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Alaska Fisheries Science Center

Assessment of Pacific cod in the Eastern Bering Sea

Grant Thompson, Jason Conner,
Kalei Shotwell, Ben Fissel, Tom Hurst, Ben Laurel,
Lauren Rogers, and Elizabeth Siddon

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Ecosystem and Socioeconomic Profile

K. Shotwell,
G. Thompson, B. Fissel, T. Hurst,
B. Laurel, L. Rogers, E. Siddon

Overview

- ESP appears as Appendix 2.2 of the SAFE chapter
- Still in draft form; final draft will be included in the 2021 assessment
  - Investigation of movement between EBS and NBS will be a priority
  - More description of multispecies model
  - Additional work on recruitment (stage 3) and ROMS model output
- 7 editors, 17 contributors
- Data Sources
  - RACE, REFM, ABL, EcoFOCI, RPA, MML, FMA, PMEL
  - CoastWatch (satellite), BEST-BSIERP, EFH, ISRC (seabirds)
  - Many contributions derived from ESR contributions
  - AKRO, ADF&G, FAO via AKFIN (thank you Jean Lee)

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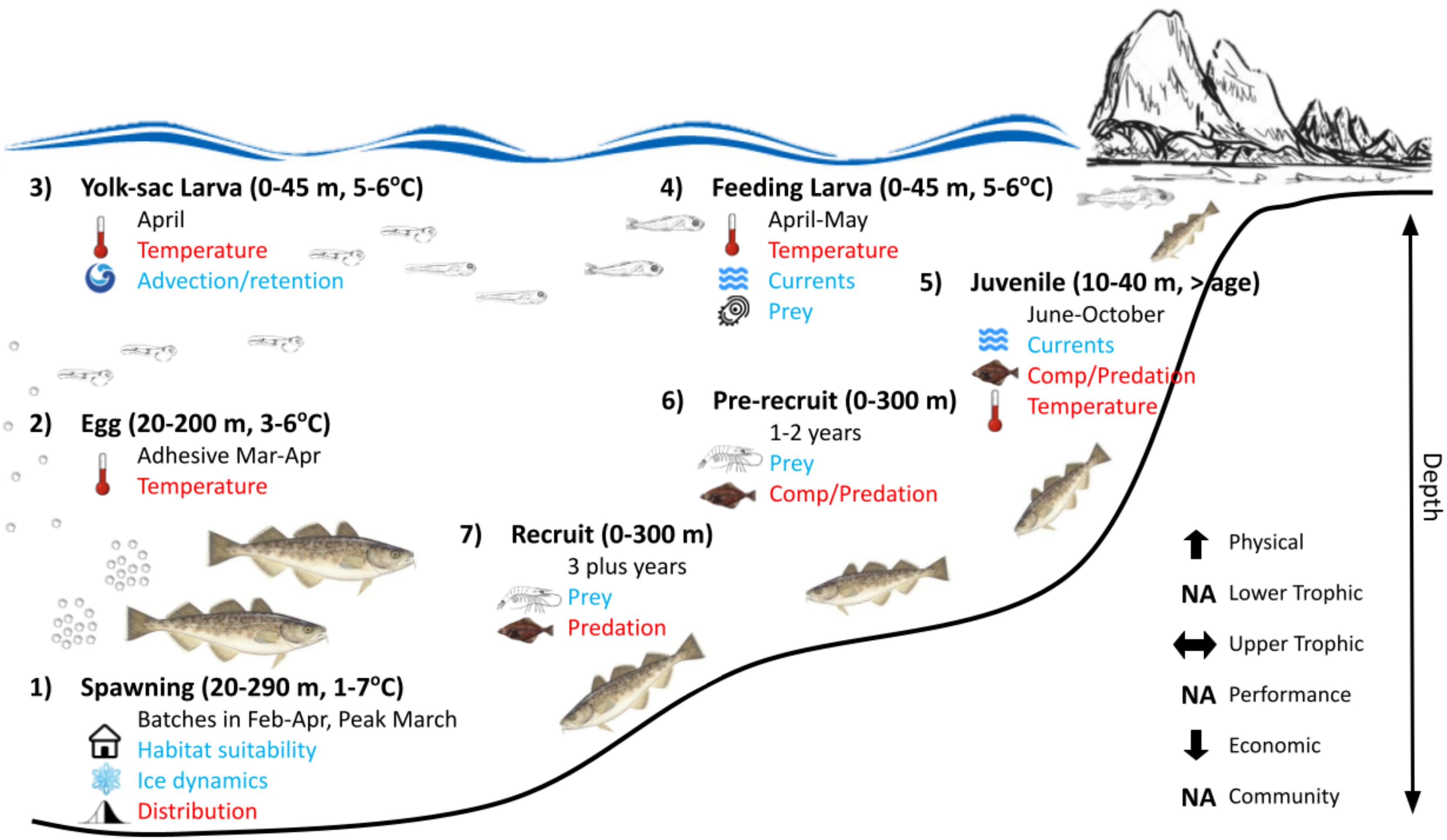
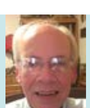
Ecosystem processes (1 of 3)





Ecosystem processes (2 of 3)

Stage	Habitat & Distribution	Phenology	Age, Length, Growth	Energetics	Diet	Predators/Competitors
Recruit	Shore to Shelf (0-500 m), depth varies by age then size(24), sublittoral-bathyal zone, move w/in, between LMEs(24)	Recruit to survey and fishery age-1, length 20-27 cm(24)	Max: 25 yrs, 147♀/134♂ cm L_inf=94 cm, K= 0.2 (24,AFSC)		Opportunistic, small on inverts, large on fish(20, 21, 24, AFSC)	Halibut, Steller sea lions, whales, tufted puffins, fisheries(24); shelf groundfish(24)
Spawning	Shelf (40-290 m)(13-16,24), semi-demersal in shelf areas(13,15,16), seasonal migrations variable duration(26)	Winter-spring, peak mid-March, 13 wks (1,20,25)	1st mature: 2 yr, 26♀/36♂cm, 50%: 4-5yr, 45-65cm (24,AFSC)	Oviparous, high fecundity (250-2220$\cdot$ 10^3) eggs (13,15), range 4-6 °C(14,16)	Opportunistic (20,21)	Halibut, Steller sea lions, whales, tufted puffins, fisheries(24); shelf groundfish(24)
Egg	Shelf (20-200 m), demersal, adhesive eggs(13,15-17,24)	Incubation is ~20 days, 6 wks(14,22)	Egg size: 0.98-1.08 mm (Laurel et al 2008)	Optimal incubation 3-6°C, 13-23 ppt, 2-3ppm dO_2 (LR, 2020)	Yolk is dense and homogenous (AFSC)	
Yolk-sac Larvae	Epipelagic, nearshore shelf, coastal, upper 45 m, semi-demersal at hatching(13-15,18,24)	Spring, peak end April, 14 wks(22)	3-4.5 mm NL at hatch (13-15,24)	1-2 weeks before onset of feeding	Endogenous	Share larval period with pollock(13)
Feeding Larvae	Epipelagic, nearshore shelf(13-15,24), 0-45 m(24)	Late spring(22)	25-35 mm SL at transformation (3,13-15,24)	1-2 weeks before onset of feeding	Copepod eggs, nauplii, and early copepodite stages (Strasburger et al. 2014)	Share larval period with pollock(13)
Juvenile	Nearshore (2-110 m), 15-30 m peak density, inside bays, coastal, mixed, structural complexity (1-6,11,21)	Nearshore settlement in June, deeper water migrations in October(3,13-15)	YOY: 35-110 mm FL(2), age 1+: 130-480 mm FL(1,3,4,6,10); growth sensitive to temp	Energy density ↑ with length, lower in pelagic stage,	Copepods, mysids, amphipods(2), small fish(10), crabs(19-21)	Pollock, halibut, arrowtooth flounder(19,20); macroalgae, eelgrass, structural inverts, king crab, skate egg case, juvenile pollock (1-5,7-9)
Pre-Recruit	Nearshore, shelf (10-216 m)(4), inside bays, coastal, mixed, mud, sand, gravel, rock pebble(1,2,4,6)	Age-2 may congregate more than age-1(25)	Begin to mature age 2-3, 480-490 mm FL (15)	Energy density and condition lower than in pelagic stage	Opportunistic, benthic invert, pollock, small fish, crabs(19-21)	Pacific cod, halibut, salmon, fur seal, sea lion, porpoise, whales, puffin(24); macroalgae, macroinvertebrate, king crab, skate egg case(4-5,7-9)

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Ecosystem processes (3 of 3)

Stage	Processes Affecting Survival	Relationship to EBS Pacific cod
Recruit	1. Competition 2. Predation 3. Temperature	Increases in main predator of Pacific cod would be negative but minor predators may indicate Pacific cod biomass increase. Increases in overall prey biomass would be positive for Pacific cod but generalists.
Spawning	1. Ice Dynamics 2. Spawning Habitat Suitability 3. Distribution	Temperatures outside the 3-6 C range contribute to poor hatching success and may impact physiological and behavioral aspects of spawning. Spring bottom temperatures outside this range are linked to observed pre-recruits and recruitment estimates (Laurel and Rogers 2020)
Egg	1. Temperature	Eggs are highly stenothermic (Laurel and Rogers 2020)
Yolk-sac Larvae	1. Temperature 2. Timing of spring bloom 3. Onshore shelf transport	Increases in temperature would increase metabolic rate and may result in rapid yolk-sac absorption that may lead to mismatch with prey. Current direction to preferred habitat would be positive for Pacific cod.
Feeding Larvae	1. Temperature 2. Prey availability 3. Onshore shelf transport	Increases in temperature would increase metabolic rate and may result in poor condition if feeding conditions are not optimal. Onshore transport to nursery habitat would be positive for Pacific cod while predation increases would be negative.
Juvenile	1. Competition 2. Predation 3. Temperature	Evidence of density-dependent growth in coastal nurseries (Laurel et al., 2016) would suggest that increases in competitors or predators would be negative for Pacific cod condition and therefore survival. Temperature increases may amplify risk of food availability and energy allocation (Laurel et al. 2017)
Pre-Recruit	1. Competition 2. Predation 3. Temperature	Evidence of density-dependent growth in coastal nurseries (Laurel et al., 2016) would suggest that increases in competitors or predators would be negative for Pacific cod condition and therefore survival. Temperature increases may amplify risk of food availability and energy allocation (Laurel et al. 2017)

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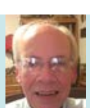
Socioeconomic processes (1 of 2)

- Economic Performance
  - Paired down version of EPR (former SAFE chapter appendix)
  - Highlight fishery status
    - Recent: value down, price up
    - Projection: both down
- Tables (national, global)
  - Five year breakdown of various economic metrics

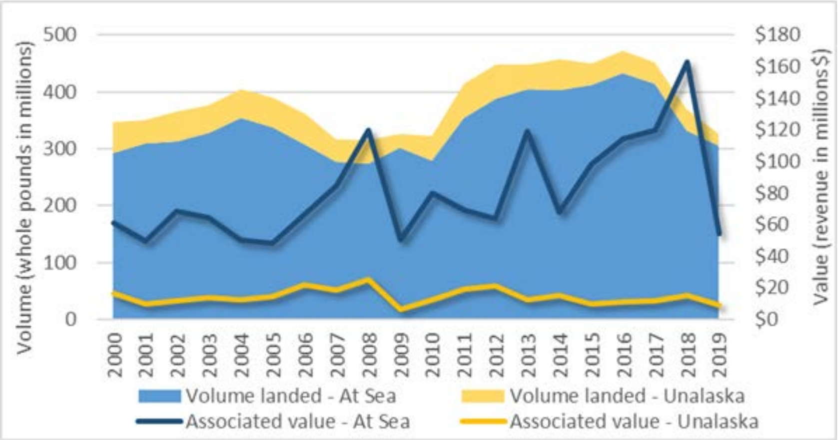
	Avg 10-14	2015	2016	2017	2018	2019
Total catch K mt	228.52	242.1	260.9	253	220.3	197.9
Retained catch K mt	224.1	239.0	257.7	250.1	218.0	195.8
Vessels #	168.4	150	162	173	193	196
CP H&L share of BSAI catch	51%	54%	49%	50%	46%	45%
CP trawl share of BSAI catch	16%	15%	14%	13%	14%	13%
Shoreside retained catch K mt	67.7	68.4	86.0	88.0	82.5	77.5
Shoreside catcher vessels #	116.4	101	110	128	144	149
CV pot gear share of BSAI catch	12%	13%	15%	17%	19%	22%
CV trawl share of BSAI catch	18%	16%	18%	18%	18%	17%
Shoreside ex-vessel value M $	$38.2	$34.1	$44.6	$54.1	$65.1	$62.3
Shoreside ex-vessel price lb $	$0.278	$0.248	$0.264	$0.316	$0.399	$0.418
Shoreside fixed gear ex-vessel price premium	$0.03	$0.06	$0.04	$0.05	$0.06	$0.11

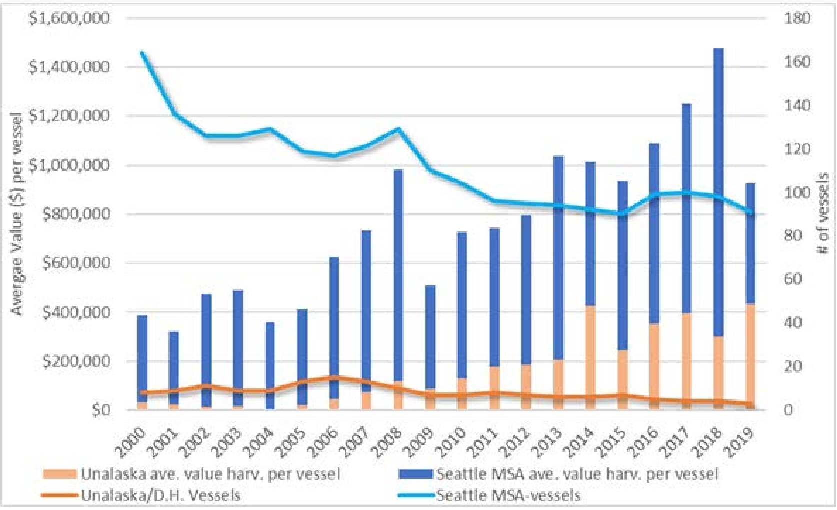
		Avg 10-14	2015	2016	2017	2018	2019
All products	volume K mt	111.82	120.47	126.40	119.54	107.41	94.97
All products	Value M $	$ 330.7	$ 365.0	$ 388.3	$ 434.7	$ 458.8	$ 346.5
All products	price lb $	$ 1.34	$ 1.37	$ 1.39	$ 1.65	$ 1.94	$ 1.65
Fillets	volume K mt	7.23	6.28	10.03	10.01	10.36	8.02
Fillets	value share	14%	10%	19%	19%	21%	20%
Fillets	price lb $	$ 2.86	$ 2.67	$ 3.37	$ 3.70	$ 4.12	$ 3.92
Head & Gut	volume K mt	91.55	100.82	98.68	92.38	79.04	70.25
Head & Gut	value share	79%	83%	72%	74%	71%	72%
Head & Gut	price lb $	$ 1.30	$ 1.36	$ 1.29	$ 1.57	$ 1.86	$ 1.60
At-sea	value share	72%	76%	69%	70%	64%	67%
At-sea	price premium ($/lb)	-$0.07	$0.07	-$0.32	-$0.33	-$0.51	-$0.36



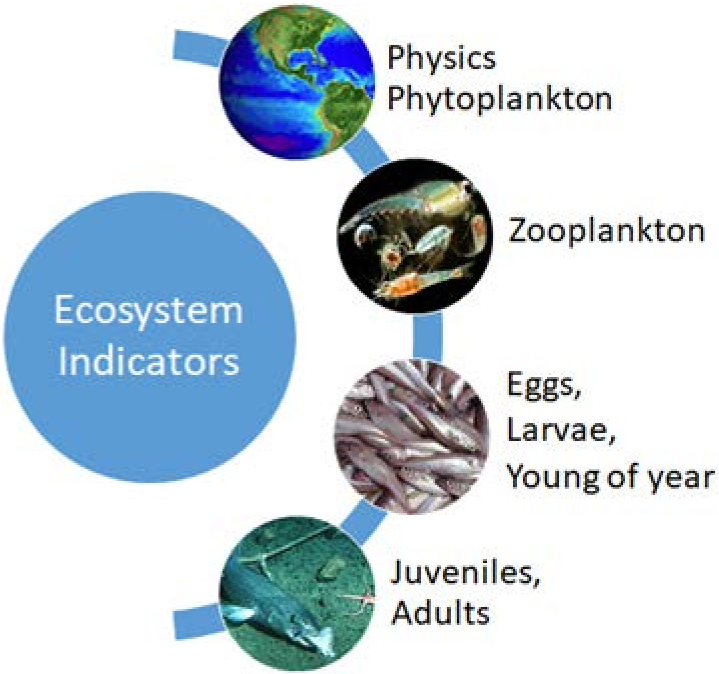
Socioeconomic processes (2 of 2)

- Communities
  - At-sea processing accounts for 73% of landed volume
  - Seattle accounts for 63% of harvest value
  - Moderate/high engagement for Unalaska/Dutch
- Engagement metrics
  - Regional quotient for processing and harvesting



