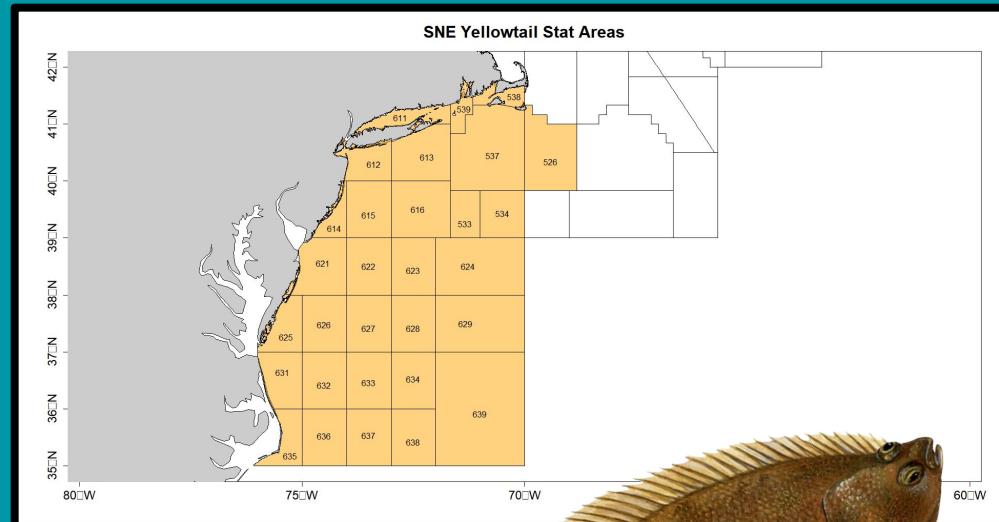




NOAA
FISHERIES

SNEMA Yellowtail ToRs 4, 5, 6

Cameron Hodgdon



Brief Data Overview

- 1973-2022
- Six age classes
- Single Aggregate Fleet
- Five Surveys:
 - NEFSC Spring, Fall, Winter
 - MARMAP and ECOMON Larval

Part One

The Model Selection Process

Pre-ECOV: ~250 WHAM Runs

Fleet Selectivity

Fishery Age Composition

Survey Selectivity

Survey Age Composition

Survey Catchability

Survey Inclusion/Exclusion

M Assumptions

Recruitment Assumptions

Numbers-at-age

The initial (bridge) model had similar settings and results to the previous ASAP model with no random effects.

All model components listed on the left have basecase assumptions that were used in this bridge run. This was the starting point of model development.

From here, model development proceeded semilinearly through these settings and past decisions were revisited when necessary.

This process was done so as to avoid large factorial combinations of all possible model configurations.

Pre-ECOV: ~250 WHAM Runs

Fleet Selectivity

Fishery Age Composition

Survey Selectivity

Survey Age Composition

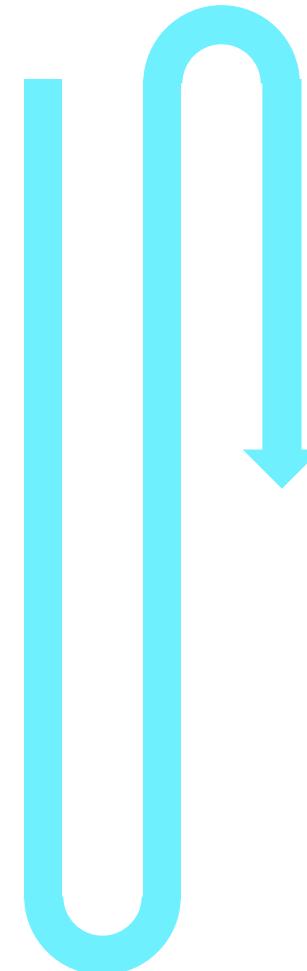
Survey Catchability

Survey Inclusion/Exclusion

M Assumptions

Recruitment Assumptions

Numbers-at-age



ECOV: ~175 WHAM Runs

Environmental Covariate effect on R

Environmental Covariate effect on M

Environmental Covariate effect on q

Final Candidate Model

The **W**HAM
ood's
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“In general, model development followed this process”

Pre-ECOV: ~250 WHAM Runs

Fleet Selectivity

Fishery Age Composition

Survey Selectivity

Survey Age Composition

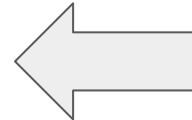
Survey Catchability

Survey Inclusion/Exclusion

M Assumptions

Recruitment Assumptions

Numbers-at-age



The first thing we looked at was fleet selectivity.

Both logistic and age-specific selectivities were compared; **logistic** led to better diagnostics.

Random effects on fleet selectivity were also considered (iid, ar1, ar1_y, and 2dar1) and **iid random effects** led to better residuals and a better overall AIC.

Pre-ECOV: ~250 WHAM Runs

Fleet Selectivity

Fishery Age Composition

Survey Selectivity

Survey Age Composition

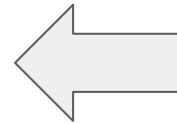
Survey Catchability

Survey Inclusion/Exclusion

M Assumptions

Recruitment Assumptions

Numbers-at-age



Multinomial, dirichlet, dirichlet multinomial, logistic normal, and multivariate tweedie all tested.

Logistic normal and dirichlet can also treat zeros as missing (miss0) or by pooling zeros with adjacent ages (pool0).

Logistic normal can also have an autoregressive process relating neighboring age classes (ar1).

Logistic-normal-ar1-miss0 age comp led to the best AICs (when comparable) and the best retrospective patterns and residuals.

Pre-ECOV: ~250 WHAM Runs

Fleet Selectivity

Fishery Age Composition

Survey Selectivity

Survey Age Composition

Survey Catchability

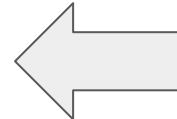
Survey Inclusion/Exclusion

M Assumptions

Recruitment Assumptions

Numbers-at-age

For each of the original five surveys (NEFSC Spring, NEFSC Fall, NEFSC Winter, MARMAP Larval, ECOMON Larval), age-specific and logistic selectivities were tested.



NEFSC Spring and Winter selectivities eventually ended up with **logistic** selectivity and the NEFSC Fall survey with **age-specific**.

Random effects were tested similarly as was done for the fleet, but none led to better fitting models.

The two larval surveys initially had selectivities resembling the maturity ogive, but these surveys were eventually removed from the candidate model.

Pre-ECOV: ~250 WHAM Runs

Fleet Selectivity

Fishery Age Composition

Survey Selectivity

Survey Age Composition

Survey Catchability

Survey Inclusion/Exclusion

M Assumptions

Recruitment Assumptions

Numbers-at-age

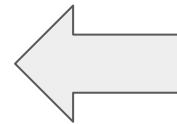
Multinomial, dirichlet, dirichlet multinomial, and logistic normal all tested.

Logistic normal and dirichlet can also treat zeros as missing (miss0) or by pooling zeros with adjacent ages (pool0).

Logistic normal can also have an autoregressive process relating neighboring age classes (ar1).

Logistic-normal-ar1-miss0 age comp for all indices led to the best residuals and best retrospective patterns.

The two larval surveys do not have associated age comps. These surveys were eventually removed from the candidate model.



Pre-ECOV: ~250 WHAM Runs

Fleet Selectivity

Fishery Age Composition

Survey Selectivity

Survey Age Composition

Survey Catchability

Survey Inclusion/Exclusion

M Assumptions

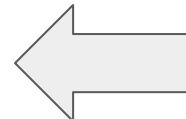
Recruitment Assumptions

Numbers-at-age

Random effects (iid, ar1_y) on catchability were examined for all surveys.

No effects on catchabilities of the NEFSC surveys led to better diagnostics.

Larval surveys required catchability random effects for model convergence, but these surveys were eventually removed from the candidate model.



Pre-ECOV: ~250 WHAM Runs

Fleet Selectivity

Fishery Age Composition

Survey Selectivity

Survey Age Composition

Survey Catchability

Survey Inclusion/Exclusion

M Assumptions

Recruitment Assumptions

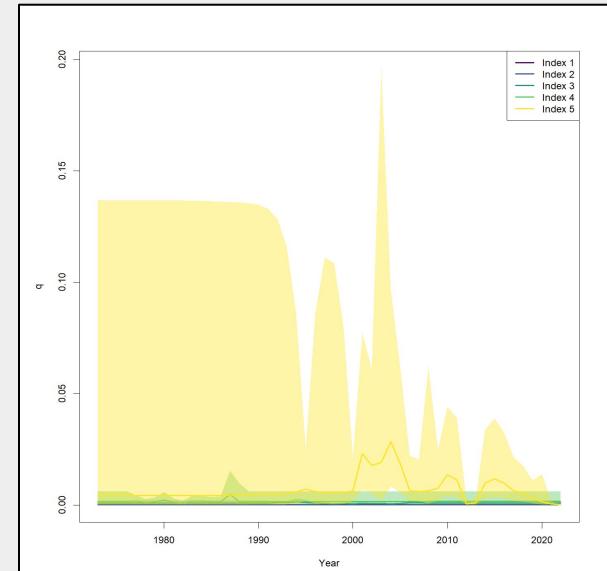
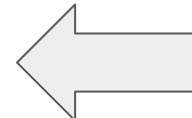
Numbers-at-age

Full “leave-one-survey-out” analysis was conducted.

This was repeated for 2, 3, and 4 surveys.

Strongly suggested removal of the larval indices:

- Selectivity needed to be fixed at all ages
- Catchability needed random effects
- Extremely low sample sizes



Pre-ECOV: ~250 WHAM Runs

Fleet Selectivity

Fishery Age Composition

Survey Selectivity

Survey Age Composition

Survey Catchability

Survey Inclusion/Exclusion

M Assumptions

Recruitment Assumptions

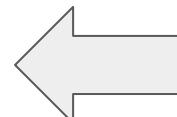
Numbers-at-age

M = 0.5 across all ages and years.

Age-specific M was also tested (where some ages were fixed and others were freely estimated).

Both age-specific and constant M were tested with and without random effects (iid, ar1_a, ar1_y, and 2dar1).

Of these 64 runs, 3 converged, but with worse diagnostics compared to constant M = 0.5.



Pre-ECOV: ~250 WHAM Runs

Fleet Selectivity

Fishery Age Composition

Survey Selectivity

Survey Age Composition

Survey Catchability

Survey Inclusion/Exclusion

M Assumptions

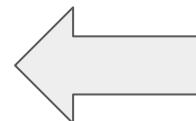
Recruitment Assumptions

Numbers-at-age

Recruitment was considered as being random around a mean, a random walk over the series, and as estimated from a Beverton-Holt SR or a Ricker SR.

In the absence of environmental covariate effects on R, a Beverton-Holt SR led to the best diagnostics.

In the presence of an environmental covariate, R was modelled as **random around a mean**.



Pre-ECOV: ~250 WHAM Runs

Fleet Selectivity

Fishery Age Composition

Survey Selectivity

Survey Age Composition

Survey Catchability

Survey Inclusion/Exclusion

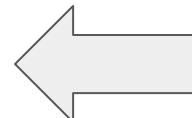
M Assumptions

Recruitment Assumptions

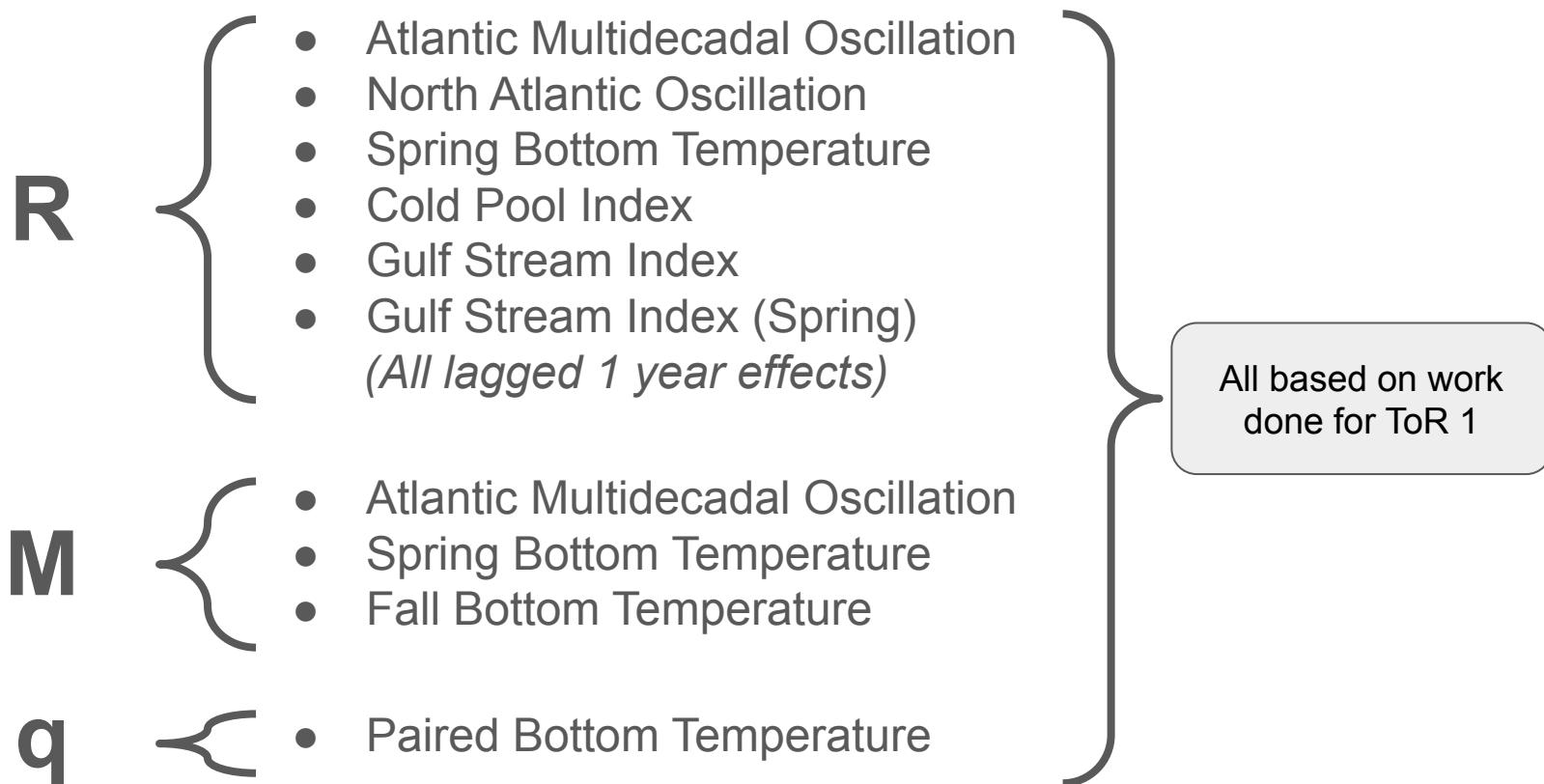
Numbers-at-age

Different NAA random effects (iid, ar1_a, ar1_y, and 2dar1) were tested and **2dar1** led to the best diagnostics.

R is **decoupled** from ages 2-6+ and so R has an ar1_y process across years and ages 2-6+ are full 2dar1.



Environmental Covariate Effects on R, M, and q



Summary Results from ECOV Runs

- Comparing AIC, Retros, Residuals:
 - All ECOV effects on q performed worse than the base model
 - Many runs did not converge
 - All ECOV effects on M performed worse than the base model
 - Most runs did not converge
 - AMO, NAO, CPI on R performed worse than the base model
 - BTS and GSI effects on R led to comparable models
 - Of BTS and GSI, GSI was the better model

GSI effect on R was moved forward to the candidate model.



THE CANDIDATE MODEL

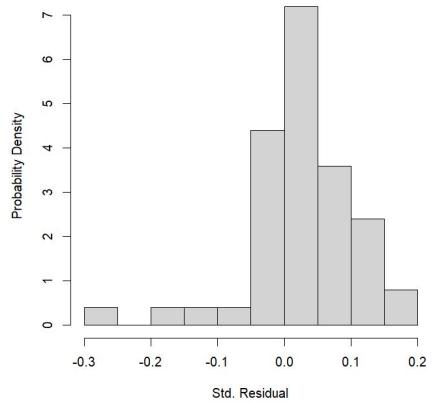
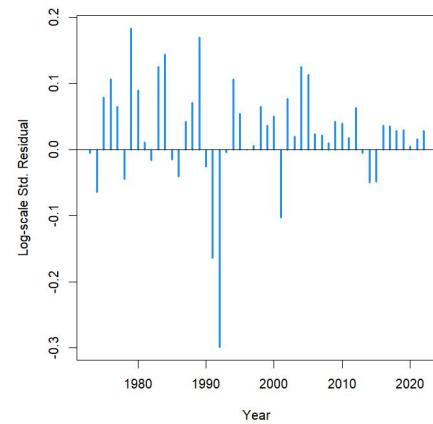
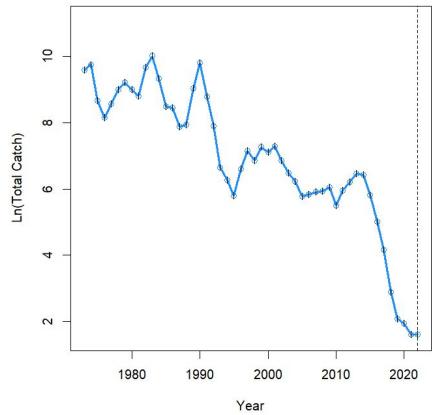
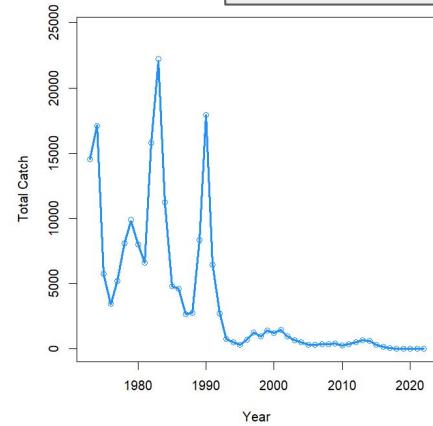


- Codename: m164_GSI
- Decoupled recruitment - modelled as random about mean
- Logistic Fleet / NEFSC Spring & Winter selectivities; Age-specific NEFSC Fall selectivity
- No larval indices
- Logistic normal-ar1-miss0 age comp for fleet and all surveys
- NAA random effects modelled as 2dar1
- Fleet selectivity has iid random effects
- No random effects on q
- GSI ar1 process on R (lagged 1 year)

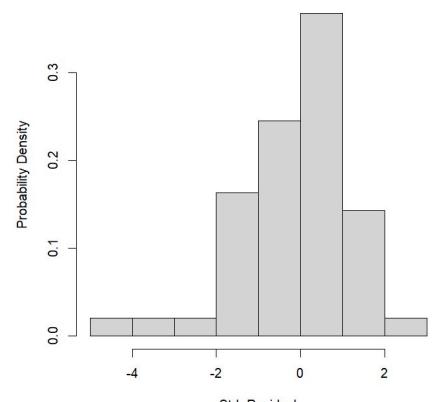
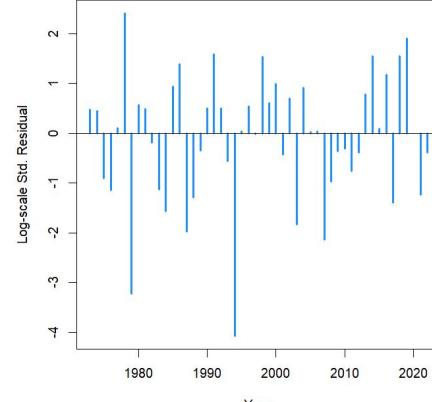
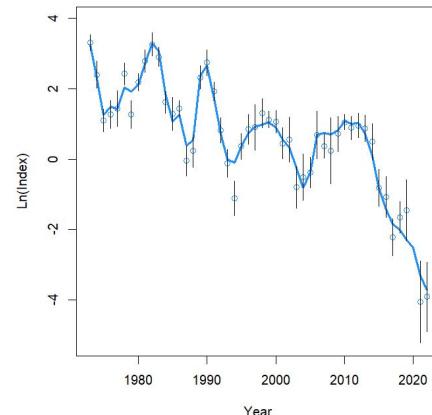
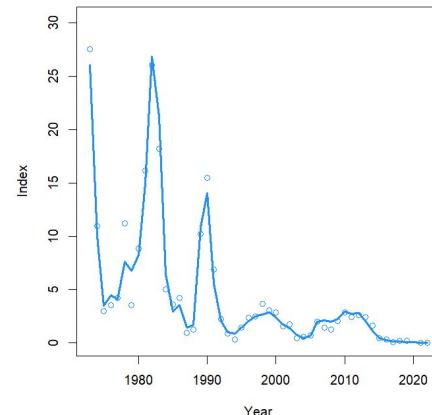
Part Two

