From theory to application: diffusion approximations for Population Viability Analysis

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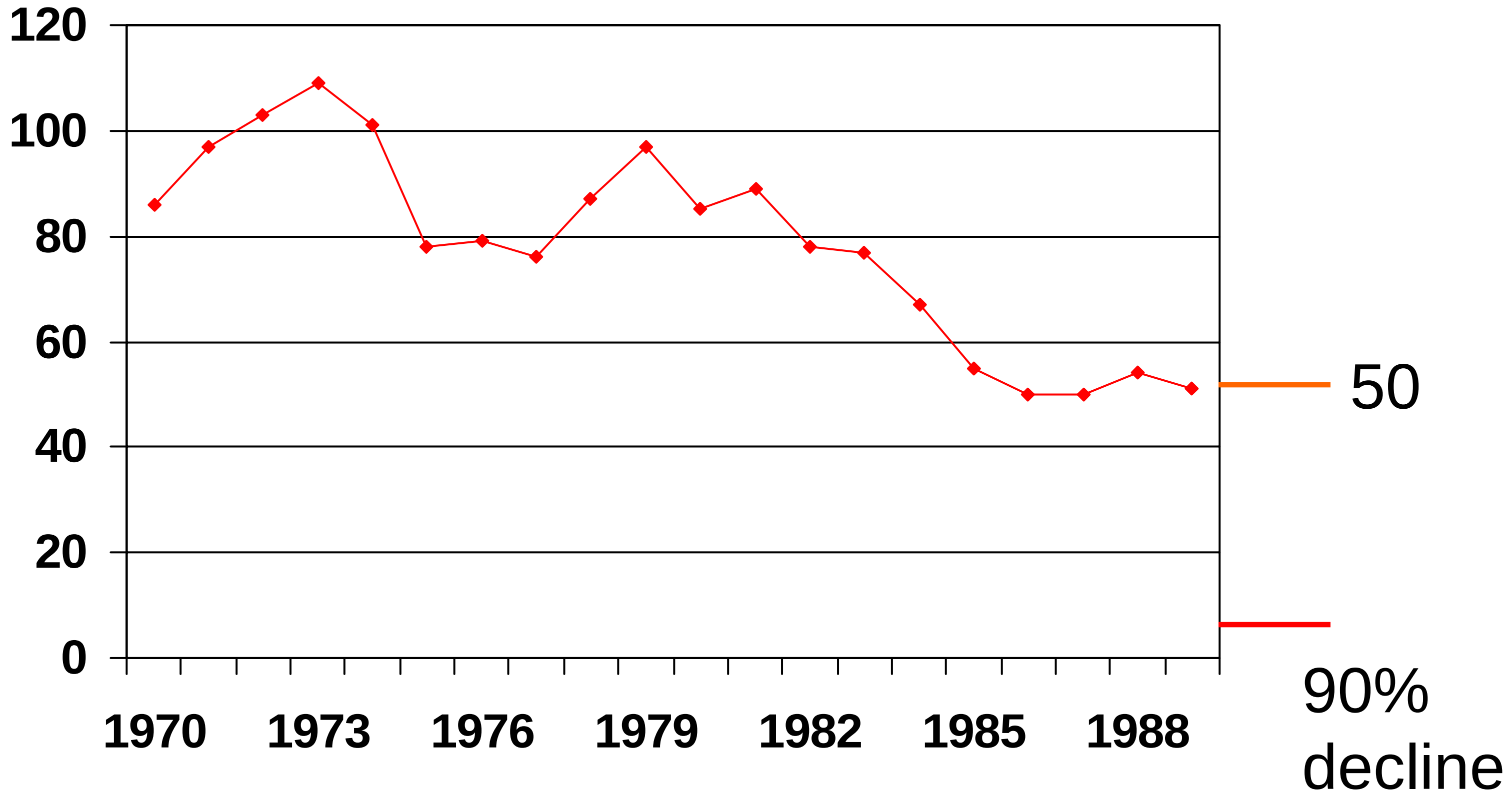
Quasi-extinction risk



Using diffusion approximations for estimating quasi-extinction risks

- Some of the problems with count data on species of conservation concern and how these problems affect DA PVA, especially parameterization
- Cross-validation of DA PVA using real data

- Salmon:
  - Leslie matrix model of Snake R. spr/sum chinook
  - Has density dependence
  - Has environmental autocorrelation
- Petrel:
  - Leslie matrix model of the Hawaiian Dark-rumped Petrel (Simons 1984);
  - Long-lived; census is of mature breeders
  - environmental autocorrelation
- Sea Turtle:
  - Leslie matrix model of the Loggerhead Sea Turtle (Crowder et al. 1994);
  - Long-lived; census is of eggs which is highly variable
  - environmental autocorrelation

A really simple DA model can predict quasi-extinction in age-structured models

$$\log(N_{t+1}) = \log(N_t) + \varepsilon_{t,p}$$

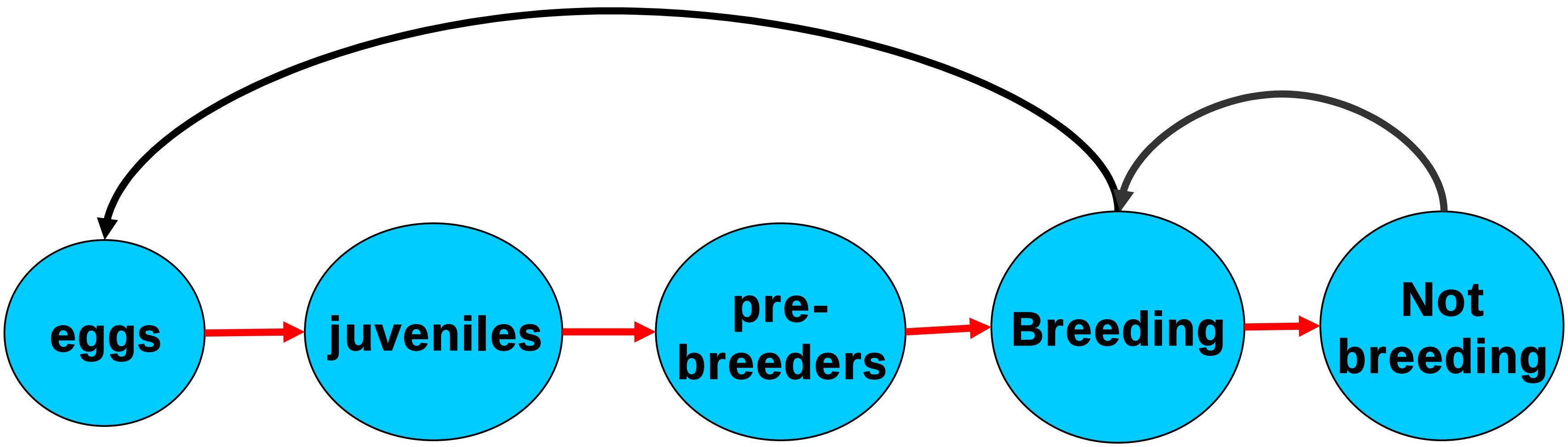
$$\varepsilon_{t,p} \sim Normal(\mu, \sigma_p^2)$$

