


The Logistic-normal as a tool to diagnose model misspecification?

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CAPAM & IATTC Workshop on Model Diagnostics in Integrated Stock Assessments

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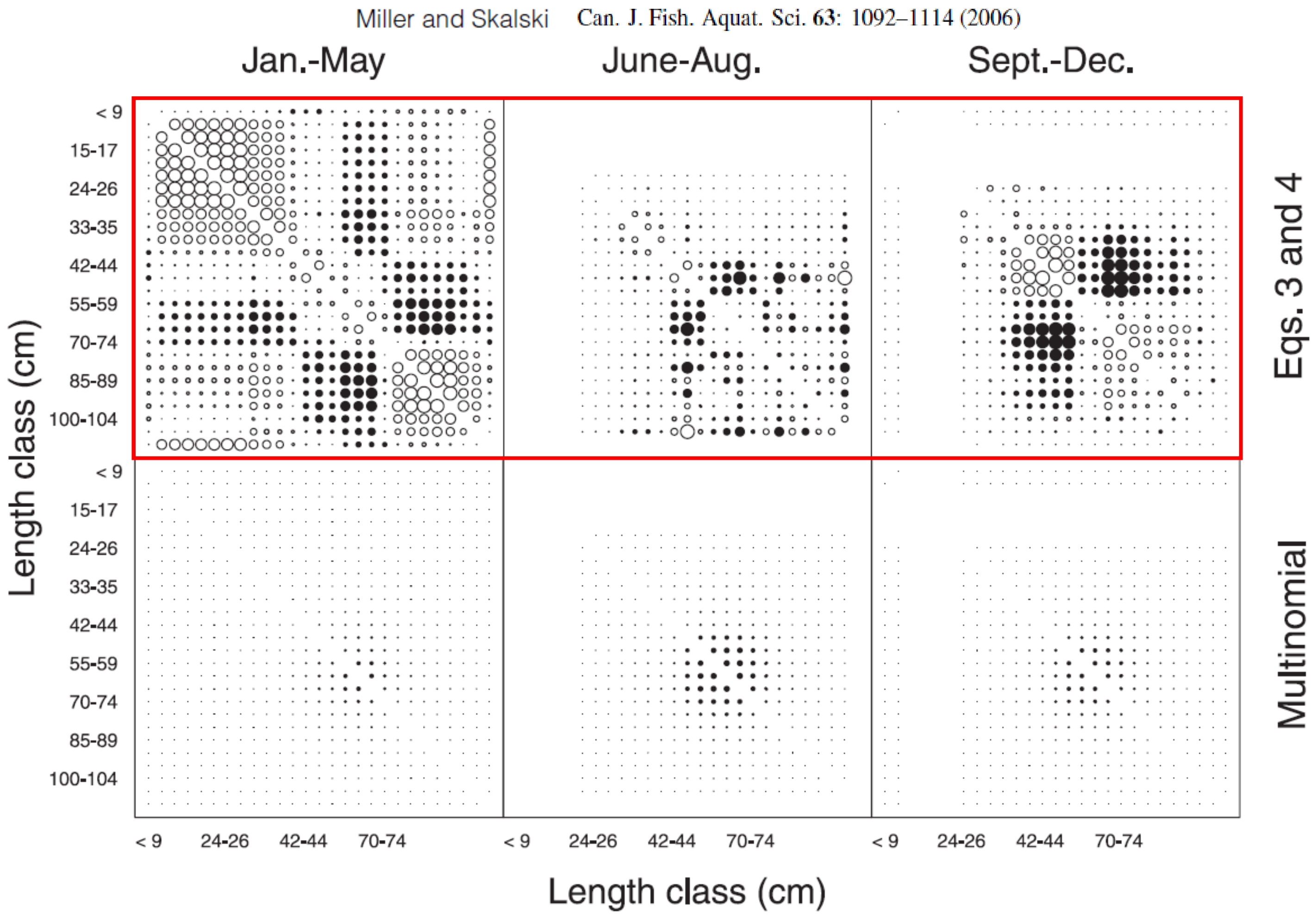
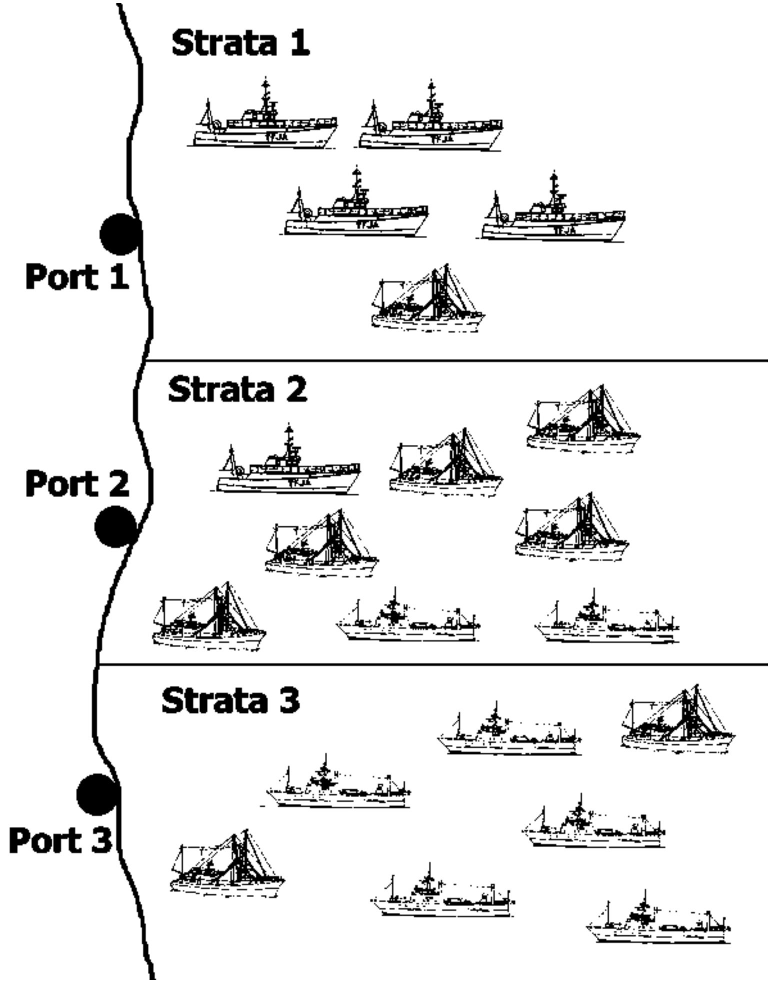
Correlations and Overdispersion

Observation / Sampling Error

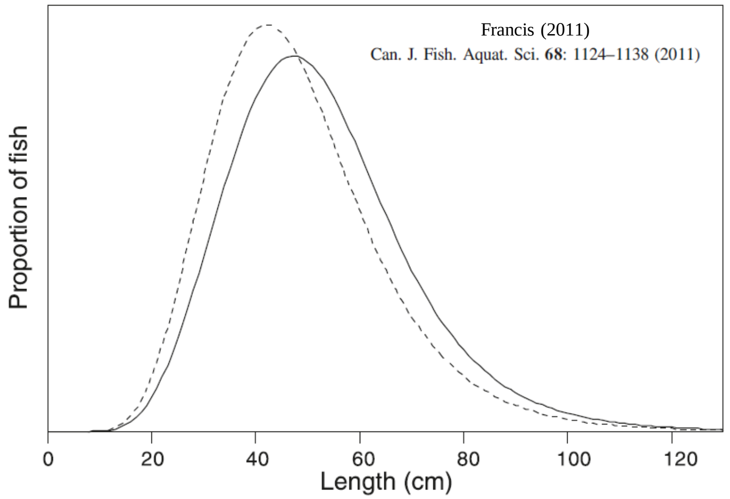


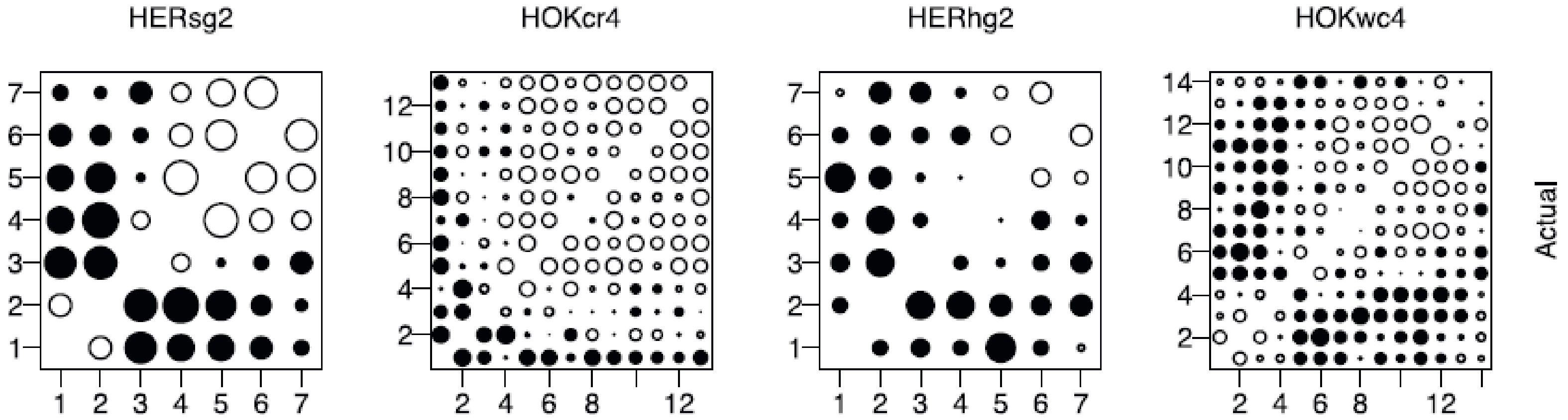


Correlations and Overdispersion

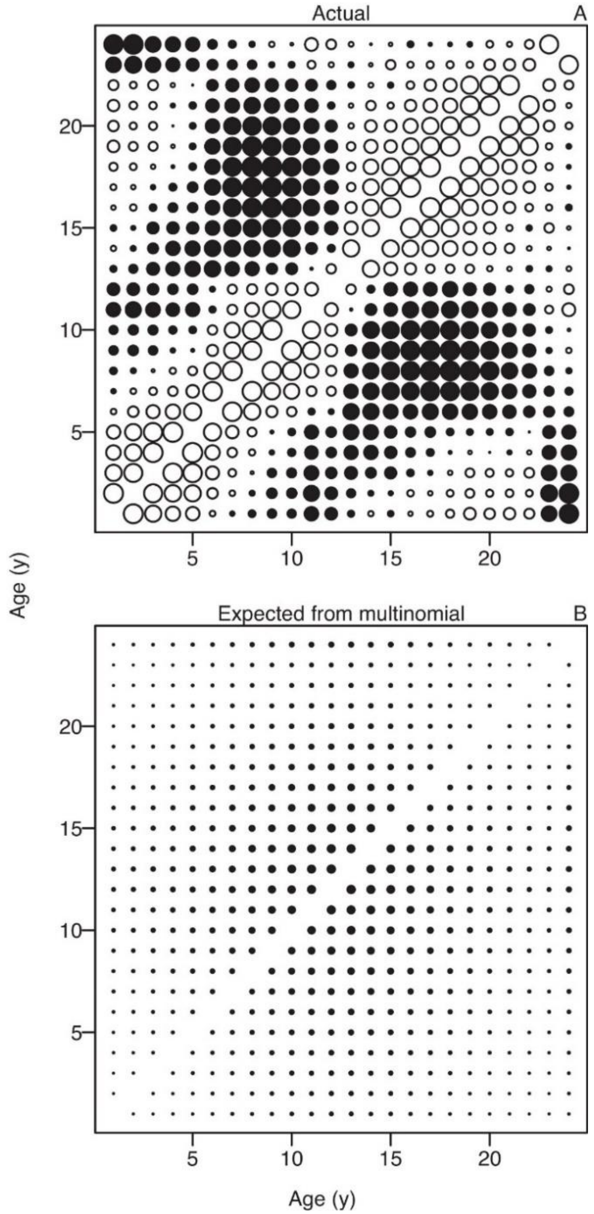
- Model Misspecification / Process Error

Fig. 3. Illustration of the relationship between the observed (solid line) and expected (broken line) catch length frequencies in a year in which the true fishery selectivity is shifted to the right of that assumed in the stock assessment model.