Candidate Model Diagnostics

FLEET

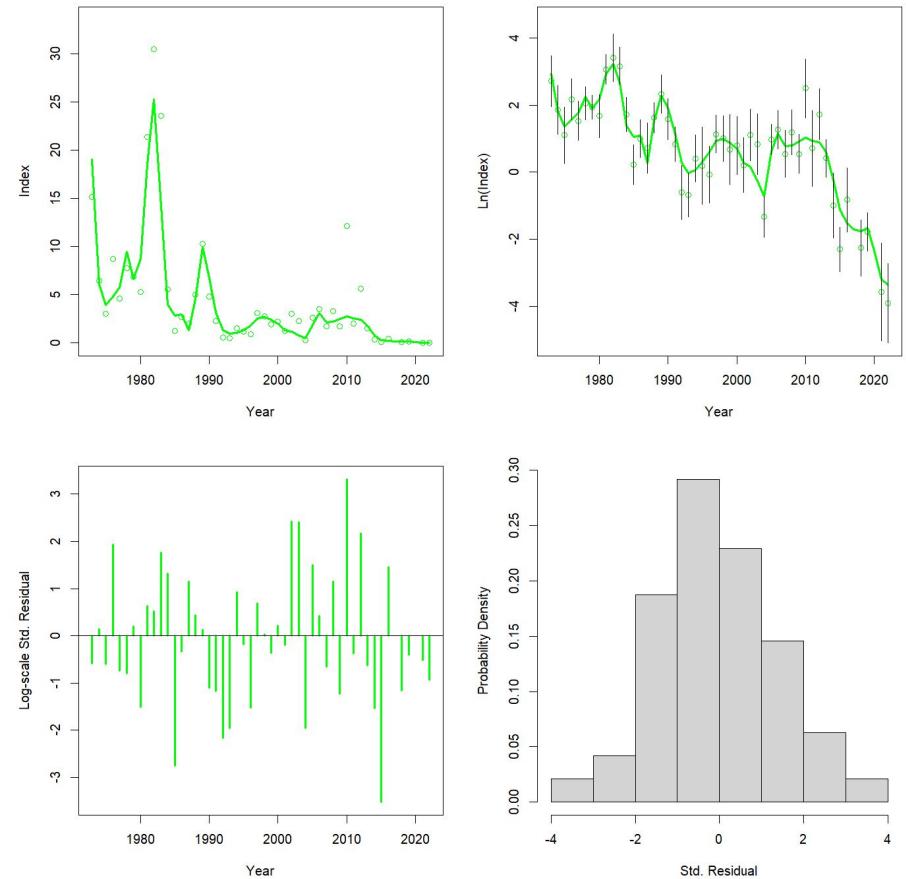


NEFSC Spring

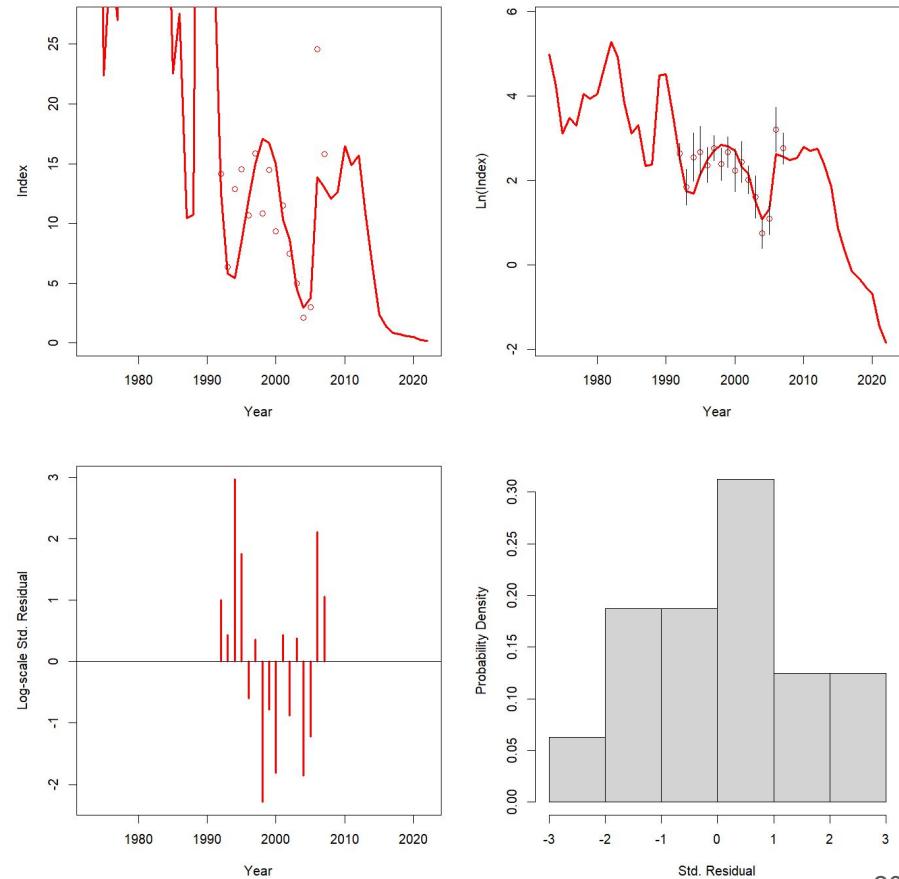


Std. Residual

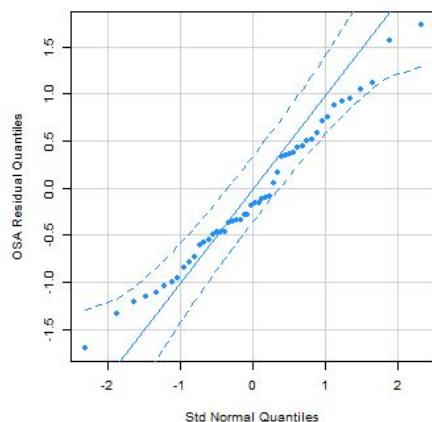
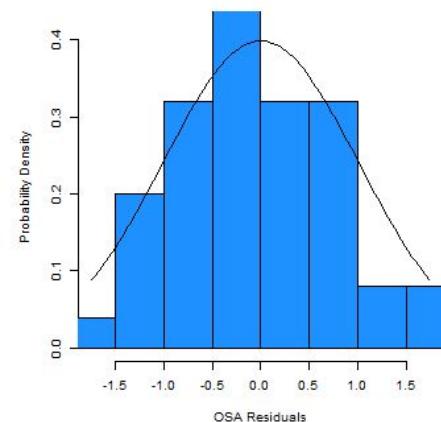
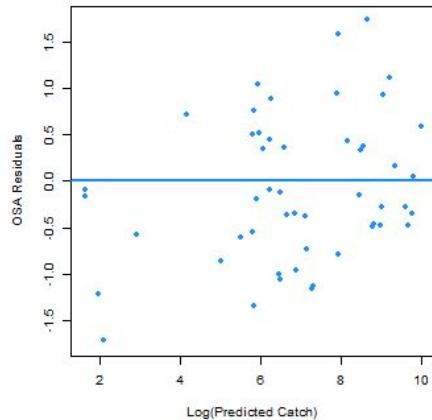
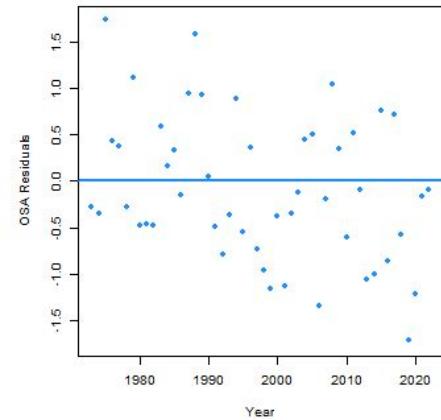
NEFSC Fall



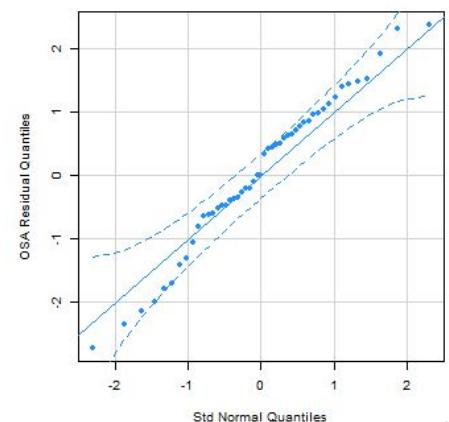
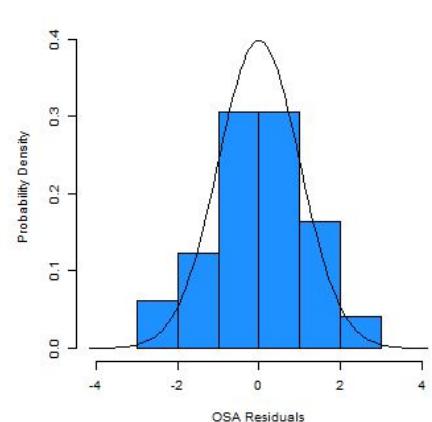
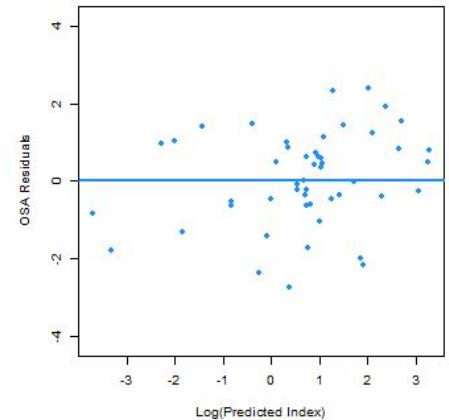
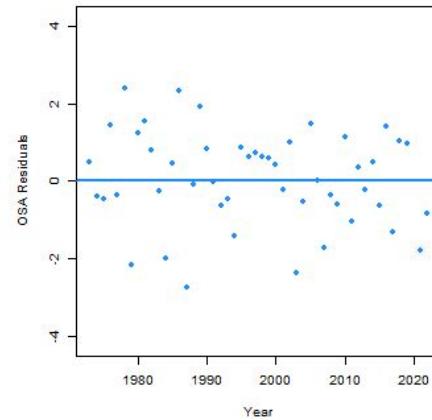
NEFSC Winter



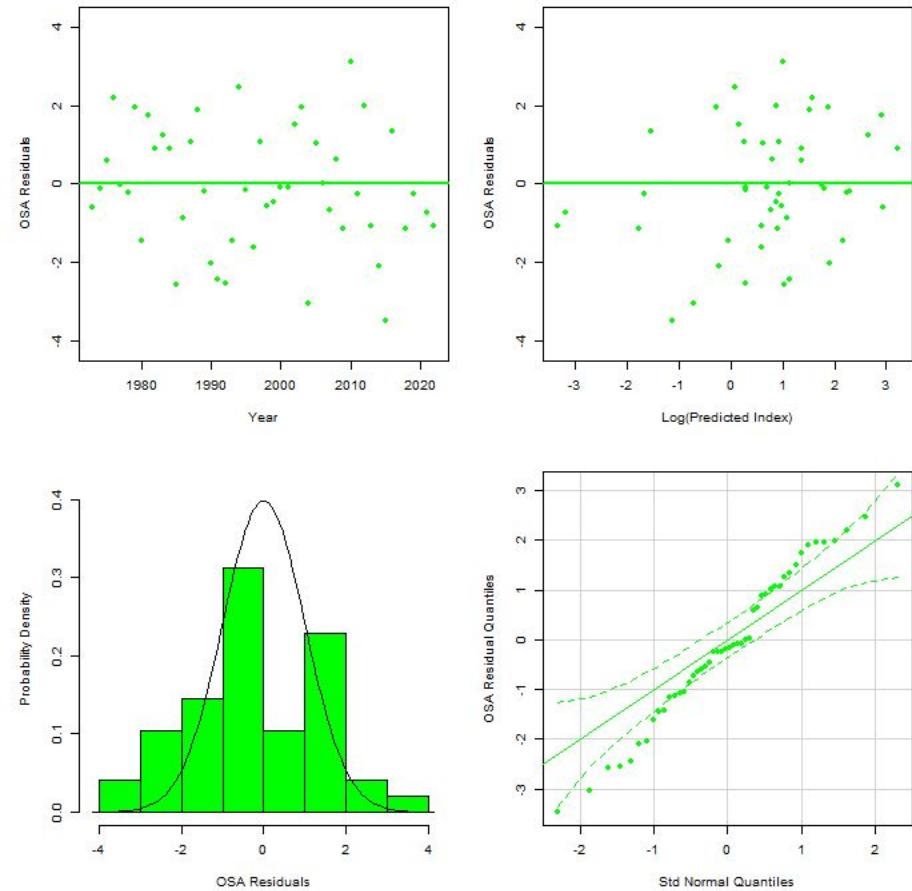
FLEET



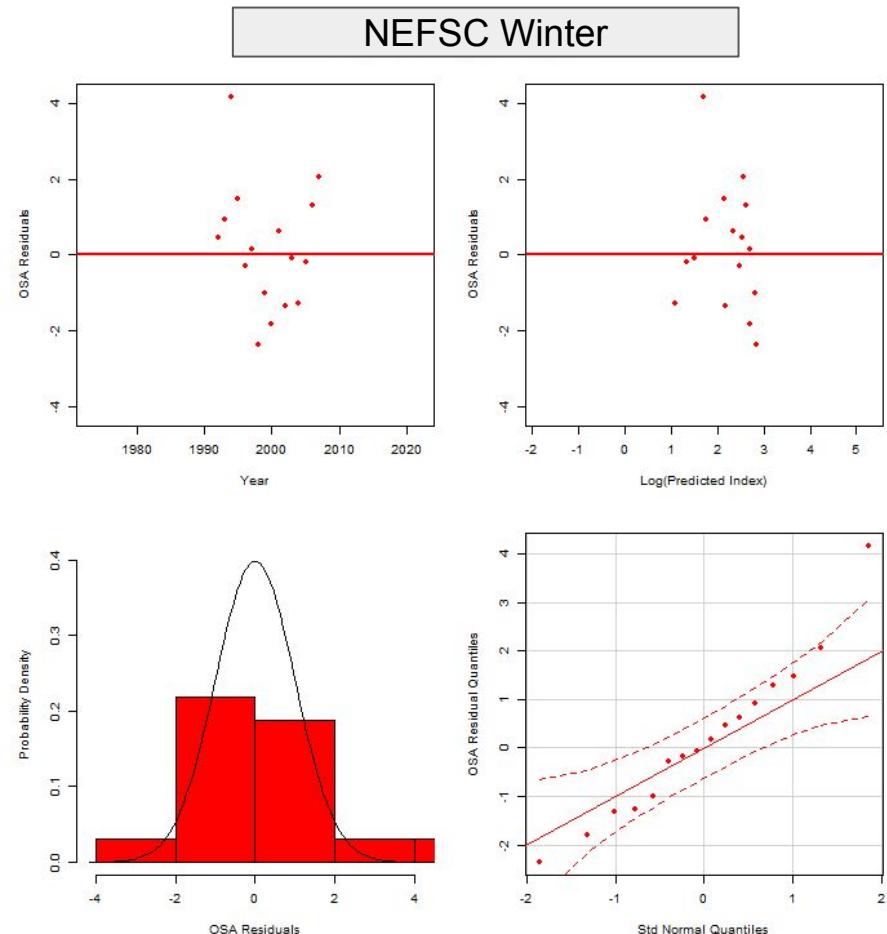
NEFSC Spring



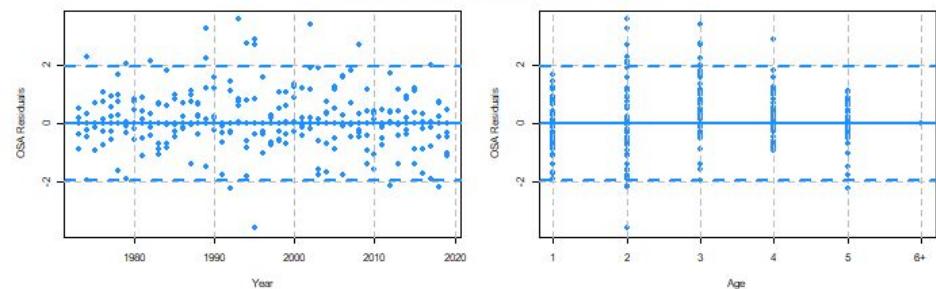
NEFSC Fall



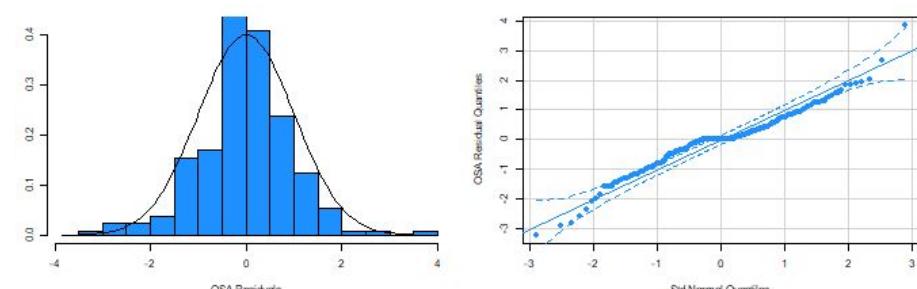
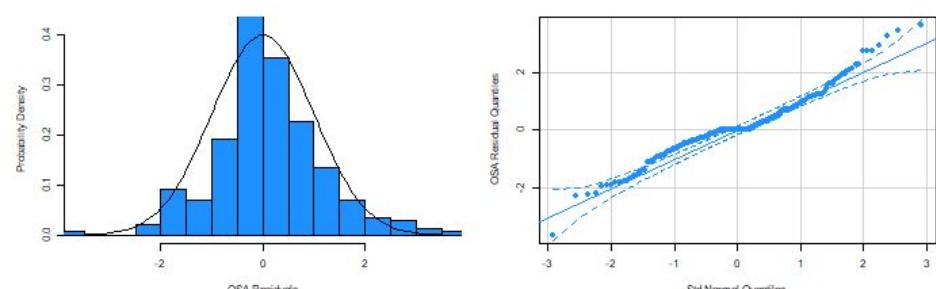
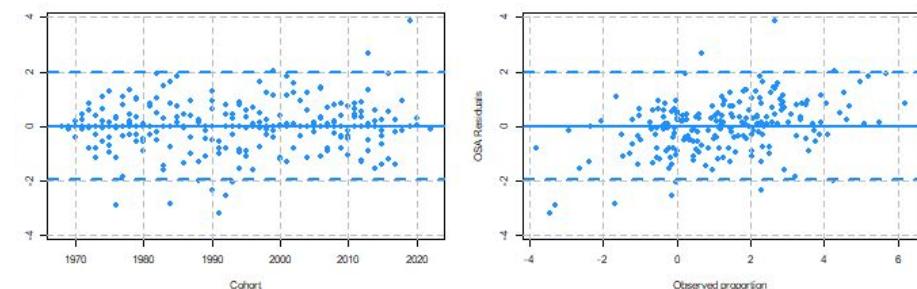
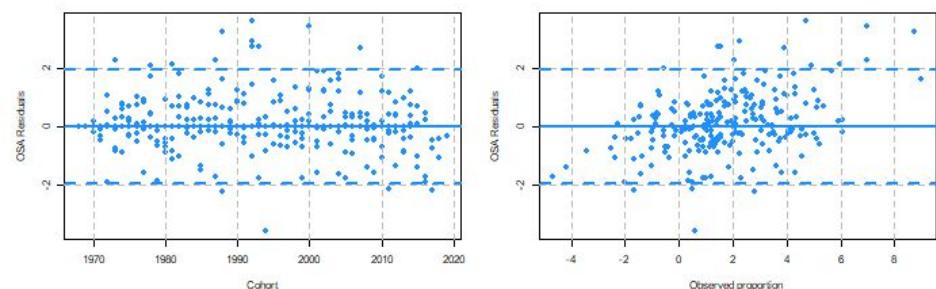
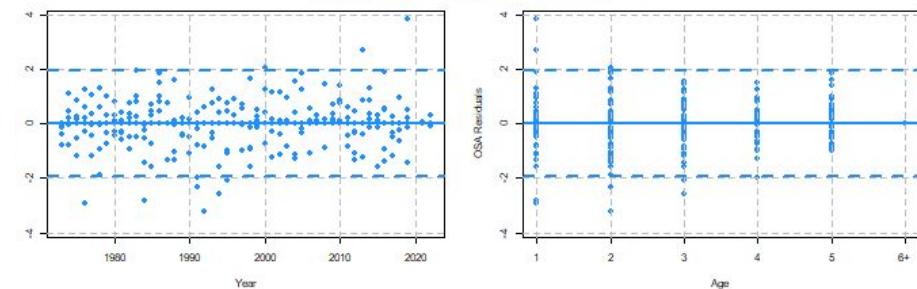
NEFSC Winter