Long-term population growth

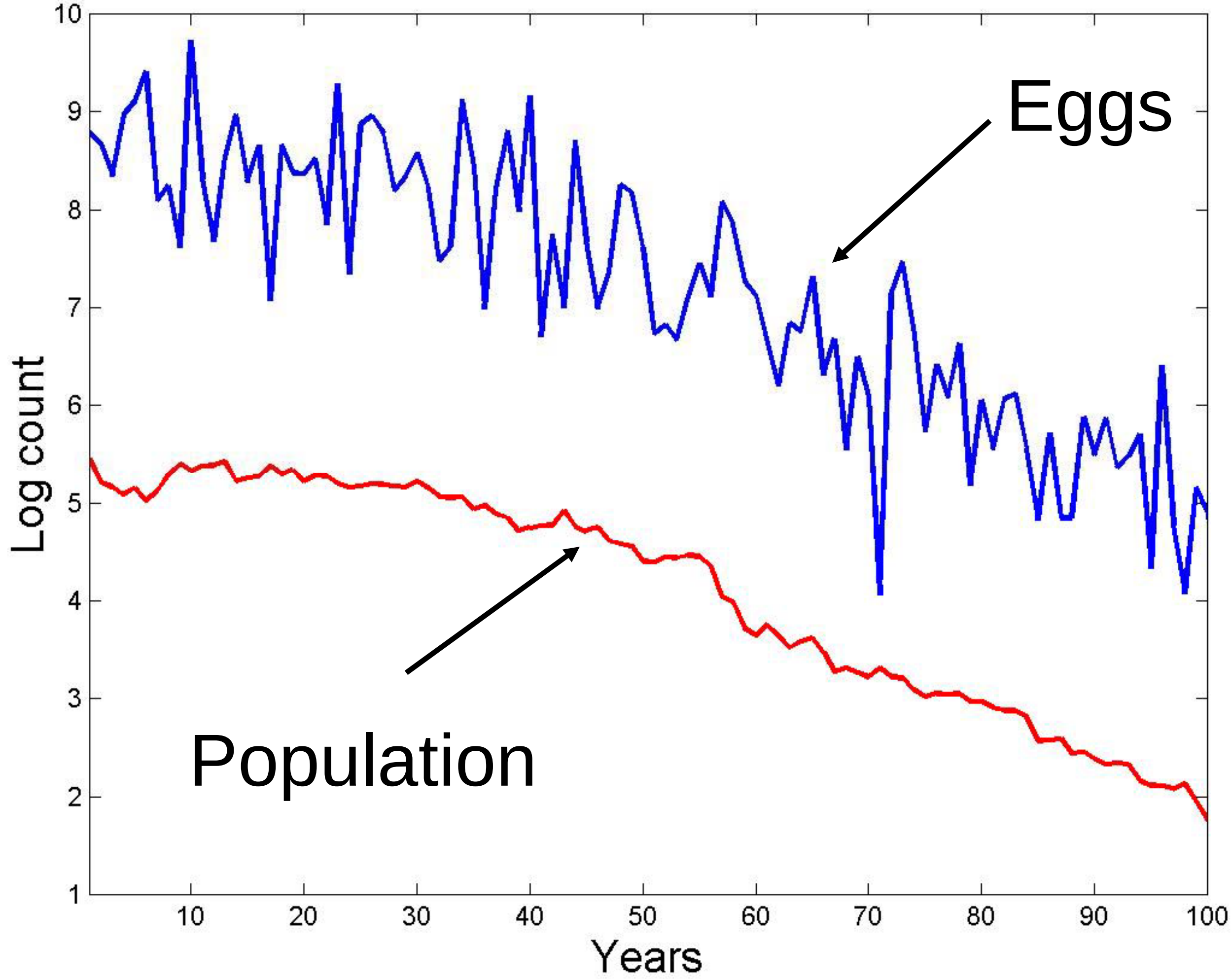
Process Error

$$\log(N_{t+\tau}) - \log(N_t) \sim Normal(\mu\tau, \sigma_p^2\tau)$$

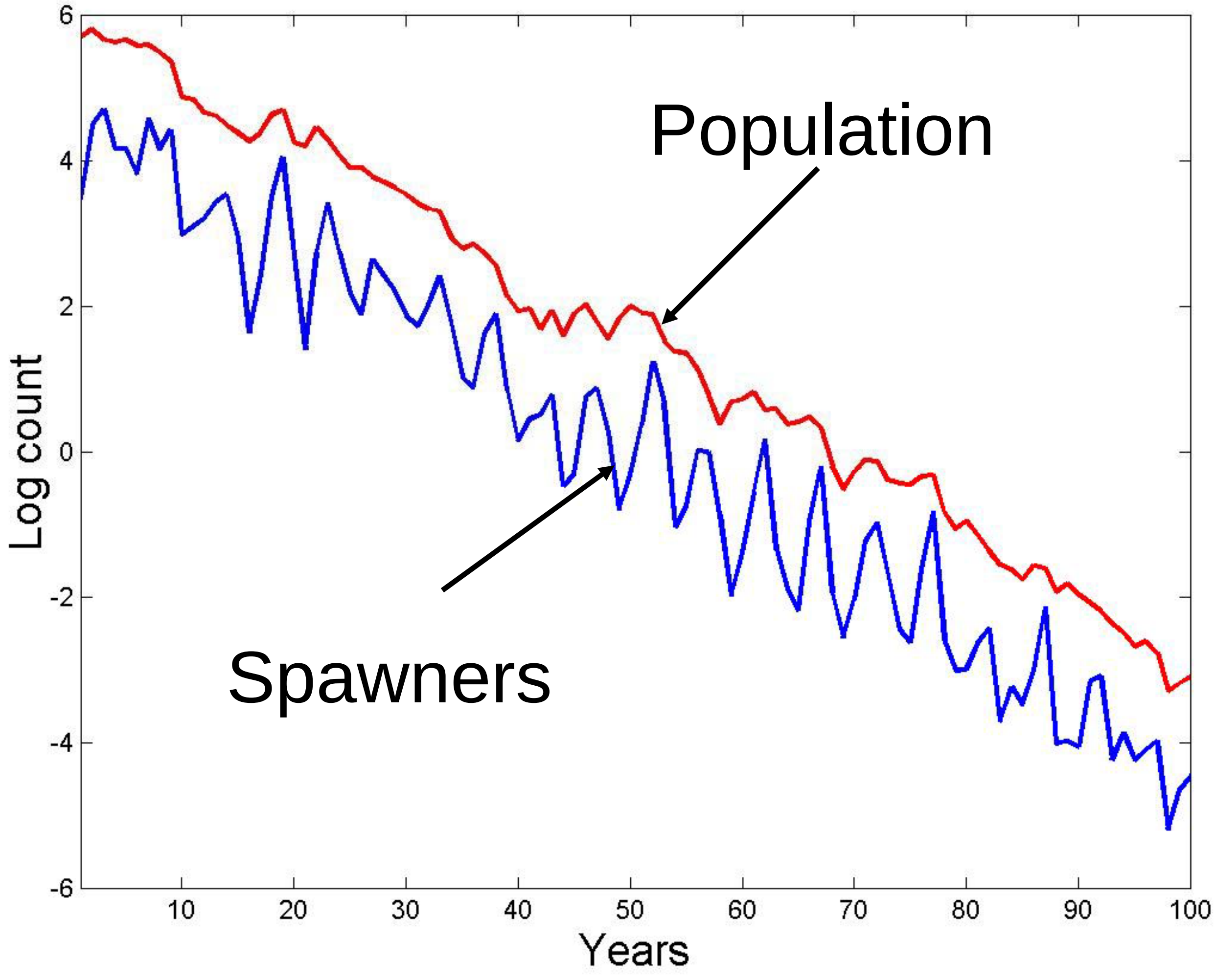
Monitoring data is often stage specific



Example with sea turtles



Example with salmon



