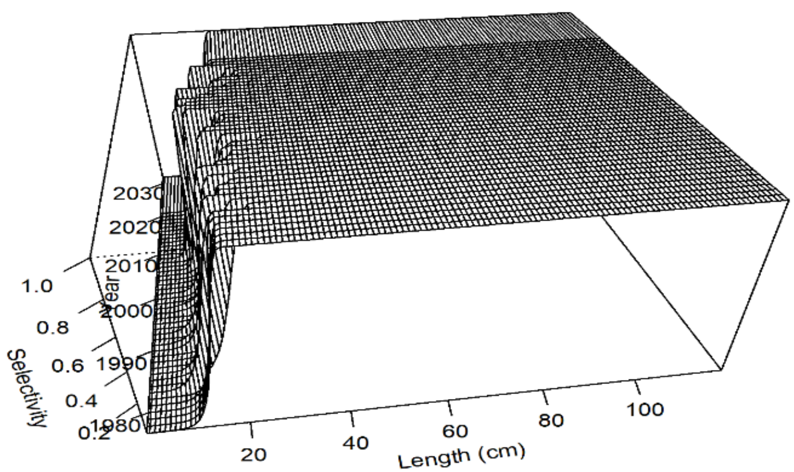
Model 19.12 (EBS+NBS)



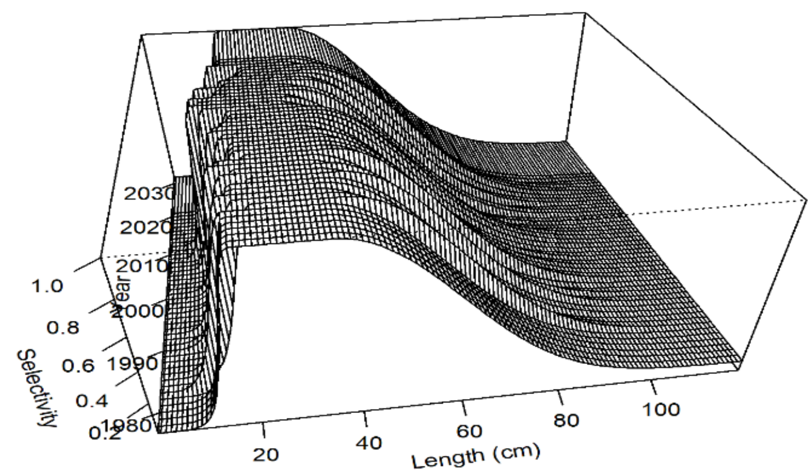
Model 20.8 (EBS+NBS)



Model 20.9 (EBS+NBS)

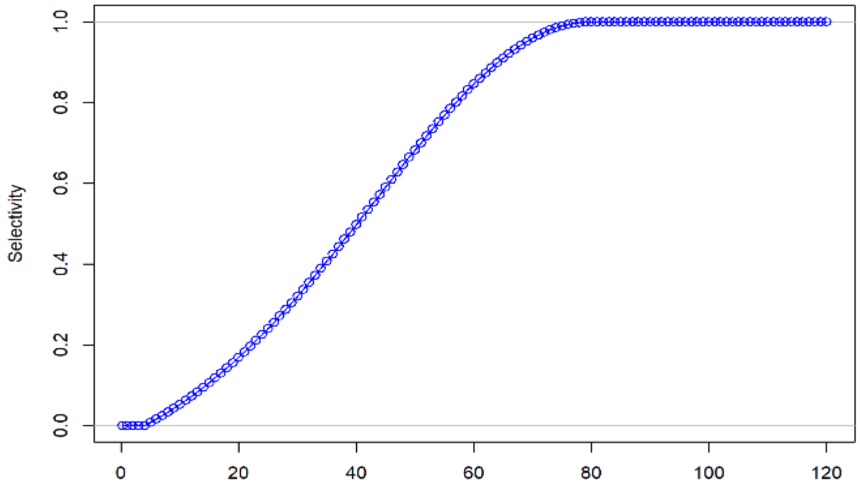


Model 20.10 (EBS+NBS)