FLEET

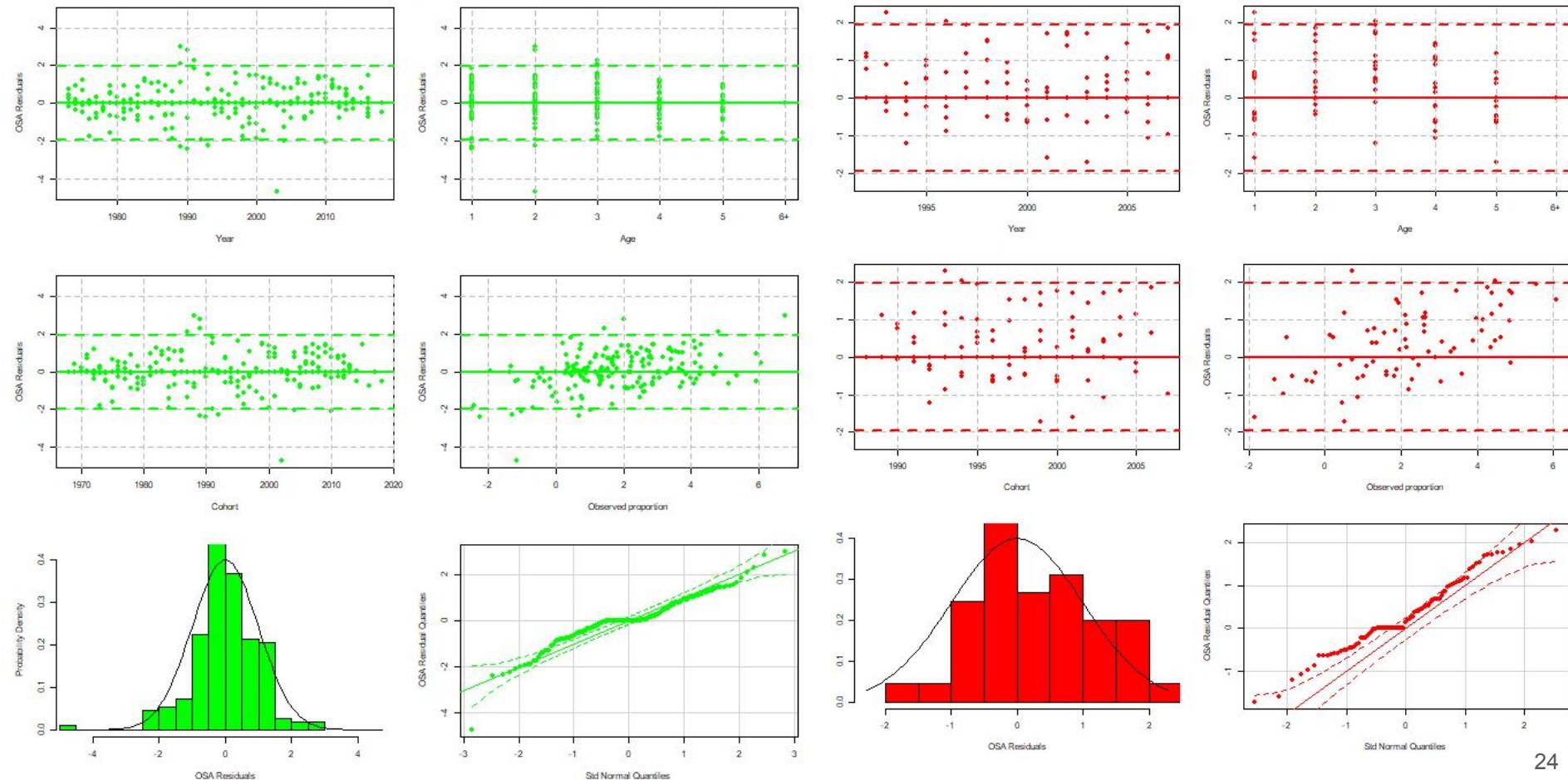


NEFSC Spring

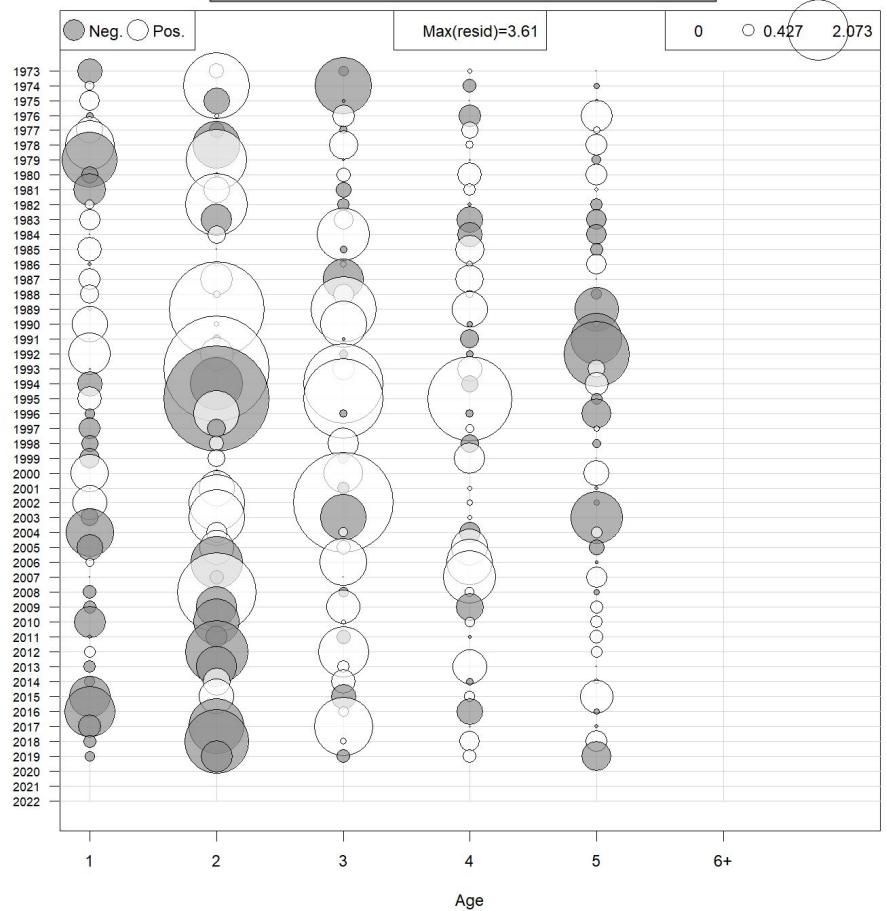


NEFSC Fall

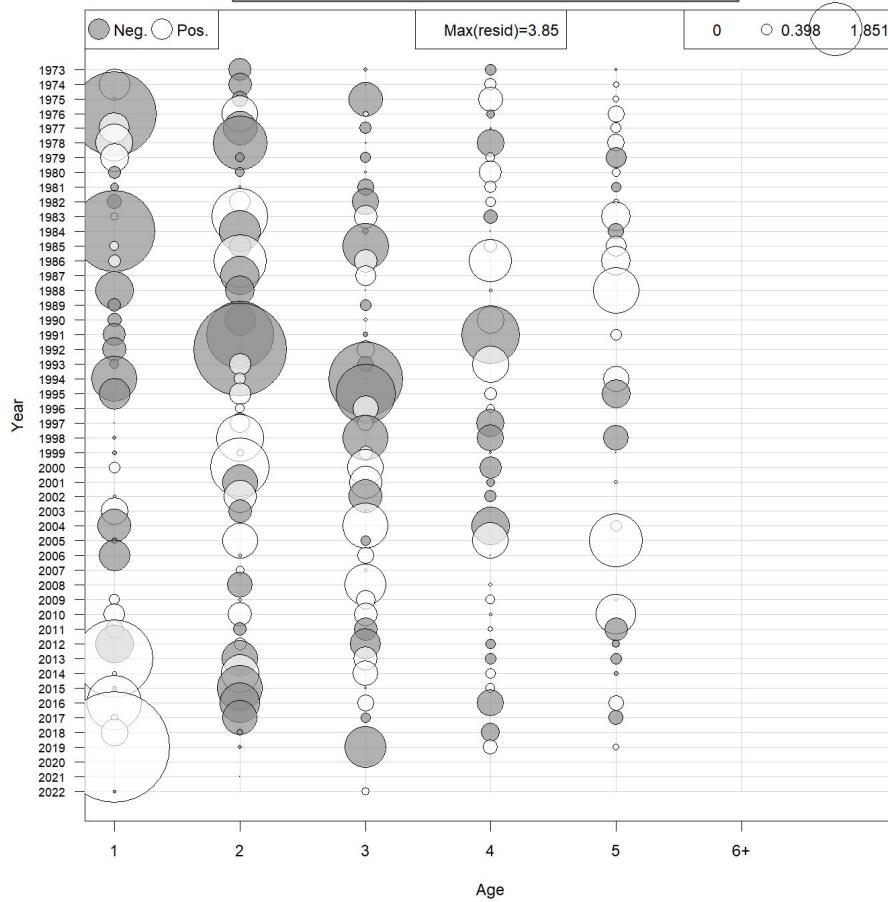
NEFSC Winter



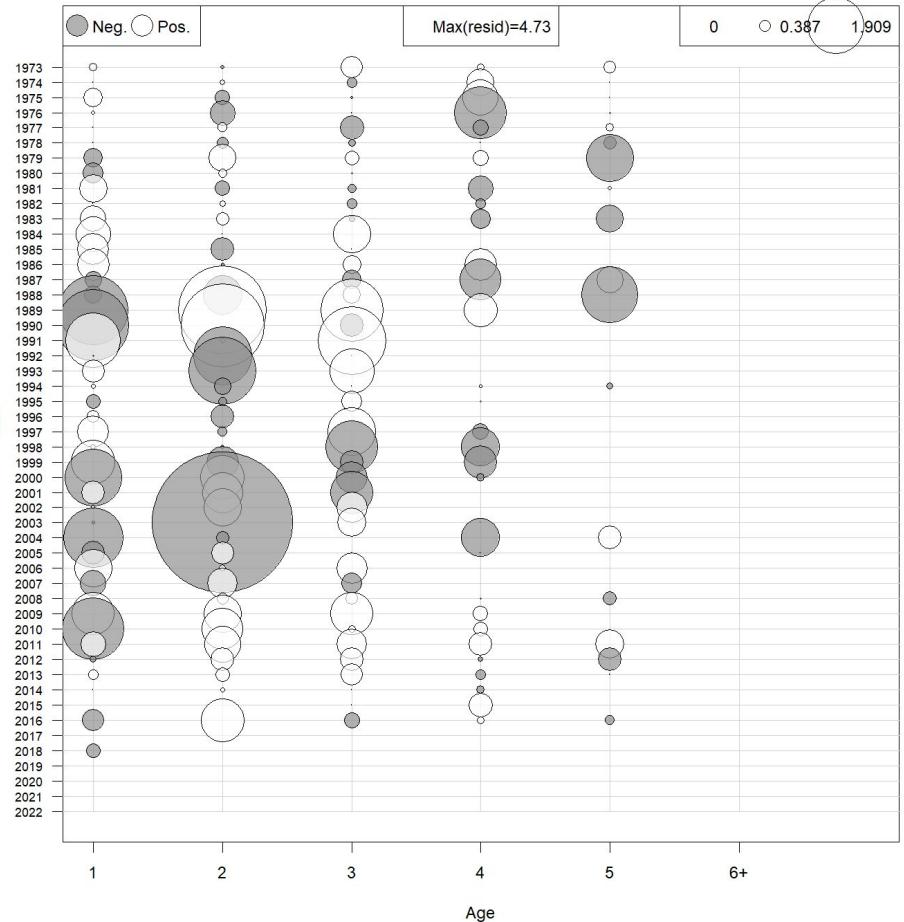
FLEET



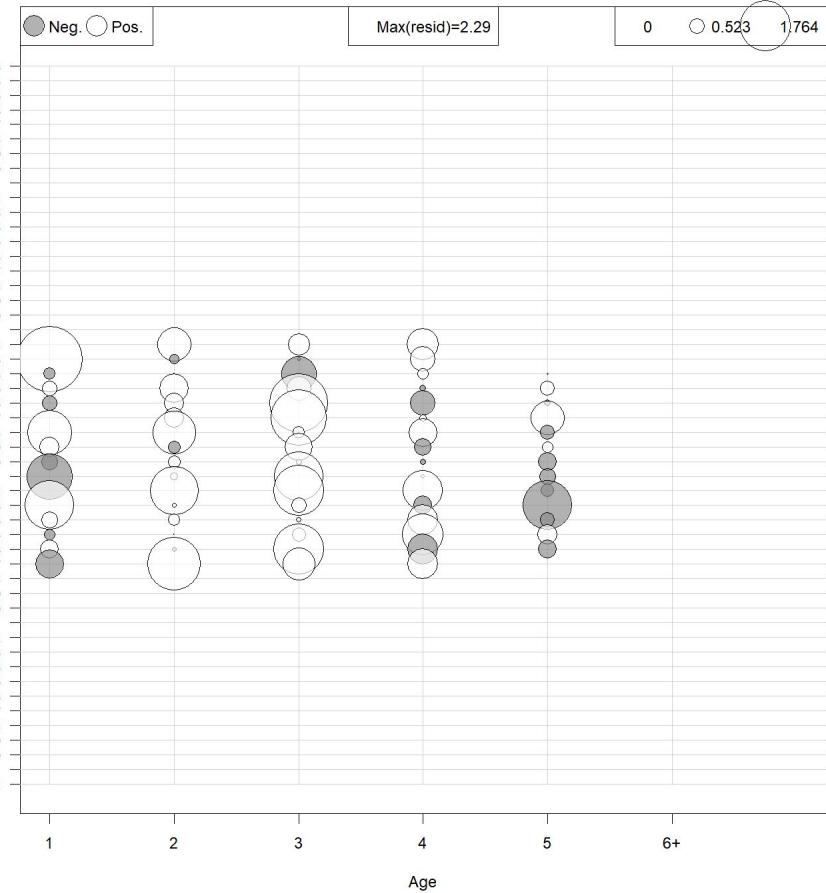
NEFSC Spring



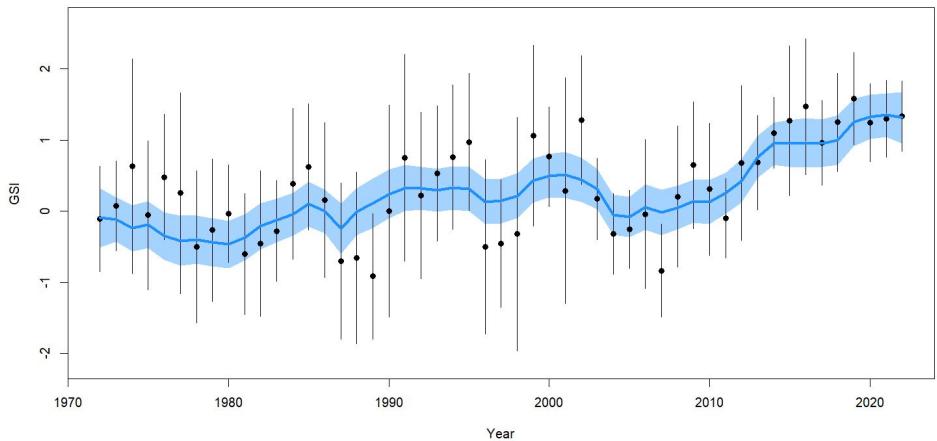
NEFSC Fall



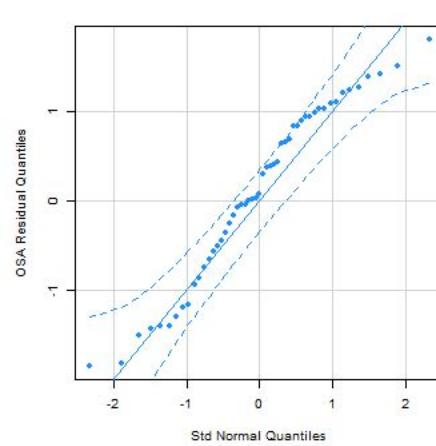
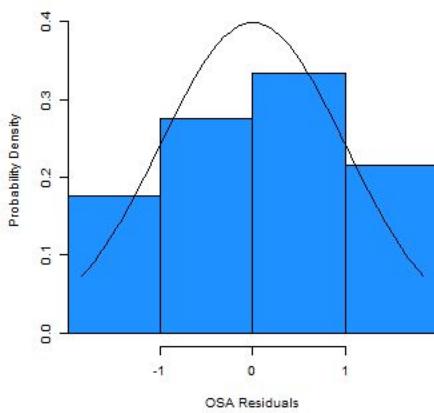
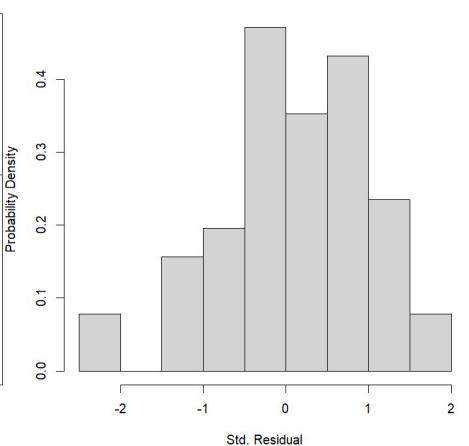
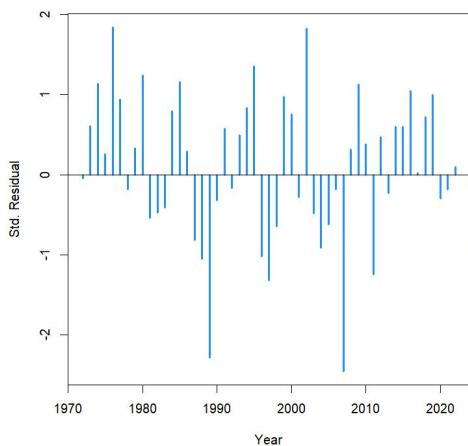
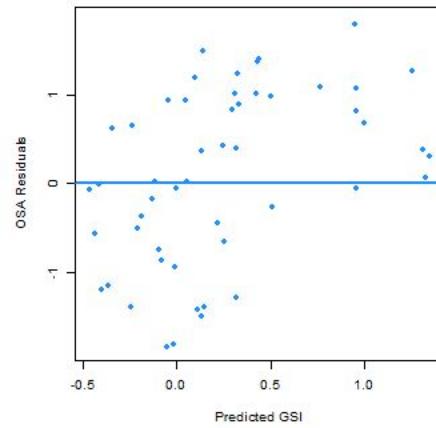
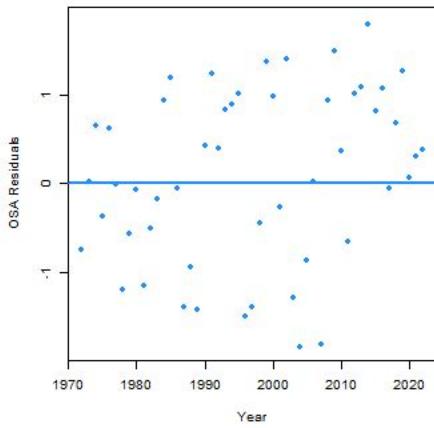
NEFSC Winter



