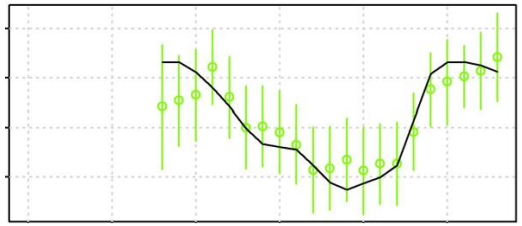
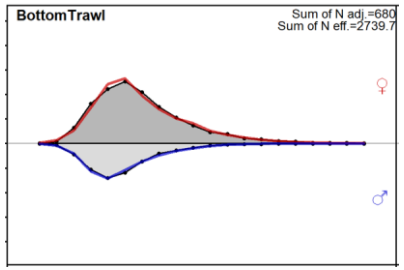
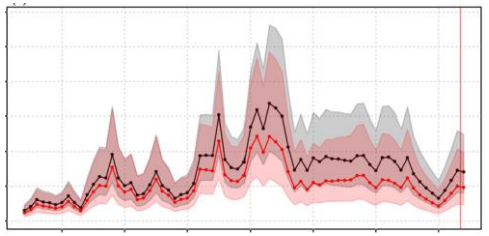
Stock Assessment of Outside Lingcod

Assessment framework, straw dog model,
diagnostics and estimates







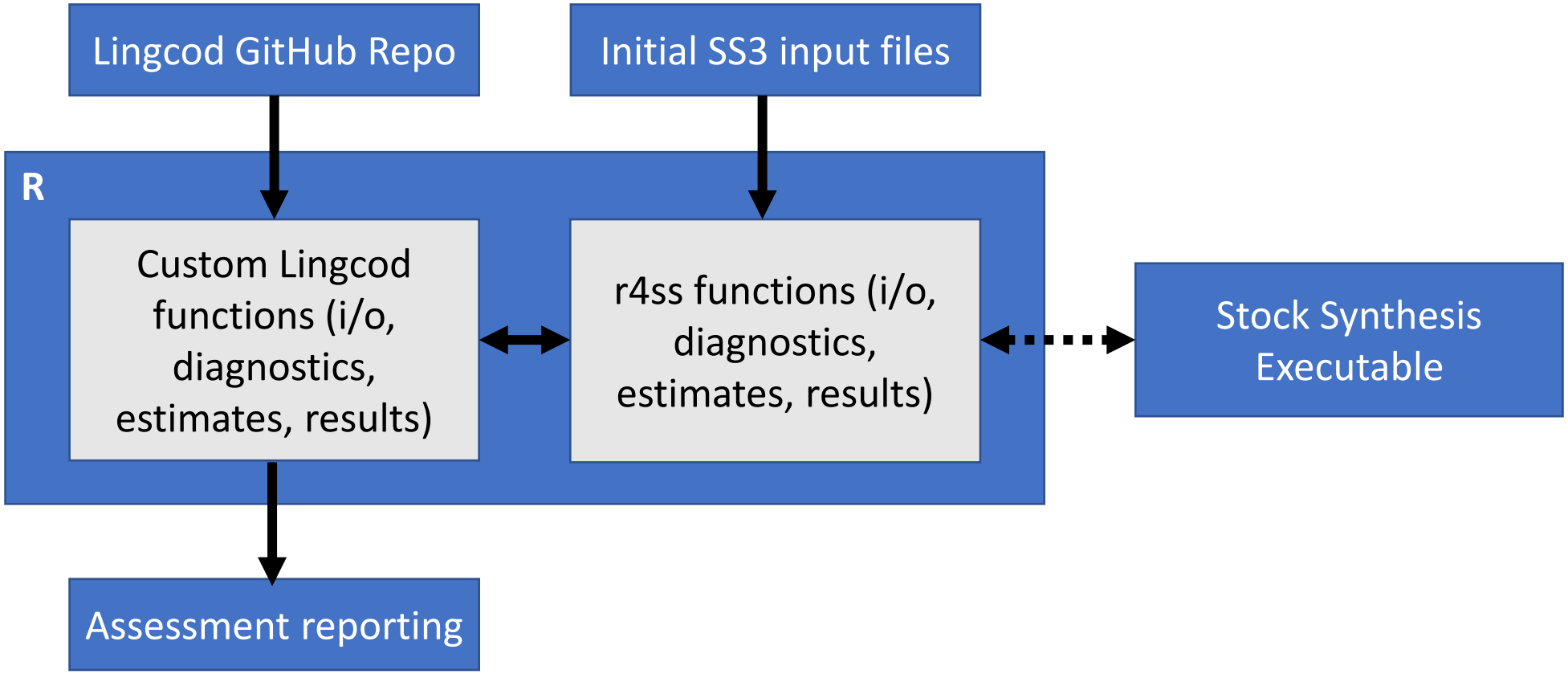
Outside Lingcod Technical Working Group
Meeting 1
21st February 2024

Tom Carruthers
(tom@bluematterscience.com)

Contents

1. Assessment framework

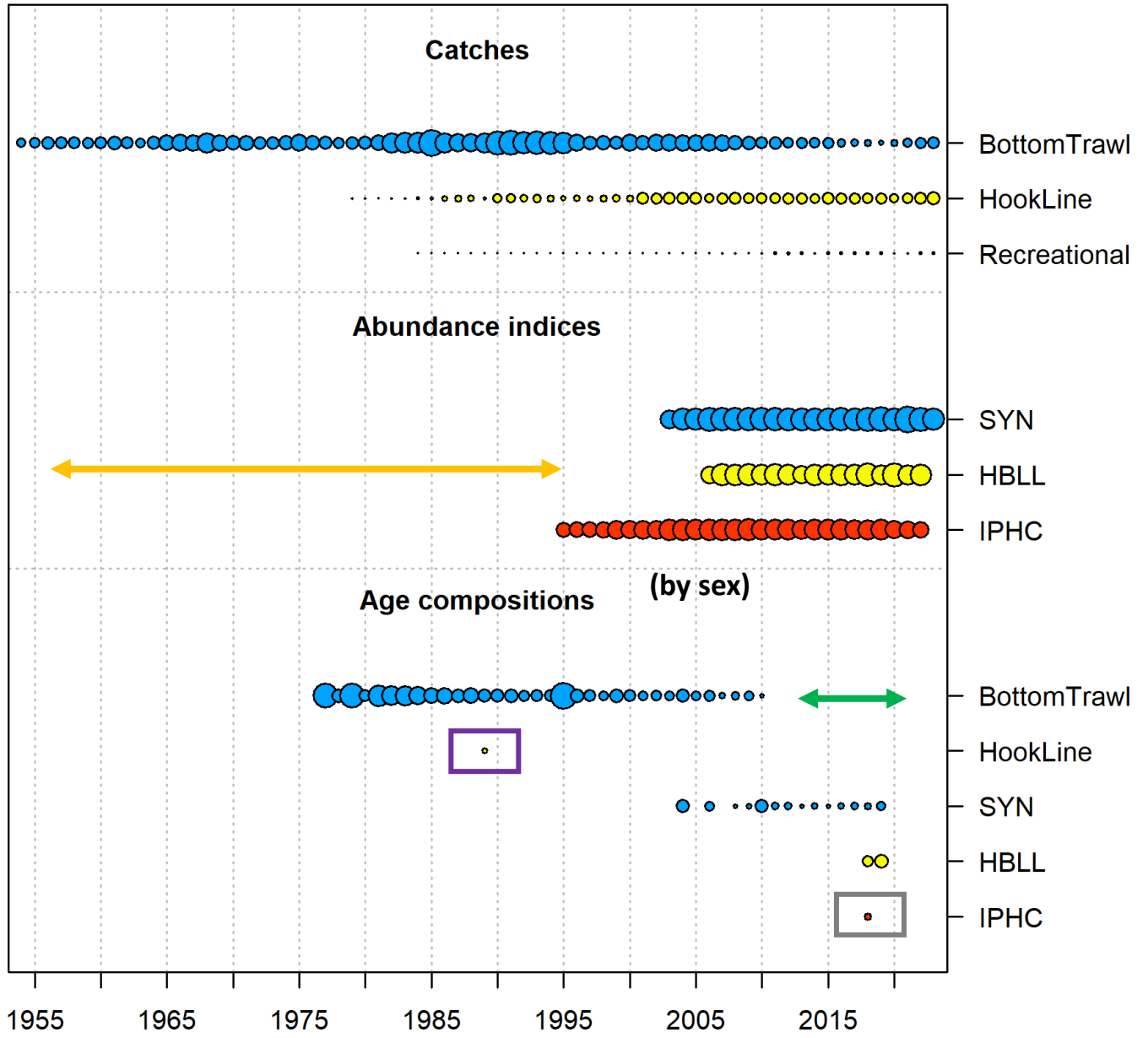
- Stock Synthesis (v3.30.22, October 31 2023) (Methot & Wetzel 2013). Well established, and allows for sex-specific modelling and statistical catch at length if required. Some experience here with using it in BC for dogfish for example.
- r4ss (v1.49.1, 2023 – from GitHub) (Taylor et al. 2021)
- R (v4.3.2)



7.1. Straw dog model & data

Straw dog model: overview of input data

1. **Survey indices do not cover the early period that experience large catches (contrast).**
2. **Most contributory commercial fleet has no composition data since 2010.**
3. **Second most contributory commercial fleet has only one year of age composition data in 1984 of low sample size.**
4. Recreational fleet has no composition data (but we may have found some sparse data)
5. IPHC survey is longest but has only a single year of age composition data
6. Recent age composition data are lacking (2019 onwards)



Interpretation of bubble area:

Quantity of catch

Magnitude of index

Sample size

Straw-dog model: fleet and survey setup

Fleet	Data	Assumed female selectivity
Bottom trawl	Catch, age composition (length composition)	Double normal
Hook & line	Catch, age composition (length composition)	Double normal
Recreational	Catch, (age composition, length composition)	As hook and line

Survey	Data	Assumed female selectivity
Synoptic	Age composition (length composition)	Double normal
HBLL	Age composition (length composition)	Double normal
IPHC	Age composition (length composition)	Double normal

Female double normal selectivity estimates only ascending / descending width + peak (3 parameters)
Male adjusts apical value(q) + ascending / descending width, peak is mirrored (4 parameters)

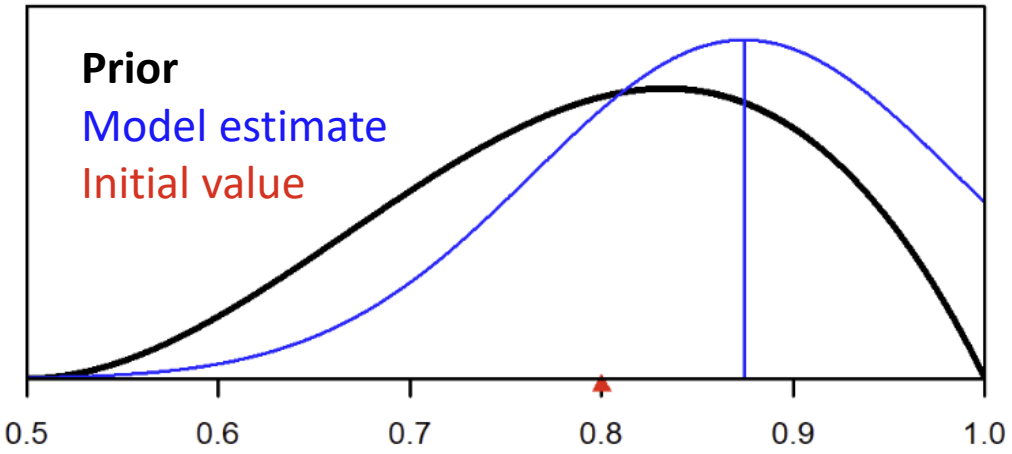
Straw-dog model parameters / data weighting

Input parameter	Fixed point value (unless otherwise stated)
Natural mortality rate, *M*	0.285 (f) 0.245(m)
von. Bert. maximum growth rate, *K*	0.15(f) 0.27(m)
von. Bert. asymptotic length, *Linf*	114.7(f) 82.8(m)
von. Bert. Age at length zero, t_0	-1.35 (f) -0.86 (m)
Length – weight, *alpha* (W = *alpha* x L ^ *beta*)	3.11 E-6 (f) 2.45 E-6(m)
Length – weight, *beta* (W = *alpha* x L ^ *beta*)	3.25 (f) 3.32(m)
Coefficient of variation of length at age	0.10 (f) 0.09 (m)
Inflection point of logistic maturity ogive (A50)	9.1 (f)
Slope of logistic maturity ogive	-0.75 (f) (as reported in SS input file)
Bev.-Holt steepness (mean unfished recruitment at 1/5 unfished spawning biomass), *h*	Estimated [0.5 – 1.0] from weakly informative beta prior
Fraction of recruits that are female	50%
Standard deviation in lognormal rec. deviations, σ_R	0.5
Effective annual sample size for age composition (among years within fleet)	20