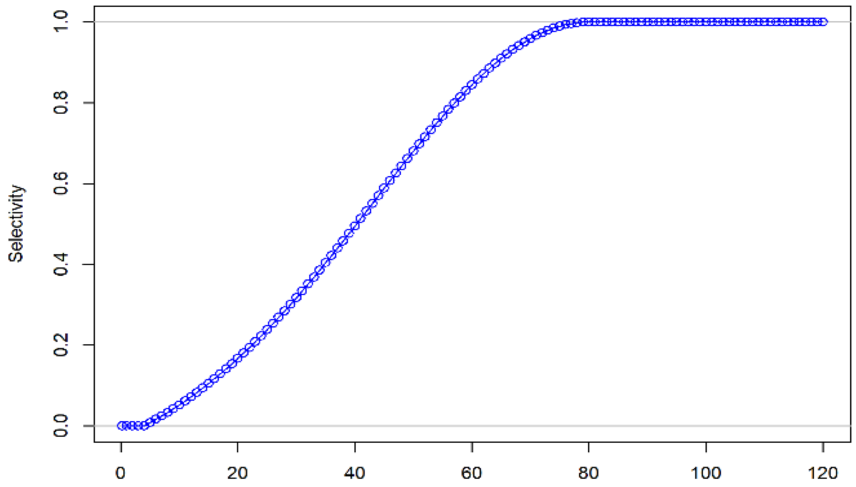


NBS survey selectivity: Models 20.4 and 19.15

Model 20.4

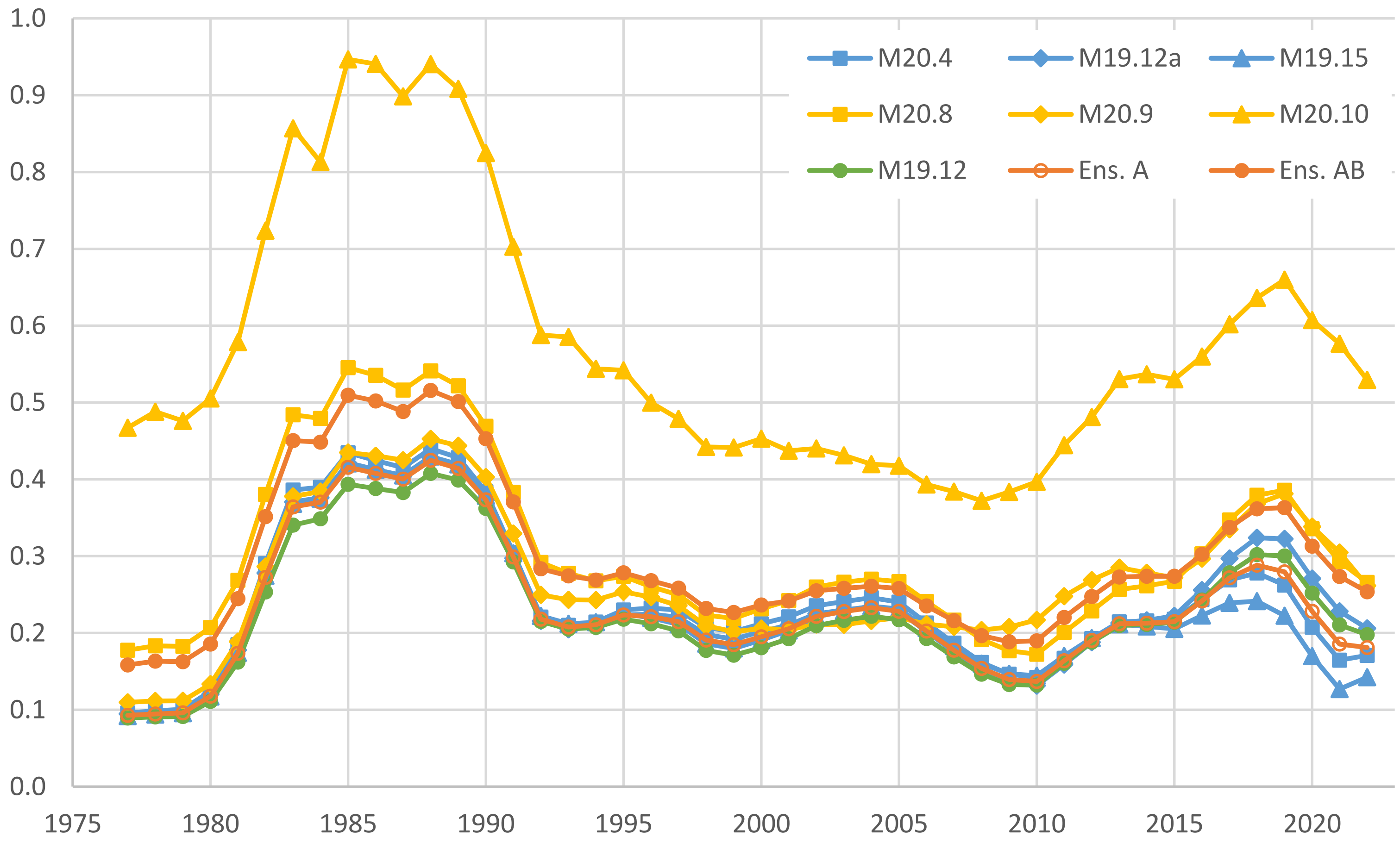


Model 19.15



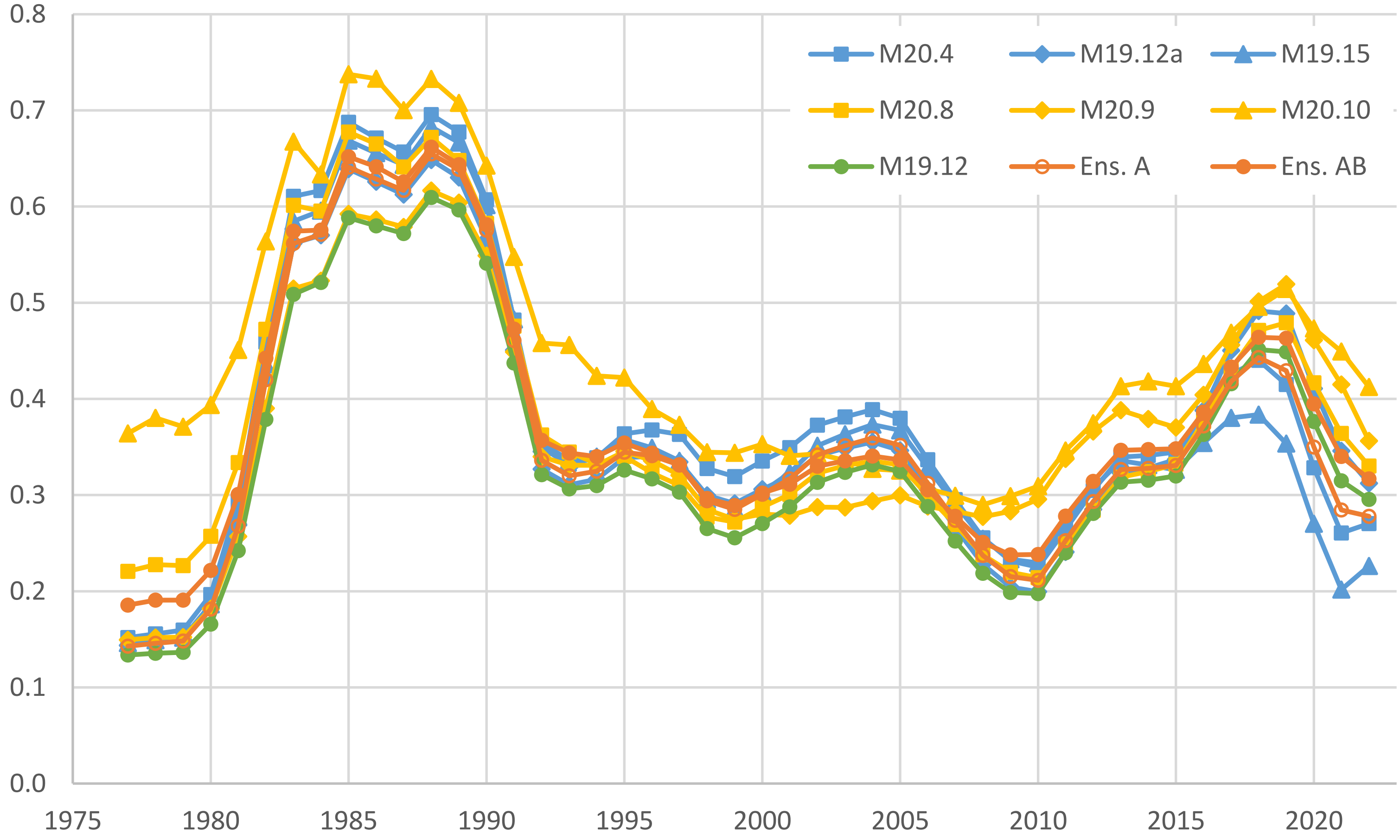
Time series: female spawning biomass

- Values are in millions of t



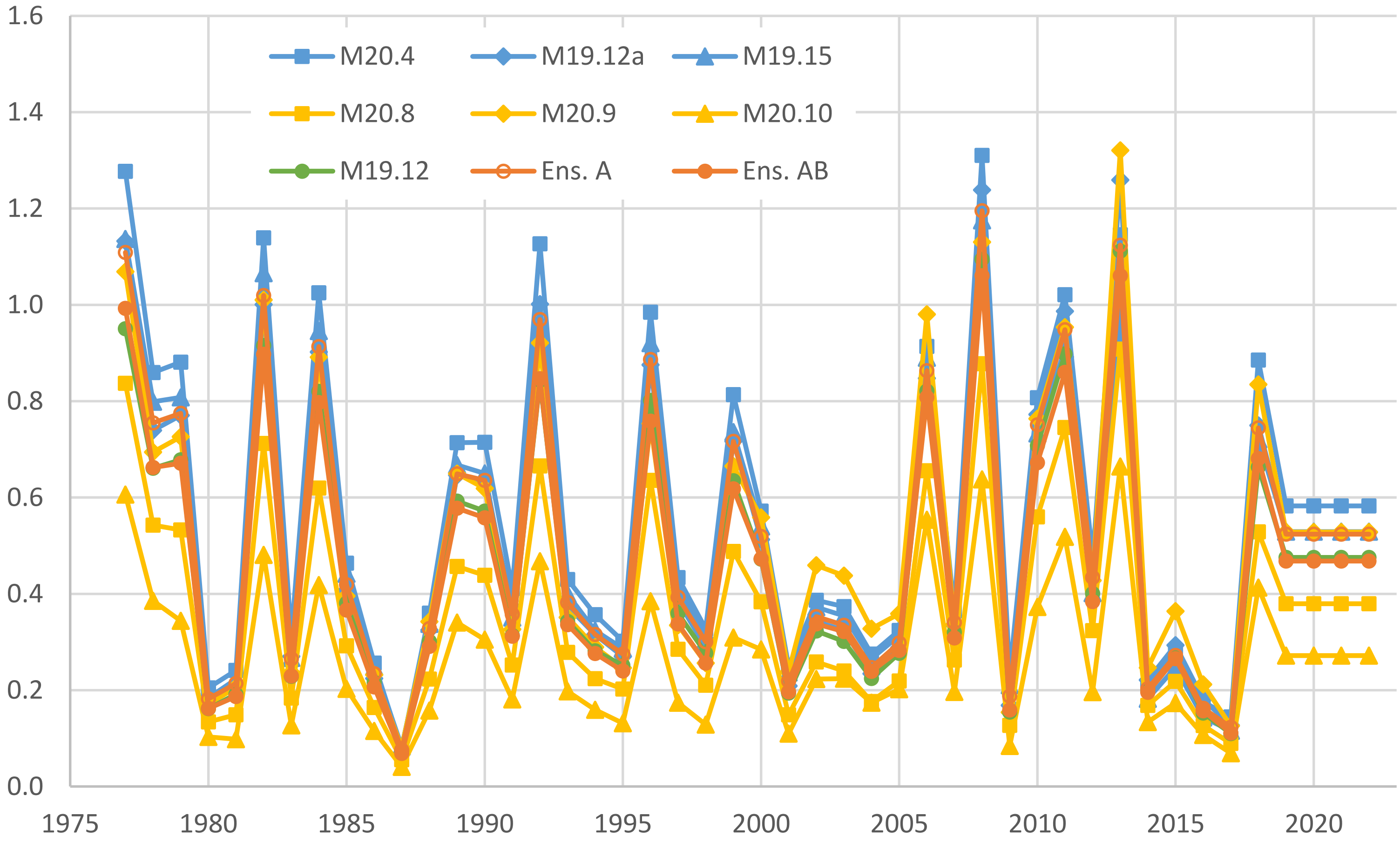
Time series: relative spawning biomass

- Relative to $B_{100\%}$



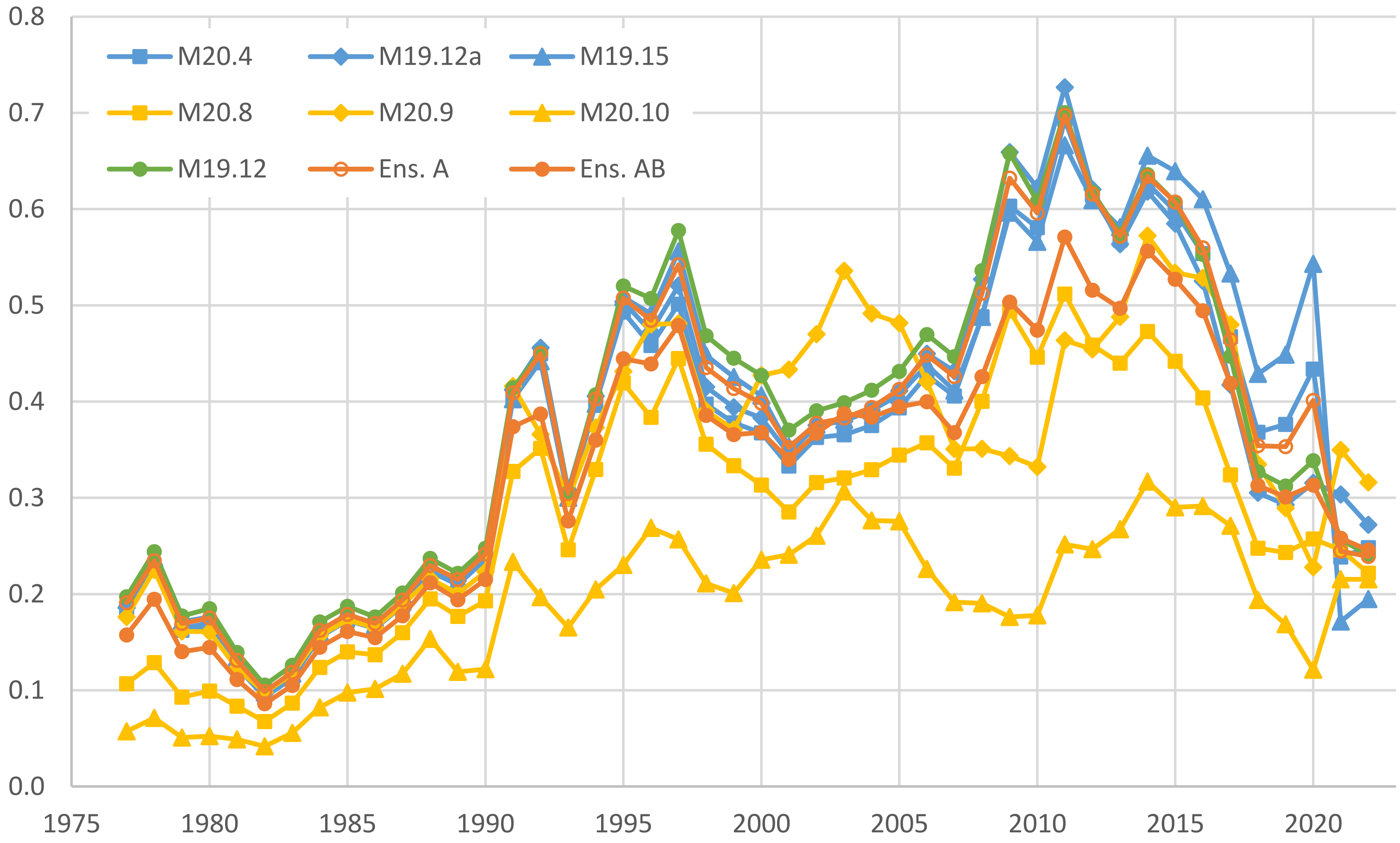
Time series: age 0 recruitment

- Values are in billions of fish



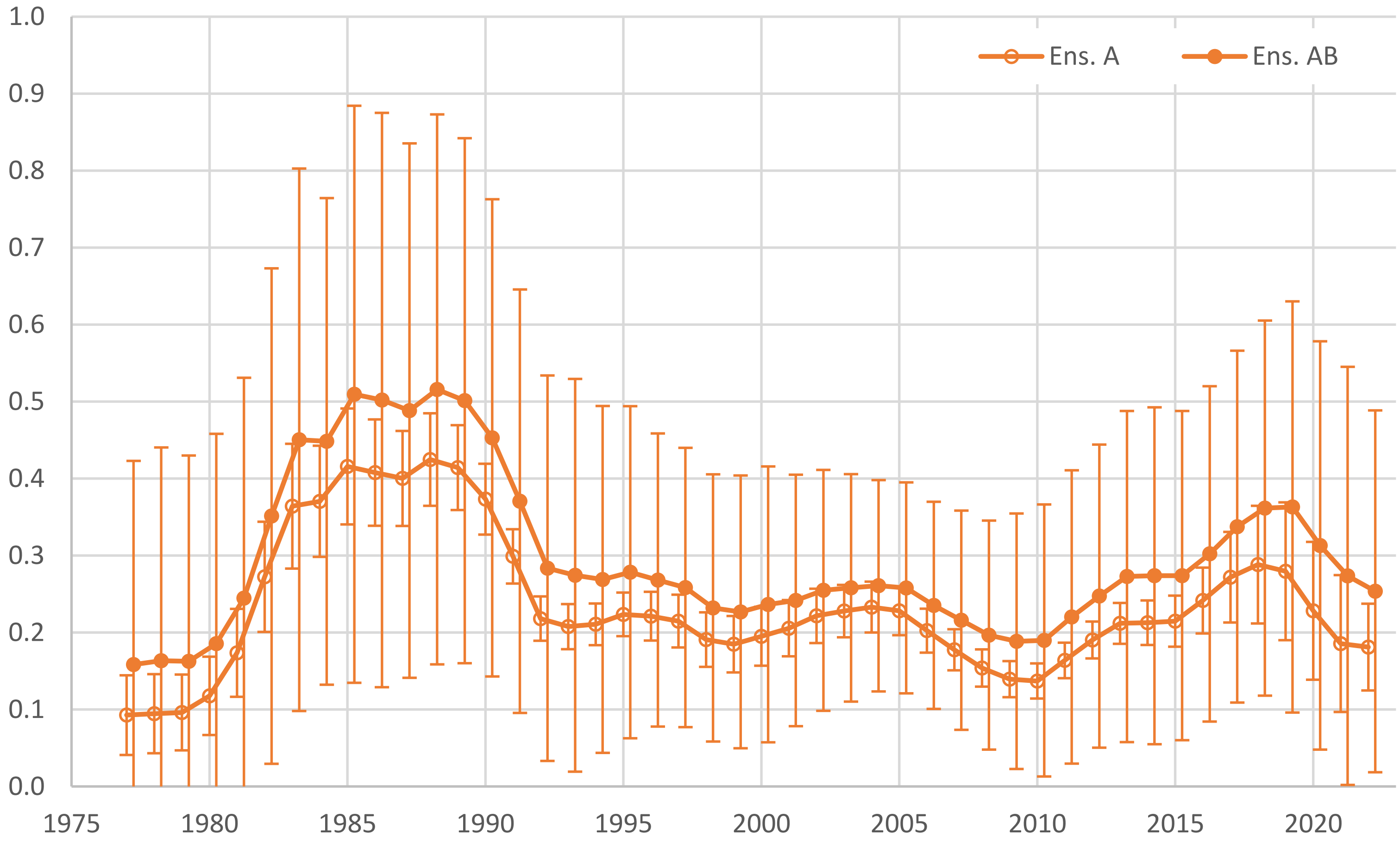
Time series: fishing mortality

- Instantaneous full-selection fishing mortality rate



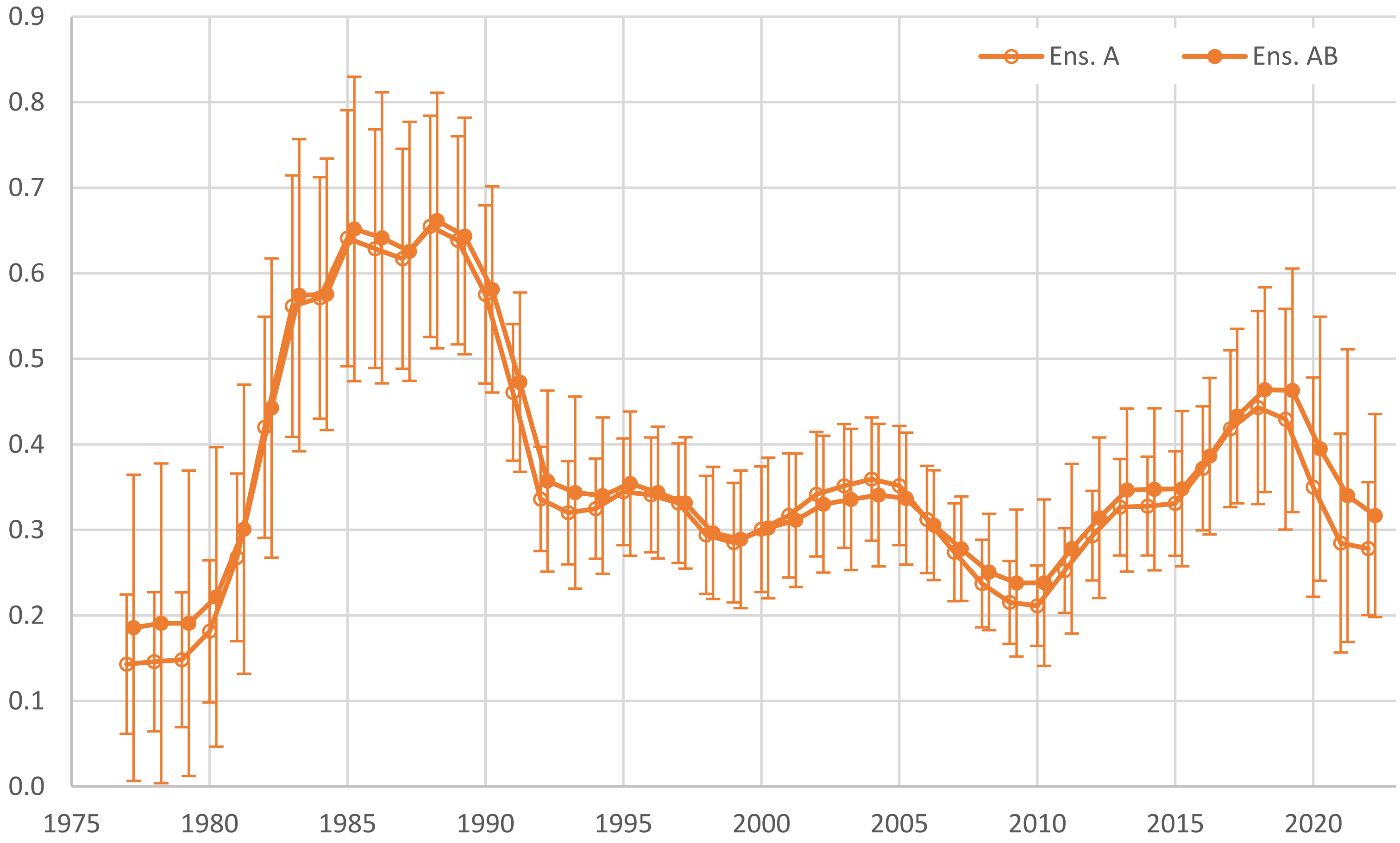
Ensemble time series: fem. spawn. biomass