R.I.C.C. Francis / Fisheries Research 151 (2014) 70–84



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Dirichlet-multinomial

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Model-based estimates of effective sample size in stock assessment models using the Dirichlet-multinomial distribution

CrossMark

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$$L\left(\boldsymbol{\pi}, \theta | \tilde{\boldsymbol{\pi}}, n\right) = \frac{\Gamma(n+1)}{\prod_{a=1}^{a_{max}} \Gamma(n\tilde{\pi}_a + 1)} \frac{\Gamma\left(\theta n\right)}{\Gamma\left(n + \theta n\right)} \prod_{a=1}^{a_{max}} \frac{\Gamma\left(n\tilde{\pi}_a + \theta N \pi_a\right)}{\Gamma\left(\theta n \pi_a\right)} \tag{10}$$

which has effective sample size:

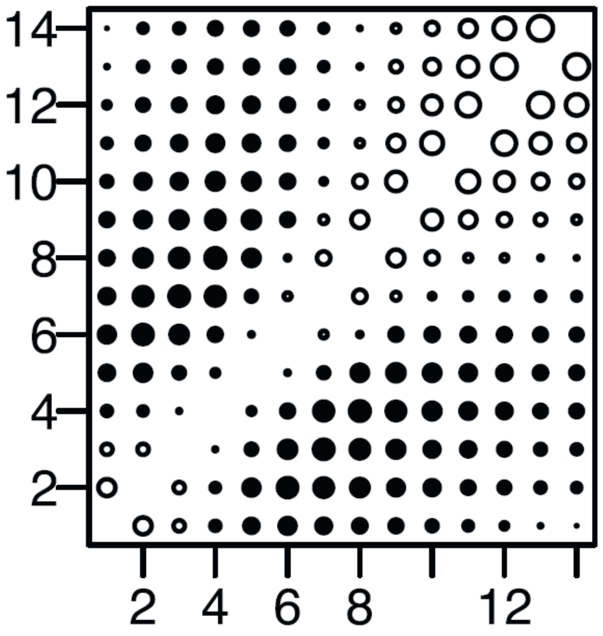
$$n_{eff} = \frac{1 + \theta n}{1 + \theta} = \frac{1}{1 + \theta} + n\frac{\theta}{1 + \theta} \tag{11}$$

Logistic-normal

$$\mathbf{X} \sim MVN\left(\log\left(\mathbf{P}\right), \mathbf{C}\right) \longrightarrow \frac{e^{X_a}}{\sum_a e^{X_a}}$$

- Variance-covariance matrix can be parameterized
  - Simple method is using AR1 process

- Can create positive and negative correlations in composition residual structure



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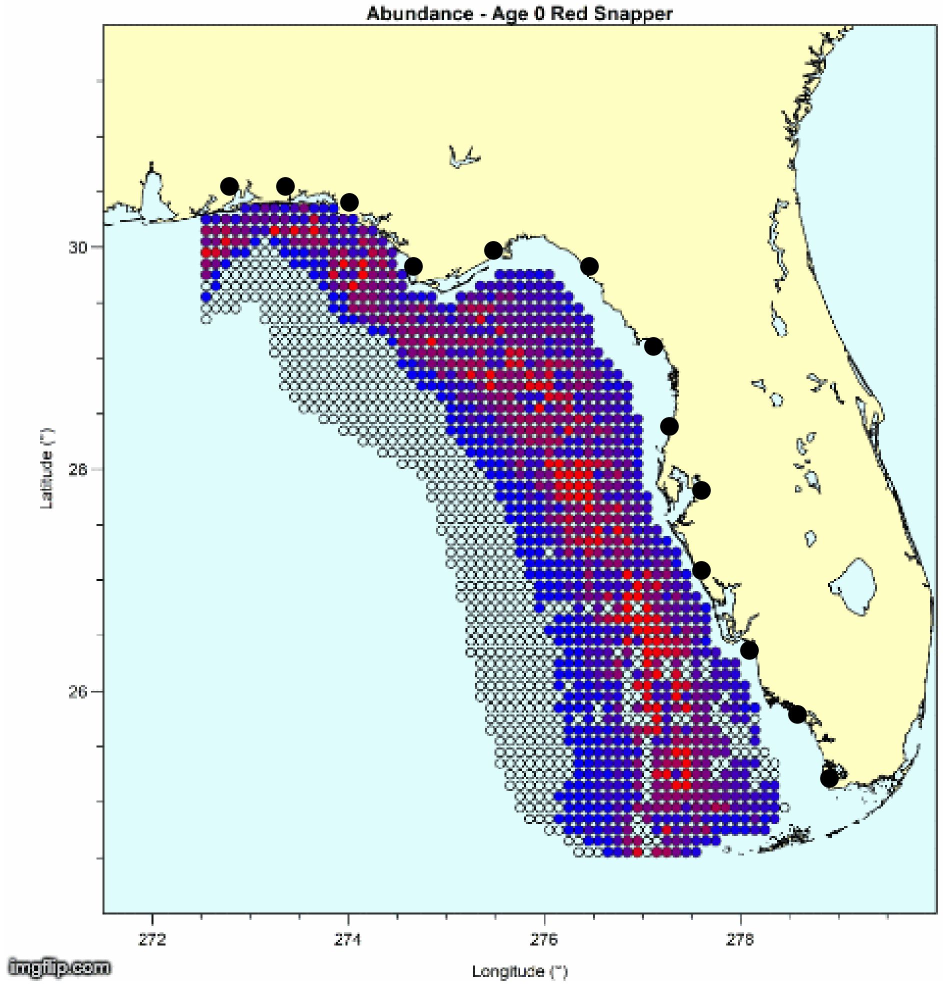
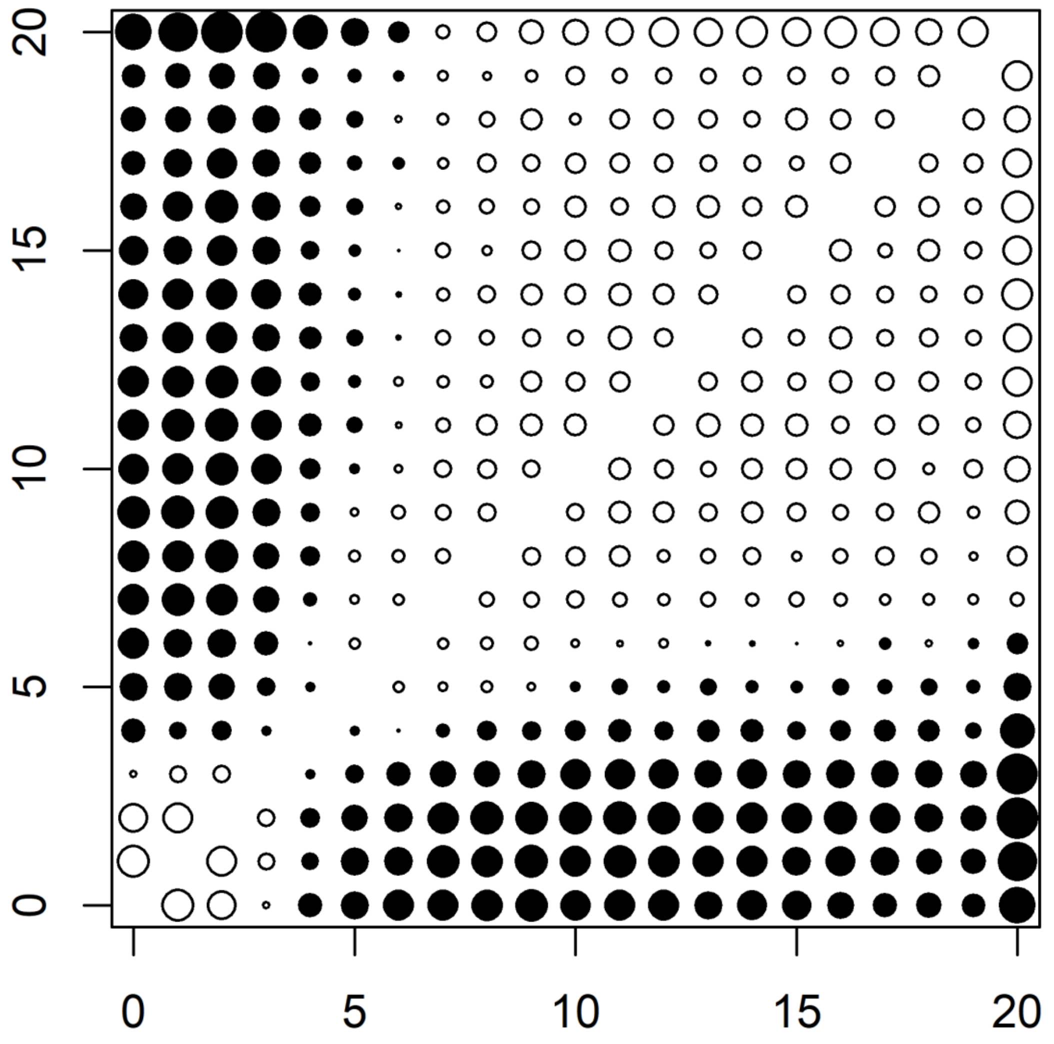
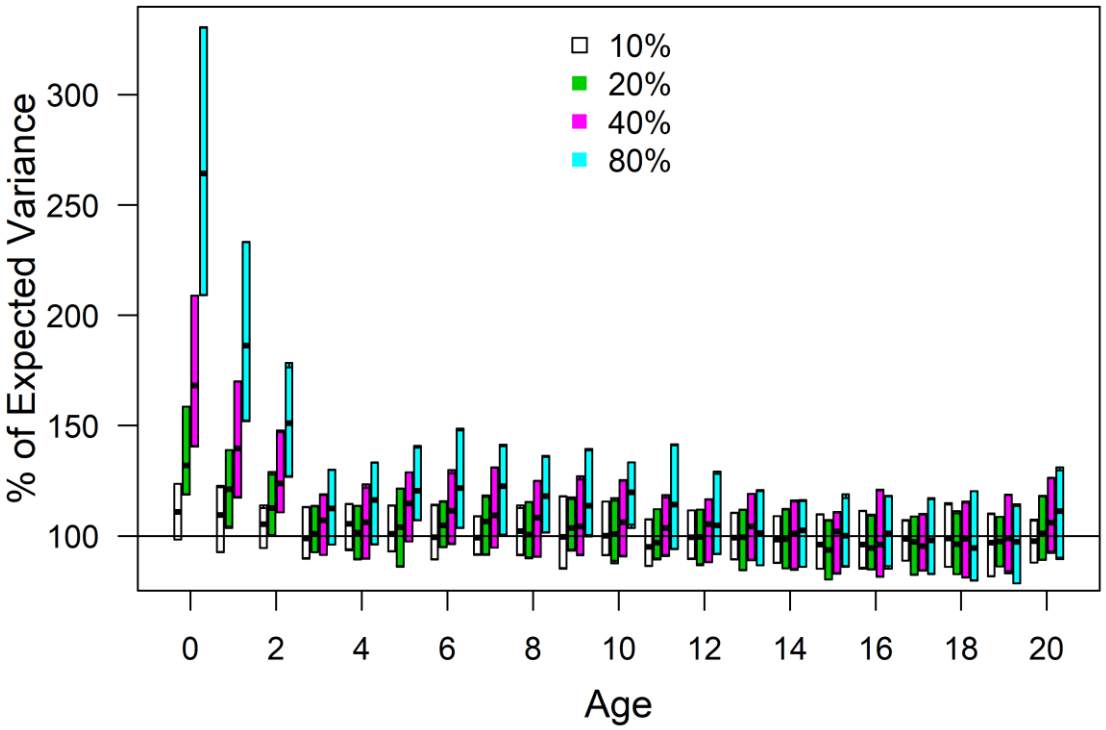
Methods: Simulation Operating Model

- Fine-scale spatially explicit model
  - Spatial Cells are 0.1°(~10km^2)
- Age-structured (Ages 0-20+)
- Based on Red Snapper Life History
  - Most Parameters taken from SEDAR Assessment
- Models age-based movement and dynamic effort distribution
  - Sampling done at scale of spatial cell to create correlations