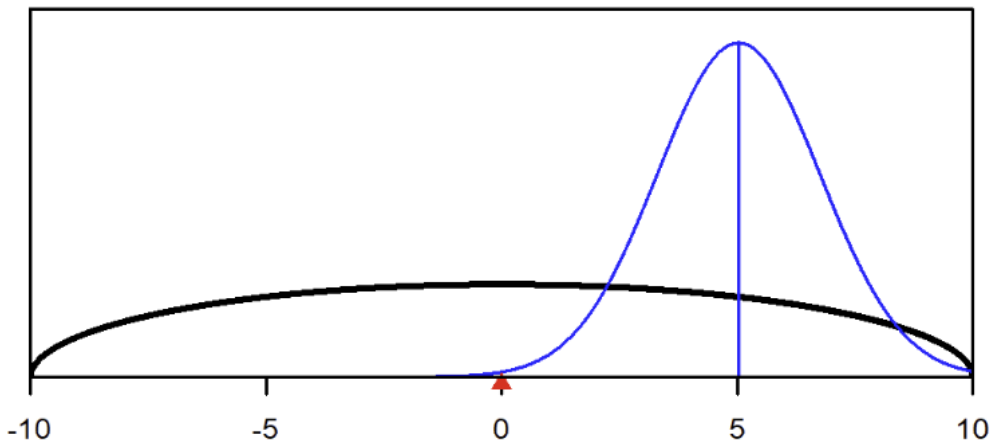
Straw dog likelihood functions and priors

Data / prior	Likelihood function / prior
Annual catches	Lognormal (sd = 0.025)
Survey indices	Lognormal (‘empirically derived precision’)
Age compositions	Multinomial (mean annual ESS is 20 within fleet)
Steepness	Estimated [0.5 – 1.0] from weakly informative beta prior
Selectivity priors (various double normal)	Very weak beta prior to avoid nearing bounds and local minima

Steepness

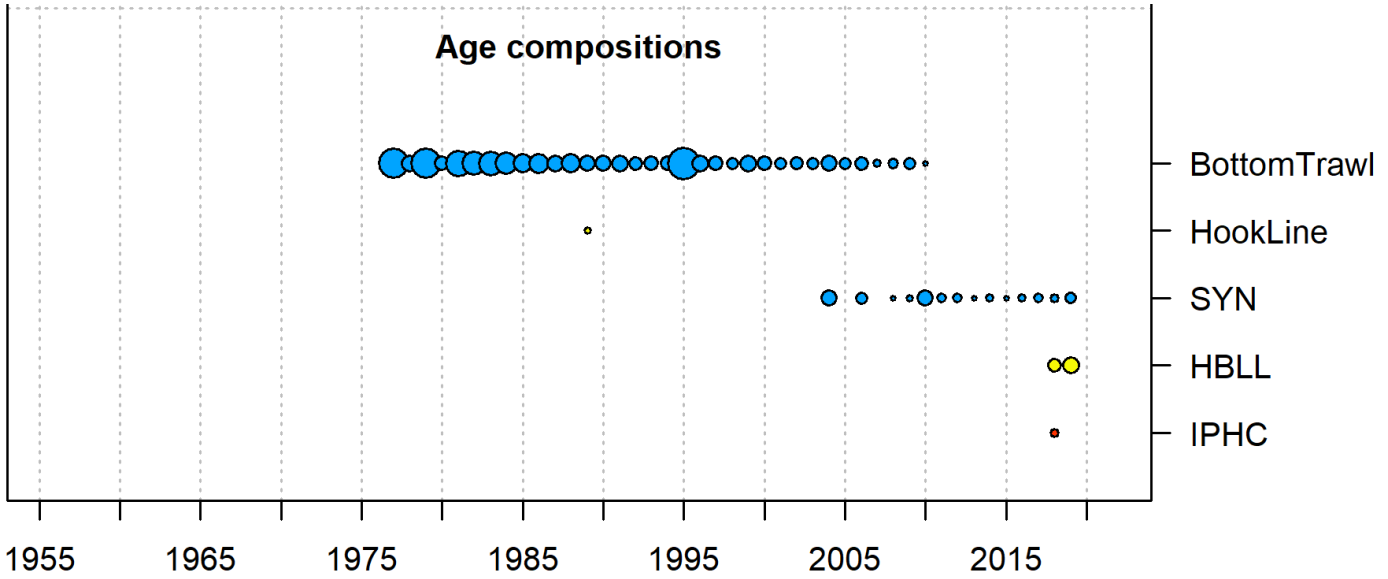


Selectivity parameter (descending width)

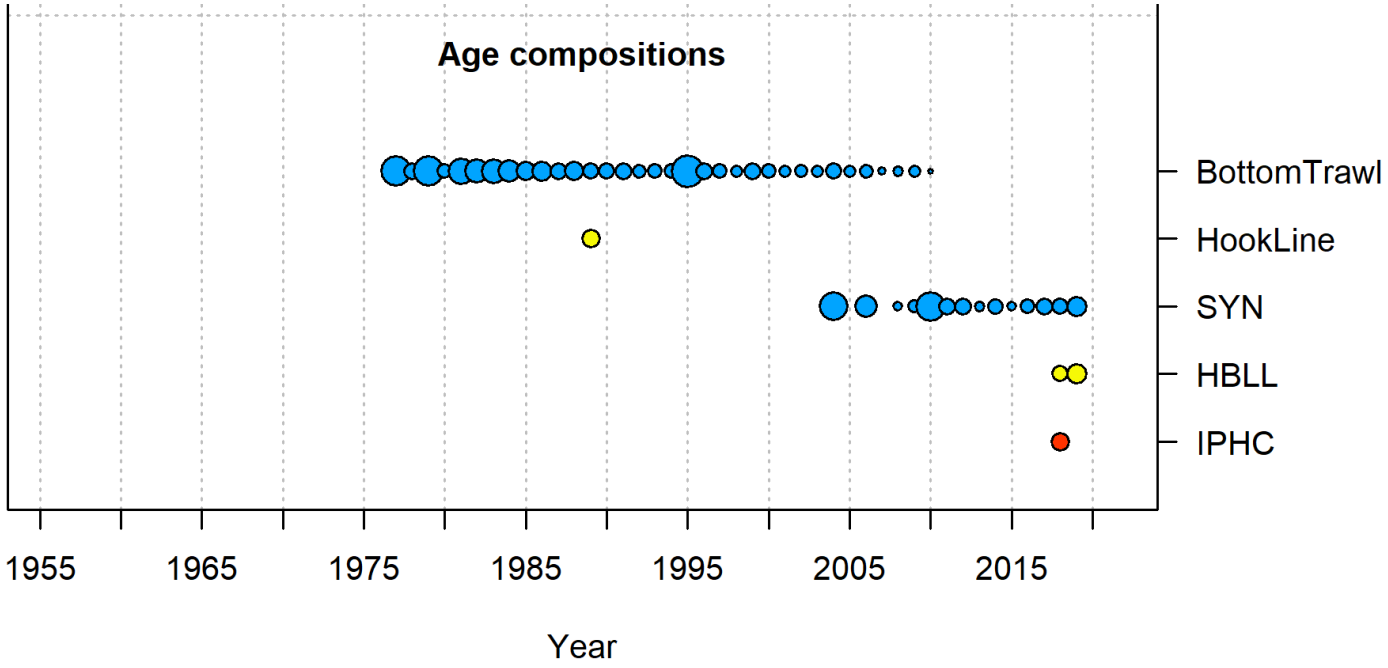


A note on data weighting

Raw data:



Weighted data has same mean among areas within fleet (each row has a mean of 50 for example):



7.2. Straw dog model diagnostics and estimates

Only evaluated for basic diagnostics

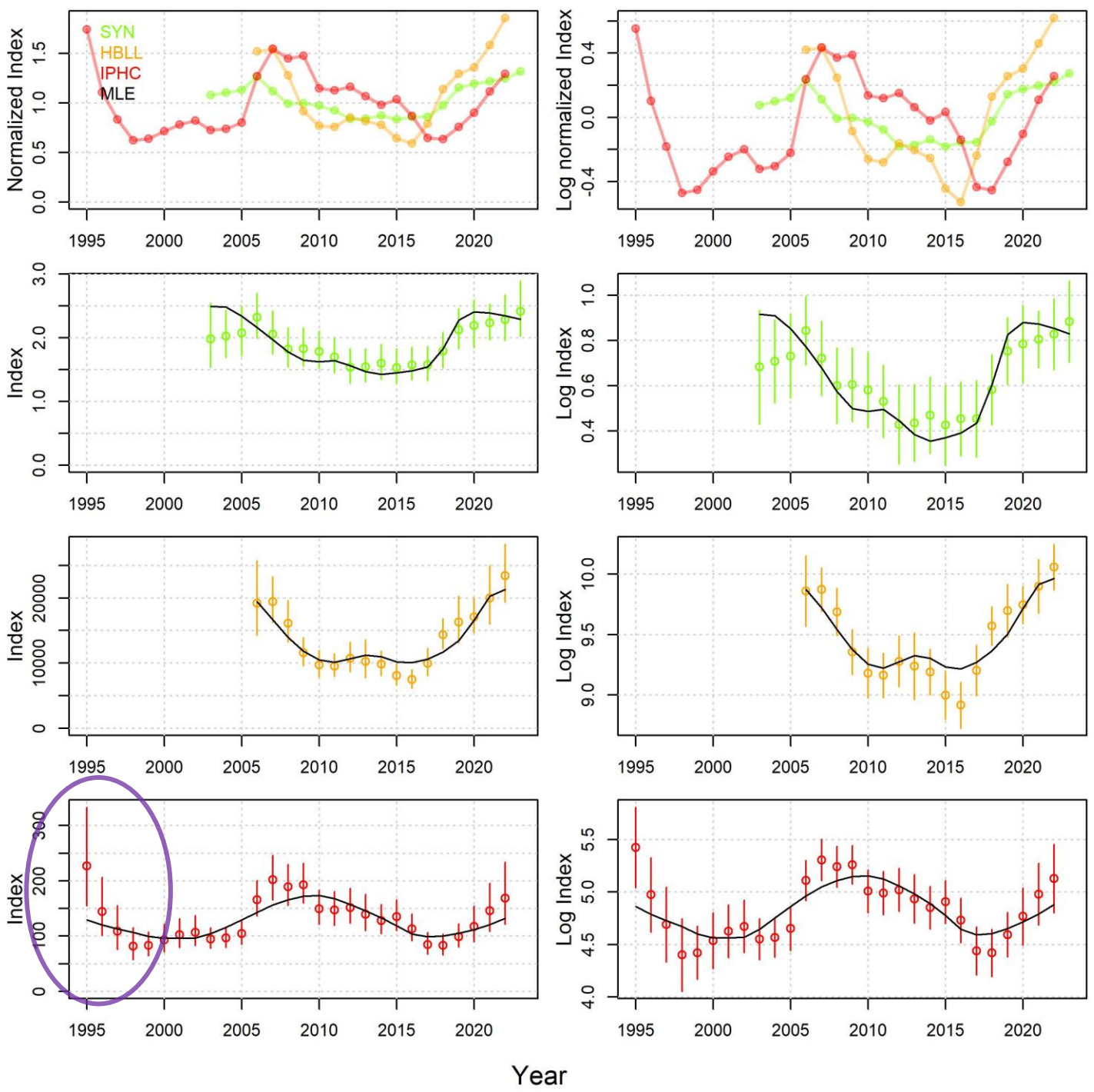
- Objective function gradient is lower than specified tolerance: 1E-5
- Model reliably converges on MLE parameter estimates from different initial parameter values.
- Model is sufficiently stable to profile on key model inputs such as natural mortality rate, steepness, recruitment variability. I.e., we can correctly interpret sensitivity analyses.
- Did not simulation self-test (if anything, a highly favourable test that, when I did the exercise, the majority of Stock Synthesis models appear to fail based on bias and precision in simulated / estimated management quantities).

Straw dog model diagnostics: fit to survey indices

Generally good to very good fit to the three survey indices.