- Values are in millions of t



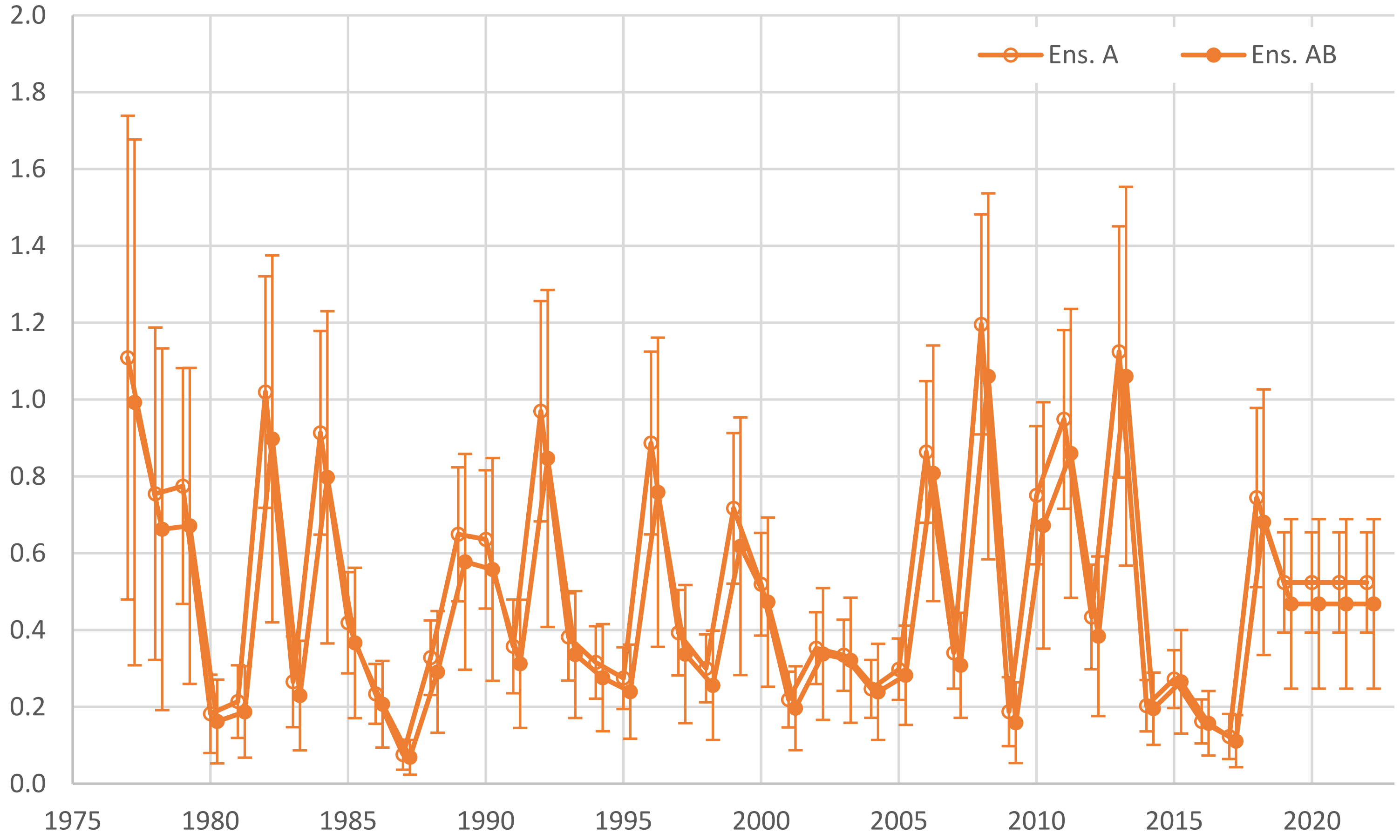
Ensemble time series: rel. spawning biomass

- Relative to $B_{100\%}$



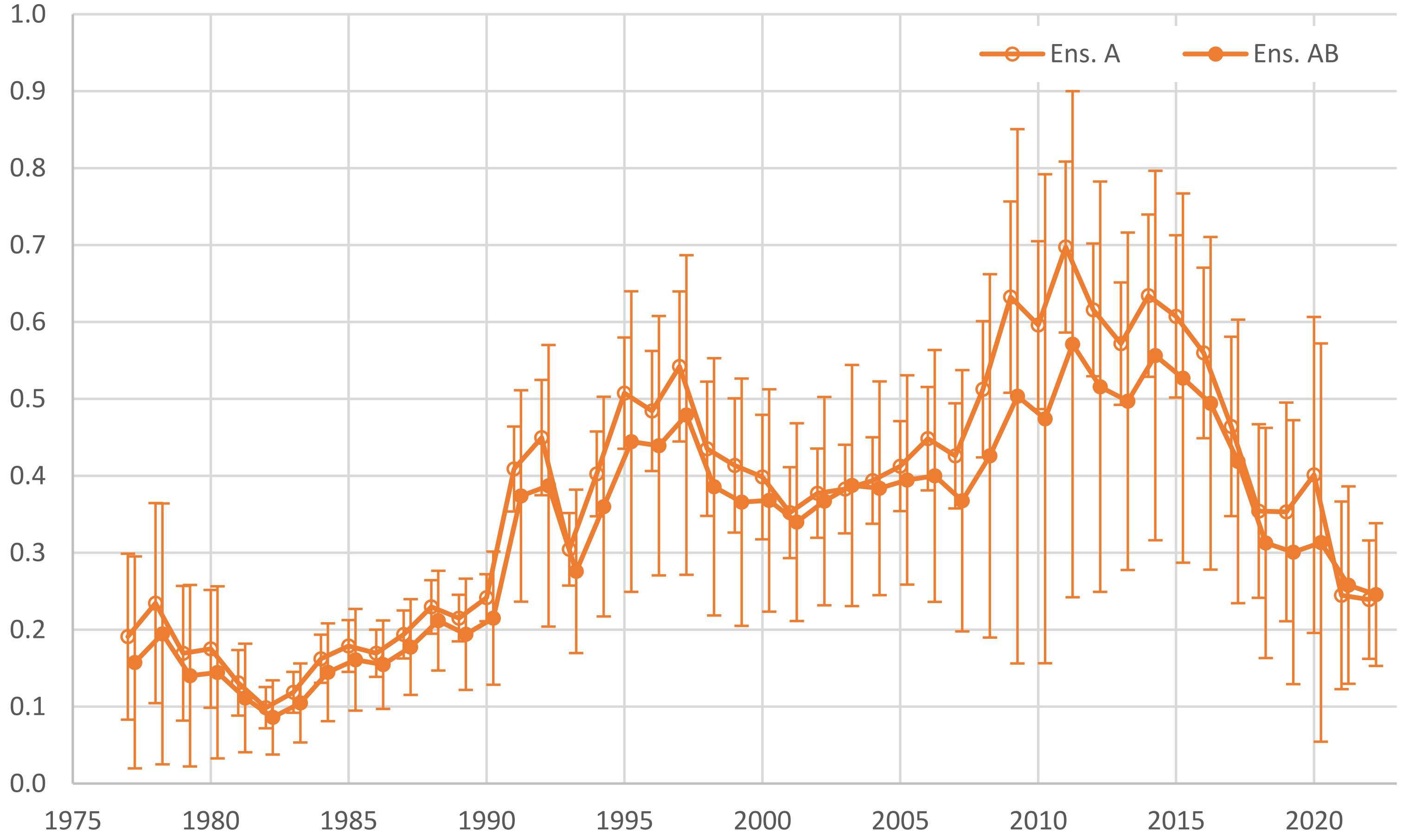
Ensemble time series: age 0 recruitment

- Values are in billions of fish

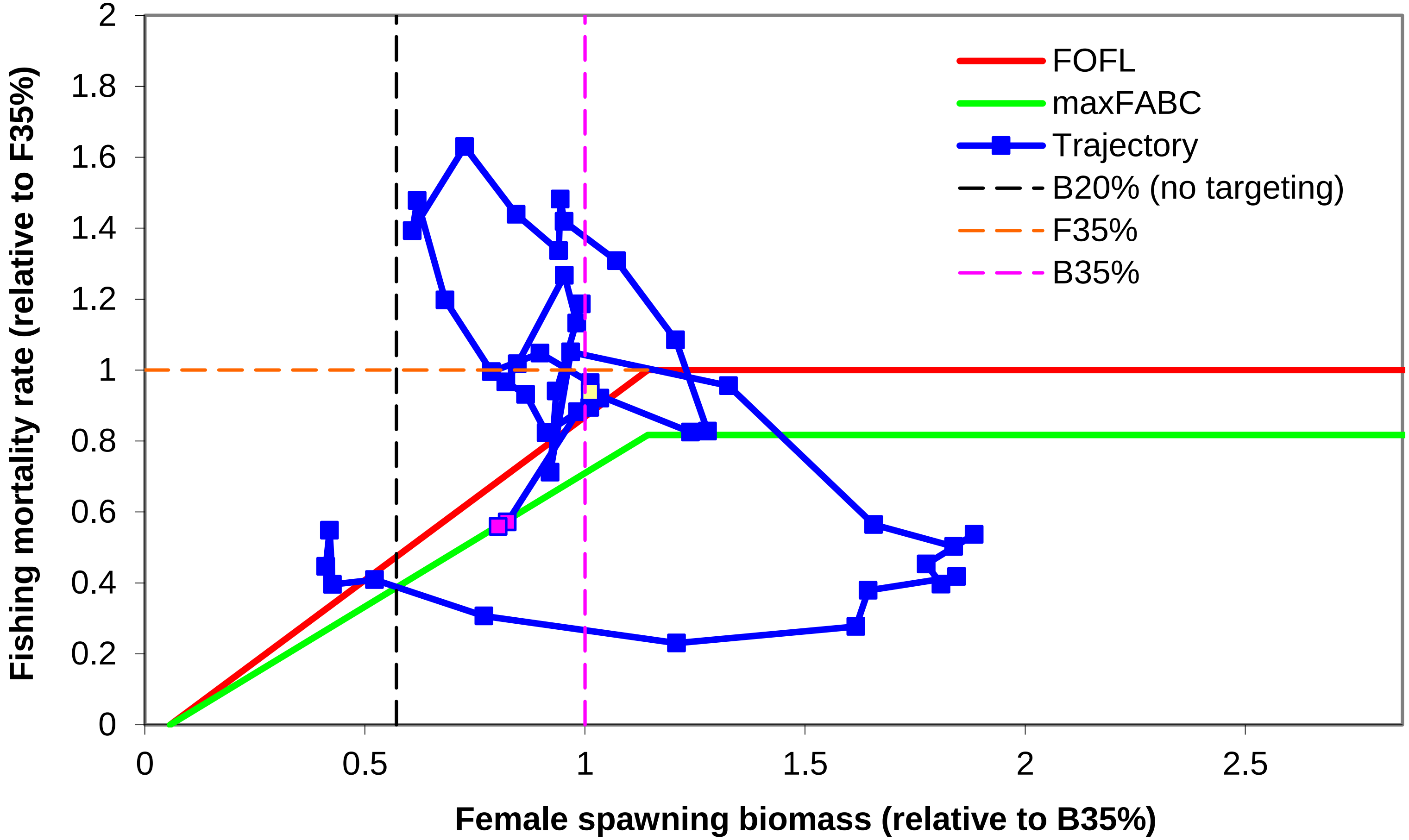


Ensemble time series: fishing mortality

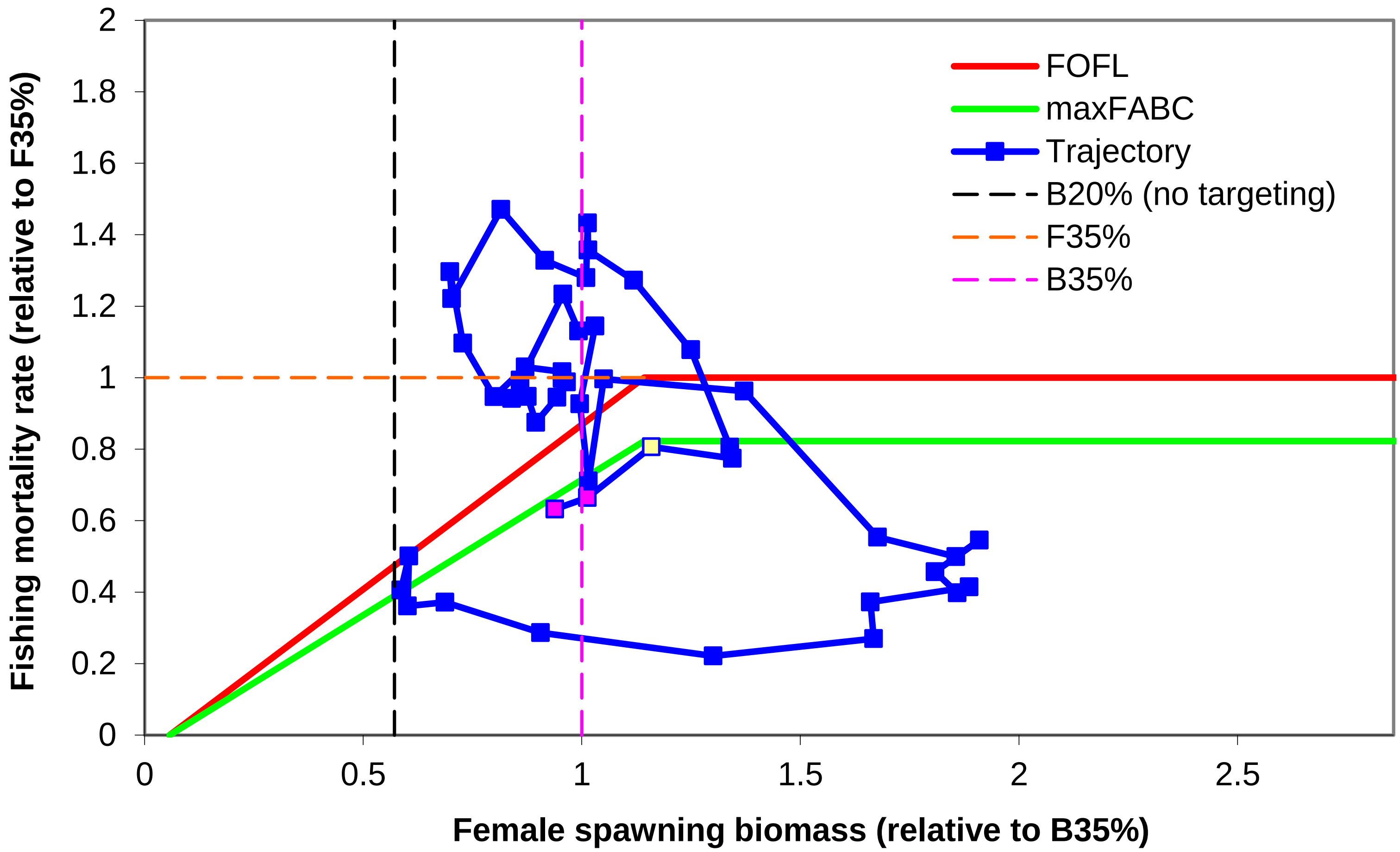
- Instantaneous, full selection fishing mortality rate