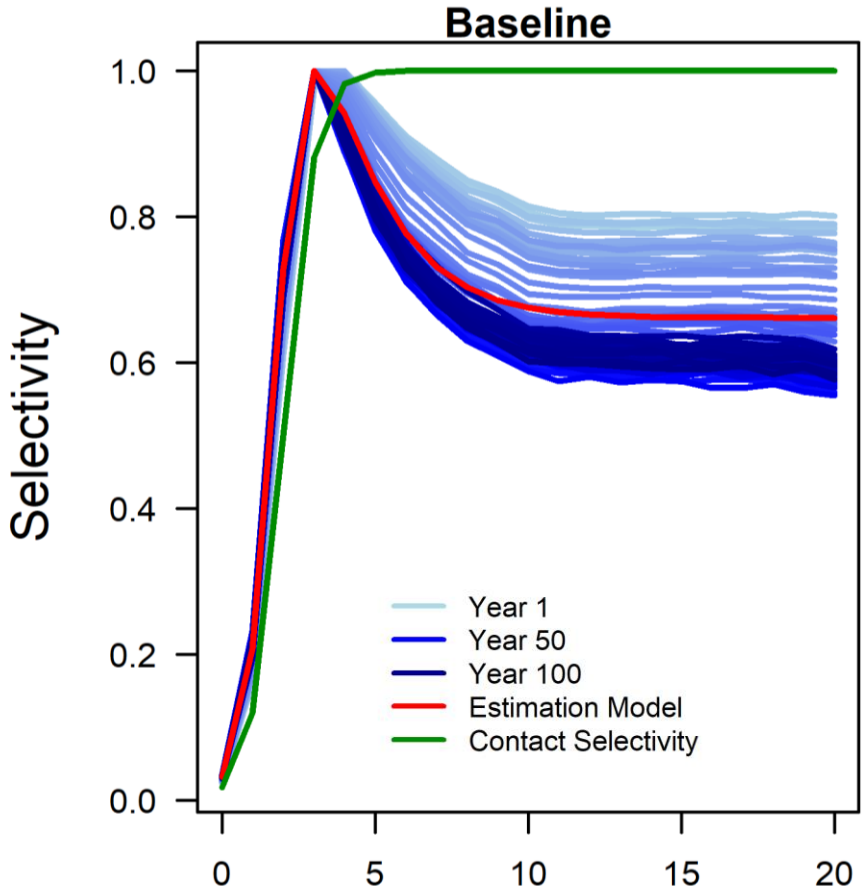
Simulated Observation Error Correlations and Overdispersion





Methods: Estimation Model

- Fit standard SCAA models to 1000 replicates of data generated from Operating Model
  - Fit to harvest, fishery index, fishery composition, survey index, and survey composition
    - 100yr time series
    - Estimating unfished rec, rec devs, fishing intensity, selectivity params, and catchabilities
      - Known M, h, and variance terms
  - Will be misspecified in Fishery Selectivity



Performance Criteria (Terminal Year)

- Depletion (Biomass/Unfished)
- Exploitation Rate (Harvest/Biomass)

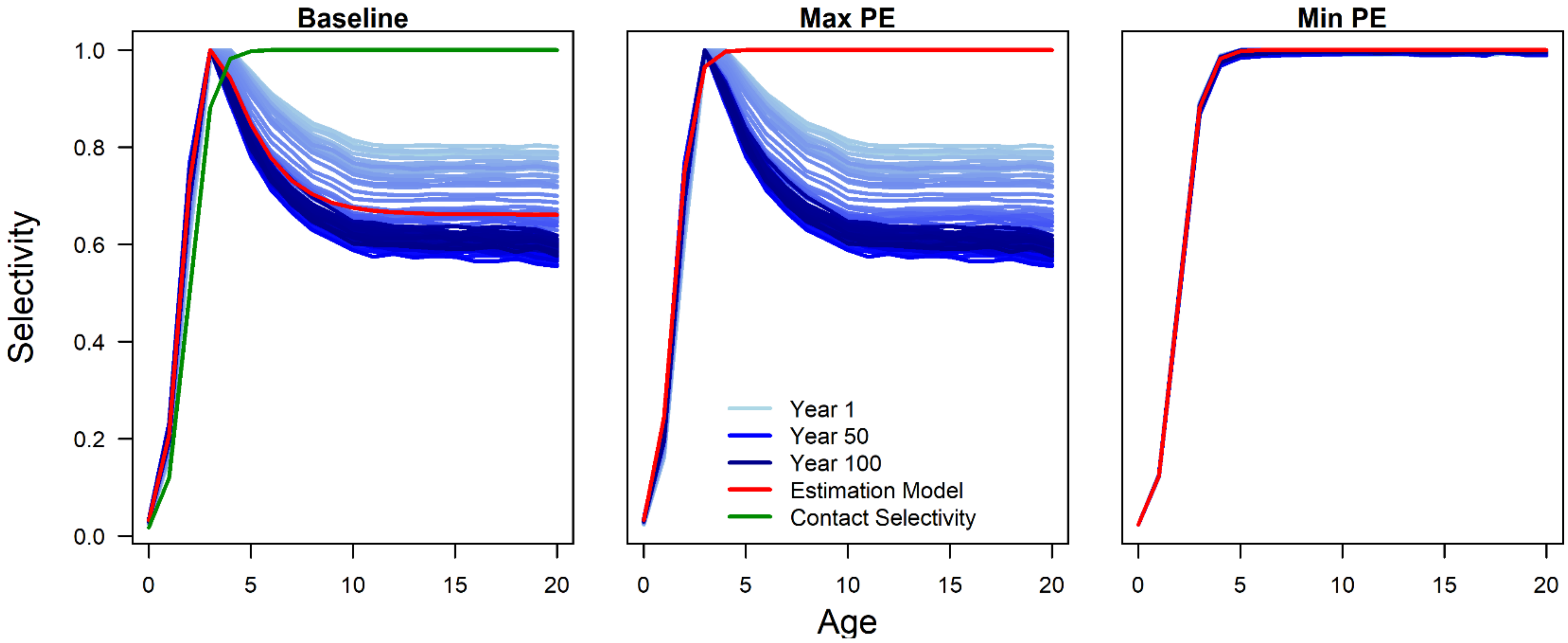
Performance Statistic

- Relative Error

  (Estimated – True)/True

Treatments: Misspecification in Selectivity

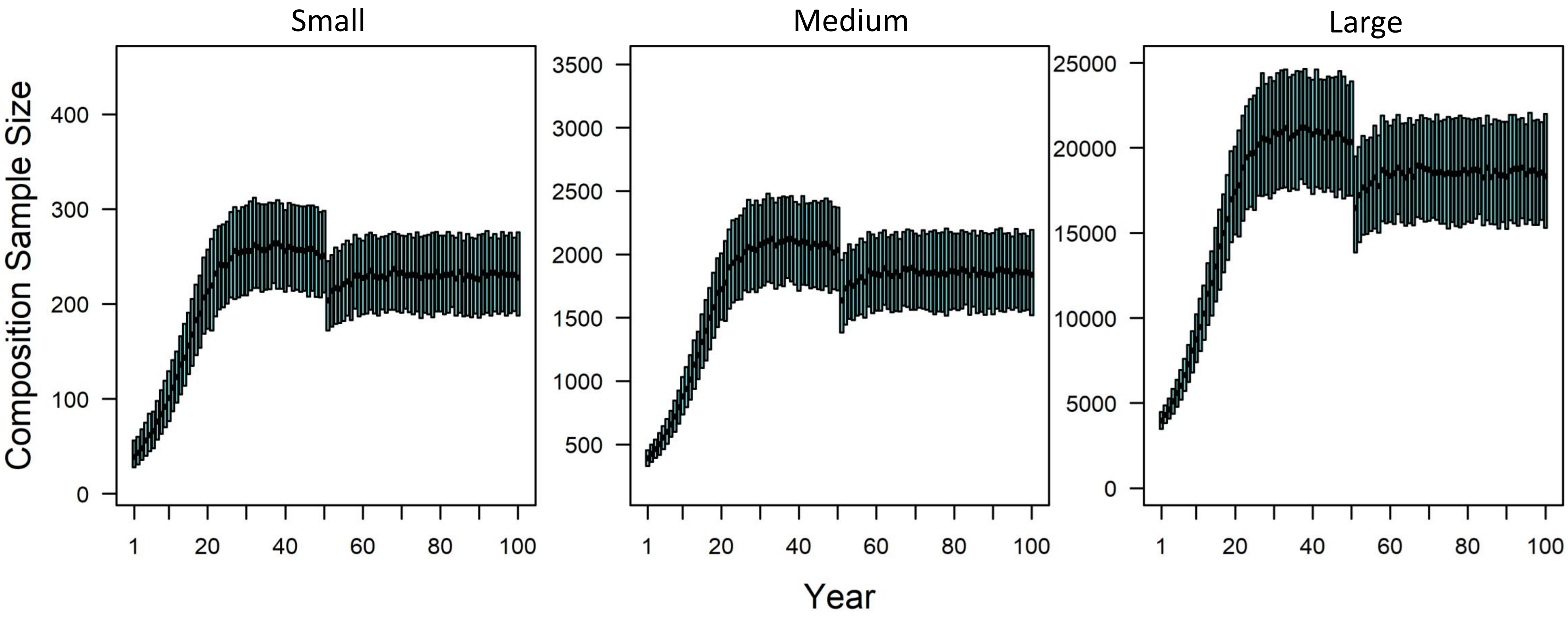
- Different degrees of model misspecification
  - Based on the form of Fishery Selectivity