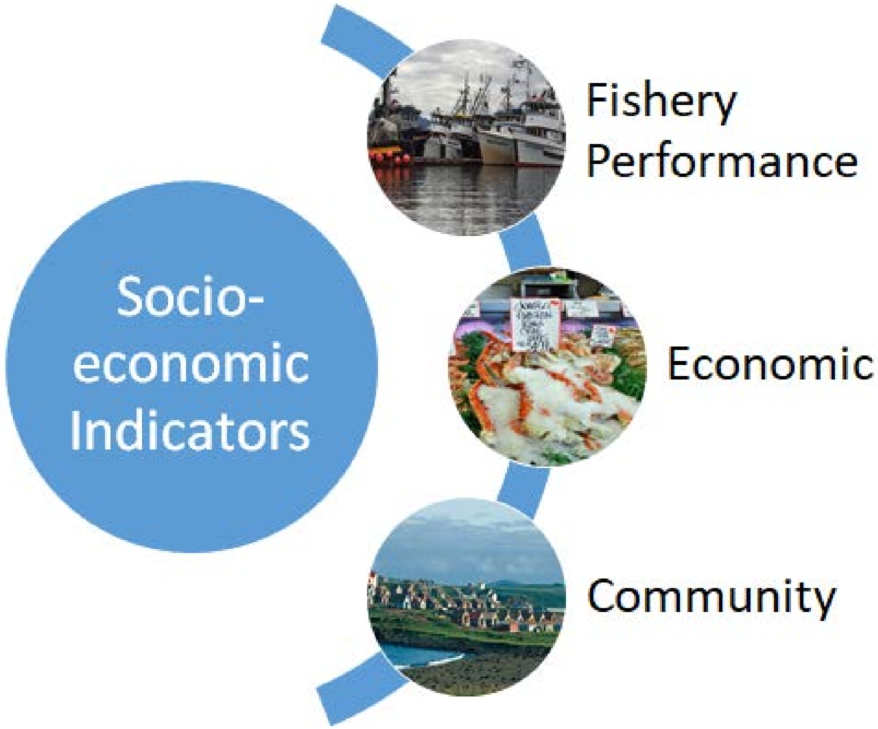


Current ecosystem indicators



- North Pacific Index
- Sea ice extent (DJF)
- Sea ice advance (MAM)
- Sea surface temperature (satellite)
- Summer bottom temperature (ROMS)
- Spring bloom peak timing (satellite)
- Euphausiids (acoustic backscatter)
- Juvenile condition, bottom trawl survey
- Adult condition, bottom trawl survey
- Center of gravity, eastings (VAST)
- Center of gravity, northings (VAST)
- Area occupied (VAST)
- Predator biomass, arrowtooth

Current socioeconomic indicators



- Ex-vessel value
- Ex-vessel price per pound
- Revenue per unit effort
- Processing regional quotient for Unalaska/Dutch Harbor
- Harvesting regional quotient for Unalaska/Dutch Harbor
- (Fishery performance is currently handled in the main text of the chapter, but may be moved to the ESP in the future)

Indicator analysis: overview

- 1st stage simple score
  - Requested by SSC for ESPs in February 2020
  - Based on value compared to 1 standard deviation from mean
  - Use +1, -1, 0 to count good/poor/stable then divide by total indicators
  - Evaluate by category and overall total
- Historical score
  - Provide a table of scores for last 20 years by category
  - Provide graphic of ecosystem and socioeconomic total

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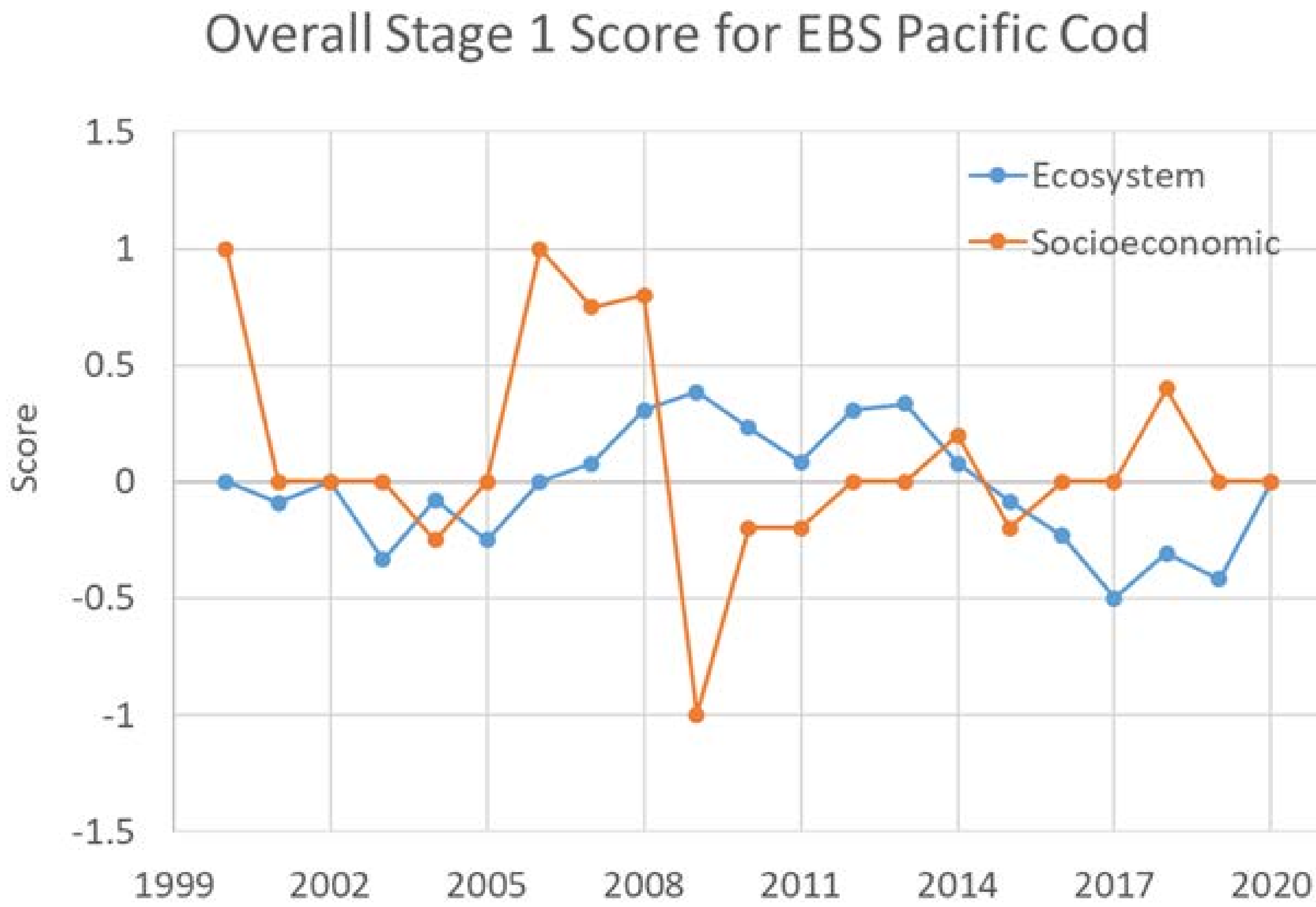
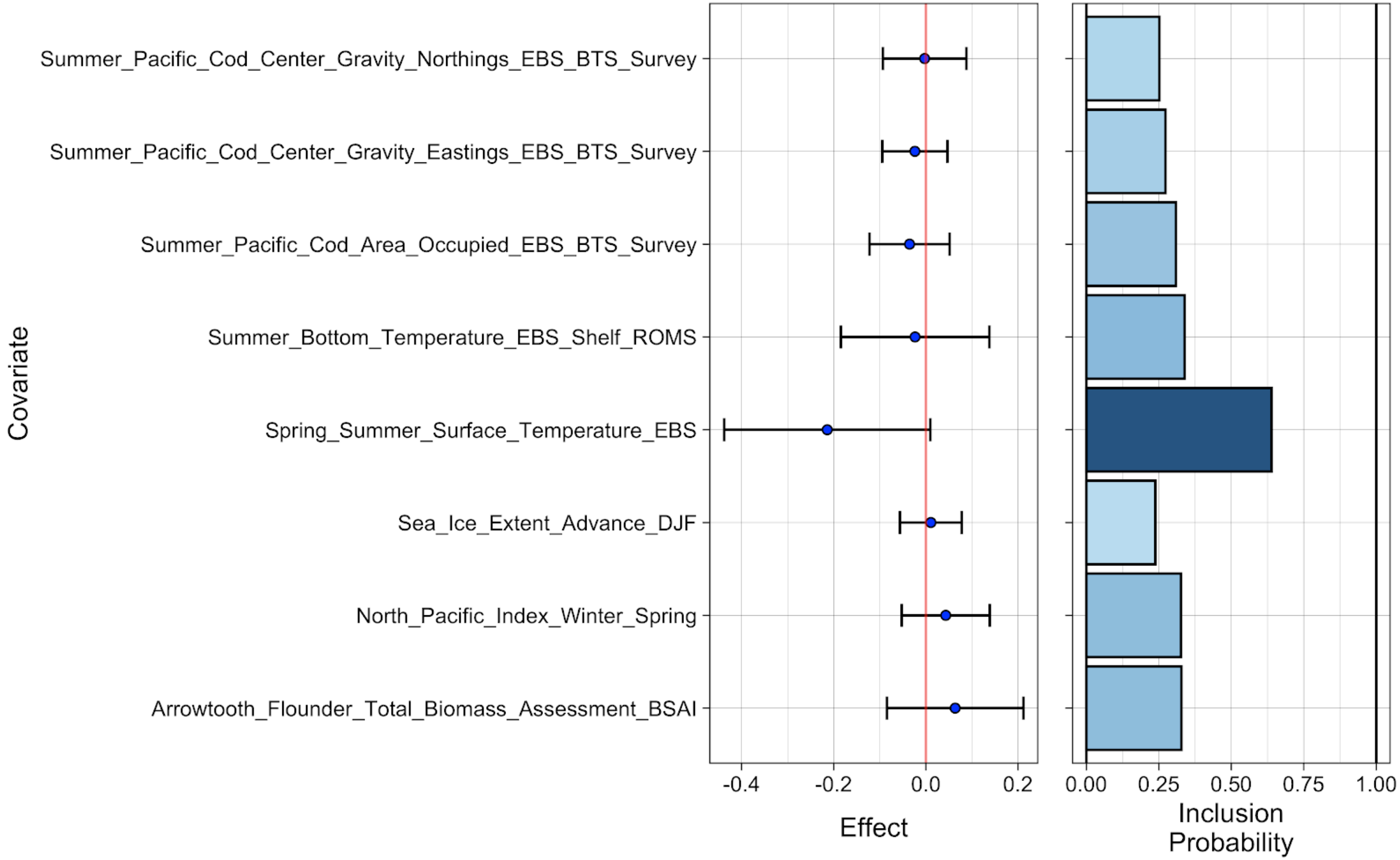
Indicator analysis: stage 1