Some evidence of possible hyperdepletion (over responsiveness) in the IPHC survey. Maybe simply an issue with early data (1995 – 2000)

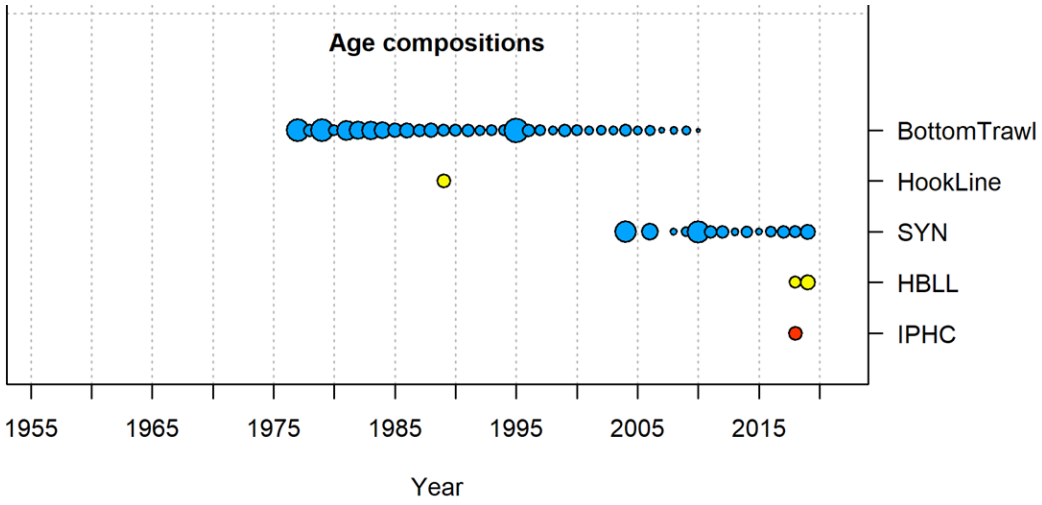
Age composition data inform selectivities that allow for lags in changes to the vulnerable biomass.

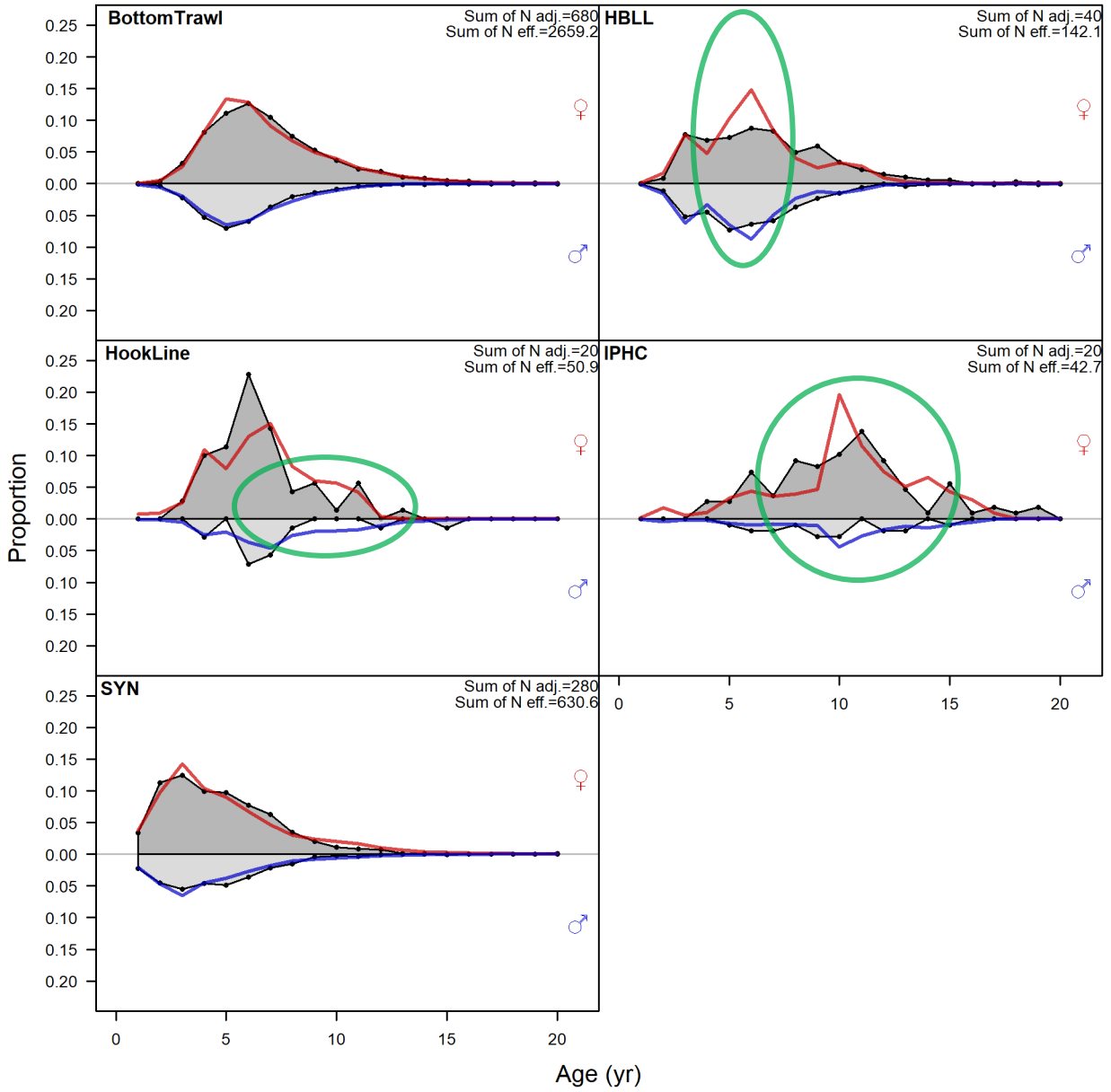


Straw dog model diagnostics: fit to age composition data

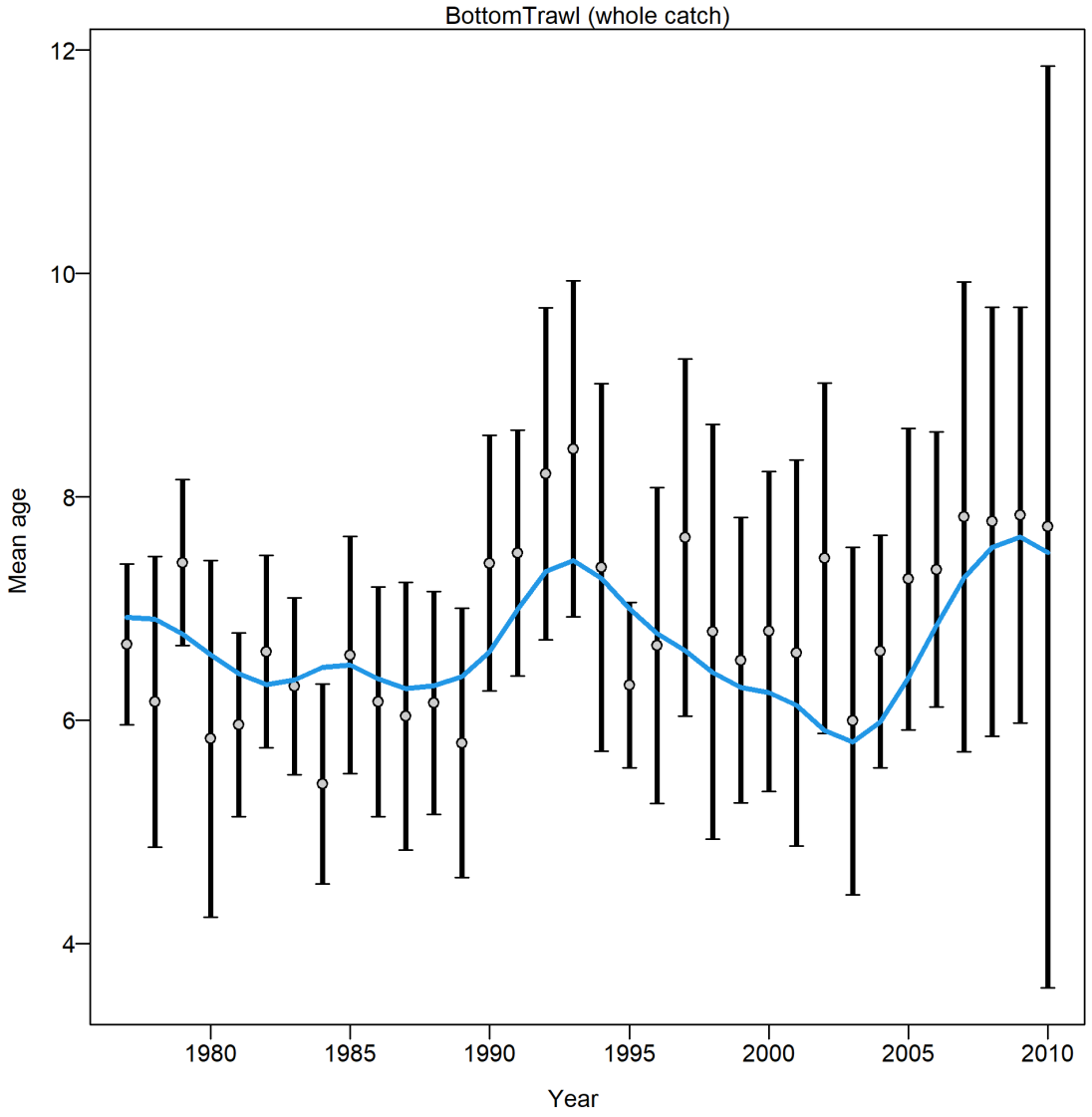
Very good fit (on aggregate) to the most heavily sampled time series (Bottom trawl and synoptic)

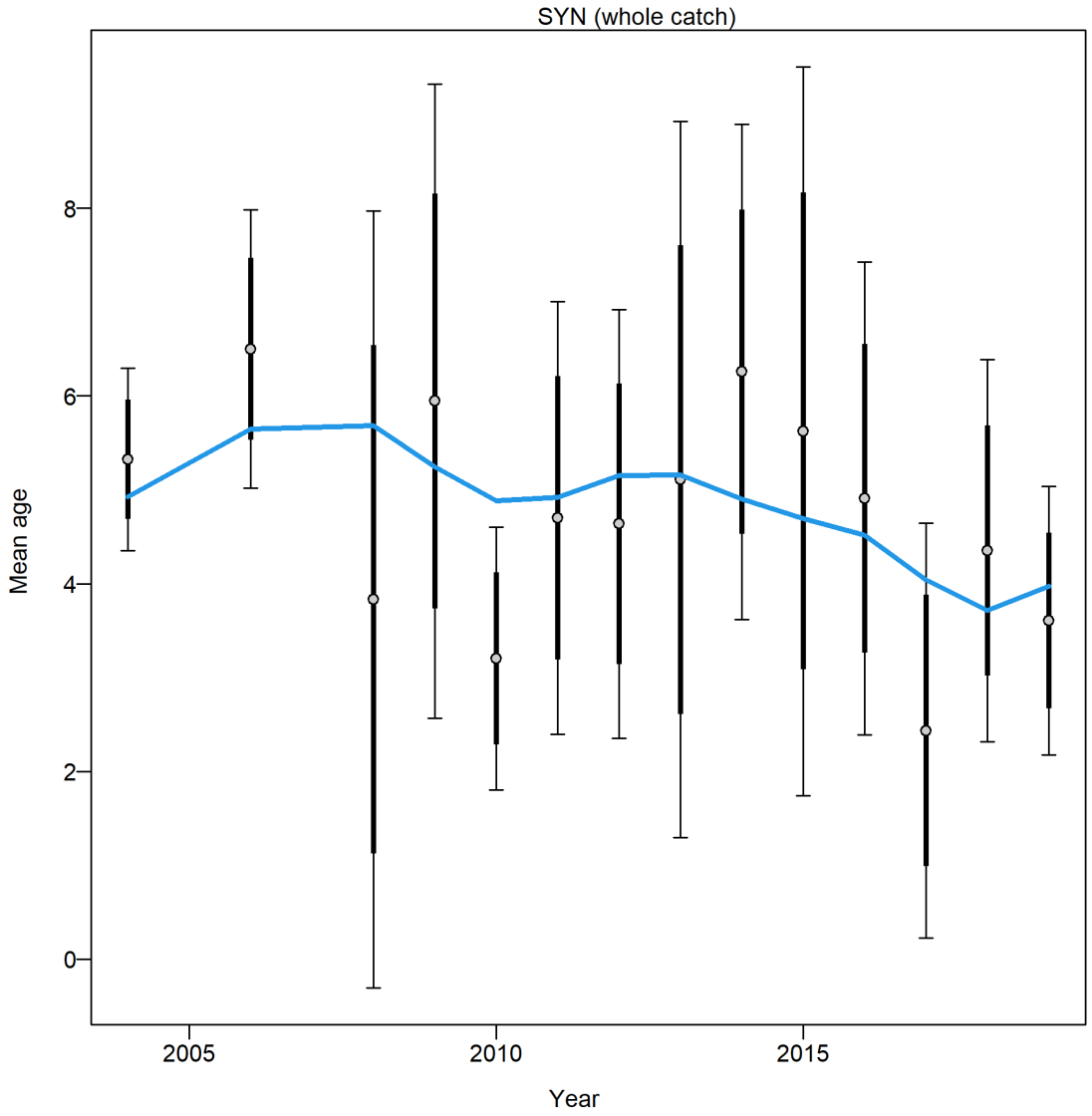
Some issues of fit for data collected in smaller frequencies for one or two years (HBLL, HookLine, IPHC)