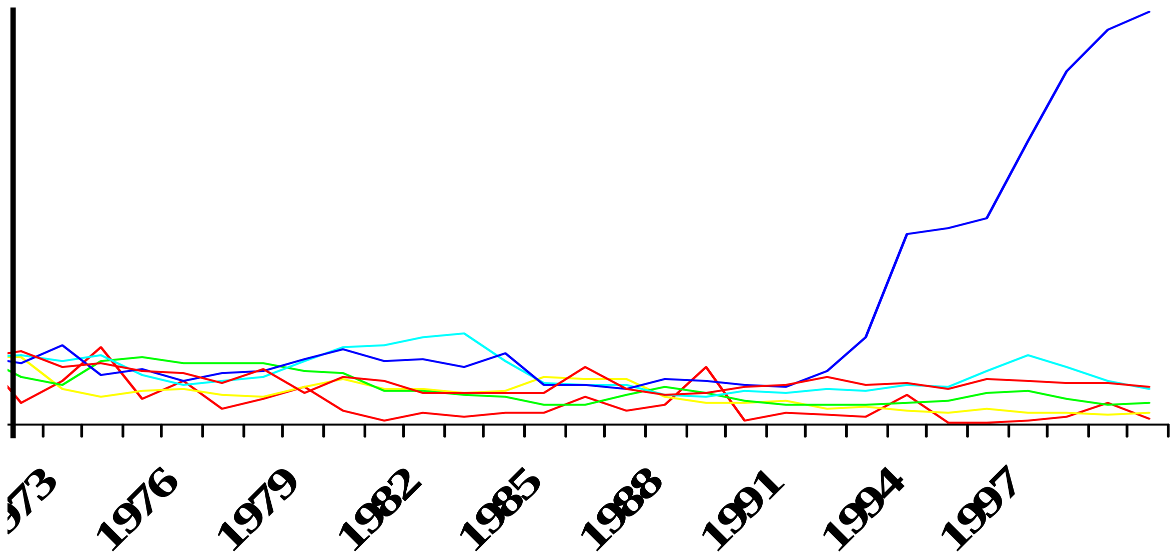
Good news: a state-space model does a good job of modeling age-specific counts:

$$\log(N_{t+1}) = \log(N_t) + \varepsilon_{t,p}$$

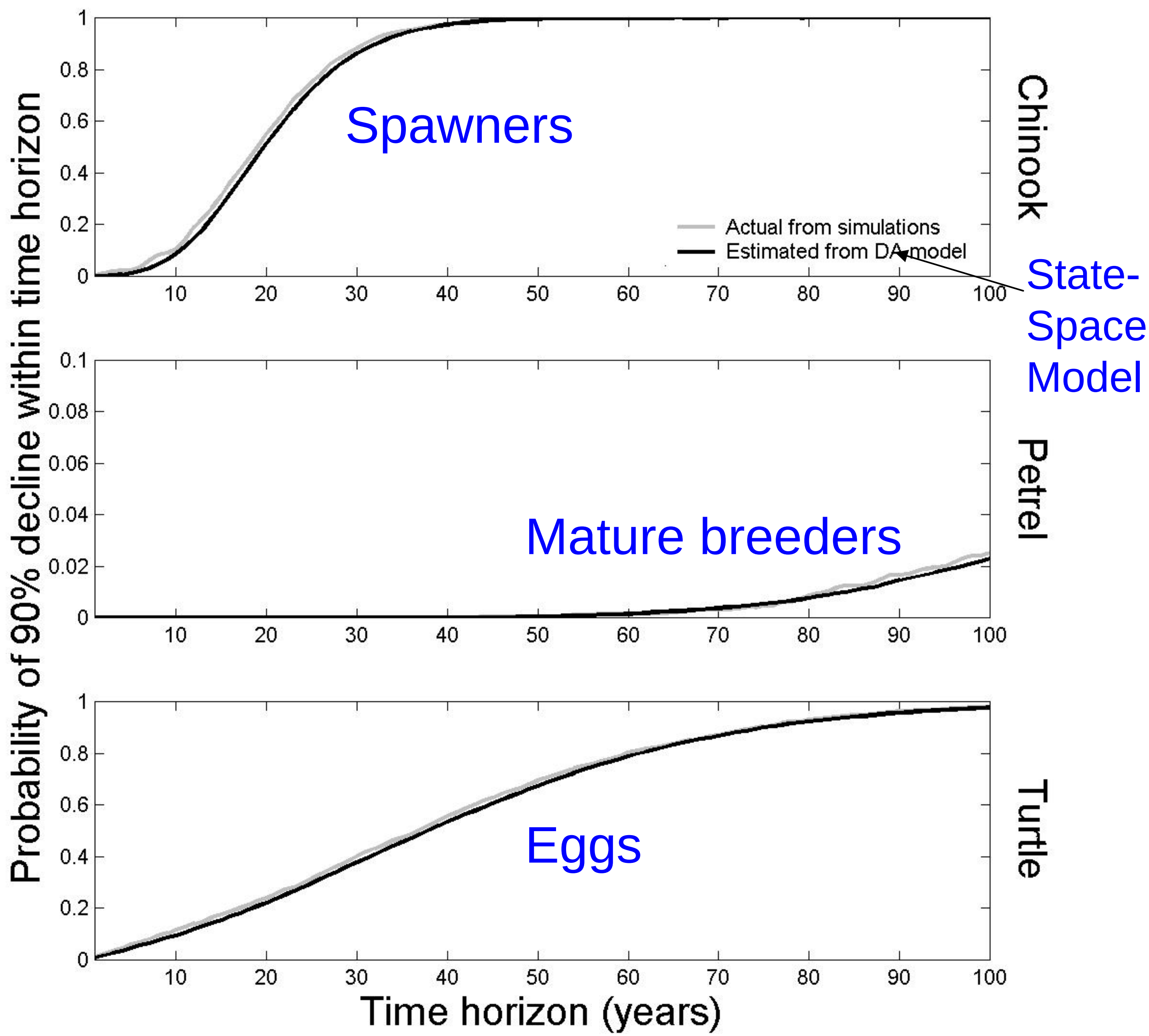
$$\log(a_{t+1}) = \log(N_{t+1}) + \varepsilon_{t+1,np}$$