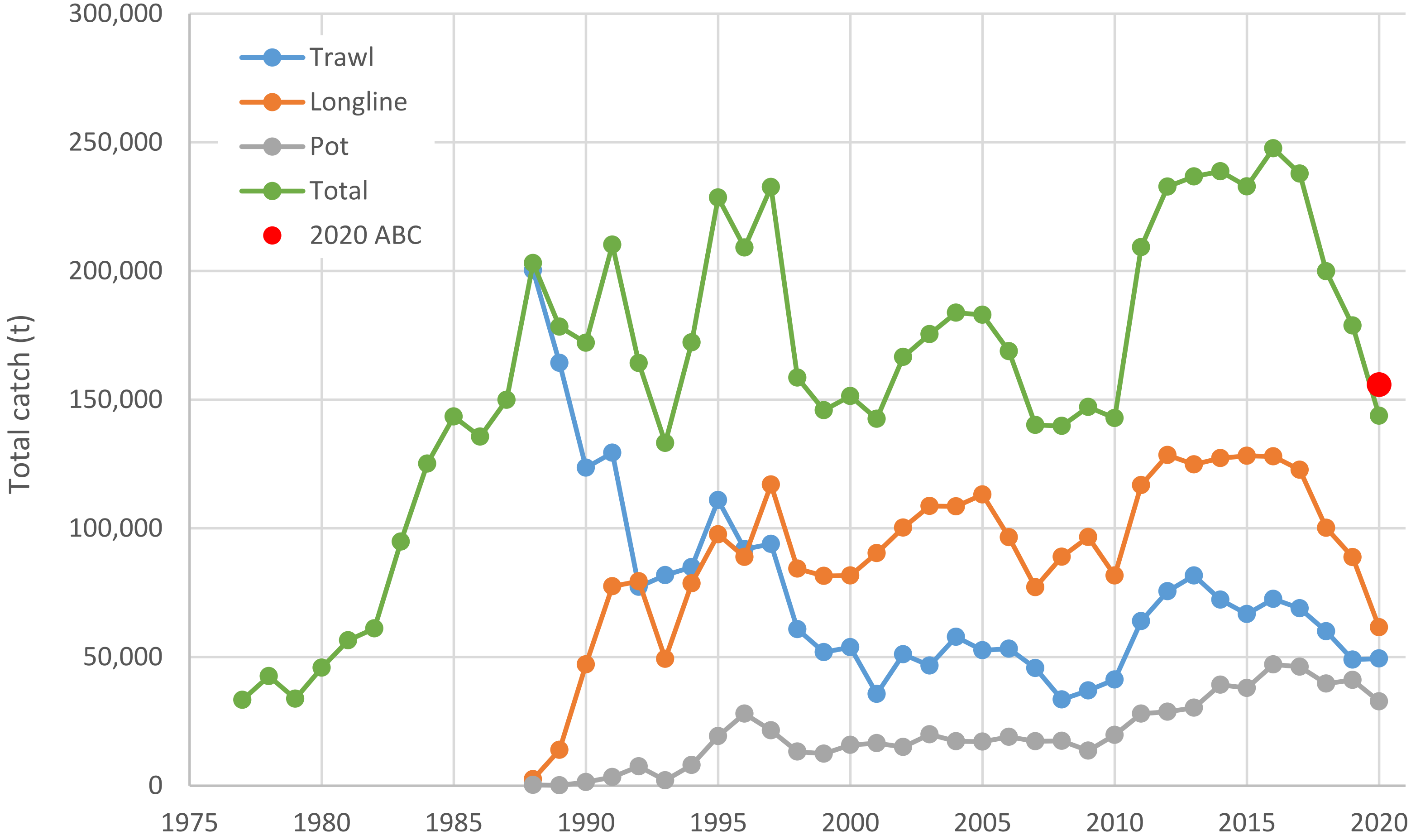
Indicator analysis: stage 2

- Results of Bayesian adaptive sampling: recruitment covariates

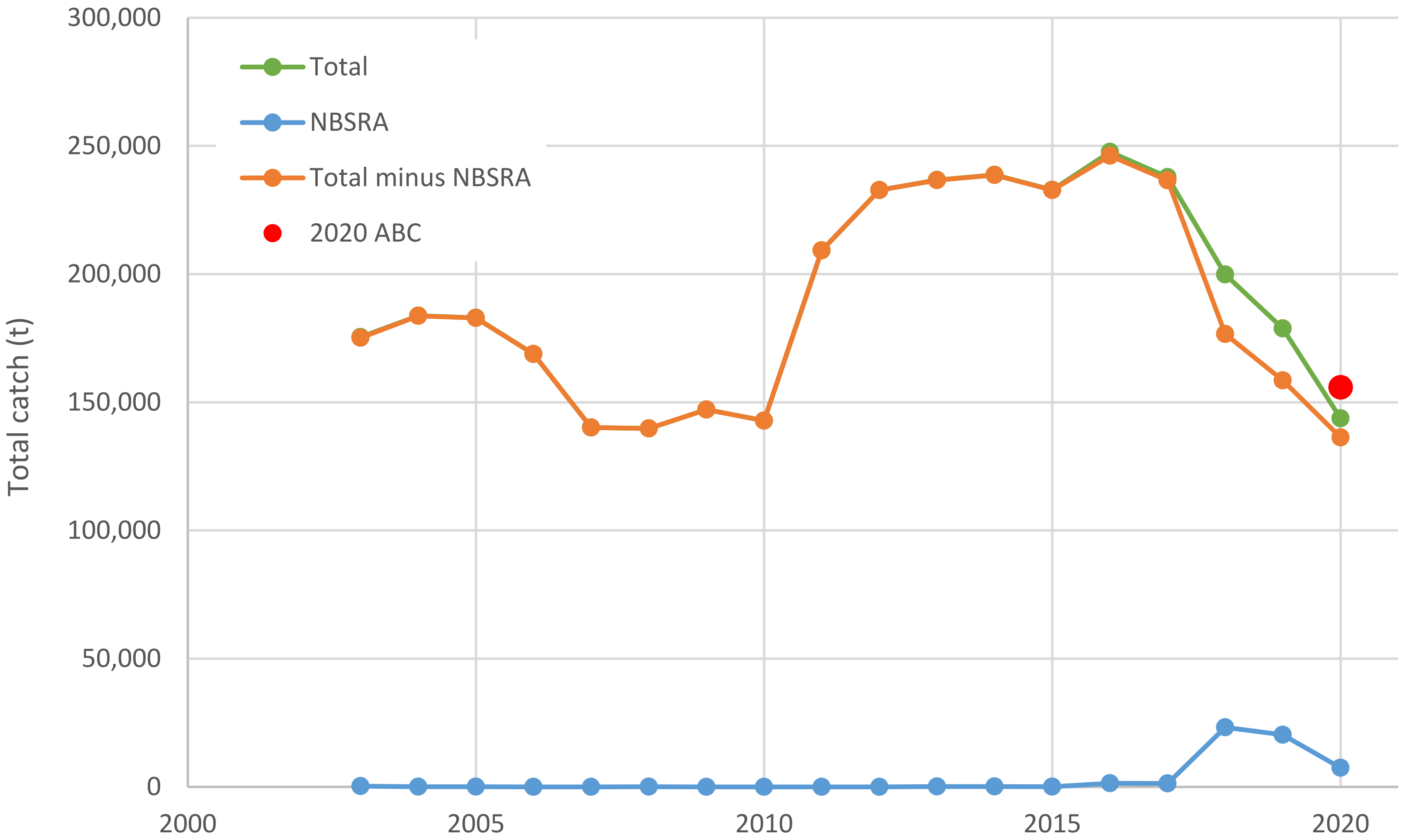


Data

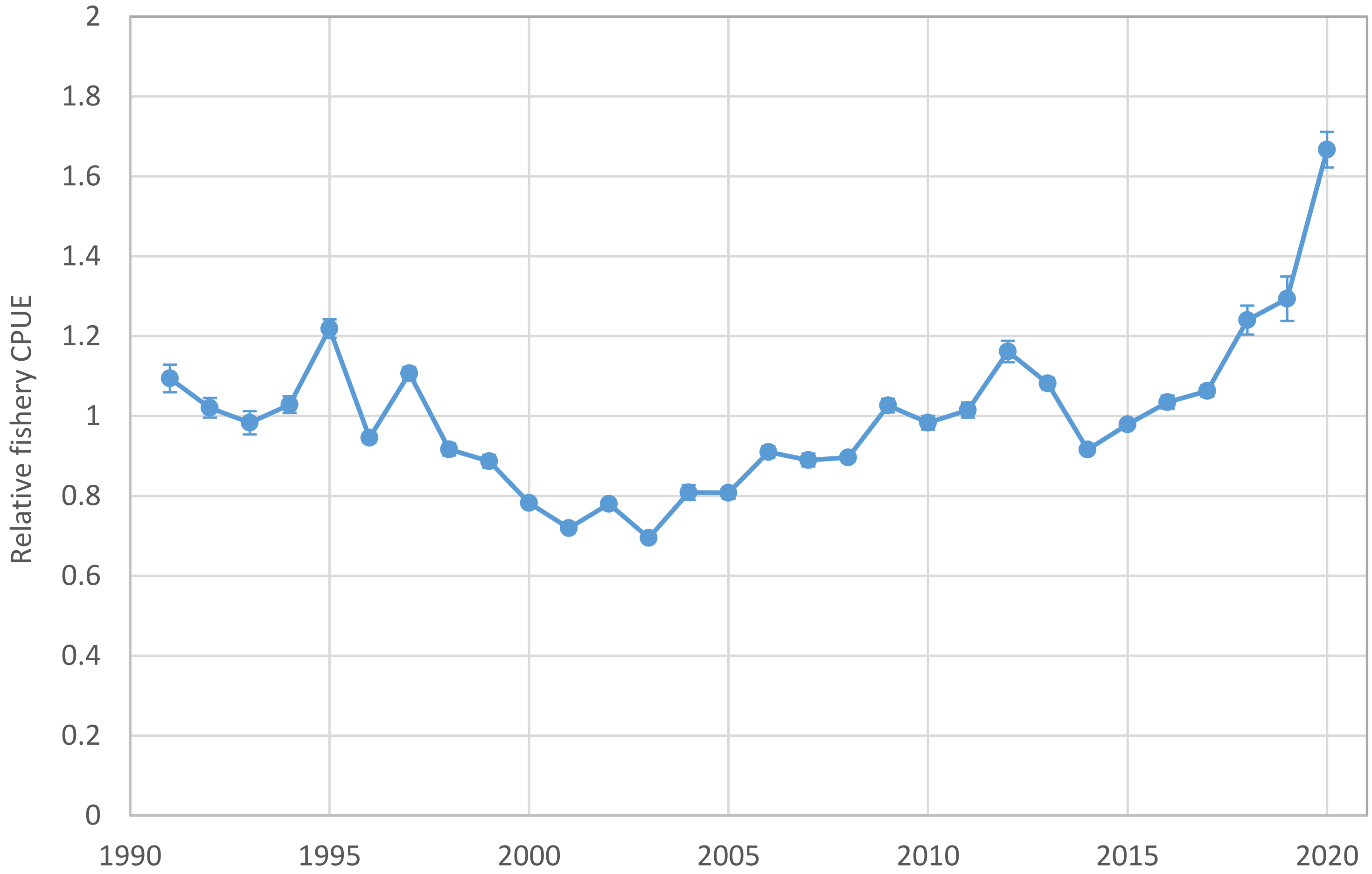
Catch time series, 1977-2020 (by gear)



Catch time series, 2003-2020 (by area)



Catch-weighted, all-gear, annual mean CPUE



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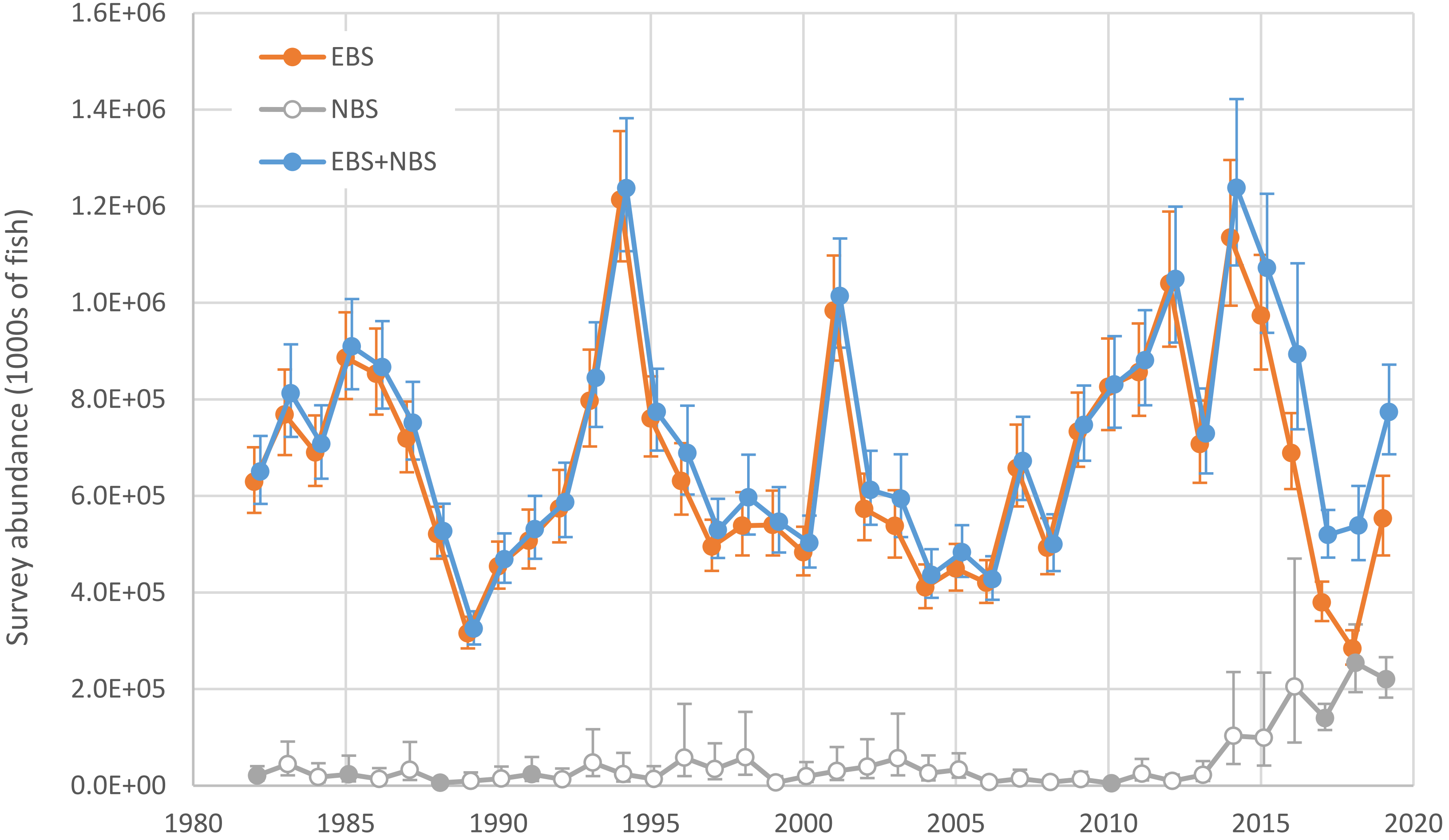
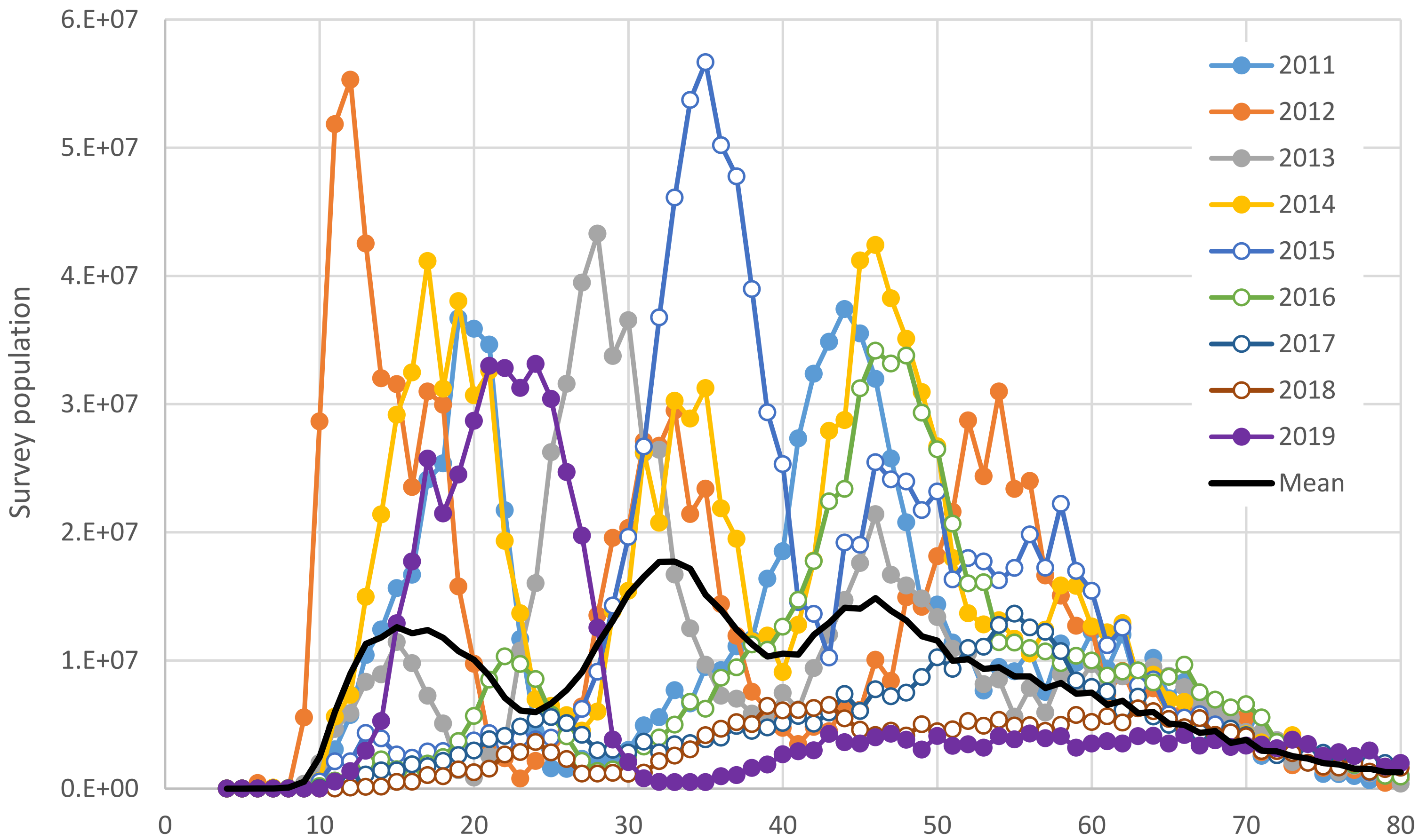
Survey abundance (VAST)



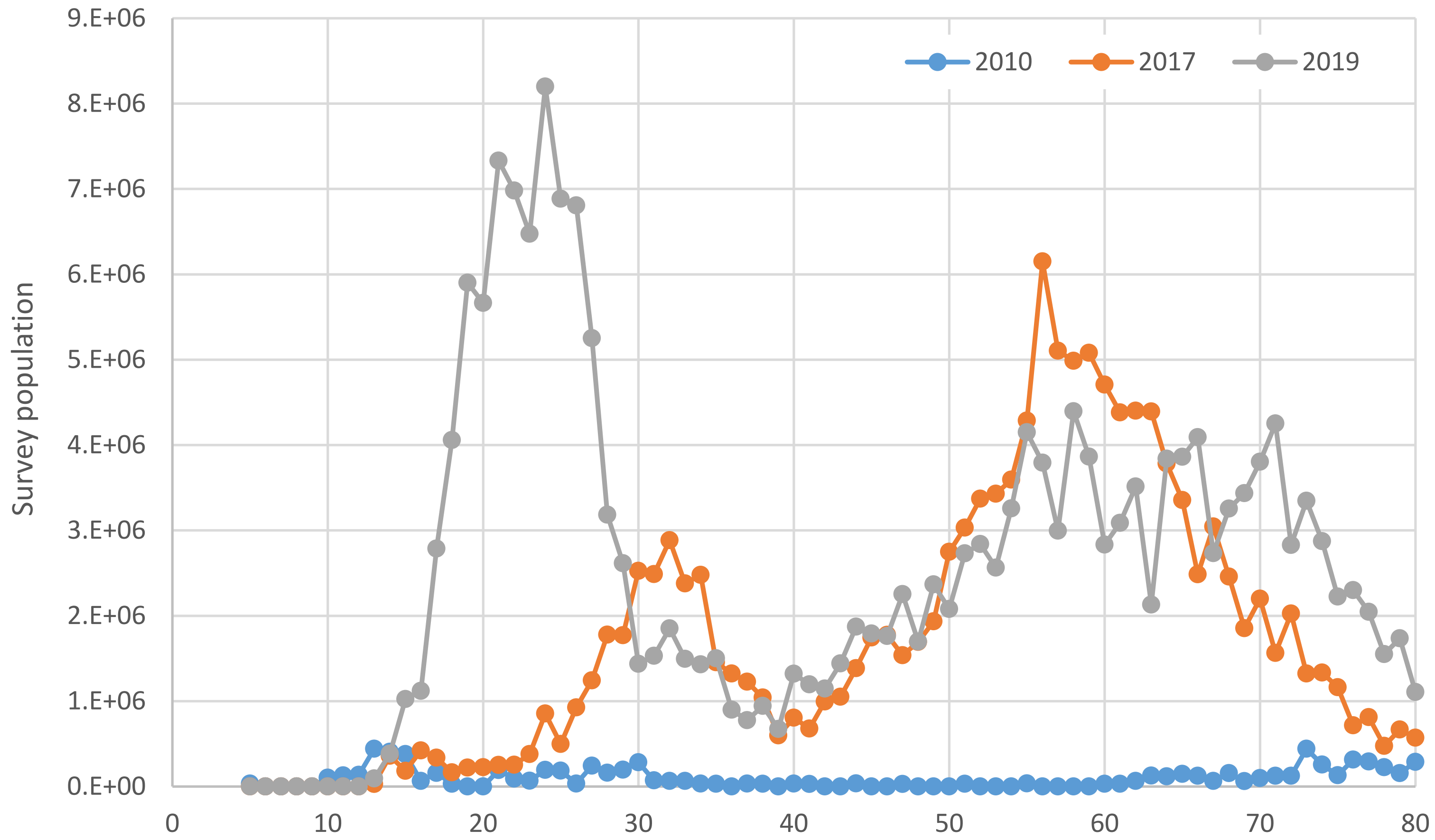
Recent survey sizecomps (EBS)

- 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

- Details were reviewed at the 12/19 and 10/20 SSC meetings; briefly:
  - Model structure is fairly simple
    - 1 sex, 1 season, 1 fishery, 1 survey (combined EBS+NBS)
  - Nearly all parameters estimated internally, including M and Q
    - Exceptions: time-invariant maturity-at-length parameters, annually varying weight-at-length parameters
  - Complexity takes the form of several time-varying parameters
    - Ageing bias estimated separately for 2 time blocks
    - Recruitment, length at age 1.5, Q, and 2 fishery and 2 survey selectivity parameters vary annually as constrained deviations
  - Sigmas for annual deviations estimated statistically
  - Input sample sizes estimated by Dirichlet-multinomial approach
    - Capped at number of sampled hauls (rescaled for fishery)

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Alternative models

- 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:
    - Two Dirichlet-multinomial parameters for the NBS survey:
  - 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 $\ln(Q)$
- Differences between 19.12 and the other Ensemble B models:
  - Models 20.8 and 20.10 include 3 additional survey selectivity parameters for the EBS+NBS survey
  - Models 20.9 and 20.10 include a base value for the fishery $\ln(Q)$, and, potentially, annual deviations for the fishery $\ln(Q)$

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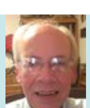
Results

Goodness of fit: abundance indices (1 of 2)

