NOAA FISHERIES
Alaska Fisheries
Science Center

Preliminary assessment of Pacific cod in the Eastern Bering Sea

Grant Thompson

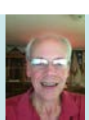
September 10, 2020

Team and SSC comments

Comments on assessments in general

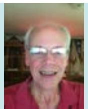
- JPT1: "The Teams recommended that authors continue to fill out the risk tables for full assessments."
- JPT2: "The Teams recommended that adjustment of ABC in response to levels of concern should be left to the discretion of the author, the Team(s), and/or the SSC, but should not be mandated by the inclusion of a >1 level in any particular category."
- SSC1: "The SSC requests that the GPTs, as time allows, update the risk tables for the 2020 full assessments...."
- SSC2: "The SSC recommends dropping the overall risk scores...."
- SSC3: "The SSC requests that the table explanations be included...."
- 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*: All of these will be addressed in the final version.

NOAA FISHERIES



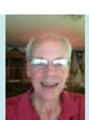
Comments specific to this assessment (1 of 10)

- Note: Given the time constraints posed by this year's meeting schedule, the SSC co-chairs have suggested that authors not feel obligated to respond to all of last year's SSC and Team comments in this year's assessments.
- BPT1: “The Team recommends continuing investigation of the CCDA model averaging method, realizing it is unlikely to be implemented this year. The Team is very enthusiastic about this approach. The Team will discuss with the author whether additional input would be useful in further testing and developing the method.” *Response*: Done.
- SSC5: “The SSC thanks Dr. Thompson for his work on developing the CCDA and supports continued efforts to explore this method. An important feature of this work will be how this method interacts with existing FMP control rules, and specifically how the level of risk aversion chosen (ra term in the loss function) maps onto existing control rule policies. *Response*: Done (Attachment 2.1.4).



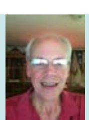
Comments specific to this assessment (2 of 10)

- BPT2: “A major discussion point was whether all three hypotheses should be retained. Hypothesis #2, combining the EBS and NBS surveys, was deemed likely given the observations of Pacific cod in the NBS, no evidence of genetic difference, and the presence of age-1 fish throughout the EBS and NBS. Hypothesis #3 is useful because it admits that dynamics in the NBS may be different than in the EBS. However, the models presented did not capture this possibility and spatial models would be worth investigating. Hypothesis #1 is the most unlikely hypothesis but ... should be retained at least another year....”
  Response: Models consistent with Hypotheses #2 and #3 are included in this preliminary assessment, but models consistent with Hypothesis #1 have been dropped, in part because this hypothesis seems inconsistent with current knowledge regarding stock structure (see SSC7) and also in the interest of reducing the number of models (see BPT5 and SSC10).



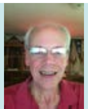
Comments specific to this assessment (3 of 10)

- BPT3: “The Team supported continued research into the abundance and mortality of Pacific cod outside of U.S. waters for inclusion in the stock assessment.” *Response*: Done (courtesy of Cecilia O’Leary).
- BPT4: “The Team recommended using spatio-temporal models for survey data (i.e., VAST with a cold pool covariate and bias correction) and also recommended that the survey team investigate the efficacy of VAST estimates using methods such as cross-validation.” *Response*: As in the ensemble of models included in last year’s final assessments, all survey data used in the models presented here are based on the VAST approach, using a cold pool covariate with bias correction, with one exception: Technical issues precluded estimation of the 2019 survey age composition using VAST, so a design-based estimate is used here instead. No new results from cross-validation are available, although efforts are underway to use a “leave-one-out” approach in the next year or two (Jim Thorson, *pers. commun.*).



Comments specific to this assessment (4 of 10)

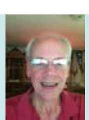
- BPT5: “The Team recommended the 3×3 factorial design for defining models in the ensemble and feels that the current nine models should be used for management advice. Hypothesis #1 is the hypothesis under which the assessment has historically operated, and it is useful to carry forward that legacy and retain the historic EBS only assessment. Hypothesis #3 is useful because it allows for a single stock with different dynamics in the two areas. Although the three models for Hypothesis #3 did not perform particularly well, this hypothesis is useful and the Team supports further development of models under this hypothesis that may incorporate spatial processes such as migration and differences in growth, for example. All three hypotheses and levels of complexity incorporate features that are of interest and useful for explaining structural uncertainty, but it would be useful to investigate reducing the number of models, such as eliminating one of the hypotheses or one of the levels of complexity.” *Response*: See comment BPT2.



Comments specific to this assessment (5 of 10)

- BPT6: “The Team recommended retaining all models in the ensemble for this assessment, but to simplify and reduce workload, only report models that are above a cutoff of 1% weight to represent the base model in the next assessment. This would include five models for comparison next year.” *Response*: In order to address several of the Team and SSC comments, it was necessary to rework the ensemble substantially for this preliminary assessment, and most of the five models referenced in this comment have been dropped.
- BPT7: “The Team recommended organizing the environmental/ ecosystem considerations content of the risk table to those items that are associated with the stock and those that are not (working with ESP and ESR editors may help with this).” *Response*: This comment will be addressed in the final assessment.

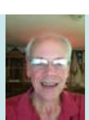
NOAA FISHERIES



Comments specific to this assessment (6 of 10)

- BPT8: “The Team recommended a continued investigation into whether a change in growth contributed to the ageing bias fit for 2008 and onward in the complex models as ageing bias and growth may be confounded.” *Response*: All models in this preliminary assessment include time-variability in length at age 1.5, but not in any of the other parameters describing size at age. This issue will likely be among the terms of reference for next year’s CIE review, and will be addressed in next year’s assessment.
- BPT9: “The Team recommended continued research into the inclusion of fishery age compositions in the models.” *Response*: This will likely be among the terms of reference for next year’s CIE review, and will be addressed in next year’s assessment (see SSC8).

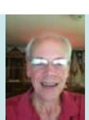
NOAA FISHERIES



Comments specific to this assessment (7 of 10)

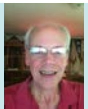
- SSC6: "The weighted ensemble was determined using a set of nine criteria with different emphasis factors.... The SSC thought this part of the weighting scheme was transparent and a reasonable step forward. However, the choice of an exponential average instead of the arithmetic average is a much more influential choice than the ad hoc 3:2:1 choice.... The SSC suggested that it may be more transparent to use a more intuitive arithmetic mean...." *Response*: This preliminary assessment explores the use of cross-conditional decision analysis, which involves two sets of model weights. The first set represents the probabilities that each of the models in the ensemble is the true model, and was computed here as the (rescaled) arithmetic mean of a set of scores, in response to this comment.

NOAA FISHERIES



Comments specific to this assessment (8 of 10)

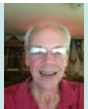
- SSC7: “A major discussion point was whether all three hypotheses should be retained going forward. Hypothesis #2, combining the EBS and NBS surveys, was considered the most likely given the observations of Pacific cod in the NBS and the lack of genetic differences between these areas. There was general support for removing the models related to Hypothesis #1 ... altogether, given our understanding of stock structure.” *Response*: Two models consistent with Hypothesis #2, including Model 19.12, are included in the new ensemble. The new ensemble does not contain any models consistent with Hypothesis #1.
- SSC8: “The SSC recommends that the authors focus on continuing to improve Model 19.12 and attempt to resolve problems with using fishery age compositions.” *Response*: This preliminary assessment presents an improved method for processing the size composition data that go into Model 19.12. Problems associated with using fishery age compositions will likely be among the terms of reference for next year’s CIE review of the assessment by the CIE (see BPT9).



Comments specific to this assessment (9 of 10)

- SSC9: “The authors should consider whether 19.12 could be ‘overfitting....’” *Response*: Half of the models in the new ensemble presented in this preliminary assessment have fewer time-varying parameters than Model 19.12. Also, the use of CCDA should help to mitigate problems of over-parameterization to the extent that it causes a model to perform poorly.
- SSC10: “The SSC recommends that if the authors bring an ensemble model forward in 2021, that it consists of a reduced set of models that still reflect adequate diversity in model structure and hypotheses about stock structure.” *Response*: The ensemble presented in here is smaller, albeit only slightly, than the ensemble used in last year’s assessment. Thorough investigation of over-parameterization (see SSC9), inter-area movement/migration (see BPT2, BPT5, and SSC11), and inclusion of both Hypotheses #2 and #3 (see BPT2, BPT5, and SSC7) proved to be a difficult task with fewer than 8 models.

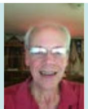
NOAA FISHERIES



Comments specific to this assessment (10 of 10)

- SSC11: “The SSC encourages further investigations into fish movement, both analytically and through tagging studies.” *Response*: Two of the models presented here include analytical treatment of fish movement. Results from tagging studies are summarized (courtesy of Susanne McDermott).
- SSC12: “The SSC requests that the use of VAST, including its assumptions, are clearly documented in next year’s assessment.” *Response*: Done (courtesy of Jim Thorson and Jason Conner).
- SSC13: “The SSC notes that development of an ESP for EBS Pacific cod would be advantageous. Given the results of the stock assessments and the vital historic economic, social, and community importance of Pacific cod, the SSC recommends that ... EBS Pacific cod (as well as AI and GOA Pacific cod) be prioritized as new ESPs are developed.” *Response*: Work on ESPs for GOA and EBS Pacific cod began this spring, with draft versions anticipated to be available in time for review in November.

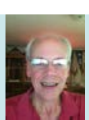
NOAA FISHERIES



Models

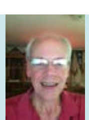
Base model (1 of 5)

- 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



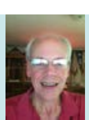
Base model (2 of 5)

- 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



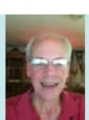
Base model (3 of 5)

- 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)

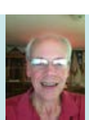
- One fishery, covering the EBS and NBS combined
  - Size-based, double-normal selectivity, with parameters as follow:
    - First size with selectivity=1 freely estimated
    - Logit of size range with selectivity=1 freely estimated
    - Base value of log of SD for 1st normal pdf freely estimated
      - 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)

NOAA FISHERIES



Primary ensemble: factorial design

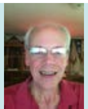
- Four topics from Team/SSC comments were interpreted as factors:

Topic	Comment(s)	Binary factor: Does the model...
M19.12 over-parameterization	SSC9	...allow time-varying survey catchability (*Q*)?
Spatial structure	BPT2	...treat the EBS and NBS as separate areas?
Hypotheses #2 and #3	BPT2, BPT5, SSC7	...use area-specific surveys?
Movement	BPT5, SSC11	...incorporate explicit inter-area movement?

- Suggests 2^4=16 models, but note that some combinations are infeasible:
  - Separate areas = “no” but movement = “yes” (4 models)
  - Separate areas = “yes” but area-specific surveys = “no” (4 models)
- This leaves the following 8 models (color = constrained to be the same):

Time-varying *Q* ?	No				Yes			
Separate areas?	No		Yes		No		Yes	
Separate surveys?	No	Yes	Yes		No	Yes	Yes	
Movement?	No		No	Yes	No		No	Yes
Temporary name	A1	B1	C1	D1	A2	B2	C2	D2

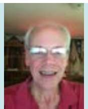
  - Model A2 is the base model (19.12)



Pri. ensemble: parameterization issues (1 of 2)

- Two-area models are complicated!
  - Require at least one parameter specifying allocation of recruits
  - If movement is allowed, require at least seven other parameters
    - Movement parameterization in SS described in Attachment 2.1.1
    - Two parameters for EBS→NBS, two others for NBS→EBS
    - These define ramps from age 2 to age 7 (first move at age 2)
  - If distribution or movement is time-varying, more parameters required
    - Tried annual random deviations (failed)
    - Instead, deterministic linkage to environmental covariates tried
      - For distribution and EBS→NBS, sea ice extent fit best
      - For NBS→EBS, North Pacific Index (NPI) fit best

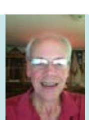
NOAA FISHERIES



Pri. ensemble: parameterization issues (2 of 2)

- Because no fishery size composition or age composition data are available for the NBS, all NBS fishery selectivity parameters were assumed to “mirror” their base EBS counterparts
- NBS catchability
  - As models were being developed, no NBS catch data were available
  - For the models that treat the EBS and NBS as separate areas, this made estimation of $\ln(Q)$ for the NBS survey difficult
  - Therefore, those models included an informative prior distribution
  - More specifically: normal prior with unit variance and mean equal to the point estimate of the EBS survey $\ln(Q)$
  - This involved tuning the prior mean iteratively for each such model.
  - Although the two models that use area-specific surveys without separate areas appeared to be capable of estimating $\ln(Q)$ without the prior distribution, it was used for those models also

NOAA FISHERIES



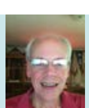
Primary ensemble: parameter counts

- Counts of parameters, for data through 2019, are as follow:

Time-varying Q?	No				Yes			
Separate areas?	No		Yes		No		Yes	
Separate surveys?	No	Yes	Yes		No	Yes	Yes	
Movement?	No		No	Yes	No		No	Yes
Temporary name	A1	B1	C1	D1	A2	B2	C2	D2
True parameters	25	30	37	46	25	30	37	46
Annual deviations	267	267	267	267	305	343	343	343
Total parameters	292	297	304	313	330	373	380	389

- Counts of “true” parameters are the same in both halves of the table
  - Increase L to R within a given half
- Counts of annual devs are equal in 1st half, increase L to R in 2nd half
- Counts of total parameters increase L to R across whole table
- Text contains detailed descriptions of differences between models

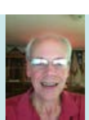
NOAA FISHERIES



Alternative ensemble

- After the models in the primary ensemble had already been largely developed, a small amount of NBS catch data became available
- This suggested that it might be possible to estimate NBS survey $\ln(Q)$ in the four models that treat the EBS and NBS as separate areas after all
- Prior-less analogues were therefore developed for all six models that used separate surveys (not just the four that used separate areas)
- These six models, together with Models A1 and A2 from the primary ensemble, can be considered to constitute an alternative ensemble
- Note that, when the prior distribution on NBS $\ln(Q)$ is removed from Model B2, it is identical to Model 19.15
- Results in this presentation will focus on the primary ensemble, with a brief set of results for the alternative ensemble

NOAA FISHERIES

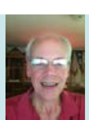


Data

Data used in the models (1 of 4)

- All data are the same as in last year's assessment, except:
  - A small change was made in the method used to compile the fishery size composition data
    - Used in all models
  - NBS catch time series was added
    - Used in the four 2-area models
  - Time series for a pair of environmental covariates was added
    - Used in the two models that incorporate movement
- As in last year's assessment, survey index and age composition data came from VAST runs, but specifications are now explicitly documented, per SSC request

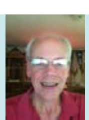
NOAA FISHERIES



Data used in the models (2 of 4)

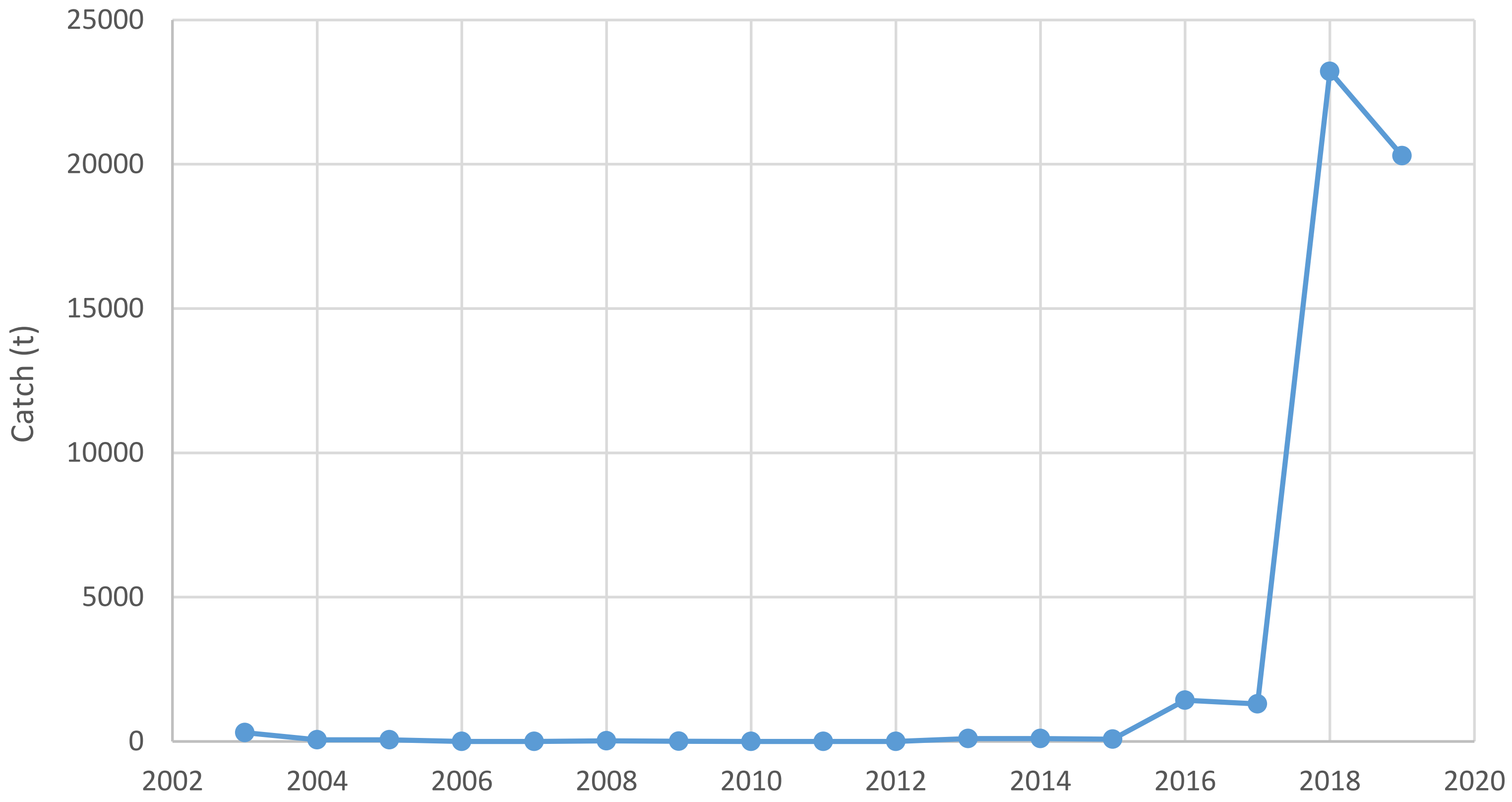
- (New) change in compilation of annual fishery size composition data
  - Previously, *all* year-, month-, area-, and gear-specific size composition were weighted by the respective catch
  - Theoretically possible for a small sample size (implying potentially large measurement error) to be associated with a large catch
  - Attachment 2.1.2 derives an optimal minimum sample size of 30
  - For the overall time series, setting $Nmin=30$ eliminates 12.1% of size composition records, but only 0.1% of the total number of fish measured and only 1.8% of the total catch
  - Rerunning the base model with $Nmin=30$ resulted in less than a 1% change in ending spawning biomass

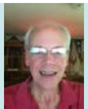
NOAA FISHERIES



Data used in the models (3 of 4)