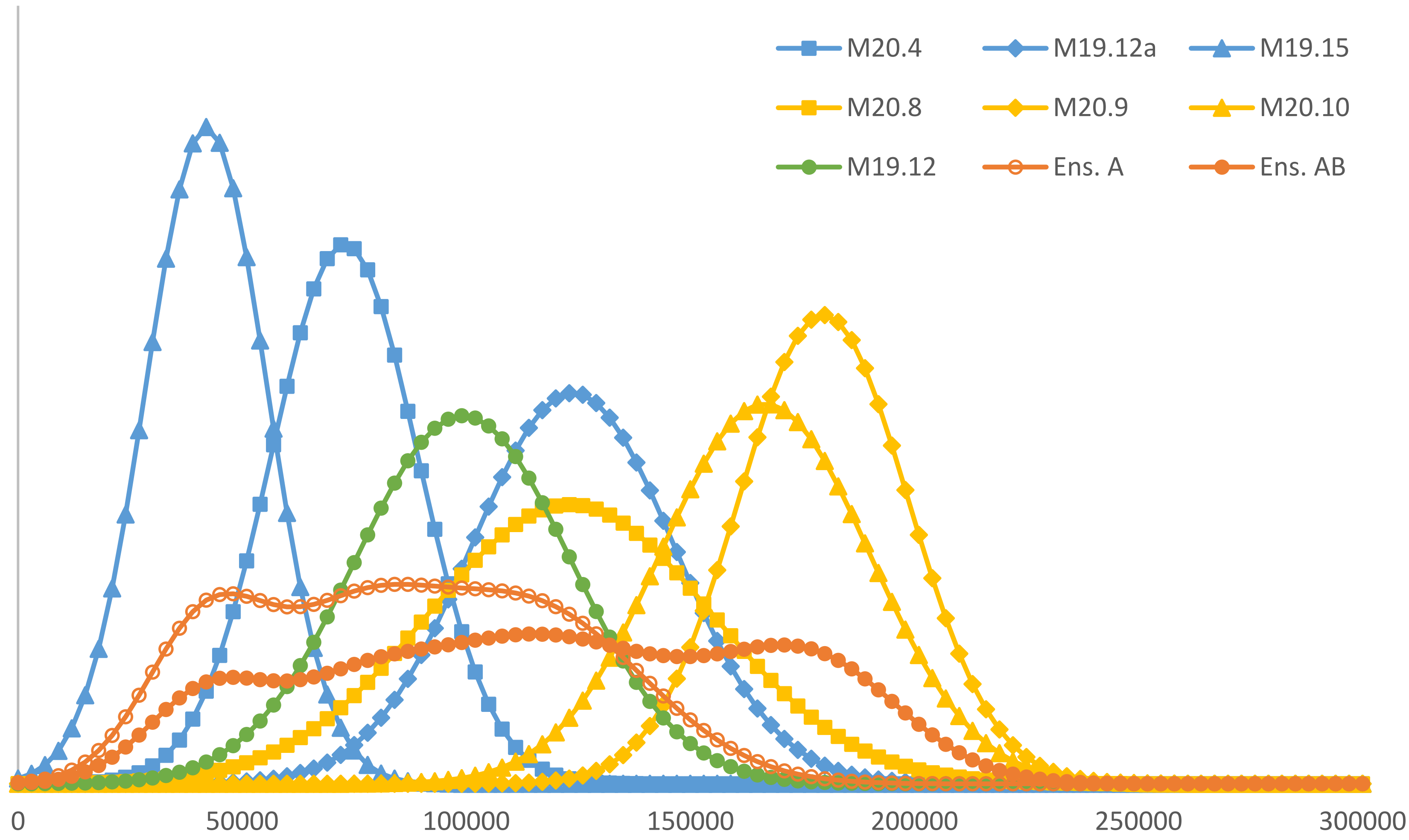
Phase plane: Ensemble A



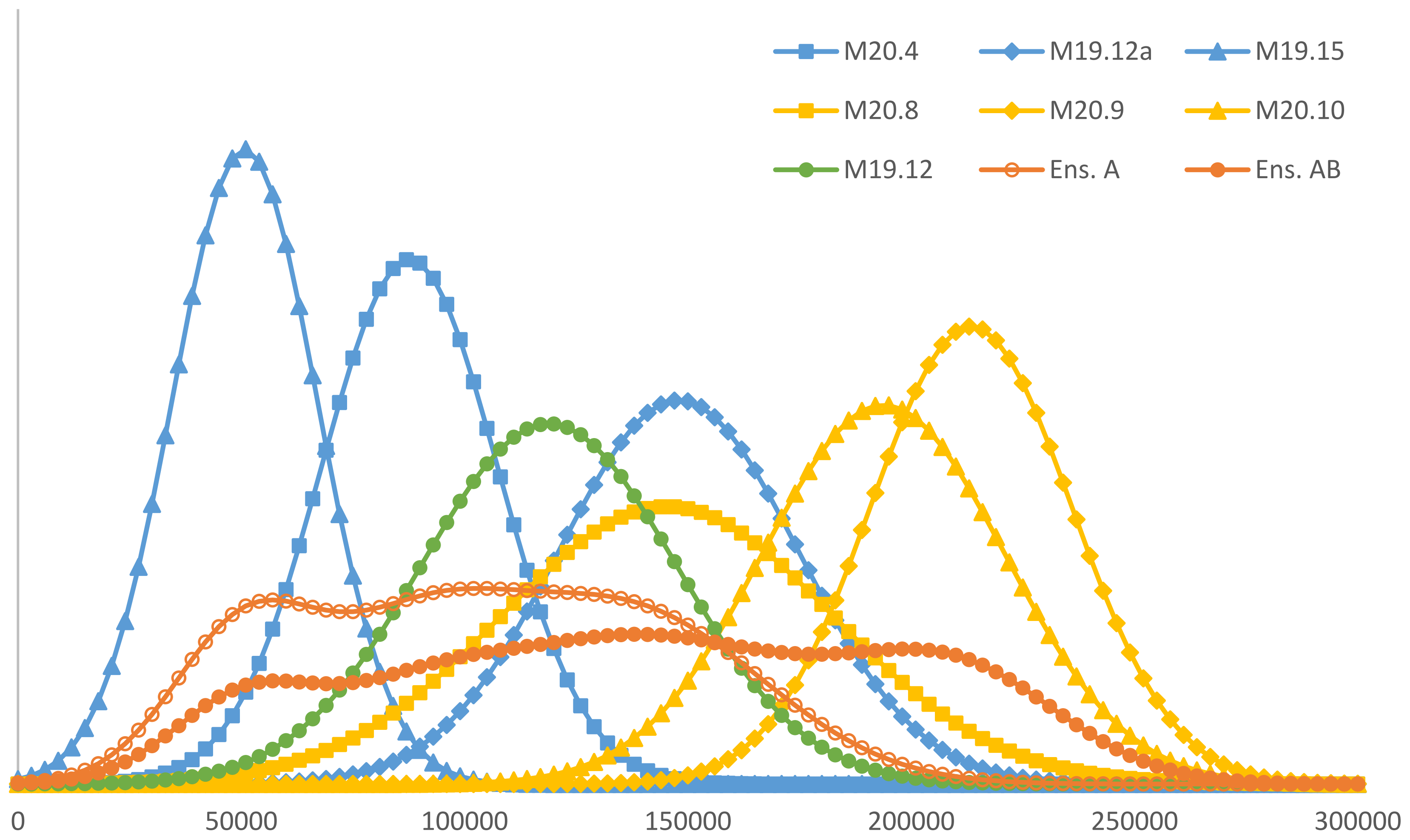
Phase plane: Ensemble AB



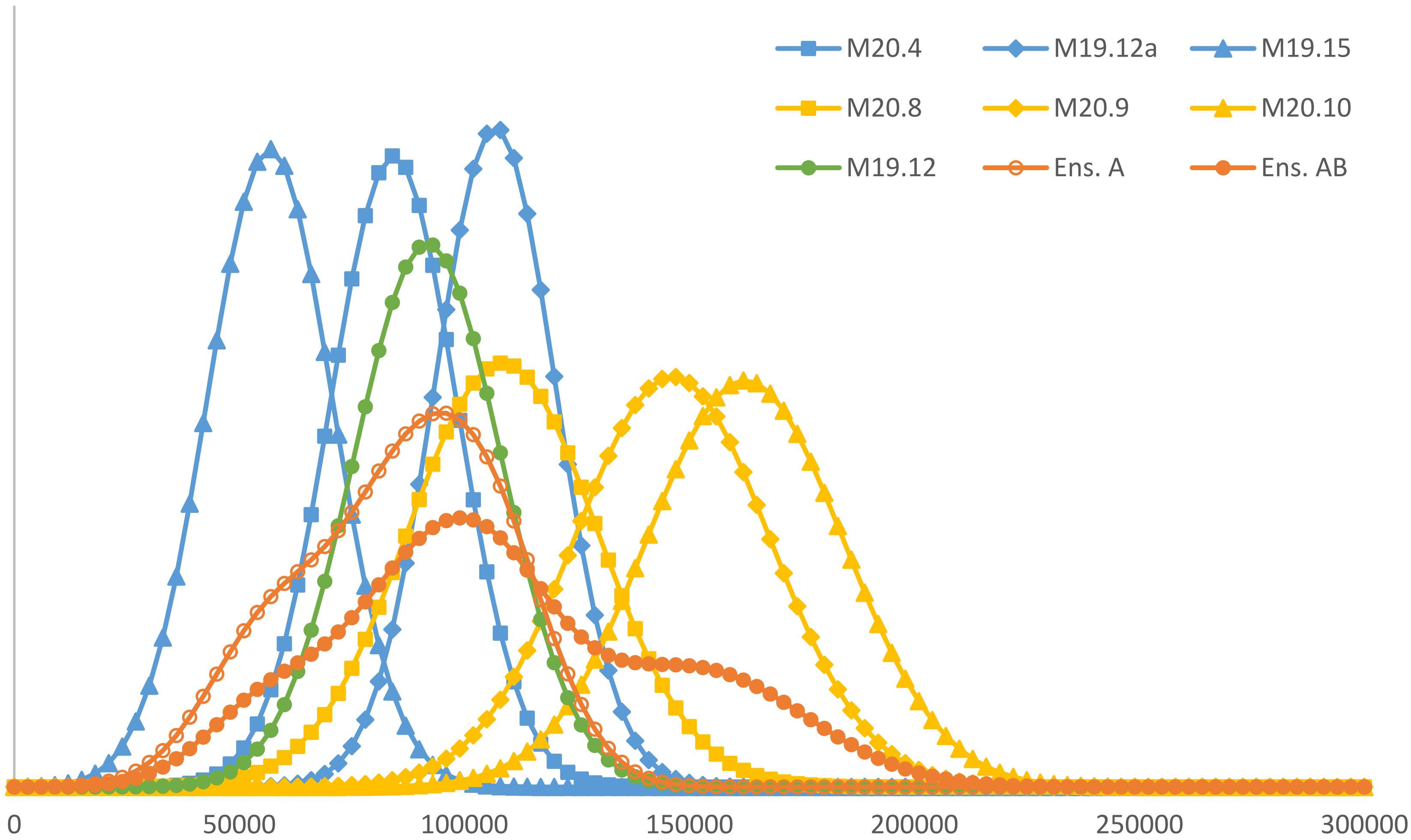
Probability densities: 2021 ABC



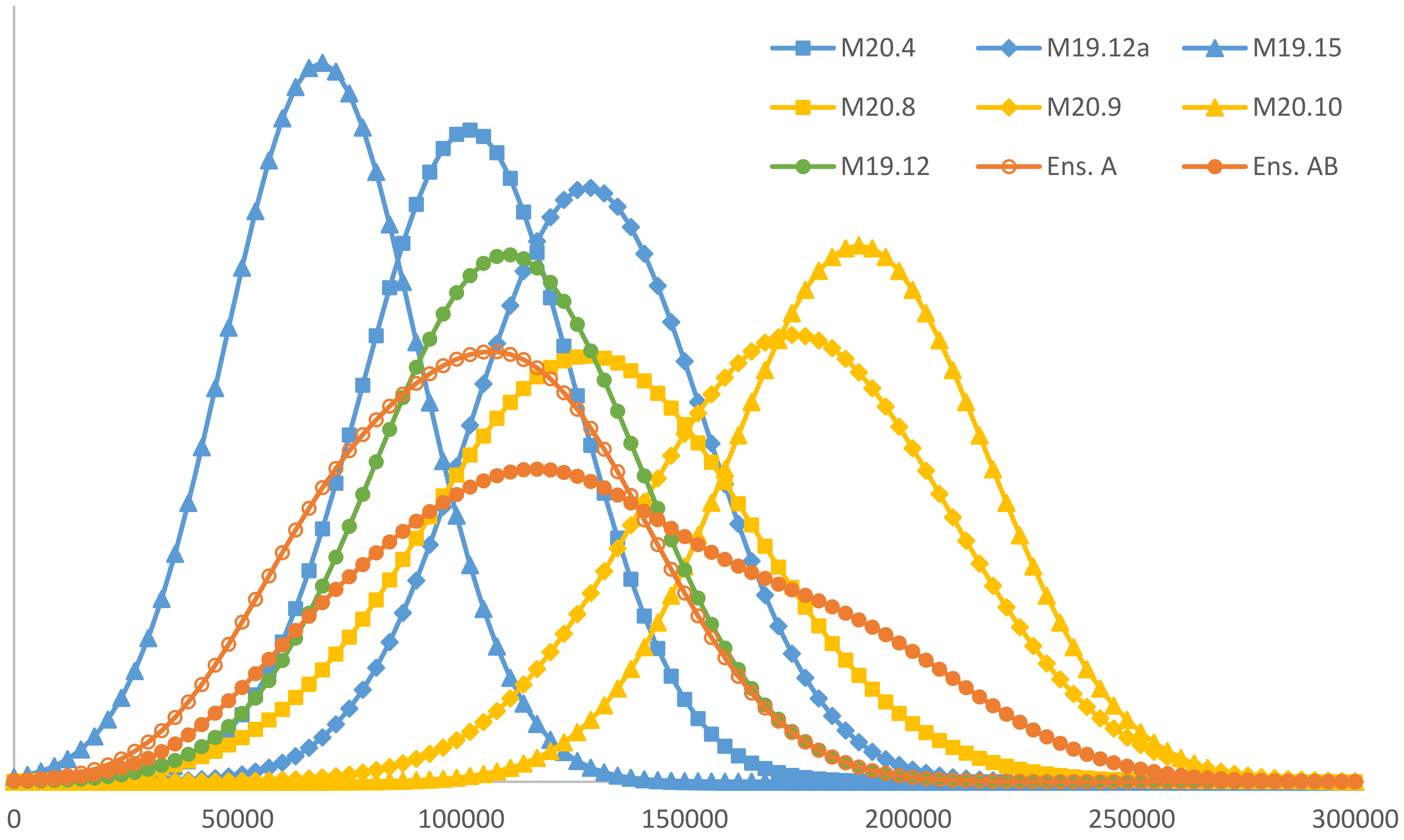
Probability densities: 2021 OFL



Probability densities: 2022 ABC



Probability densities: 2022 OFL



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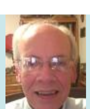
Management reference points