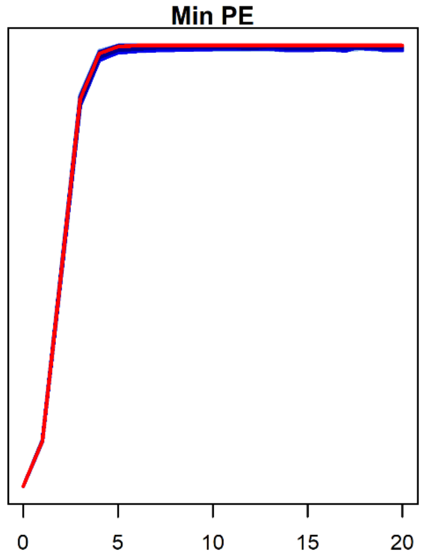
Treatments: Composition Sample Size

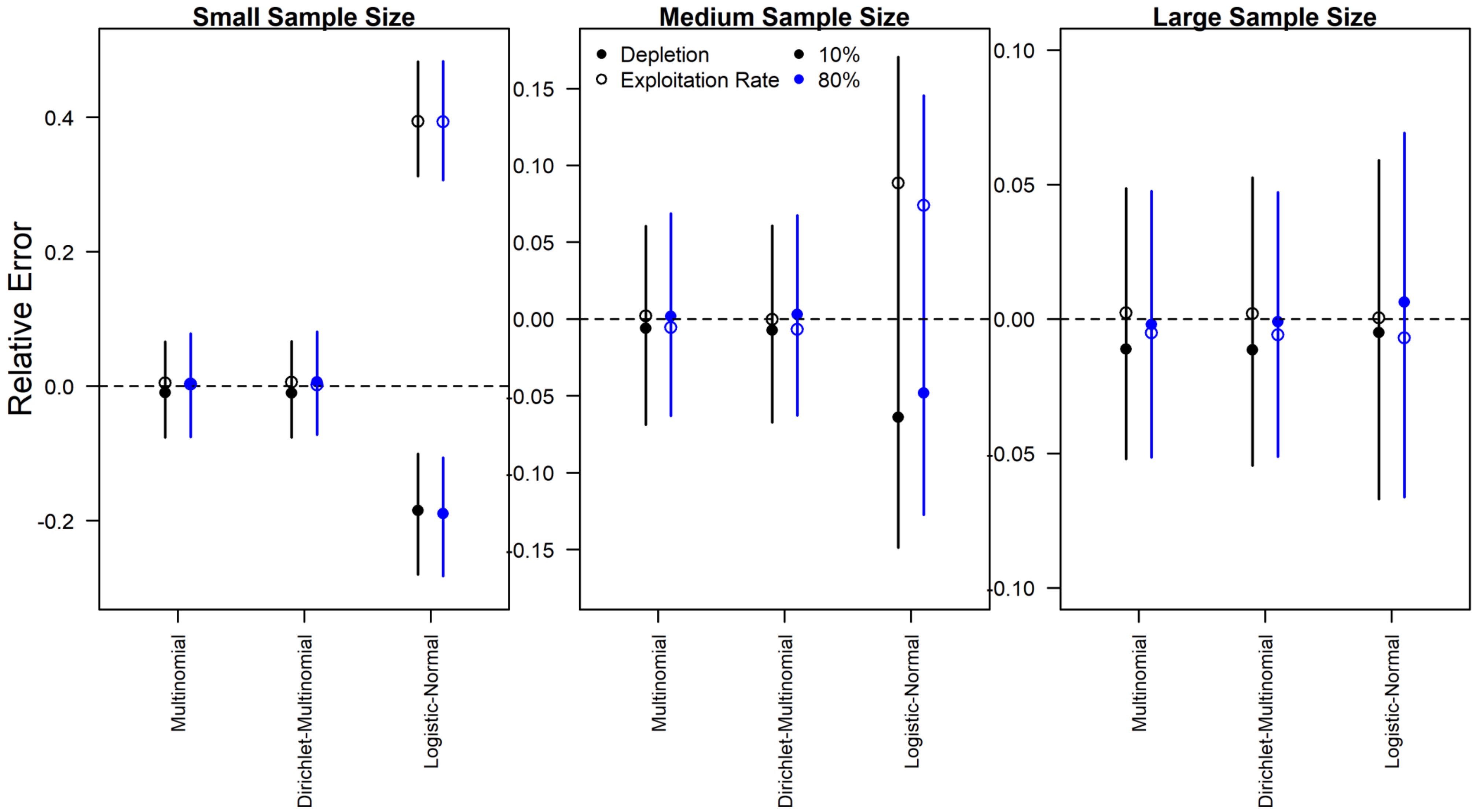
Sample Size of Composition Data

- Varied the number of fish sampled/aged for fishery composition data

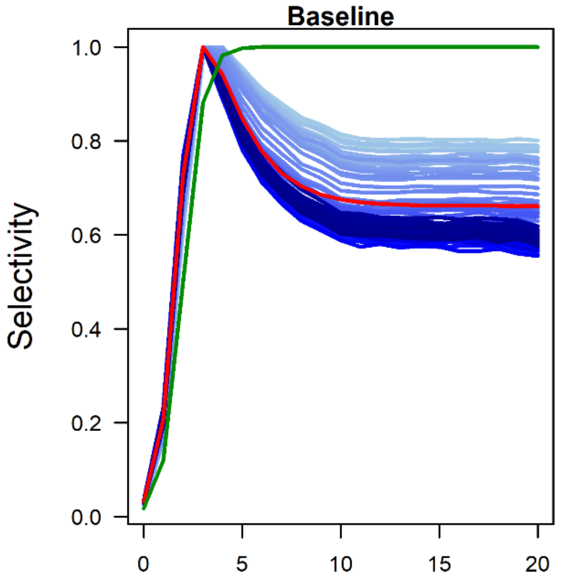


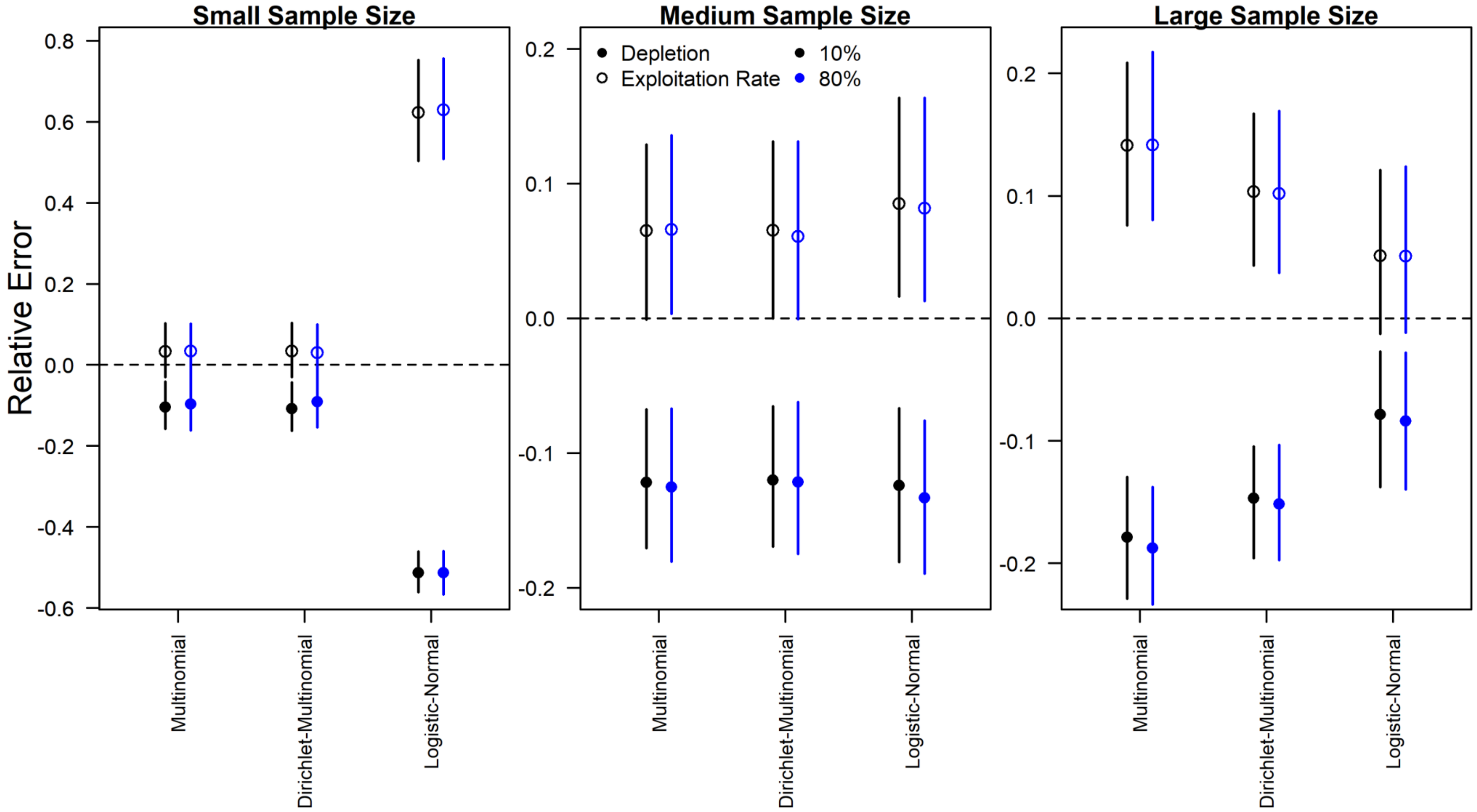
Results: Minimal PE



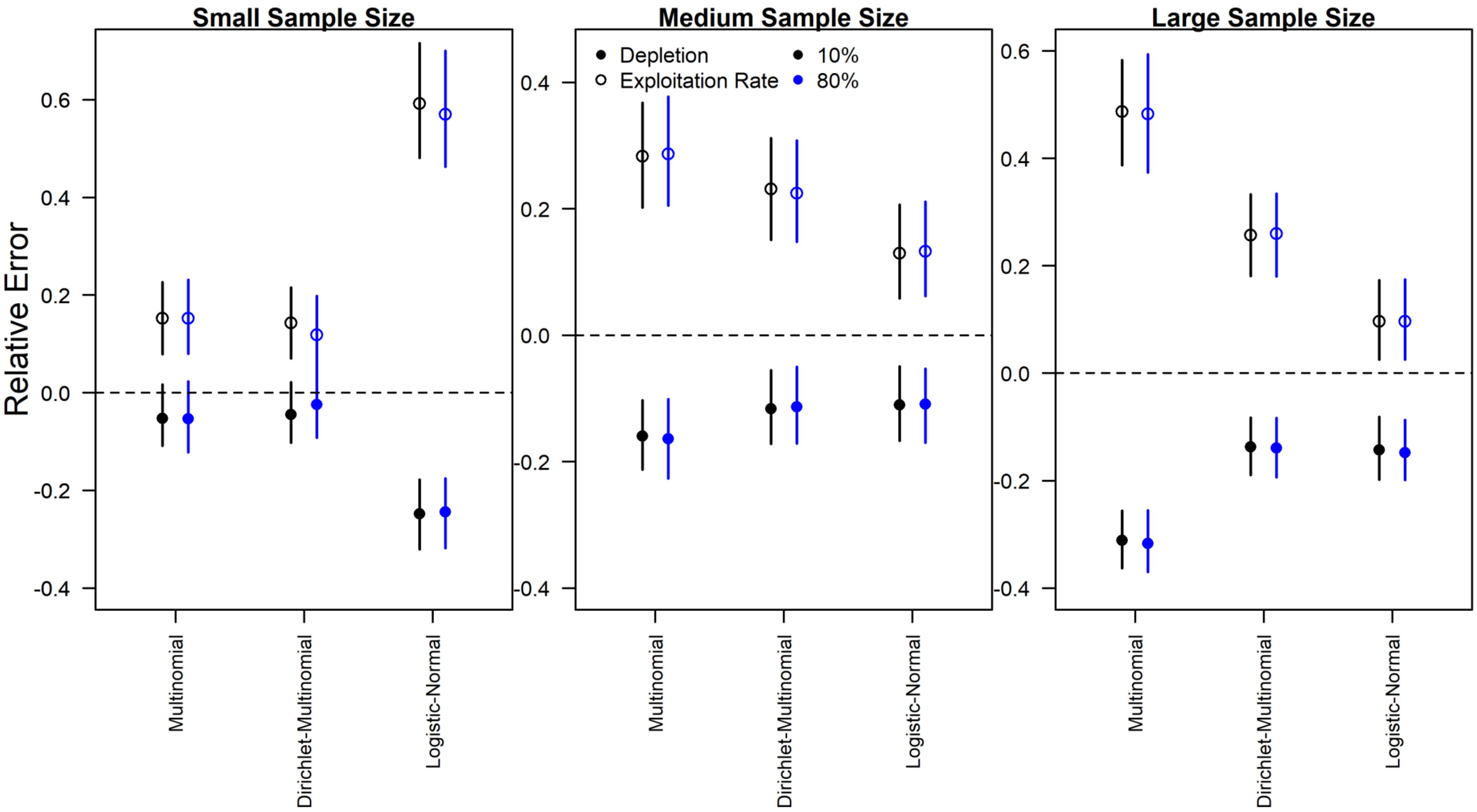


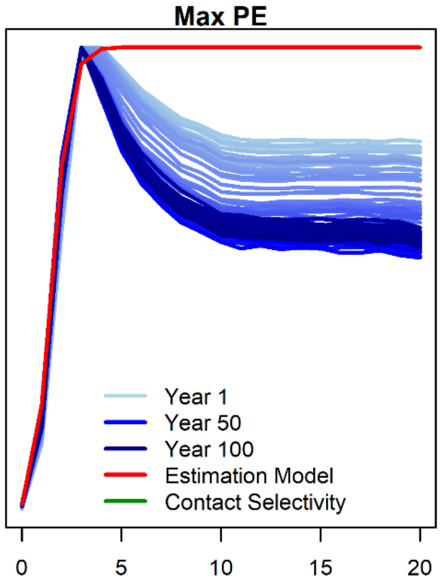
Results: Baseline



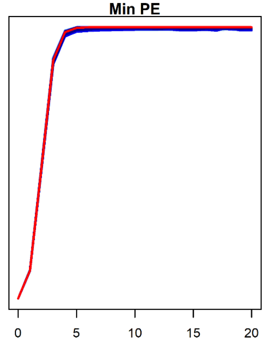


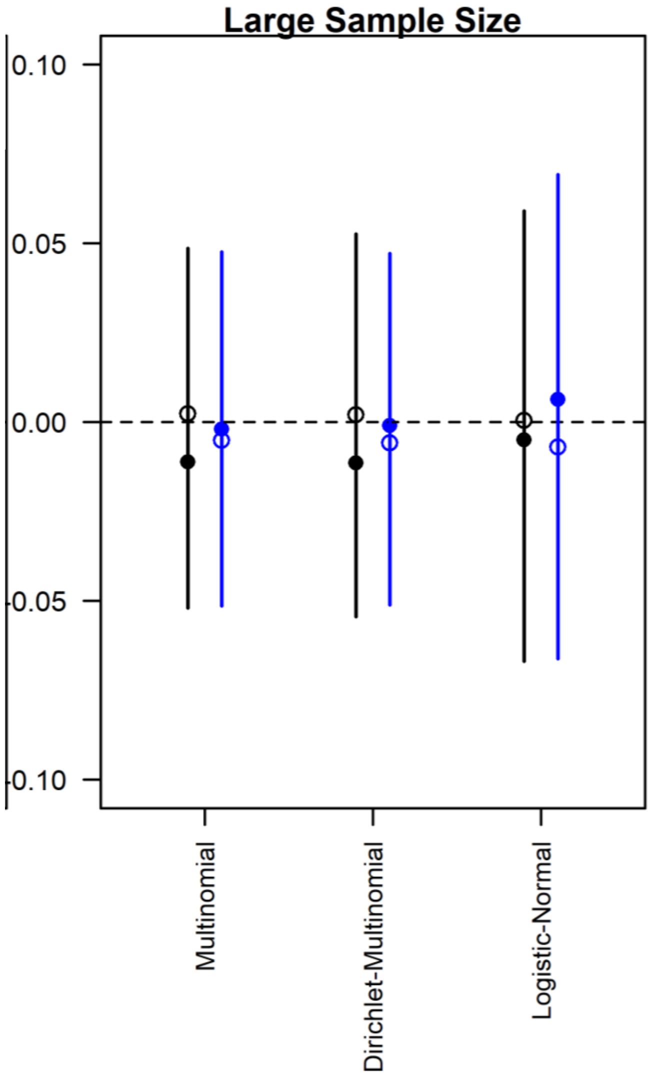
Results: Max PE

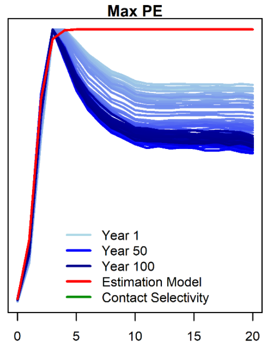


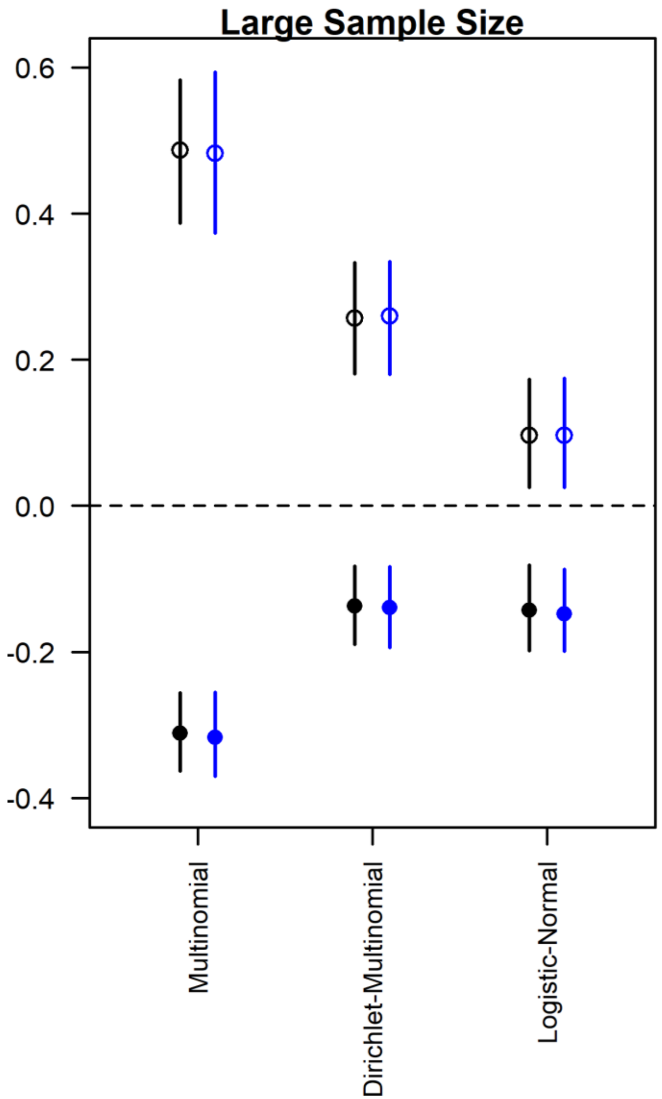


The Logistic-normal as a Diagnostic?





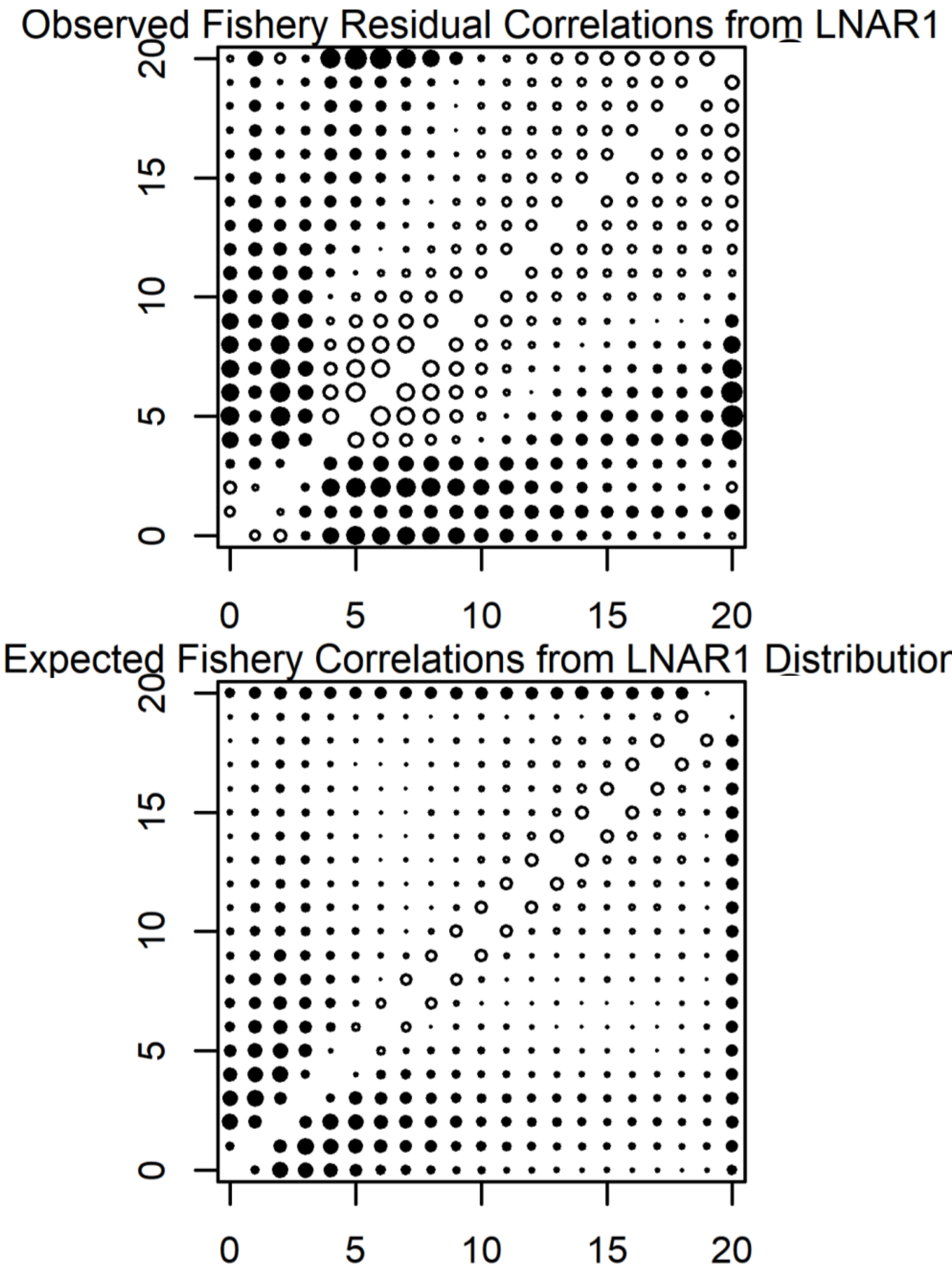




The Logistic-normal as a Diagnostic?

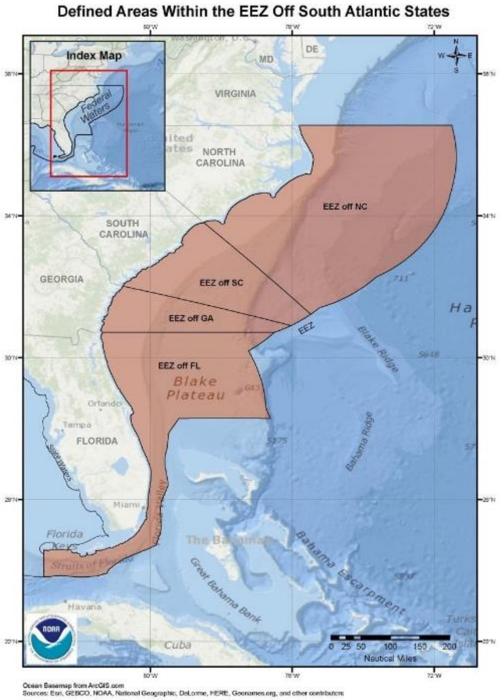