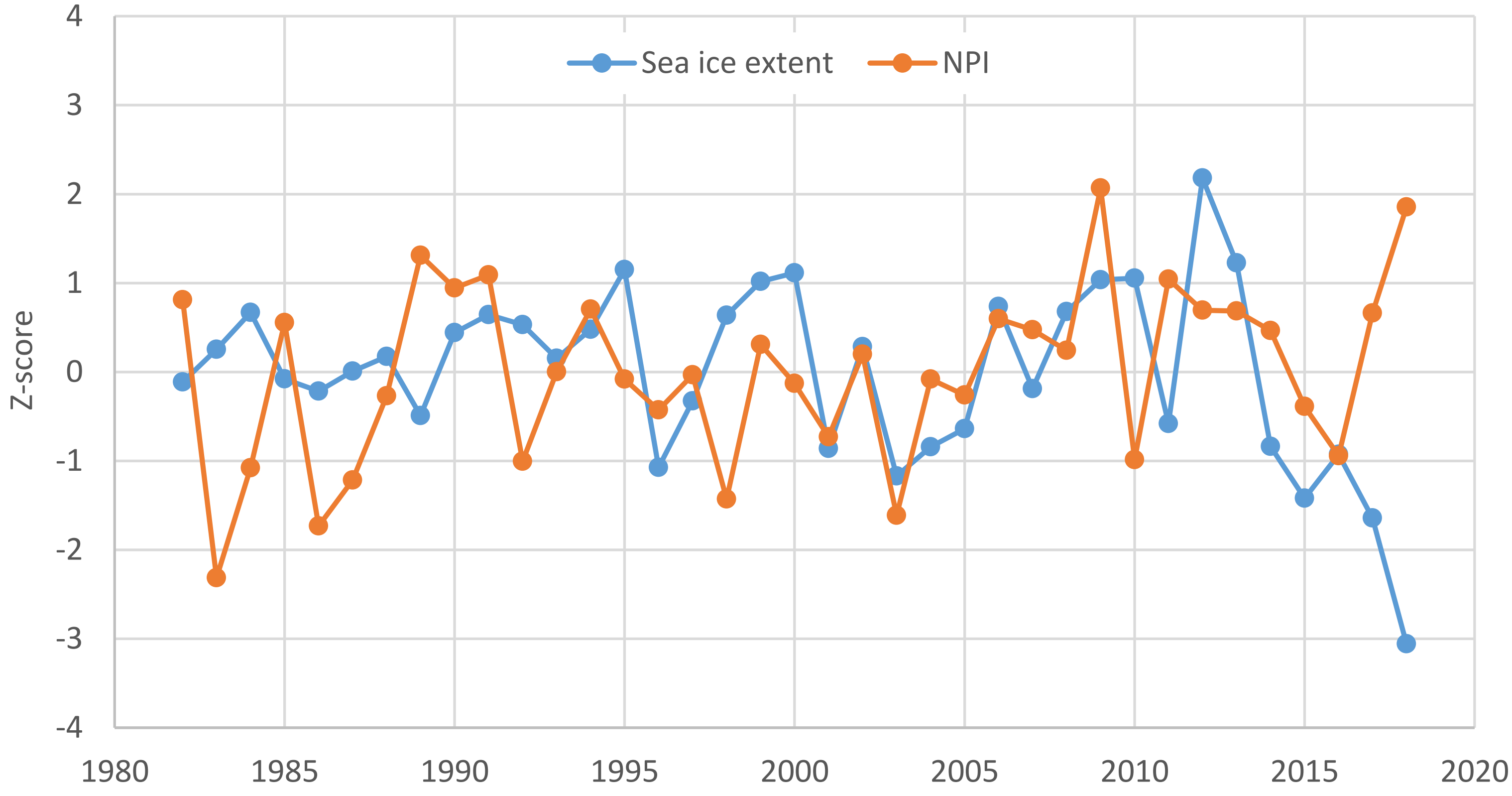
- (New) NBS catch time series





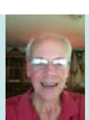
Data used in the models (4 of 4)

- (New) sea ice extent and NPI, expressed as z-scores



Preview of data changes in final (1 of 2)

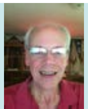
- Environmental covariate time series (existing z-scores will change a bit)
  - Sea ice extent z-scores: -2.114 (2019), -0.763 (2020)
  - NPI z-scores: 0.245 (2019), 1.284 (2020)
- Size composition
  - Fishery size compositions have been updated through August 2020
    - Broadly speaking, no surprises
    - Mode has been shifting toward larger sizes each of last 3 years
    - Few age 2 fish are taken, but some hint of strong 2018 cohort
  - NBS survey time series currently includes a record for 2018
    - This will likely be dropped, due to unbalanced design



Preview of data changes in final (2 of 2)

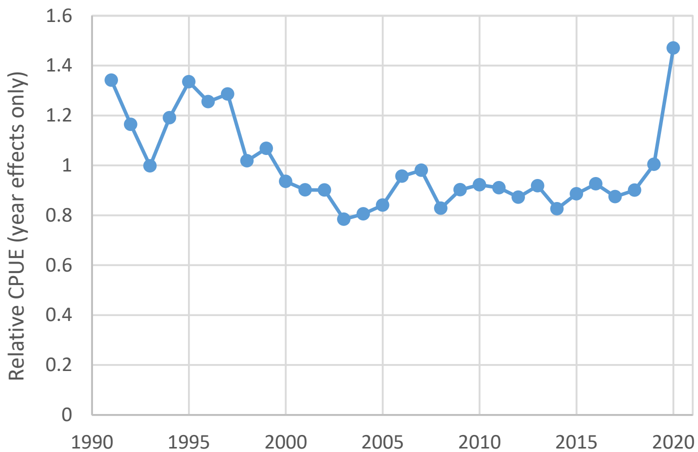
- EBS survey age composition
  - The otoliths from the 2019 EBS survey have now been processed
  - Technical issues have precluded a VAST estimate of the 2019 age composition, so a design-based estimate will be used for 2019

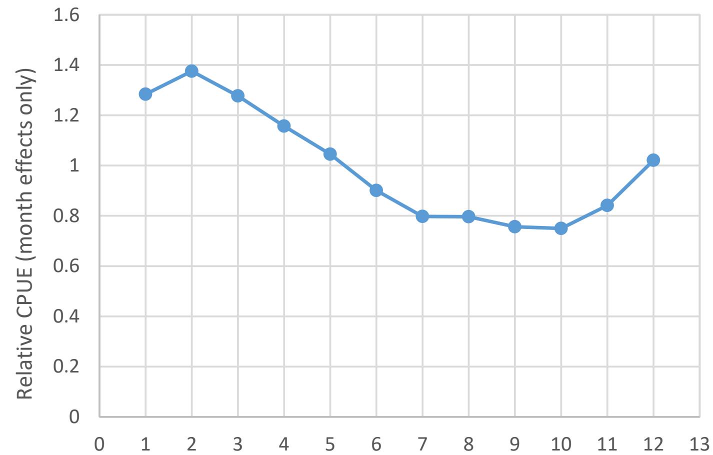
Year	0	1	2	3	4	5	6	7	8	9	10	11	12+
1994	0.00014	0.09613	0.40395	0.17319	0.11261	0.10797	0.07225	0.01885	0.00719	0.00419	0.00127	0.00109	0.00116
1995	0.00010	0.05819	0.26053	0.42510	0.10262	0.07361	0.05060	0.01300	0.00666	0.00523	0.00141	0.00155	0.00140
1996	0.00003	0.06610	0.20487	0.19054	0.28907	0.13770	0.06404	0.03050	0.00856	0.00355	0.00183	0.00161	0.00161
1997	0.00022	0.26517	0.17172	0.16133	0.15060	0.11976	0.09091	0.02379	0.01050	0.00246	0.00183	0.00103	0.00069
1998	0.00005	0.07845	0.43779	0.20042	0.11281	0.05824	0.05939	0.03005	0.01704	0.00369	0.00076	0.00085	0.00045
1999	0.00006	0.08528	0.20960	0.31480	0.21893	0.07289	0.05280	0.02580	0.01176	0.00507	0.00103	0.00135	0.00062
2000	0.00000	0.21363	0.11948	0.16697	0.24416	0.15478	0.06074	0.01415	0.01521	0.00502	0.00365	0.00150	0.00072
2001	0.00003	0.29245	0.23927	0.18907	0.08810	0.08647	0.06788	0.02470	0.00733	0.00181	0.00141	0.00105	0.00043
2002	0.00035	0.08038	0.19872	0.30697	0.23702	0.06869	0.05722	0.03609	0.00957	0.00291	0.00095	0.00050	0.00064
2003	0.00001	0.17330	0.16086	0.24003	0.20847	0.12118	0.04409	0.03070	0.01583	0.00370	0.00049	0.00060	0.00076
2004	0.00003	0.14206	0.15181	0.27385	0.13242	0.13298	0.09559	0.03803	0.02036	0.00788	0.00216	0.00203	0.00080
2005	0.00000	0.16085	0.23187	0.20703	0.13136	0.07043	0.09116	0.06183	0.02580	0.01090	0.00382	0.00439	0.00055
2006	0.00000	0.32732	0.14621	0.17330	0.11701	0.08947	0.06074	0.04509	0.02659	0.00932	0.00297	0.00125	0.00074
2007	0.00000	0.66271	0.10804	0.07737	0.04920	0.04994	0.01963	0.01592	0.00825	0.00530	0.00170	0.00102	0.00092
2008	0.00000	0.19811	0.43937	0.15456	0.09171	0.05198	0.03097	0.01097	0.01018	0.00616	0.00254	0.00209	0.00135
2009	0.00000	0.45311	0.18811	0.23141	0.06606	0.02852	0.01488	0.00933	0.00472	0.00181	0.00094	0.00071	0.00041
2010	0.00000	0.04654	0.48121	0.18329	0.19871	0.06219	0.01489	0.00793	0.00257	0.00140	0.00050	0.00060	0.00017
2011	0.00006	0.32372	0.07444	0.36511	0.10766	0.08847	0.02708	0.00687	0.00286	0.00157	0.00107	0.00064	0.00045
2012	0.00000	0.34130	0.26174	0.06302	0.23036	0.06137	0.02983	0.00755	0.00230	0.00165	0.00054	0.00015	0.00020
2013	0.00000	0.09807	0.40589	0.19757	0.11512	0.11578	0.05059	0.01181	0.00341	0.00096	0.00021	0.00031	0.00026
2014	0.00002	0.28151	0.16686	0.24402	0.20263	0.05073	0.03919	0.01039	0.00220	0.00095	0.00084	0.00010	0.00057
2015	0.00002	0.06356	0.43477	0.20238	0.18886	0.07797	0.01825	0.01087	0.00231	0.00047	0.00023	0.00011	0.00020
2016	0.00000	0.10111	0.09245	0.35833	0.22552	0.15171	0.05281	0.01203	0.00365	0.00143	0.00051	0.00030	0.00015
2017	0.00007	0.12941	0.16222	0.16720	0.29456	0.13708	0.07948	0.02114	0.00338	0.00333	0.00065	0.00066	0.00082
2018	0.00004	0.09856	0.11454	0.26881	0.15622	0.23896	0.08099	0.03415	0.00351	0.00254	0.00074	0.00035	0.00059
2019	0.00000	0.69868	0.06224	0.06420	0.05415	0.04050	0.04793	0.02339	0.00620	0.00163	0.00048	0.00043	0.00018

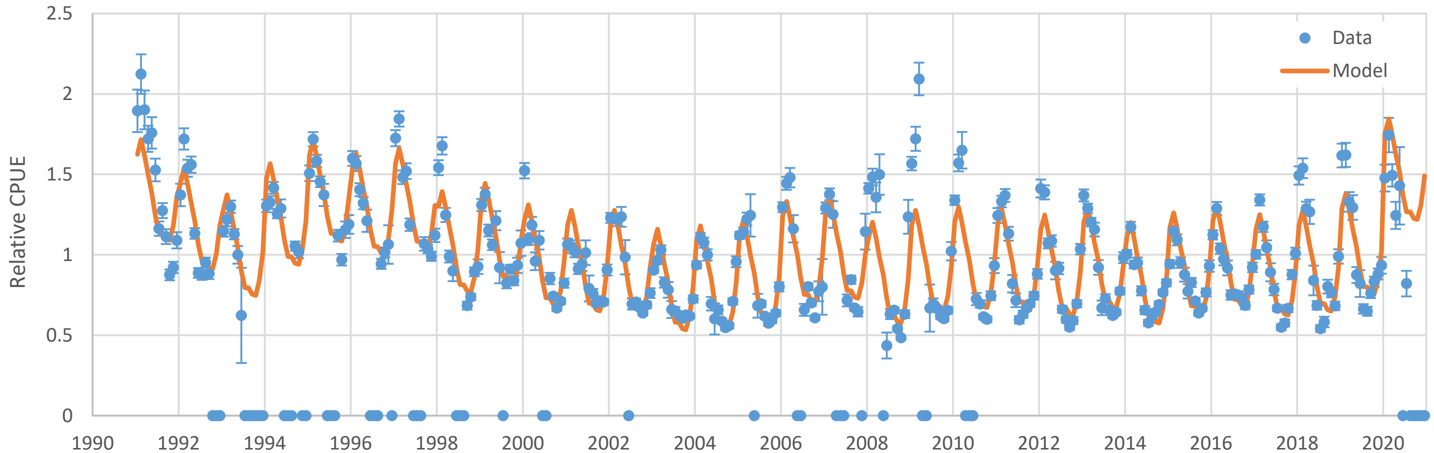


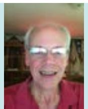
Data provided for context only (1 of 2)

- Longline fishery CPUE



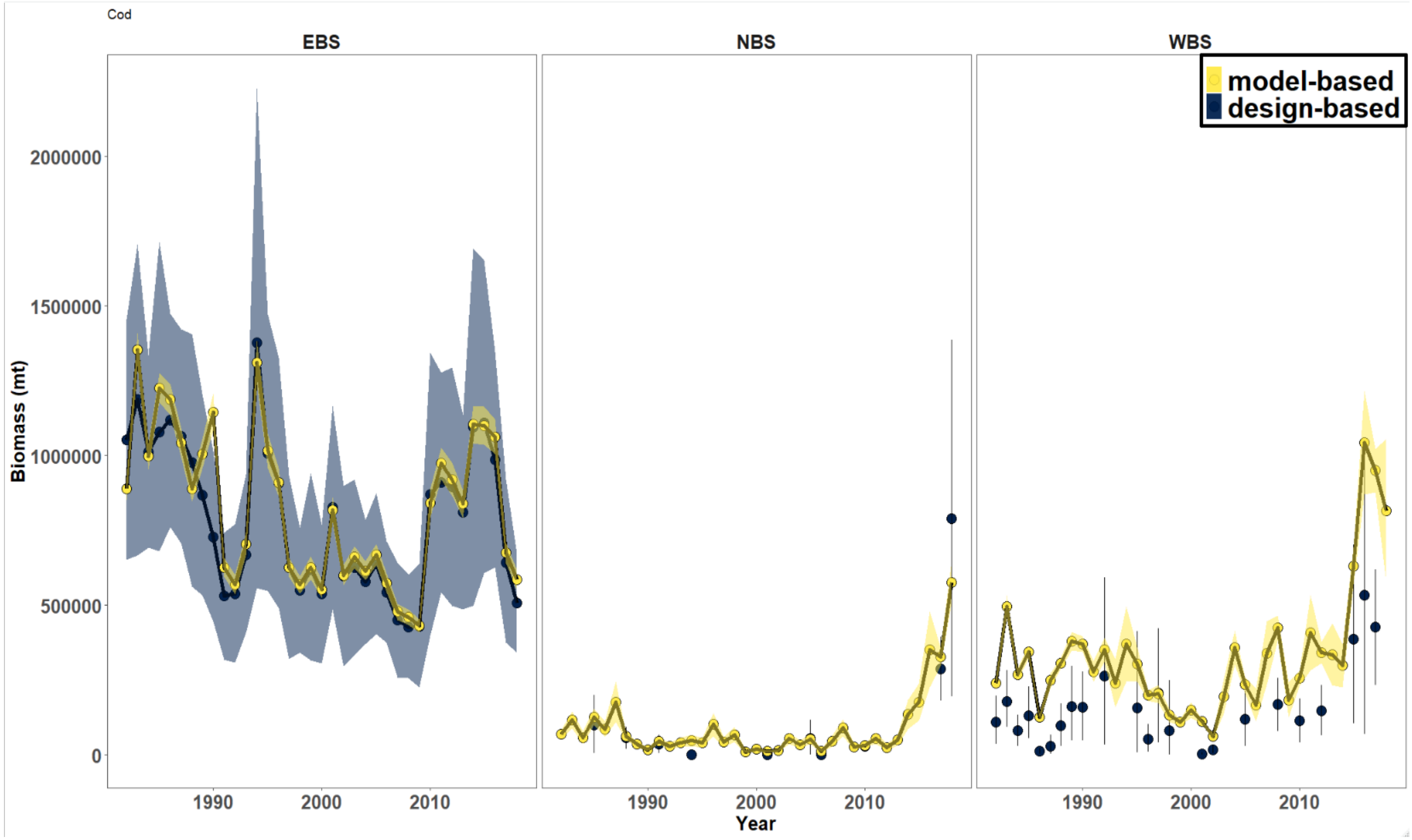






Data provided for context only (2 of 2)

- Tagging data were summarized in presentation by Britt and McDermott
- Western Bering Sea (WBS) abundance (courtesy of Cecilia O'Leary)

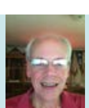


Results
(primary ensemble except as noted)

Final model names

- Based on the spawning biomass time series estimates, ADSB values...
  - ... < 0.1 imply *minor* changes from the base model (19.12), and so get names of the form "19.12x," where x is a letter
  - ... ≥ 0.1 imply *major* changes from the base model (19.12), and so get names of the form "20.j," where j is a number

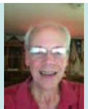
Time-varying *Q* ?	No				Yes			
Separate areas?	No		Yes		No		Yes	
Separate surveys?	No	Yes	Yes		No	Yes	Yes	
Movement?	No		No	Yes	No		No	Yes
Temporary name	A1	B1	C1	D1	A2	B2	C2	D2
ADSB	0.0755	0.0981	1.2983	0.0732	n/a	0.0775	0.1692	0.3918
Final name	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3



Parameter estimates & derived series (1 of 17)

- Common time-invariant parameters (T2.1.3a, slide 1 of 2)

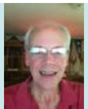
Time-varying *Q* ?	No								Yes							
Separate areas?	No				Yes				No				Yes			
Separate surveys?	No		Yes		Yes				No		Yes		Yes			
Movement?	No				No		Yes		No				No		Yes	
Model	M19.12a		M19.12b		M20.1		M19.12c		M19.12		M19.12d		M20.2		M20.3	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
Natural_mortality	0.358	0.011	0.372	0.012	0.372	0.011	0.332	0.011	0.348	0.013	0.358	0.012	0.374	0.011	0.344	0.013
L_at_1.5_base	14.815	0.398	14.799	0.400	14.794	0.404	14.805	0.400	14.894	0.401	14.903	0.418	14.807	0.416	14.594	0.400
L_infinity	113.4	3.123	114.2	3.340	112.9	3.189	118.2	4.594	115.1	3.315	114.6	3.265	116.5	4.188	111.2	3.467
VonBert_K	0.117	0.009	0.117	0.010	0.118	0.010	0.106	0.011	0.114	0.009	0.117	0.009	0.108	0.011	0.123	0.011
Richards_coef	1.444	0.042	1.435	0.045	1.444	0.043	1.480	0.047	1.445	0.042	1.419	0.043	1.479	0.047	1.438	0.046
SD_len_at_1	3.493	0.067	3.483	0.066	3.466	0.066	3.481	0.066	3.510	0.066	3.473	0.065	3.485	0.067	3.490	0.065
SD_len_at_20	9.905	0.383	9.945	0.397	10.136	0.387	10.153	0.446	9.705	0.388	9.882	0.391	10.014	0.430	9.397	0.392
RecrDist_NBS_base					-0.676	0.759	-3.037	0.245					-3.345	0.177	-1.690	0.213
AgeBias_at_1_1977_2007	0.339	0.017	0.349	0.015	0.349	0.015	0.347	0.015	0.337	0.017	0.347	0.015	0.348	0.014	0.346	0.015
AgeBias_at_1_2008_2019	0.014	0.025	-0.002	0.025	0.001	0.024	0.009	0.023	0.019	0.025	0.002	0.026	0.004	0.023	0.008	0.024
AgeBias_at_20_1977_2007	0.859	0.221	0.776	0.205	0.772	0.198	0.843	0.200	0.898	0.221	0.804	0.204	0.825	0.200	0.954	0.205
AgeBias_at_20_2008_2019	-1.532	0.316	-1.697	0.325	-1.646	0.313	-1.698	0.305	-1.708	0.326	-1.930	0.345	-1.790	0.324	-2.179	0.365
ln(Recr_ave_1977_2018)	13.208	0.097	13.271	0.099	13.678	0.271	12.991	0.089	13.121	0.105	13.144	0.103	13.313	0.097	13.185	0.123
ln(Recr_ave_pre1977_offset)	-0.903	0.202	-0.885	0.204	-0.862	0.206	-0.986	0.181	-0.925	0.195	-0.909	0.199	-0.839	0.208	-0.919	0.180
InitF_main_fsh	0.122	0.038	0.127	0.040	0.119	0.037	0.147	0.046	0.127	0.039	0.134	0.043	0.114	0.035	0.173	0.056
InitF_NBS_fsh					0.000	0.000	0.000	0.000					0.000	0.000	0.000	0.000



