Explorations of alternative stock assessment models for Eastern Bering Sea Pacific cod

BSAI Groundfish Plan Team - September 2023.

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https://afsc-assessments.github.io/EBS_PCOD/2023_ASSESSMENT/SEPTEMBER_MODELS/

Issues with 2022 ensemble models

- Dirichlet multinomial log(Θ) values for length composition approach the upper bound and were fixed to ensure models convergence.
- Failing residual runs tests for length and age composition data in all ensembles indicating autocorrelation in the residuals pointing at poor residual behavior.
- Potential confounding of aging bias, annually varying growth, and annually varying selectivity result in the models being highly unstable with considerable tuning of the annual devs. on growth and selectivity required for model convergence.
- Models are highly sensitive to changes in catchability and natural mortality with small changes in either resulting in substantial changes in management advice with only small changes in negative log likelihood.

General recommendations

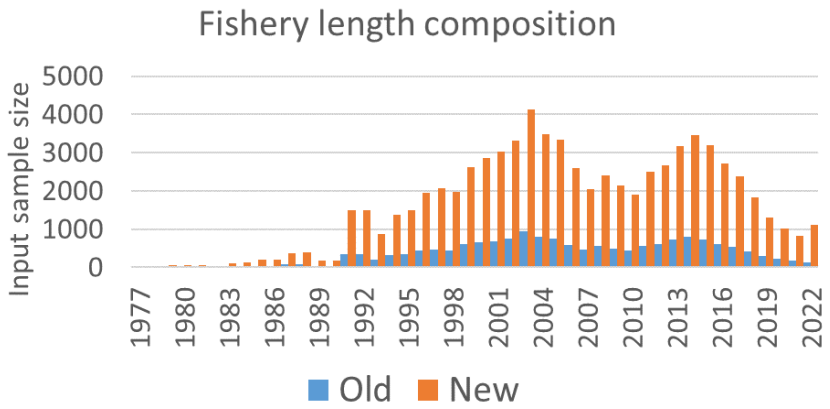
- Move away from the ensemble approach.
- Simpler model with fewer and/or more constrained, annually varying parameters on growth and selectivity as these parameters are confounded.
- Fix one or more key parameters in the model or using more constrained priors would provide improved model stability.

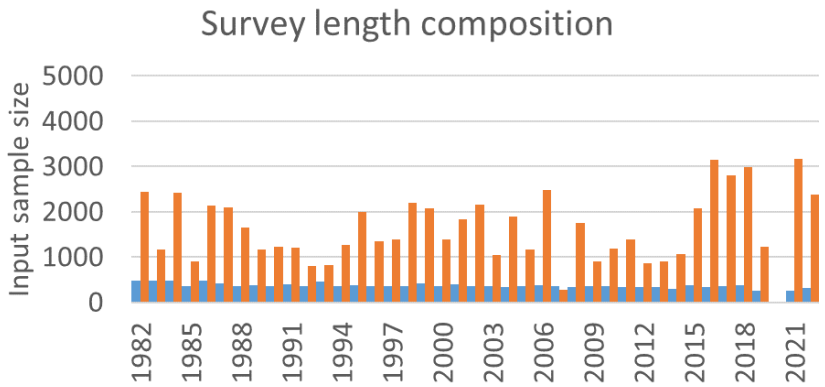
New analyses presented for 2023

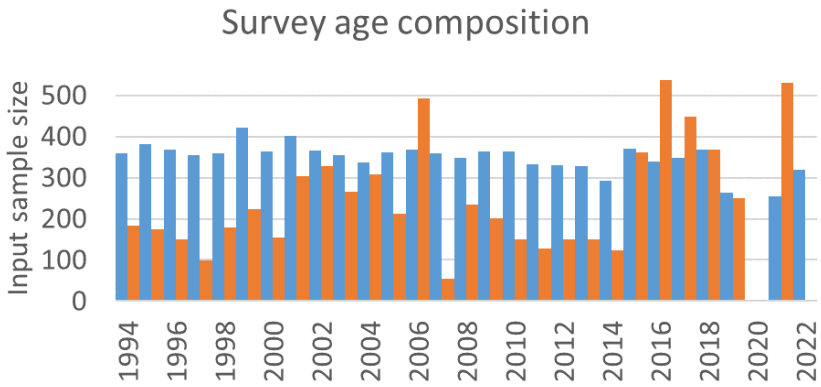
- Changing initial input sample size Model 22.2
- A simplified model (Model 23.1.0.a)
- Sequential analyses with added features to the simplified model
  - Annually varying growth
  - Annually varying selectivity
  - Change max age from 20 to 12
  - Catch back to 1964 and removal of regime parameter on recruitment
  - Conditional age-at-length (CAAL)

Changing initial input sample size

- Model 22.2 updated
  - Input sample size changed to bootstrap proposed by Hulson et al. (2023)
    - Survey size and age composition input sample size bootstrapped
    - Fishery size composition input sample size uses haul number standardized to the average bootstrapped survey size composition input sample size
    - Old mean for both = 369; length new mean = 1623, age new mean = 250