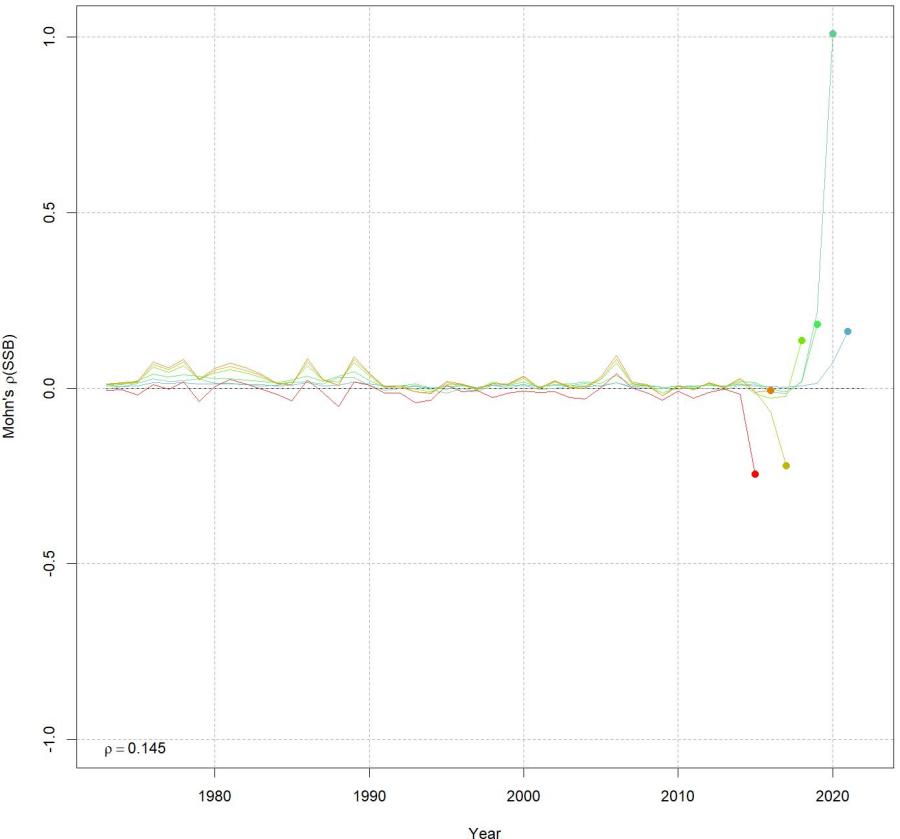
Ecov 1: GSI



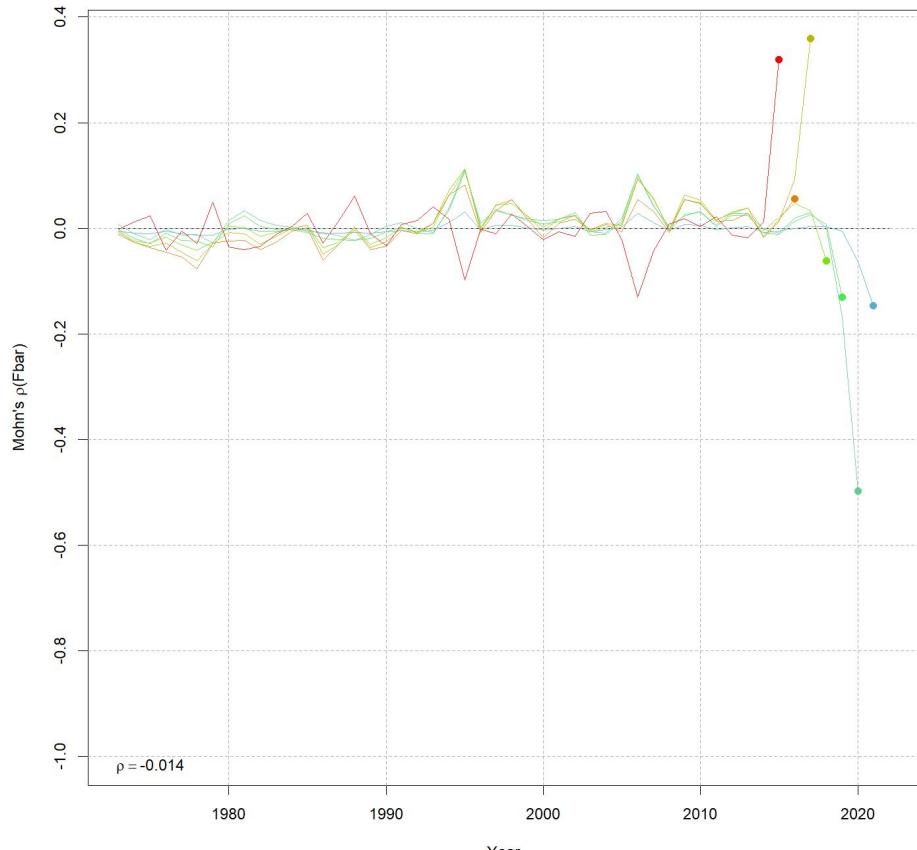
OSA residual diagnostics: Ecov 1 (GSI)

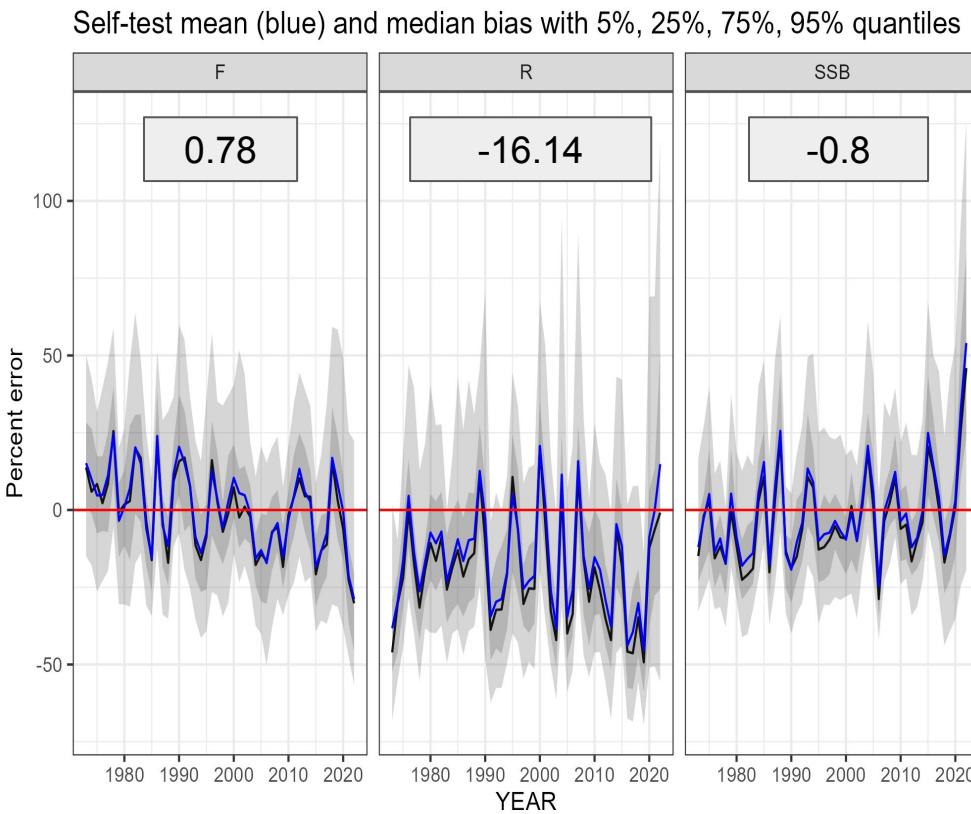
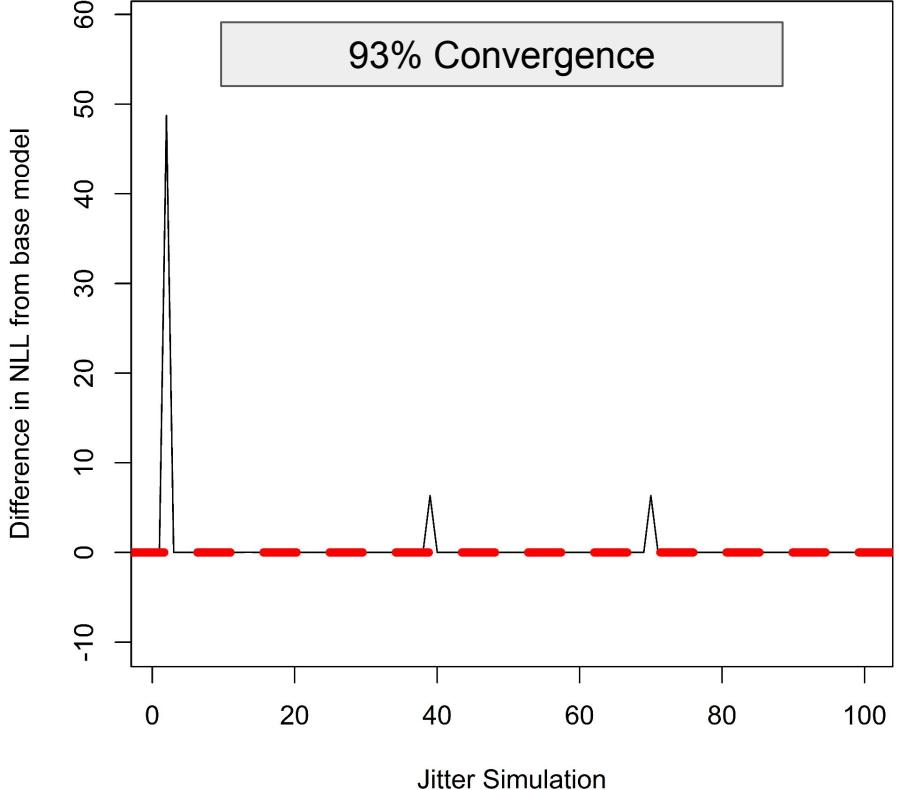


SSB



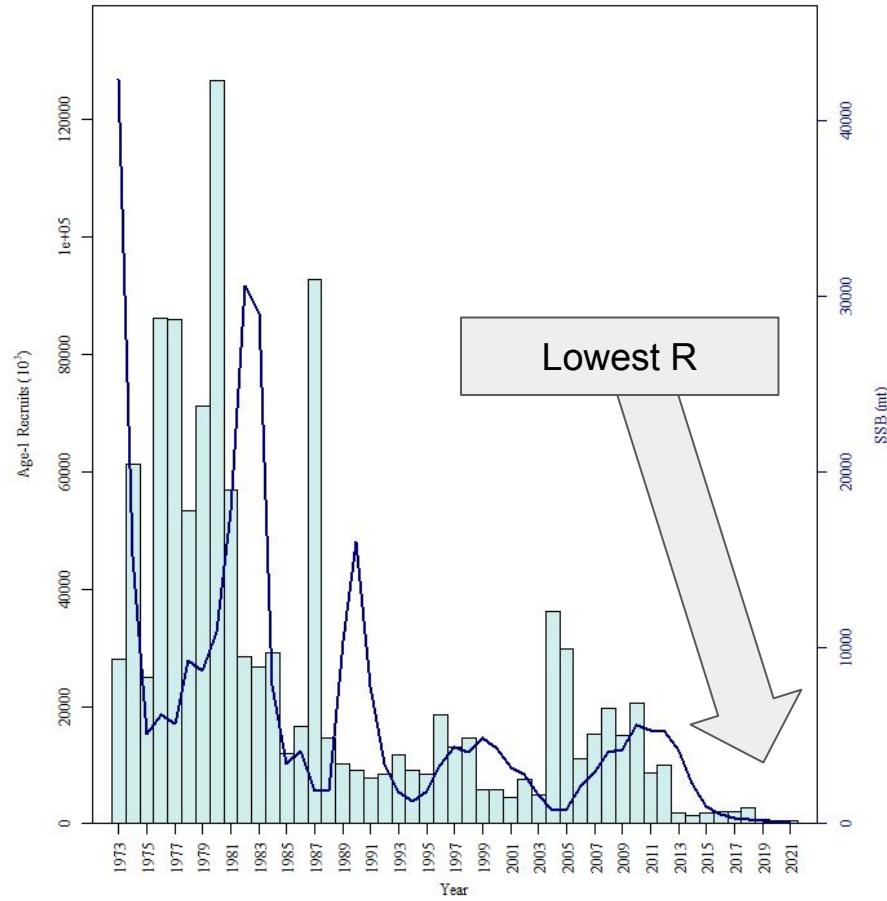
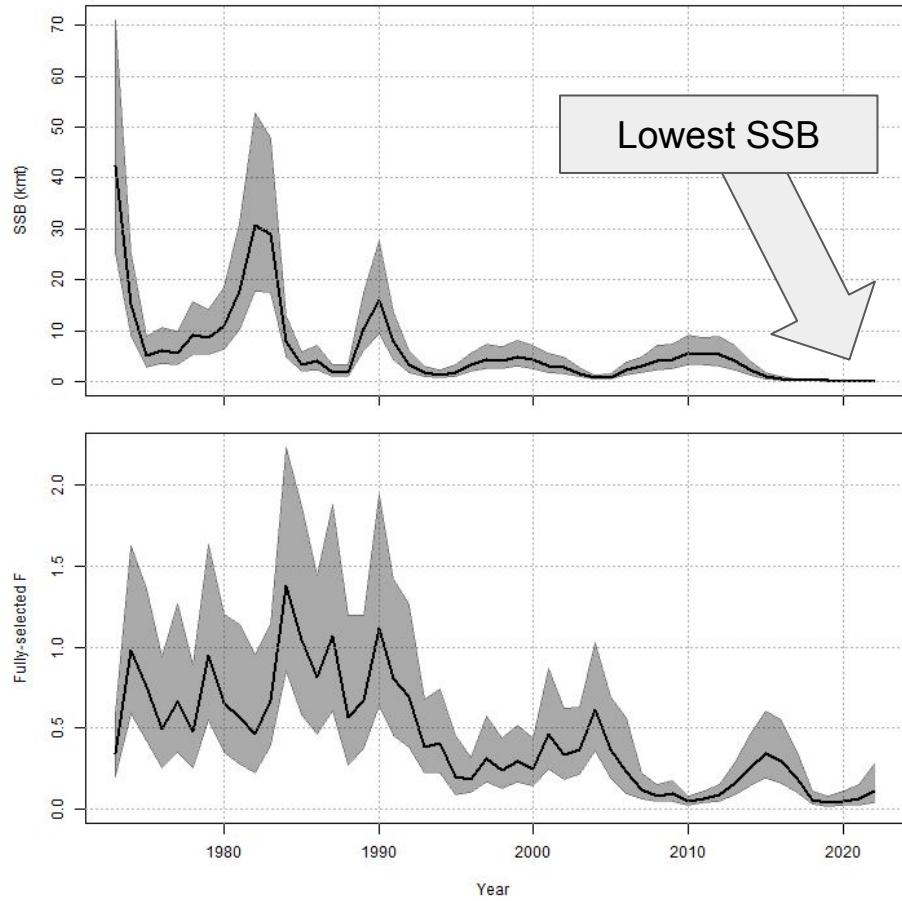
F