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

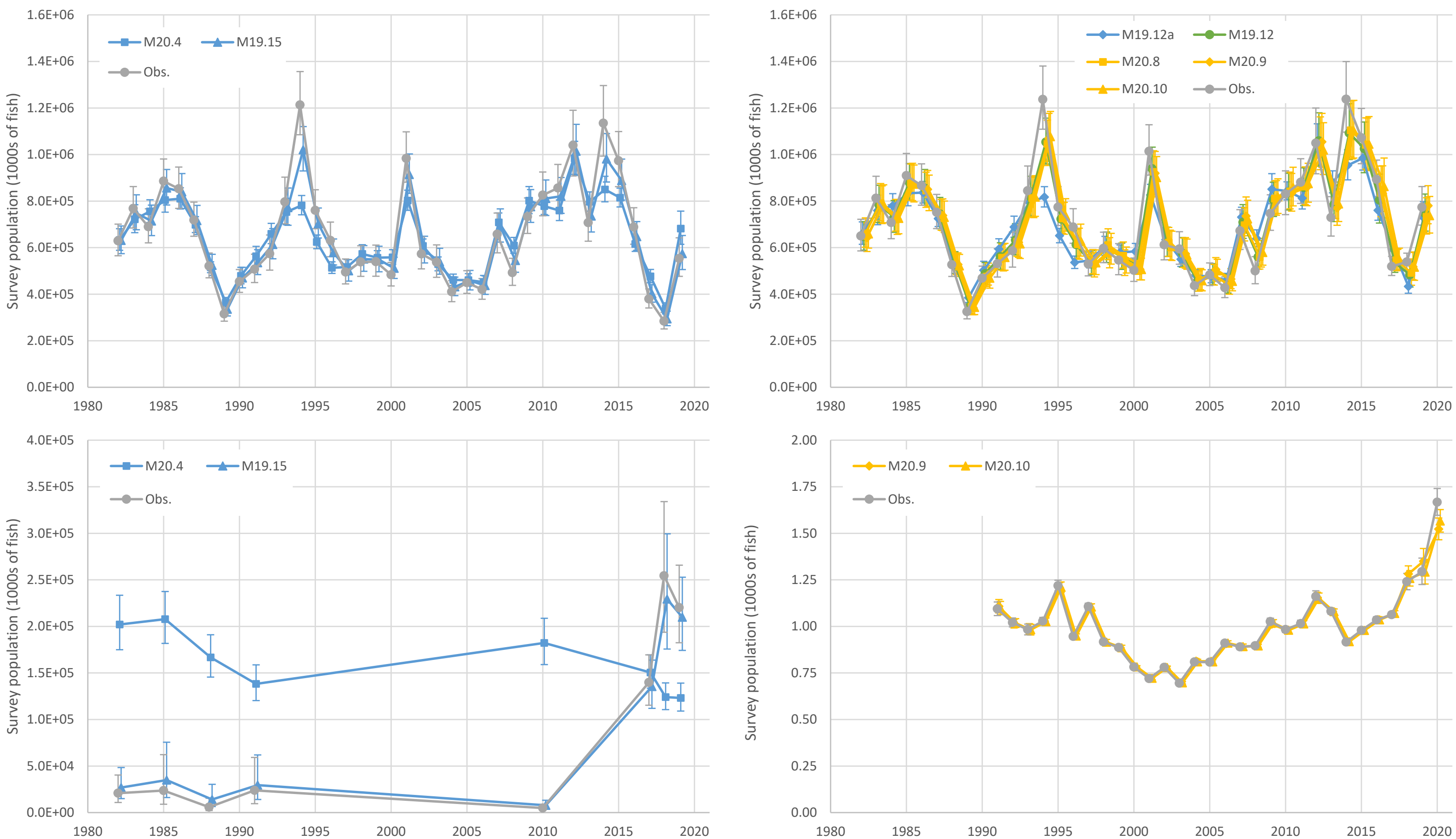
Index:	EBS		NBS	
Model:	M20.4	M19.15	M20.4	M19.15
RMSSR:	2.448	1.001	6.516	1.000

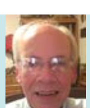
Index:	EBS+NBS					Fishery	
Model:	M19.12a	M19.12	M20.8	M20.9	M20.10	M20.9	M20.10
RMSSR:	2.319	0.999	1.000	0.999	1.000	0.992	0.659



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

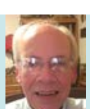
- Size composition

	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

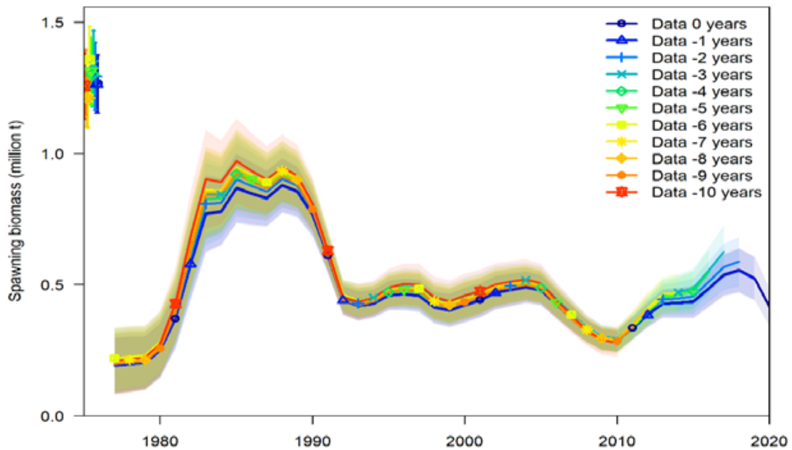
- Age composition

	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

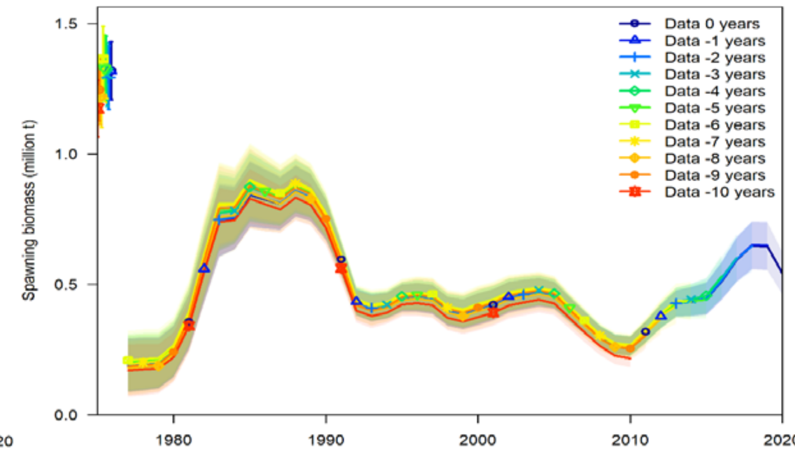


Retrospective analysis: Ensemble A models

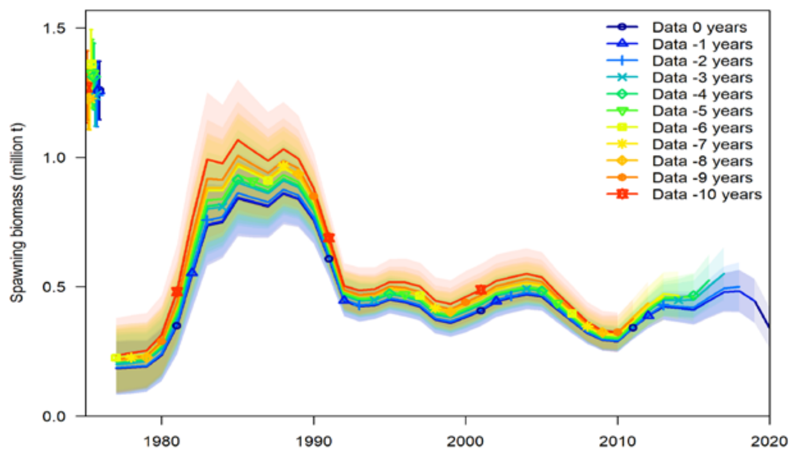
Model 20.4 (ρ = 0.0601)



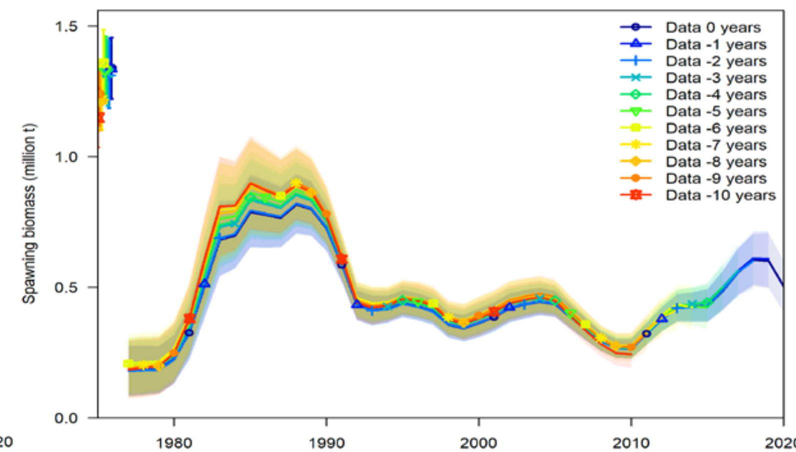
Model 19.12a (ρ = -0.0211)



Model 19.15 (ρ = 0.1046)



Model 19.12 (ρ = -0.0028)



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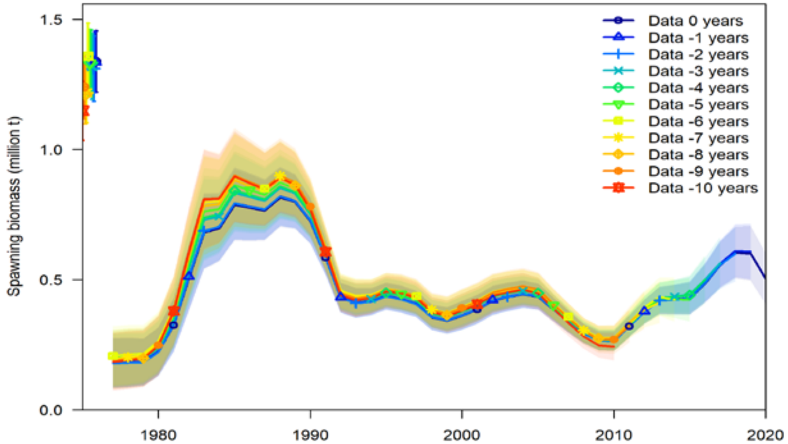
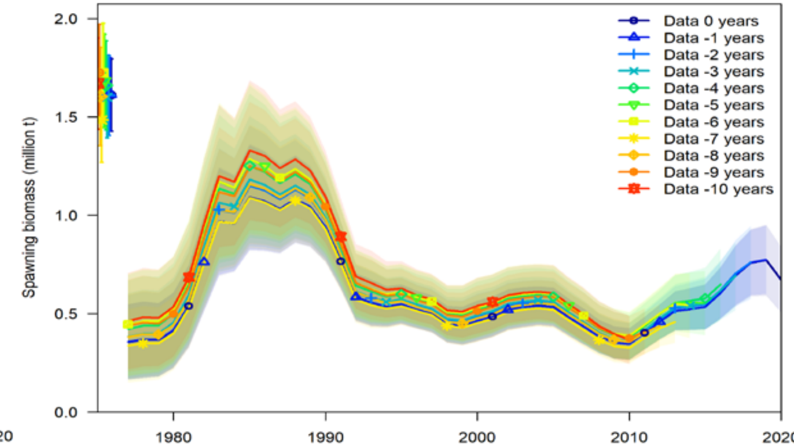
Retrospective analysis: Ensemble B models

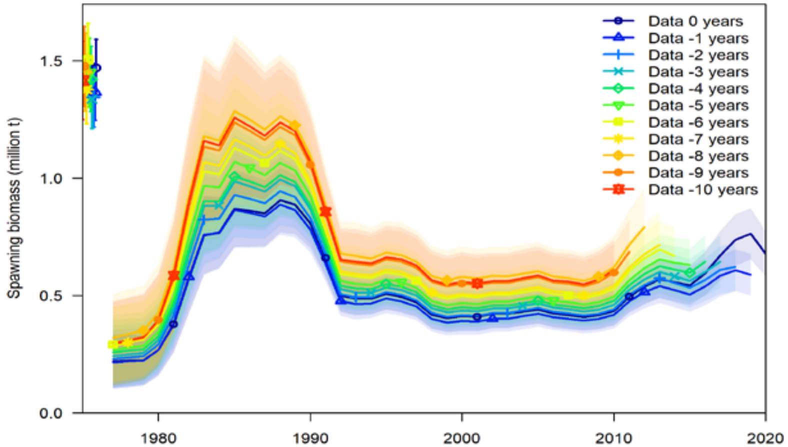
Model 19.12 (ρ = -0.0028)



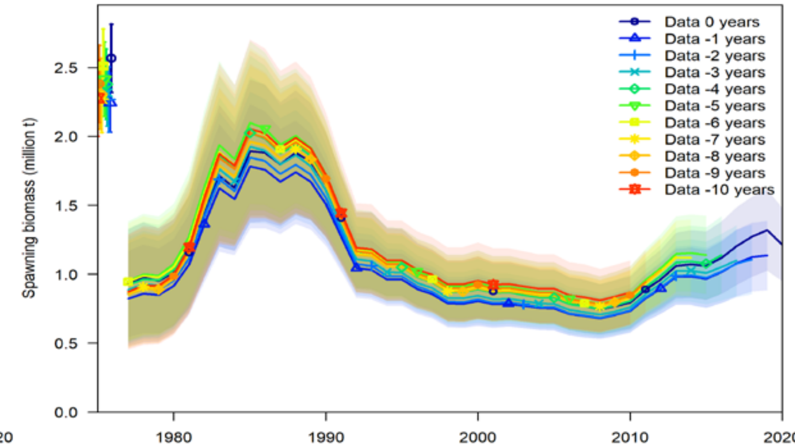
Model 20.8 (ρ = 0.0076)



Model 20.9 (ρ = 0.1533)



Model 20.10 (ρ = 0.0071)



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

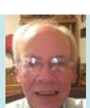
Evaluating the models w.r.t. criteria 1-3

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



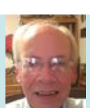
Evaluating the models w.r.t. criteria 4-9

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 $0.99 < \text{RMSSR} < 1.01$ 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

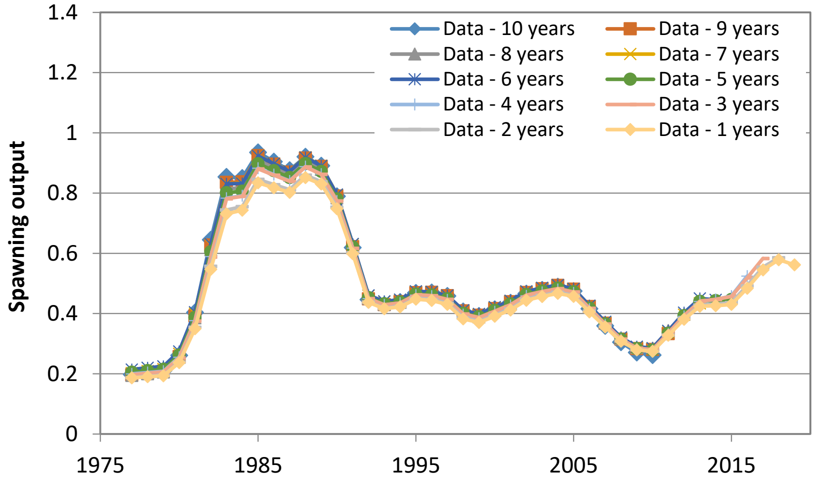
- Separate sets of weights computed for Ensemble A and Ensemble AB

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

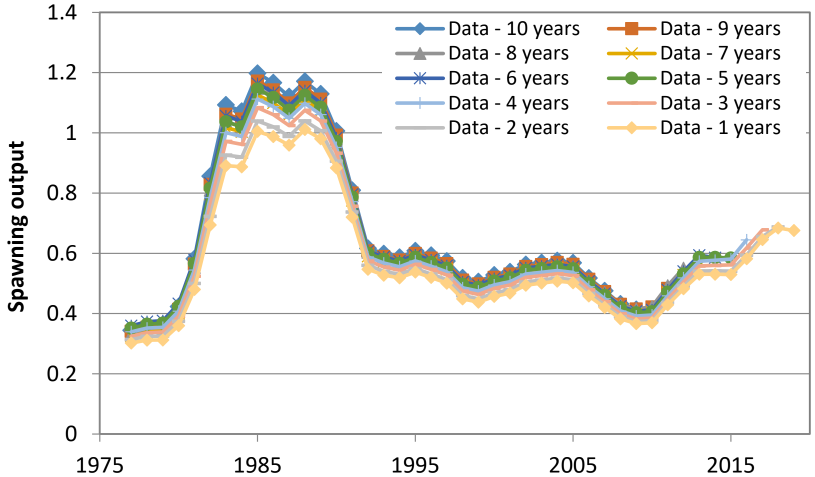


Retrospective analysis: ensemble averages

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

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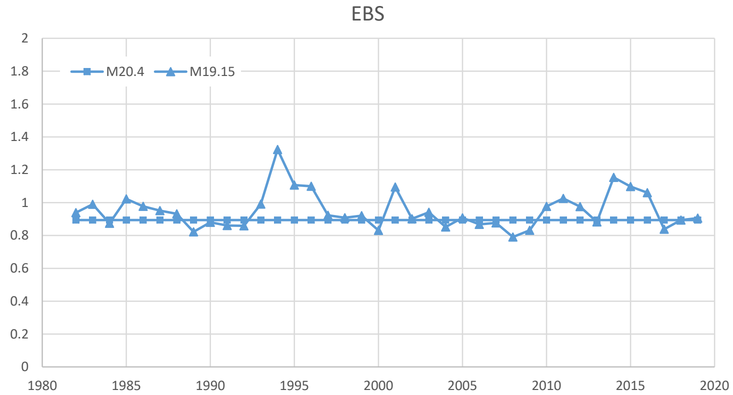
Sigmas for annual deviations (except ln(Q))