$$\varepsilon_{t,p} \sim Normal(\mu, \sigma_p^2)$$

$$\varepsilon_{t,np} \sim f(\beta, \sigma_a^2)$$



1973
1976
1979
1982
1985
1988
1991
1994
1997



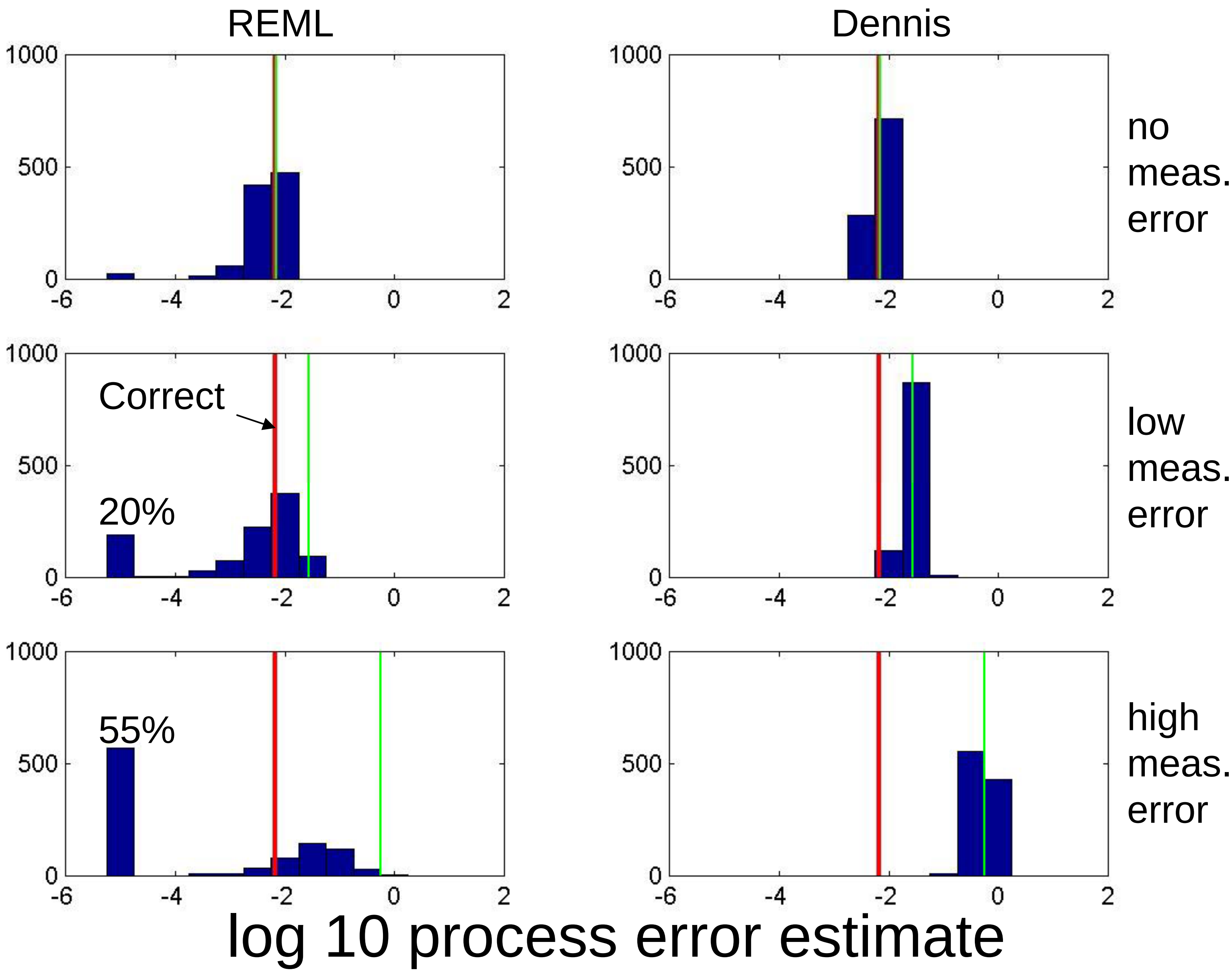
Probability of 90% decline within time horizon
Spawners
Chinook
Actual from simulations
Estimated from DA model
State-Space Model
Mature breeders
Petrel
Eggs
Turtle
Time horizon (years)