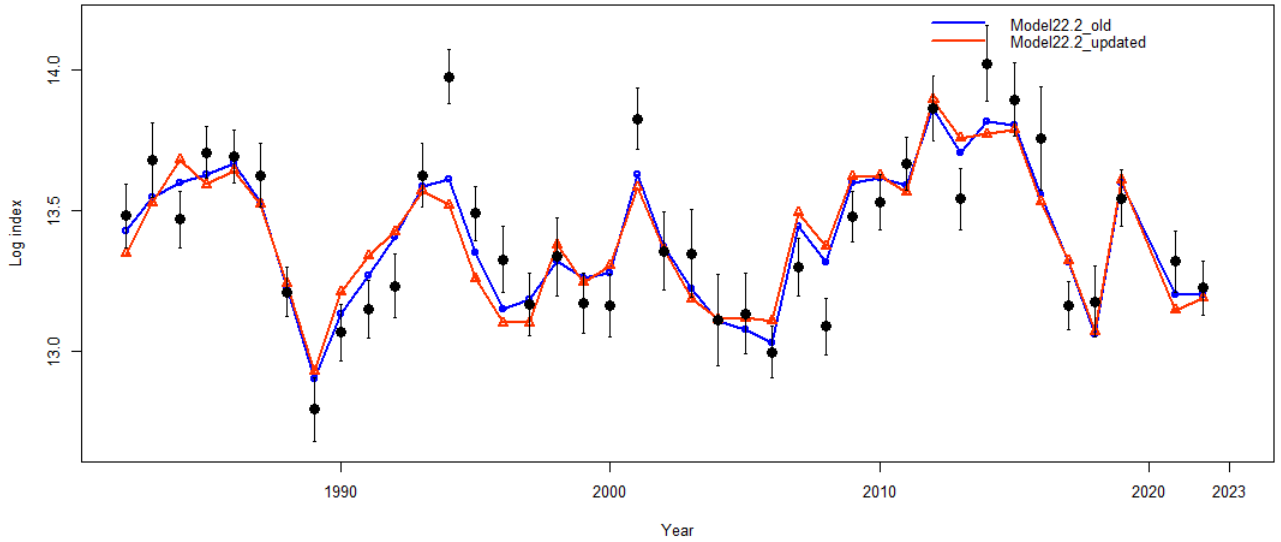




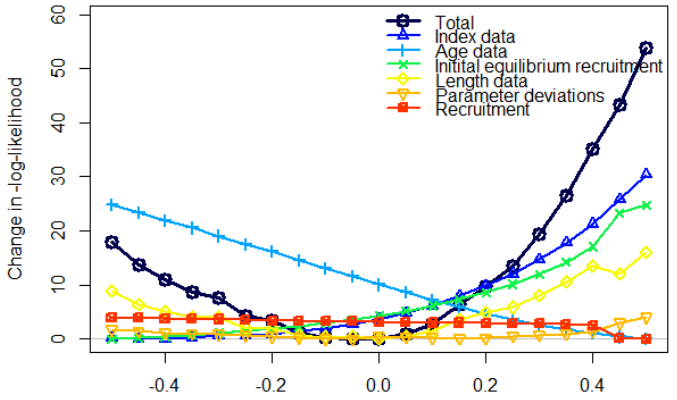
Hulson, P-J. F., B. C. Williams, M. R. Siskey, M. D. Bryan, and J. Conner. 2023. Bottom trawl survey age and length composition input sample sizes for stocks assessed with statistical catch-at-age assessment models at the Alaska Fisheries Science Center. U.S. Dep. Commer., NOAA Tech. Memo.NMFS-AFSC-470, 38 p.

Changing initial input sample size

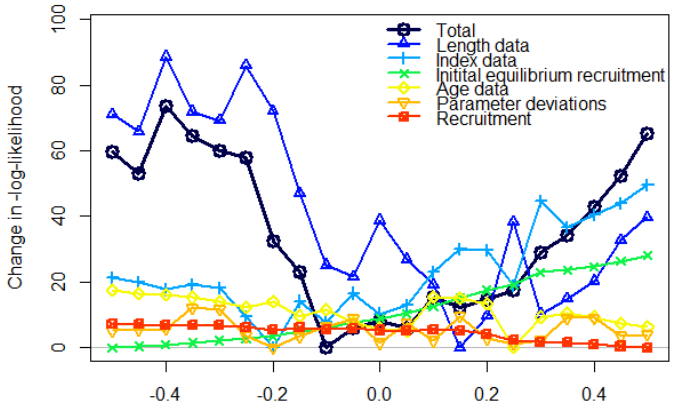
- Model 22.2 updated
  - Degraded fit to survey
  - Poor convergence
  - Log(Θ) continues to be at bound for fishery comps



Model 22.2 old



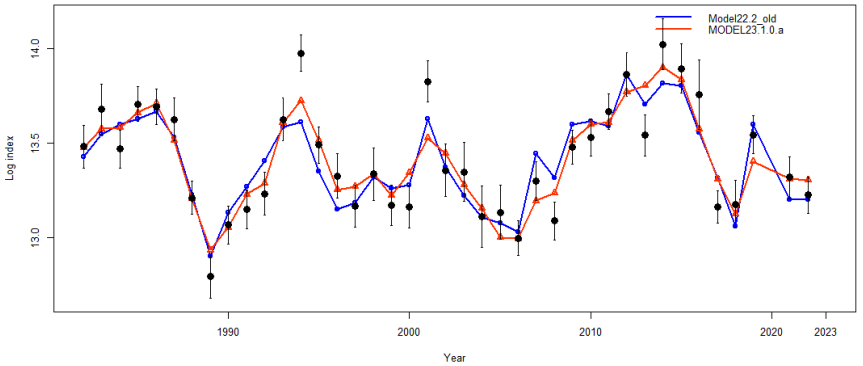
Model 22.2 Update



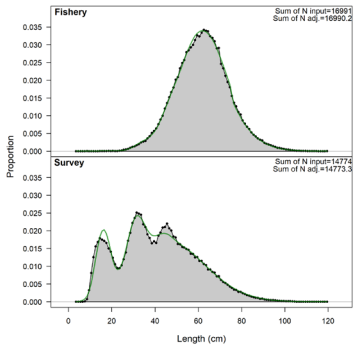
Note: When testing the removal of the Dirichlet multinomial and changing to simple multinomial with Francis weighting the model failed to come to a resolution on weighting with the Fishery comp suggested weights increasing until the model no longer converged

A simplified model (Model 23.1.0.a)

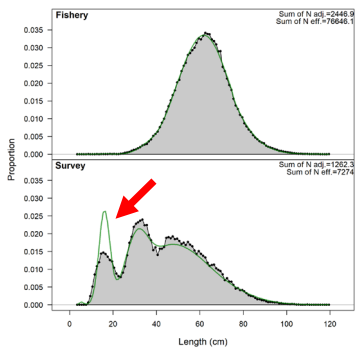
- Model 22.2 (Barbeaux et al. 2022) with 222 fewer parameters (220 devs)
  - Improved fit to survey and better model behavior
    - Better residual behavior (runs tests pass all but fishery comps)
    - Slightly degraded retrospective bias from -0.06 to 0.08.
    - Improved index mean absolute scaled error (MASE) prediction skill from 0.69 to 0.42
  - Poorer overall fit to size composition data
    - Higher residuals on peak of small fish in survey length comps