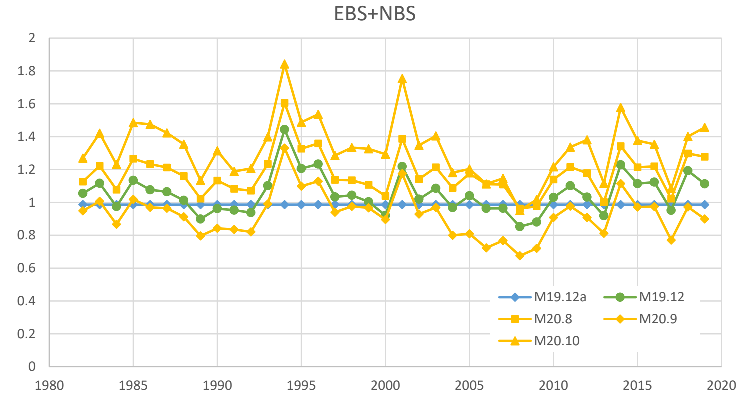
A1: Allow Q to vary?	no						yes					
A2: Combine surveys?	no			yes			no			yes		
	Model 20.4			Model 19.12a			Model 19.15			Model 19.12		
Parameter	var_dev	ave_var	sigma	var_dev	ave_var	sigma	var_dev	ave_var	sigma	var_dev	ave_var	sigma
ln(Recruits)	0.4498	0.0119	0.6827	0.4628	0.0126	0.6896	0.4408	0.0124	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

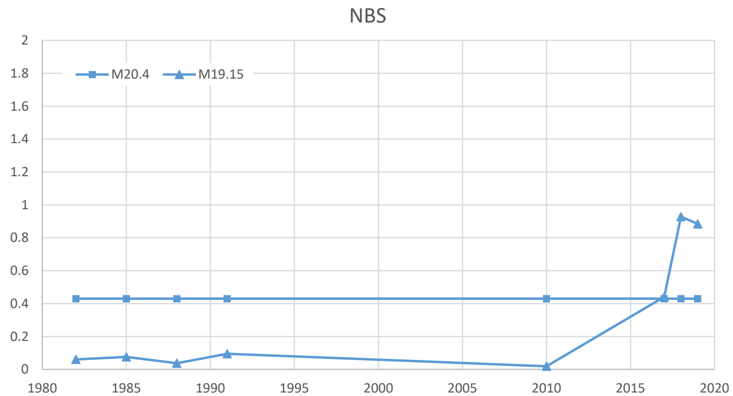
B1: Use fishery CPUE?	no						yes					
B2: Allow domed selex?	no			yes			no			yes		
	Model 19.12			Model 20.8			Model 20.9			Model 20.10		
Parameter	var_dev	ave_var	sigma	var_dev	ave_var	sigma	var_dev	ave_var	sigma	var_dev	ave_var	sigma
ln(Recruits)	(see above)			0.4470	0.0135	0.6787	0.4320	0.0142	0.6678	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

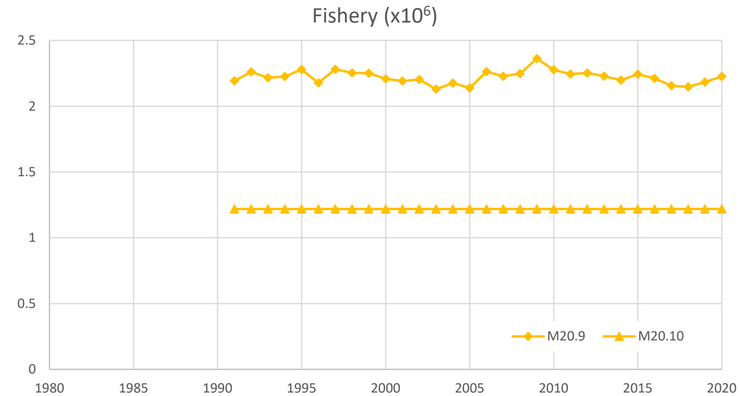
Sigmas for $\ln(Q)$ and back-transformed values

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



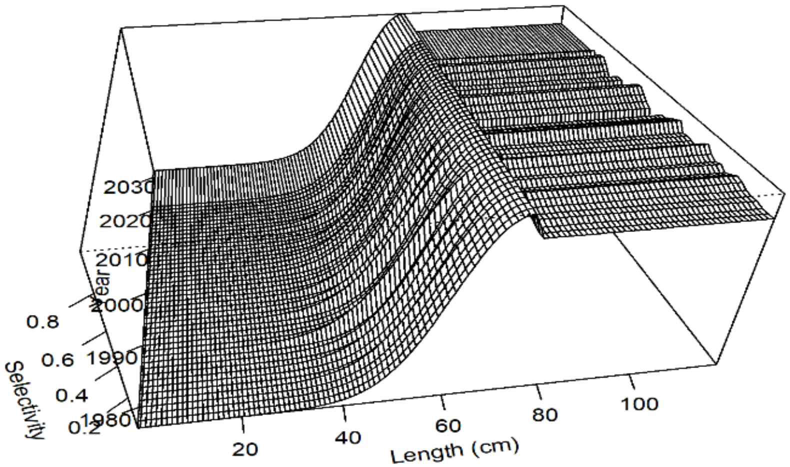




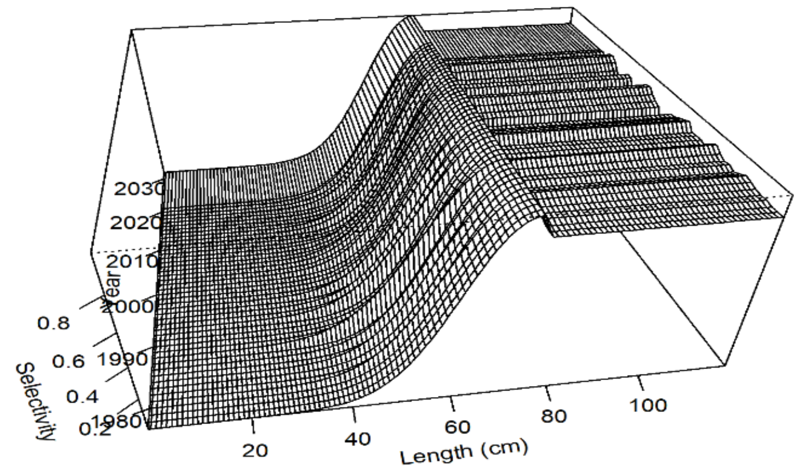


Fishery selectivity: Ensemble A models

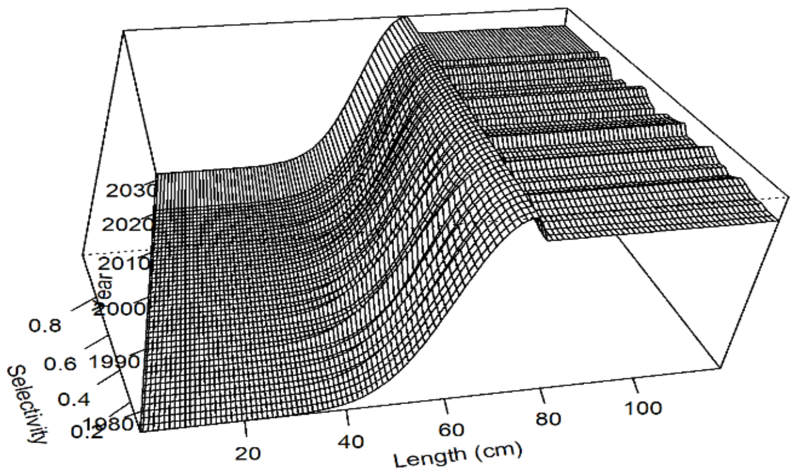
Model 20.4



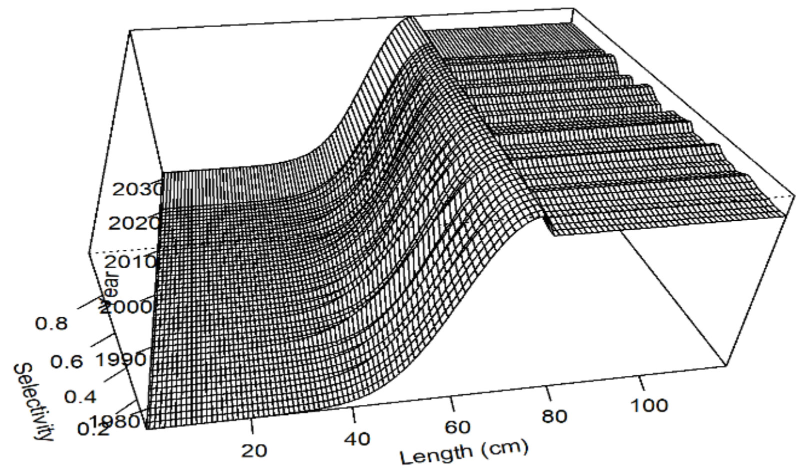
Model 19.12a



Model 19.15

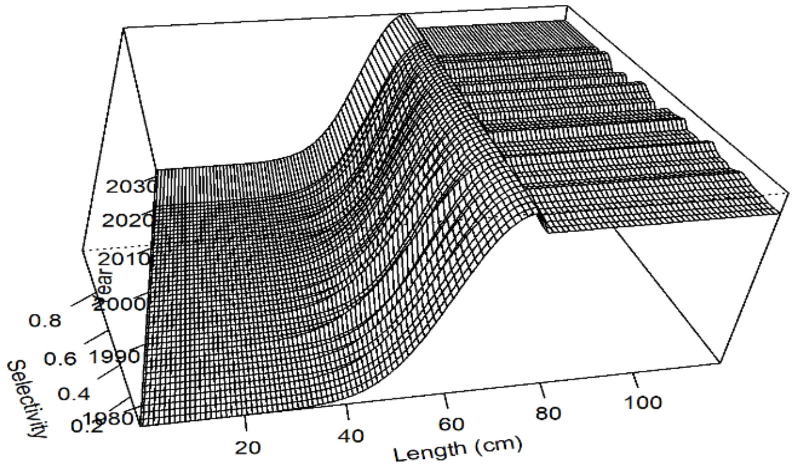


Model 19.12

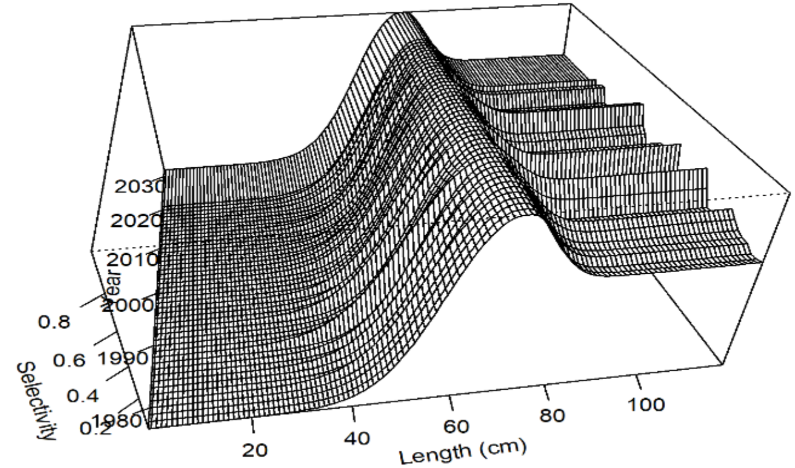


Fishery selectivity: Ensemble B models

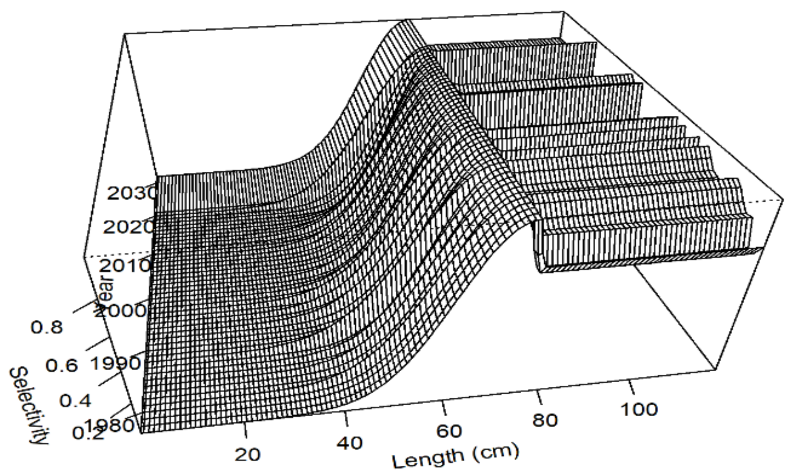
Model 19.12



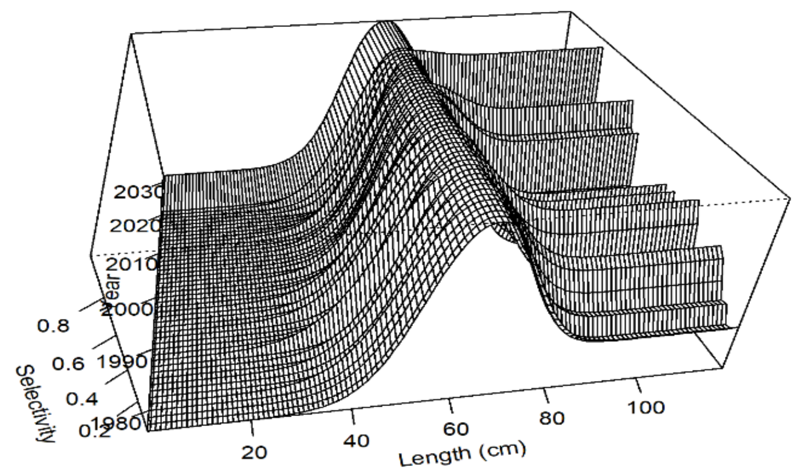
Model 20.8



Model 20.9

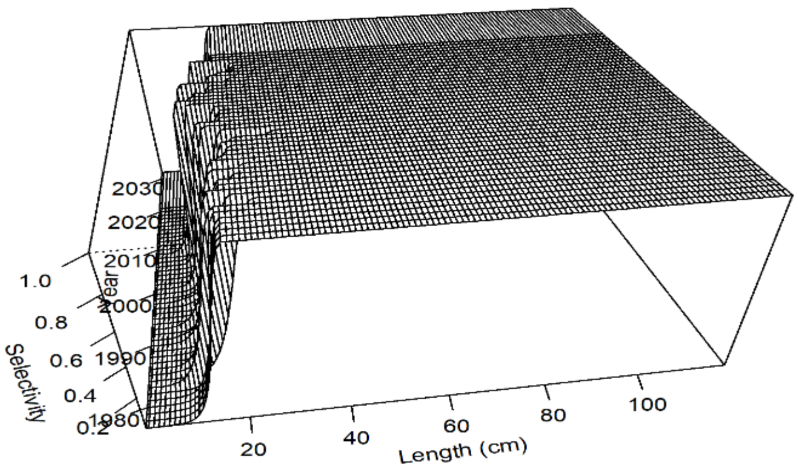


Model 20.10

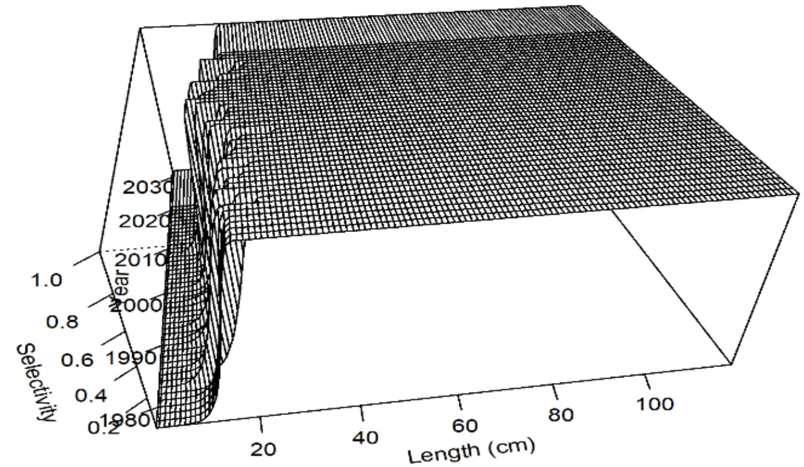


“Main” survey selectivity: Ensemble A

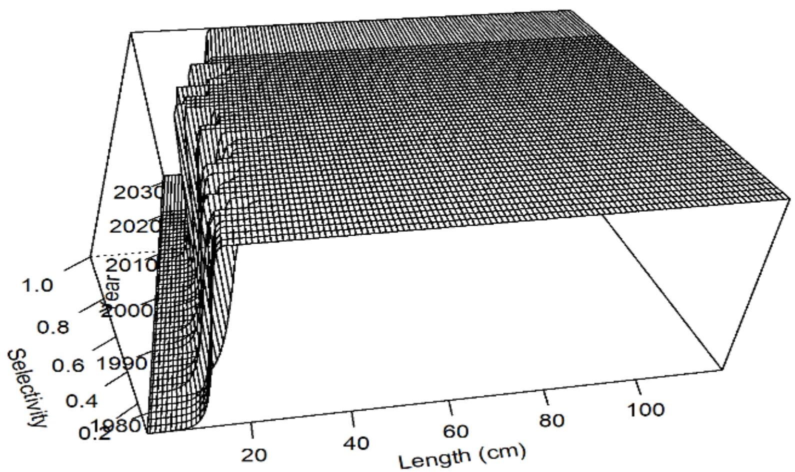
Model 20.4 (EBS only)