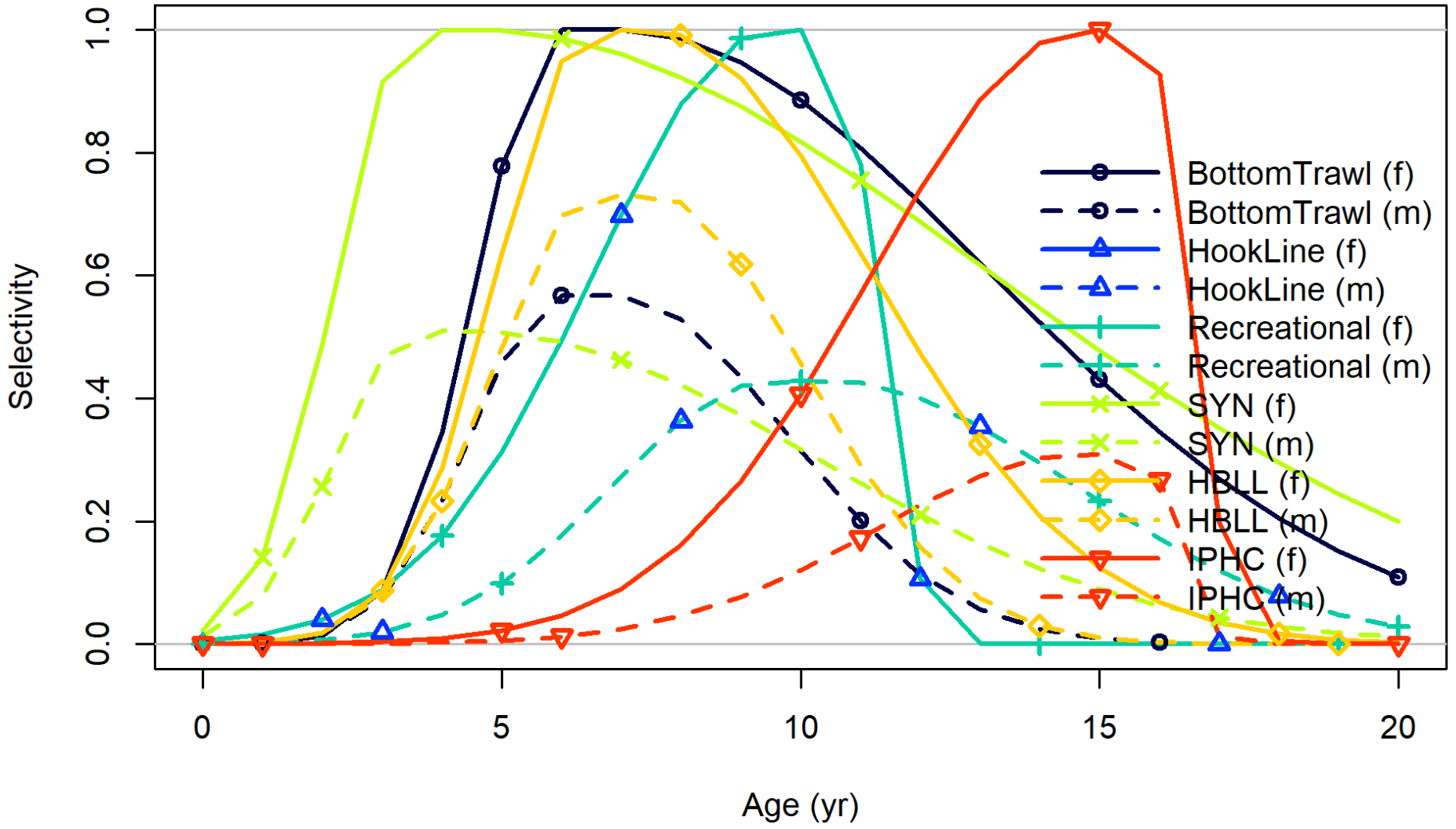


Straw dog model diagnostics: fit to age composition data





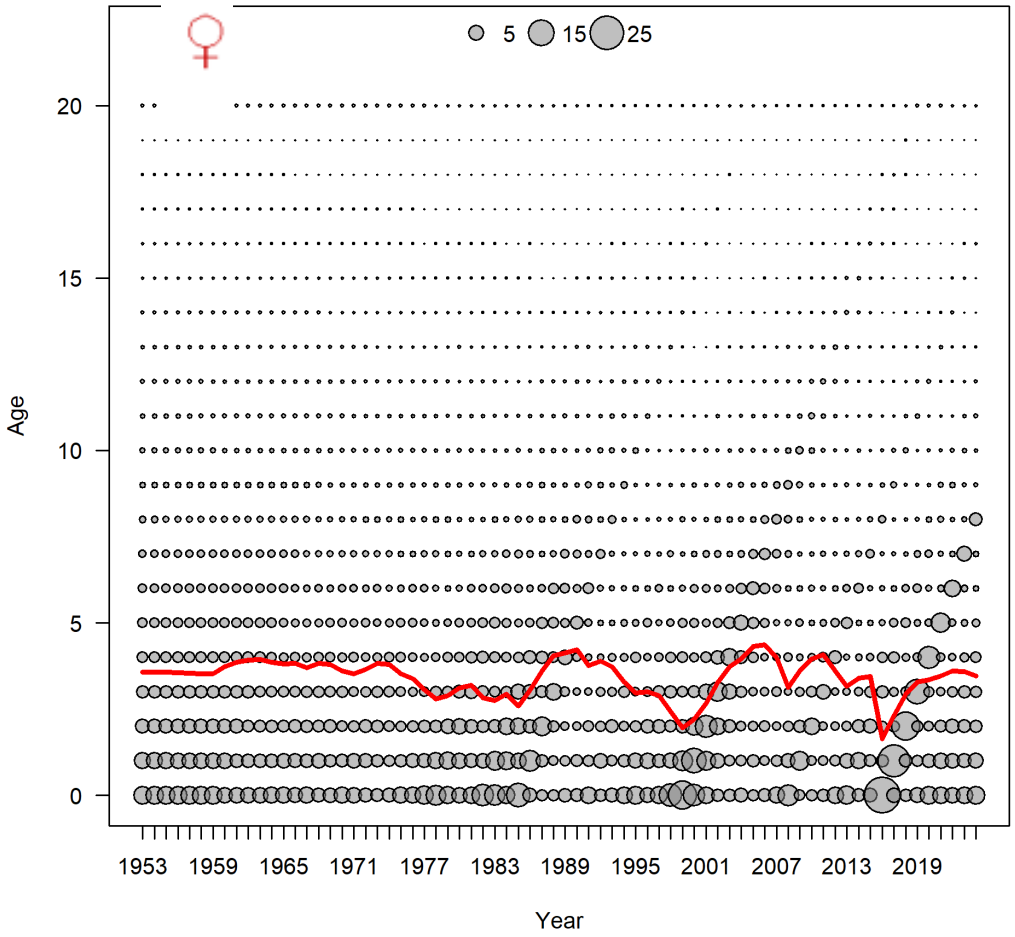
Estimated ‘selectivities’