Factor A1: Allow *Q* to vary?		no		yes		(yes)				
Factor A2: Combine surveys?		no	yes	no	yes					
Factor B1: Use fishery CPUE?		(no)			no		yes			
Factor B2: Allow domed selex?					no	yes	no	yes	Ensemble	
Year	Quantity	20.4	19.12a	19.15	19.12	20.8	20.9	20.10	A	AB
n/a	B100%	632,190	659,545	629,325	669,025	805,200	734,275	1,283,340	649,506	771,600
n/a	B40%	252,876	263,818	251,730	267,610	322,080	293,710	513,336	259,803	308,640
n/a	B35%	221,267	230,841	220,264	234,159	281,820	256,996	449,169	227,328	270,060
n/a	F40%	0.37	0.35	0.36	0.33	0.27	0.35	0.22	0.35	0.32
n/a	F35%	0.46	0.43	0.44	0.40	0.33	0.43	0.25	0.43	0.39
2021	Female spawning biomass	164,682	228,219	126,883	210,551	293,096	304,723	576,525	185,645	273,584
2021	Relative spawning biomass	0.26	0.35	0.20	0.31	0.36	0.41	0.45	0.28	0.34
2021	Pr(B/B100%<0.2)	0.02	0.00	0.48	0.00	0.00	0.00	0.00	0.12	0.06
2021	maxFABC	0.24	0.30	0.17	0.26	0.25	0.35	0.22	0.24	0.26
2021	maxABC	72,848	123,805	42,029	99,310	123,210	179,712	166,665	86,480	118,013
2021	Catch	72,848	123,805	42,029	99,310	123,210	179,712	166,665	86,480	118,013
2021	FOFL	0.29	0.37	0.21	0.31	0.30	0.43	0.25	0.30	0.31
2021	OFL	87,678	147,949	50,770	118,895	145,354	213,427	193,833	103,668	139,984
2021	Pr(maxABC>truOFL)	0.23	0.18	0.30	0.25	0.28	0.07	0.16	0.38	0.37
2022	Female spawning biomass	170,874	205,906	142,384	197,652	265,895	261,637	529,300	181,032	253,506
2022	Relative spawning biomass	0.27	0.31	0.23	0.30	0.33	0.36	0.41	0.28	0.32
2022	Pr(B/B100%<0.2)	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.03	0.02
2022	maxFABC	0.25	0.27	0.19	0.24	0.22	0.32	0.22	0.24	0.25
2022	maxABC	84,295	106,852	56,788	91,845	108,512	146,209	162,378	85,758	109,266
2022	Catch	84,295	106,852	56,788	91,845	108,512	146,209	162,378	85,758	109,266
2022	FOFL	0.30	0.33	0.24	0.29	0.27	0.39	0.25	0.29	0.30
2022	OFL	101,682	128,340	68,639	110,353	128,447	174,509	188,997	103,208	130,076
2022	Pr(maxABC>truOFL)	0.23	0.20	0.29	0.26	0.29	0.21	0.18	0.30	0.37



Why does ABC decrease so much?

- Related: Why are the catch/biomass ratios lower than before?
- Two years may be helpful to examine as examples, using Model 19.12:
  1. 2012, because the 2020 assessment indicates that the catch/biomass ratios in that year were at or near the peak of the time series over the last 20 years
  2. 2019, because the 2020 assessment indicates that it was the last year that the stock was above $B_{40\%}$

Example 1: 2012 (1 of 5)

- Three sets of comparisons involving aggregate quantities for 2012:

Quantity	Equilibrium	2012	Difference
Age 0+ biomass	942,000	855,000	87,000
Fem. spawn. bio.	268,000	188,000	80,000
Rel. spawn. bio.	0.40	0.28	0.12
Fishing mortality	0.33	0.62	-0.29
Catch	165,000	233,000	-68,000

Quantity	2021	2012	Difference
Age 0+ biomass	693,000	855,000	-161,000
Fem. spawn. bio.	211,000	188,000	23,000
Rel. spawn. bio.	0.32	0.28	0.03
Fishing mortality	0.26	0.62	-0.36
Catch	99,000	233,000	-133,000

Quantity	2012 (ideal)	2012 (actual)	Difference
Fishing mortality	0.23	0.62	-0.39
Catch	95,000	233,000	-138000

Example 1: 2012 (2 of 5)

- From 2020 assessment: equilibrium values minus 2012 values

Quantity	0	1	2	3	4	5	6	7	8	9	10	11	12
Beg.-year nos. at age (1000s)	74765	-300027	-117226	114519	-149317	27208	-19272	14963	9908	5108	2833	1664	745
Beg.-year wt. at age (kg)	0.000	0.004	-0.013	0.069	0.001	0.144	0.256	0.327	0.354	0.450	0.377	0.639	0.694
Beg.-year biom. at age (t)	0	-1260	-23742	78498	-208243	70406	-49158	70707	57449	35811	22963	15310	7753
Fecundity at age	0.000	0.000	0.000	0.017	-0.004	0.119	0.243	0.314	0.331	0.431	0.347	0.625	0.680
Fem. spawn. biom. at age (t)	0	0	-197	4147	-30889	19729	-15912	29925	26097	16919	11074	7479	3814
Natural mortality (M)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Full-selection F	-0.289	-0.289	-0.289	-0.289	-0.289	-0.289	-0.289	-0.289	-0.289	-0.289	-0.289	-0.289	-0.289
Selectivity at age	0.000	0.000	0.003	0.028	0.012	0.035	0.027	0.009	0.002	0.001	0.001	0.001	0.001
Exploitation rate at age	0.000	0.000	-0.001	-0.008	-0.060	-0.096	-0.127	-0.143	-0.148	-0.149	-0.148	-0.148	-0.148
Mid-year wt. at age (kg)	-0.001	0.018	-0.085	-0.002	-0.096	0.039	0.134	0.202	0.236	0.335	0.273	0.538	0.604
Catch at age (t)	0	0	-499	3041	-62736	-1412	-45089	10221	10950	6577	4375	3192	1383
maxFABC	0.101	0.101	0.101	0.101	0.101	0.101	0.101	0.101	0.101	0.101	0.101	0.101	0.101
maxFABC expl. rate at age	0.000	0.000	0.001	0.013	0.026	0.049	0.059	0.061	0.062	0.061	0.061	0.061	0.061
maxABC at age (t)	0	1	38	4455	-12153	19686	1165	19405	14606	9009	5632	3604	1900

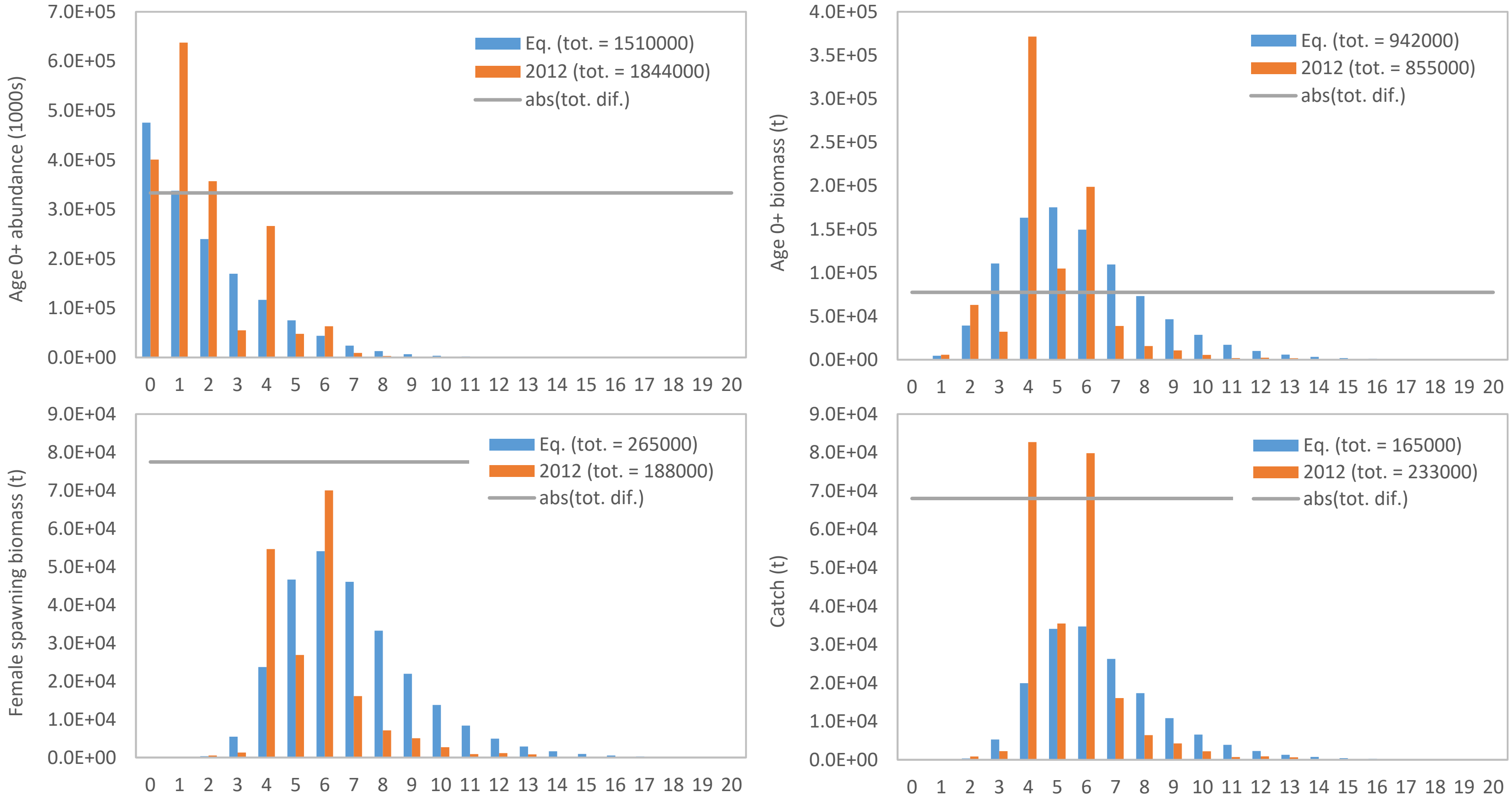
Example 1: 2012 (3 of 5)

- From 2020 assessment: 2021 values minus 2012 values

Quantity	0	1	2	3	4	5	6	7	8	9	10	11	12
Beg.-year nos. at age (1000s)	74765	-300027	-117218	181395	-239165	-25130	-39236	503	25329	3702	4825	1546	-82
Beg.-year wt. at age (kg)	0.000	0.003	-0.021	0.050	-0.095	0.470	0.412	0.595	0.598	0.459	0.331	0.659	0.576
Beg.-year biom. at age (t)	-9	-1762	-25797	117682	-336375	-44299	-113089	7910	152159	26206	38660	14269	-682
Fecundity at age	0.000	0.000	0.000	0.013	-0.062	0.482	0.440	0.640	0.616	0.444	0.300	0.646	0.558
Fem. spawn. biom. at age (t)	0	-1	-240	5846	-49896	-8621	-38008	3995	69980	12395	18640	6973	-337
Natural mortality (M)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Full-selection F	-0.361	-0.361	-0.361	-0.361	-0.361	-0.361	-0.361	-0.361	-0.361	-0.361	-0.361	-0.361	-0.361
Selectivity at age	0.000	0.000	0.001	0.024	-0.014	0.121	0.052	0.023	0.006	0.004	0.004	0.004	0.004
Exploitation rate at age	0.000	0.000	-0.002	-0.014	-0.082	-0.110	-0.161	-0.183	-0.190	-0.191	-0.191	-0.190	-0.190
Mid-year wt. at age (kg)	-0.001	0.023	-0.043	0.066	-0.081	0.478	0.422	0.605	0.635	0.513	0.391	0.714	0.635
Catch at age (t)	0	0	-589	3597	-79326	-24782	-62993	-6739	26483	2842	6194	2297	-595
maxFABC	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029
maxFABC expl. rate at age	0.000	0.000	0.001	0.007	0.004	0.035	0.025	0.022	0.019	0.019	0.019	0.019	0.019
maxABC at age (t)	0	0	-52	5012	-28744	-3682	-16736	2447	30146	5275	7452	2710	-78