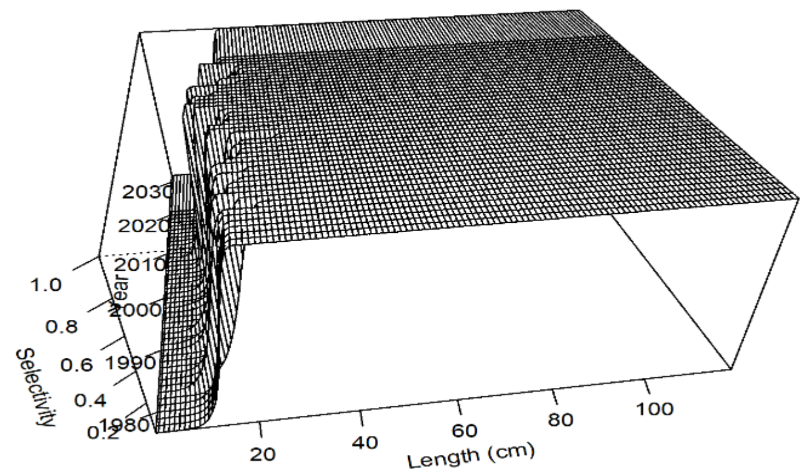
Model 19.12a (EBS+NBS)



Model 19.15 (EBS only)

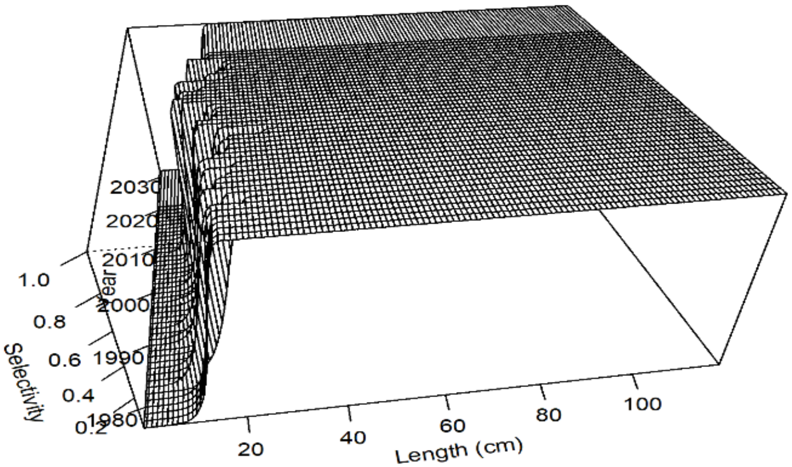


Model 19.12 (EBS+NBS)

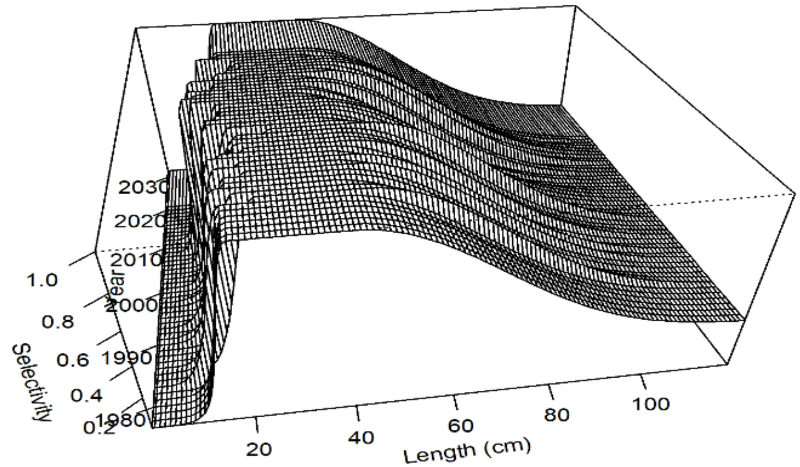


“Main” selectivity: Ensemble B

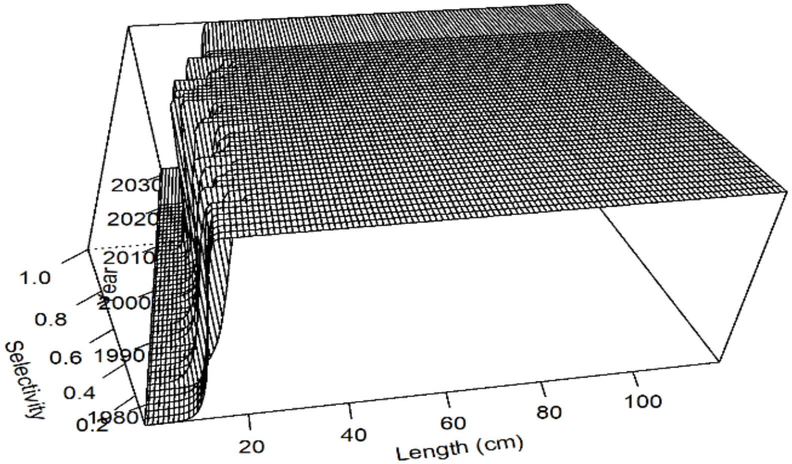
Model 19.12 (EBS+NBS)



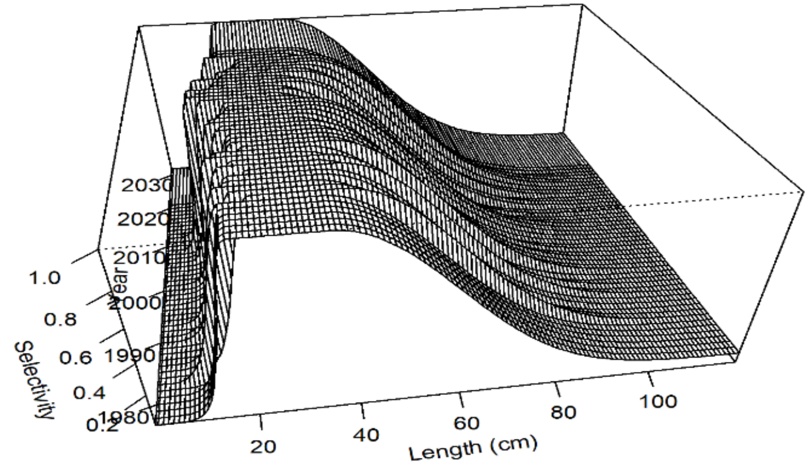
Model 20.8 (EBS+NBS)



Model 20.9 (EBS+NBS)

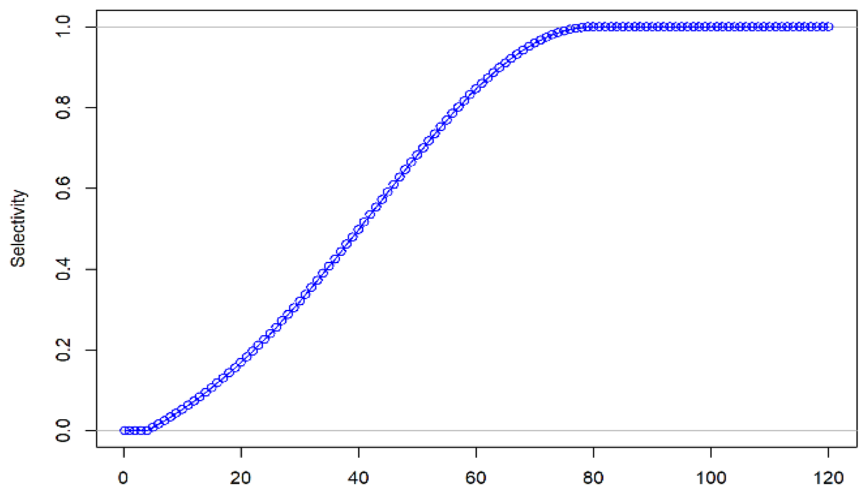


Model 20.10 (EBS+NBS)