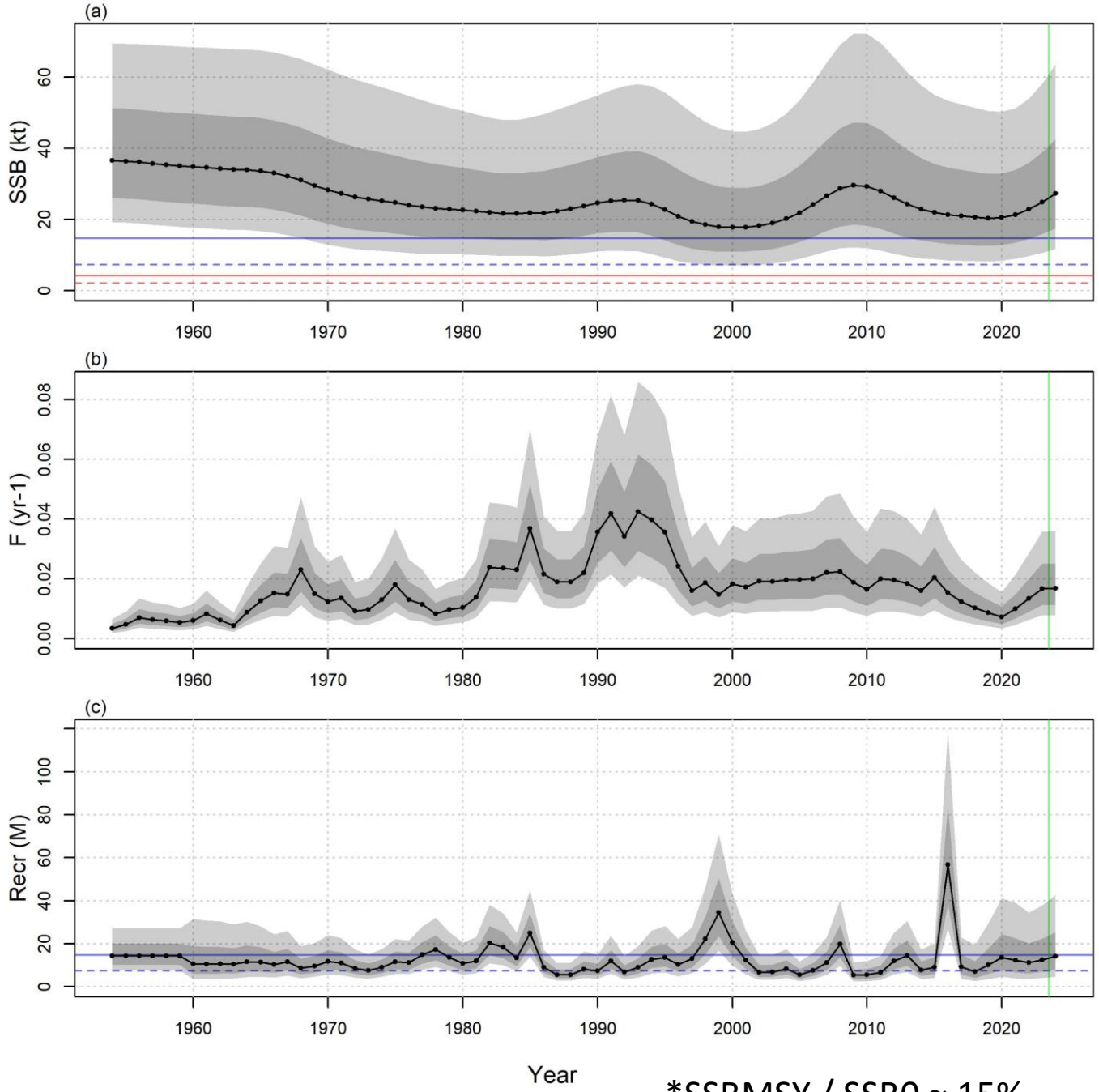


Mirrors HookLine

Straw dog model estimates: SSB, F, Recruitment

Median
50% CI
80% CI
20% / 40% SSB0
40% / 80% SSBMSY*

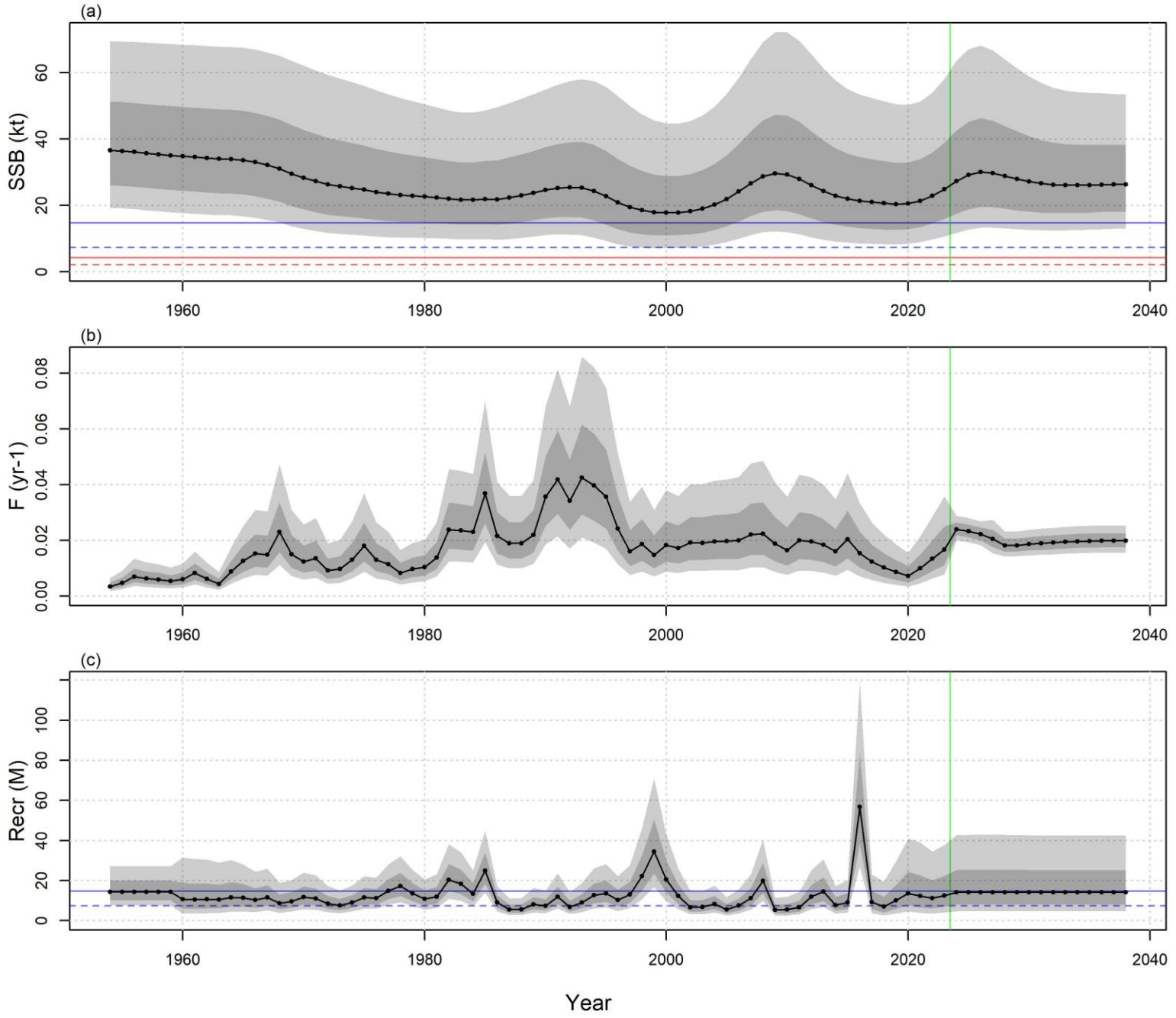




*SSBMSY / SSB0 ≈ 15%

Straw dog model estimates: projection of current (approx.) F

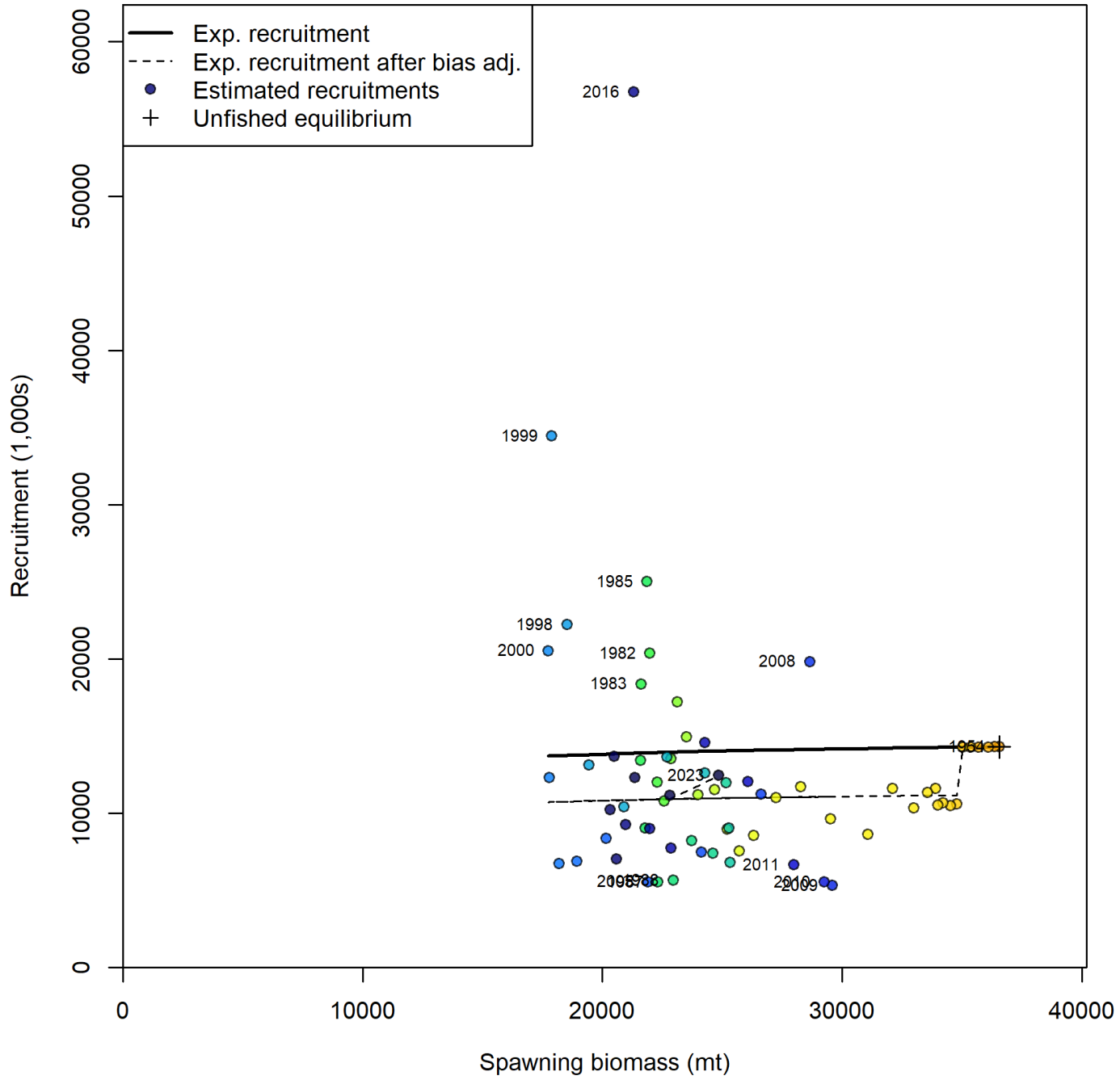
Median
50% CI
80% CI
20% / 40% SSB0
40% / 80% SSBMSY



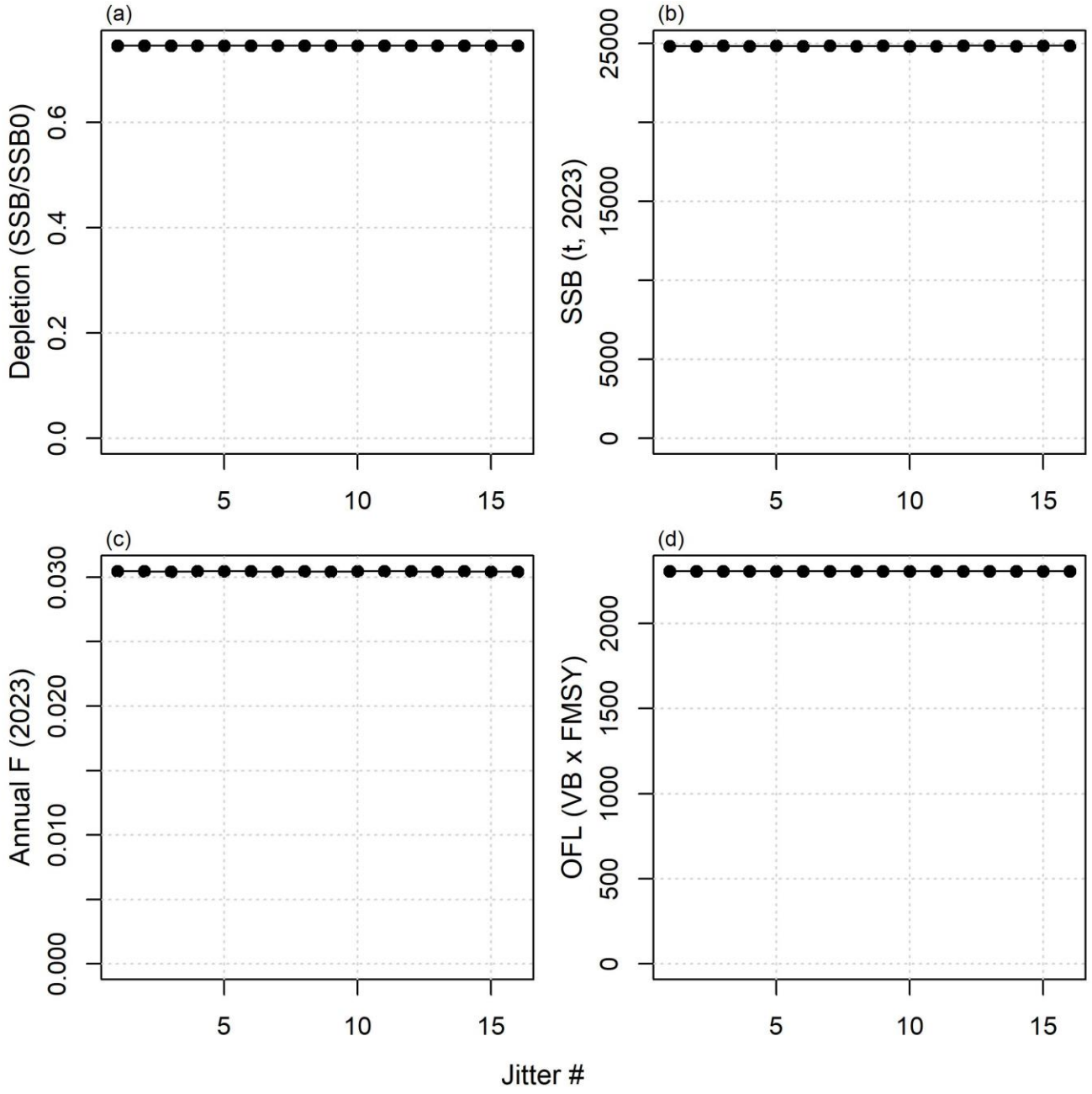
Straw dog model estimates: SSB - Recruitment

Very little information regarding resilience (recruitment-driven biomass and no model estimates at low SSB)

Appearance of resilience may simply be a product of recruitment-driven SSB (the ‘mad scientist’ problem)