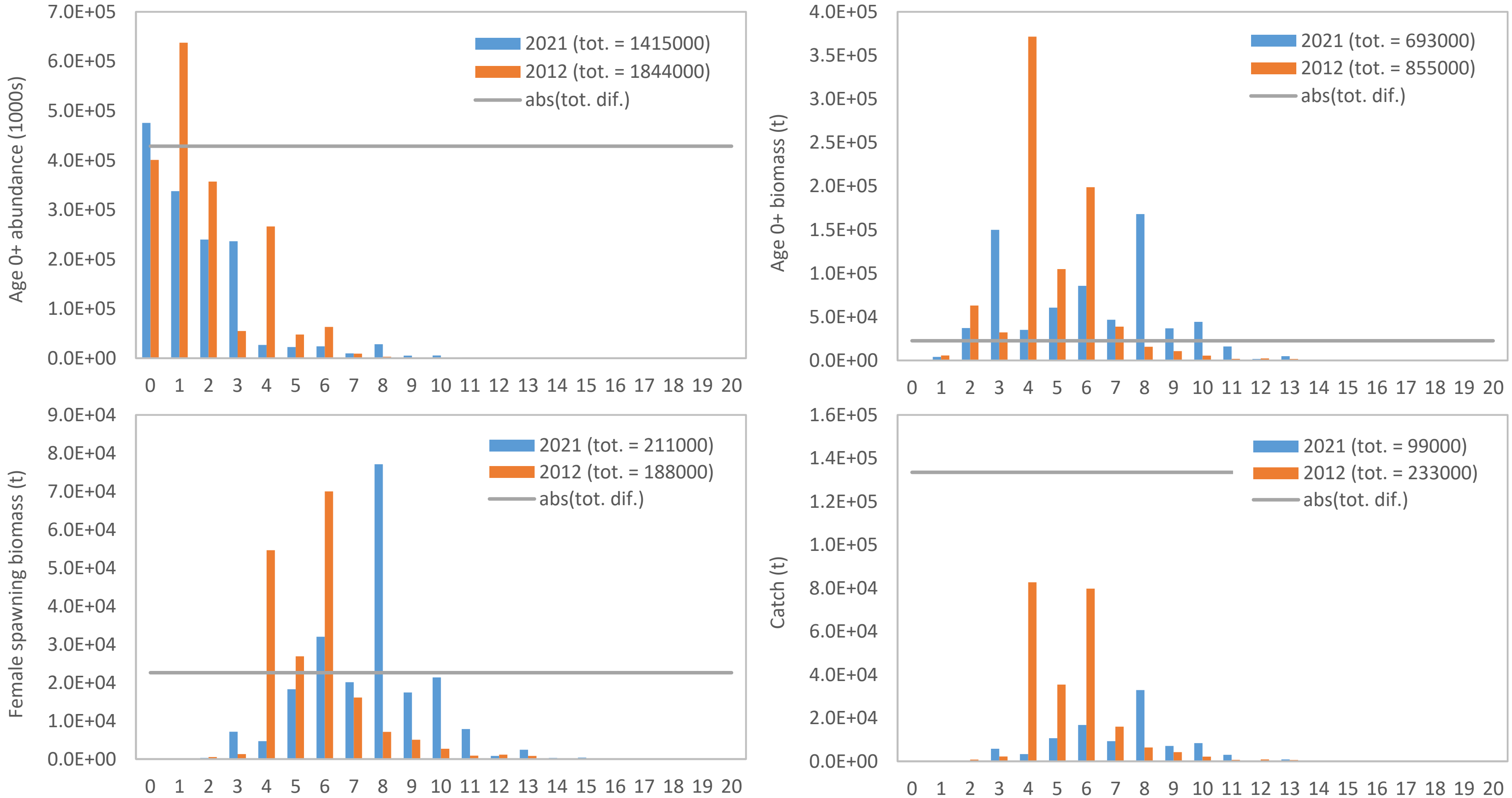
Example 1: 2012 (4 of 5)

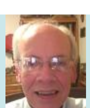
- From 2020 assessment: equilibrium values and 2012 values



Example 1: 2012 (5 of 5)

- From 2020 assessment: 2021 values and 2012 values





Example 2: 2019 (1 of 5)

- Three sets of comparisons involving aggregate quantities for 2019:

Quantity	Equilibrium	2019	Difference
Age 0+ biomass	942,000	875,000	66,000
Fem. spawn. bio.	268,000	300,000	-33,000
Rel. spawn. bio.	0.40	0.45	-0.05
Fishing mortality	0.33	0.31	0.02
Catch	165,000	179,000	-14,000

Quantity	2021	2019	Difference
Age 0+ biomass	693,000	875,000	-182,000
Fem. spawn. bio.	211,000	300,000	-90,000
Rel. spawn. bio.	0.32	0.45	-0.13
Fishing mortality	0.26	0.31	-0.06
Catch	99,000	179,000	-79,000

Quantity	2019 (ideal)	2019 (actual)	Difference
Fishing mortality	0.33	0.31	0.02
Catch	187,000	179,000	8000

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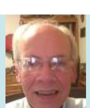
Example 2: 2019 (2 of 5)

- From 2020 assessment: equilibrium values minus 2019 values

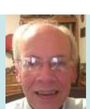
Quantity	0	1	2	3	4	5	6	7	8	9	10	11	12
Beg.-year nos. at age (1000s)	0	-133315	184496	115444	50936	43919	-53948	5123	-7013	483	2978	305	791
Beg.-year wt. at age (kg)	0.000	-0.017	0.042	-0.192	-0.105	-0.234	-0.261	-0.071	-0.051	-0.172	-0.063	-0.275	-0.216
Beg.-year biom. at age (t)	25	-9637	32630	64901	64222	95190	-208539	21826	-40949	2235	23805	2342	7998
Fecundity at age	0.000	0.000	0.001	-0.058	-0.084	-0.260	-0.309	-0.073	-0.042	-0.171	-0.049	-0.273	-0.210
Fem. spawn. biom. at age (t)	0	-26	307	2132	7580	23214	-81279	9052	-18547	1029	11490	1141	3936
Natural mortality (M)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Full-selection F	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016
Selectivity at age	0.000	0.000	0.004	-0.048	-0.035	-0.058	-0.028	0.008	0.015	0.019	0.021	0.023	0.023
Exploitation rate at age	0.000	0.000	0.001	-0.011	-0.005	-0.006	0.003	0.011	0.013	0.013	0.014	0.014	0.014
Mid-year wt. at age (kg)	0.001	-0.100	0.019	-0.338	-0.248	-0.379	-0.400	-0.240	-0.226	-0.345	-0.239	-0.448	-0.384
Catch at age (t)	0	-11	306	2193	6647	17508	-48881	5677	-8874	938	5526	700	1835
maxFABC	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
maxFABC expl. rate at age	0.000	0.000	0.001	-0.013	-0.009	-0.013	-0.006	0.002	0.003	0.004	0.004	0.005	0.005
maxABC at age (t)	0	-12	303	2035	5990	16728	-52703	4743	-10059	490	5479	554	1815



Example 2: 2019 (3 of 5)

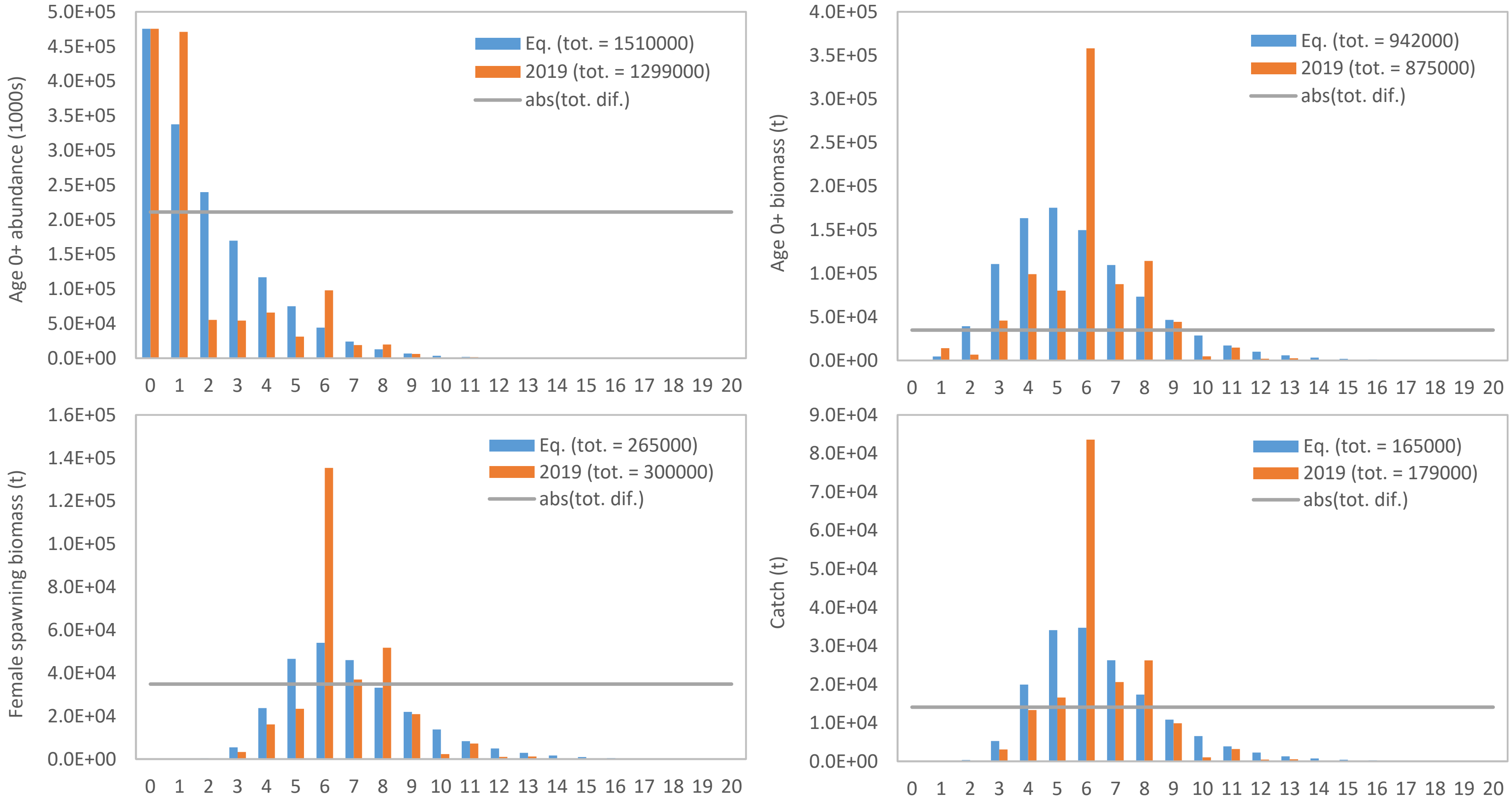
- From 2020 assessment: 2021 values minus 2019 values

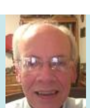
Quantity	0	1	2	3	4	5	6	7	8	9	10	11	12
Beg.-year nos. at age (1000s)	0	-133315	184504	182320	-38911	-8419	-73912	-9337	8408	-924	4970	187	-37
Beg.-year wt. at age (kg)	0.000	-0.018	0.034	-0.211	-0.202	0.092	-0.104	0.198	0.193	-0.163	-0.108	-0.256	-0.334
Beg.-year biom. at age (t)	16	-10138	30575	104085	-63910	-19515	-272470	-40971	53761	-7370	39502	1301	-437
Fecundity at age	0.000	0.000	0.001	-0.062	-0.141	0.104	-0.112	0.253	0.242	-0.157	-0.096	-0.252	-0.332
Fem. spawn. biom. at age (t)	0	-28	264	3831	-11426	-5136	-103375	-16878	25336	-3495	19056	634	-215
Natural mortality (M)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Full-selection F	-0.055	-0.055	-0.055	-0.055	-0.055	-0.055	-0.055	-0.055	-0.055	-0.055	-0.055	-0.055	-0.055
Selectivity at age	0.000	-0.001	0.003	-0.052	-0.061	0.028	-0.002	0.021	0.019	0.022	0.024	0.026	0.027
Exploitation rate at age	0.000	0.000	0.000	-0.017	-0.027	-0.020	-0.031	-0.029	-0.030	-0.029	-0.028	-0.028	-0.028
Mid-year wt. at age (kg)	0.001	-0.095	0.061	-0.270	-0.233	0.060	-0.112	0.164	0.174	-0.168	-0.121	-0.272	-0.353
Catch at age (t)	0	-12	215	2749	-9944	-5863	-66785	-11283	6660	-2797	7345	-196	-143
maxFABC	-0.071	-0.071	-0.071	-0.071	-0.071	-0.071	-0.071	-0.071	-0.071	-0.071	-0.071	-0.071	-0.071
maxFABC expl. rate at age	0.000	0.000	0.000	-0.019	-0.031	-0.027	-0.040	-0.038	-0.039	-0.038	-0.038	-0.037	-0.037
maxABC at age (t)	0	-13	213	2592	-10600	-6640	-70604	-12215	5481	-3244	7299	-341	-163



Example 2: 2019 (4 of 5)

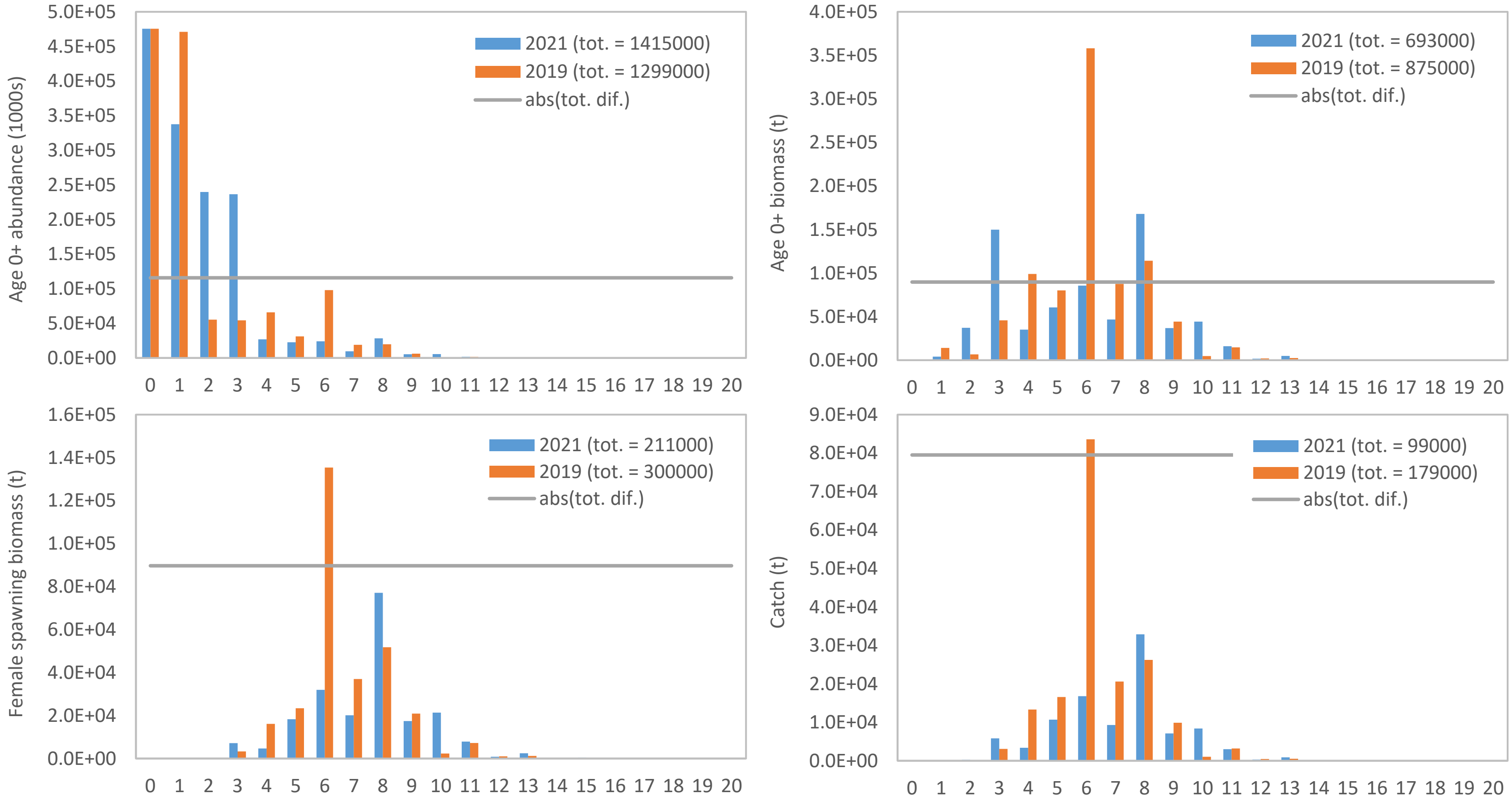
- From 2020 assessment: equilibrium values and 2019 values