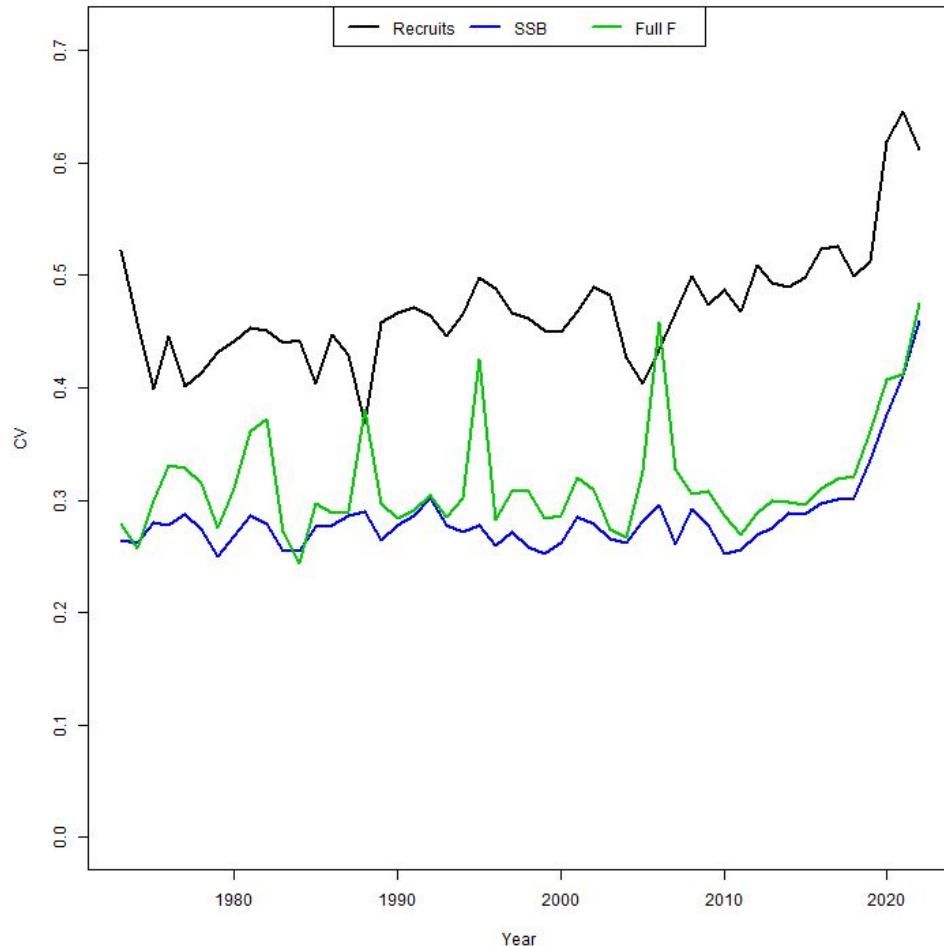




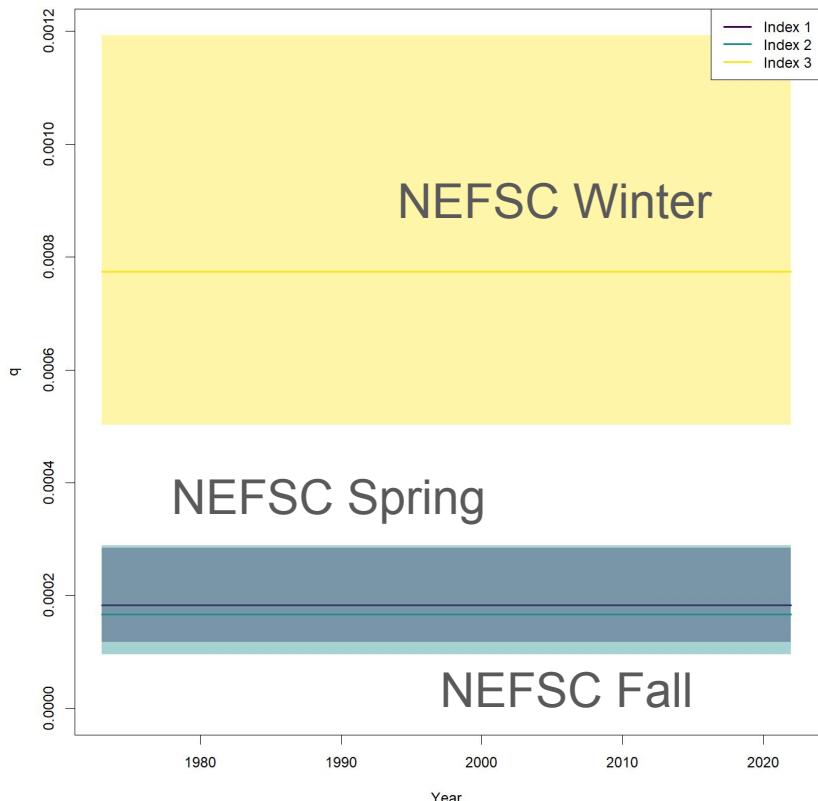
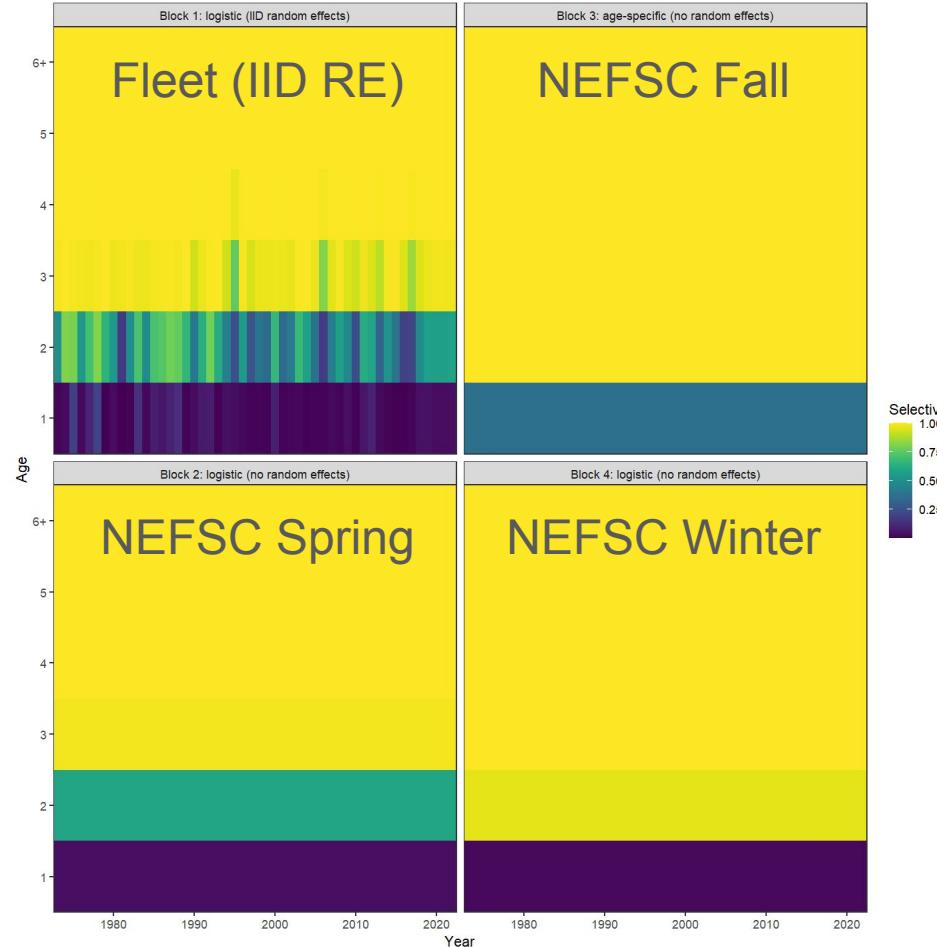
Part Three

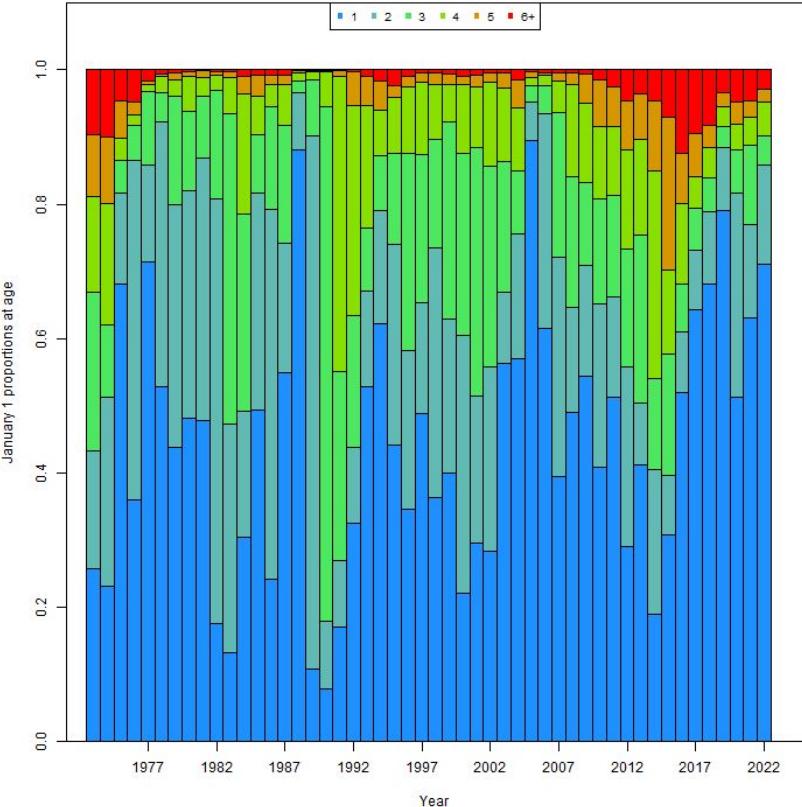
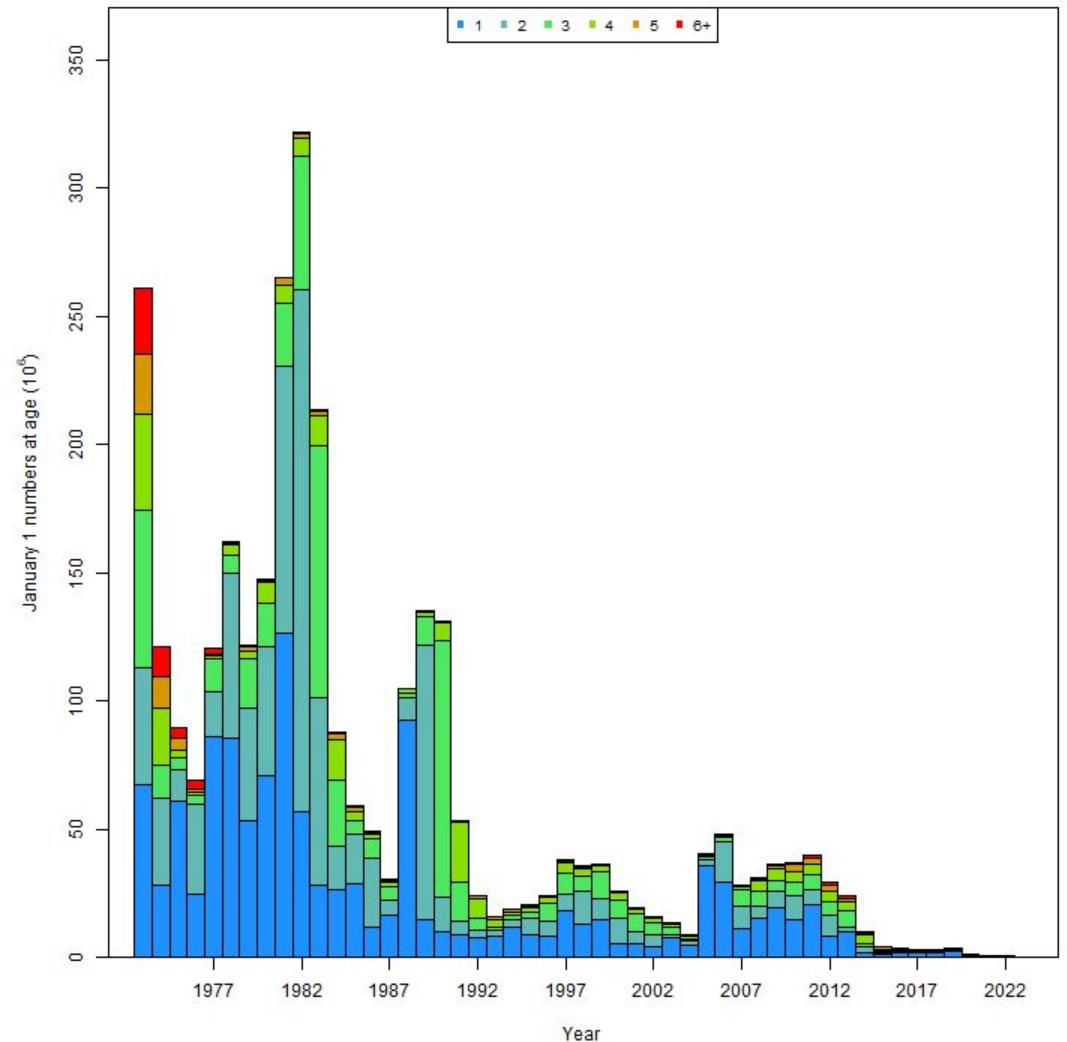
Candidate Model Results



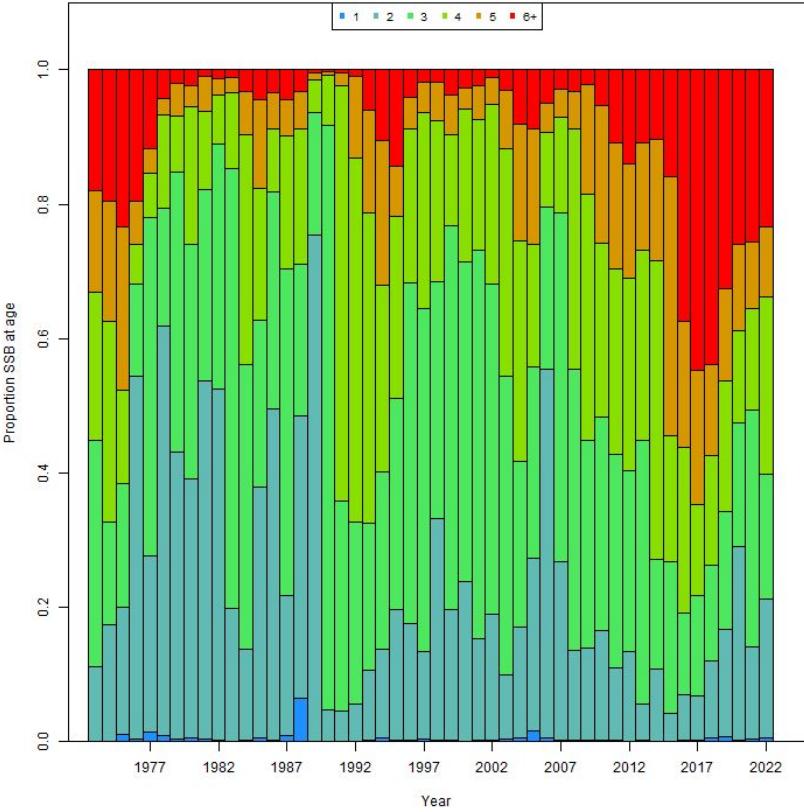
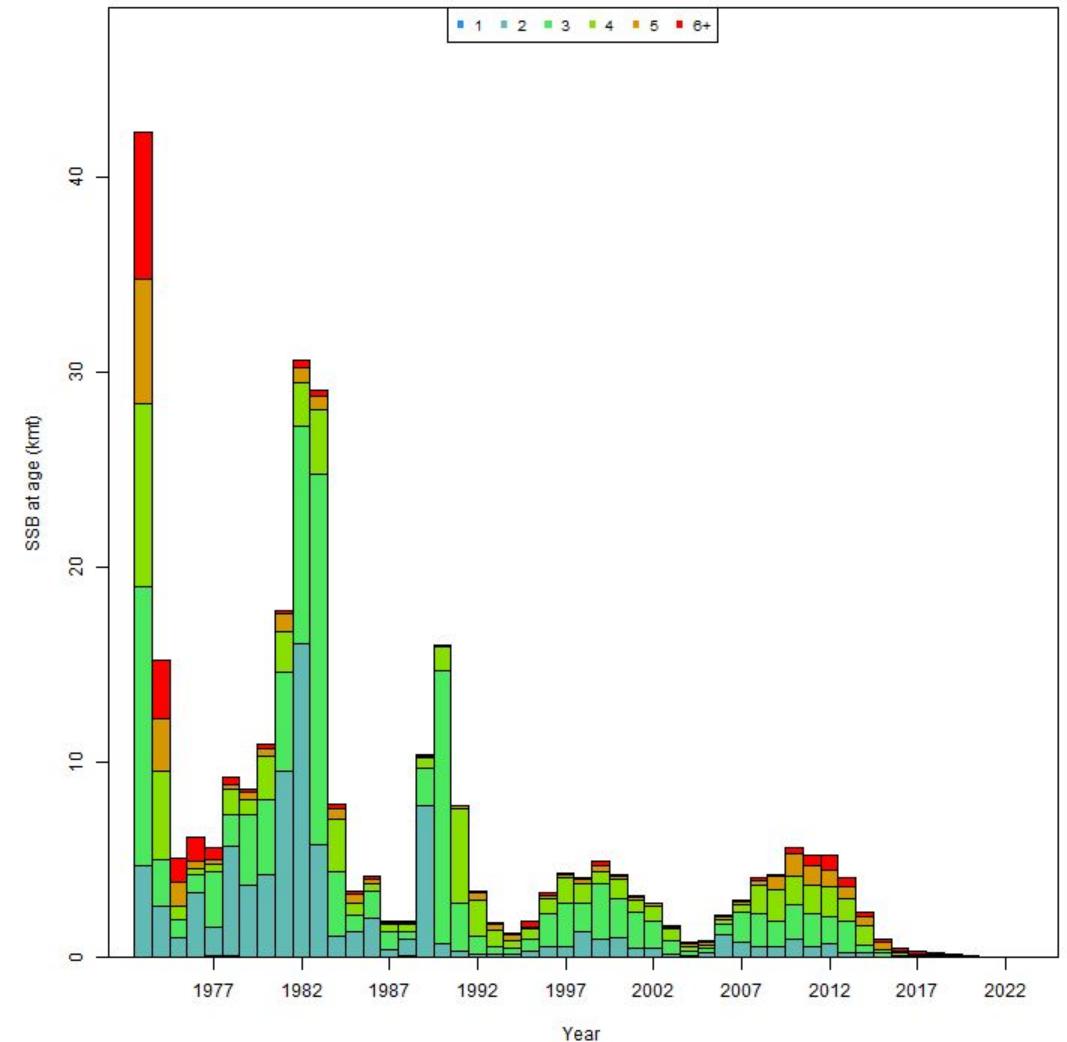


CVs for F, SSB, and R relatively steady with the end of the time series seeing the highest values-coinciding with the lowest SSB and R levels seen in the series.





NAA mostly younger ages, slight increase in older ages at end of time series.



SSBAA historically ages 2-4, large increase in older ages at end of series (coinciding with lowest SSB).

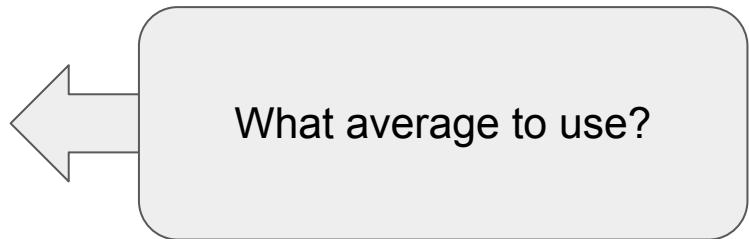
Part Four

$F_{40\%}$

F_{MSY} cannot be used because there is no stock-recruit relationship, so we default to a F_{MSY} proxy, $F_{40\%}$

Inputs and options (SNEMA Specific)

- Weight-at-age (varies)
- Fleet selectivity (varies only via IID RE)
- Maturity (constant)
- Natural mortality (constant)



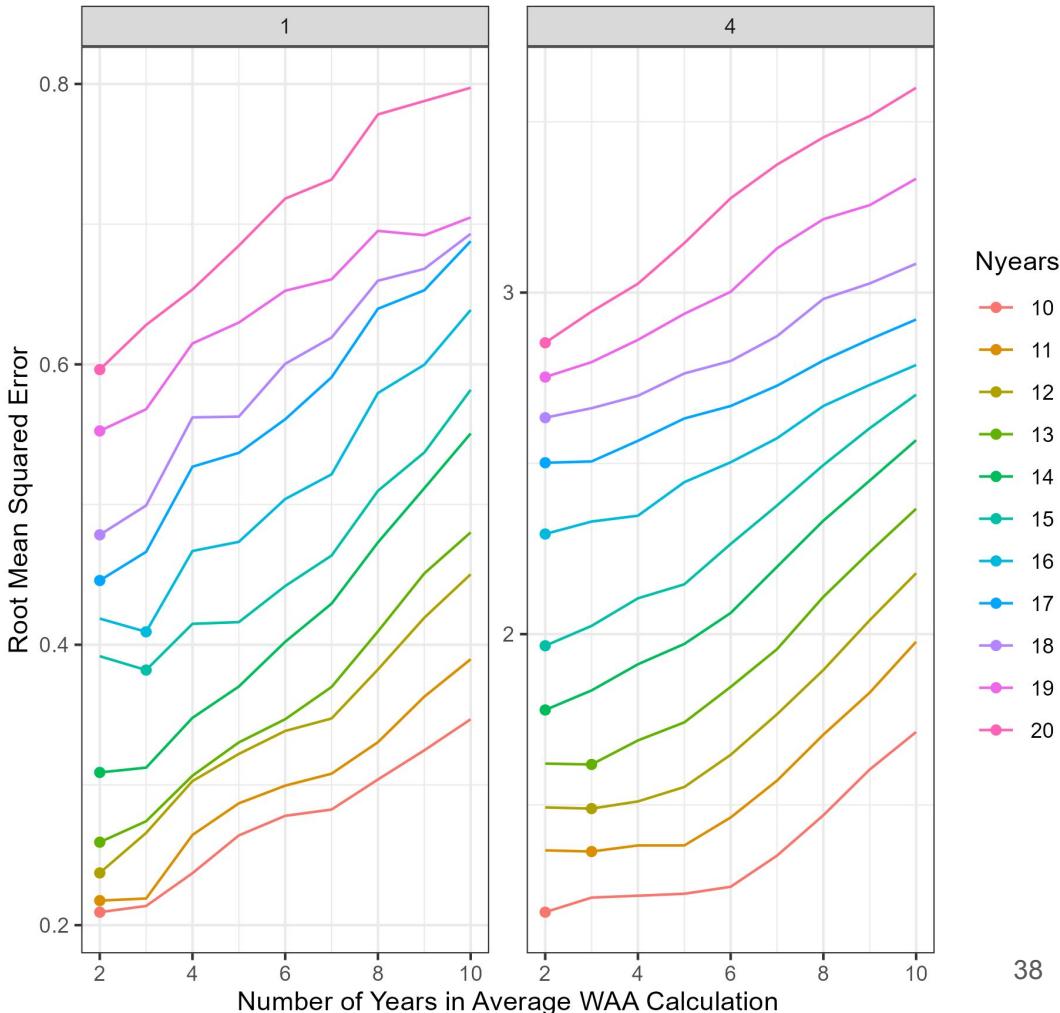
Optimal average for WAA was determined through a moving window analysis.

A 2 year average WAA was the best for predicting near-term WAA values (better than the default of 5 years)

WHAM also applies this same 2 year average to fleet selectivity.