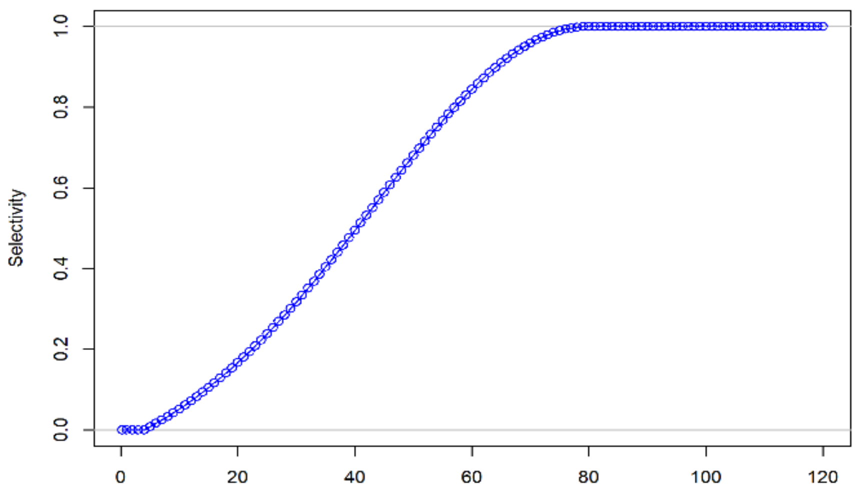


NBS survey selectivity: Models 20.4 and 19.15

Model 20.4

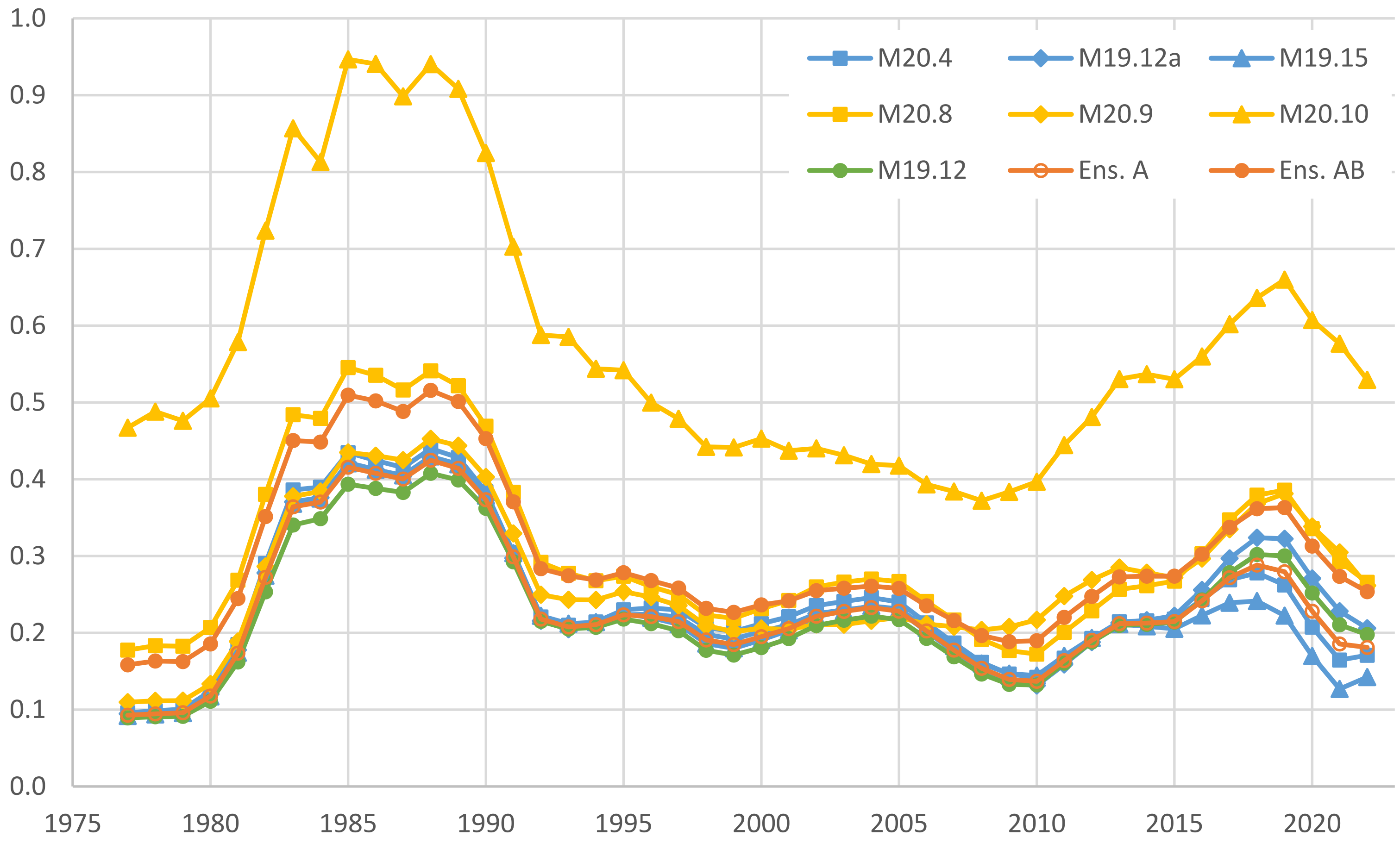


Model 19.15



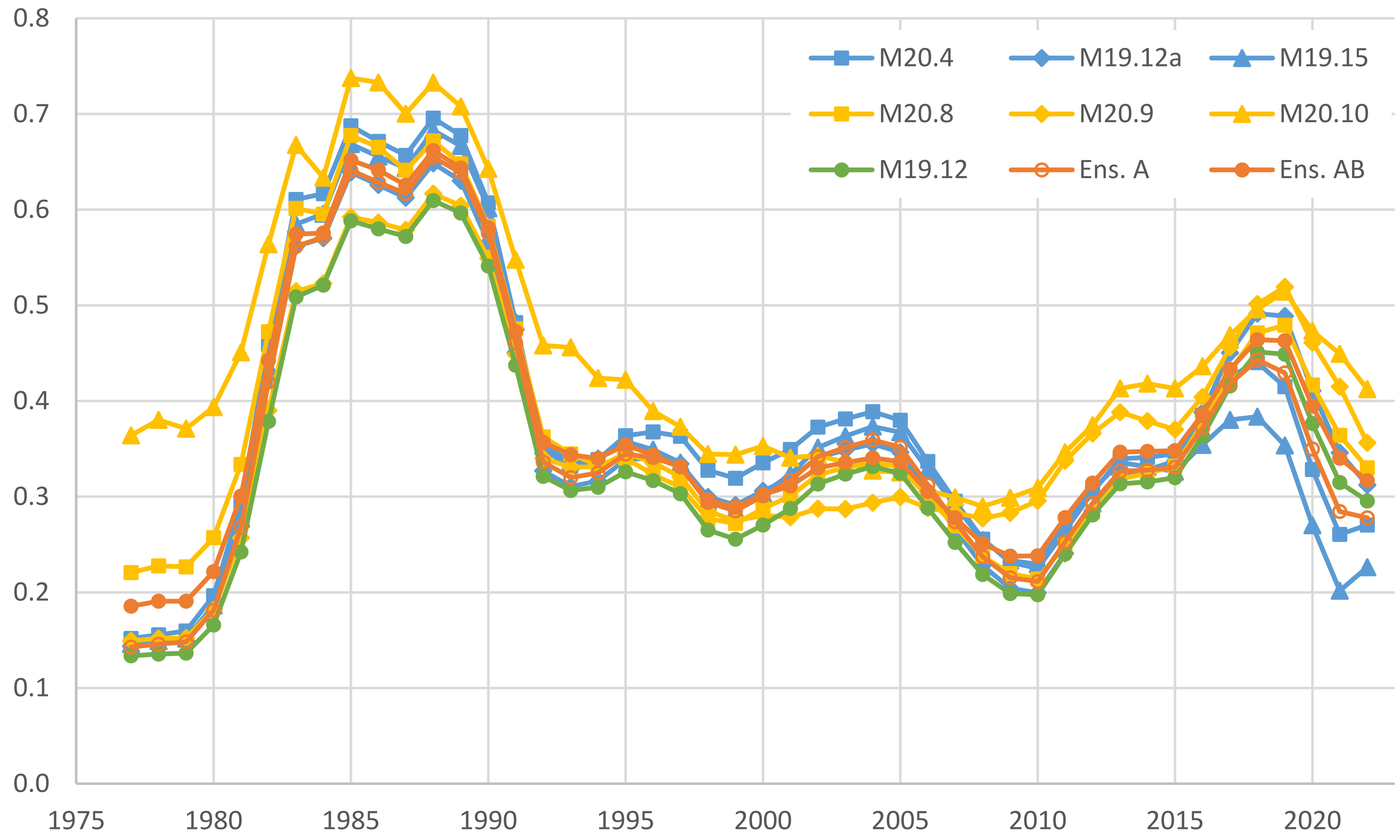
Time series: female spawning biomass

- Values are in millions of t



Time series: relative spawning biomass

- Relative to $B_{100\%}$



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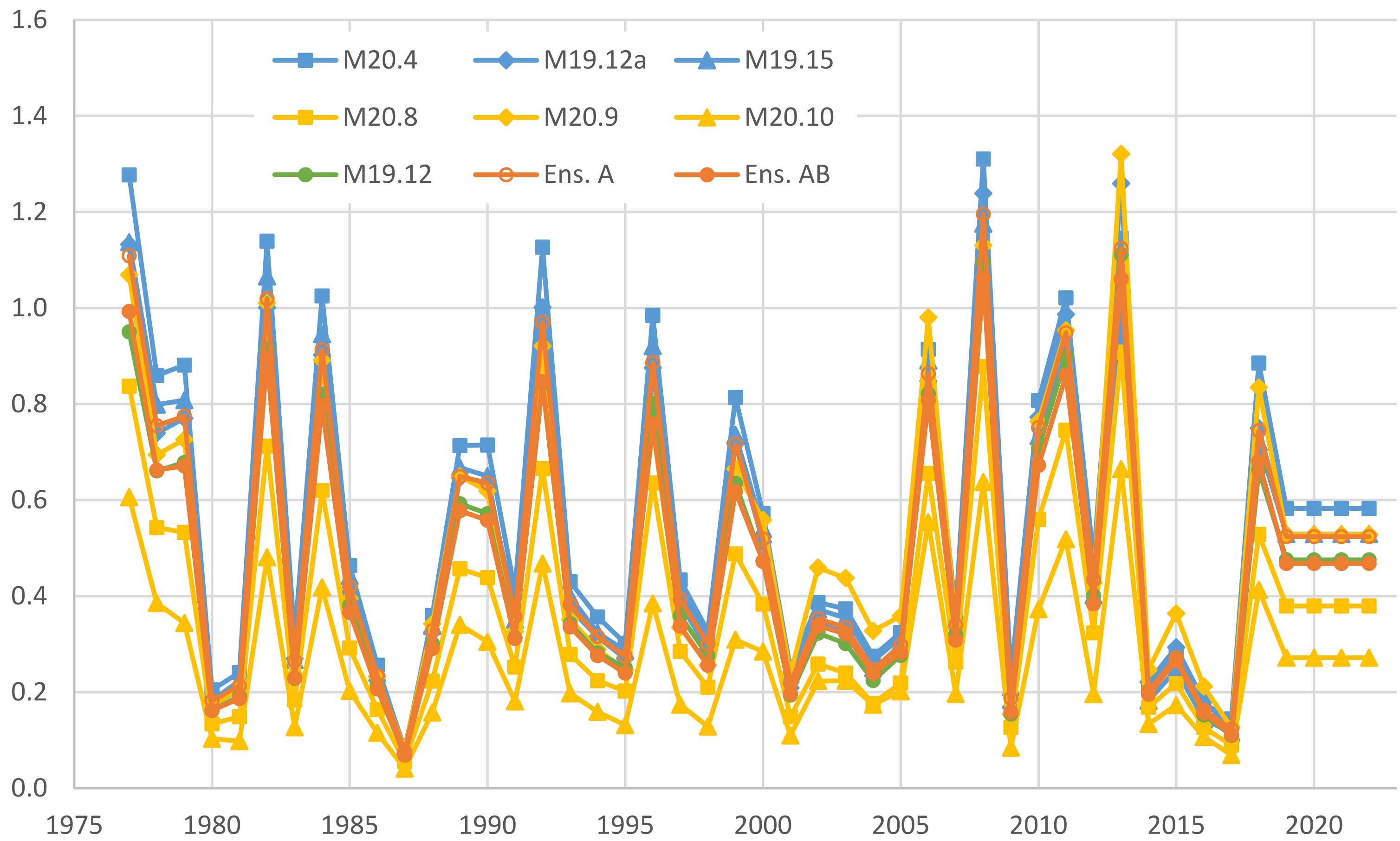
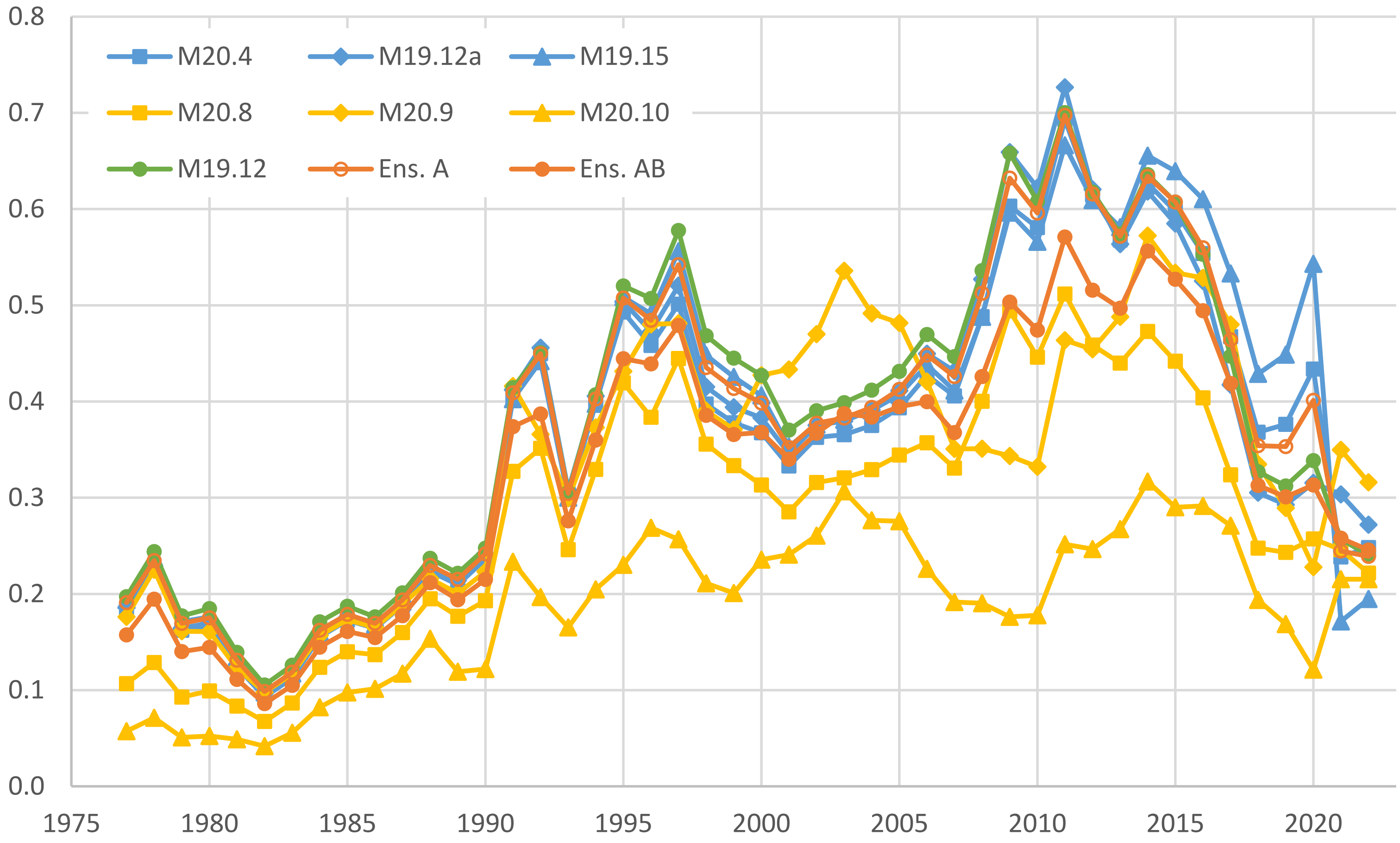
Time series: age 0 recruitment

- Values are in billions of fish

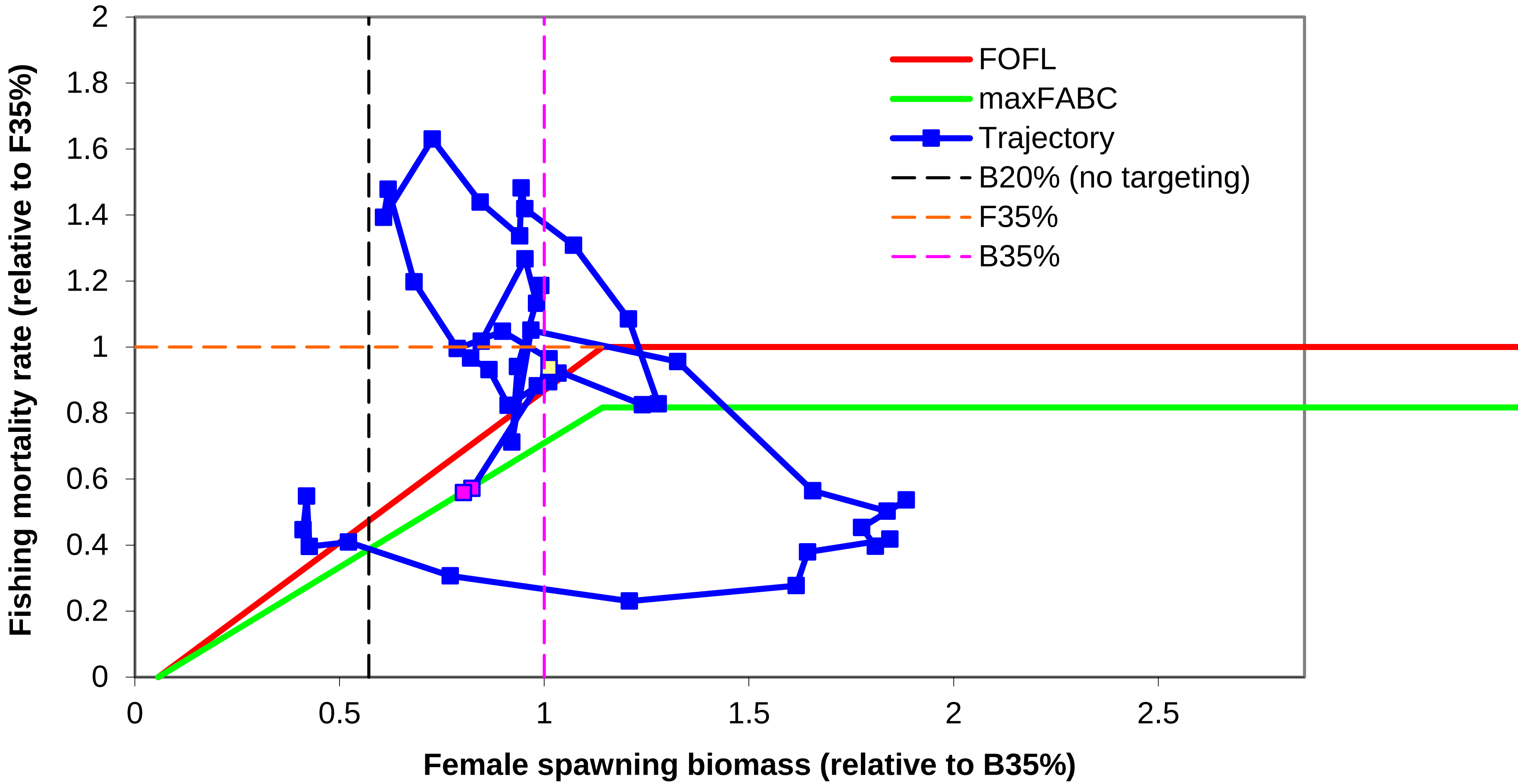


Time series: fishing mortality

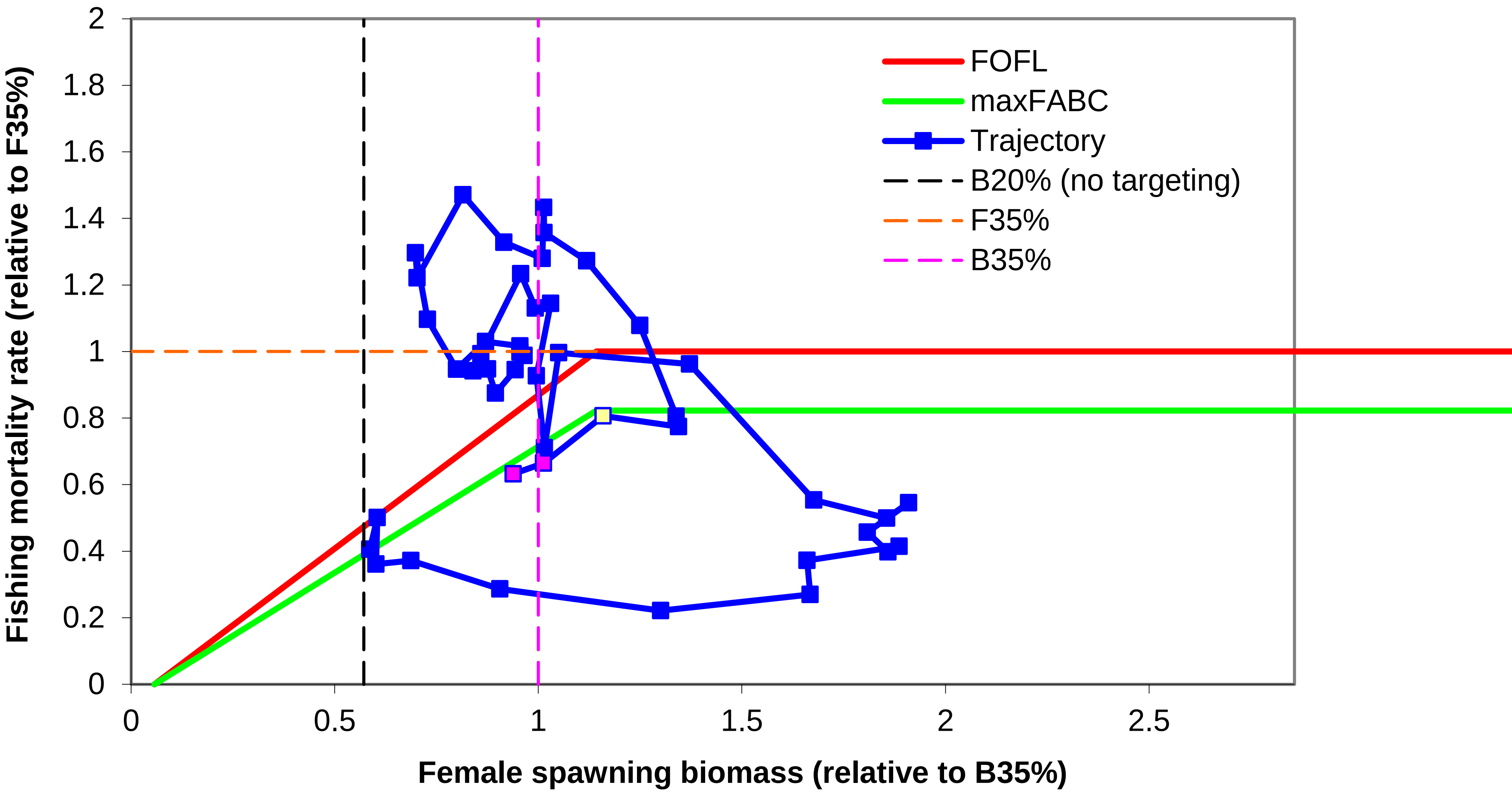
- Instantaneous full-selection fishing mortality rate