Example 2: 2019 (5 of 5)

- From 2020 assessment: 2021 values and 2019 values



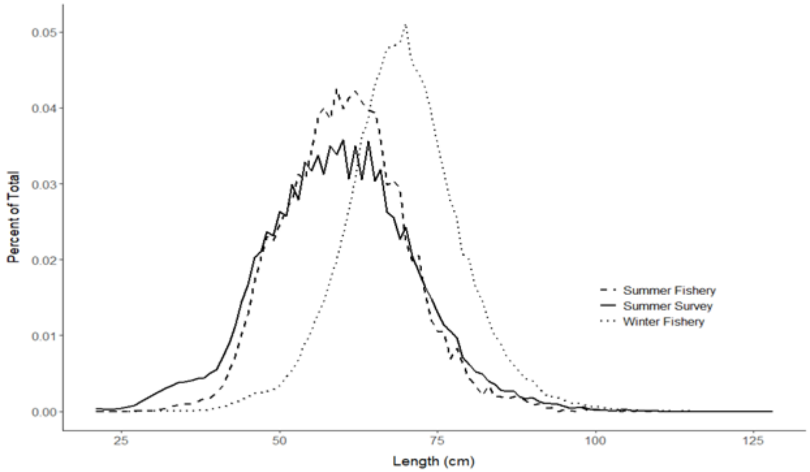
Recommendations and discussion

Model recommendation

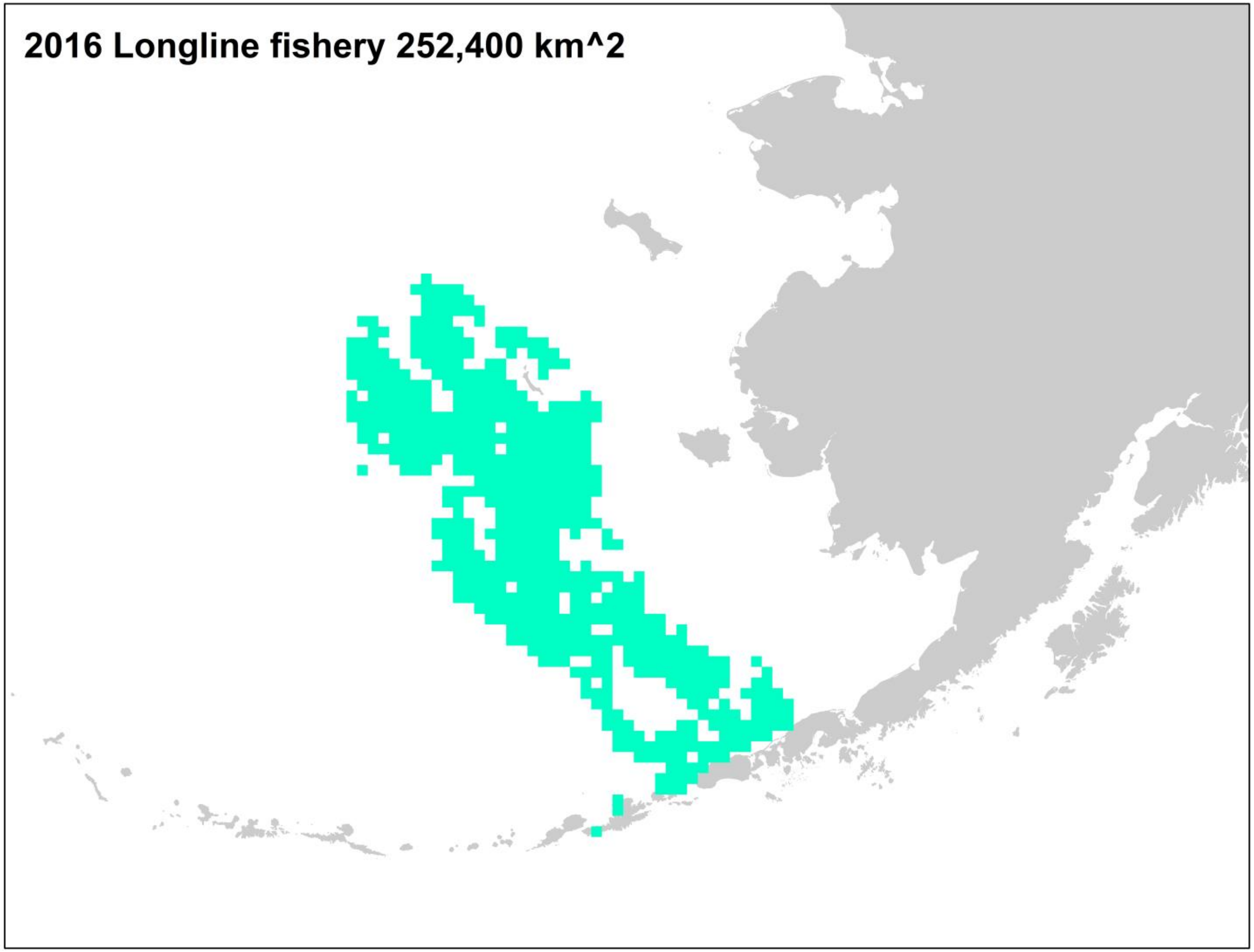
- Ensemble AB is recommended for the purpose of harvest specifications
  - Pro:
    - Responsive to both Team/SSC and public comment
    - Given the large decrease in ABC projected last year, it seems prudent to consider a wide range of alternative model structures, so long as they are appropriately weighted
  - Con:
    - Alternative models in Ensemble B not previewed in September
      - Team policy (11/18): The "standard for acceptance" of such models "will be higher" than for models that are previewed
    - Allowing dome-shaped survey selectivity may not be reasonable
    - Fishery CPUE may not be a good index of abundance
    - See next 6 slides

Allowing dome-shaped survey selectivity

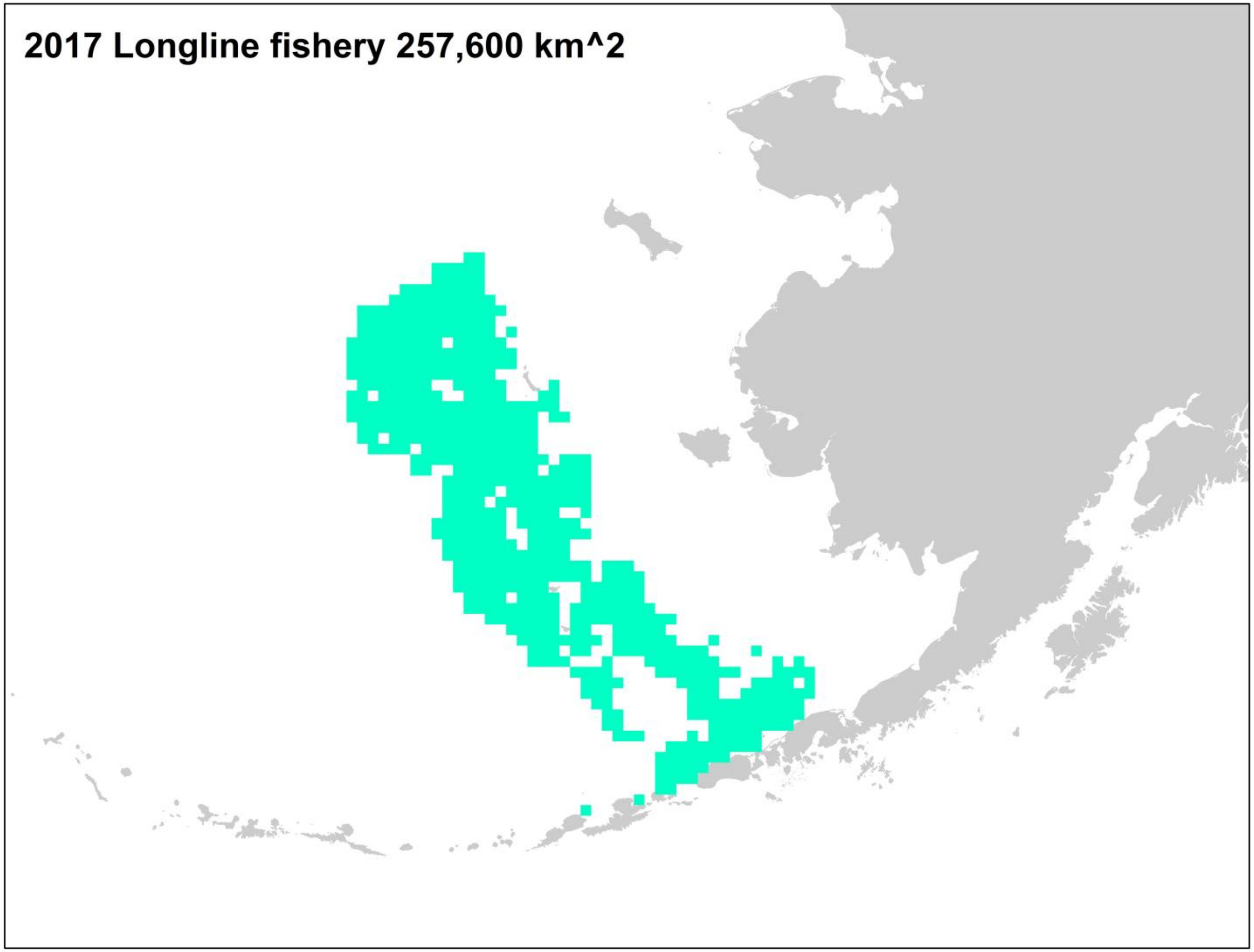
- Allowing dome-shaped survey selectivity was a standard feature of EBS Pacific cod assessment models for many years prior to 2016
- 2016 CIE review and 2016 Joint Team subcommittee recommended shifting to models with “reasonable” fits, as opposed to optimized fits
- Weinberg et al. (2016) found that the evidence from field studies did not lend support to dome-shaped selectivity
- Comparing survey sizecomp to summer and winter fishery sizecomp:



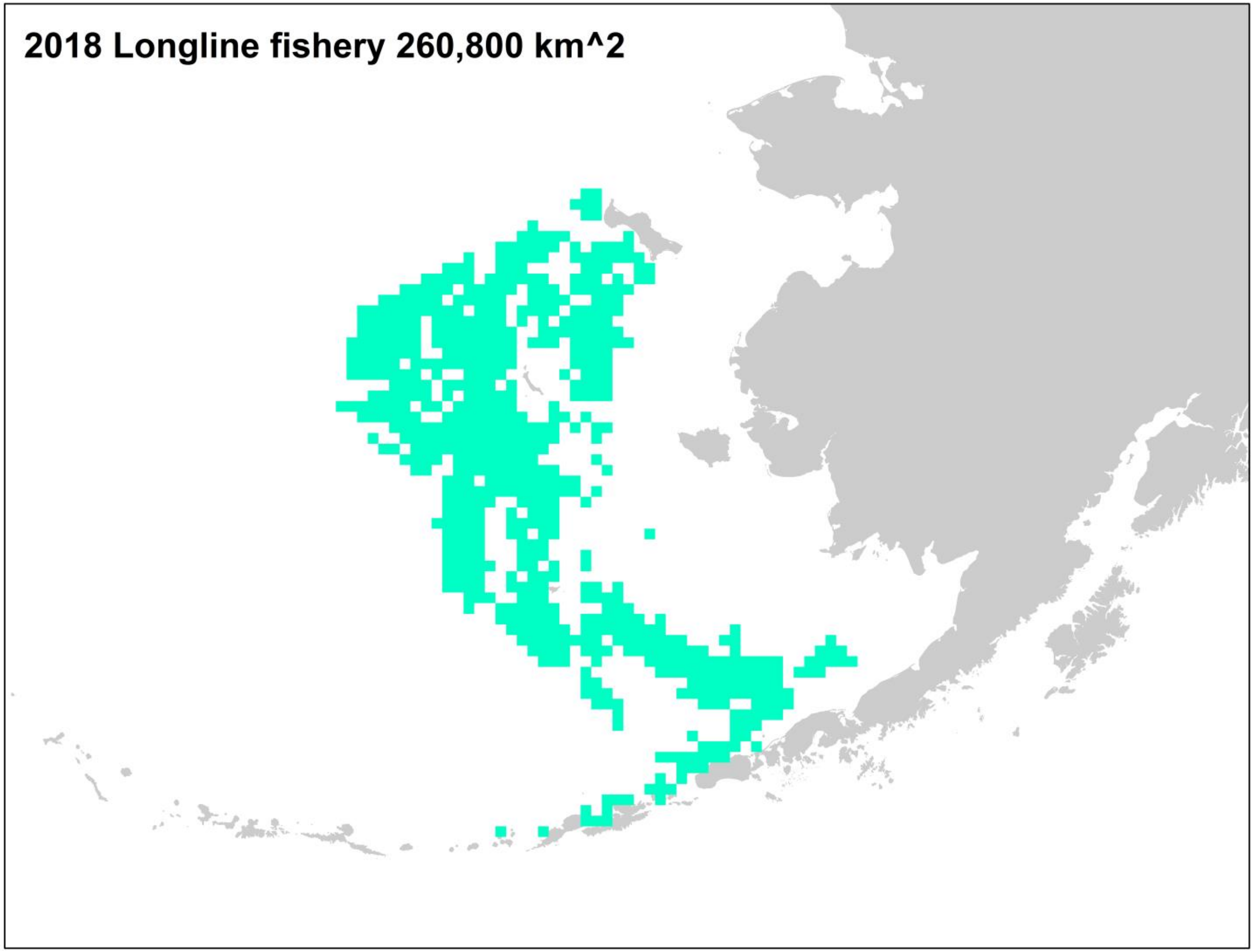
Fishery CPUE: effort distribution (1 of 5)