Model 22.2 old



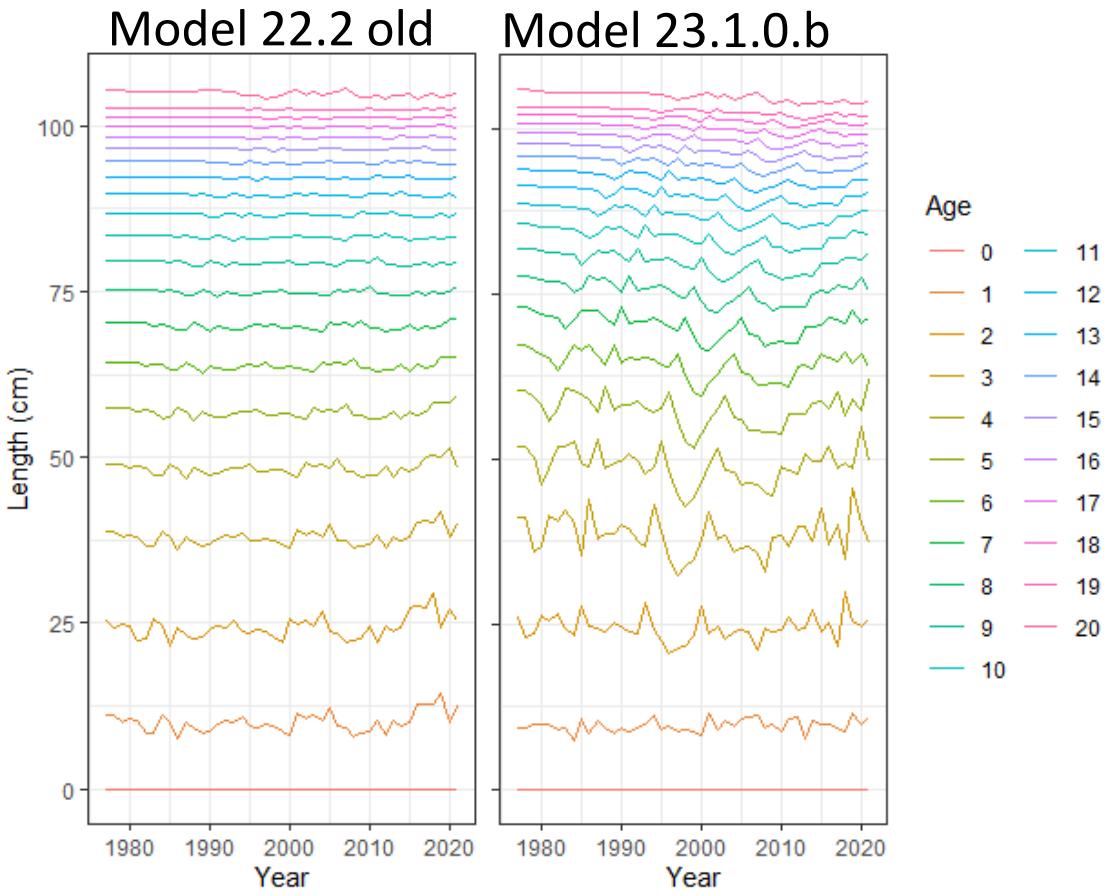
Model 23.1.0.a



Barbeaux, S.J., Barnett, L., Connor, J., Nielson, J., Shotwell, S.K., Siddon, E., Spies, I., Ressler, H.R., Rohan, S., Sweeney, K. and Thompson, G., 2022. 2. Assessment of the Pacific Cod Stock in the Eastern Bering Sea. Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea and Aleutian Islands. North Pacific Fishery Management Council, 1007.