Bad news: this high non-process error makes parameterization difficult

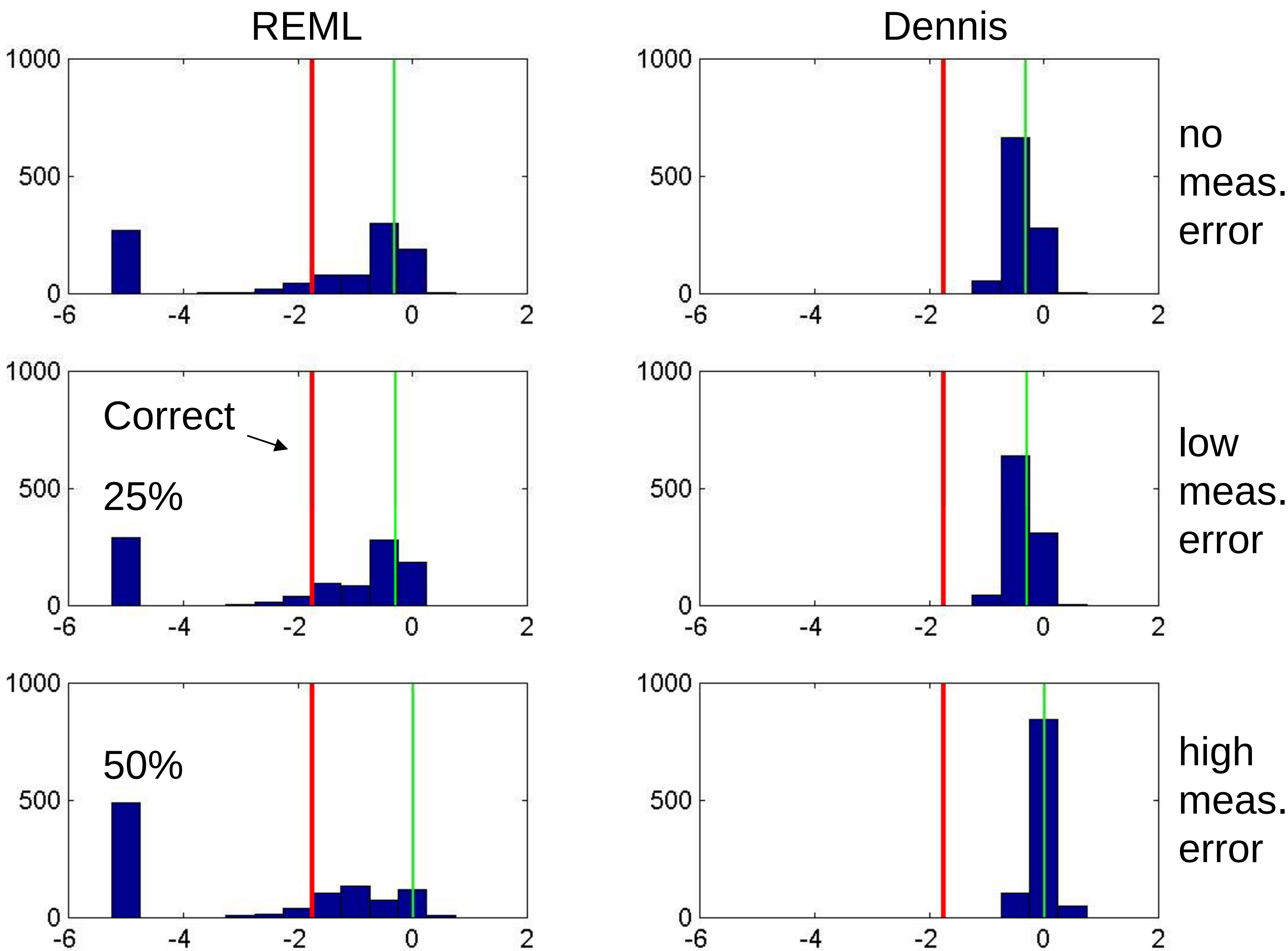
Estimation of σ^2 (process error).

- "REML": Restricted ML estimation (Staples et al. 2004)
- Regression estimating the increase in variance in log $N_{t+\tau}/N_t$ with τ (Holmes 2001)
- Kalman filter (Lindley 2003)