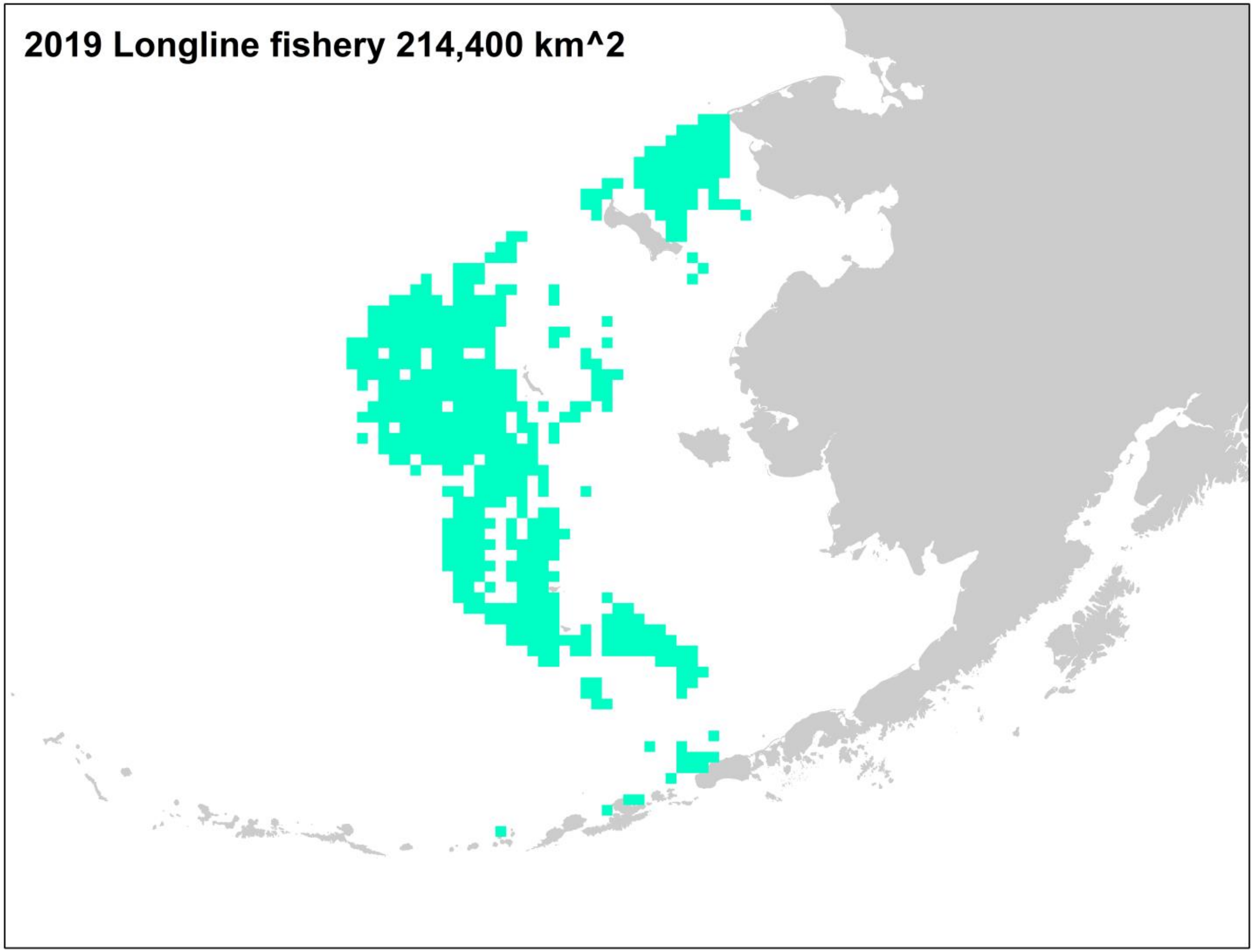
Fishery CPUE: effort distribution (2 of 5)



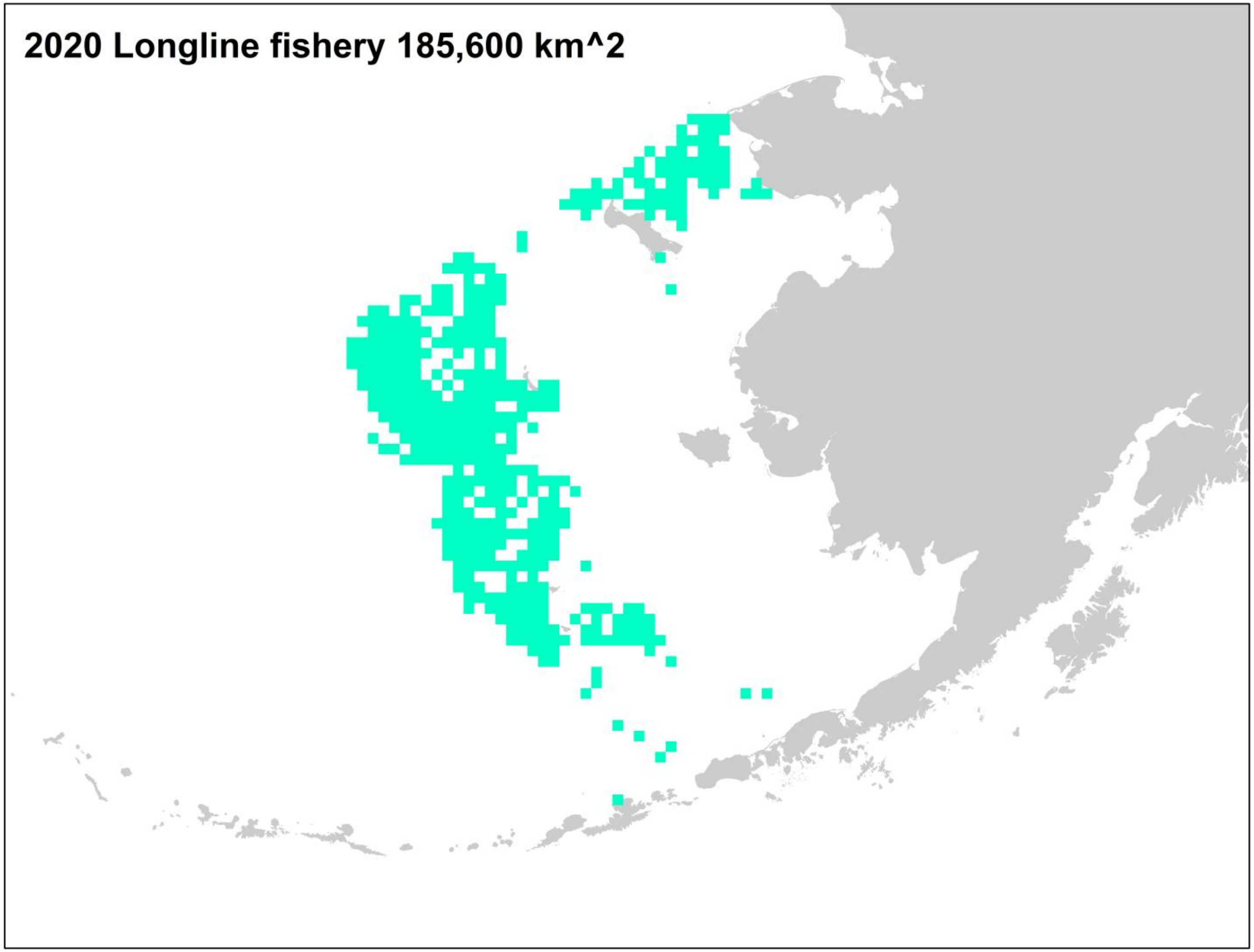
Fishery CPUE: effort distribution (3 of 5)



Fishery CPUE: effort distribution (4 of 5)



Fishery CPUE: effort distribution (5 of 5)



Risk table: assessment (1 of 2)

- Recent range expansion of the stock into the NBS has made assessment modeling more difficult
- Detailed investigation of multiple models gives some confidence that relevant uncertainties have been explored
- Use of model averaging likewise gives some confidence that alternative explanations of the data are considered
- Individual ABC values span a wide range
- Ageing bias, and changes in ageing criteria, are addressed
- Data-rich assessment, with (almost) annual surveys showing small CVs
- Bryan et al. (2020) show that, for this stock, uncertainty resulting from a missed survey is about average for stocks in general
- (Continued on next slide)

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Risk table: assessment (2 of 2)

- Review of all BSAI and GOA ABC recommendations from 2003-2017 found only 1 case where survey cancellation led to a reduction
- Models are not affected by whether lack of a survey was anticipated
- Relative to other assessments, the assessment of this stock must be considered among the most intensively explored and reviewed, with full results for multiple models presented for Team and SSC review twice every year (Appendix 2.3), including responses to dozens of Team and SSC comments annually
- Rating: Level 1 (same as last year)
    - More specifically, toward the low end of Level 1

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Risk table: population dynamics

- EBS survey biomass has been going sharply down since 2015
- EBS+NBS survey biomass decline is much less pronounced
- Numerical abundance in 2019 was up sharply, due to 2018 cohort
- Is the 2018 cohort truly strong?
  - Surveys in both EBS and NBS say yes
  - Did high 2018 temps cause inshore fish to move into survey area?
    - Models 20.4 and 19.12a (constant Q) give higher estimates
  - All models say 2018 is 39-62% above average (CVs = 0.10-0.17)
- 2014-2017 cohorts all very weak (2016-2017 are 2 of all-time lowest 3)
- Note that all of the above are accounted for in the models
- Rating: Level 1 (same as last year)
  - More specifically, toward the lower end of Level 1

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Risk table: environmental/ecosystem (1 of 2)

- Sea ice formation was delayed into late winter 2019
- A rapid build-up of sea ice occurred after late winter, even exceeding median ice extent in parts of February and March 2020
- Sea ice concentration (i.e., thickness) was low, and retreated at a faster rate than the previous 5 years after June
- Late winter sea surface temperatures were closer to the long term means over the southeastern and northern shelves
- Above-average temperatures returned in spring and summer, especially over the southeast shelf
- Summer temperatures remained above average in the SEBS and NBS
- Bottom water temperatures from ROMS show 2020 was an average year
- Spatial extent of the cold pool in 2020 most closely resembles 1997
- (Continued on next slide)

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Risk table: environmental/ecosystem (2 of 2)

- Pacific cod expanded their range into the NBS in 2018 and 2019
- Based on conditions metrics, both juvenile and adult Pacific cod were able to find sufficient prey resources in 2018 and 2019
- Low abundances of euphausiids were observed in 2018 (MACE acoustic survey), while higher abundances were indicated in 2019 (RPA RZA)
- Effects of cannibalism might be mediated by spatial mismatch between juvenile and adult cod
- 2019/2020 gray whale UME reflects poor feeding conditions in the NBS during 2018/2019
- 2019 Shearwater die-offs could reflect poor 2018 NBS feeding conditions
- Decoupling of recruitment time series for cod and walleye pollock around 2008-2009 suggests a shift in drivers of survival; cod less understood
- Rating: Level 2 (same as last year)
  - More specifically, toward the lower end of Level 2

Risk table: fishery performance

- The estimated "year effect" for longline fishery mean CPUE in 2020 (not catch-weighted) is the highest since 1997 and is 26% above the average for the time series
- The catch-weighted, all-gear mean CPUE estimate for 2020 is the all-time high for the time series, and is 67% above the time series average
- The fact that the fishery CPUE data tend to paint a somewhat different picture than the survey data is concerning, but hardly a reason to reduce ABC, as including fishery CPUE data in the assessment model (20.9 and 20.10) results in higher, not lower, maxABC values
- Recent expansion of the fishery into the NBS is noteworthy, but is not necessarily a concern in terms of fishery performance
- Rating: Level 1 (same as last year
    - More specifically, toward the lower end of Level 1

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Risk table: summary (1 of 2)

- If all categories had been ranked as level 1 (normal), the expectation would be that no reduction is necessary
- However, because one of the category ratings exceeds level 1, it is necessary to consider whether ABC may need to be reduced
- Last year the same set ratings was assigned, and the SSC chose to reduce ABC
- Nevertheless, the SSC has also said that identification of a level greater than 1 does not mandate an ABC reduction
- Appendix 2.6 was developed in an attempt to provide a formulaic approach to answering the following pair of questions:
    - How do the levels of concern identified in the risk table map into the need for an ABC reduction?
    - If an ABC reduction is needed, how large should the reduction be?

Risk table: summary (2 of 2)

- Based on the method described in Appendix 2.6 and given the 2021 OFL distributions for Ensembles A and AB described in Table 2.39 and Figure 2.26b, a reduction in this particular case would be necessary only if the degree of concern for each of the four categories was, on average, much closer to the upper end of the assigned level than to the lower end
- Specifically, for both Ensembles A and AB, the degree of concern would have to be about twice as far from the lower end of the respective level than the upper end, on average
- However, as indicated above, this is not the case, as the degree of concern for each category was identified as being near the lower end of the designated level
- Therefore, no ABC reduction is recommended here, and the authors' ABC recommendations for 2021 and 2022 are 118,013 t and 109,266 t, respectively, based on Ensemble AB

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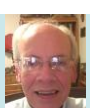

Some context for the recommended 2021 ABC

- ABCs of the magnitudes suggested by Model 19.12, Ensemble A, or Ensemble AB would be smaller than any EBS catch since 1983
- Change in 2021 ABC relative to 2020 ABC:

Ens. A	M19.12	Ens. AB
-45%	-36%	-24%

- Change in 2021 ABC relative to 2021 ABC *as currently specified*:

Ens. A	M19.12	Ens. AB
-16%	-4%	15%

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