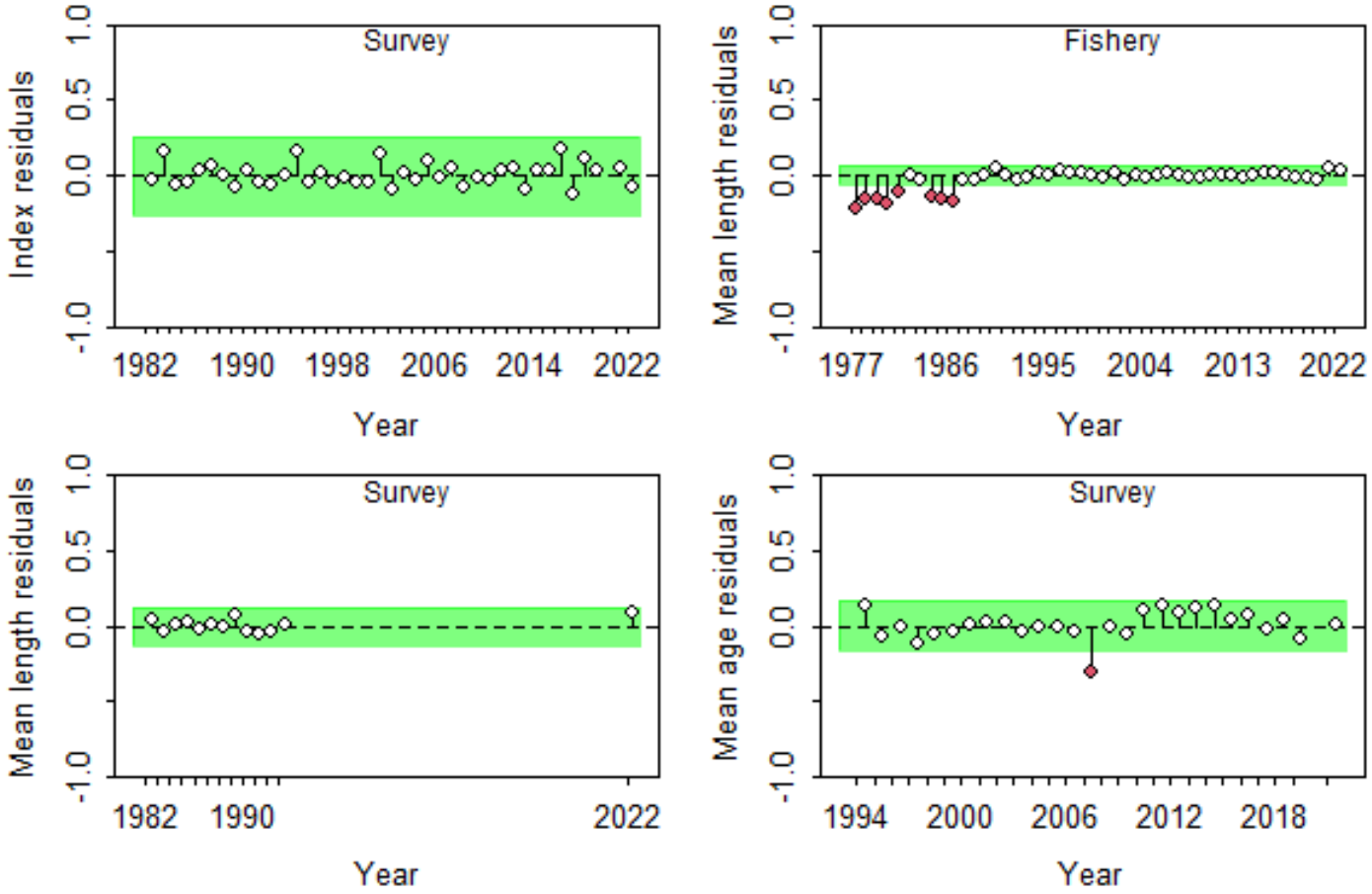
Model 23.1.0.b

- Annually varying growth +94 dev pars
  - Mean tending random walk devs
    - L_{min} (SD=0.44) and Richard (SD=0.30)
  - -108 -LL vs. Model 23.1.0.a
    - Survey index -53.08
    - Length comp -53.63
    - Age comp -17.55



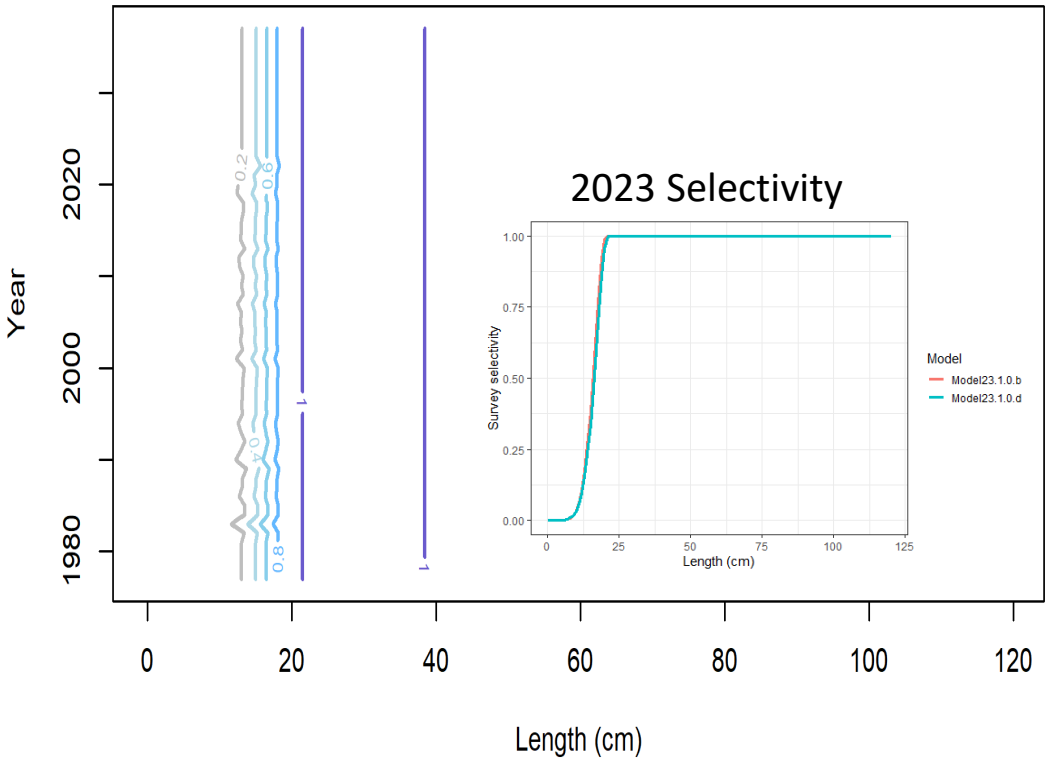
Model 23.1.0.b

- Improved residual runs test
- Small change in SSB Mohn's Rho from 0.08 to 0.09
- Small changes in MASE prediction skill across all data components +length and -age