The Logistic-normal, through its ability to specify a flexible variance-covariance matrix (incorporating positive correlation structure), is better able to account for increased variability and correlations in residuals as a function of model misspecification than is the Dirichlet-multinomial.

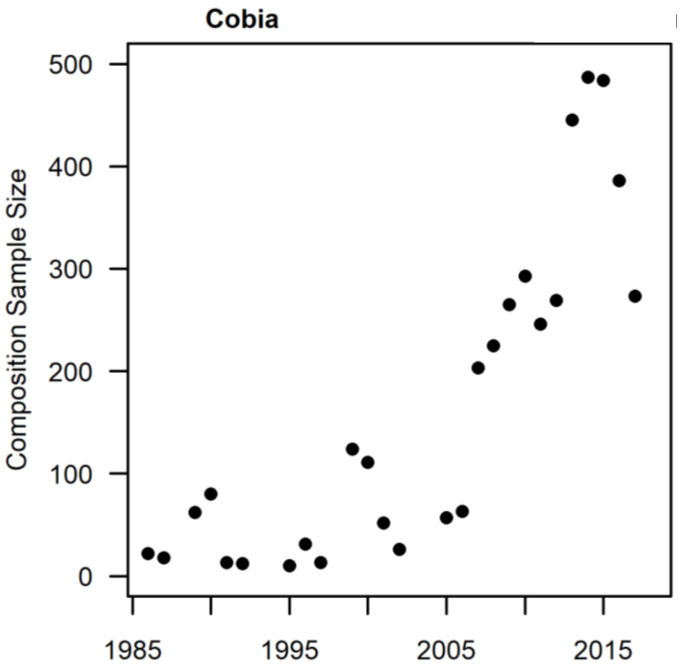
- Conditional on an adequate sample size, differences between a model fit with the Dirichlet-multinomial and the Logistic-normal suggest misspecification in the model



Empirical Follow Up

Cobia





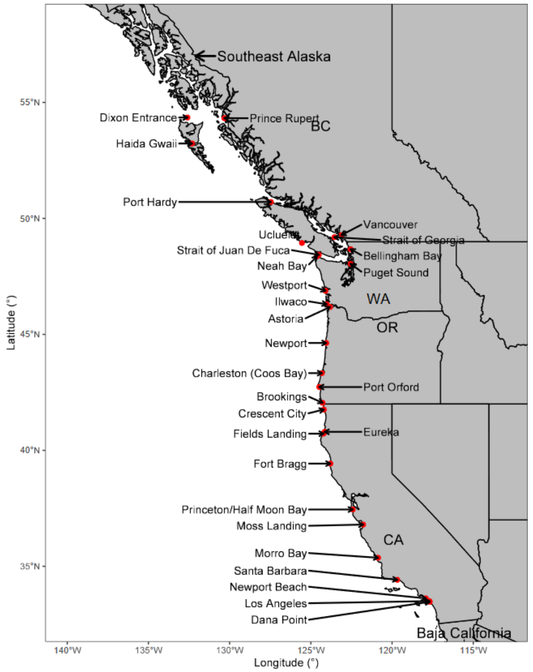
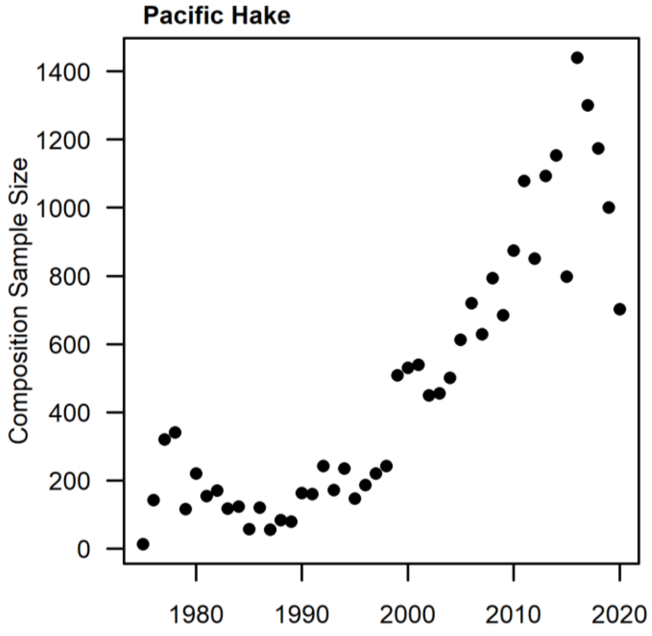


Figure 1. Overview map of the area in the Northeast Pacific Ocean occupied by Pacific Hake. Common areas referred to in this document are shown.