Parameter estimates & derived series (2 of 17)

- Common time-invariant parameters (T2.1.3a, slide 2 of 2)

Time-varying *Q* ?	No								Yes							
Separate areas?	No				Yes				No				Yes			
Separate surveys?	No		Yes		Yes				No		Yes		Yes			
Movement?	No				No		Yes		No				No		Yes	
Model	M19.12a		M19.12b		M20.1		M19.12c		M19.12		M19.12d		M20.2		M20.3	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD	Est.	SD
lnQ_main_srv_base	-0.029	0.063	-0.111	0.066	-0.102	0.057	0.172	0.059	0.019	0.069	-0.037	0.068	-0.116	0.064	0.261	0.065
lnQ_NBS_srv_base			-0.788	0.105	-0.747	0.767	-0.260	0.108			-1.842	0.254	0.827	0.325	-1.466	0.284
Main_fsh_sel_PeakStart	74.984	0.039	75.220	0.598	74.971	0.196	74.982	0.528	74.985	0.035	74.986	0.030	74.931	0.520	75.968	0.590
Main_fsh_sel_logitPeakWidth	-9.765	6.733	-5.712	18.562	-9.439	14.705	0.208	0.465	-9.782	6.361	-9.761	6.755	0.469	0.593	0.097	0.522
Main_fsh_sel_lnSD1_base	5.908	0.029	5.913	0.039	5.898	0.029	5.907	0.039	5.911	0.028	5.905	0.027	5.896	0.037	5.950	0.039
Main_fsh_sel_lnSD2	-9.867	4.111	-1.410	8.489	-9.091	18.173	4.707	1.251	-9.883	3.621	-9.886	3.556	4.345	1.767	4.827	1.357
Main_fsh_sel_logitEnd_base	2.135	0.313	1.987	0.301	3.114	0.786	-3.140	3.513	2.225	0.348	2.084	0.296	-2.647	3.443	-2.855	3.301
Main_srv_sel_PeakStart_base	20.923	0.779	21.036	0.801	20.986	0.794	21.110	0.811	20.817	0.807	20.699	0.831	20.970	0.819	21.827	0.905
Main_srv_sel_lnSD1_base	3.529	0.151	3.532	0.151	3.522	0.151	3.535	0.154	3.503	0.156	3.460	0.161	3.513	0.155	3.613	0.157
NBS_srv_sel_PeakStart			79.998	0.072	74.051	8.817	15.530	1.383			79.997	0.113	68.696	7.855	14.453	1.161
NBS_srv_sel_lnSD1			7.784	0.139	8.881	0.882	2.067	0.640			7.821	0.146	7.925	0.490	1.750	0.675
lnDM_size_main_fish	9.989	0.337	9.989	0.351	9.989	0.358	9.990	0.325	9.989	0.355	9.989	0.358	9.990	0.347	9.989	0.343
lnDM_size_main_sur	9.984	0.520	9.984	0.524	9.985	0.499	9.984	0.496	9.984	0.540	9.984	0.522	9.985	0.470	9.984	0.482
lnDM_size_NBS_sur			9.656	9.374	9.717	7.603	9.923	2.327			9.756	7.420	9.712	8.223	9.935	1.982
lnDM_age_main_srv	-0.006	0.213	0.281	0.252	0.444	0.278	0.478	0.280	0.075	0.225	0.432	0.274	0.522	0.297	0.541	0.282
lnDM_age_NBS_srv			0.213	0.568	-1.511	0.343	0.381	1.052			0.383	0.609	-1.342	0.362	-0.201	0.578

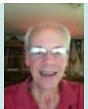


Parameter estimates & derived series (3 of 17)

- Full-selection fishing mortality rates (T2.1.4)

	19.12a	19.12b	20.1		19.12c		19.12	19.12d	20.2		20.3	
Year	XBS	XBS	EBS	NBS	EBS	NBS	XBS	XBS	EBS	NBS	EBS	NBS
1977	0.186	0.186	0.176	0.000	0.232	0.000	0.195	0.200	0.168	0.000	0.257	0.000
1978	0.225	0.225	0.212	0.000	0.290	0.000	0.237	0.244	0.202	0.000	0.315	0.000
1979	0.162	0.162	0.153	0.000	0.215	0.000	0.172	0.177	0.145	0.000	0.226	0.000
1980	0.167	0.167	0.158	0.000	0.226	0.000	0.178	0.182	0.150	0.000	0.236	0.000
1981	0.124	0.124	0.118	0.000	0.169	0.000	0.134	0.135	0.114	0.000	0.182	0.000
1982	0.095	0.094	0.090	0.000	0.127	0.000	0.102	0.100	0.088	0.000	0.140	0.000
1983	0.114	0.113	0.110	0.000	0.146	0.000	0.122	0.120	0.106	0.000	0.162	0.000
1984	0.157	0.157	0.153	0.000	0.198	0.000	0.166	0.164	0.146	0.000	0.220	0.000
1985	0.173	0.173	0.167	0.000	0.213	0.000	0.182	0.180	0.158	0.000	0.236	0.000
1986	0.164	0.164	0.158	0.000	0.194	0.000	0.171	0.170	0.149	0.000	0.217	0.000
1987	0.190	0.189	0.184	0.000	0.226	0.000	0.196	0.195	0.174	0.000	0.252	0.000
1988	0.224	0.223	0.218	0.000	0.269	0.000	0.231	0.230	0.208	0.000	0.303	0.000
1989	0.211	0.210	0.207	0.000	0.257	0.000	0.216	0.215	0.198	0.000	0.291	0.000
1990	0.240	0.238	0.239	0.000	0.279	0.000	0.243	0.241	0.227	0.000	0.320	0.000
1991	0.409	0.407	0.406	0.000	0.466	0.000	0.407	0.408	0.379	0.000	0.528	0.000
1992	0.452	0.451	0.442	0.000	0.507	0.000	0.442	0.449	0.404	0.000	0.567	0.000
1993	0.305	0.306	0.303	0.000	0.355	0.000	0.300	0.304	0.279	0.000	0.384	0.000
1994	0.402	0.401	0.400	0.000	0.474	0.000	0.400	0.402	0.377	0.000	0.516	0.000
1995	0.498	0.496	0.496	0.000	0.592	0.000	0.510	0.514	0.482	0.000	0.666	0.000
1996	0.469	0.464	0.472	0.000	0.580	0.000	0.498	0.500	0.476	0.000	0.682	0.000
1997	0.514	0.506	0.515	0.000	0.665	0.000	0.566	0.565	0.537	0.000	0.800	0.000
1998	0.410	0.402	0.410	0.000	0.552	0.000	0.458	0.456	0.431	0.000	0.682	0.000
1999	0.390	0.381	0.388	0.000	0.548	0.000	0.435	0.434	0.407	0.000	0.665	0.000
2000	0.379	0.372	0.377	0.000	0.523	0.000	0.418	0.414	0.391	0.000	0.637	0.000
2001	0.343	0.337	0.334	0.000	0.453	0.000	0.363	0.360	0.339	0.000	0.539	0.000
2002	0.372	0.365	0.354	0.000	0.479	0.000	0.384	0.383	0.353	0.000	0.554	0.000
2003	0.376	0.368	0.367	0.001	0.482	0.004	0.391	0.387	0.365	0.007	0.563	0.001
2004	0.388	0.379	0.382	0.000	0.532	0.001	0.406	0.397	0.380	0.001	0.587	0.000
2005	0.408	0.397	0.406	0.000	0.585	0.000	0.425	0.413	0.402	0.001	0.643	0.000
2006	0.447	0.432	0.451	0.000	0.695	0.000	0.464	0.446	0.443	0.000	0.755	0.000
2007	0.430	0.411	0.433	0.000	0.630	0.000	0.442	0.419	0.421	0.000	0.729	0.000
2008	0.526	0.494	0.517	0.000	0.724	0.000	0.532	0.500	0.497	0.001	0.861	0.000
2009	0.657	0.613	0.635	0.000	0.897	0.000	0.652	0.613	0.601	0.000	1.079	0.000
2010	0.619	0.593	0.609	0.000	0.643	0.000	0.600	0.582	0.569	0.000	0.800	0.000
2011	0.721	0.708	0.734	0.000	0.813	0.000	0.690	0.683	0.685	0.000	0.861	0.000
2012	0.616	0.627	0.640	0.000	0.712	0.000	0.608	0.623	0.612	0.000	0.752	0.000
2013	0.557	0.574	0.580	0.000	0.647	0.010	0.563	0.593	0.562	0.003	0.699	0.001
2014	0.608	0.631	0.634	0.000	0.711	0.007	0.618	0.670	0.615	0.002	0.801	0.001
2015	0.571	0.604	0.613	0.000	0.691	0.003	0.585	0.654	0.603	0.002	0.830	0.001
2016	0.510	0.560	0.570	0.002	0.741	0.013	0.528	0.627	0.571	0.031	0.838	0.006
2017	0.403	0.471	0.482	0.002	0.674	0.007	0.423	0.547	0.491	0.027	0.788	0.004
2018	0.295	0.368	0.330	0.031	0.597	0.065	0.309	0.437	0.336	0.582	0.567	0.057
2019	0.288	0.380	0.324	0.029	0.592	0.054	0.300	0.464	0.326	0.934	0.543	0.051

NOAA FISHERIES



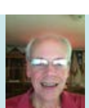
Parameter estimates & derived series (4 of 17)

- Iteratively tuned σ values for annual random deviations (T2.1.5)
  - For $\ln(Recruits)$, set σ so that $var\_dev + ave\_var = \sigma^2$
  - For all others, set σ so that $var\_dev + ave\_var = 1$

	Model 19.12a			Model 19.12b			Model 20.1			Model 19.12c		
Parameter	var_dev	ave_var	sigma	var_dev	ave_var	sigma	var_dev	ave_var	sigma	var_dev	ave_var	sigma
ln(Recruits)	0.4701	0.0134	0.6954	0.4448	0.0124	0.6762	0.4602	0.0129	0.6877	0.4351	0.0124	0.6690
Length_at_1.5	0.7825	0.2159	0.1494	0.7955	0.2018	0.1524	0.8005	0.2011	0.1548	0.7889	0.2112	0.1508
Sel_fsh_lnSD1	0.7155	0.2879	0.1560	0.6940	0.3081	0.1434	0.7060	0.2961	0.1486	0.7234	0.2807	0.1601
Sel_fsh_logitEnd	0.1803	0.8161	0.7517	0.2183	0.7790	0.7504	0.0000	1.0000	0.1004	0.0000	1.0000	0.1000
Sel_srv_PeakStart	0.8399	0.1572	0.2034	0.8511	0.1502	0.2085	0.8471	0.1505	0.2072	0.8498	0.1490	0.2106
Sel_srv_lnSD1	0.7220	0.2729	0.7641	0.7297	0.2692	0.7640	0.7265	0.2705	0.7631	0.7307	0.2672	0.7824

	Model 19.12			Model 19.12d			Model 20.2			Model 20.3		
Parameter	var_dev	ave_var	sigma	var_dev	ave_var	sigma	var_dev	ave_var	sigma	var_dev	ave_var	sigma
ln(Recruits)	0.4525	0.0139	0.6830	0.4451	0.0130	0.6766	0.4477	0.0133	0.6791	0.4172	0.0131	0.6559
Length_at_1.5	0.7791	0.2188	0.1502	0.8066	0.1900	0.1603	0.8085	0.1939	0.1601	0.8000	0.2060	0.1512
Sel_fsh_lnSD1	0.7107	0.2936	0.1532	0.6810	0.3104	0.1433	0.7031	0.2975	0.1482	0.7099	0.2921	0.1514
Sel_fsh_logitEnd	0.1557	0.8422	0.7670	0.2134	0.7812	0.7976	0.0000	1.0000	0.1004	0.0000	1.0000	0.1000
Sel_srv_PeakStart	0.8472	0.1485	0.2153	0.8530	0.1486	0.2227	0.8453	0.1557	0.2136	0.8453	0.1542	0.2203
Sel_srv_lnSD1	0.7345	0.2581	0.8064	0.7410	0.2602	0.8318	0.7250	0.2759	0.7829	0.7321	0.2713	0.7850

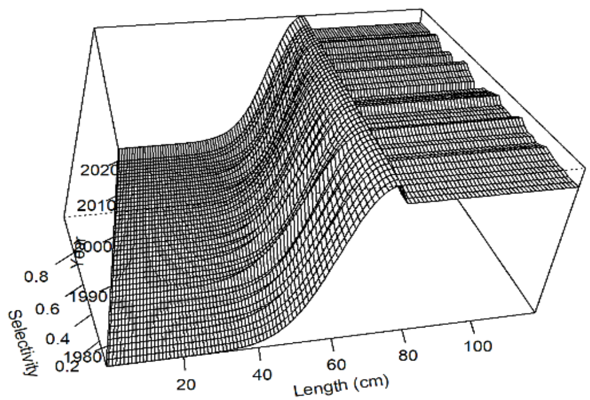
NOAA FISHERIES



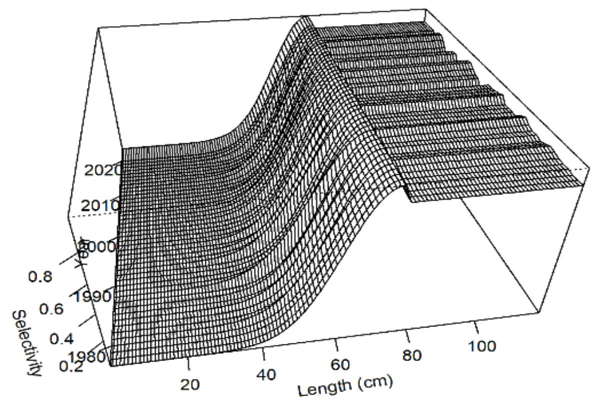
Parameter estimates & derived series (5 of 17)

- Fishery selectivity (1-area models)

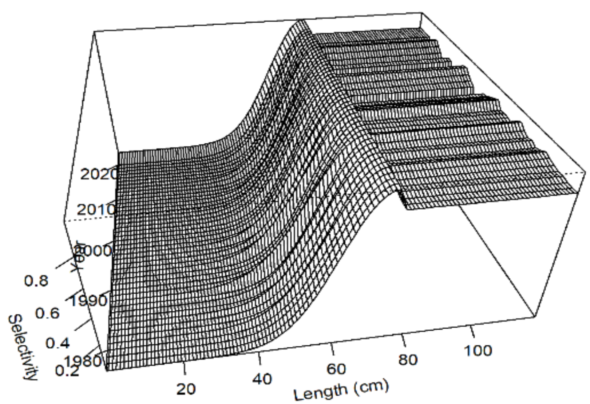
Model 19.12a



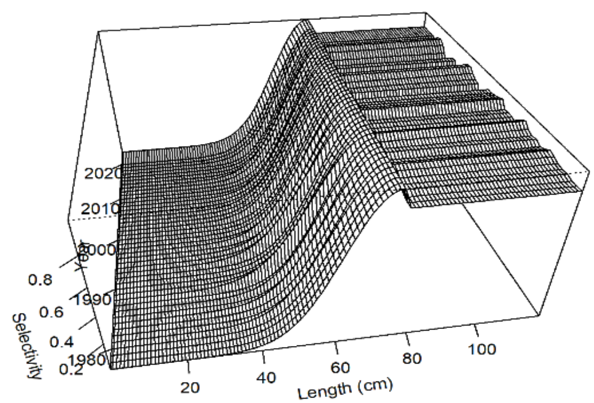
Model 19.12

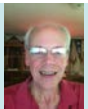


Model 19.12b



Model 19.12d

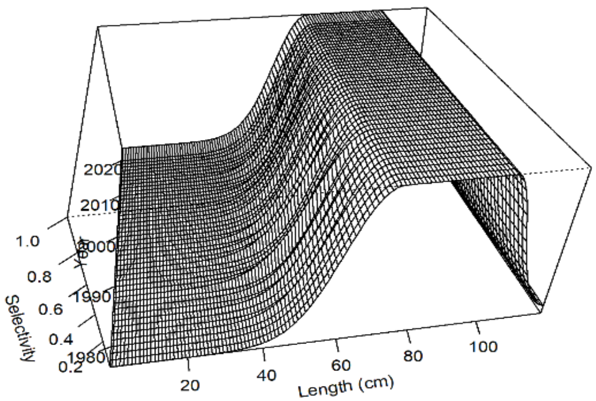




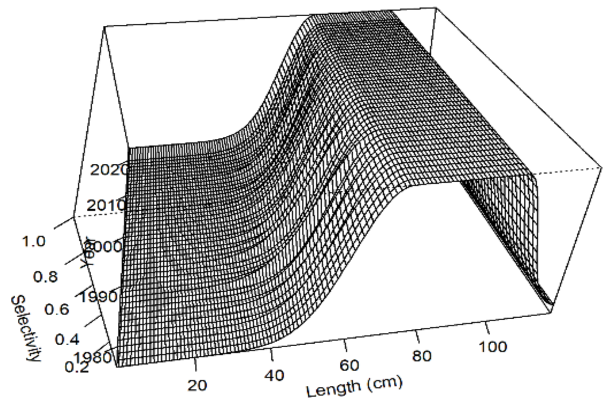
Parameter estimates & derived series (6 of 17)

- Fishery selectivity (2-area models)