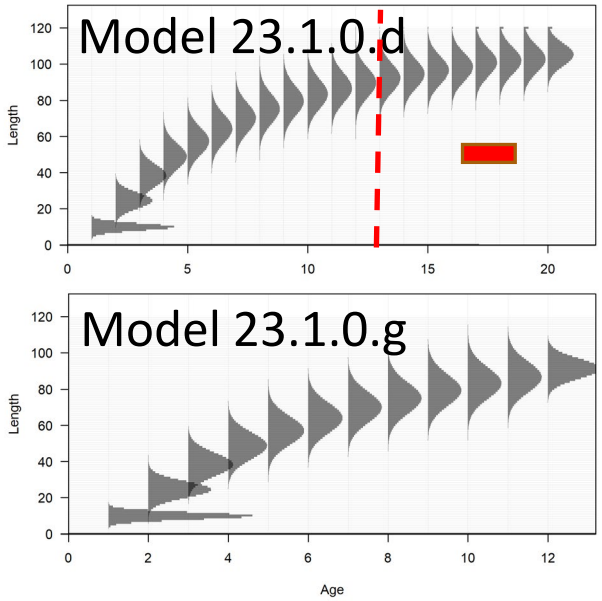
Model 23.1.0.d

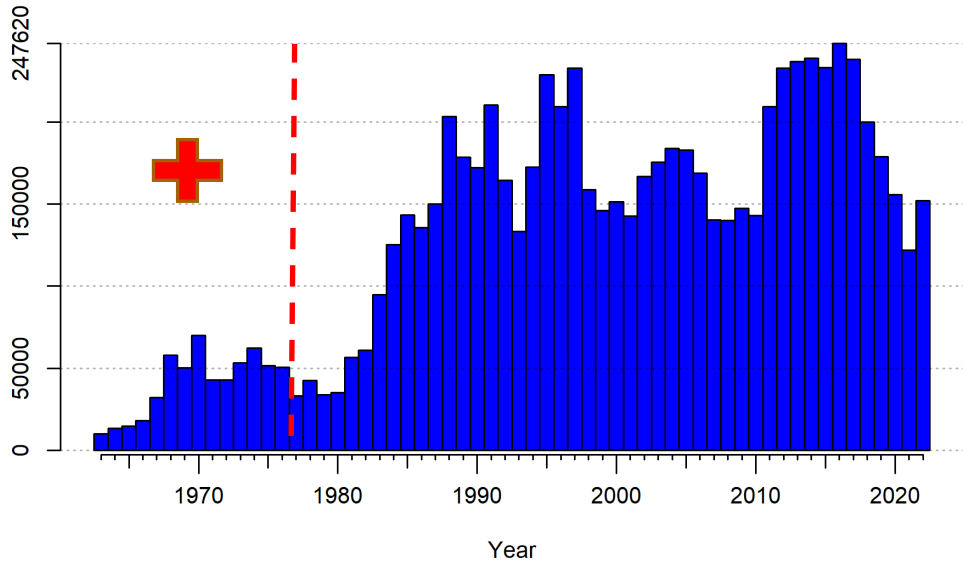
- Annually varying survey selectivity (+42 devs)
  - Additive devs on ascending parameter 1982-2023
  - -10.19 -LL vs. Model 23.1.0.b
    - -5.49 Survey index
    - -9.66 Survey length comps
    - -0.51 Fishery length comps
    - +2.21 Survey age comps
  - Same SSB retrospective and runs test
  - MASE results nearly identical



Model 23.1.0.g

- Change max age from 20 to 12 in model dynamics
- Catch back to 1964 and removal of regime parameter on recruitment (-1 par)
- Change in equilibrium catch
  - 42.5kt to 10kt





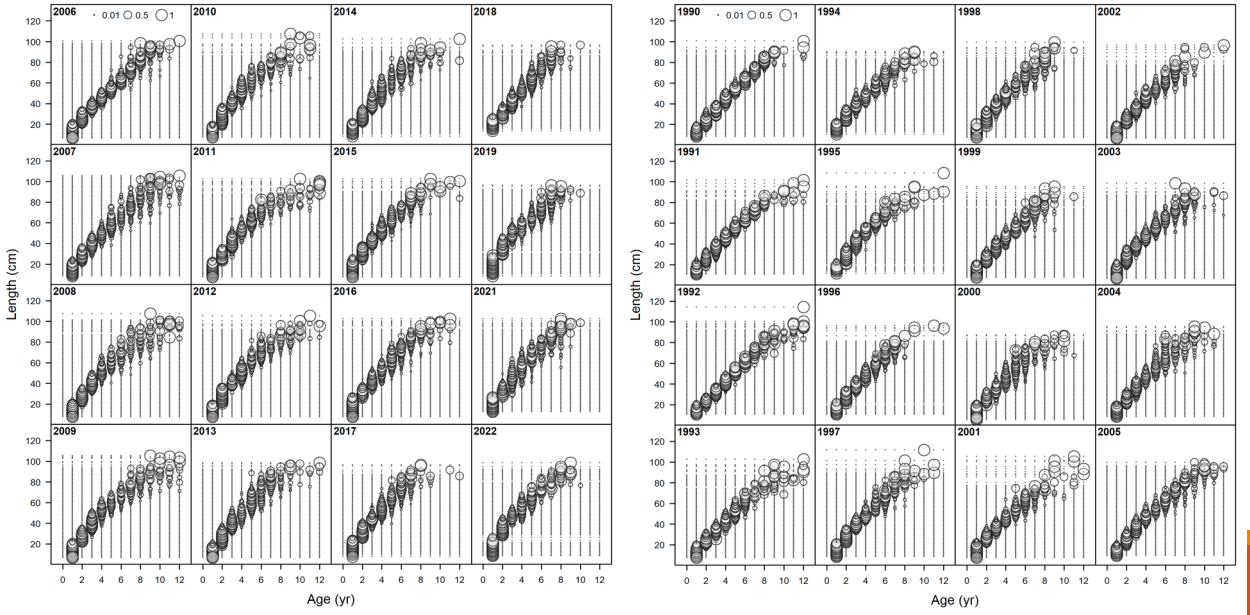
Model 23.1.0.g

- Fit to data nearly indistinguishable visually from Model 23.1.0.d
  - Overall +4.91 -LL vs Model 23.1.0.d
    - Survey index -1.12
    - Survey length comp +1.92
    - Fishery length comp +0.68
    - Survey age comp +3.46

- Slight change in Mohn's rho from 0.09 to 0.11
- Similar runs test results
- Similar MASE prediction skill
- Potential bias in growth parameters due to shortening of age vector which needs further analysis