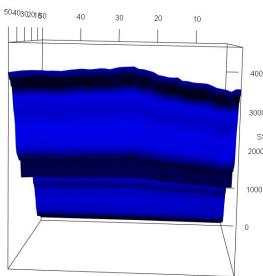
$$F_{40\%} = 0.73$$

Southern New England-Mid Atlantic WAA



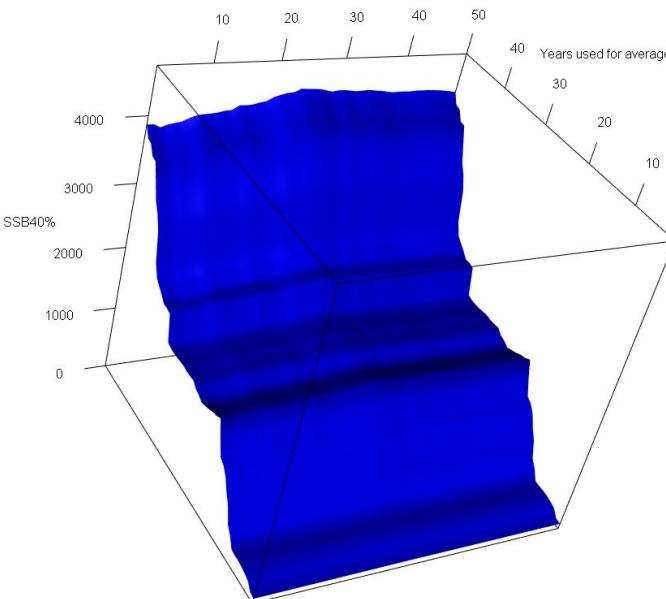
Years used for average R

Years used for average WAA



Years used for average R

Years used for average WAA



SSB_{40%} very dependent on what years are used for average R.

With such a pronounced decreasing trend in R over time, this is very much expected.

We want a SSB_{40%} value representative of the low stock size.

Because R is informed by GSI, a long-term projection of the stock fishing at F_{40%} may not necessarily cause SSB to reach the internally estimated SSB_{40%} value.

SSB_{40%} should instead be estimated from these long-term projections.

Part Five

Projections (and revisit of SSB_{40%})

Projection Settings Decisions

- 1) How to project the Gulf Stream Index
- 2) Over what years to average for WAA and fleet selectivity (2-year to match BRPs)
- 3) Over what years to average for maturity (constant)

Note: For our projections, we chose to use terminal year catch (2022) for 2023 and then project at $F_{40\%}$ for all years after unless otherwise specified.

Gulf Stream Index Settings

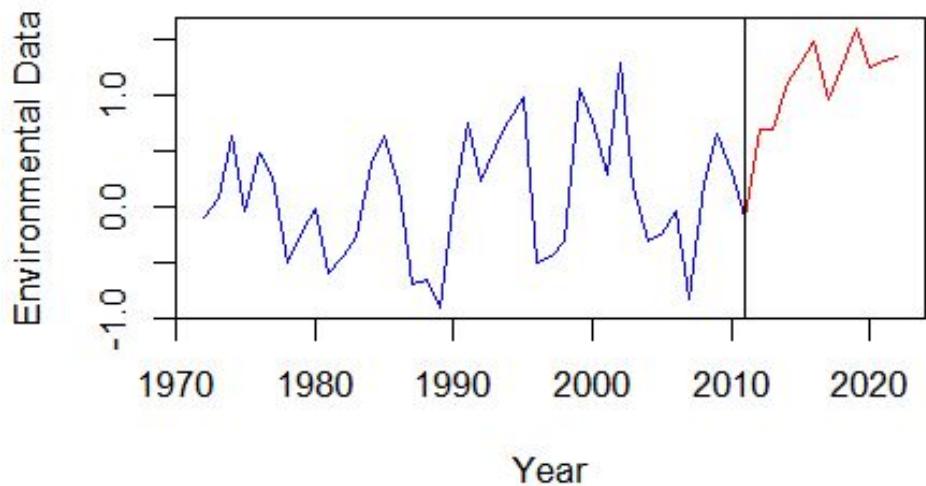
- Project using the ar1 process
- Project using a mean
 - Time series mean or a shorter series more representative of recent conditions?
- Project using a linear regression
 - Regression over the entire time series or regression over a shorter series more representative of recent conditions?

What would be “recent conditions”?

Changepoint analysis showed that the series 2012-2022 is most unlike the historical period.

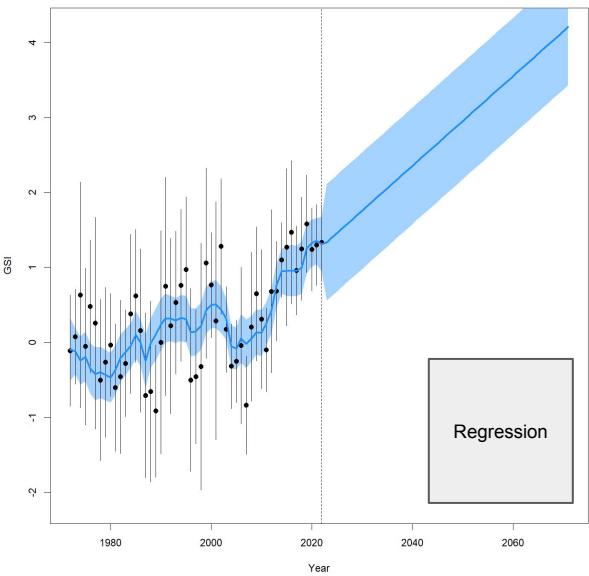
This period is most representative of current recruitment conditions.

Projecting at a mean over this series (instead of the entire series 1973-2022) would be more realistic for recruitment.

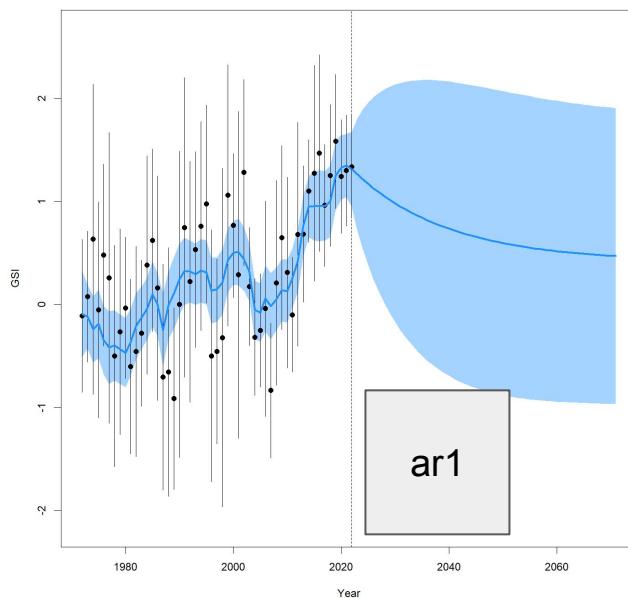


GSI Projection Options

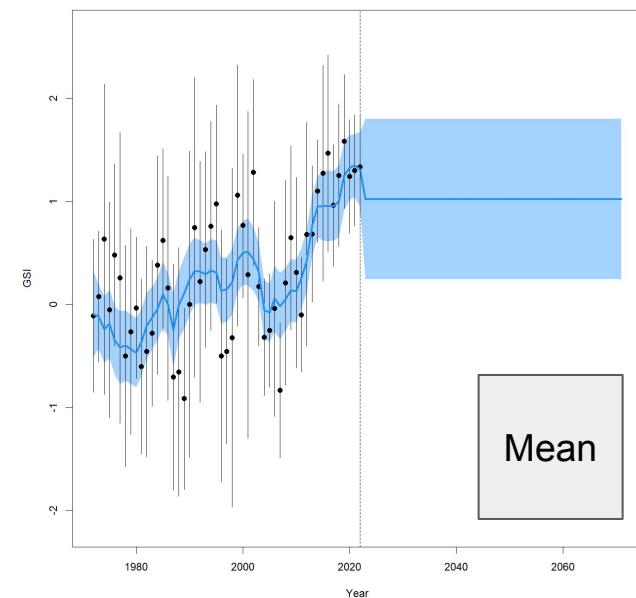
Ecov 1: GSI

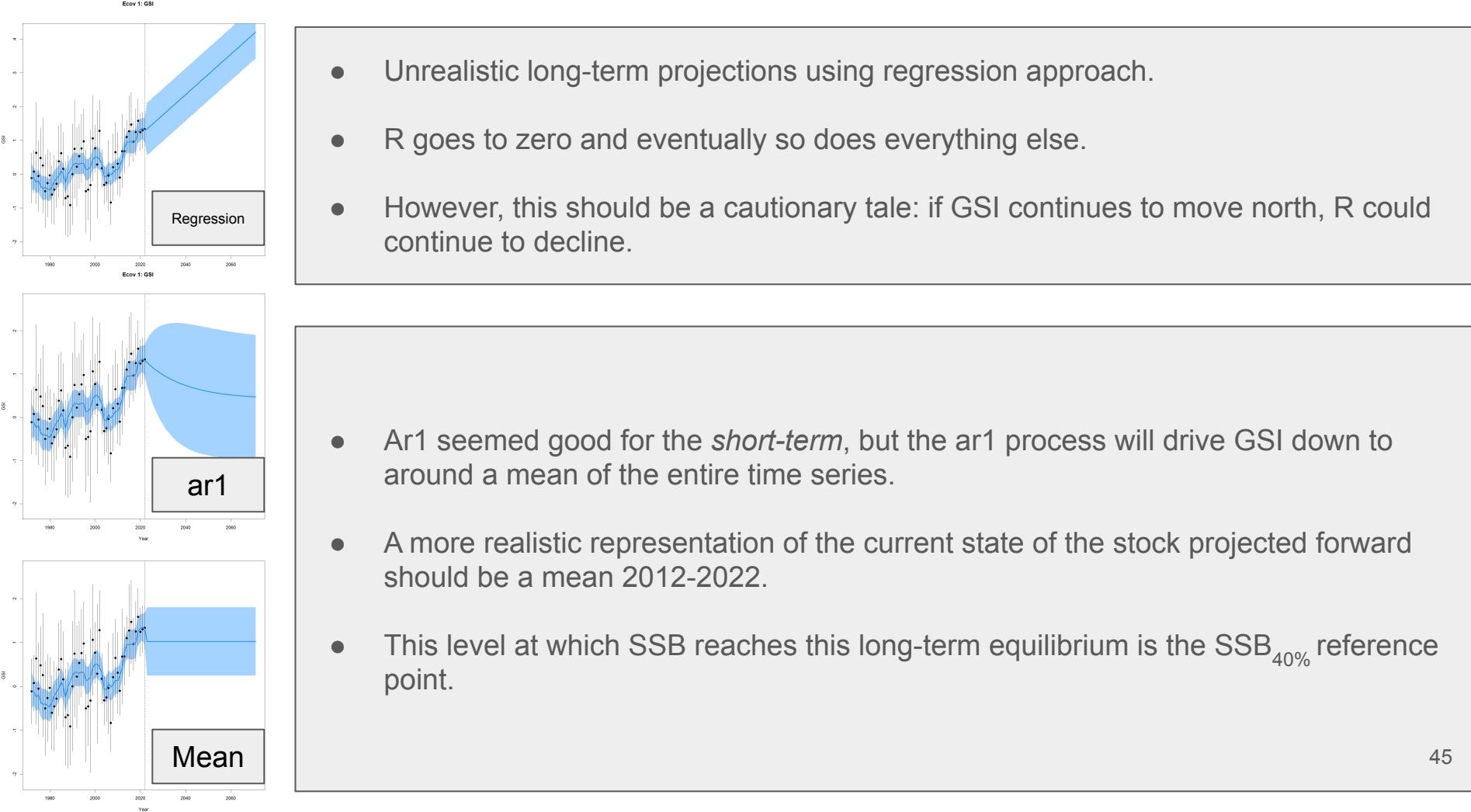


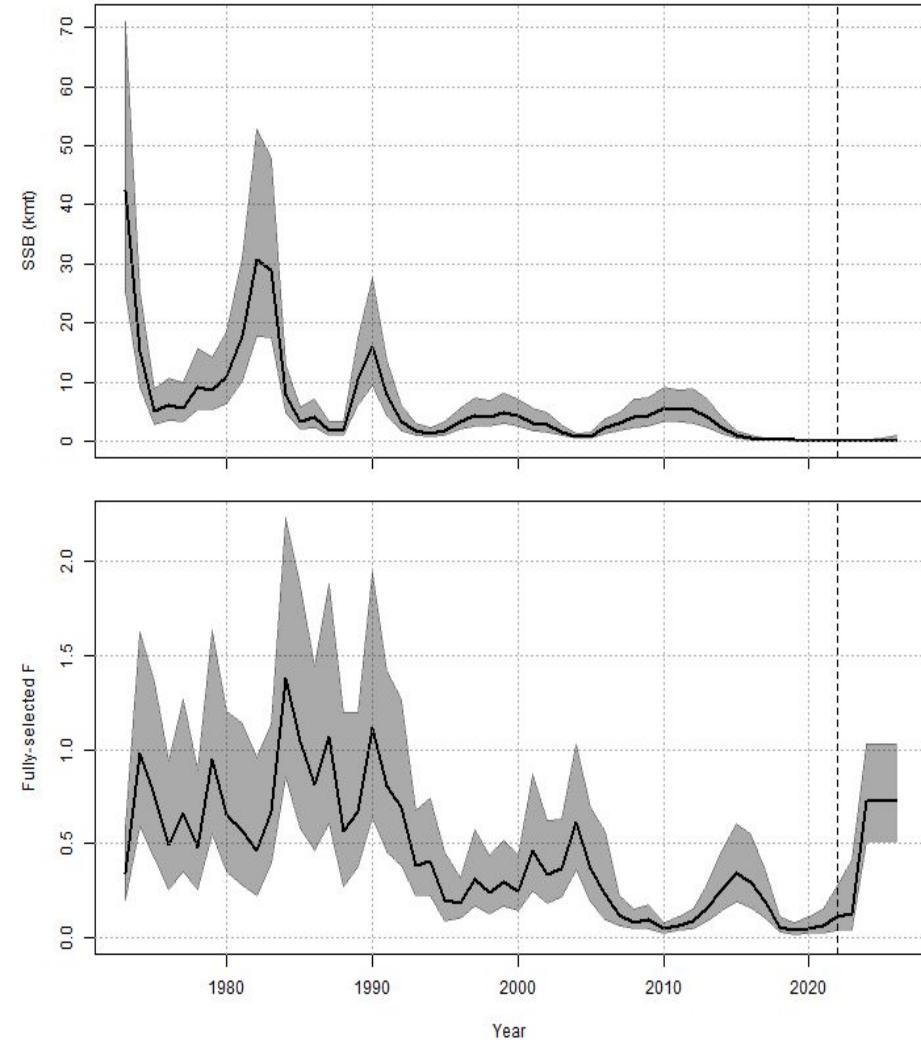
Ecov 1: GSI



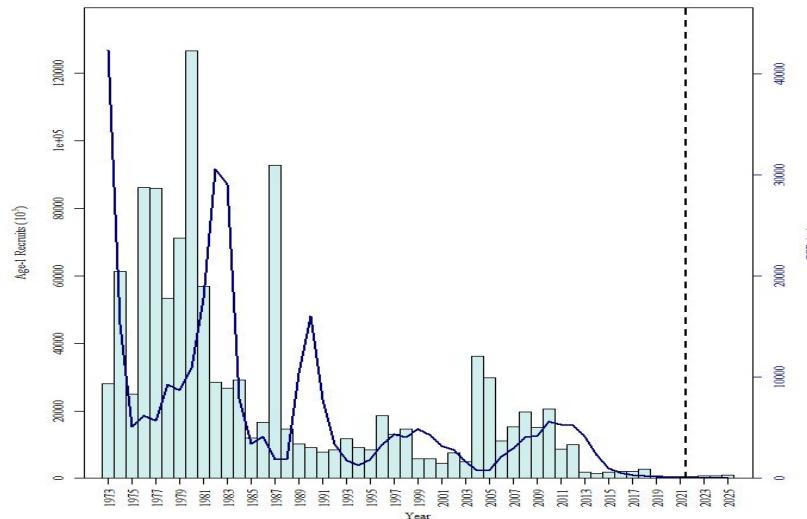
Ecov 1: GSI







Fishing at $F_{40\%}$ and projecting at 2012-2022 average GSI shows increases of both SSB and R in the short-term (still relatively very low values compared to time series).



Final BRPs

F_{40%}	SSB_{40%}	MSY Proxy
0.73	126 mt	97 mt

Project GSI using mean 2012-present
Determine SSB_{40%} using long-term projections.

Summary

Candidate model

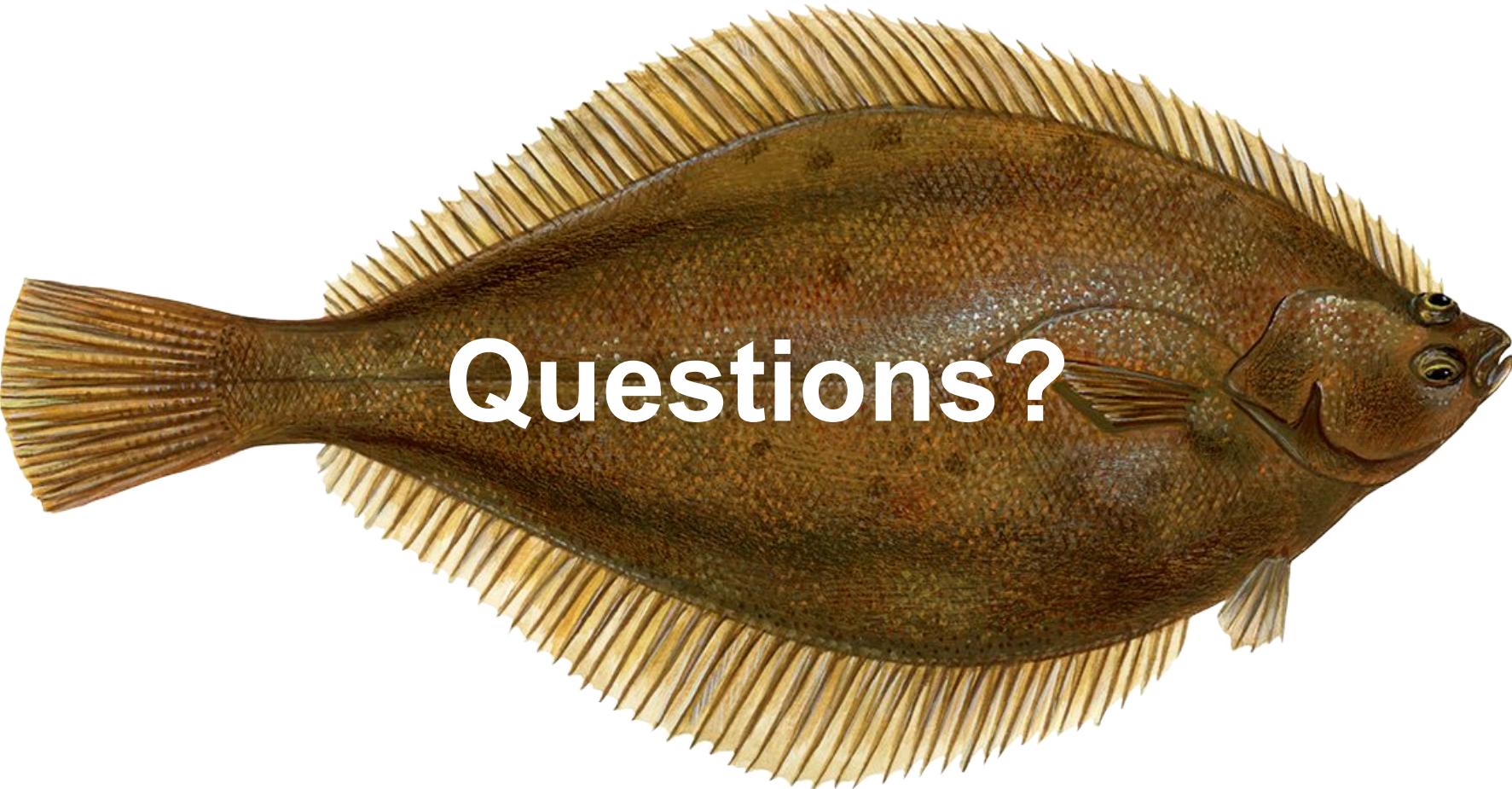
- WHAM
- 3 indices (NEFSC Spring, Fall, Winter)
- 1 fleet
- Lognormal-ar1-miss0 age comp
- Lifetime M & maturity
- Time-varying WAA
- RE on NAA (2dar1)
- RE on fleet selectivity (iid)
- GSI effect on R

BRPs

- $F_{40\%}$: 0.73
- $SSB_{40\%}$: 126 mt
- MSY Proxy: 97 mt

Projections

- 2-year average WAA
- 2-year average fleet selectivity
- Constant maturity
- GSI mean 2012-2022



Questions?