Petrel: pretty good…

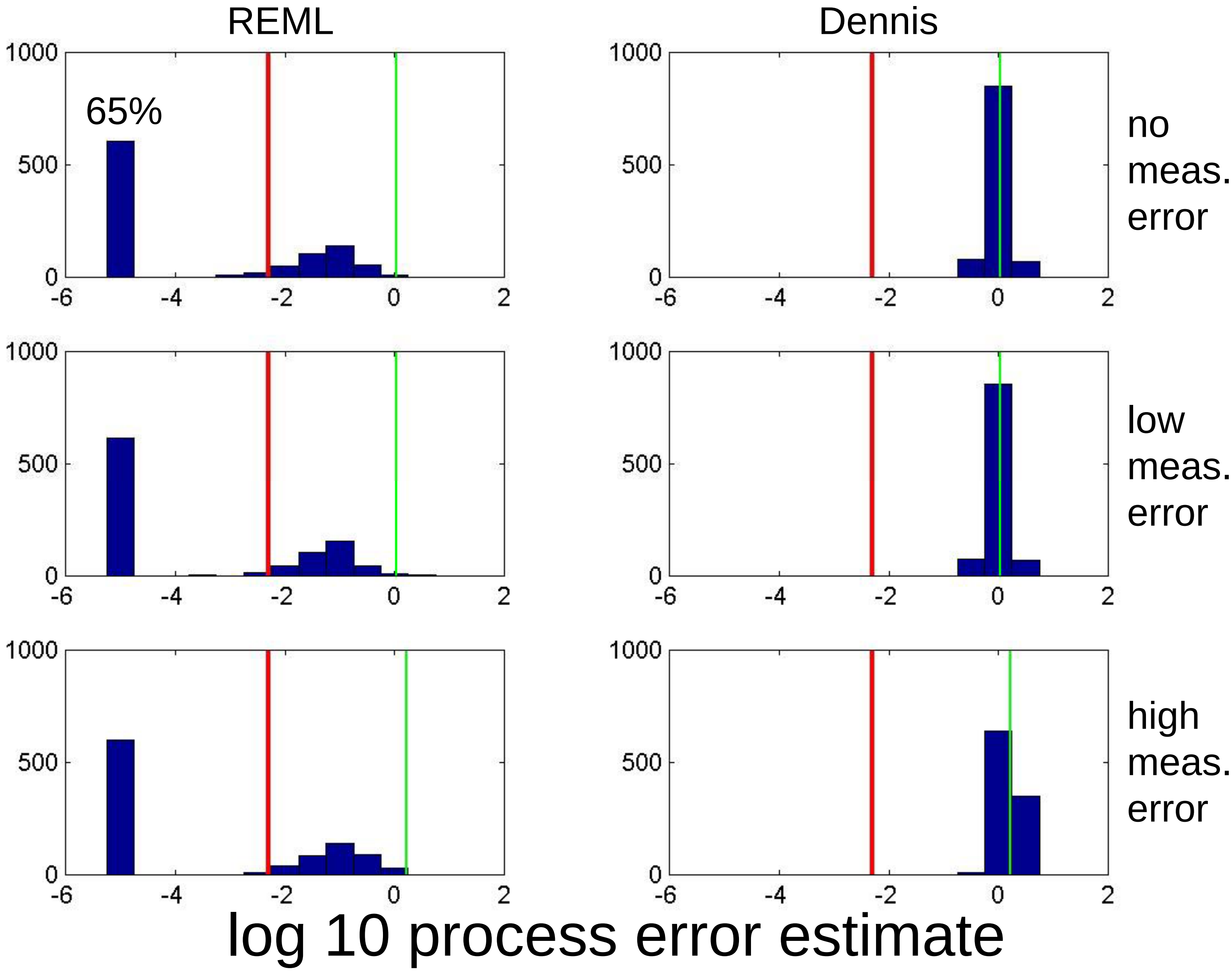


Salmon: struggling…



log 10 process error estimate

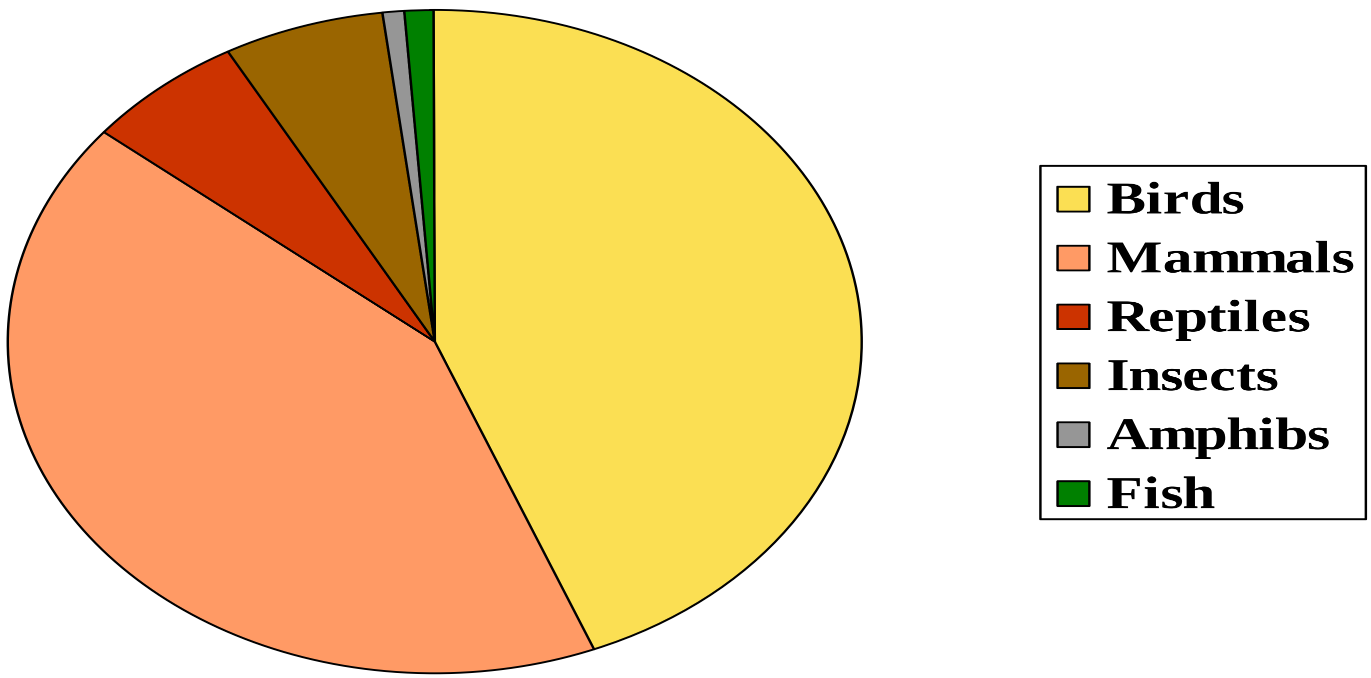
Turtle: more struggling…



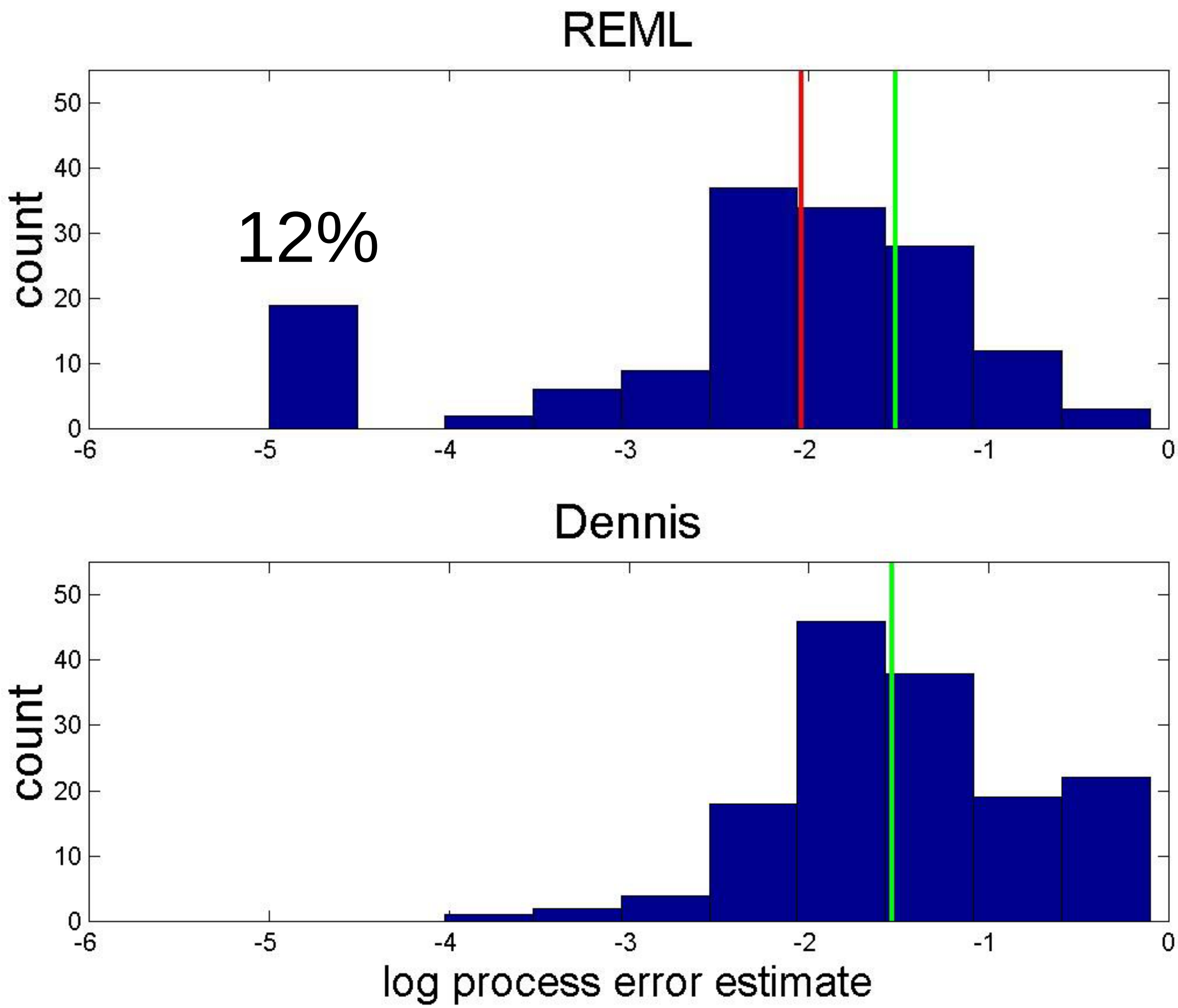
Estimating parameters might be challenging for some species