Model 23.1.0.h

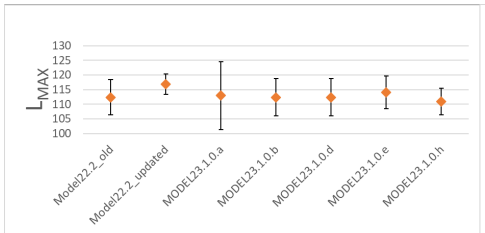
- Addition of conditional age-at-length data
- Overall likelihood not comparable
  - Degradation in index and length comp fits
    - Survey index +9.25
    - Survey length comp +12.21
    - Fishery length comp +15.58
    - Survey age comp -1.29
- Generally good fit to CAAL
- Mohn's rho to 0.15
- Fails runs tests
- Similar MASE prediction skill

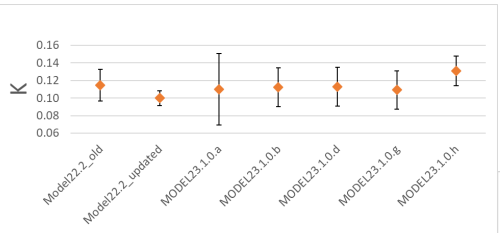


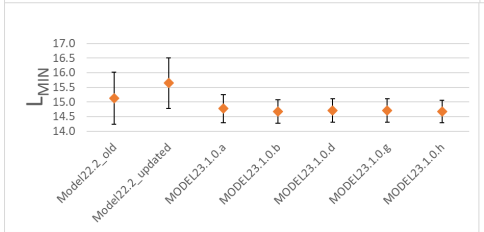
Sequential analyses with added features to simplified model

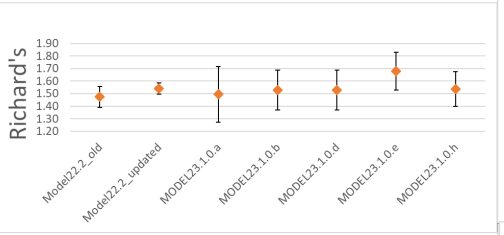
Model	Npars	Ndevs	-LL	M	Q	B_0 (kt)	F_{MSY}	B_{23} (kt)	B_{23}/B_0
MODEL 23.1.0.a	18	64	251	0.344	1.097	586.1	0.332	205.9	0.351
MODEL 23.1.0.b	18	158	143	0.414	0.822	605.4	0.441	314.1	0.519
MODEL 23.1.0.d	18	200	133	0.429	0.765	623.4	0.465	343.4	0.551
MODEL 23.1.0.g	17	200	141	0.435	0.792	542.6	0.488	331.8	0.612
MODEL 23.1.0.h	17	200	631	0.424	0.808	611.4	0.466	313.1	0.512

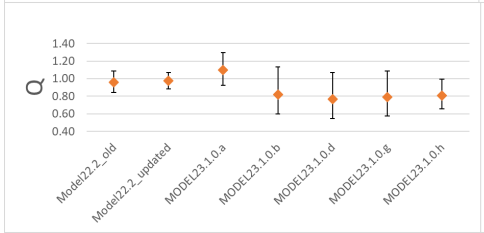
Increased uncertainty in parameters and derived quantities