EXTRA SLIDES

**WHAT ARE THE UNITS OF
THE LARVAL SURVEY?**

The larval index corresponds to an estimated annual production of age 0 day larvae per 10 m²

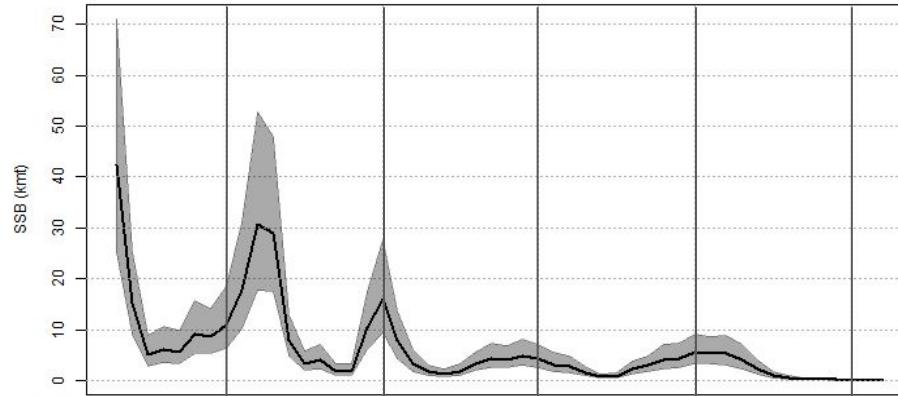
Thus, abundance- not biomass.

Details in Richardson et al. 2010:

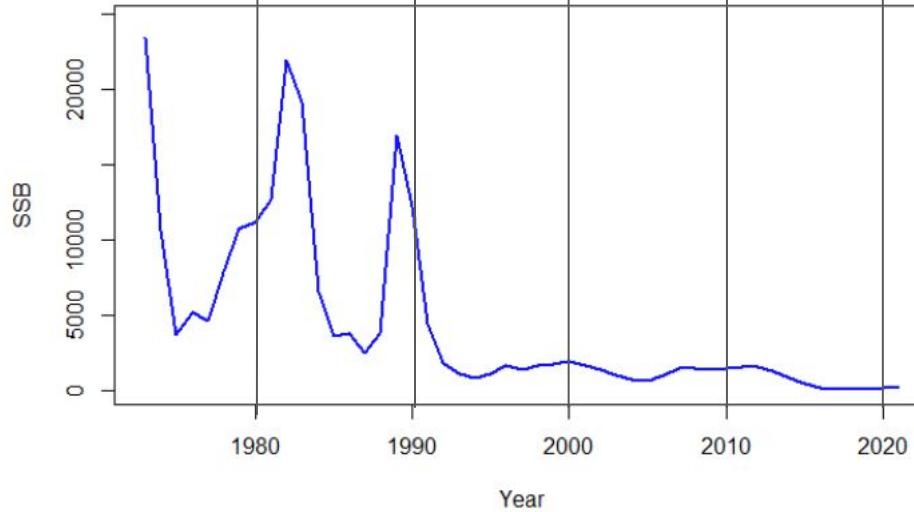
<https://academic.oup.com/icesjms/article/67/4/617/680402>

COMPARISON OF 2024 RT TO 2022 MT RESULTS

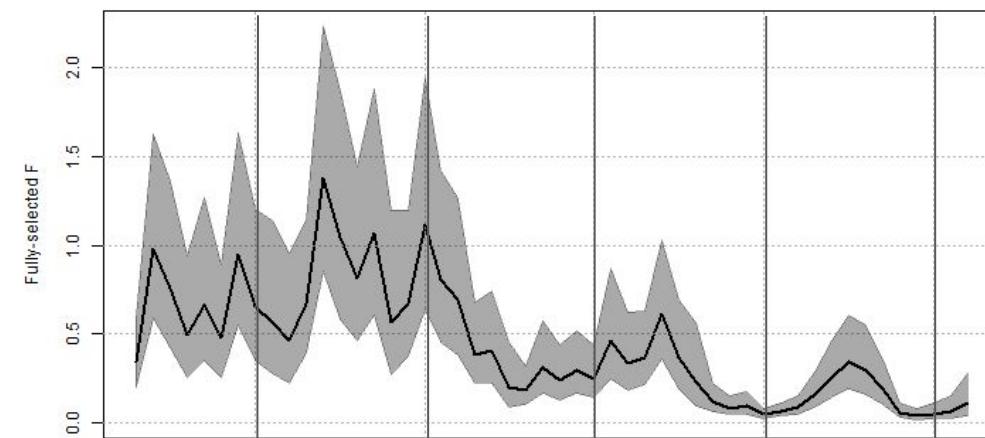
2024 RT WHAM



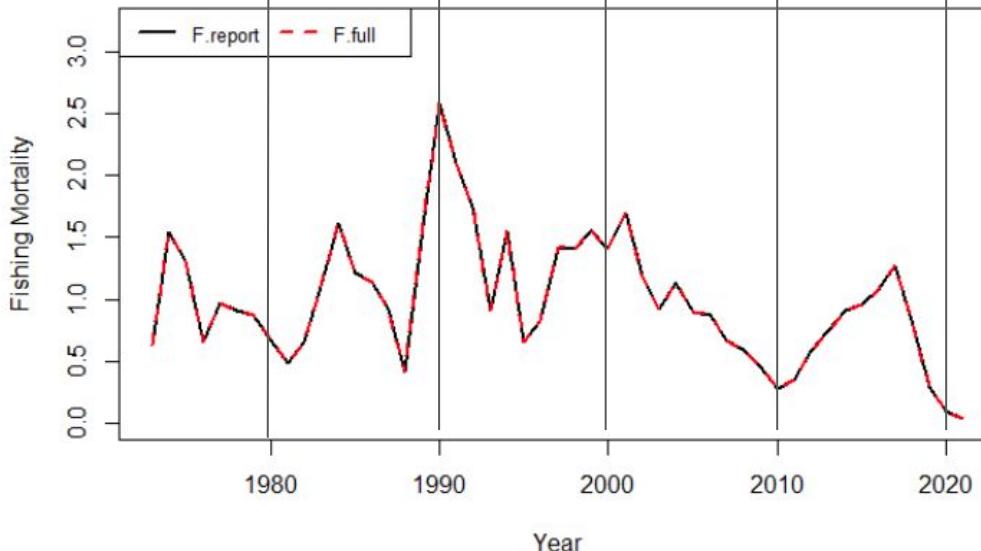
2022 MT ASAP



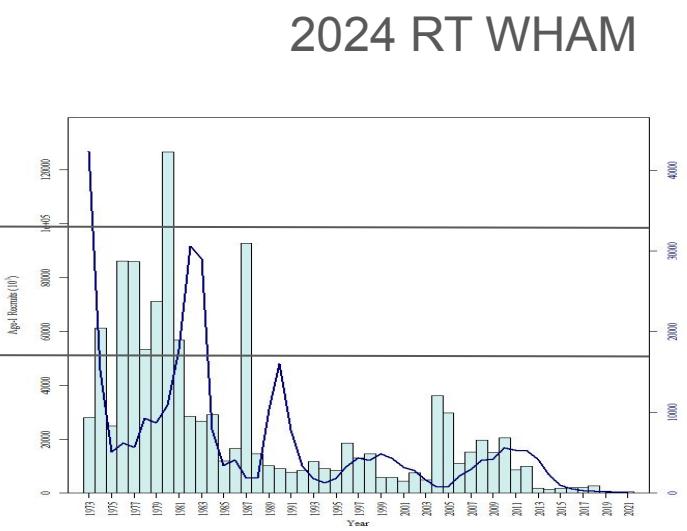
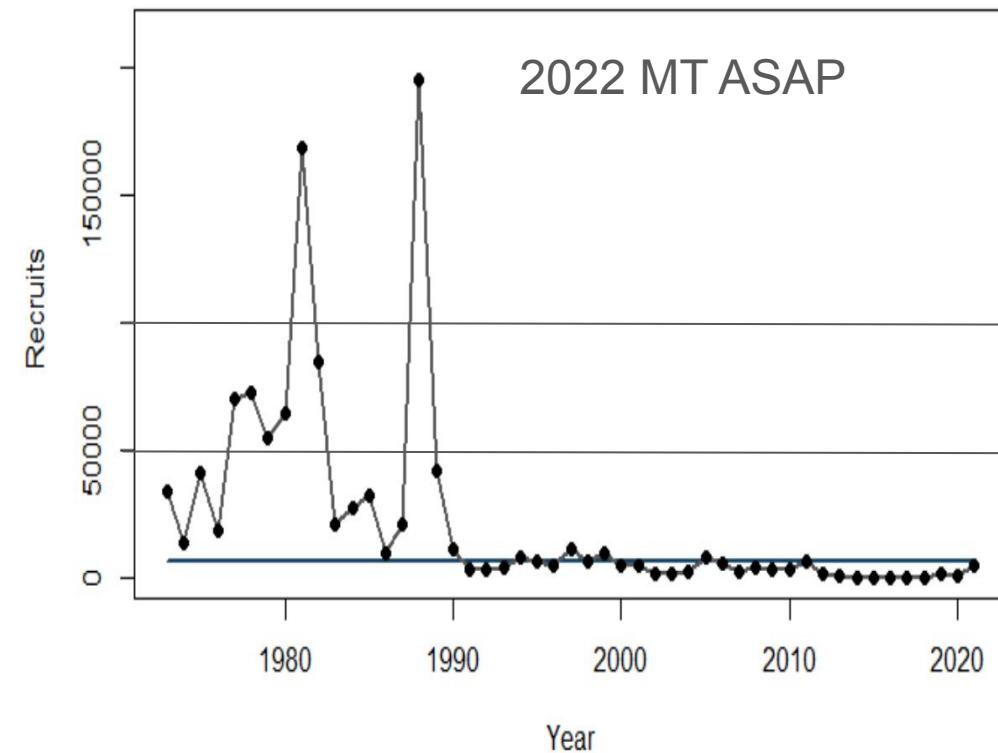
2024 RT WHAM



2022 MT ASAP



ASAP model has more R earlier in time series; WHAM has more R later in time series



	2019	2022	2024
F_{MSY} proxy	0.355	0.349	0.73
SSB_{MSY} (mt)	1,756	1,715 (908 - 2,739)	126 (8 - 1965)*
MSY (mt)	495	461 (245 - 739)	97 (51 - 182)

CANDIDATE MODEL REPLACING
 $M = 0.5$ WITH M -AT-AGE

Candidate Model

Uses lifetime M = 0.5

Candidate Model M-at-age

Uses M-at-age values from Cadrin WP

1: 0.97
2: 0.45
3: 0.37
4: 0.34
5: 0.33
6: 0.33

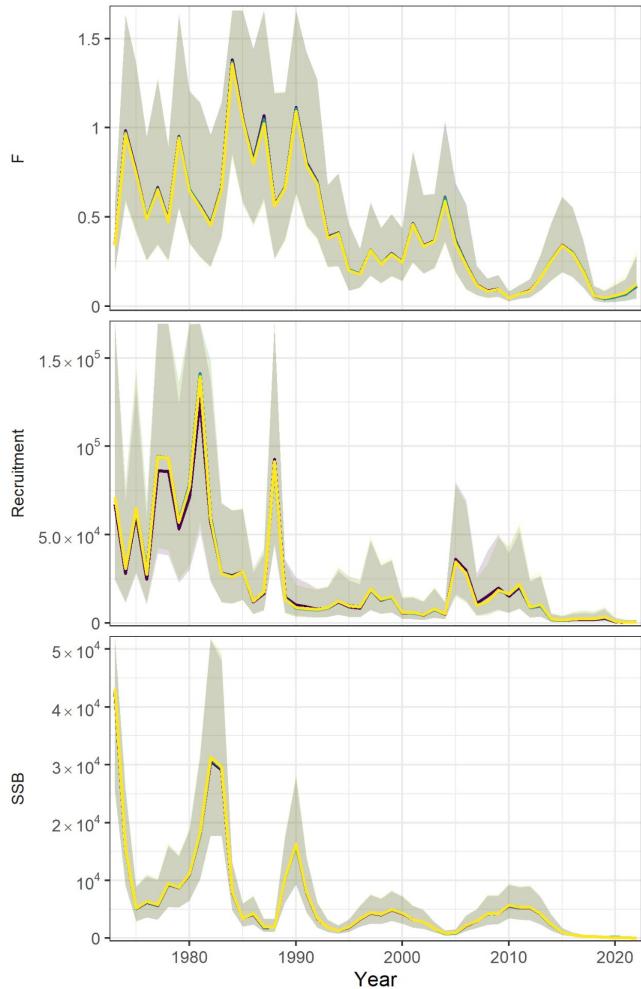
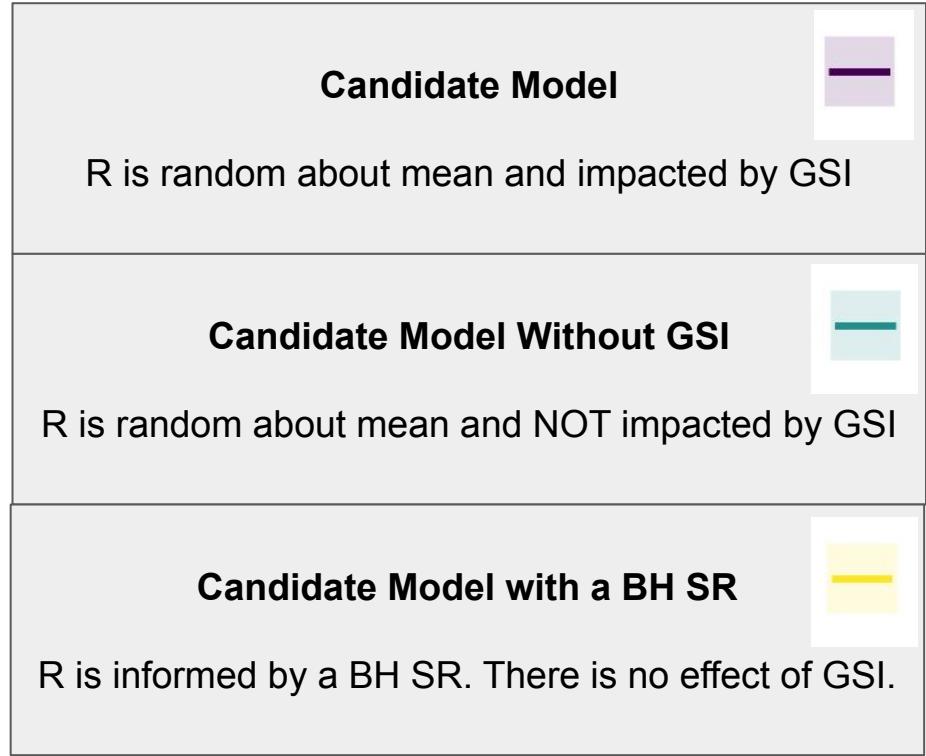
```
> check_convergence(m)
stats::nlminb thinks the model has NOT converged: mod$opt$convergence != 0
Maximum gradient component: 8.06e+00
Max gradient parameter: logit_selpars
TMB::sdreport() was performed for this model, but it appears hessian was not invertible
> |
```

CANDIDATE MODEL WITH BEVERTON-HOLT SR

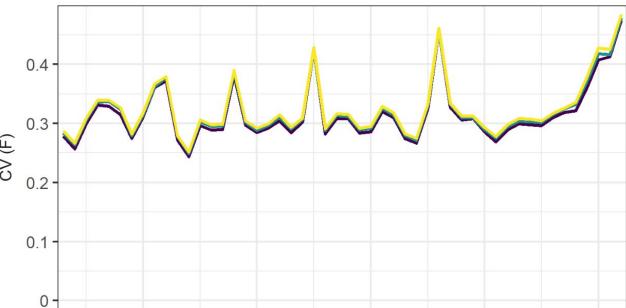
*Residuals for fleet/surveys very similar across runs

Delta AIC	Rho F	Rho SSB	Rho R
0.0	-0.014	0.145	0.671
13.6	-0.019	0.175	1.572
13.1	-0.028	0.223	1.427

del m4er_GSI_DEVEL_test m4er_GSI_DEVEL_test_NO_GSI m4er_GS



| — m4er_GSI_DEVEL_test — m4er_GSI_DEVEL_test_NO_GSI — m4er_GSI_I



Candidate Model



R is random about mean and impacted by GSI

Candidate Model Without GSI

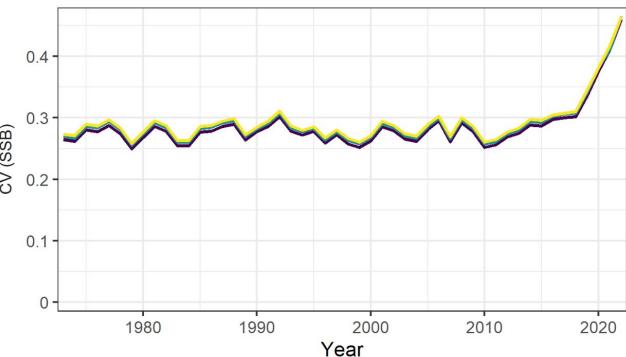
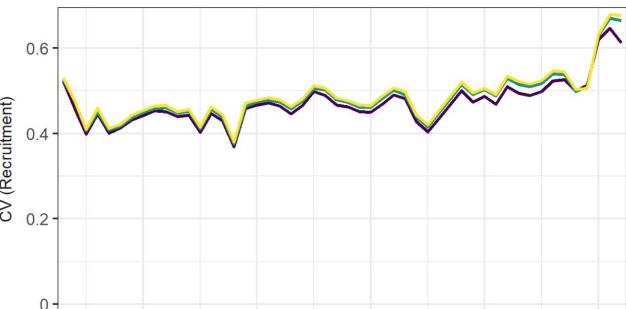


R is random about mean and NOT impacted by GSI

Candidate Model with a BH SR



R is informed by a BH SR. There is no effect of GSI.



Candidate Model

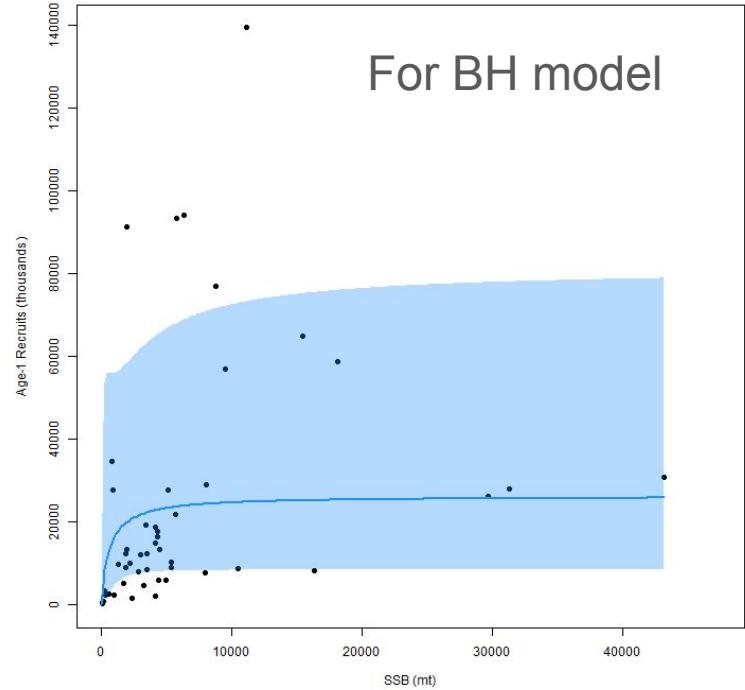
R is random about mean and impacted by GSI

Candidate Model Without GSI

R is random about mean and NOT impacted by GSI

Candidate Model with a BH SR

R is informed by a BH SR. There is no effect of GSI.