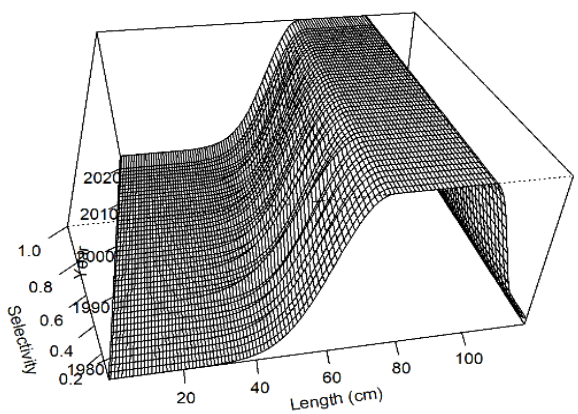
Model 20.1



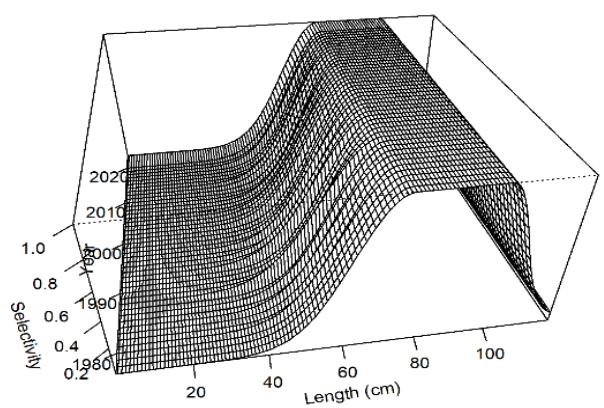
Model 20.2

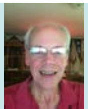


Model 19.12c



Model 20.3

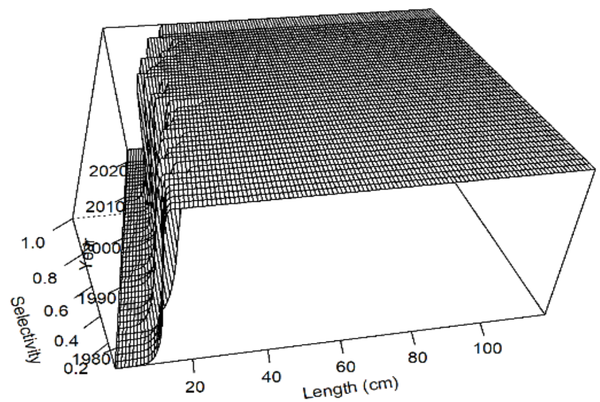




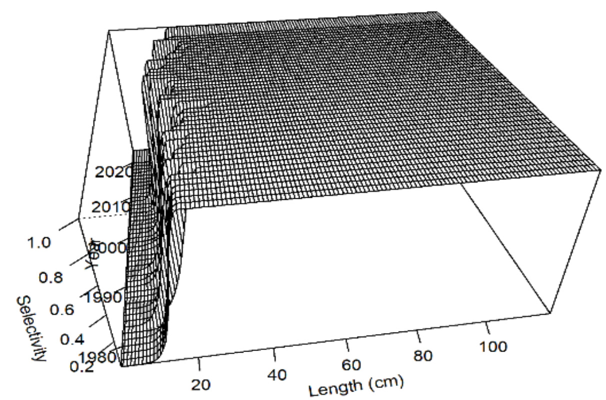
Parameter estimates & derived series (7 of 17)

- “Main” survey selectivity (1-area models)

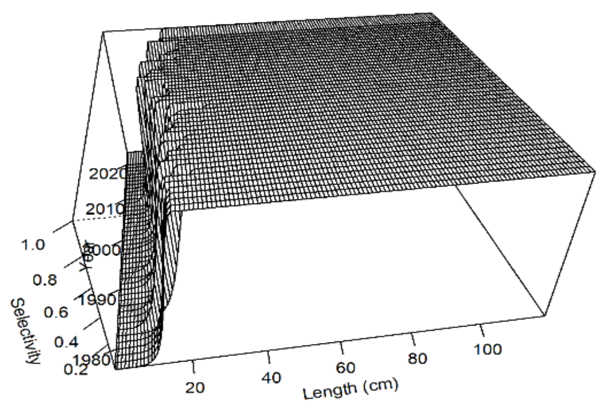
Model 19.12a



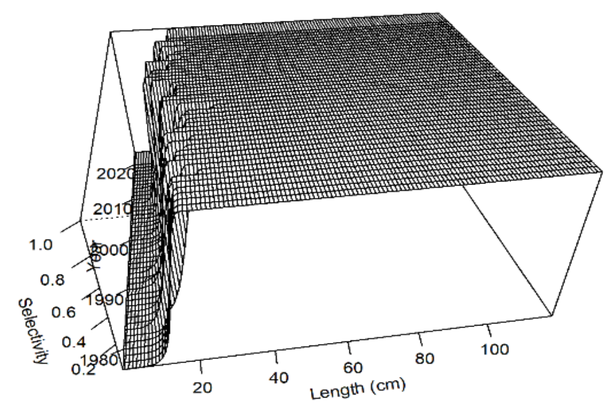
Model 19.12

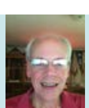


Model 19.12b



Model 19.12d

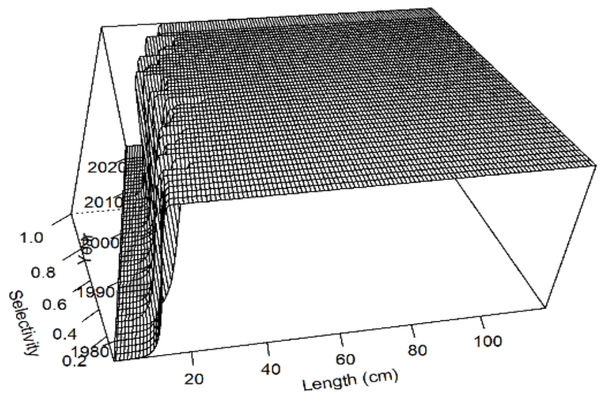




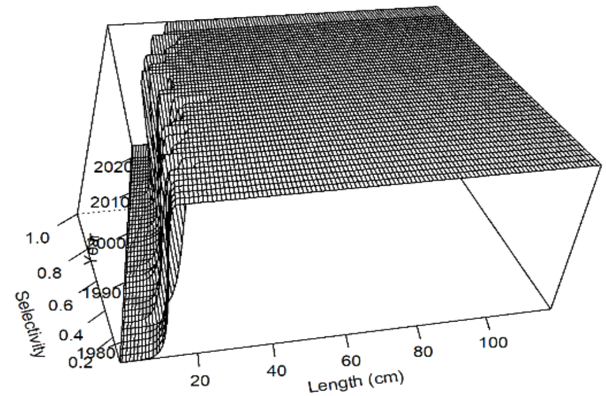
Parameter estimates & derived series (8 of 17)

- “Main” survey selectivity (2-area models)

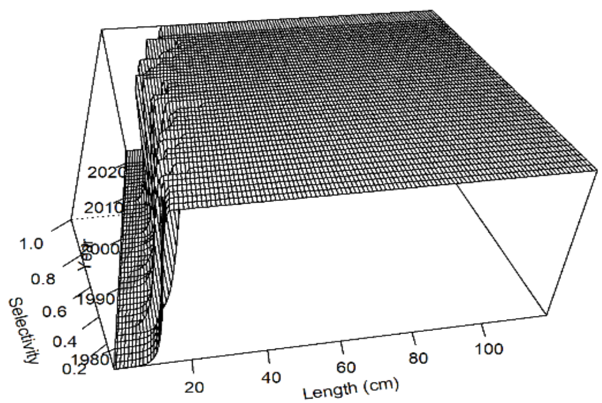
Model 20.1



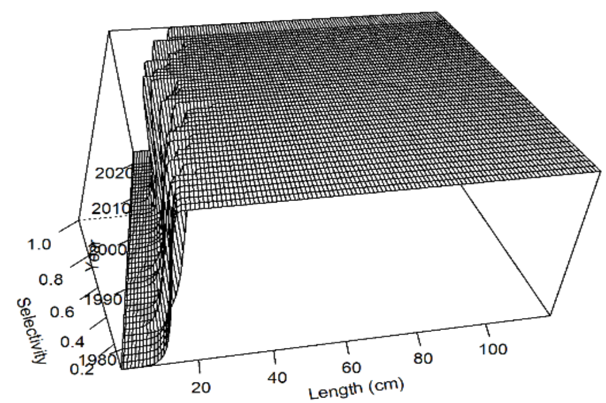
Model 20.2

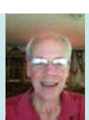


Model 19.12c



Model 20.3

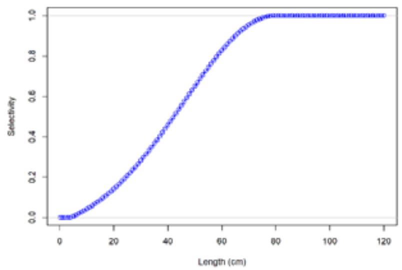




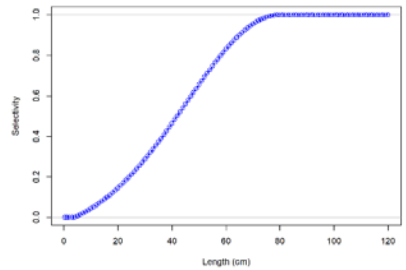
Parameter estimates & derived series (9 of 17)

- NBS survey selectivity (2-survey models)

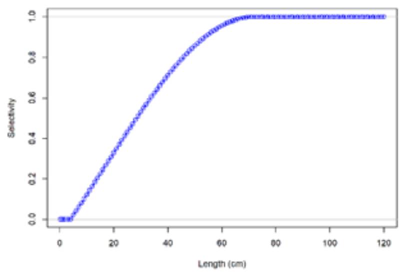
Model 19.12b



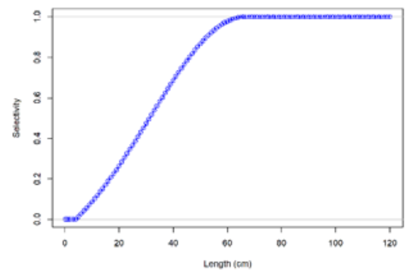
Model 19.12d



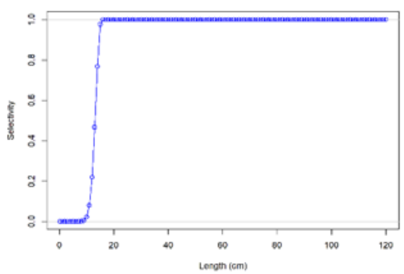
Model 20.1



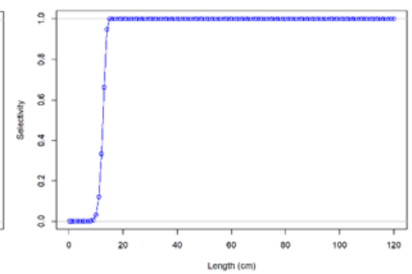
Model 20.2

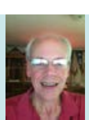


Model 19.12c



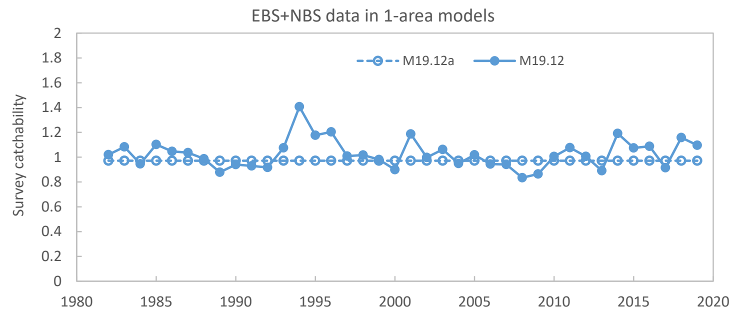
Model 20.3





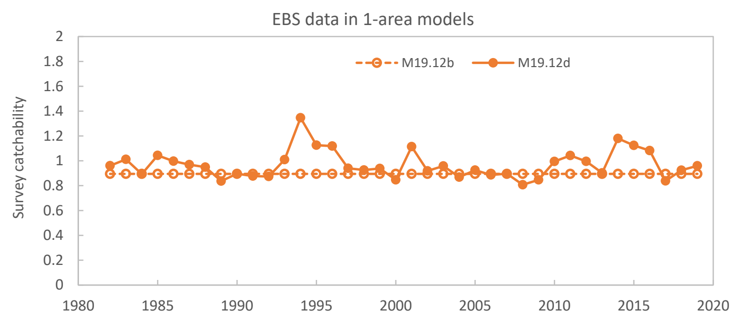
Parameter estimates & derived series (10 of 17)

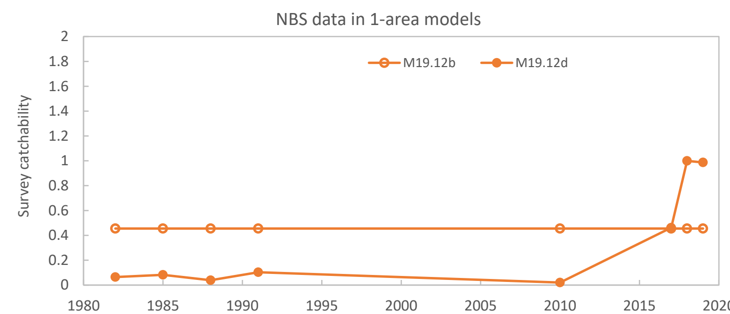
- Survey catchability (F2.1.5)

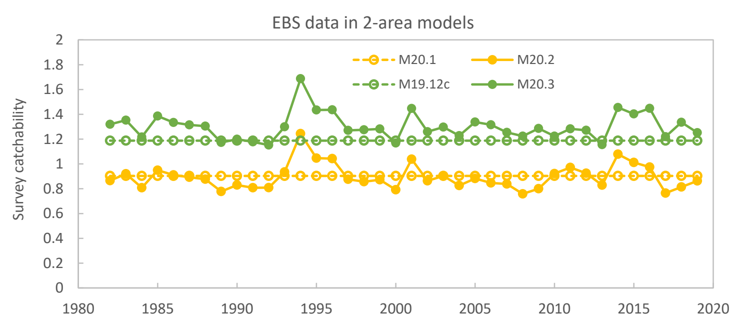


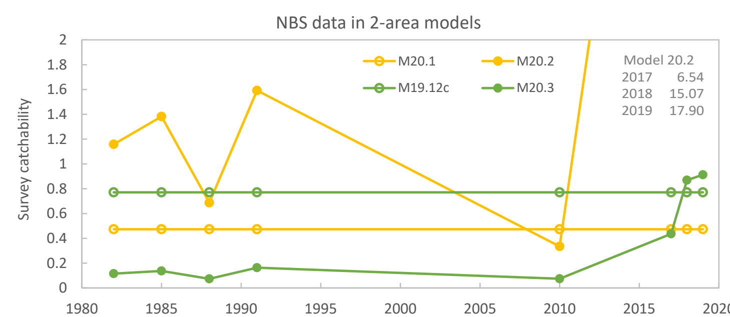
blue = 1-area models *without* separate surveys
orange = 1-area models *with* separate surveys
yellow = 2-area models *without* movement
green = 2-area models *with* movement

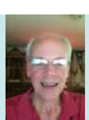
dashed lines with open circles = models *without* time-varying Q
solid lines with filled circles = models *with* time-varying Q







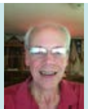




Parameter estimates & derived series (11 of 17)

- Movement probabilities (T2.1.6, slide 1 of 3)

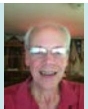
Year	Src.	Dst.	M19.12c						M20.3					
			2	3	4	5	6	7+	2	3	4	5	6	7+
1981	EBS	NBS	0.033	0.005	0.001	0.000	0.000	0.000	0.187	0.019	0.002	0.000	0.000	0.000
	NBS	EBS	0.001	0.004	0.010	0.028	0.075	0.185	0.000	0.001	0.004	0.011	0.035	0.103
1982	EBS	NBS	0.040	0.007	0.001	0.000	0.000	0.000	0.202	0.023	0.002	0.000	0.000	0.000
	NBS	EBS	0.112	0.148	0.192	0.245	0.307	0.378	0.059	0.066	0.074	0.083	0.092	0.103
1983	EBS	NBS	0.022	0.003	0.000	0.000	0.000	0.000	0.156	0.013	0.001	0.000	0.000	0.000
	NBS	EBS	0.000	0.000	0.000	0.000	0.001	0.014	0.000	0.000	0.000	0.000	0.002	0.102
1984	EBS	NBS	0.011	0.001	0.000	0.000	0.000	0.000	0.114	0.007	0.000	0.000	0.000	0.000
	NBS	EBS	0.000	0.000	0.000	0.001	0.008	0.058	0.000	0.000	0.000	0.001	0.009	0.102
1985	EBS	NBS	0.038	0.007	0.001	0.000	0.000	0.000	0.197	0.021	0.002	0.000	0.000	0.000
	NBS	EBS	0.029	0.048	0.081	0.131	0.206	0.308	0.012	0.019	0.029	0.045	0.068	0.103
1986	EBS	NBS	0.048	0.010	0.002	0.000	0.000	0.000	0.217	0.026	0.003	0.000	0.000	0.000
	NBS	EBS	0.000	0.000	0.000	0.000	0.002	0.027	0.000	0.000	0.000	0.000	0.004	0.102
1987	EBS	NBS	0.033	0.005	0.001	0.000	0.000	0.000	0.186	0.019	0.002	0.000	0.000	0.000
	NBS	EBS	0.000	0.000	0.000	0.001	0.006	0.050	0.000	0.000	0.000	0.001	0.008	0.102
1988	EBS	NBS	0.025	0.003	0.000	0.000	0.000	0.000	0.165	0.015	0.001	0.000	0.000	0.000
	NBS	EBS	0.000	0.001	0.004	0.013	0.044	0.141	0.000	0.000	0.001	0.006	0.025	0.103
1989	EBS	NBS	0.075	0.021	0.006	0.001	0.000	0.000	0.260	0.039	0.005	0.001	0.000	0.000
	NBS	EBS	0.676	0.648	0.618	0.588	0.557	0.526	0.592	0.466	0.345	0.241	0.161	0.104
1990	EBS	NBS	0.016	0.001	0.000	0.000	0.000	0.000	0.135	0.010	0.001	0.000	0.000	0.000
	NBS	EBS	0.209	0.244	0.282	0.324	0.369	0.416	0.125	0.120	0.116	0.111	0.107	0.103
1991	EBS	NBS	0.011	0.001	0.000	0.000	0.000	0.000	0.116	0.007	0.000	0.000	0.000	0.000
	NBS	EBS	0.379	0.395	0.411	0.427	0.444	0.460	0.267	0.224	0.187	0.155	0.127	0.103
1992	EBS	NBS	0.014	0.001	0.000	0.000	0.000	0.000	0.126	0.009	0.001	0.000	0.000	0.000
	NBS	EBS	0.000	0.000	0.000	0.001	0.010	0.063	0.000	0.000	0.000	0.001	0.010	0.102
1993	EBS	NBS	0.026	0.003	0.000	0.000	0.000	0.000	0.167	0.015	0.001	0.000	0.000	0.000
	NBS	EBS	0.001	0.004	0.010	0.028	0.076	0.186	0.000	0.001	0.004	0.012	0.035	0.103



Parameter estimates & derived series (12 of 17)

- Movement probabilities (T2.1.6, slide 2 of 3)