Pacific Hake



Methods

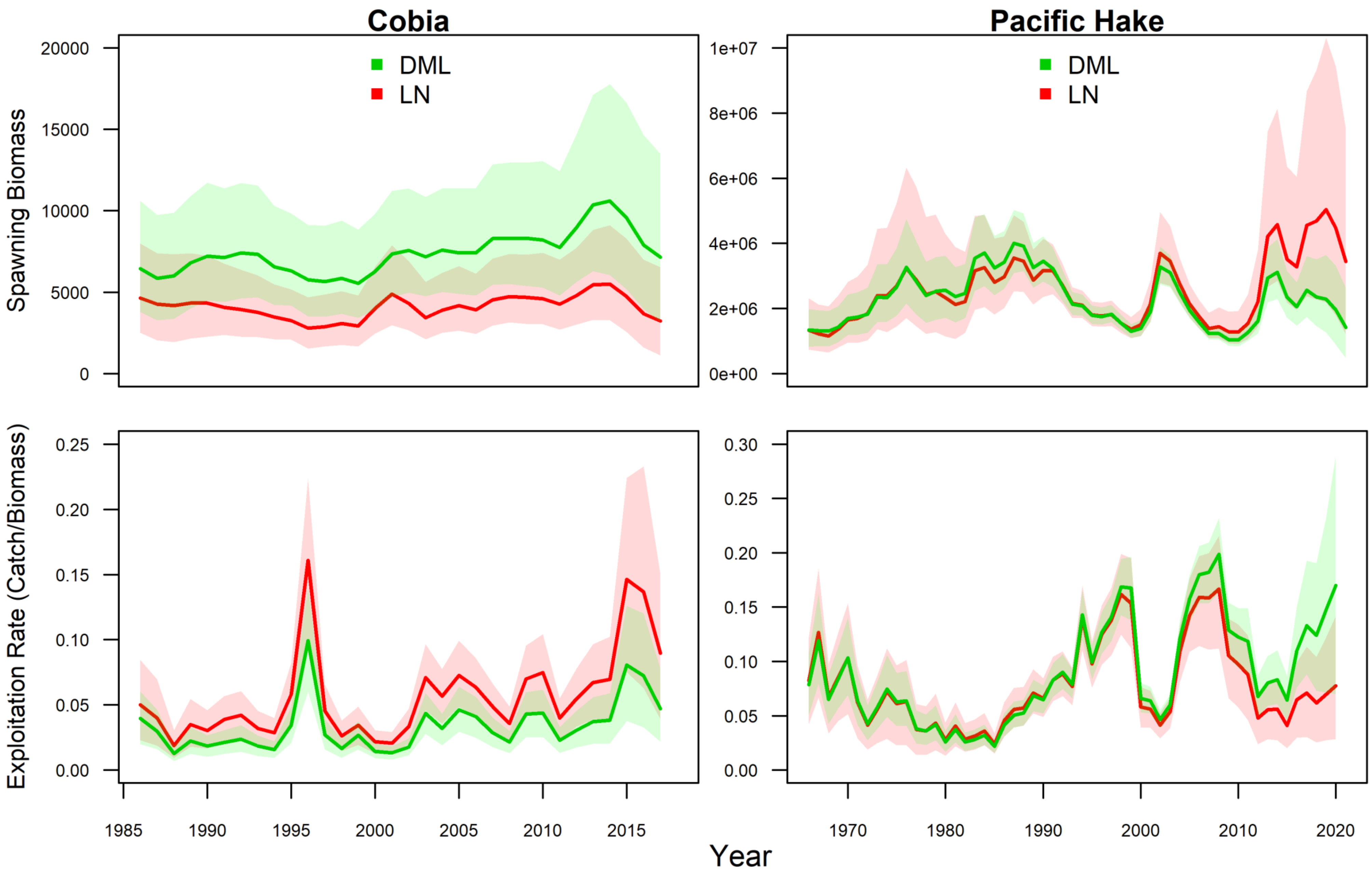
Cobia (1986-2017)
- Recreational Harvest
- Recreational Age Composition
- Commercial Harvest
- Recreational Headboat Index
- Pooled commercial length composition

Pacific Hake (1966-2020)
- Fishery Harvest
- Fishery Age Composition
- Survey Index data
- Survey Age composition

- Age-structured
- Run in a Bayesian framework

- Diagnostics explored
  - Retrospective Analyses
  - Fit to data
    - Runs tests
    - SDNRs
  - Hindcasting

Results – Assessment Output

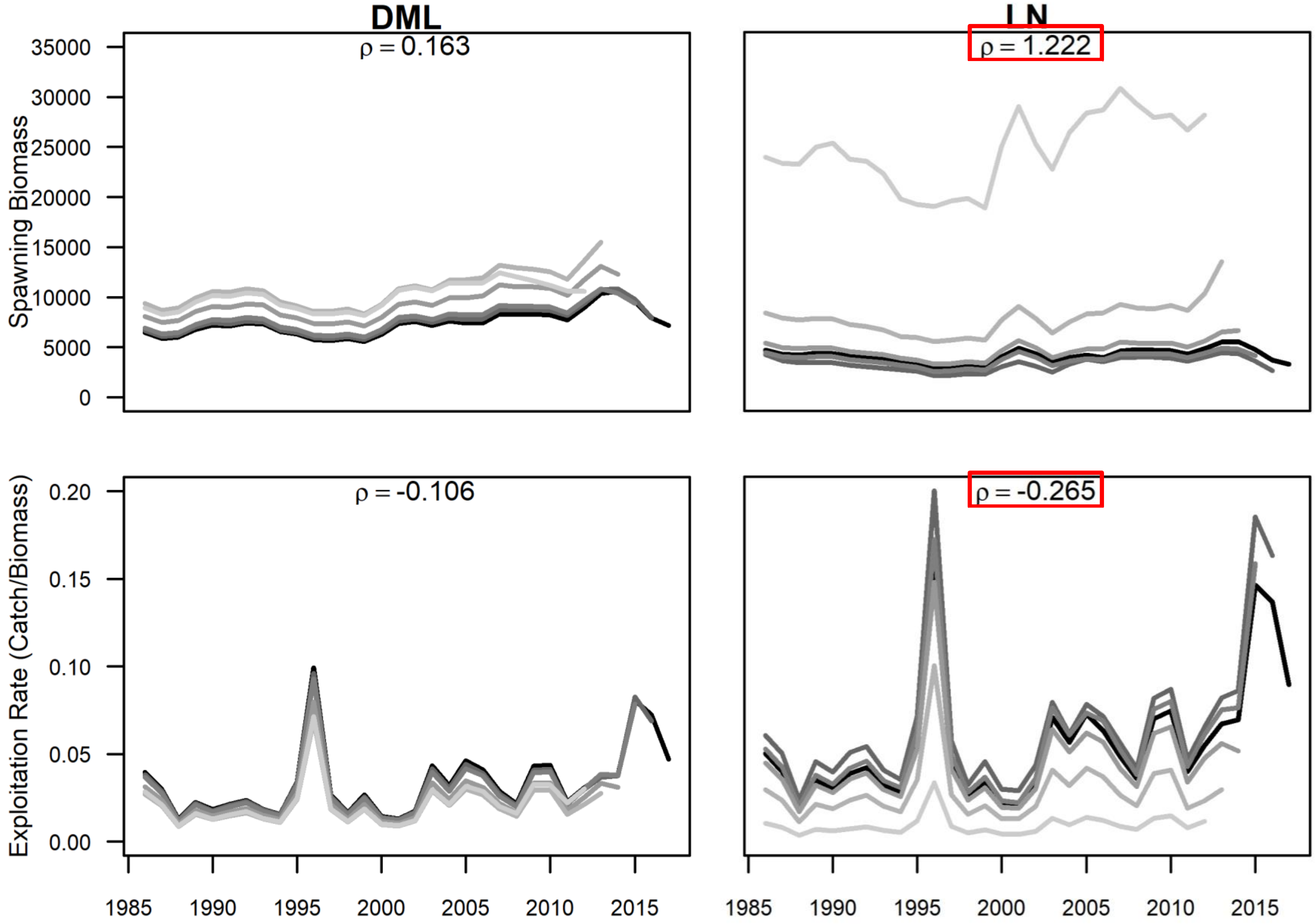


Retrospective Analysis - Cobia

ρ- **Mohn's rho**

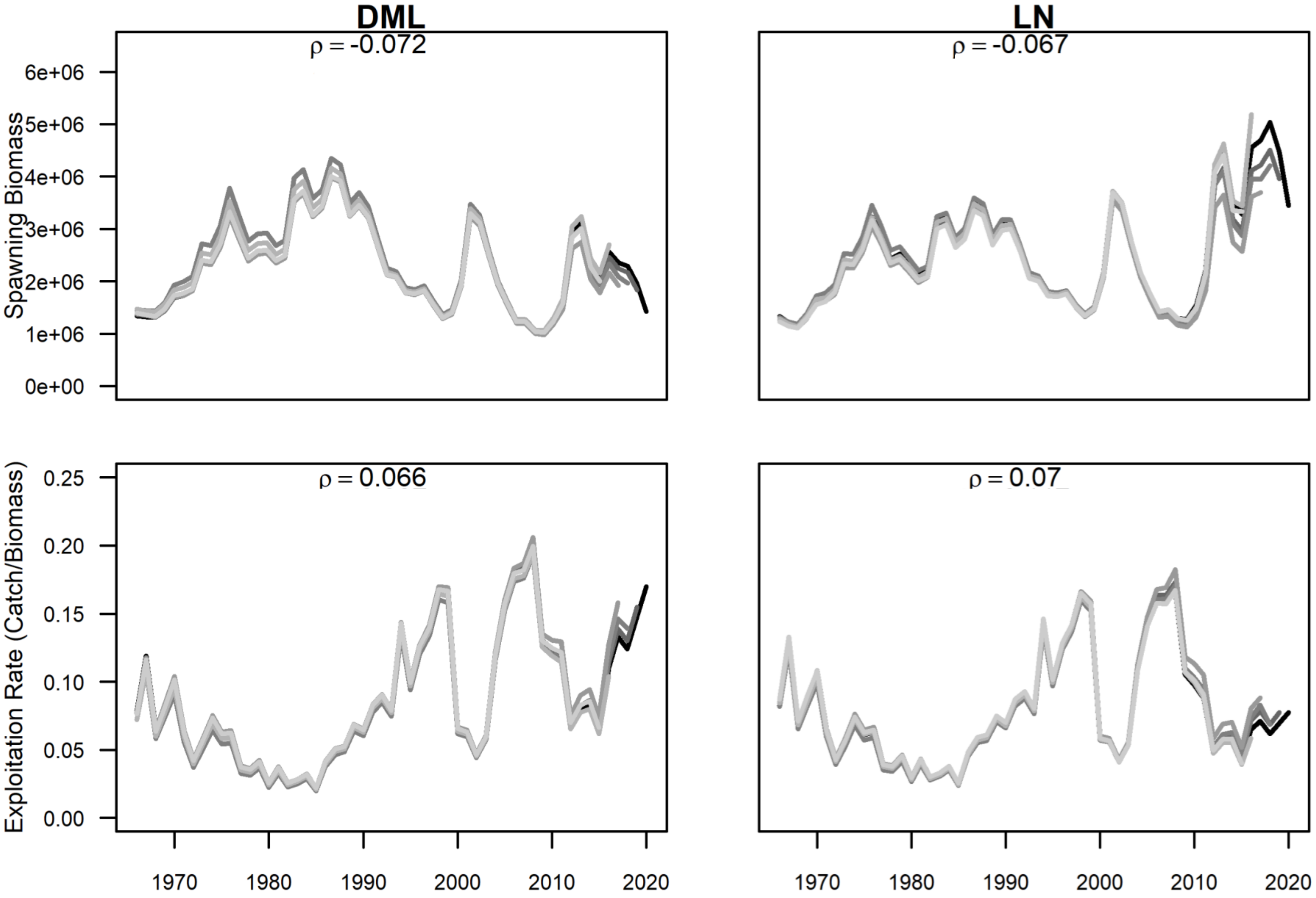
Mean relative divergence from full model