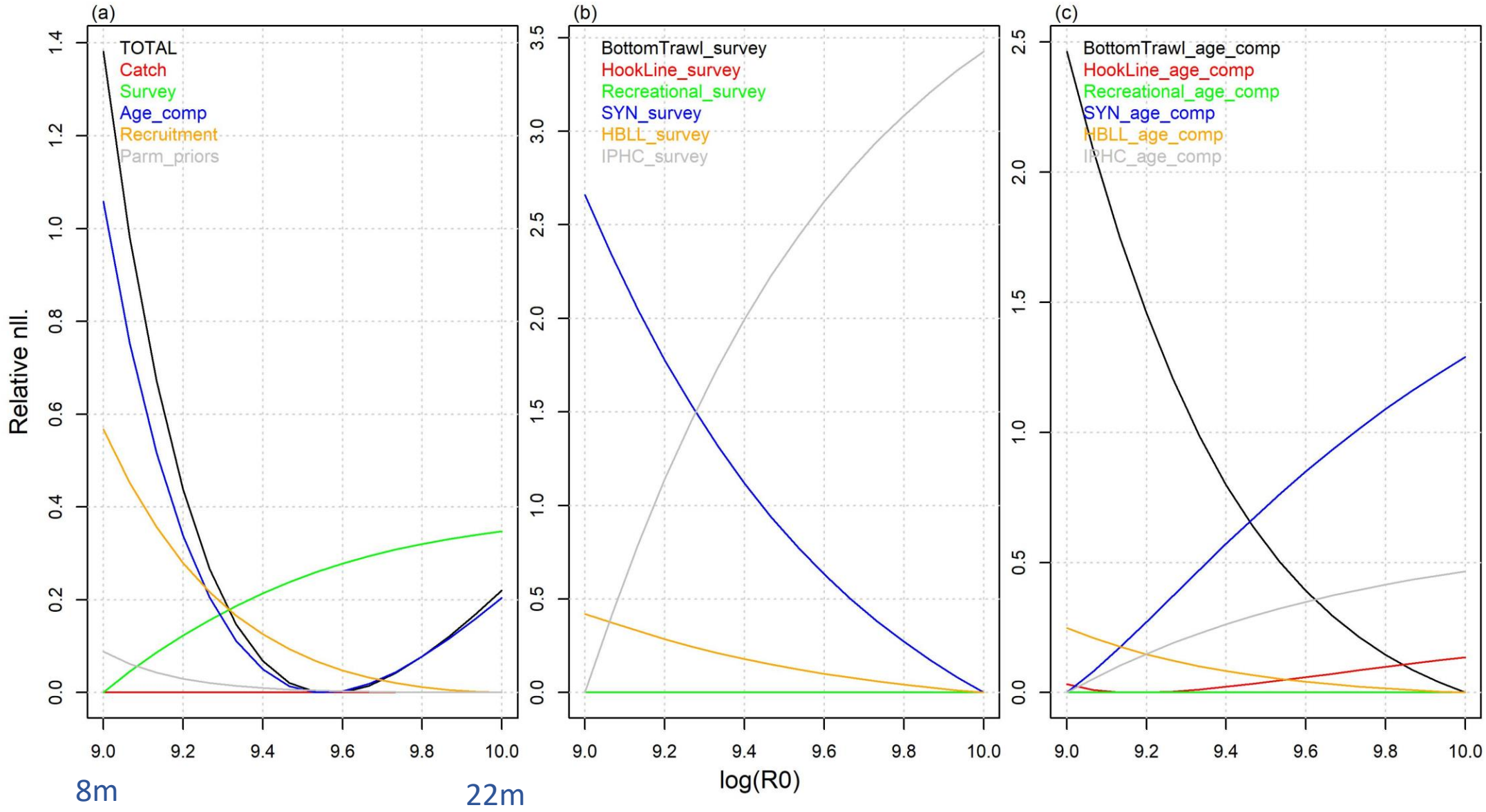


Straw dog model diagnostics 2: jitter analysis (numerical stability / definition in estimation problem)

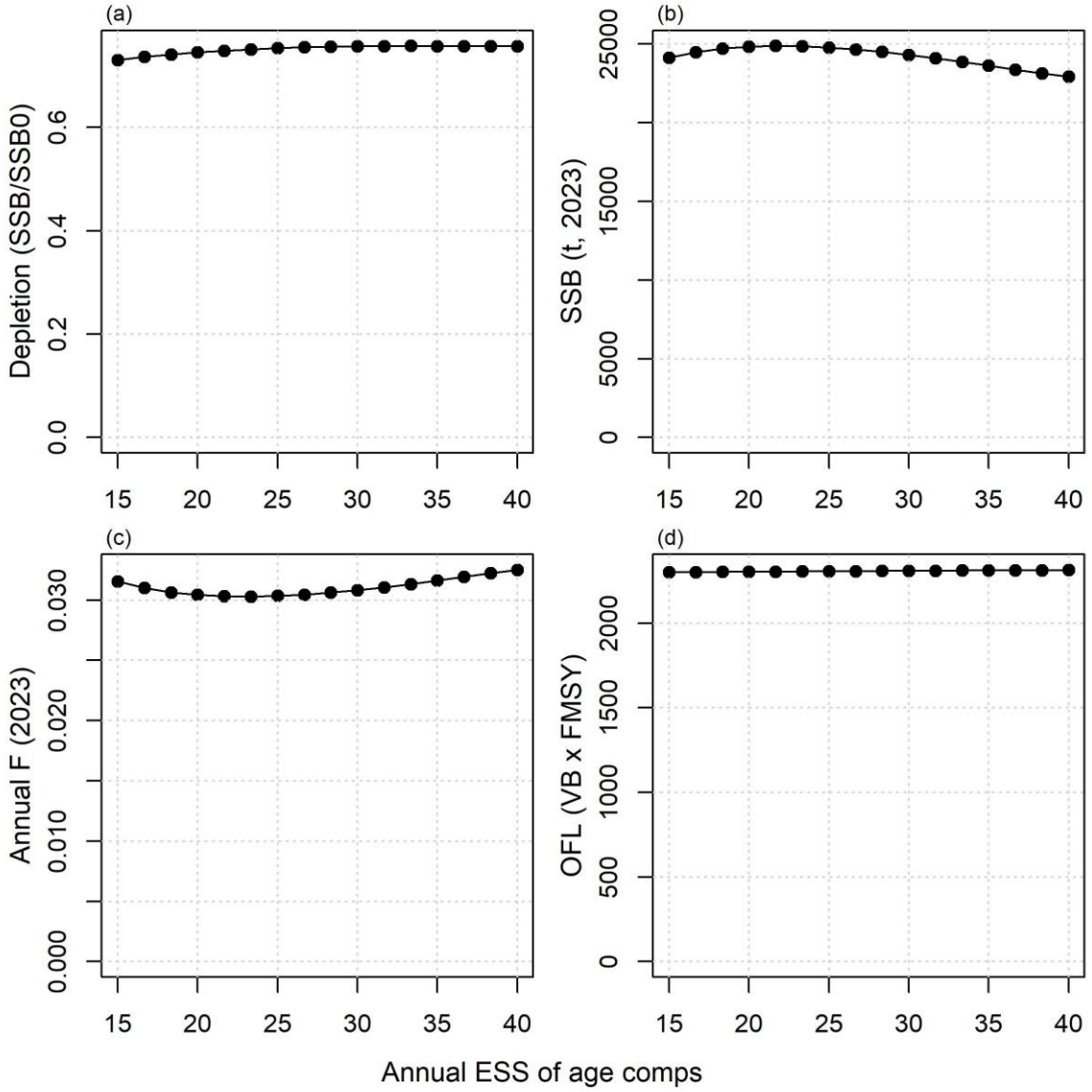


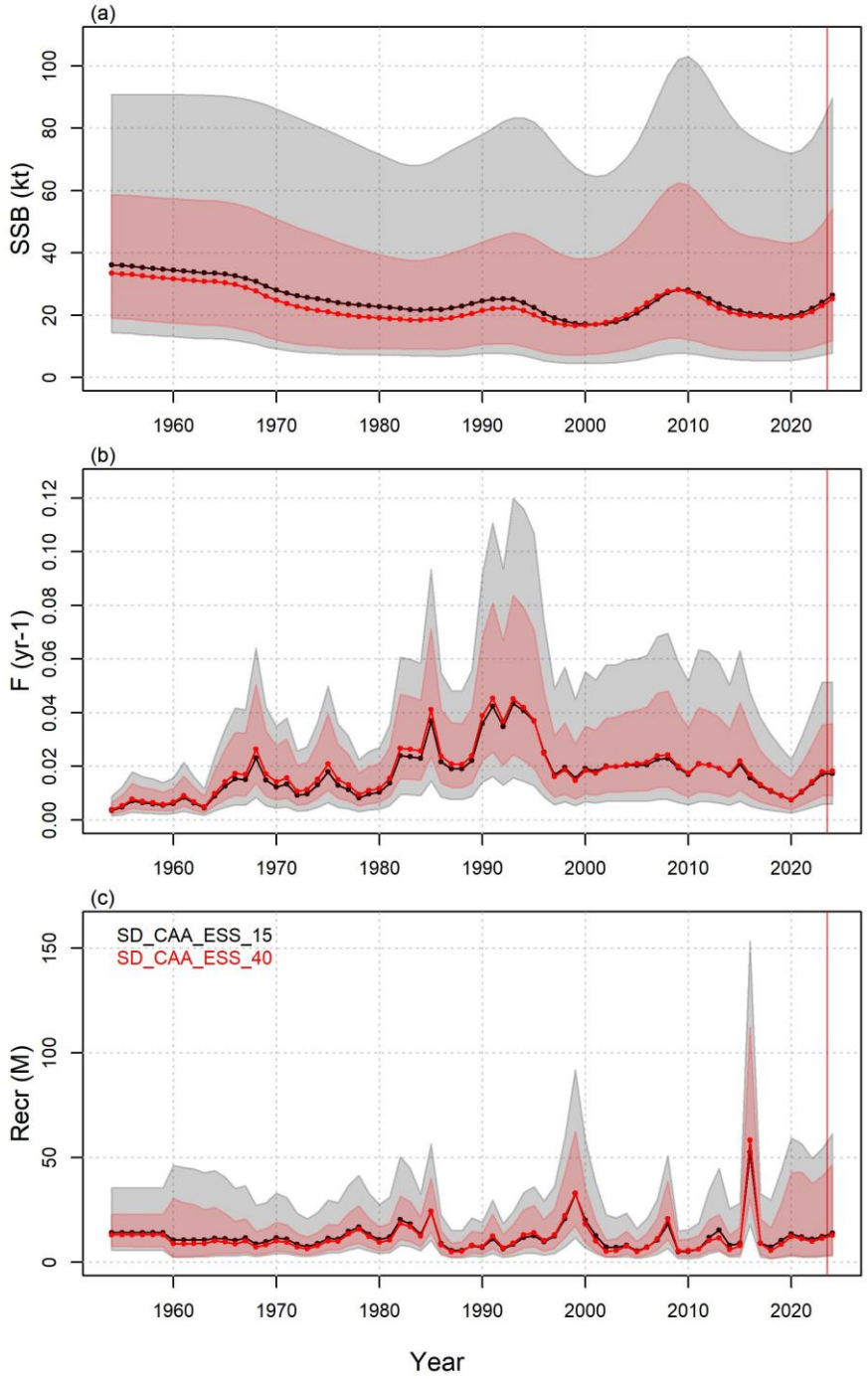
Straw dog model diagnostics 2: parameter profiling (R0 – unfished recruitment)