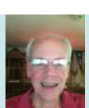
Year	Src.	Dst.	M19.12c 2	M19.12c 3	M19.12c 4	M19.12c 5	M19.12c 6	M19.12c 7+	M20.3 2	M20.3 3	M20.3 4	M20.3 5	M20.3 6	M20.3 7+
1994	EBS	NBS	0.015	0.001	0.000	0.000	0.000	0.000	0.132	0.009	0.001	0.000	0.000	0.000
	NBS	EBS	0.066	0.095	0.136	0.192	0.263	0.349	0.031	0.040	0.051	0.065	0.082	0.103
1995	EBS	NBS	0.005	0.000	0.000	0.000	0.000	0.000	0.078	0.003	0.000	0.000	0.000	0.000
	NBS	EBS	0.001	0.003	0.008	0.022	0.064	0.171	0.000	0.001	0.003	0.009	0.032	0.103
1996	EBS	NBS	0.183	0.101	0.053	0.027	0.014	0.007	0.369	0.088	0.016	0.003	0.000	0.000
	NBS	EBS	0.000	0.000	0.002	0.008	0.032	0.120	0.000	0.000	0.001	0.004	0.021	0.103
1997	EBS	NBS	0.057	0.013	0.003	0.001	0.000	0.000	0.234	0.031	0.003	0.000	0.000	0.000
	NBS	EBS	0.001	0.003	0.009	0.026	0.071	0.180	0.000	0.001	0.003	0.011	0.034	0.103
1998	EBS	NBS	0.011	0.001	0.000	0.000	0.000	0.000	0.117	0.007	0.000	0.000	0.000	0.000
	NBS	EBS	0.000	0.000	0.000	0.000	0.004	0.039	0.000	0.000	0.000	0.000	0.006	0.102
1999	EBS	NBS	0.006	0.000	0.000	0.000	0.000	0.000	0.087	0.004	0.000	0.000	0.000	0.000
	NBS	EBS	0.007	0.016	0.033	0.068	0.134	0.248	0.003	0.006	0.012	0.025	0.051	0.103
2000	EBS	NBS	0.005	0.000	0.000	0.000	0.000	0.000	0.080	0.004	0.000	0.000	0.000	0.000
	NBS	EBS	0.001	0.002	0.006	0.019	0.058	0.163	0.000	0.001	0.002	0.008	0.030	0.103
2001	EBS	NBS	0.134	0.058	0.024	0.009	0.004	0.001	0.327	0.066	0.010	0.001	0.000	0.000
	NBS	EBS	0.000	0.000	0.001	0.003	0.017	0.086	0.000	0.000	0.000	0.002	0.014	0.102
2002	EBS	NBS	0.021	0.002	0.000	0.000	0.000	0.000	0.152	0.013	0.001	0.000	0.000	0.000
	NBS	EBS	0.004	0.009	0.022	0.050	0.110	0.225	0.001	0.003	0.008	0.019	0.045	0.103
2003	EBS	NBS	0.209	0.129	0.076	0.044	0.025	0.014	0.389	0.100	0.019	0.003	0.001	0.000
	NBS	EBS	0.000	0.000	0.000	0.000	0.003	0.031	0.000	0.000	0.000	0.000	0.005	0.102
2004	EBS	NBS	0.130	0.055	0.022	0.009	0.003	0.001	0.323	0.064	0.010	0.001	0.000	0.000
	NBS	EBS	0.001	0.003	0.008	0.022	0.064	0.171	0.000	0.001	0.003	0.009	0.032	0.103
2005	EBS	NBS	0.095	0.031	0.010	0.003	0.001	0.000	0.286	0.048	0.006	0.001	0.000	0.000
	NBS	EBS	0.000	0.001	0.004	0.013	0.045	0.142	0.000	0.000	0.001	0.006	0.026	0.103
2006	EBS	NBS	0.010	0.001	0.000	0.000	0.000	0.000	0.108	0.006	0.000	0.000	0.000	0.000
	NBS	EBS	0.037	0.059	0.094	0.146	0.221	0.319	0.016	0.023	0.034	0.050	0.072	0.103



Parameter estimates & derived series (13 of 17)

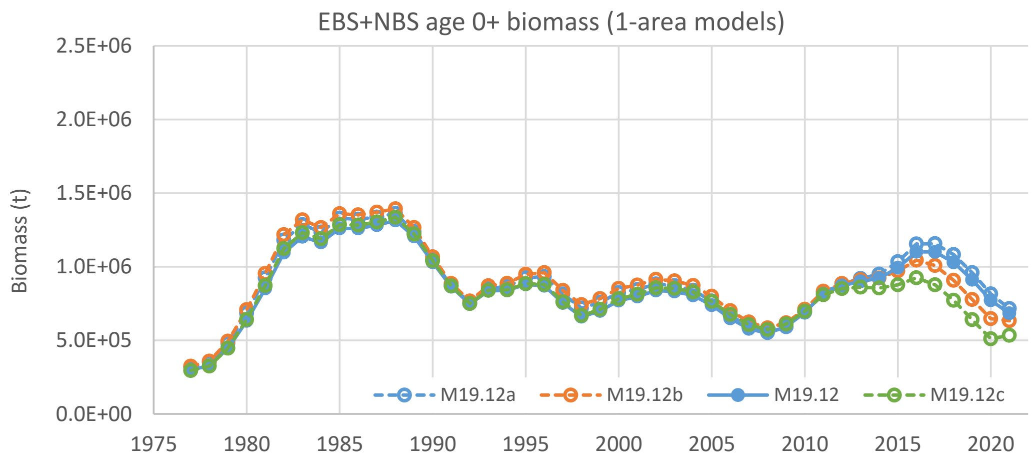
- Movement probabilities (T2.1.6, slide 3 of 3)

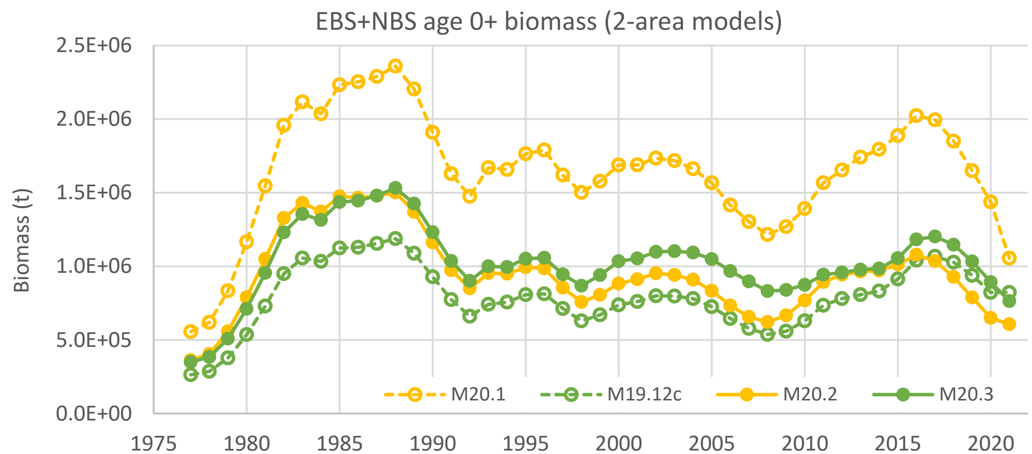
Year	Src.	Dst.	M19.12c						M20.3					
			2	3	4	5	6	7+	2	3	4	5	6	7+
2007	EBS	NBS	0.046	0.009	0.002	0.000	0.000	0.000	0.213	0.025	0.002	0.000	0.000	0.000
	NBS	EBS	0.019	0.034	0.061	0.106	0.180	0.288	0.007	0.013	0.022	0.037	0.062	0.103
2008	EBS	NBS	0.010	0.001	0.000	0.000	0.000	0.000	0.113	0.007	0.000	0.000	0.000	0.000
	NBS	EBS	0.005	0.012	0.026	0.056	0.119	0.234	0.002	0.004	0.009	0.021	0.047	0.103
2009	EBS	NBS	0.006	0.000	0.000	0.000	0.000	0.000	0.085	0.004	0.000	0.000	0.000	0.000
	NBS	EBS	0.993	0.985	0.968	0.931	0.860	0.735	0.994	0.976	0.903	0.683	0.333	0.104
2010	EBS	NBS	0.005	0.000	0.000	0.000	0.000	0.000	0.084	0.004	0.000	0.000	0.000	0.000
	NBS	EBS	0.000	0.000	0.000	0.002	0.010	0.065	0.000	0.000	0.000	0.001	0.010	0.102
2011	EBS	NBS	0.087	0.027	0.008	0.002	0.001	0.000	0.276	0.044	0.006	0.001	0.000	0.000
	NBS	EBS	0.318	0.342	0.367	0.393	0.419	0.446	0.212	0.185	0.161	0.139	0.120	0.103
2012	EBS	NBS	0.001	0.000	0.000	0.000	0.000	0.000	0.033	0.001	0.000	0.000	0.000	0.000
	NBS	EBS	0.061	0.090	0.131	0.186	0.257	0.345	0.029	0.037	0.048	0.063	0.081	0.103
2013	EBS	NBS	0.004	0.000	0.000	0.000	0.000	0.000	0.073	0.003	0.000	0.000	0.000	0.000
	NBS	EBS	0.058	0.087	0.127	0.182	0.254	0.343	0.027	0.036	0.047	0.061	0.080	0.103
2014	EBS	NBS	0.129	0.054	0.022	0.008	0.003	0.001	0.323	0.064	0.010	0.001	0.000	0.000
	NBS	EBS	0.018	0.033	0.059	0.104	0.177	0.286	0.007	0.012	0.021	0.036	0.062	0.103
2015	EBS	NBS	0.290	0.230	0.180	0.138	0.105	0.079	0.441	0.139	0.032	0.007	0.001	0.000
	NBS	EBS	0.000	0.001	0.002	0.009	0.035	0.125	0.000	0.000	0.001	0.004	0.022	0.103
2016	EBS	NBS	0.148	0.068	0.030	0.013	0.006	0.002	0.340	0.072	0.012	0.002	0.000	0.000
	NBS	EBS	0.000	0.000	0.000	0.002	0.011	0.068	0.000	0.000	0.000	0.001	0.011	0.102
2017	EBS	NBS	0.375	0.360	0.346	0.331	0.317	0.304	0.489	0.184	0.050	0.012	0.003	0.001
	NBS	EBS	0.052	0.079	0.118	0.172	0.245	0.337	0.024	0.032	0.043	0.058	0.078	0.103
2018	EBS	NBS	0.876	0.969	0.993	0.998	1.000	1.000	0.767	0.650	0.513	0.374	0.253	0.161
	NBS	EBS	0.978	0.960	0.929	0.878	0.797	0.682	0.978	0.931	0.804	0.556	0.276	0.104
2019	EBS	NBS	0.018	0.020	0.023	0.026	0.029	0.033	0.187	0.019	0.002	0.000	0.000	0.000
	NBS	EBS	0.001	0.004	0.010	0.028	0.075	0.185	0.000	0.001	0.004	0.011	0.035	0.103



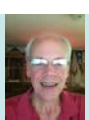
Parameter estimates & derived series (14 of 17)

- Age 0+ biomass time series, combined areas



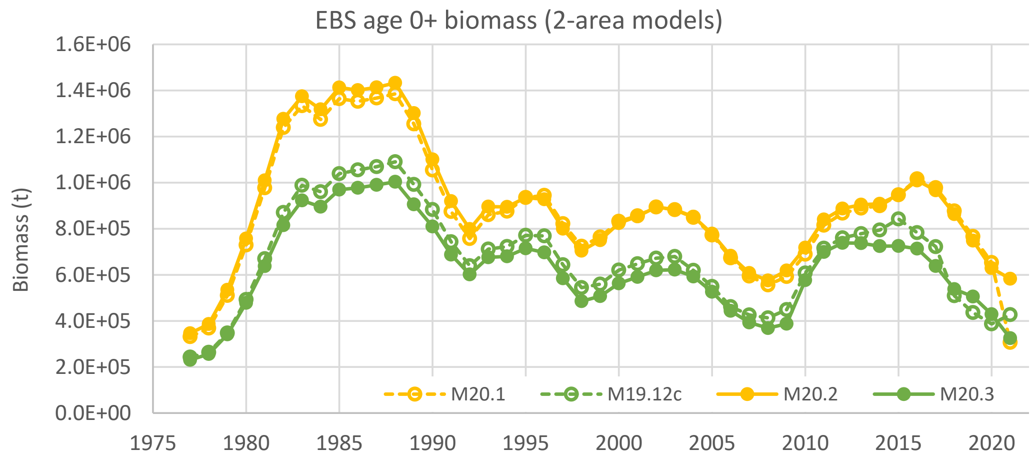


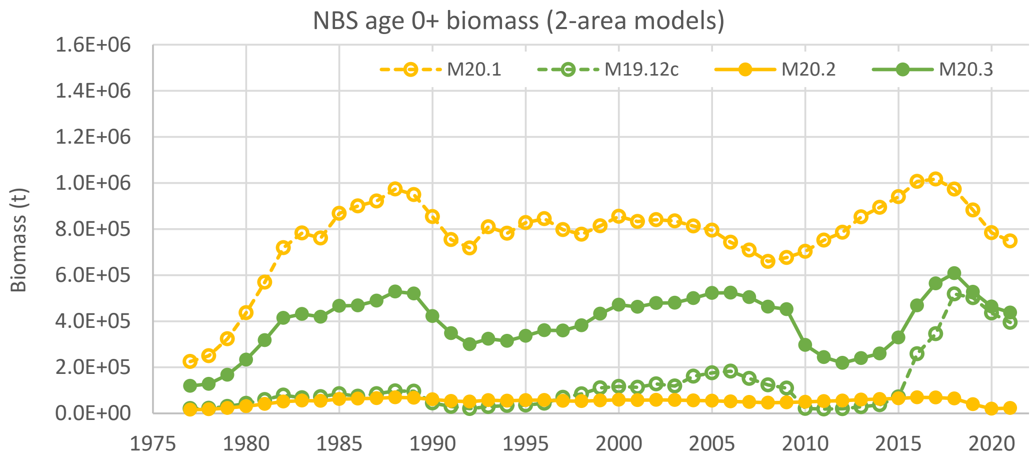
NOAA FISHERIES

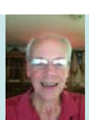


Parameter estimates & derived series (15 of 17)

- Age 0+ biomass time series, separate areas (2-area models only)

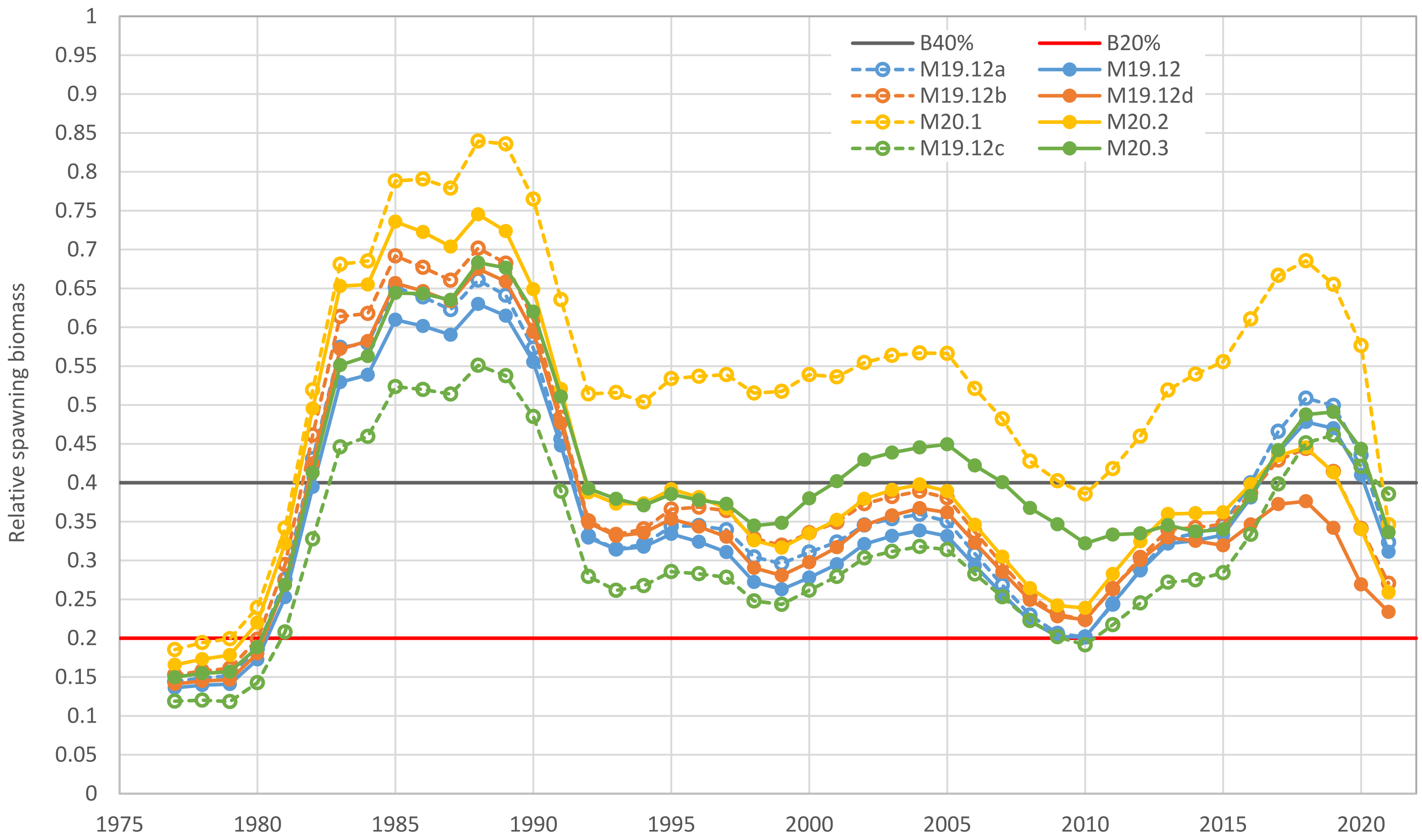


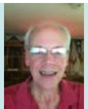




Parameter estimates & derived series (16 of 17)

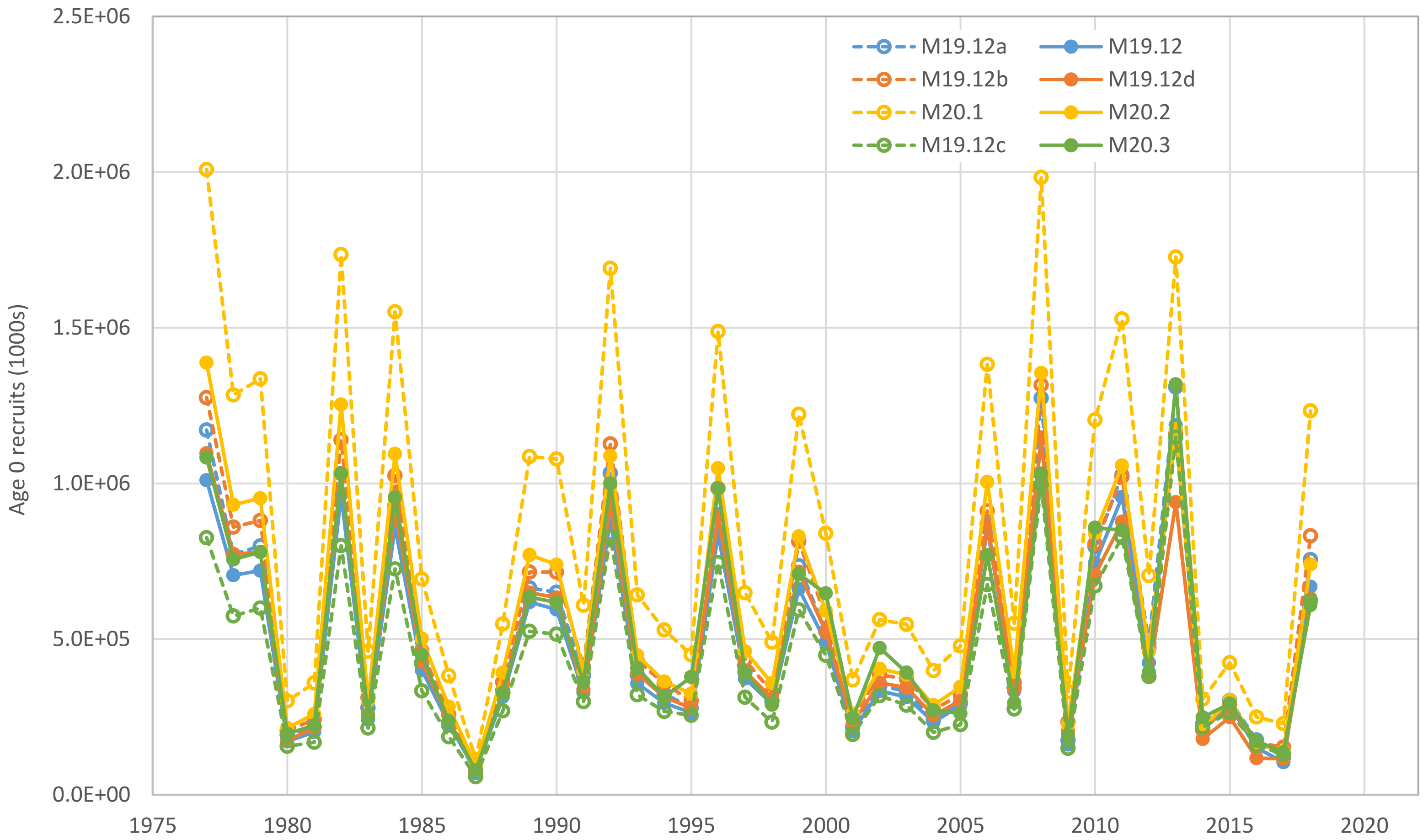
- Relative spawning biomass time series, combined areas