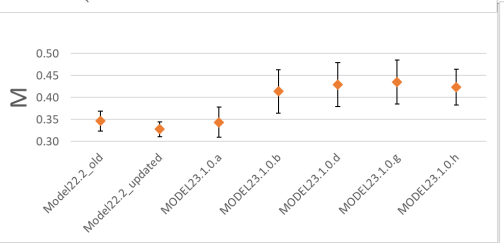


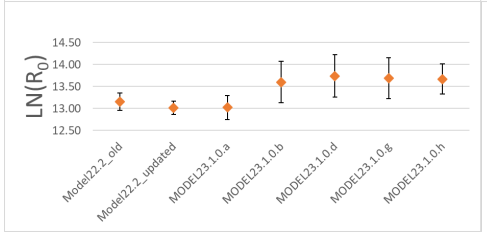


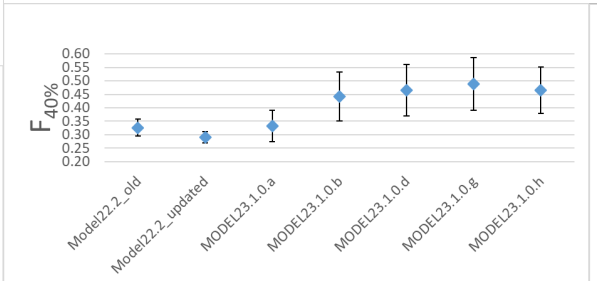


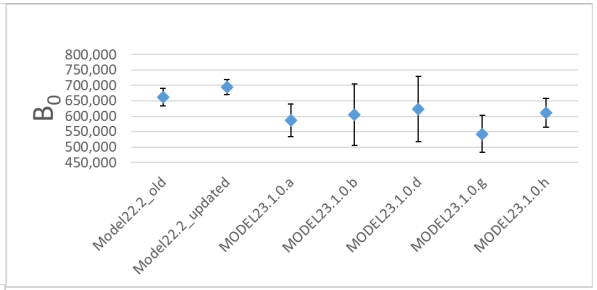


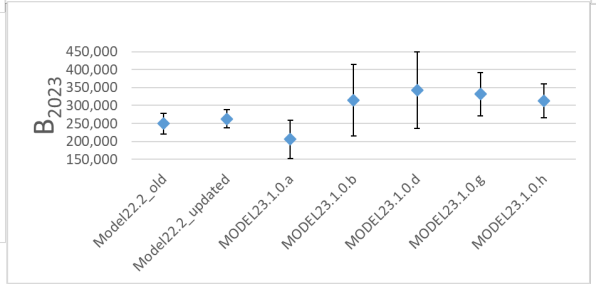






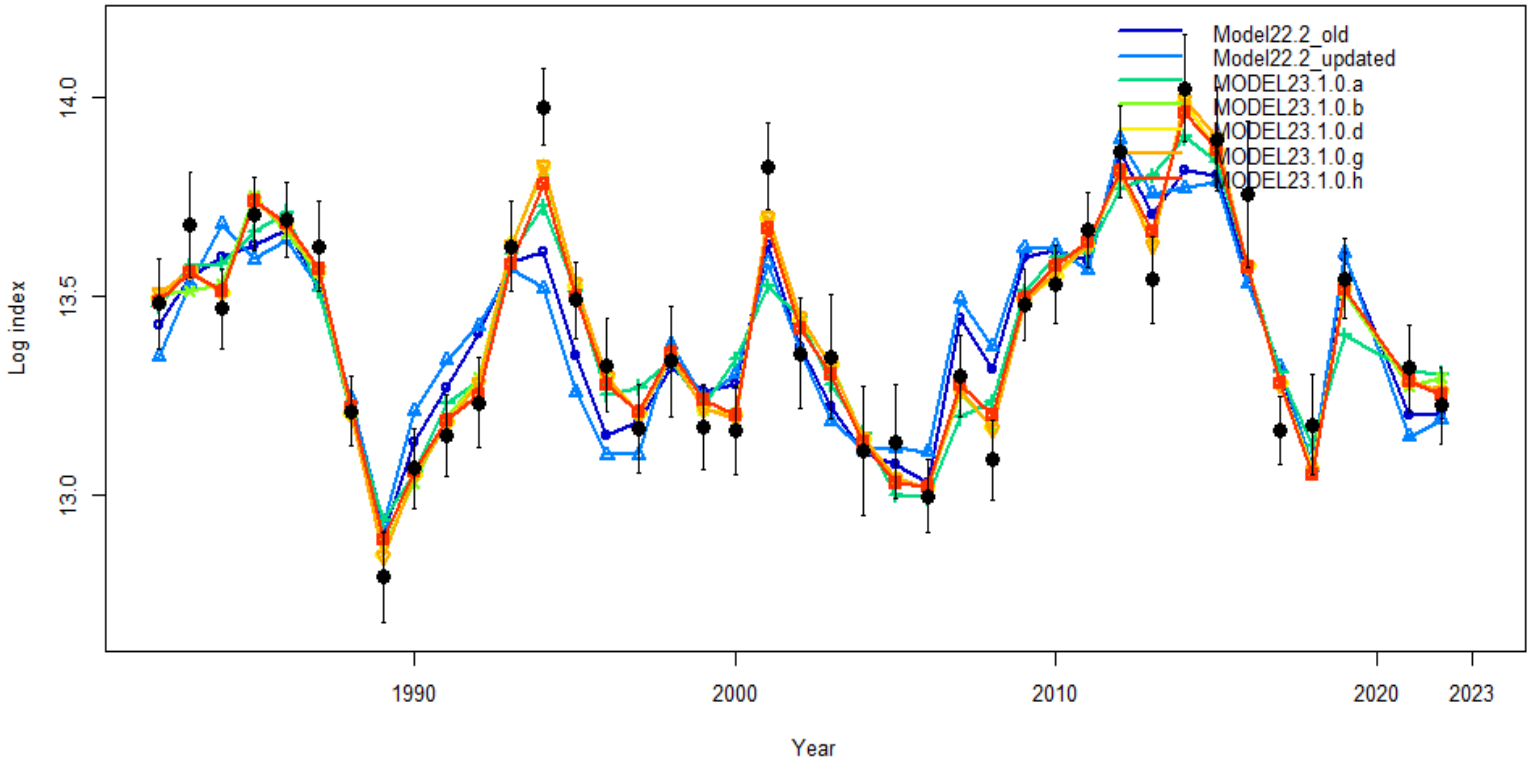






Sequential analyses with added features to simplified model

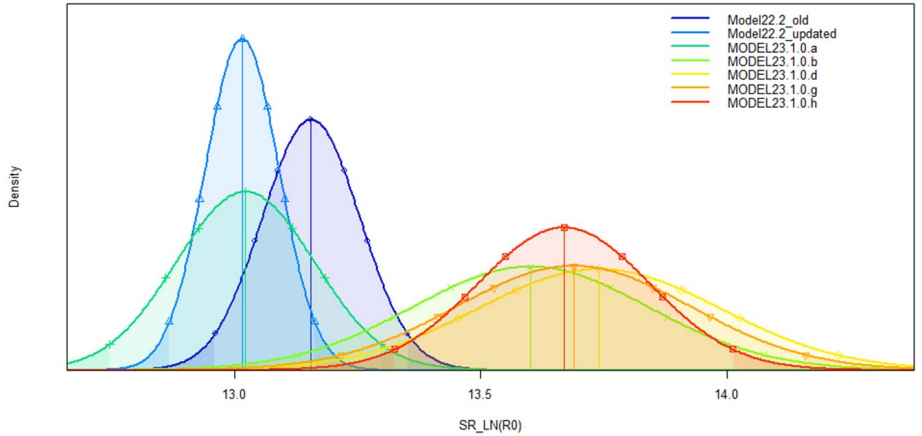
- Overall better fits to the survey index for all new models

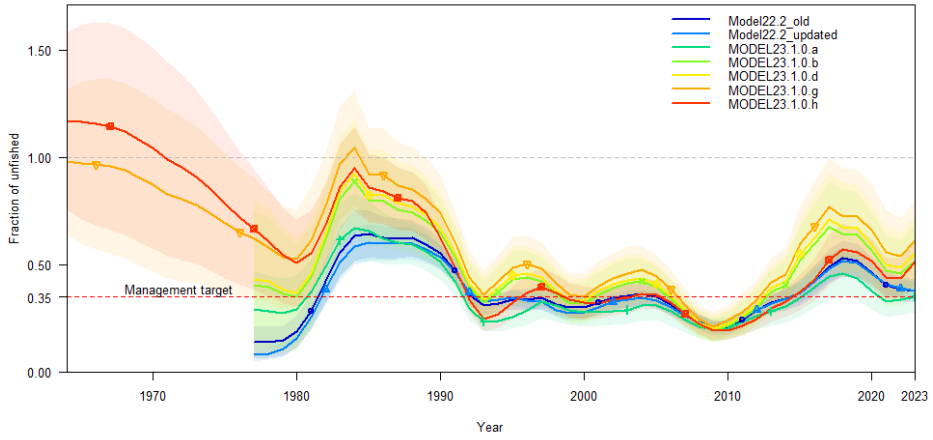


Sequential analyses with added features to simplified model

- Addition of annually varying growth increases R_0 and uncertainty in reference points