Very little information about overall scale in the data

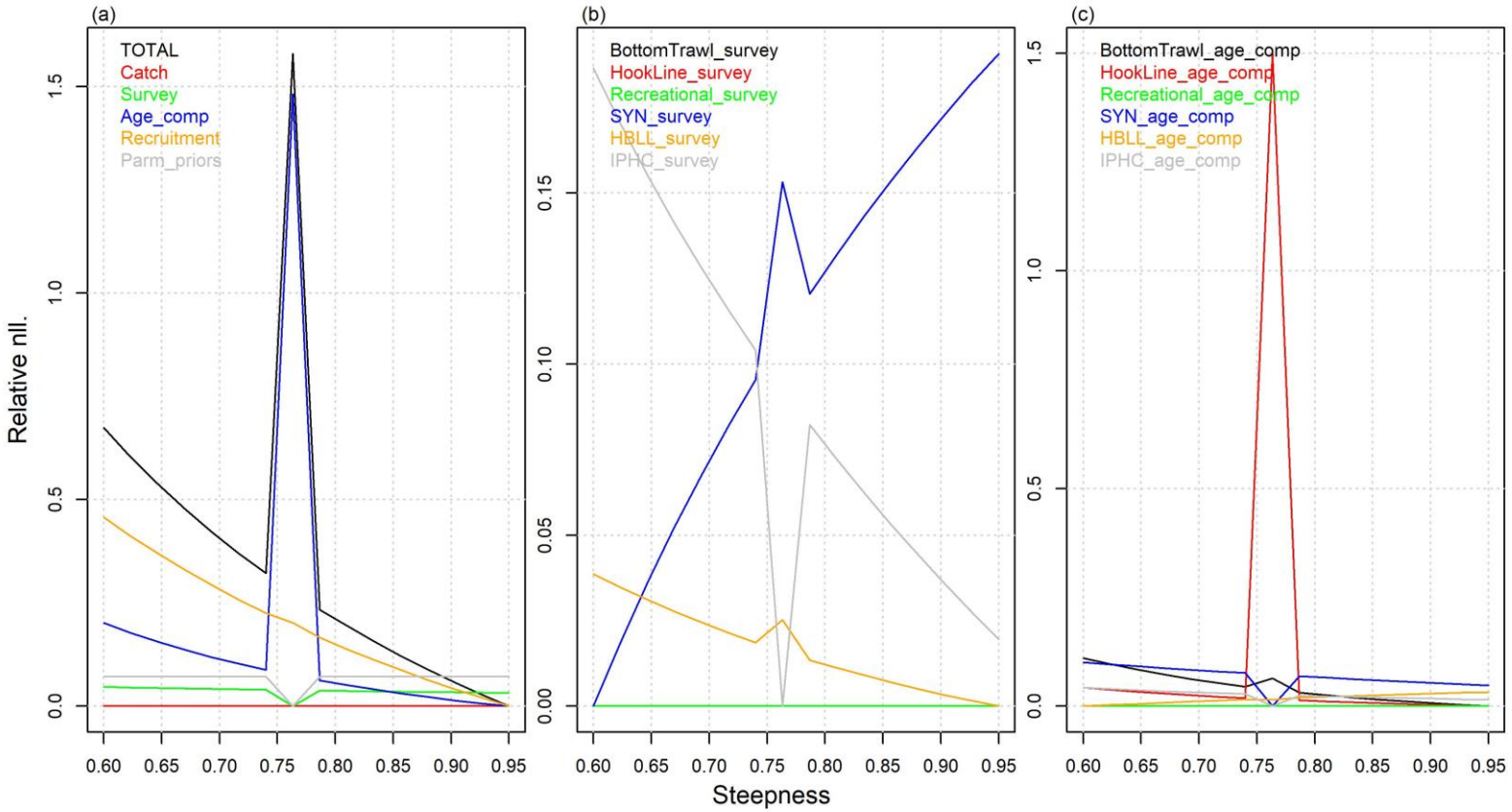


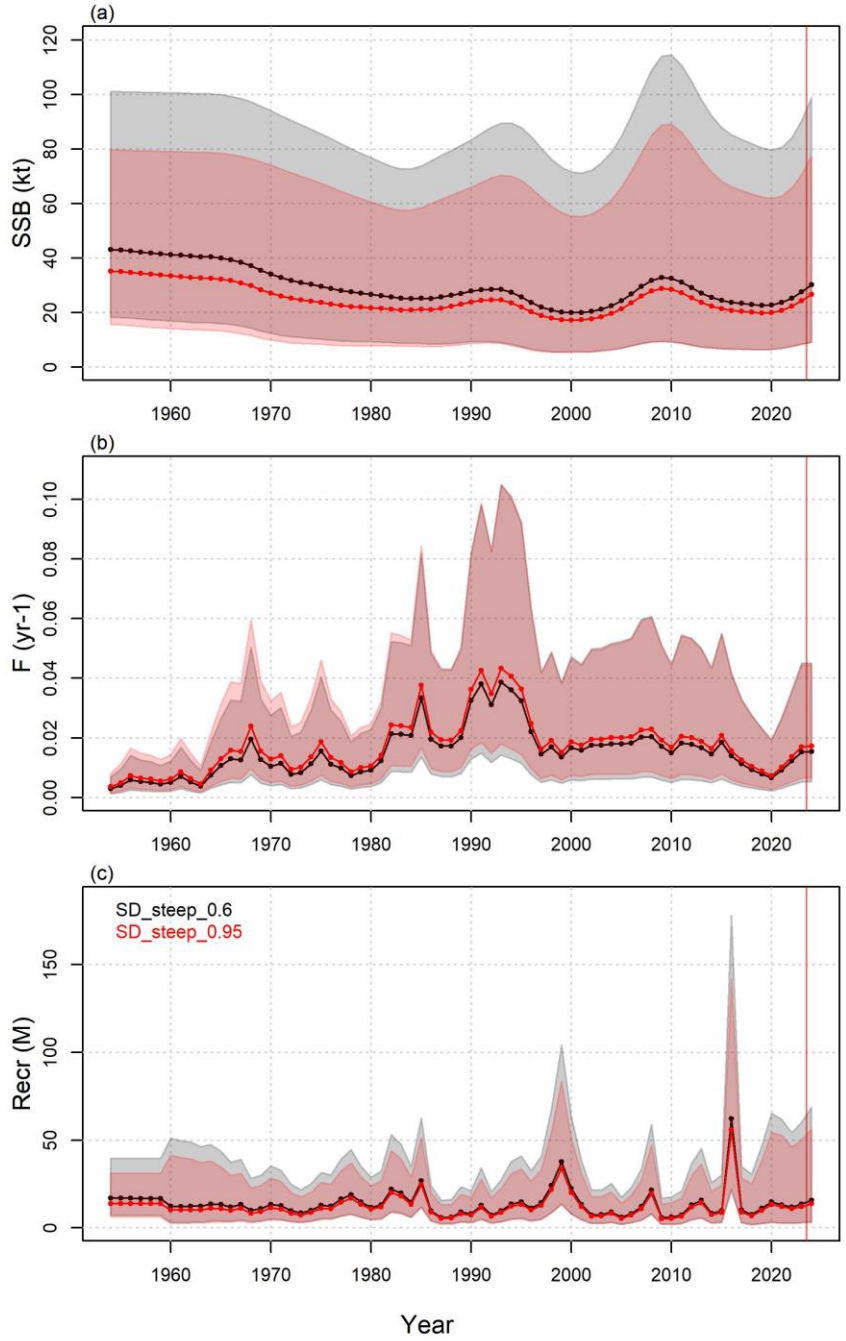
Straw dog model diagnostics 2: parameter profiling (CAA effective sample size)



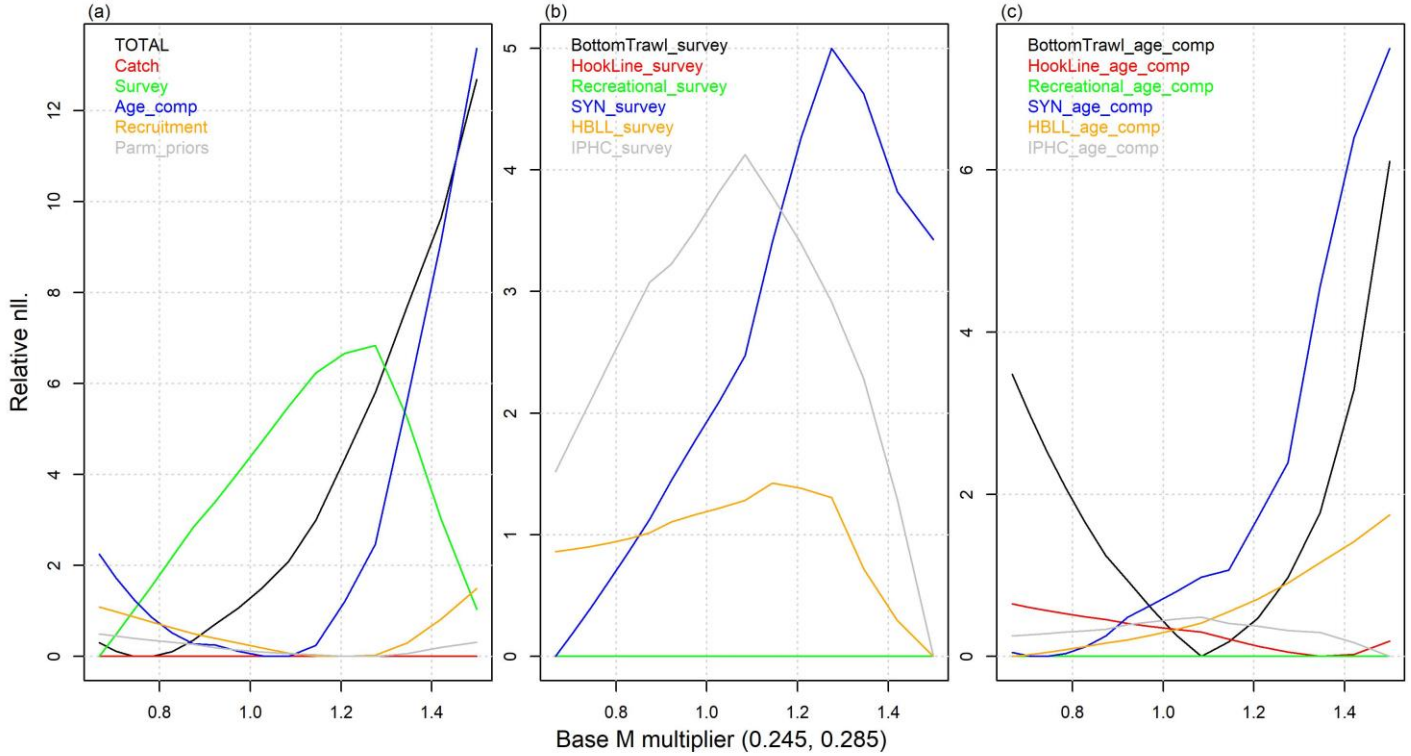


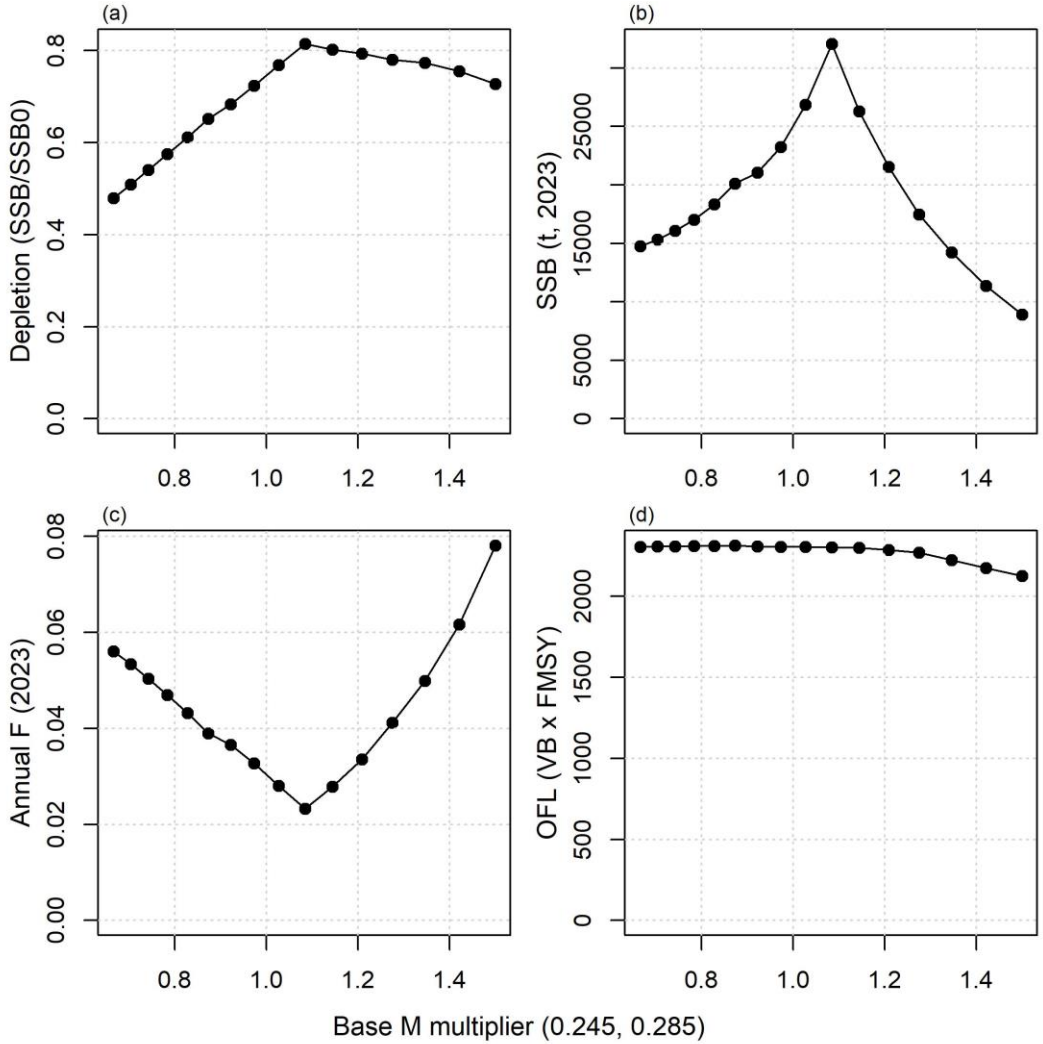
Straw dog model diagnostics 2: parameter profiling (steepness)





Straw dog model diagnostics 2: parameter profiling (M)





Straw dog narrative

- Age composition data infer occasional strong recruitments that explain much of the temporal fluctuations of the survey indices.
- After accounting for recruitment, there is little contrast among catches (exploitation) and remaining inference of population changes.
- As a result, the catch and survey data provide little information about the scale of the stock.
- Scale is therefore informed primarily by the descending distribution of the composition data – ‘how much exploitation rate must there be to see the declining frequency of older fish beyond what is expected by natural mortality rate’.
- Asymptotic (logistic, flat-topped) selectivities provide the strongest inference of exploitation rate via the strongest assumptions. But these do not fit the composition data well & impact the numerical stability of the model. Logistic selectivity may only be suitable for the IPHC survey which has very sparse age composition data.