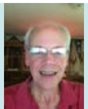




Parameter estimates & derived series (17 of 17)

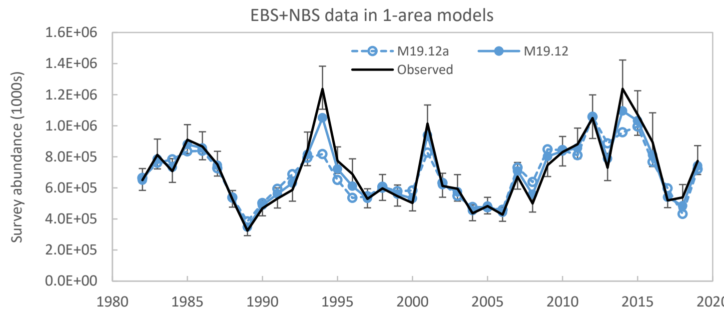
- Age 0 recruitment, combined areas

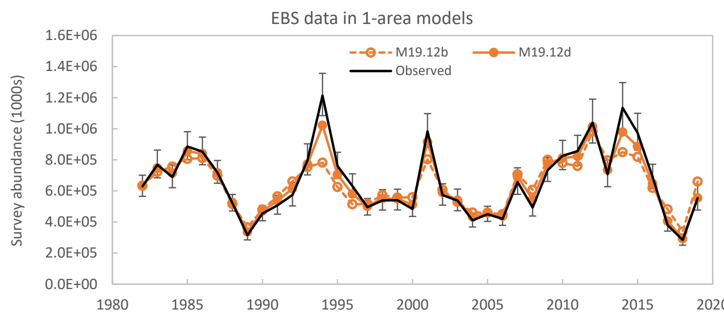


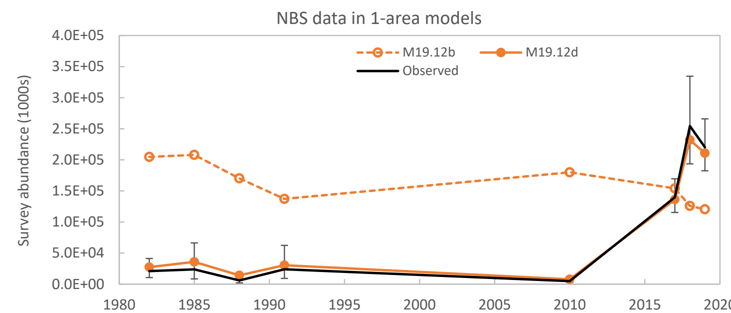


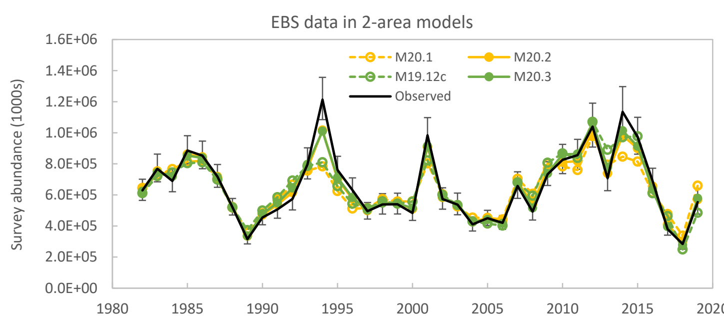
Performance measures (1 of 5)

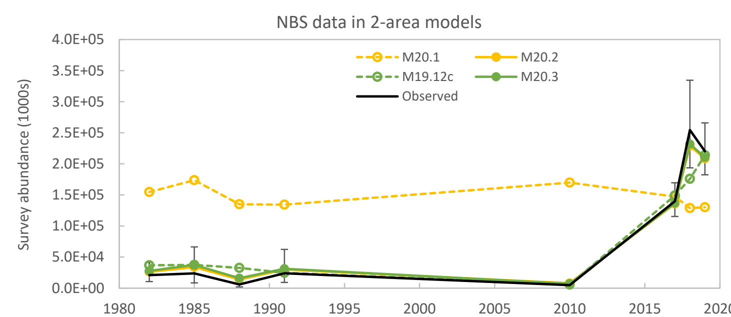
- Fit to survey indices (F2.1.7)

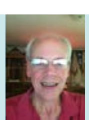








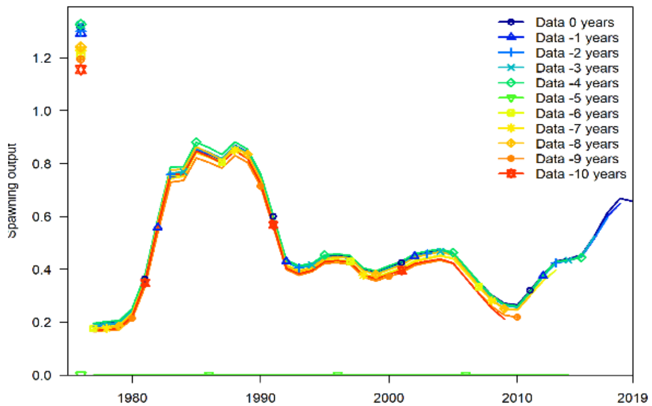




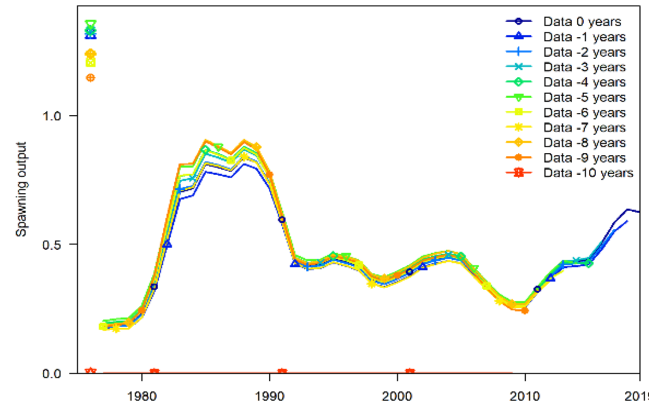
Performance measures (2 of 5)

- Retrospective plots, 1-area models (F2.1.8)

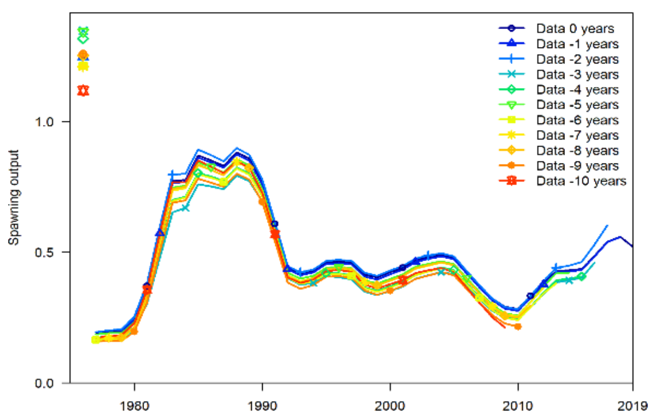
Model 19.12a (ρ = -0.070)



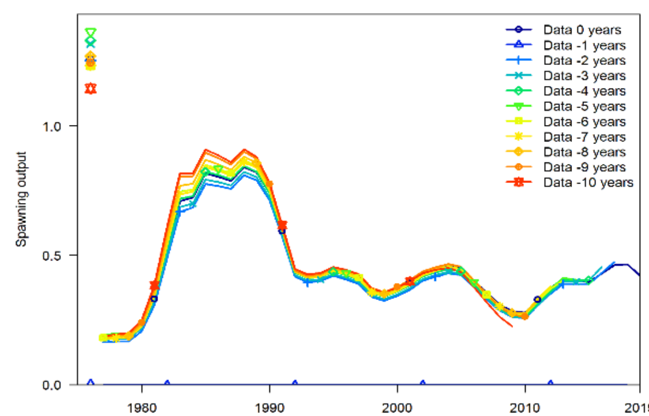
Model 19.12 (ρ = -0.053)

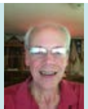


Model 19.12b (ρ = -0.080)



Model 19.12d (ρ = 0.025)

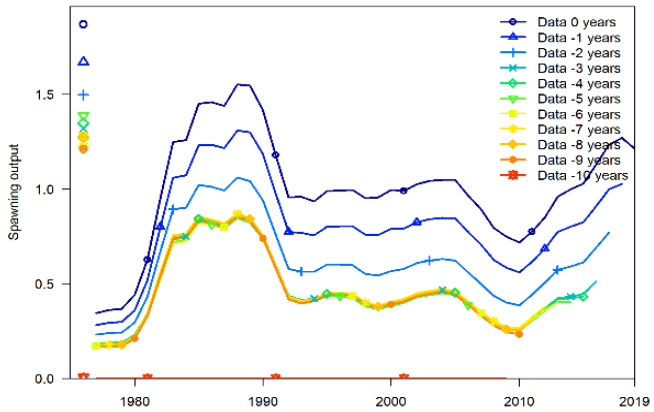




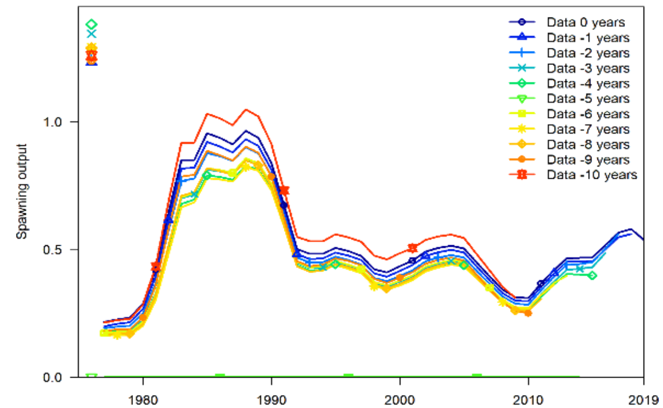
Performance measures (3 of 5)

- Retrospective plots, 2-area models (F2.1.8)

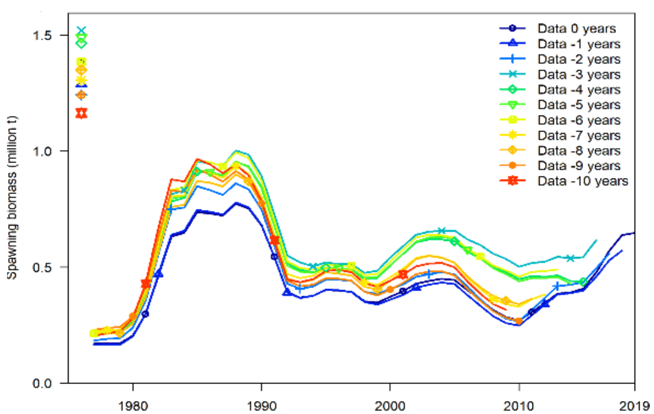
Model 20.1 (ρ = -0.539)



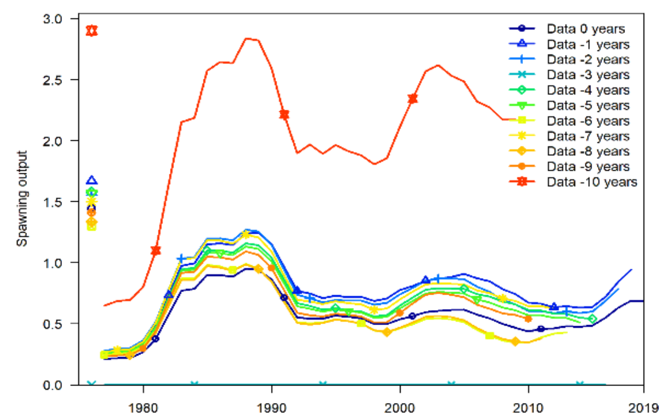
Model 20.2 (ρ = -0.108)



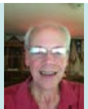
Model 19.12c (ρ = 0.100)



Model 20.3 (ρ = 0.467)



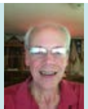
NOAA FISHERIES



Performance measures (4 of 5)

- The value of Mohn's ρ for Model 20.3 is heavily influenced by the 10th peel, which will disappear when the final draft is produced
- Bootstrap estimates of the st. dev. and 95% confidence interval for ρ:

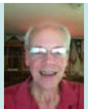
Statistic	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3
mean	-0.070	-0.079	-0.539	0.100	-0.053	-0.025	-0.109	0.466
st. dev.	0.022	0.034	0.045	0.038	0.014	0.023	0.022	0.339
L95%	-0.116	-0.146	-0.615	0.027	-0.081	-0.074	-0.150	0.028
U95%	-0.031	-0.015	-0.443	0.174	-0.028	0.014	-0.065	1.212



Performance measures (5 of 5)

- Goodness of fit summary (T2.1.11)
  - For abundance data, ratio = log-scale RMSE / mean(log-scale SE)
  - For composition data, ratio = $Nsamp / Ninit$

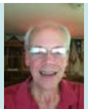
			Area		Ratio of output to input							
Component	Stat.	Type	Actual	Assumed	M19.12a	M19.12b	M20.1	M19.12c	M19.12	M19.12d	M20.2	M20.3
Abundance	RMSE	Survey	EBS	EBS			0.41	0.47			0.99	1.00
Abundance	RMSE	Survey	EBS	XBS		0.41				0.99		
Abundance	RMSE	Survey	NBS	NBS			0.15	0.45			0.78	0.70
Abundance	RMSE	Survey	NBS	XBS		0.14				0.75		
Abundance	RMSE	Survey	XBS	XBS	0.43				0.98			
Sizecomp	N	Fishery	EBS	EBS			1.00	1.00			1.00	1.00
Sizecomp	N	Fishery	EBS	XBS	1.00	1.00			1.00	1.00		
Sizecomp	N	Survey	EBS	EBS			1.00	1.00			1.00	1.00
Sizecomp	N	Survey	EBS	XBS		1.00				1.00		
Sizecomp	N	Survey	NBS	NBS			1.00	1.00			1.00	1.00
Sizecomp	N	Survey	NBS	XBS		1.00				1.00		
Sizecomp	N	Survey	XBS	XBS	1.00				1.00			
Agecomp	N	Survey	EBS	EBS			0.63	0.59			0.63	0.61
Agecomp	N	Survey	EBS	XBS		0.57				0.62		
Agecomp	N	Survey	NBS	NBS			0.18	0.47			0.20	0.34
Agecomp	N	Survey	NBS	XBS		0.56				0.60		
Agecomp	N	Survey	XBS	XBS	0.50				0.52			



Alternative ensemble (1 of 7)

- Final model names for “prior-less” versions of the six 2-survey models
  - Models 19.12a and 19.12 (gray) are common to both ensembles
  - Model 19.15 was already named (last year)

Time-varying *Q* ?	No				Yes			
Separate areas?	No		Yes		No		Yes	
Separate surveys?	No	Yes	Yes		No	Yes	Yes	
Movement?	No		No	Yes	No		No	Yes
ADSB:	0.0755	0.1105	36.5771	0.0724	n/a	n/a	0.1874	0.3642
Model name:	19.12a	20.4	20.5	19.12e	19.12	19.15	20.6	20.7

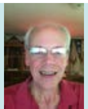


Alternative ensemble (2 of 7)

- Changes in time-invariant parameters, compared to primary (slide 1 of 2)
  - These are parameters that are expressed on the “natural” scale
  - Changes are expressed in *relative* terms (i.e., Alt/Pri – 1)

Time-varying *Q*?	No									Yes								
Separate areas?	No			Yes						No			Yes					
Separate surveys?	Yes			Yes						Yes			Yes					
Movement?	No			No			Yes			No			No			Yes		
Parameter	19.12b	20.4	Δ	20.1	20.5	Δ	19.12c	19.12e	Δ	19.12d	19.15	Δ	20.2	20.6	Δ	20.3	20.7	Δ
Natural_mortality	0.372	0.373	0.004	0.372	0.369	-0.006	0.332	0.332	0.001	0.358	0.359	0.004	0.374	0.373	-0.001	0.344	0.346	0.006
L_at_1.5_base	14.799	14.798	0.000	14.794	14.796	0.000	14.805	14.804	0.000	14.903	14.900	0.000	14.807	14.808	0.000	14.594	14.577	-0.001
L_infinity	114.2	113.5	-0.006	112.9	115.9	0.027	118.2	118.1	0.000	114.6	114.5	-0.001	116.5	116.5	0.000	111.2	111.1	-0.001
VonBert_K	0.117	0.119	0.019	0.118	0.109	-0.074	0.106	0.106	0.000	0.117	0.117	0.000	0.108	0.108	0.000	0.123	0.123	0.002
Richards_coef	1.435	1.427	-0.006	1.444	1.477	0.023	1.480	1.480	0.000	1.419	1.420	0.001	1.479	1.478	0.000	1.438	1.439	0.001
SD_len_at_1	3.483	3.484	0.000	3.466	3.465	0.000	3.481	3.481	0.000	3.473	3.474	0.000	3.485	3.485	0.000	3.490	3.490	0.000
SD_len_at_20	9.945	9.892	-0.005	10.136	10.393	0.025	10.153	10.150	0.000	9.882	9.869	-0.001	10.014	10.017	0.000	9.397	9.384	-0.001
InitF_main_fsh	0.127	0.124	-0.018	0.119	0.119	0.003	0.147	0.147	-0.001	0.134	0.132	-0.011	0.114	0.115	0.004	0.173	0.172	-0.002
InitF_NBS_fsh				0.000	0.000	-0.965	0.000	0.000	-0.005				0.000	0.000	0.040	0.000		
Main_fsh_sel_PeakStart	75.220	75.012	-0.003	74.971	74.889	-0.001	74.982	74.980	0.000	74.986	74.986	0.000	74.931	74.937	0.000	75.968	75.976	0.000
Main_srv_sel_PeakStart_base	21.036	21.054	0.001	20.986	20.932	-0.003	21.110	21.112	0.000	20.699	20.704	0.000	20.970	20.968	0.000	21.827	21.893	0.003
NBS_srv_sel_PeakStart	79.998	79.998	0.000	74.051	73.453	-0.008	15.530	15.528	0.000	79.997	79.996	0.000	68.696	69.355	0.010	14.453	14.418	-0.002

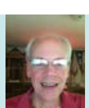
NOAA FISHERIES



Alternative ensemble (3 of 7)

- Changes in time-invariant parameters, compared to primary (slide 2 of 2)
  - These are parameters that are expressed on the whole real line
  - Changes are expressed in *absolute* terms (i.e., Alt – Pri)