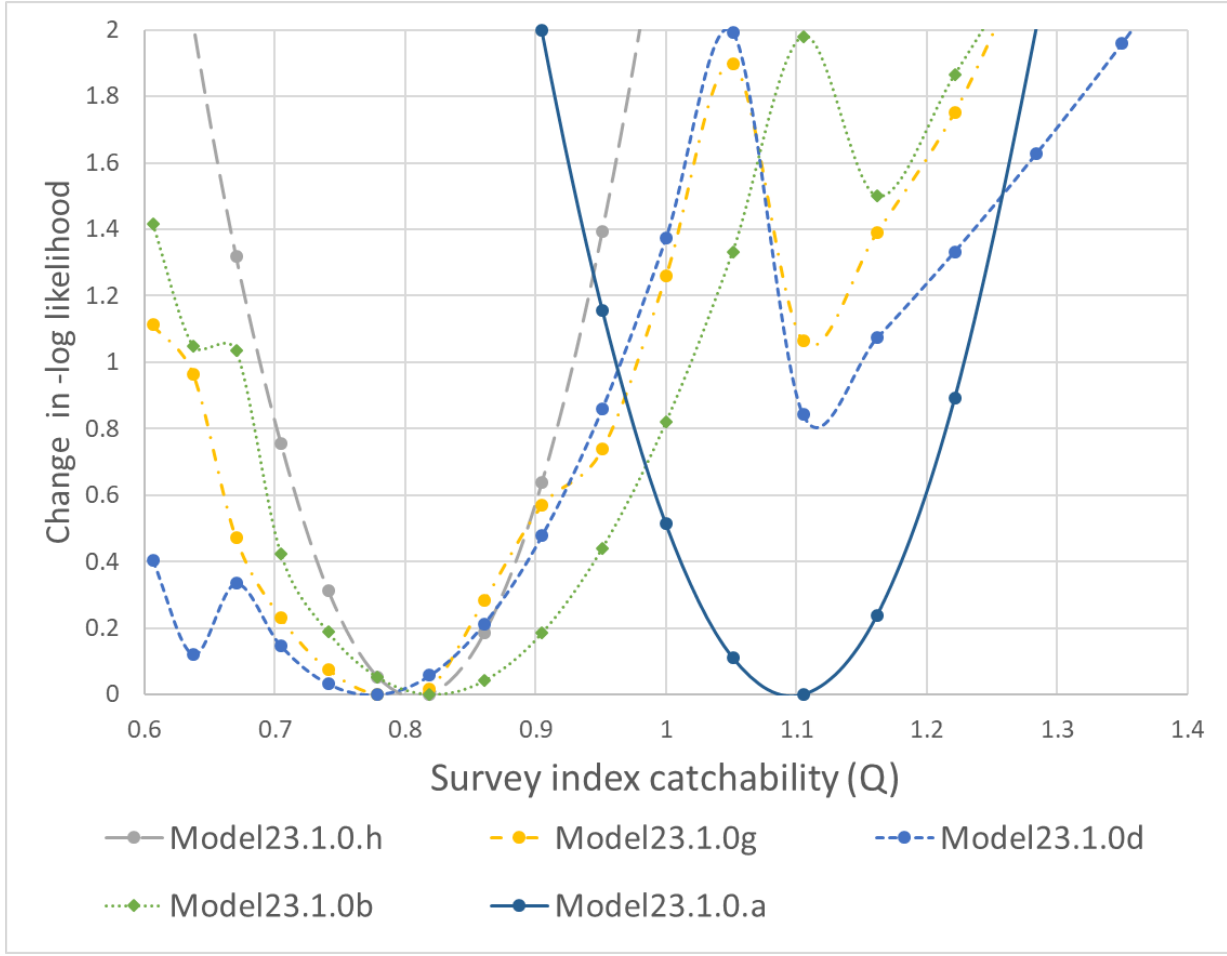
- New models with varying growth scales population higher





Likelihood profiles over Q

- Models are highly sensitive with large changes in catchability results in small changes in likelihood
- As Q scales the population this results in large changes in spawning biomass and management advice



Fixed natural mortality

- Phylogenetic structural equation model (PSEM)
- Max age since 2008 (t_max= 14)
- M = 0.3866 log SE = 0.4

Model	Free M					Fixed M					Change in -LL
	-LL	B_0	B_{2023}	B_{2023}/B_0	ABC_{2024}	-LL	B_0	B_{2023}	B_{2023}/B_0	ABC_{2024}	
M22.2 old	10,875	661,455	249,809	0.378	144,694	10,881	653,795	295,111	0.451	192,152	+6
M22.2 up	18,362	694,750	263,189	0.379	141,115	18,405	683,985	332,473	0.486	204,657	+43
M23.1.0.a	251	586,050	205,914	0.351	131,883	253	568,340	246,505	0.434	178,060	+2
M23.1.0.b	143	605,435	314,146	0.519	219,817	144	590,270	274,837	0.466	187,374	+1
M23.1.0.d	133	623,435	343,431	0.551	243,533	134	594,955	276,042	0.464	188,263	+1
M23.1.0.g	141	542,635	331,845	0.612	239,088	143	531,915	264,534	0.497	181,473	+2
M23.1.0.h	631	611,365	313,052	0.512		632	613,550	276,694	0.451		+1

Specific recommendations

- If we adopt single model management:
  - Model 23.1.0.d with fixed M
    - Improved over 2022 ensemble models
      - No DM theta on the upper bound issue
      - Improved residual runs (All pass)
      - Simpler model with less possibility of confounding
      - Input sample sizes consistent with best available science
    - Best performance and fit of all ‘New’ models
      - Near toss-up with Model 23.1.0.b
- Note that the ‘New’ models have increased uncertainty compared to individual 2022 ensemble models

Thank you!