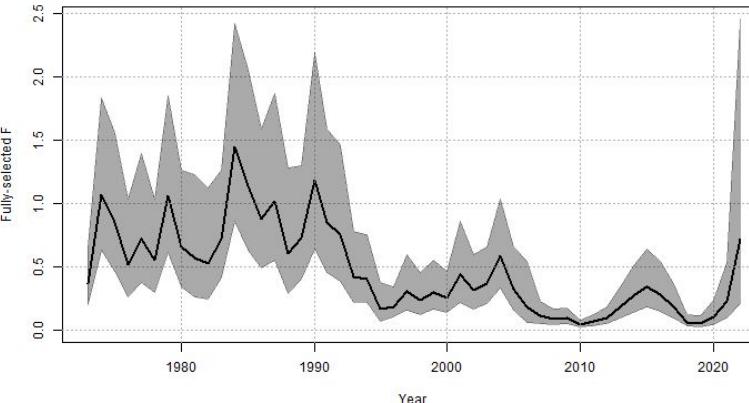
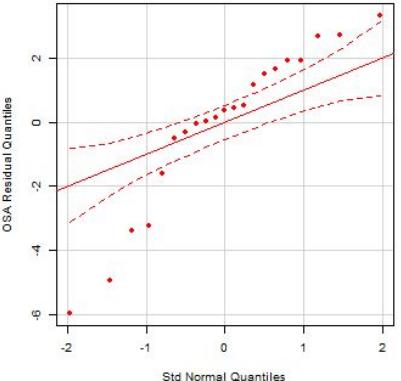
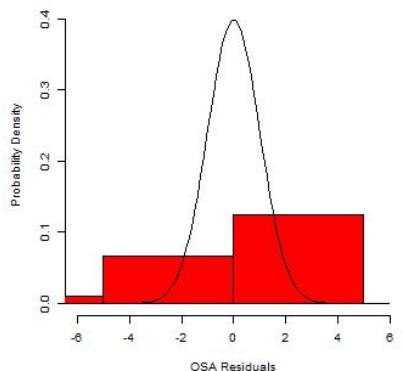
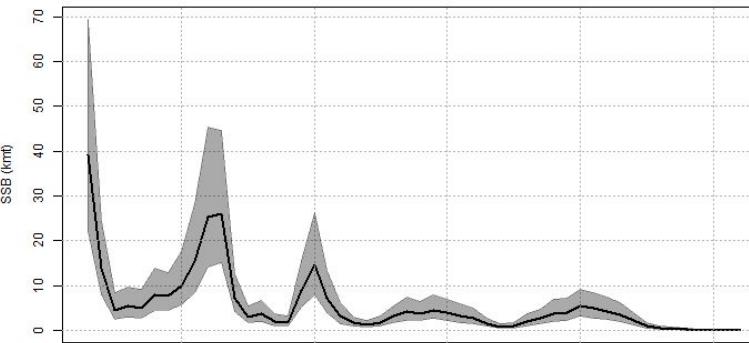
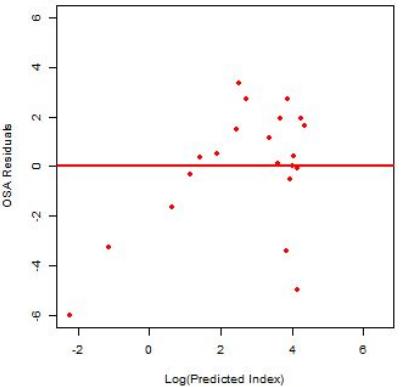
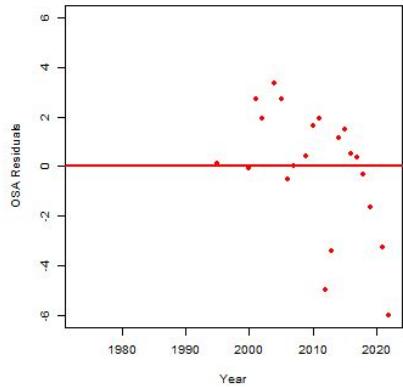
Similar results, but worse diagnostics and very bad SR fit

CANDIDATE MODEL WITH THE
LARVAL INDICES RE-INCLUDED

	d_S	C_S	σ_{TC}	ρ_{R}	ρ_{SSB}	ρ_{Fbar}
Candidate model	0.0	1948.5	0.6705	0.1454	-0.0144	
Larval Re-Inserted	1.5	5.2	-1.634	1.2350	0.3917	-0.0634



OSA residual diagnostics: Index 5



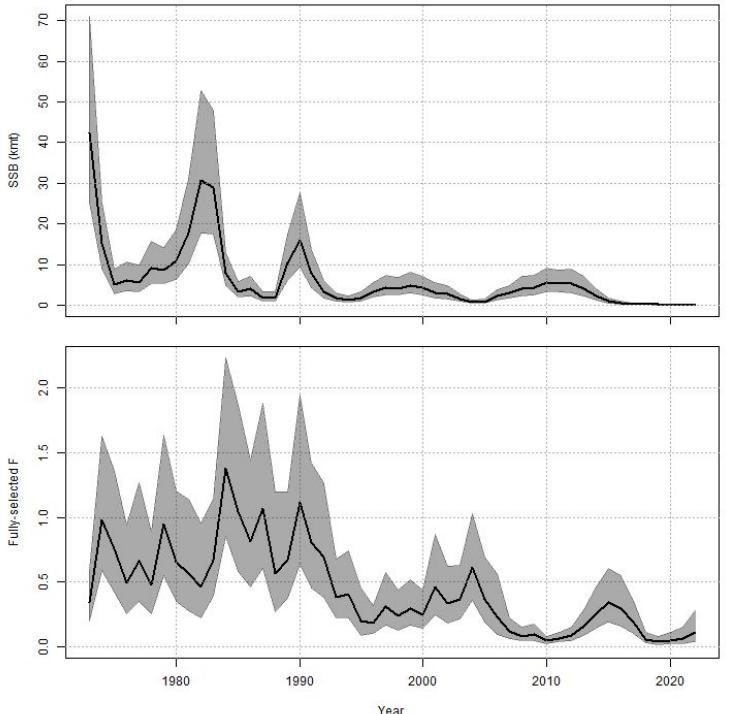
High
terminal
year F
uncertainty

CANDIDATE MODEL RAISING
FLEET CV FROM 0.05 TO 0.2

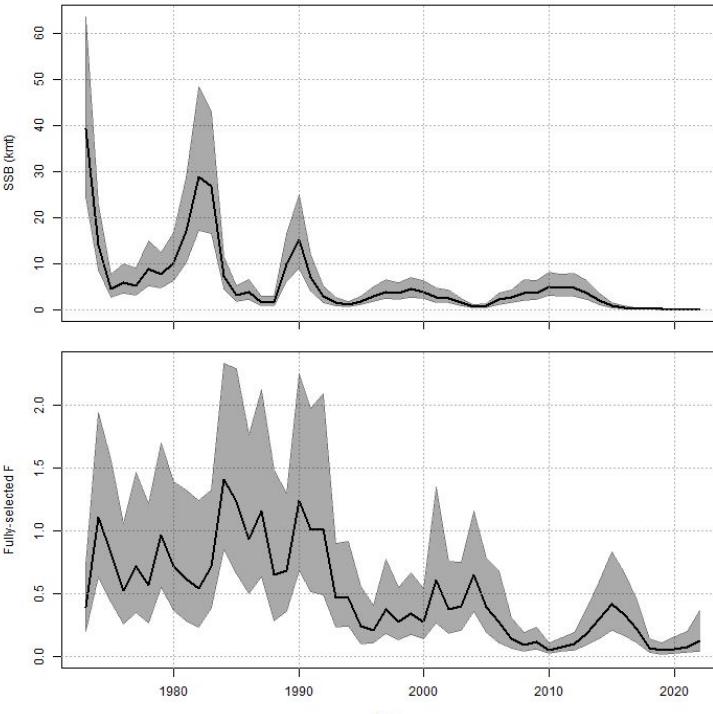
Candidate model

CV = 0.2

dAIC	AIC	rho_R	rho_SSB	rho_Fbar
0.0	-1948.6	0.6705	0.1454	-0.0144
34.9	-1913.7	0.6594	0.1682	-0.0235



Candidate model

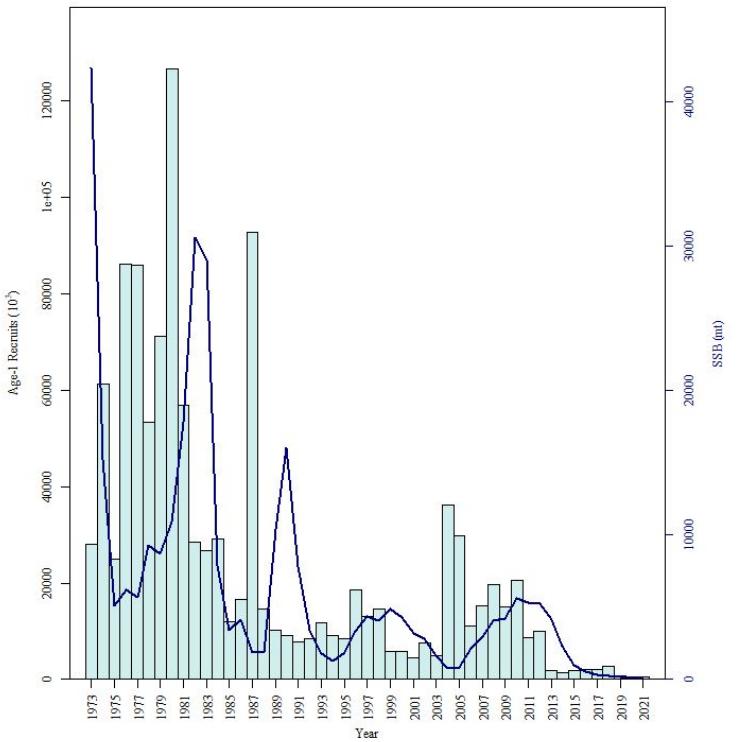


CV = 0.2

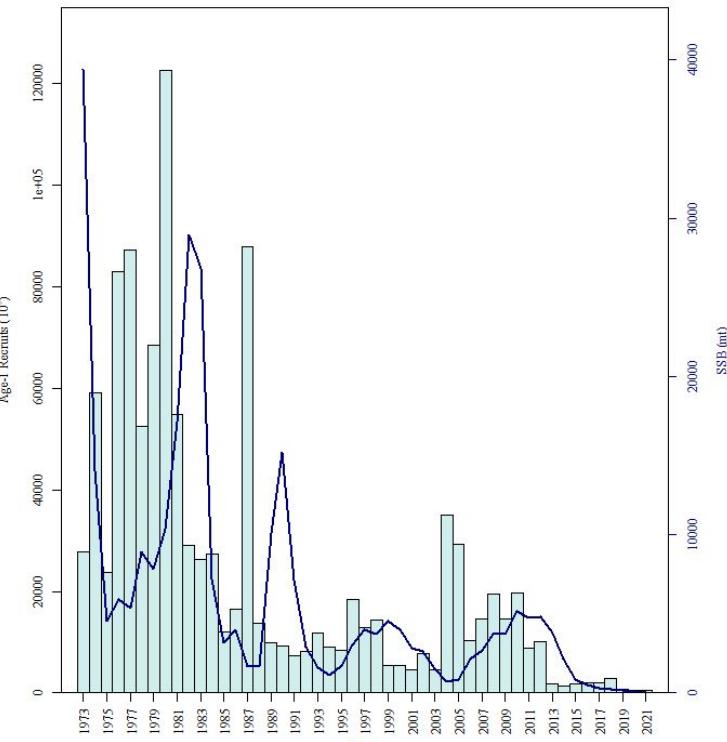
Candidate model

CV = 0.2

dAIC	AIC	rho_R	rho_SSB	rho_Fbar
0.0	-1948.6	0.6705	0.1454	-0.0144
34.9	-1913.7	0.6594	0.1682	-0.0235



Candidate model

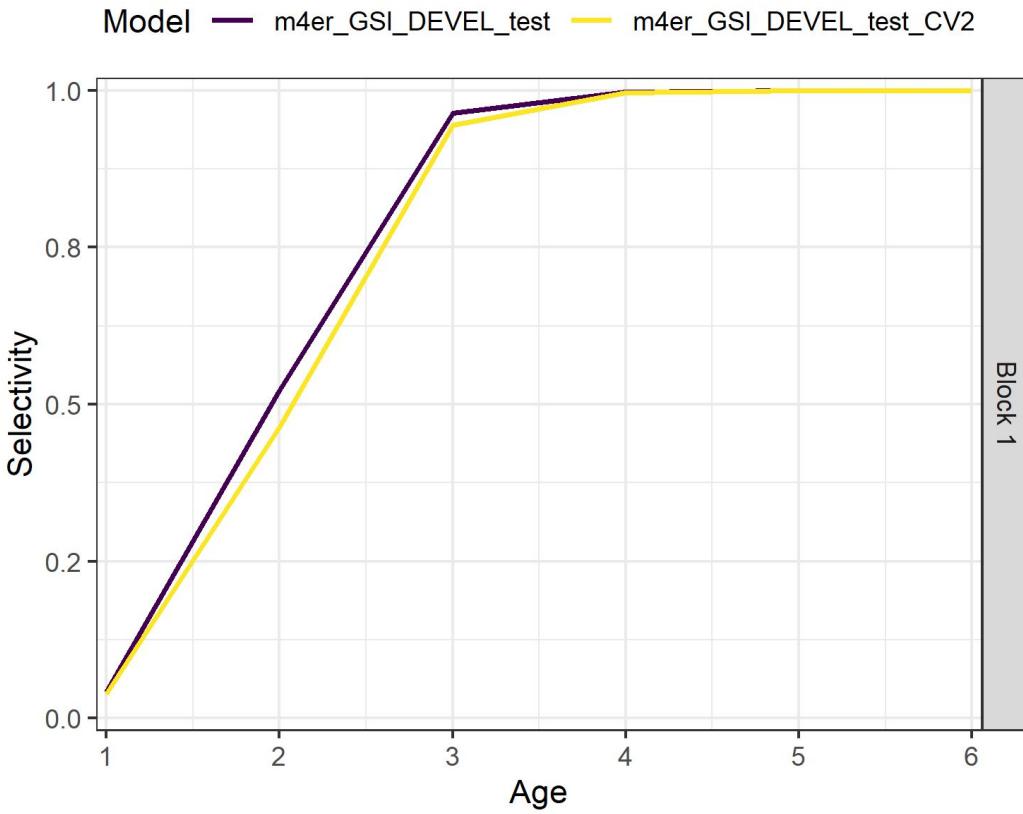
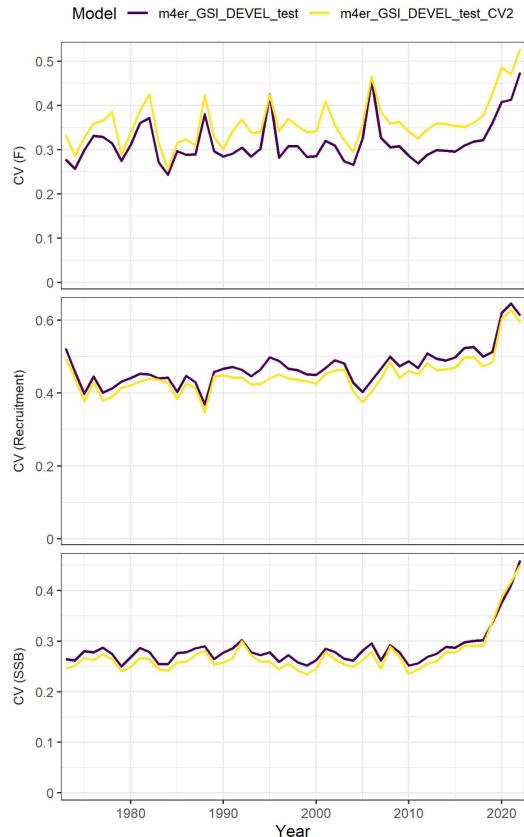


CV = 0.2

Candidate model

CV = 0.2

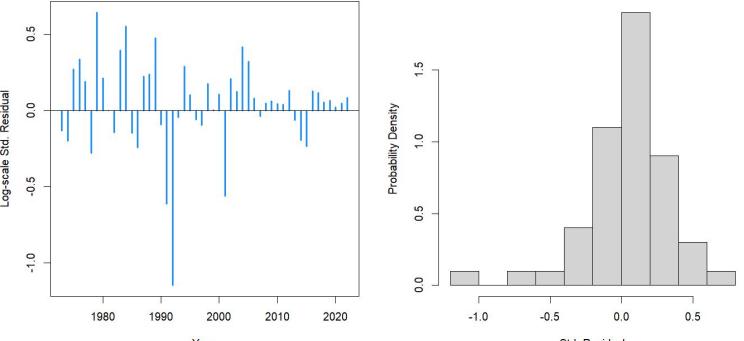
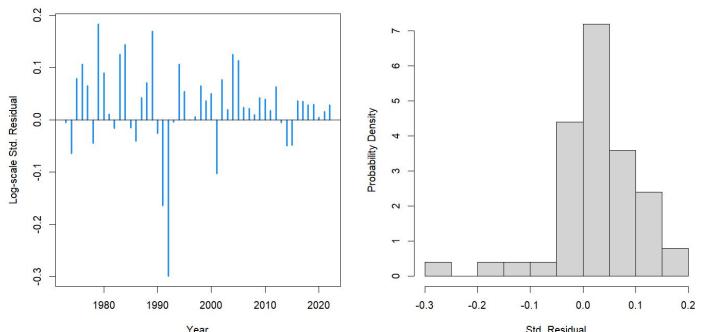
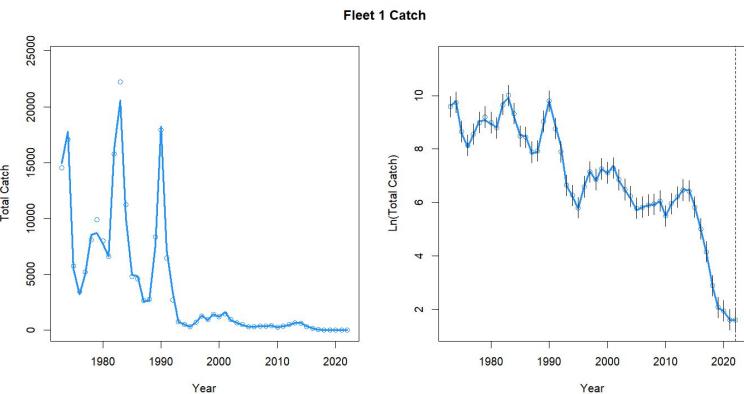
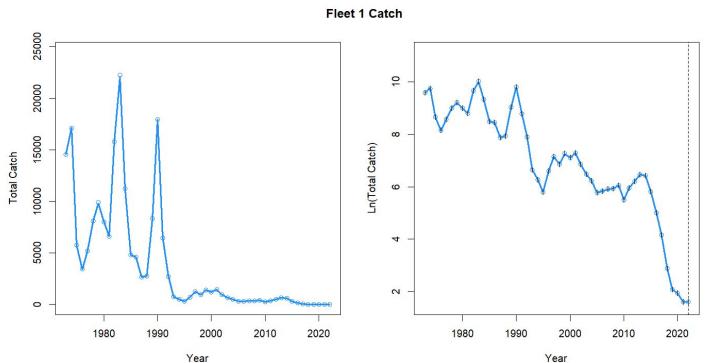
dAIC	AIC	rho_R	rho_SSB	rho_Fbar
0.0	-1948.6	0.6705	0.1454	-0.0144
34.9	-1913.7	0.6594	0.1682	-0.0235



Candidate model

CV = 0.2

dAIC	AIC	rho_R	rho_SSB	rho_Fbar
0.0	-1948.6	0.6705	0.1454	-0.0144
34.9	-1913.7	0.6594	0.1682	-0.0235



Candidate model

CV = 0.2

A FEW OTHER QUICK
COMPARISONS

What if you remove random effects on NAA from the candidate model?

	dAIC	AIC	rho_R	rho_SSB	rho_Fbar
Candidate model	0	-1948.6	0.6705	0.1454	-0.0144
No NAA RE	234	-1714.6	5.2114	0.3020	-0.1263

What if you change the age comps from miss0 to pool0 in the candidate model?

	dAIC	AIC	rho_R	rho_SSB	rho_Fbar
Candidate model	0.0	-1948.6	0.6705	0.1454	-0.0144
logistic-normal-pool0	128.4	-1820.2	0.5314	0.2233	-0.0459

What if you change fleet selectivity from logistic to age-specific in the candidate model?

Changing fleet selectivity from logistic to age-specific led to a model that did not converge