Time-varying Q?	No									Yes								
Separate areas?	No			Yes						No			Yes					
Separate surveys?	Yes			Yes						Yes			Yes					
Movement?	No			No			Yes			No			No			Yes		
Parameter	19.12b	20.4	Δ	20.1	20.5	Δ	19.12c	19.12e	Δ	19.12d	19.15	Δ	20.2	20.6	Δ	20.3	20.7	Δ
RecrDist_NBS_base				-0.676	2.691	3.367	-3.037	-3.033	0.004				-3.345	-3.382	-0.037	-1.690	-1.640	0.050
AgeBias_at_1_1977_2007	0.349	0.349	0.000	0.349	0.348	-0.001	0.347	0.347	0.000	0.347	0.347	0.000	0.348	0.348	0.000	0.346	0.347	0.001
AgeBias_at_1_2008_2019	-0.002	-0.002	0.000	0.001	0.001	0.000	0.009	0.009	0.000	0.002	0.002	0.000	0.004	0.004	0.000	0.008	0.007	-0.001
AgeBias_at_20_1977_2007	0.776	0.771	-0.005	0.772	0.782	0.010	0.843	0.842	0.000	0.804	0.802	-0.002	0.825	0.825	0.000	0.954	0.954	0.000
AgeBias_at_20_2008_2019	-1.697	-1.700	-0.003	-1.646	-1.648	-0.002	-1.698	-1.698	0.000	-1.930	-1.932	-0.003	-1.790	-1.790	0.000	-2.179	-2.201	-0.022
ln(Recr_ave_1977_2018)	13.271	13.285	0.014	13.678	16.000	2.321	12.991	12.993	0.002	13.144	13.157	0.013	13.313	13.308	-0.005	13.185	13.220	0.034
ln(Recr_ave_pre1977_offset)	-0.885	-0.877	0.008	-0.862	-0.866	-0.004	-0.986	-0.986	0.001	-0.909	-0.903	0.006	-0.839	-0.841	-0.002	-0.919	-0.912	0.007
lnQ_main_srv_base	-0.111	-0.121	-0.010	-0.102	-0.085	0.017	0.172	0.171	-0.001	-0.037	-0.046	-0.009	-0.116	-0.114	0.002	0.261	0.254	-0.007
lnQ_NBS_srv_base	-0.788	-0.804	-0.016	-0.747	-4.122	-3.375	-0.260	-0.265	-0.005	-1.842	-1.967	-0.125	0.827	0.933	0.106	-1.466	-1.618	-0.151
Main_fsh_sel_logitPeakWidth	-5.712	-9.672	-3.960	-9.439	0.434	9.873	0.208	0.208	0.001	-9.761	-9.772	-0.011	0.469	0.470	0.001	0.097	0.093	-0.004
Main_fsh_sel_lnSD1_base	5.913	5.903	-0.010	5.898	5.892	-0.006	5.907	5.907	0.000	5.905	5.905	0.000	5.896	5.896	0.000	5.950	5.951	0.000
Main_fsh_sel_lnSD2	-1.410	-9.947	-8.537	-9.091	4.406	13.497	4.707	4.707	0.000	-9.886	-9.880	0.006	4.345	4.342	0.00	4.827	4.829	0.00
Main_fsh_sel_logitEnd_base	1.987	2.000	0.013	3.114	-2.759	-5.873	-3.140	-3.137	0.003	2.084	2.079	-0.006	-2.647	-2.643	0.005	-2.855	-2.860	-0.005
Main_srv_sel_lnSD1_base	3.532	3.535	0.003	3.522	3.512	-0.010	3.535	3.535	0.000	3.460	3.460	0.000	3.513	3.513	0.000	3.613	3.620	0.006
NBS_srv_sel_lnSD1	7.784	7.790	0.006	8.881	8.930	0.049	2.067	2.066	-0.001	7.821	7.834	0.014	7.925	7.922	-0.003	1.750	1.738	-0.012
lnDM_size_main_fish	9.989	9.989	0.000	9.989	9.990	0.001	9.990	9.990	0.000	9.989	9.989	0.000	9.990	9.990	0.000	9.989	9.989	0.000
lnDM_size_main_sur	9.984	9.984	0.000	9.985	9.984	-0.001	9.984	9.984	0.000	9.984	9.984	0.000	9.985	9.985	0.000	9.984	9.984	0.000
lnDM_size_NBS_sur	9.656	9.655	0.000	9.717	9.714	-0.003	9.923	9.924	0.002	9.756	9.687	-0.069	9.712	9.712	0.000	9.935	9.936	0.001
lnDM_age_main_srv	0.281	0.252	-0.029	0.444	0.520	0.076	0.478	0.475	-0.002	0.432	0.419	-0.013	0.522	0.527	0.005	0.541	0.540	0.000
lnDM_age_NBS_srv	0.213	0.196	-0.017	-1.511	-1.528	-0.016	0.381	0.377	-0.005	0.383	0.380	-0.003	-1.342	-1.346	-0.004	-0.201	-0.192	0.009



Alternative ensemble (4 of 7)

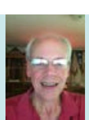
- Relative change in age 0+ biomass (Alt/Pri – 1), combined areas:

Q vary?	No			Yes		
2 area?	No	Yes		No	Yes	
2 srv?	Yes	Yes		Yes	Yes	
Move?	No	No	Yes	No	No	Yes
Pri. model	M19.12b	M20.1	M19.12c	M19.12d	M20.2	M20.3
Alt. model	M20.4	M20.5	M19.12e	M19.5	M20.6	M20.7
Ave. change	0.0120	13.2172	0.0014	0.0095	-0.0045	0.0362

- Relative change in age 0+ biomass (Alt/Pri – 1), separate areas:

Area:	Eastern Bering Sea				Northern Bering sea			
Q vary?	No		Yes		No		Yes	
2 area?	Yes		Yes		Yes		Yes	
2 srv?	Yes		Yes		Yes		Yes	
Move?	No	Yes	No	Yes	No	Yes	No	Yes
Pri. mod.	M20.1	M19.12c	M20.2	M20.3	M20.1	M19.12c	M20.2	M20.3
Alt. mod.	M20.5	M19.12e	M20.6	M20.7	M20.5	M19.12e	M20.6	M20.7
Ave. chg.	-0.0200	0.0010	-0.0025	0.0071	27.9210	0.0044	-0.0399	0.0830

NOAA FISHERIES

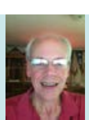


Alternative ensemble (5 of 7)

- Objective function comparison (Alt – Pri), major components:

Time-varying *Q* ?	No			Yes		
Separate areas?	No	Yes		No	Yes	
Separate surveys?	Yes	Yes		Yes	Yes	
Movement?	No	No	Yes	No	No	Yes
Primary model	M19.12b	M20.1	M19.12c	M19.12d	M20.2	M20.3
Alternative model	M20.4	M20.5	M19.12e	M19.15	M20.6	M20.7
Catch	0.00	0.00	0.00	0.00	0.00	0.00
Initial_eq_catch	0.00	0.00	0.00	0.00	0.00	0.00
Survey index	-0.31	-1.08	-0.02	-0.39	0.20	-0.39
Size composition	-0.74	-1.20	0.00	-0.22	-0.09	0.60
Age composition	0.39	-0.48	0.04	0.34	-0.11	-0.44
Recruitment	-0.01	0.06	0.00	0.02	-0.01	-0.01
Initial_eq_recr	-0.11	0.10	-0.02	-0.11	0.03	-0.17
Priors	-0.23	-0.21	-0.09	-1.64	-0.46	-1.52
"Softbounds"	0.01	0.00	0.00	0.00	0.00	0.00
Deviations	0.17	0.27	-0.01	0.24	-0.06	0.27
Total	-0.84	-2.55	-0.09	-1.76	-0.50	-1.65

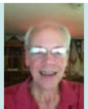
NOAA FISHERIES



Alternative ensemble (6 of 7)

- Objective function comparison (Alt – Pri), subcomponents:

Time-varying *Q* ?			No			Yes		
Separate areas?			No	Yes		No	Yes	
Separate surveys?			Yes	Yes		Yes	Yes	
Movement?			No	No	Yes	No	No	Yes
Primary model			M19.12b	M20.1	M19.12c	M19.12d	M20.2	M20.3
Alternative model			M20.4	M20.5	M19.12e	M19.15	M20.6	M20.7
Index	Survey	Main	-0.14	0.31	-0.06	-0.01	-0.01	-0.09
		NBS	-0.17	-1.39	0.04	-0.38	0.21	-0.30
		Total	-0.31	-1.08	-0.02	-0.39	0.20	-0.39
Sizecomp	Fishery	Main	-0.64	-3.04	0.04	0.01	-0.04	0.32
		NBS		0.00	0.00		0.00	0.00
	Survey	Main	0.19	0.28	-0.05	-0.17	0.07	-0.47
		NBS	-0.30	1.56	0.01	-0.06	-0.13	0.75
	All	Total	-0.74	-1.20	0.00	-0.22	-0.09	0.60
Agecomp	Survey	Main	0.41	-0.72	0.03	0.30	-0.08	-0.20
		NBS	-0.03	0.25	0.01	0.04	-0.03	-0.24
		Total	0.39	-0.48	0.04	0.34	-0.11	-0.44



Alternative ensemble (7 of 7)

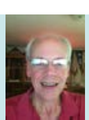
- Mohn's ρ values for the primary ensemble (reprise):

Statistic	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3
mean	-0.070	-0.079	-0.539	0.100	-0.053	-0.025	-0.109	0.466
st. dev.	0.022	0.034	0.045	0.038	0.014	0.023	0.022	0.339
L95%	-0.116	-0.146	-0.615	0.027	-0.081	-0.074	-0.150	0.028
U95%	-0.031	-0.015	-0.443	0.174	-0.028	0.014	-0.065	1.212

- Mohn's ρ values for the alternative ensemble, for comparison:

Statistic	19.12a	20.4	20.5	19.12e	19.12	19.15	20.6	20.7
mean	-0.070	-0.094	-0.012	0.790	-0.053	-0.034	-0.013	0.052
st. dev.	0.022	0.032	0.012	0.329	0.014	0.023	0.038	0.075
L95%	-0.116	-0.158	-0.036	0.231	-0.081	-0.082	-0.078	-0.091
U95%	-0.031	-0.034	0.010	1.509	-0.028	0.006	0.068	0.199

NOAA FISHERIES

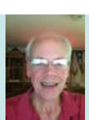


Cross-conditional decision analysis

Introduction to CCDA (1 of 2)

- CCDA was introduced during the September 2019 Team meeting
- Briefly, CCDA is a systematic method for answering a question that regularly plagues attempts to choose a single model from a set of alternatives, namely, *“But what if we’re wrong?”*
- CCDA answers this question by considering not only the performance of a given model within the ensemble when the structure of that model is the “true” one, but also the performance of that model when any of the *other* models in the ensemble is the “true” one, repeating this process for each model in the ensemble
- Performances are measured by generating a series of bootstrap data sets from each fitted model, then applying each model to each data set and comparing the respective estimates of the quantity of interest to the best estimate from the model that generated the bootstrap data (the “pivot” model)

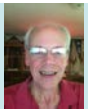
NOAA FISHERIES



Introduction to CCDA (2 of 2)

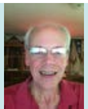
- Those performances, together with a set of user-specified values representing the subjective probabilities that each of the models in the ensemble is the “true” one, are then used to estimate a set of model weights that optimize the performance of the overall ensemble
- This results in a probability mass function, *pmf*, for the estimated quantity
- Finally, decision theory is then used to obtain an optimal point estimate, given the *pmf* and a specified level of risk aversion, *ra*, where $ra<0$ implies risk proclivity, $ra=0$ implies risk neutrality, and $ra>0$ represents true risk aversion
- A full description of the steps involved is given in Attachment 2.1.3

NOAA FISHERIES



Overview of this application of CCDA

- CCDA was applied here to the primary ensemble for the purpose of developing preliminary estimates of the OFL and ABC for 2021
- Due to time constraints, a fairly small sample of 10 bootstrap data sets was generated from each of the 8 models in the ensemble
- When each of the 8 models was fit to each of the 8×10 bootstrap data sets, the estimates of 2021 OFL shown in T2.1.18 resulted
  - See next slide for an example subset

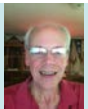


Bootstrap estimates

- Example subset of T2.1.18; values are for 2021 OFL (millions of t)

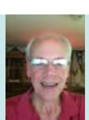
Pivot	Bootstrap	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3
19.12a	1	0.173737	0.086842	0.205788	0.117112	0.182797	0.347790	0.155245	0.123295
19.12a	2	0.130955	0.612486	0.183632	0.159884	0.137460	0.460267	0.118251	0.084947
19.12a	3	0.144781	0.888500	0.174957	0.175976	0.139972	0.503465	0.128246	0.098897
19.12a	4								
19.12a	5	0.140907	0.813571	0.188078	0.169968	0.149442	0.720794	0.125180	0.091742
19.12a	6	0.123061	0.635104	0.184306	0.081843	0.123493	0.327995	0.114028	0.081357
19.12a	7								
19.12a	8	0.135166	0.696681	0.168117	0.088548	0.141402	0.449962	0.121584	0.098517
19.12a	9	0.156612	1.976270	0.199516	0.109585	0.161574	0.740566	0.142221	0.113775
19.12a	10	0.145384	0.645751	0.162544	0.137253	0.150044	0.330400	0.124064	0.095015
19.12a	Mean:	0.143825	0.794401	0.183367	0.130021	0.148273	0.485155	0.128602	0.098443
19.12b	1								
19.12b	2	0.152494	0.094537	0.155844	0.102819	0.148098	0.102465	0.173651	0.098581
19.12b	3	0.189535	0.129290	0.174717	0.151174	0.170709	0.126970	0.192962	0.160842
19.12b	4	0.170058	0.106575	0.177122	0.123438	0.159576	0.109069	0.175323	0.127174
19.12b	5	0.188338	0.119969	0.175631	0.120163	0.178696	0.125905	0.181572	0.208493
19.12b	6	0.174678	0.113795	0.163867	0.230344	0.158695	0.116166	0.188448	0.120425
19.12b	7	0.138569	0.092467	0.156156	0.096059	0.127208	0.091422	0.147605	0.113901
19.12b	8	0.178934	0.107990	0.149150	0.117374	0.154957	0.109561	0.177806	0.119380
19.12b	9	0.169921	0.110958	0.168141	0.117143	0.154050	0.110399	0.162895	0.118692
19.12b	10	0.214668	0.124157	0.200153	0.131974	0.190791	0.122530	0.203910	0.139028
19.12b	Mean:	0.175244	0.111082	0.168976	0.132276	0.160309	0.112721	0.178241	0.134057

NOAA FISHERIES



Model probabilities (1 of 2)

- The probability that any given model in the ensemble is the “true” one was based on scores that were derived from factor-specific formulas that considered the following:
  - The extent to which the model structure seems consistent with observed inter-area trends
  - Goodness of fit
  - Retrospective performance (Mohn’s ρ)
  - The extent to which the time series of catchability (combined area or by separate areas) deviates from unity

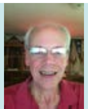


Model probabilities (2 of 2)

- The details of the formulas are omitted here in the interest of brevity, given that the choice of functional forms was ultimately subjective, but the resulting scores are shown below:

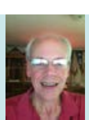
Model	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3
Structure	0.667	0.667	0.333	0.667	1.000	1.000	0.667	1.000
Fit	0.838	0.764	0.712	0.813	1.000	0.972	0.912	0.922
Mohn's ρ	0.956	0.947	0.598	0.927	0.972	1.000	0.920	0.643
Catchability	1.000	0.762	0.673	0.829	0.962	0.824	0.514	0.425
Mean	0.865	0.785	0.579	0.809	0.984	0.949	0.753	0.747
Probability	0.134	0.121	0.089	0.125	0.152	0.147	0.116	0.115

- The arithmetic mean of the scores was used as the basis for assigning the probabilities (by rescaling so that the values sum to unity), following the recommendation of the SSC (see comment SSC6)



Performance weights (1 of 4)

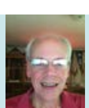
- An important distinction in CCDA is that the probability of a given model being the “true” one is not necessarily equal to, or even related to, how well that model performs when either it or one of the other models in the ensemble is *actually* the true model
- The latter concept is represented in CCDA by a vector of model *weights* (as distinguished from probabilities)
- The model weights are used to form a conditional mean squared error (CMSE) for each pivot model, where the weighted average is computed across models for each bootstrap data set, and then the bootstrap-specific weighted average squared errors are averaged across bootstrap data sets (without weighting, because the bootstrap data sets for a given pivot model are considered to be a random sample)
- T2.1.19 shows example calculations for the equal-weight case
  - See next slide for an example subset



Performance weights (2 of 4)

- Example subset of T2.1.19, where the values in each column labeled by a model number are 1/8th of the values in T2.1.8

Pivot	Boot.	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3	Sum	Best	SqErr
19.12a	1	0.0217	0.0109	0.0257	0.0146	0.0228	0.0435	0.0194	0.0154	0.1741	0.1438	0.0009
19.12a	2	0.0164	0.0766	0.0230	0.0200	0.0172	0.0575	0.0148	0.0106	0.2360	0.1438	0.0085
19.12a	3	0.0181	0.1111	0.0219	0.0220	0.0175	0.0629	0.0160	0.0124	0.2818	0.1438	0.0191
19.12a	4											
19.12a	5	0.0176	0.1017	0.0235	0.0212	0.0187	0.0901	0.0156	0.0115	0.3000	0.1438	0.0244
19.12a	6	0.0154	0.0794	0.0230	0.0102	0.0154	0.0410	0.0143	0.0102	0.2089	0.1438	0.0042
19.12a	7											
19.12a	8	0.0169	0.0871	0.0210	0.0111	0.0177	0.0562	0.0152	0.0123	0.2375	0.1438	0.0088
19.12a	9	0.0196	0.2470	0.0249	0.0137	0.0202	0.0926	0.0178	0.0142	0.4500	0.1438	0.0938
19.12a	10	0.0182	0.0807	0.0203	0.0172	0.0188	0.0413	0.0155	0.0119	0.2238	0.1438	0.0064
19.12a	Mean:											0.0207
19.12b	1											
19.12b	2	0.0191	0.0118	0.0195	0.0129	0.0185	0.0128	0.0217	0.0123	0.1286	0.1111	0.0003
19.12b	3	0.0237	0.0162	0.0218	0.0189	0.0213	0.0159	0.0241	0.0201	0.1620	0.1111	0.0026
19.12b	4	0.0213	0.0133	0.0221	0.0154	0.0199	0.0136	0.0219	0.0159	0.1435	0.1111	0.0011
19.12b	5	0.0235	0.0150	0.0220	0.0150	0.0223	0.0157	0.0227	0.0261	0.1623	0.1111	0.0026
19.12b	6	0.0218	0.0142	0.0205	0.0288	0.0198	0.0145	0.0236	0.0151	0.1583	0.1111	0.0022
19.12b	7	0.0173	0.0116	0.0195	0.0120	0.0159	0.0114	0.0185	0.0142	0.1204	0.1111	0.0001
19.12b	8	0.0224	0.0135	0.0186	0.0147	0.0194	0.0137	0.0222	0.0149	0.1394	0.1111	0.0008
19.12b	9	0.0212	0.0139	0.0210	0.0146	0.0193	0.0138	0.0204	0.0148	0.1390	0.1111	0.0008
19.12b	10	0.0268	0.0155	0.0250	0.0165	0.0238	0.0153	0.0255	0.0174	0.1659	0.1111	0.0030
19.12b	Mean:											0.0015



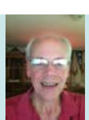
Performance weights (3 of 4)