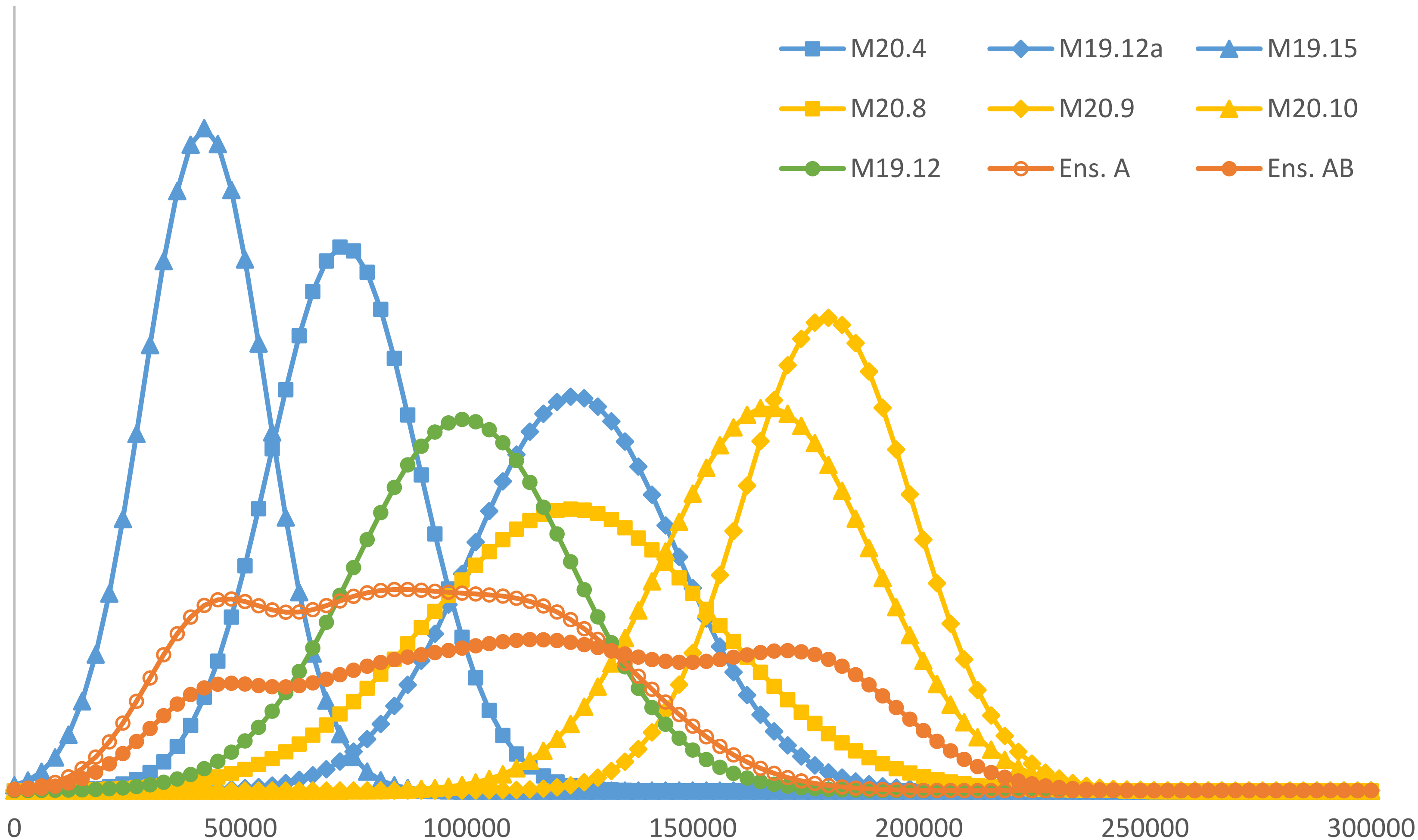
Phase plane: Ensemble A



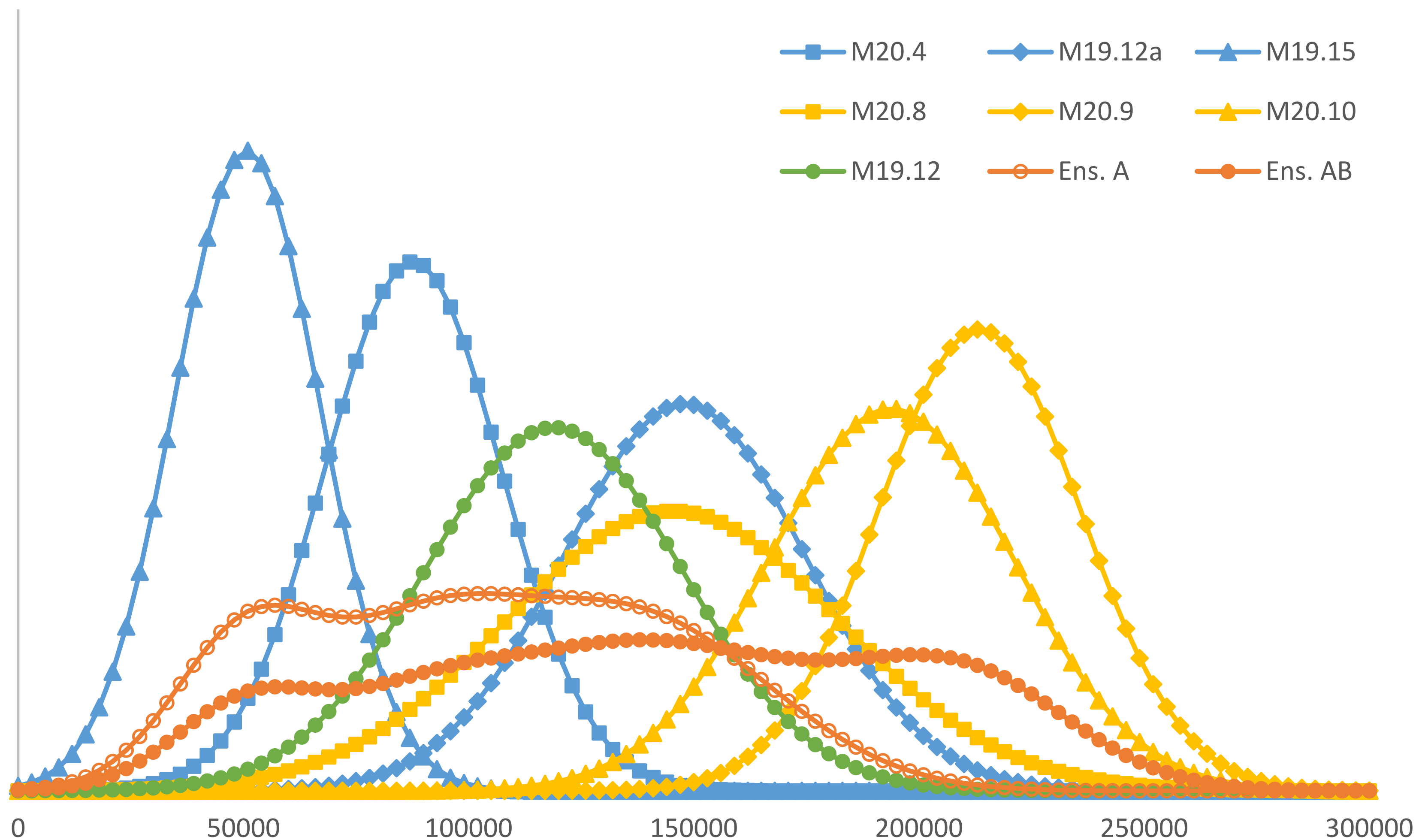
Phase plane: Ensemble AB



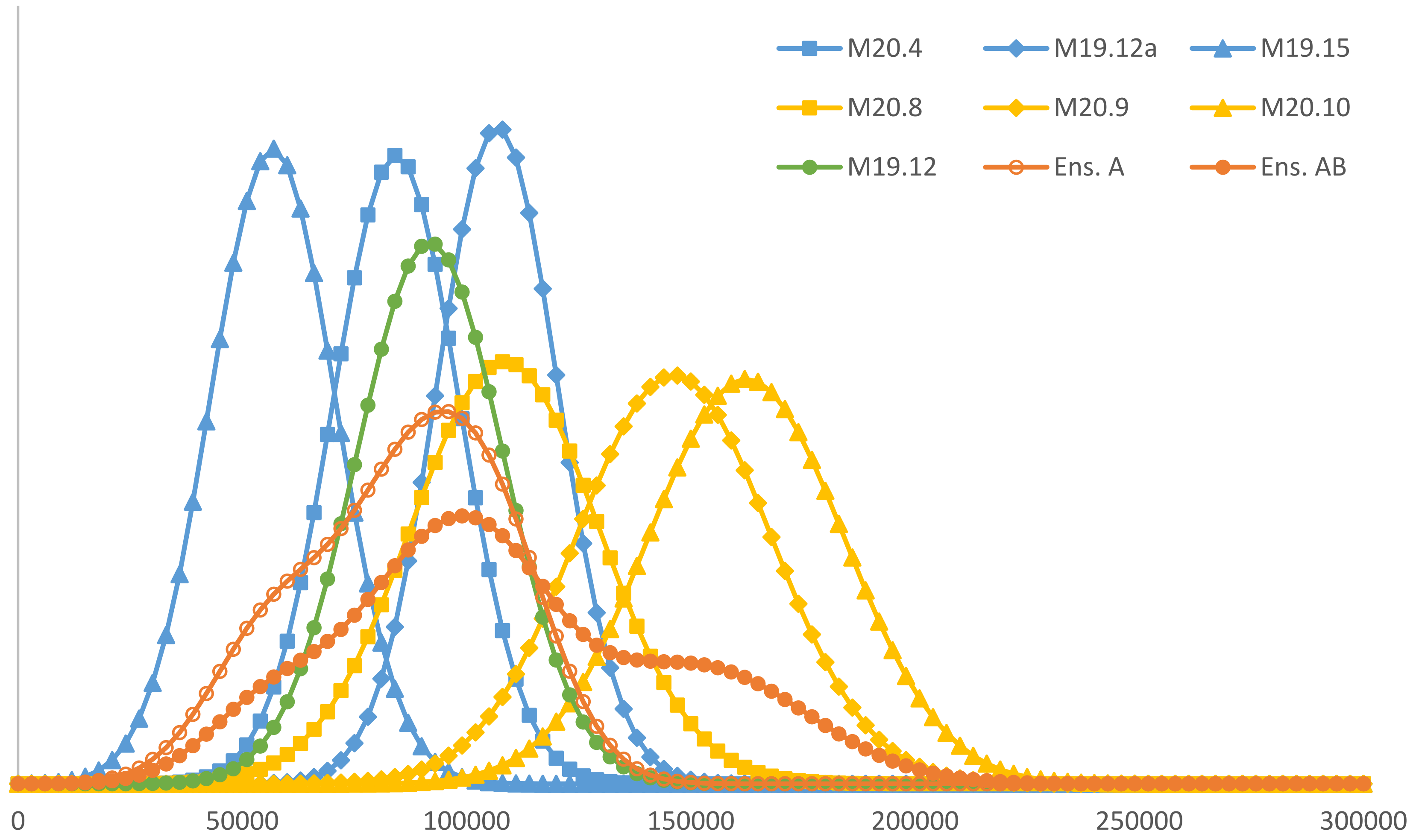
Probability densities: 2021 ABC



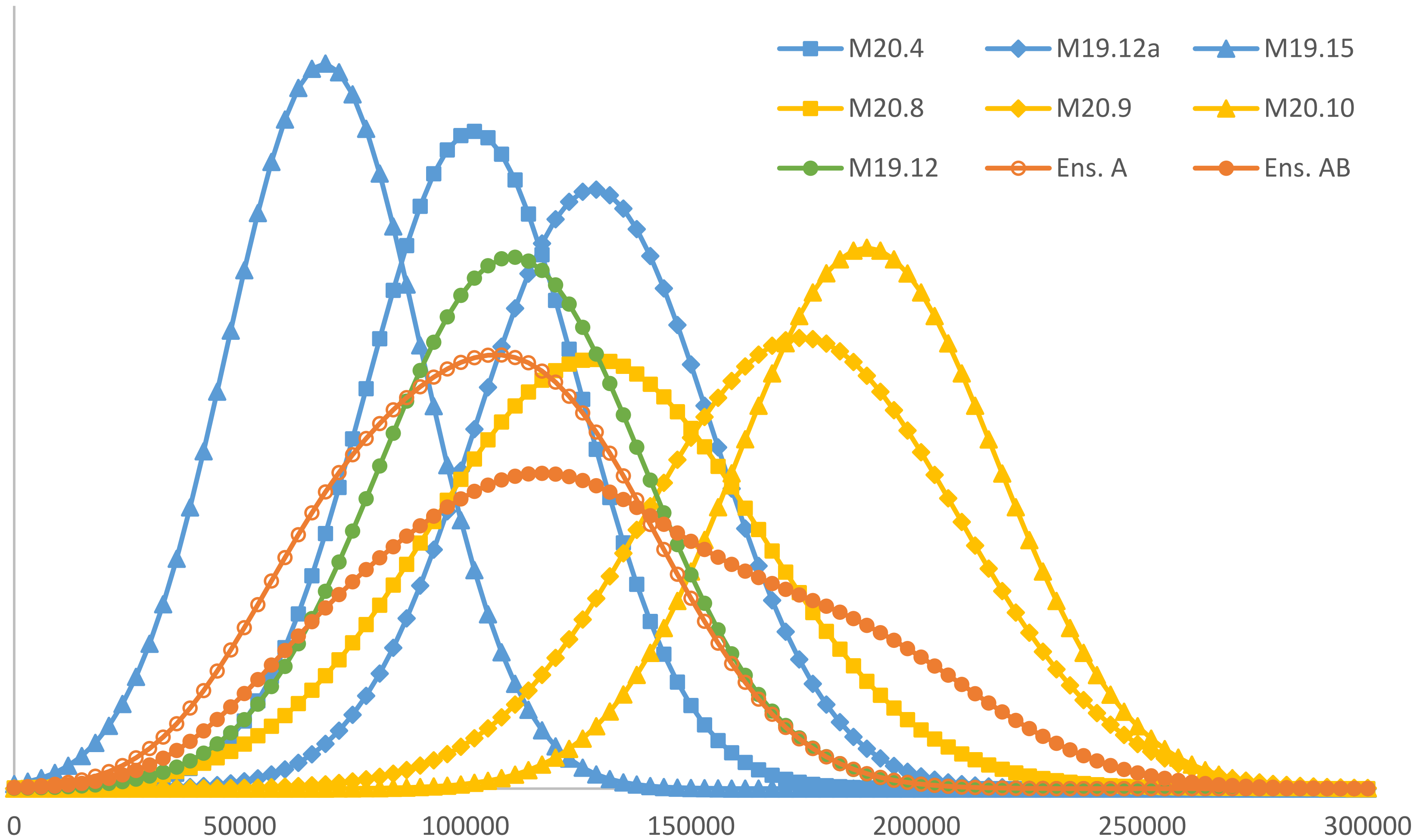
Probability densities: 2021 OFL



Probability densities: 2022 ABC



Probability densities: 2022 OFL



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

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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 2 slides

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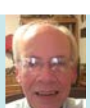
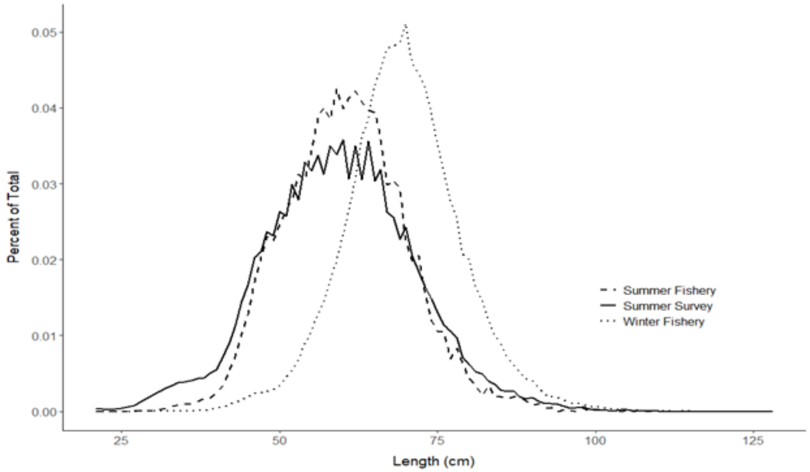
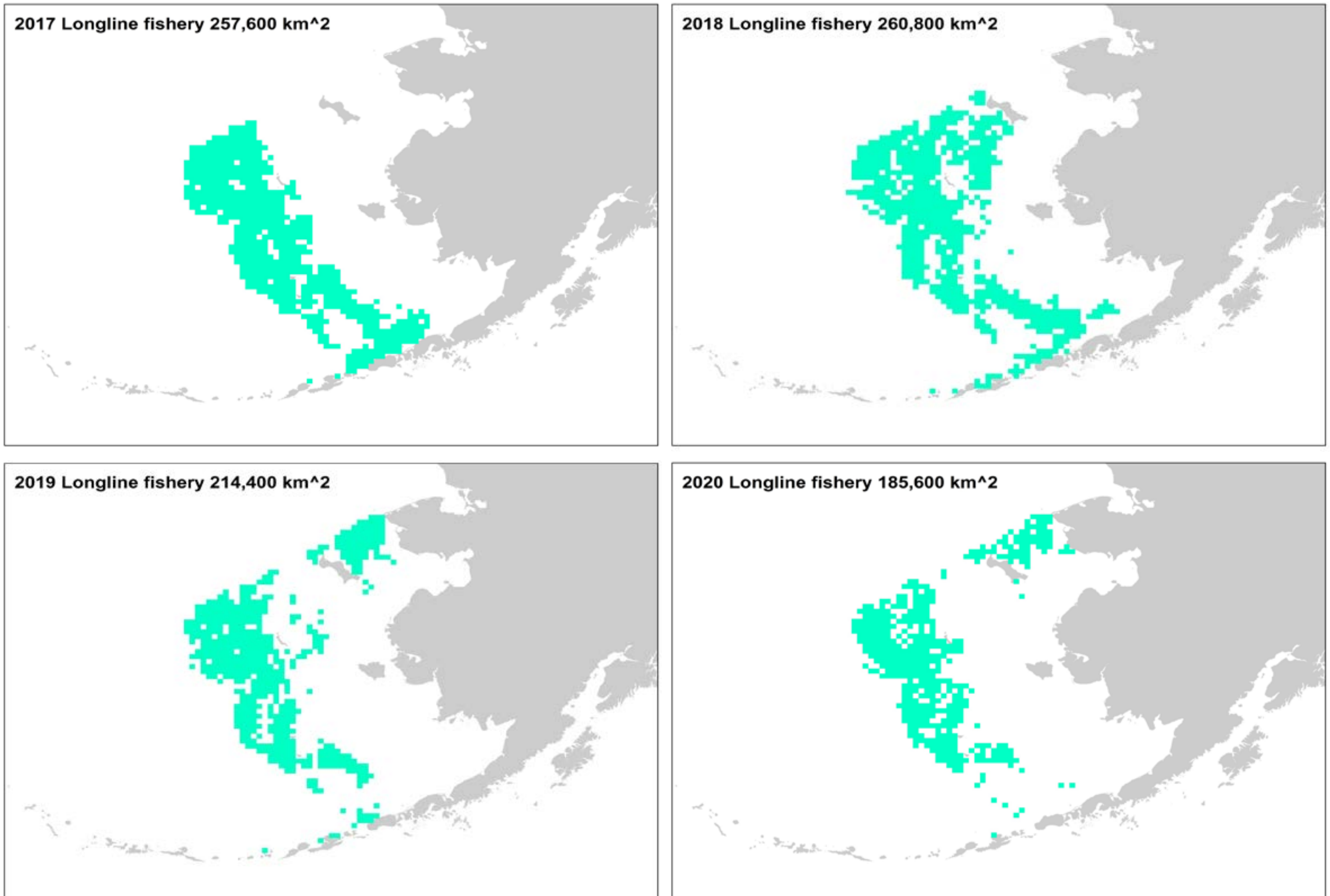


Allowing dome-shaped survey selectivity

- 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



Risk table: overview

- All categories rated Level 1 except environmental/ecosystem
  - Same ratings as last year
  - A summary of issues for the environmental/ecosystem category is provided on the next two slides
    - Full details are provided in the ESP
- Appendix 2.6 describes a method for determining:
  - Whether a reduction from maxABC is warranted
  - The magnitude of such reduction
- Given the risk table results and the 2021 OFL distributions for Ensembles A and AB, the method described in Appendix 2.6 indicates that a reduction from maxABC is not warranted

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

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)

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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%

- Low 2021 ABC has been projected in the 4 most recent assessments:

Assessment year:	2017	2018	2019	2020		
Option:				Ens. A	M19.12	Ens. AB
Projected 2021 ABC:	91,580	91,100	102,975	86,480	99,310	118,013