- What does real data tell us about the performance of these methods? Are most data “petrel-like” or “sea turtle-like”?

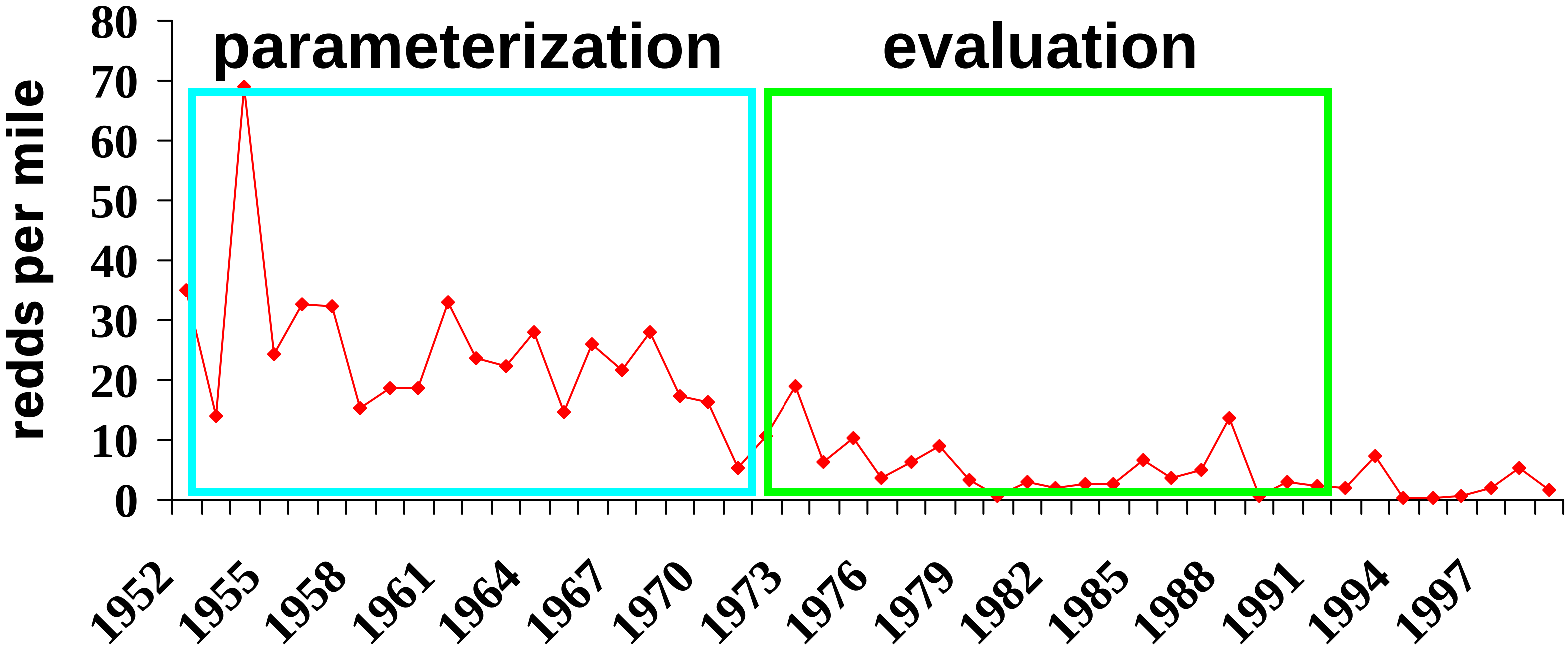
117 Time series 20-50 yrs long
72 are listed species