- The CMSE for a given pivot model describes the performance of the ensemble, conditional on that pivot model being the true model
- Given the CMSE for each pivot model, an ensemble mean squared error is calculated as the sum of the product of the model CMSEs and the model probabilities, which describes the expected (not conditional) performance of the ensemble
- The results for the equal weighting example are shown below:

Model:	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3
probability	0.1337	0.1213	0.0895	0.1250	0.1520	0.1467	0.1164	0.1155
CMSE:	0.0207	0.0015	0.0001	0.0005	0.0215	0.0018	0.0014	0.0002
probability×CMSE:	0.0028	0.0002	0.0000	0.0001	0.0033	0.0003	0.0002	0.0000

- The sum of the values on the bottom row (=0.0067, or -5.0007 on the log scale) is the ensemble MSE when equal weights are used

NOAA FISHERIES



Performance weights (4 of 4)

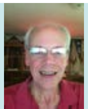
- However, a central feature of CCDA is that the model weights are estimated statistically by minimizing the ensemble MSE
- The model weights estimated in this application are shown below:

Model	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3
Weight	0.000	0.012	0.000	0.244	0.000	0.060	0.000	0.684

- T2.1.20 shows the results of calculations analogous to those in T2.1.19 when the optimized model weights are used instead of equal weighting
- The CMSE values from T2.1.20 are then multiplied by the model probabilities as shown below:

Model:	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3
probability	0.1337	0.1213	0.0895	0.1250	0.1520	0.1467	0.1164	0.1155
CMSE:	0.0004	0.0010	0.0005	0.0002	0.0006	0.0006	0.0003	0.0002
probability×CMSE:	0.0001	0.0001	0.0000	0.0000	0.0001	0.0001	0.0000	0.0000

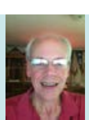
- The sum of the values on the bottom row (=0.0005, or -7.6132 on the log scale) is the ensemble MSE when the optimized weights are used



Model-specific weighted average *pmf*s (1 of 2)

- For a given pivot model, the OFL estimates in each column of the corresponding section of T2.1.18 can be converted into a scaled histogram, which can then be weighted by the respective performance weight, and then the columns can be summed to generate a conditional weighted average *pmf* for that pivot model
- These are shown in T2.1.21
  - See next slide for an example subset

NOAA FISHERIES

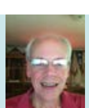


Model-specific weighted average ***pmfs*** (2 of 2)

- Example subset of T2.1.19

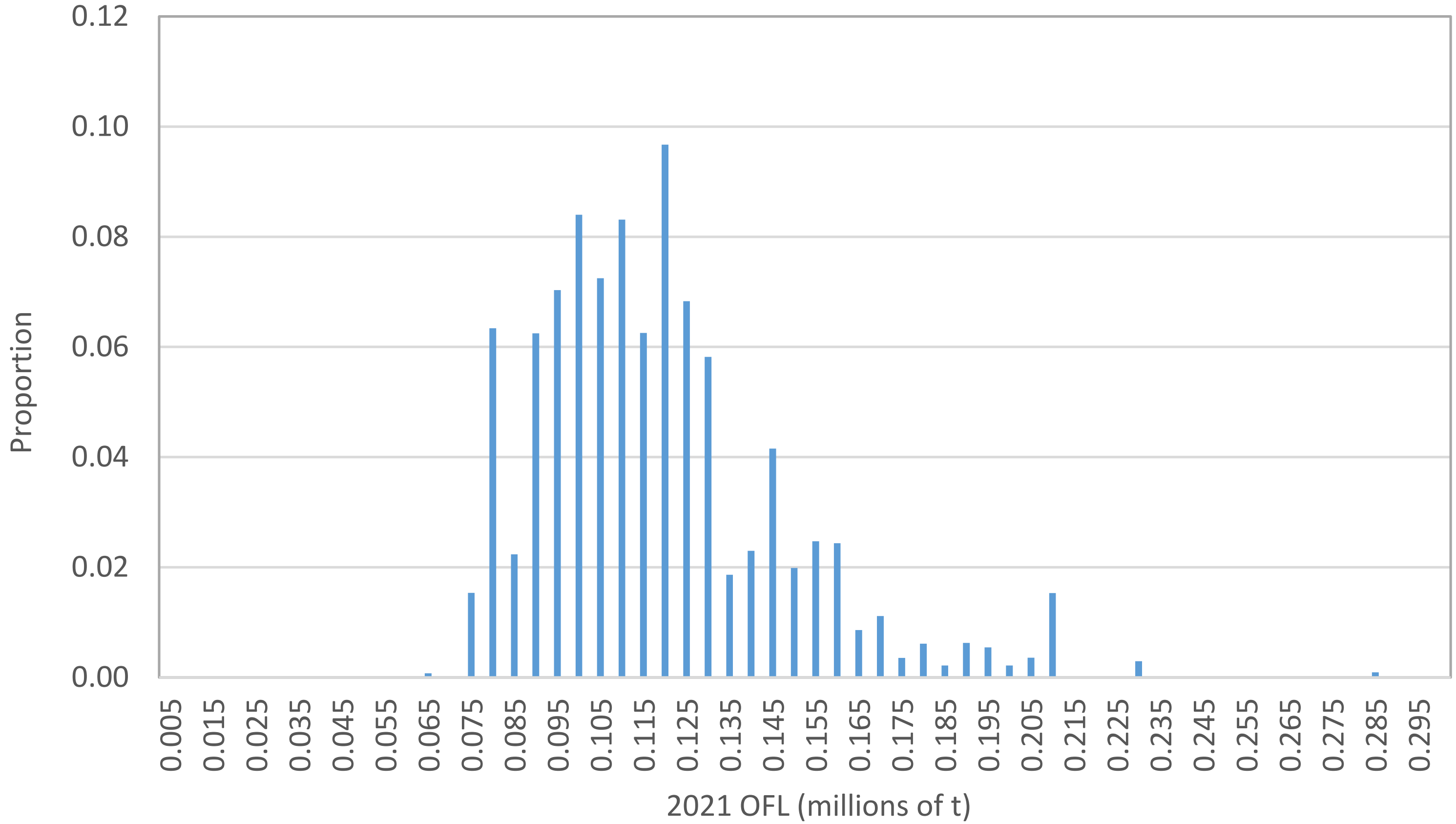
	Pivot model = 19.12a									Pivot model = 19.12b								
OFL	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3	WtAve	19.12a	19.12b	20.1	19.12c	19.12	19.12d	20.2	20.3	WtAve
0.005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.030	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.035	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.040	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.045	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.050	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.055	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.060	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.065	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.070	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.075	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.080	0	0	0	0.100	0	0	0	0.200	0.161	0	0	0	0	0	0	0	0	0
0.085	0	0.100	0	0	0	0	0	0.100	0.070	0	0	0	0	0	0	0	0	0
0.090	0	0	0	0.100	0	0	0	0.100	0.093	0	0.100	0	0	0	0.100	0	0	0.007
0.095	0	0	0	0.100	0	0	0	0.100	0.093	0	0.100	0	0.200	0	0	0	0	0.050
0.100	0	0	0	0	0	0	0	0.200	0.137	0	0	0	0	0	0.100	0	0.111	0.082
0.105	0	0	0	0	0	0	0	0.100	0.068	0	0.200	0	0.100	0	0.100	0	0	0.033
0.110	0	0	0	0.100	0	0	0.100	0	0.024	0	0.200	0	0	0	0.300	0	0	0.021
0.115	0	0	0	0.100	0	0	0.100	0.100	0.093	0	0.100	0	0.200	0	0.100	0	0.111	0.132
0.120	0	0	0	0	0.100	0	0.200	0	0.000	0	0.100	0	0.100	0	0	0	0.333	0.253
0.125	0.111	0	0	0	0.100	0	0.200	0.100	0.068	0	0.100	0	0.100	0.100	0.300	0	0.111	0.120
0.130	0.111	0	0	0	0	0	0.100	0	0.000	0	0.100	0	0.100	0	0	0	0	0.026
0.135	0.111	0	0	0.100	0.100	0	0.100	0	0.024	0	0	0	0	0	0	0	0	0
0.140	0.111	0	0	0	0.200	0	0.100	0	0.000	0.100	0	0	0	0	0	0	0.111	0.076
0.145	0.222	0	0	0	0	0	0	0	0.000	0	0	0.100	0	0	0	0	0	0.000
0.150	0	0	0	0	0.200	0	0	0	0.000	0.100	0	0.100	0.100	0.200	0	0.200	0	0.024
0.155	0.222	0	0	0	0.100	0	0.100	0	0.000	0	0	0.200	0	0.200	0	0	0	0.000
0.160	0	0	0	0.100	0.100	0	0	0	0.024	0.100	0	0	0	0.200	0	0	0.111	0.076
0.165	0	0	0.200	0	0	0	0	0	0.000	0	0	0.100	0	0	0	0.100	0	0.000
0.170	0	0	0.100	0.100	0	0	0	0	0.024	0.200	0	0.100	0	0.100	0	0	0	0.000
0.175	0.111	0	0.100	0.100	0	0	0	0	0.024	0.100	0	0.300	0	0	0	0.200	0	0.000
0.180	0	0	0	0	0	0	0	0	0	0.100	0	0	0	0.100	0	0.200	0	0.000
0.185	0	0	0.200	0	0.100	0	0	0	0.000	0	0	0	0	0	0	0	0	0
0.190	0	0	0.200	0	0	0	0	0	0.000	0.200	0	0	0	0.100	0	0.100	0	0.000
0.195	0	0	0	0.100	0	0	0	0	0.024	0	0	0	0	0	0	0.100	0	0.000
0.200	0	0	0.100	0	0	0	0	0	0.000	0	0	0.100	0	0	0	0	0	0.000
> 0.2	0	0.900	0.100	0	0	1.000	0	0	0.071	0.100	0	0	0.100	0	0	0.100	0.111	0.100

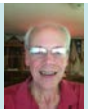
NOAA FISHERIES



Overall ensemble *pmf*

- The model-specific, performance-weighted average *pmf*s are then weighted by the model probabilities, giving the overall ensemble *pmf*

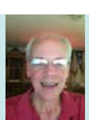




Estimation of OFL and ABC (1 of 2)

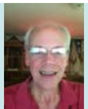
- Given this pmf, the only other quantities that need to be specified in order to estimate OFL and ABC in the CCDA approach are the corresponding values of ra
- Because OFL is commonly understood as being a risk-neutral estimate of the fishing mortality rate corresponding to maximum sustainable yield, it seems reasonable to identify $ra=0$ for estimation of OFL
- Because ABC is constrained to be less than OFL, it can be viewed as a risk-averse alternative, but this begs the question of *how much* risk aversion is appropriate for estimation of ABC (see SSC5)
- For the present application, Atttachment 2.1.4 identifies $ra=2$ as a reasonable value for estimation of ABC

NOAA FISHERIES



Estimation of OFL and ABC (2 of 2)

- Given $ra=0$, the estimate of OFL from CCDA is simply the arithmetic mean of the pmf; and given $ra=2$, the estimate of ABC from CCDA is simply the harmonic mean of the pmf
- The arithmetic and harmonic means of the ensemble pmf are 127,119 t (OFL) and 114,101 t (ABC), respectively, representing a buffer of approximately 10%
- Of course, the ABC harvest control rule identified in the BSAI Groundfish FMP still applies, so the CCDA estimate of ABC could be used only if it does not exceed the value resulting from application of that control rule

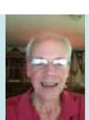


Discussion

Issue 1: structure of final ensemble (1 of 2)

- Two ensembles have been presented here:
  - The primary ensemble: 8 models, one of which is M19.12
  - An alternative ensemble: same as the primary except that the 6 models that use an informative prior distribution on NBS survey $\ln(Q)$ are replaced by counterparts that lack the prior distribution
- Other options:
  - Mix and match from among the ensembles presented
  - Replace one or more models in the ensemble with new models
  - Forgo an ensemble for this year (at least)
    - Perhaps use an ensemble only in years with a CIE review
- Fitting and documenting 8 models in the brief time available for development of the final draft will likely prove to be a challenging undertaking, based on last year's experience with a 9-model ensemble

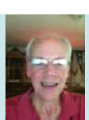
NOAA FISHERIES



Issue 1: structure of final ensemble (2 of 2)

- Both of the ensembles presented here have the desirable attribute of being based on a factorial design, so eliminating models from either ensemble would remove this attribute unless done carefully
- Minor note: If any of the 2-area models are to be included in the final draft, experience to date suggests that fixing the value of initial fishing mortality in the NBS fishery at some very small value would likely be of negligible consequence in terms of parameter estimation but would likely result in improved performance in terms of model convergence

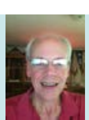
NOAA FISHERIES



Issue 2: use of CCDA in the final draft

- The main reason to use CCDA in this year's final draft is that it provides a statistically rigorous answer to the "*But what if we're wrong?*" question
- However, there are several disadvantages as well:
  - It is much harder to understand than typical ensemble approaches
  - It is currently very time-consuming
    - A major impediment: some models have spatial structures that are nested within those of other models
    - Even if a CCDA could be conducted in time for this year's final draft, it would be limited to estimation of OFL and ABC
  - Use of bootstrap distributions as an approximation of Bayesian posterior distributions is controversial
    - Even if the approximation is acceptable in principle, the precision of the *pmf* based on only 10 bootstraps per model may not be

NOAA FISHERIES

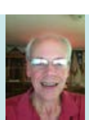


PS: An alternative version of M19.12

Introduction and methods

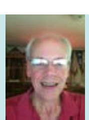
- At the request of an industry representative, an alternative version of the current base model for EBS Pacific cod (Model 19.12) was run
- In the base model, the base value of catchability (Q) for the trawl survey is estimated freely at 1.034
- In the alternative version, the base value of catchability was fixed at 0.465, which is the value that sets the average of the product of Q and survey selectivity for fish in the 60-81 cm size range equal to 0.47, corresponding to the proportion of the population within that size range estimated by Nichol et al. (2007) to be present within the depth range sampled by the survey gear
- The values of the “sigma” terms that constrain the various vectors of annual random deviations were not re-tuned in the alternative version

NOAA FISHERIES



Results: impacts on management quantities

- As expected, fixing Q in the manner described has a substantial impact on projections for 2021:
  - The estimate of 2021 rel. spawn. biom. increases from 0.30 to 0.60
    - i.e., the stock goes from being well below, to well above, the kink in the harvest control rule
  - The estimate of $F_{40\%}$ increases from 0.415 to 0.522
  - The estimate of 2021 maxABC increases from 113,071 t to 371,530 t
    - Conditional on the 2020 catch being equal to the 2020 ABC



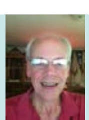
Results: impacts on objective function

- The alternative version does not fit the data as well (T1):

Component	Qfree	Qfixed	Change
Catch	0.00	0.00	0.00
Initial_eq_catch	0.00	0.00	0.00
Survey index	-87.65	-86.31	1.34
Size composition	814.26	827.90	13.64
Age composition	251.33	273.82	22.50
Recruitment	-0.41	1.88	2.30
Initial_eq_recr	5.36	0.51	-4.85
Priors	0.00	0.00	0.00
"Softbounds"	0.02	0.02	0.00
Deviations	97.79	99.76	1.97
Total	1080.68	1117.58	36.90

- T2 shows the breakdown of the sizecomp and agecomp components by fleet and year (skipped here in the interest of brevity)

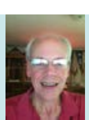
NOAA FISHERIES



Results: impacts on main parameters (1 of 2)

- Top part of T3 shows changes in time-invariant parameters that are constrained to be positive (measured as Qfixed/Qfree – 1):

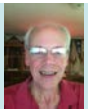
Parameter	Qfree	Qfixed	Change
Natural_mortality	0.346	0.443	0.280
L_at_1.5_base	14.904	14.671	-0.016
L_infinity	117.310	111.147	-0.053
VonBert_K	0.108	0.111	0.029
Richards_coef	1.467	1.550	0.056
SD_len_at_1	3.511	3.582	0.020
SD_len_at_20	9.860	9.169	-0.070
InitF_main_fsh	0.133	0.049	-0.634
Main_fsh_sel_PeakStart	76.012	76.011	0.000
Main_srv_sel_PeakStart_base	20.797	21.394	0.029



Results: impacts on main parameters (2 of 2)

- Bottom part of T3 shows changes in time-invariant parameters that can be either positive or negative (measured as Qfixed – Qfree):

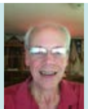
Parameter	Qfree	Qfixed	Change
AgeBias_at_1_1977_2007	0.336	0.352	0.016
AgeBias_at_1_2008_2019	0.020	0.015	-0.005
AgeBias_at_20_1977_2007	0.907	0.835	-0.072
AgeBias_at_20_2008_2019	-1.715	-1.794	-0.078
ln(Recr_ave_1977_2018)	13.104	14.183	1.079
ln(Recr_ave_pre1977_offset)	-0.946	-0.397	0.549
lnQ_main_srv_base	0.034	-0.766	-0.799
Main_fsh_sel_lnSD1_base	5.976	5.965	-0.011
Main_fsh_sel_lnSD2	-9.985	-9.994	-0.008
Main_fsh_sel_logitEnd_base	2.006	1.548	-0.459
Main_srv_sel_lnSD1_base	3.499	3.573	0.074
lnDM_size_main_fish	9.990	9.990	0.000
lnDM_size_main_sur	9.984	9.984	0.000
lnDM_age_main_srv	0.099	-0.563	-0.662



Discussion: past uses of Nichol et al. (1 of 3)

- The 2007 and 2008 assessments compared the average product of Q (internally estimated) and selectivity across the 60-81 cm size range against the estimate of 0.47 obtained by Nichol et al. (2007) as one of the model selection criteria
- The 2009 assessment estimated Q iteratively by tuning it so that the average product of Q and selectivity across the 60-81 cm size range matched the Nichol et al. estimate of 0.47, giving Q=0.77
- The resulting estimate was retained in all assessments through 2015
- The 2016-2020 assessments returned to the practice of freely estimating Q, based on comments from the BSAI Team, the SSC, the 2016 CIE review, and the paper by Weinberg et al. (2016)
  - Some of relevant excerpts are shown on the next 2 slides

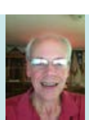
NOAA FISHERIES



Discussion: past uses of Nichol et al. (2 of 3)

- BSAI Team minutes, 9/15: “The fixed survey Q (0.77) based on archival tags ... has become less and less credible as careful experiments and analysis performed by RACE have produced no evidence that cod in the path of the survey trawl avoid capture by any means (e.g., vertical distribution or out-swimming). A higher value of catchability, as estimated by the other models, therefore seems more plausible and prudent.”
- SSC minutes, 10/15: “The SSC has been on record encouraging the development of an alternative model that estimates Q, due to the very weak or non-existent evidence for net avoidance, which has been corroborated by recent work. This makes the fixed value for Q, which was always based on weak evidence, even less tenable than before.”

NOAA FISHERIES



Discussion: past uses of Nichol et al. (3 of 3)

- CIE reviewer, 4/16: “It is a mistake to force a given value of *Q* into the assessment since the assumptions on which the calculations are based are quite different.... It is probably more useful to estimate *Q* within the model and regard it as a value that reconciles the assessment scale to the survey scale. Fixing *Q* within the model will add a degree of rigidity that may lead to severely biased estimates of fishing mortality, especially where the catch is treated as a known constant.”
- Weinberg et al. (2016): “We agree with Nichol et al. (2007), in that it seems unlikely for the survey trawl to catch 100% of the Pacific cod in its path 100% of the time; however, we cast doubt on the conclusion that more than 50% of large fish swim above the trawl in the presence of trawling activity.”

NOAA FISHERIES