LN outside of "Rule of Thumb" range from Hurtado-Ferro et al., (2015)



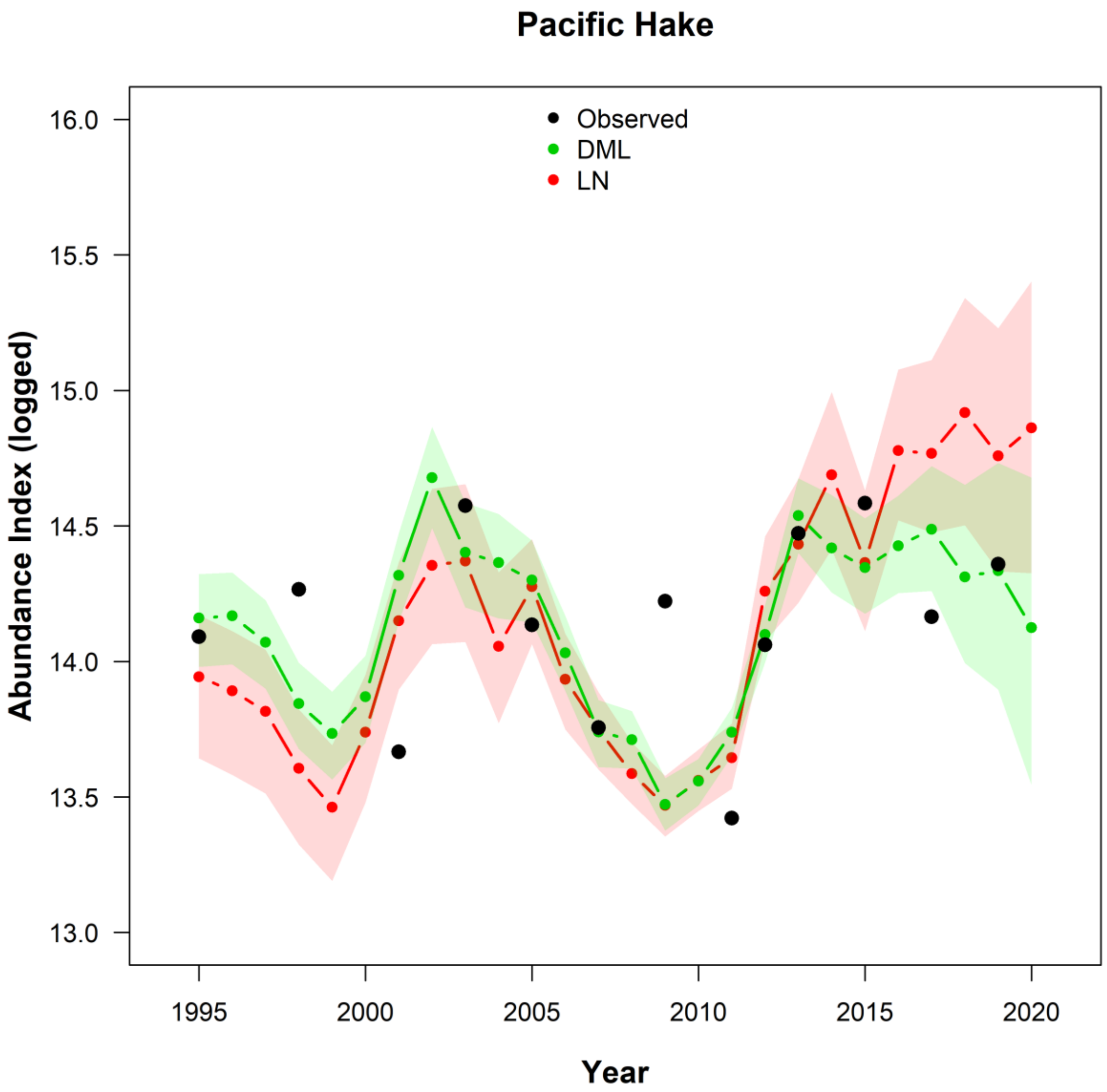
Retrospective Analysis – Pacific Hake

- No retrospective statistics drew a red flag



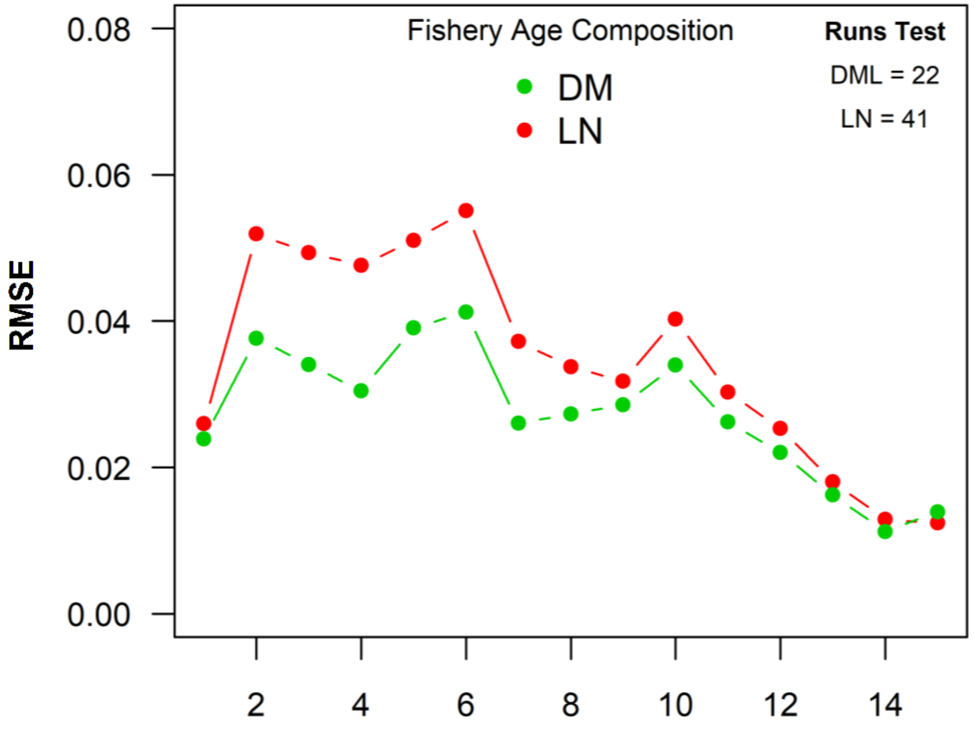
Fit to Index data – Pacific Hake

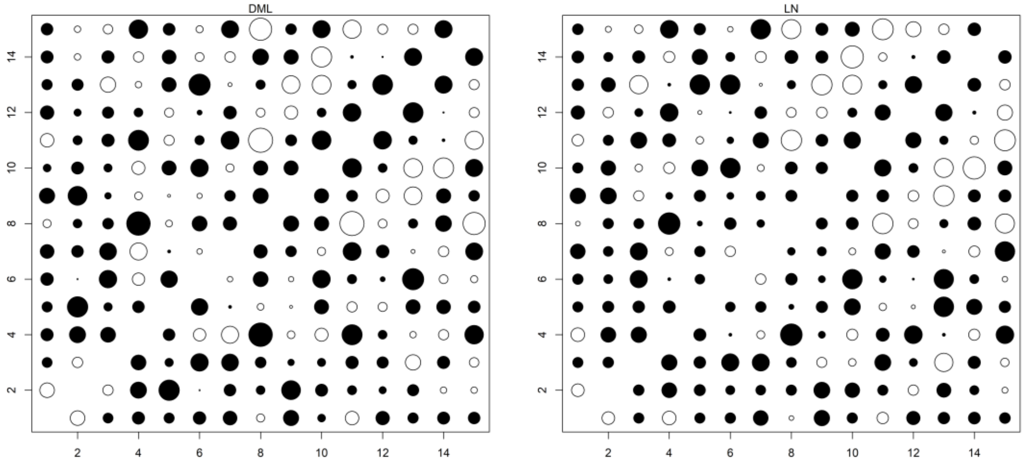
- SDNRs
  - DM = 1.04 (0.65,1.45)
  - LN = 1.03 (0.65,1.42)
- Estimated Additive SD
  - DM = 0.27 (0.14, 0.44)
  - LN = 0.34 (0.16, 0.58)
- Runs test
  - DM = 19% of MCMC iterations failed
  - LN = 4% of MCMC iterations failed



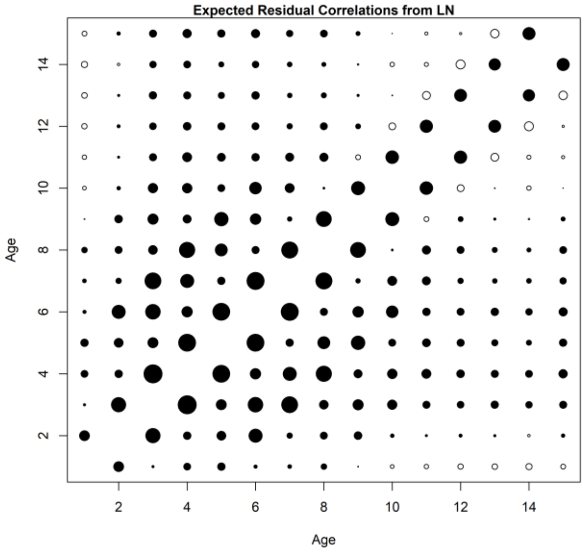
Fit to Composition data – Pacific Hake

- RMSE
  - LN allowing for more residual variance
- Runs test
  - DM 22%
  - LN 41%





Observed Residual Correlations



Expected from LN

Hindcasting – Pacific Hake

Model free Hindcasting

- Fitting model with reduced data and predicting those data.
  - It is suggested that a model which predicts better than the naïve prediction "passes" diagnostic (Carvalho et al., 2021)

Prediction residual

$$MASE = \frac{\frac{1}{h}\sum_{y=T-h}^{T}\left|E_y - O_y\right|}{\frac{1}{h}\sum_{y=T-h}^{T}\left|O_y - O_{y-1}\right|}$$

Naïve prediction

	h	**DM**	**LN**
Hindcast Index	3	0.905	$\boxed{2.024}$
Hindcast Fishery Composition	3	$\boxed{1.08}$	0.86