Straw dog model summary

Diagnostics

- Generally good to very good fit to survey data.
- Poor fit to some age composition data may be forgivable given low sample sizes.
- Uncertainty over scale (recruitment driven vulnerable biomass attenuates contrast in fishery data) and depletion
- Some conflict in inference of scale among and within age-comps and surveys.
- Relatively certain pseudo management recommendations (OFL = FMSY x Vuln.Bio).

Estimates

- Recruitment driven pulses in vulnerable biomass / SSB (1985, 1998-2000, 2016).
- Strong recent age class (2016) leading to recent increases in VB and SSB (note that no comp data after 2019 so informed by only a handful of data points).
- Steepness is poorly informed and tends weakly to 1 – potentially problematic for reference points and numerical stability of the model. This is also a known issue for fisheries where variability in SSB is driven substantially by recruitment strength.
- Relative to both SSBMSY and SSB0 reference points, the model is underfished and projections of current fishing mortality suggest it is also subject to underfishing.

7.3. Where to go with Base Case model?

Do we continue with the sex-specific SS3 model with three fleets, three surveys, statistical catch at age?

If so:

- Investigate more restrictive selectivities for fleets / surveys.
- Can we reasonably constrain scale? E.g., occasional anomalous runs have unfished recruitment (R0) estimates 2 order of magnitude higher than 98% of other runs.
- Investigate ‘additional variance’ options for survey series to lessen conflict with age composition (this is really just tantamount to down weighting surveys).
- Evaluate impact of including length composition data – does it add any useful information or simply further conflict among data sources?
- Consider including age composition data for recreational fleet (some sparse data exist)
- Investigate the Dirichlet-multinomial for the age composition data.
- Additional age-composition data available for synoptic survey?

7.4. Reference points

- Both ‘unfished’ (equilibrium & dynamic) and MSY (equilibrium) reference points can be calculated and are available in SS outputs.
- As steepness values approach 1, conventional MSY reference points are sometimes dropped in favor of spawner per recruit formulations.
- High resilience (steepness) & rapid growth provide very low estimates of SSBMSY relative to equilibrium unfished SSB0 (~ 15%)

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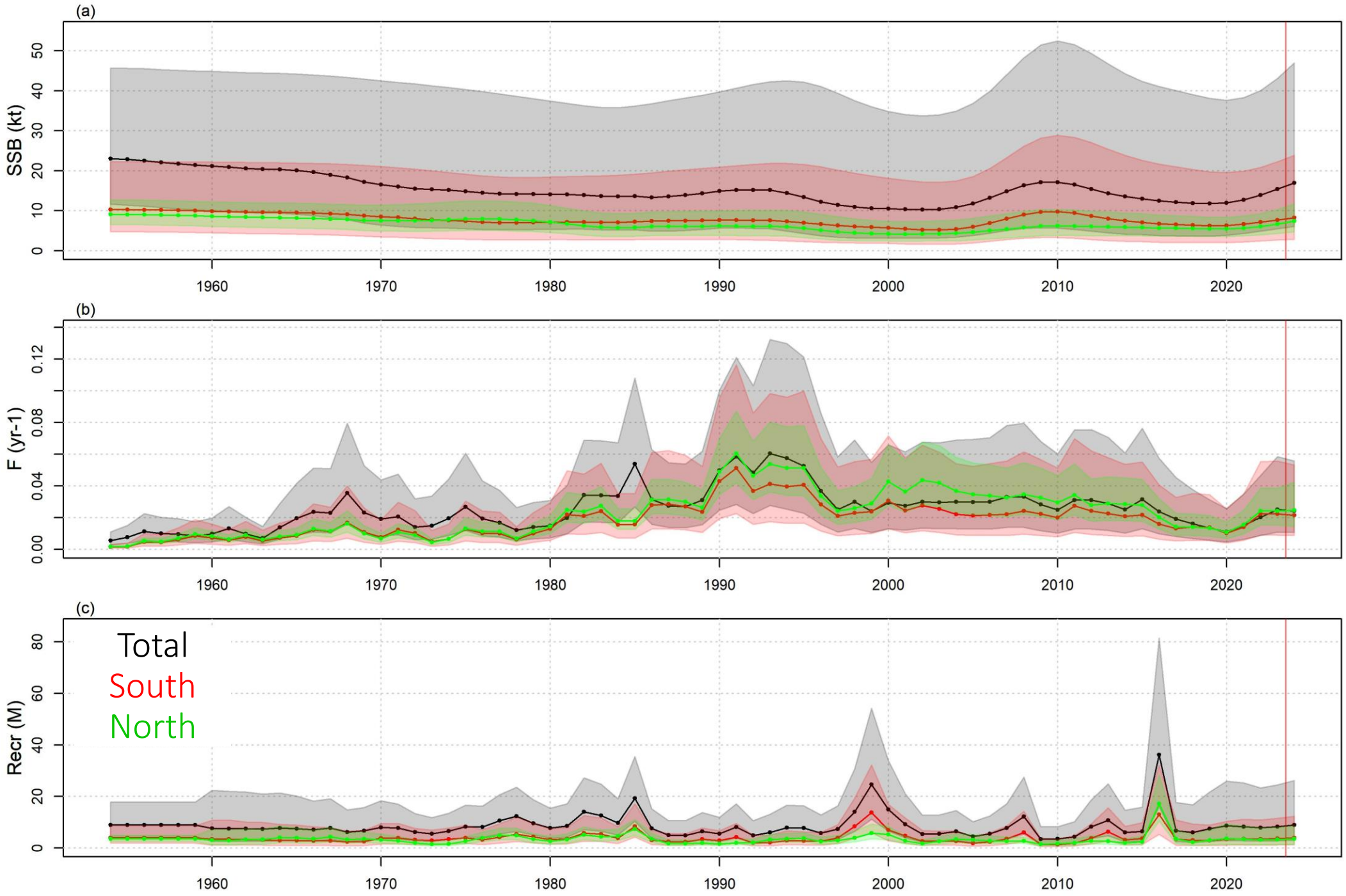
7.5. Straw dog model & stock structure

Historical patterns in estimated exploitation rate and recruitment are remarkably similar among North and South areas.



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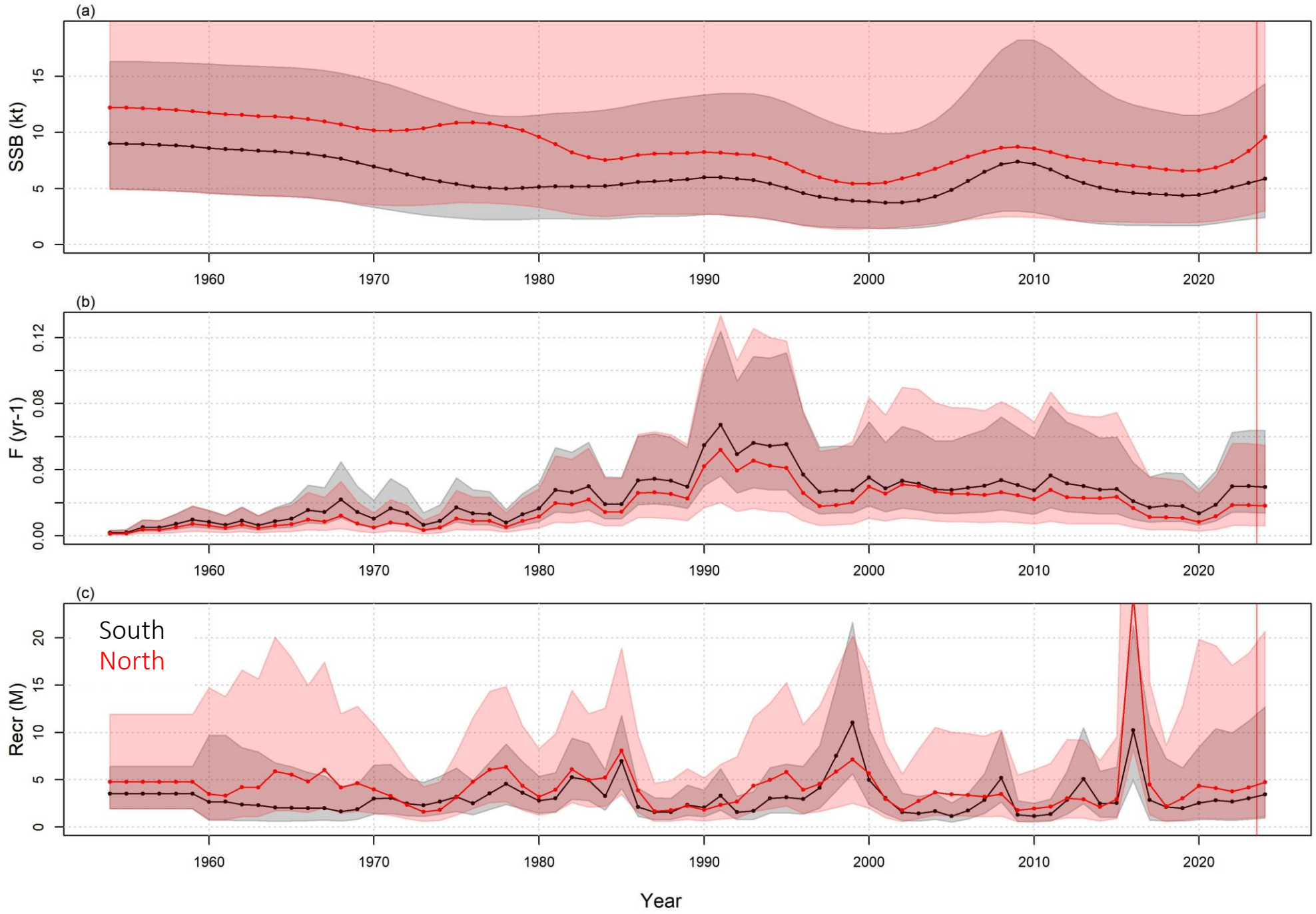

8. Problems and possible solutions

Potential stock assessment peer-review issues:

- Acceptance of a scale-uncertain model that nevertheless has conclusive management implications (i.e. a stock that is consistently estimated to be underfished subject to underfishing)?
- Is uncertainty over the Limit Reference Point (LRP) (a tonnage of fish, possibly) tolerable?

The alternative is the operating-model (OM) approach (MP framework):

- Establish a simple and robust management procedure (MP) that, for example specifies catches as a ratio of the three survey indices:

$$TAC_y = \alpha\, I_{SYN,y-1} + \beta\, I_{IPHC,y-1} + \gamma\, I_{HBLL,y-1}$$

- Demonstrate the robustness to scale using multiple operating models based on the stock synthesis model (natural mortality rate, resilience, data weighting)
- Use a single base-case operating model to get your LRP

Thanks

Dana Haggarty

Quang Huynh

Leah Walker

Luke Rogers

App. Reporting and diagnostics

Conventional stocks assessment reporting and diagnostics relate to five general aspects:

- **Implementation**: whether the methods were applied correctly;
- **Reproducibility**: whether sufficient information is provided to be able to obtain the same results from the same data;
- **Objectivity**: whether there is a sound empirical basis for model structure and interpretation of data, so that results are not strongly determined by subjective judgement;
- **Performance**: how well the approaches capture the apparent system dynamics and match empirical observations;
- **Informing management:** support managers decision making.

App. Reporting and diagnostics

Conventional stocks assessment reporting and diagnostics relate to five general aspects:

- **Implementation**: code, use of established software, simulation testing;
- **Reproducibility**: model equations, code repository, description of all non-estimated parameters / assumptions and basis;
- **Objectivity**: sensitivity to alternative data interpretations and weighting, model assumptions and model parameters, parameter profiling;
- **Performance**: fit to data, patterns in residuals, retrospective analysis, hindcasting.
- **Informing management:** projections, decision tables, risk trade-off figures etc.

Sensitivity analyses

Parameters	Model assumptions	Data
Natural Mortality rate	Ricker stock-recruitment	Composition weighting
Steepness	Selectivity functions	IPHC weighting
Sigma R		Length data
		Recreational composition

Diagnostics

Numerical stability	Model misspecification	Uncertainty
Objective function gradients	Fit to data	MLE var-covariance
Jitter analysis	Residual patterns	MCMC mixing
Simulation self-testing	Retrospective analysis	Sensitivity analysis
Evaluation of MCMC chains	Hind casting	