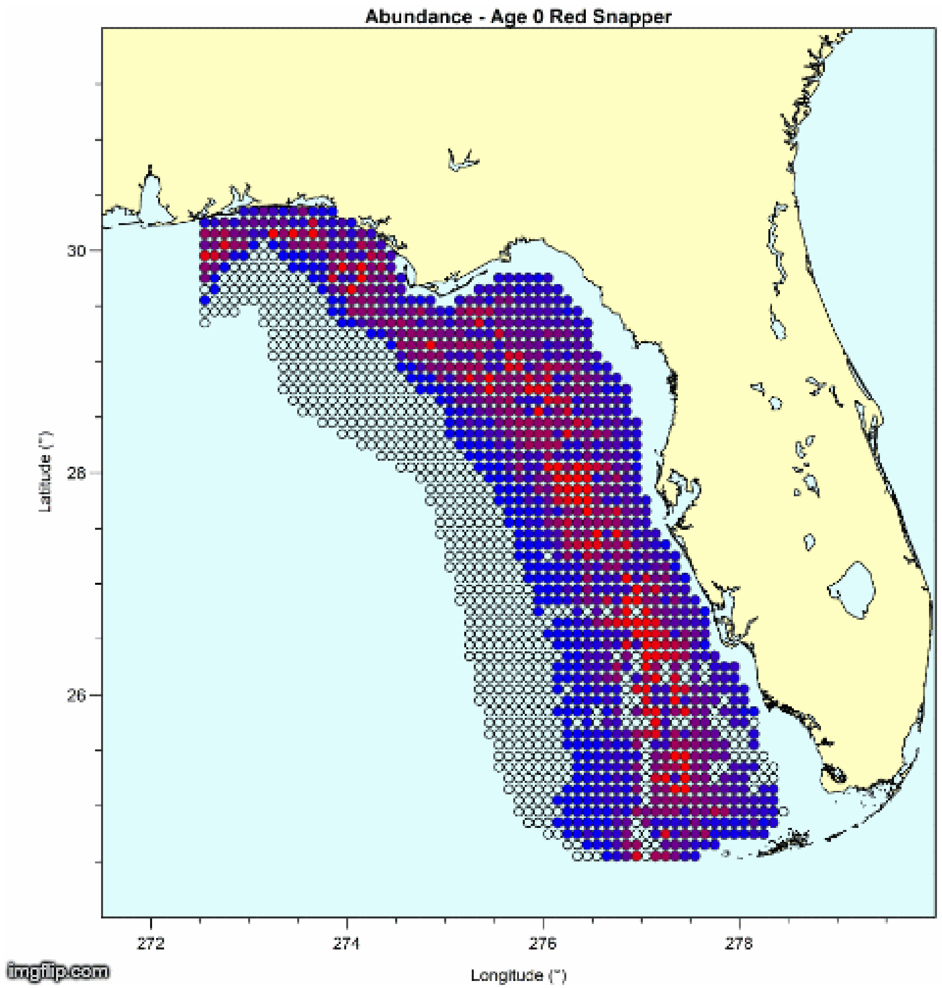
Discussion/Implications

- More evidence that the Logistic-normal seems to break down at small sample sizes for composition data.
- Tough to corroborate LN as a diagnostic tool based on Hake results
  - Accounting for process error in index fit
  - Variability in reliability of different diagnostics
    - “No individual diagnostic was sufficient to ensure high power of detecting all forms of misspecification tested. However, applying multiple diagnostic tests did increase the power to detect misspecification.” – Carvalho et al., (2017)

Diagnostic	**DM**	**LN**
Convergence	✓	✓
Retro	✓	✓
Fit to Data	~	~
Index Hindcast	✓	✗
Comp Hindcast	✗	✓

Cautions

- This is new…
  - Simulation study was based on one fish life history, one exploitation history, one type of misspecification…, was quite data rich
- LN performance seems to be highly conditional on sample size
  - How to relate to sim study?
- How much of a difference constitutes diagnostic pass/fail?
- Zero-data



Acknowledgements

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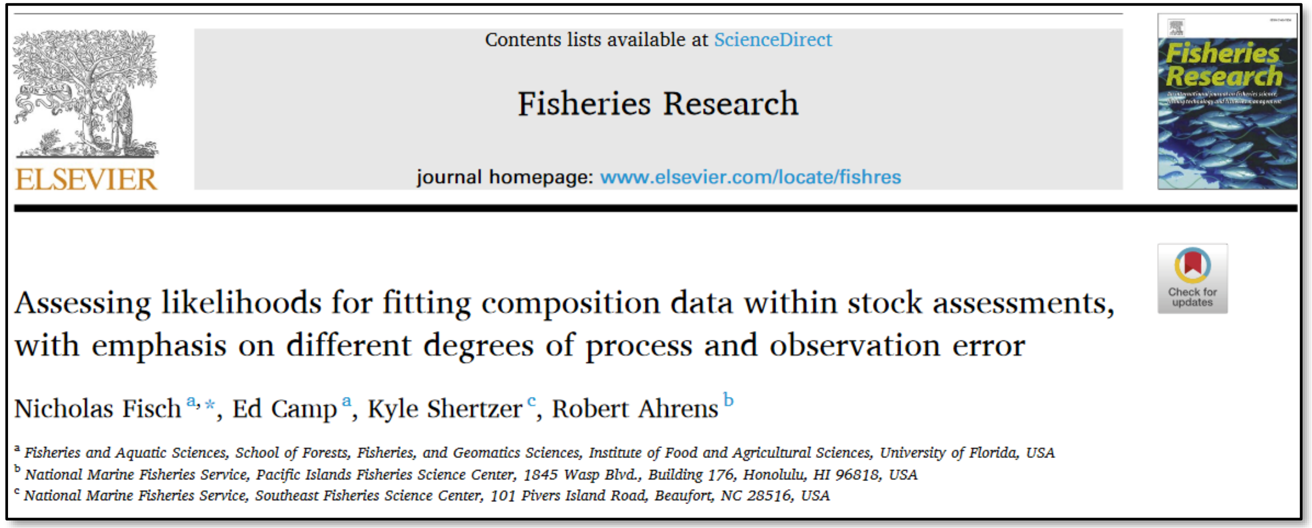

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Assessing likelihoods for fitting composition data within stock assessments, with emphasis on different degrees of process and observation error

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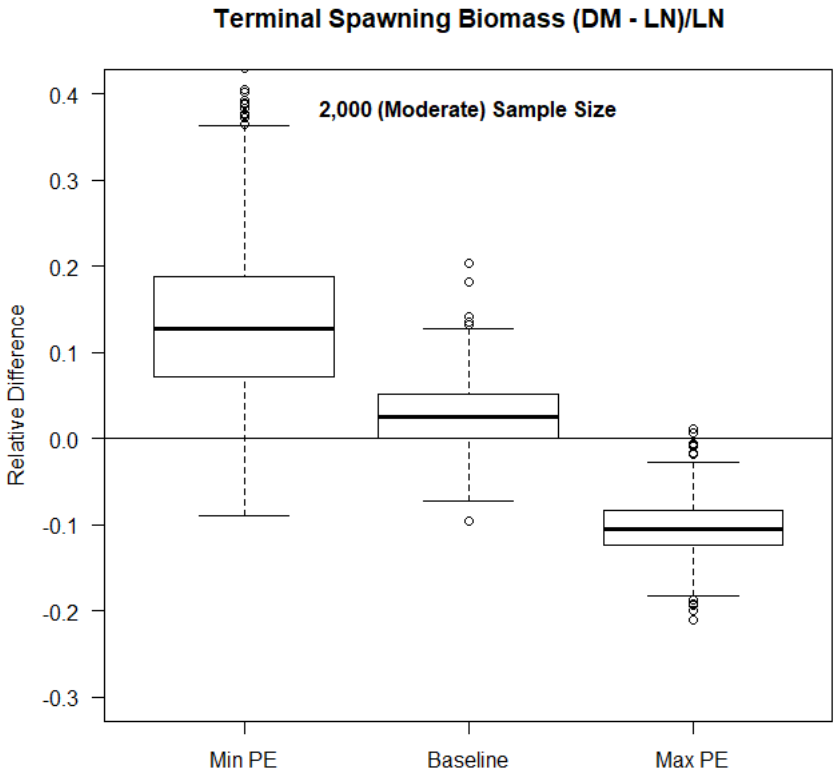
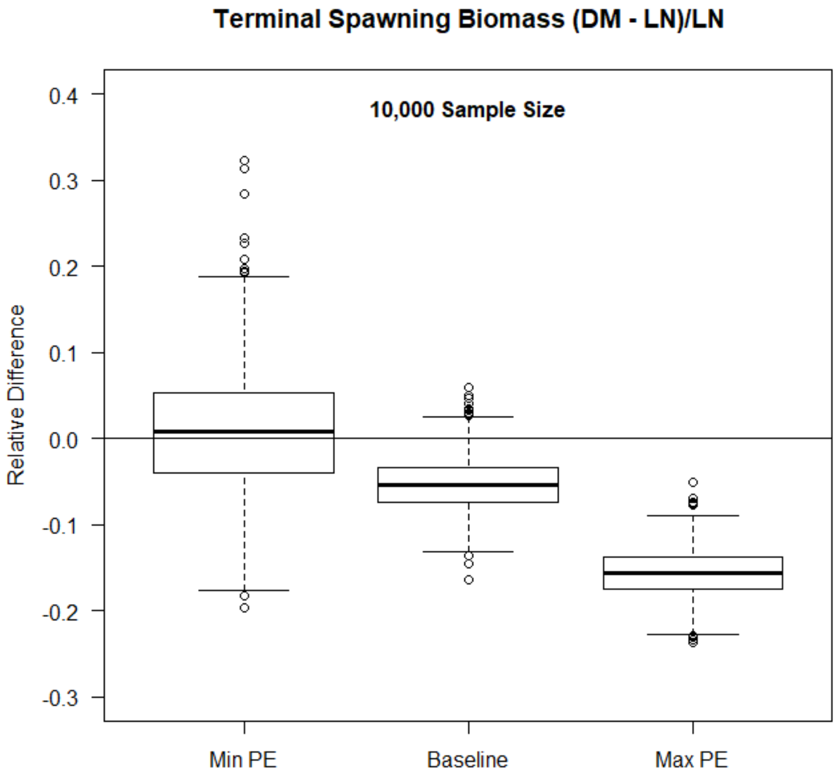
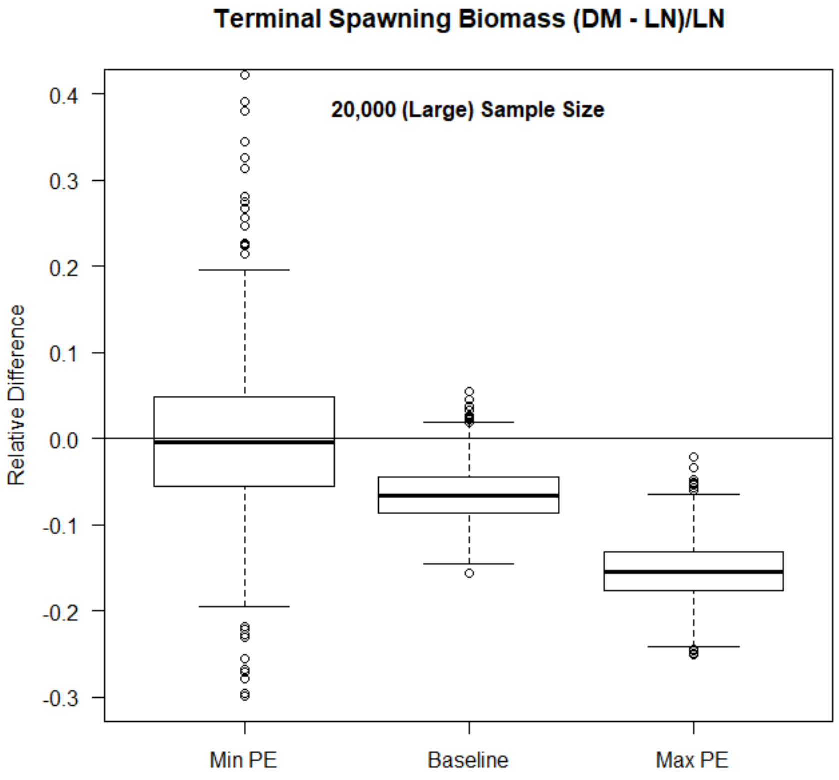
Relative Difference







Model Misspecification / Treatment of Error

- All of our models are approximations of reality and thus are guaranteed to be misspecified…

Hulson et al., (2012)

- Measurement error
- Observation error
- Process error
- Model-specification error

Where is this misspecification?

- Types of misspecification

Francis (2014; 2017)

- Sampling error
- Process error
  - Process variation
  - Model misspecification

CAPAM Workshop Intro

- Sampling error
- Process variation
- Model structure uncertainty
- Parameter estimation uncertainty

Maunder and Piner (2015)

- Sampling error
- Observation model misspecification
- System dynamics misspecification