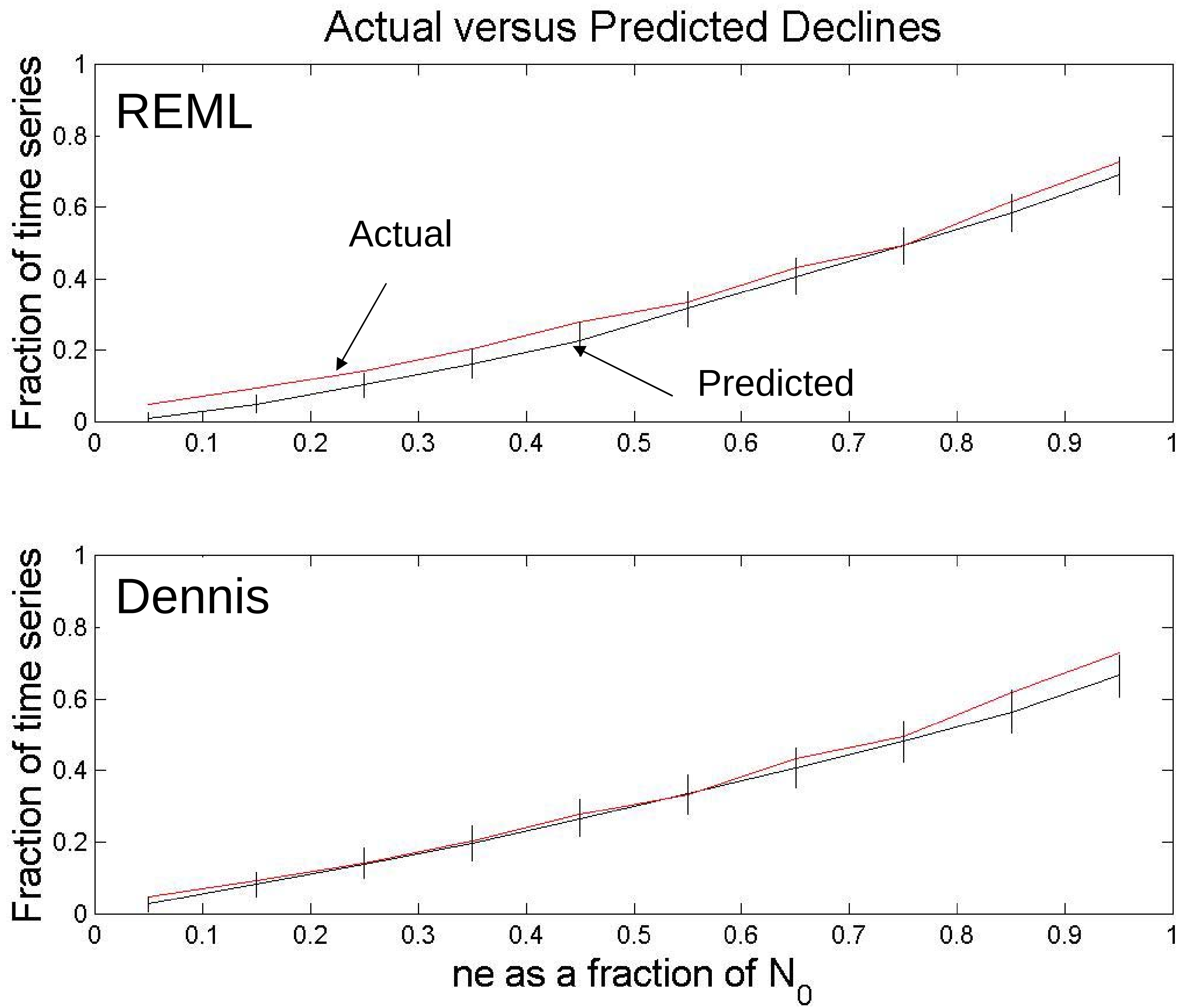


Distribution of process error estimates



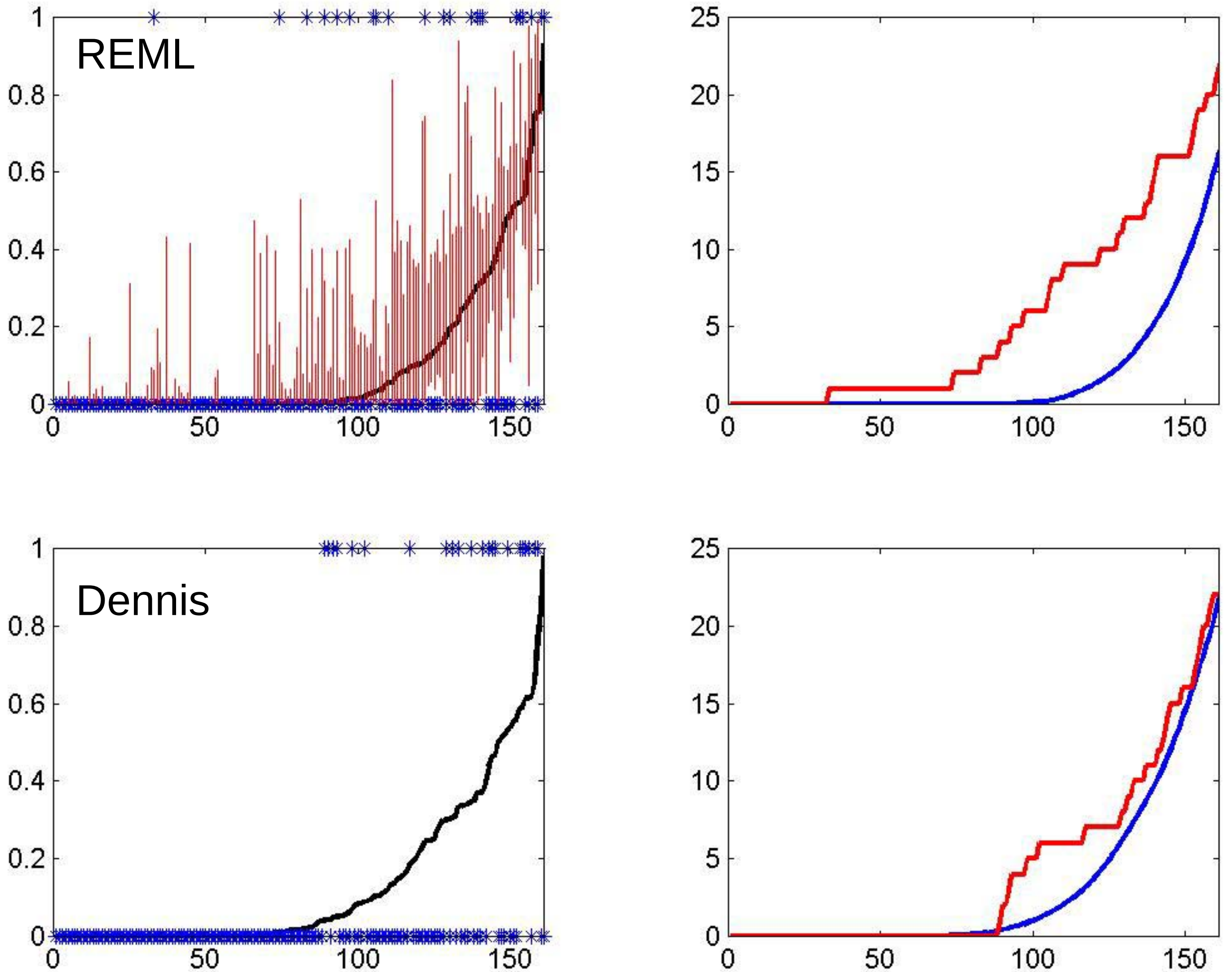
Cross-validation




Actual versus Predicted Declines
REML
Actual
Predicted
Dennis
Fraction of time series
Fraction of time series
ne as a fraction of N0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.2
0.4
0.6
0.8
1

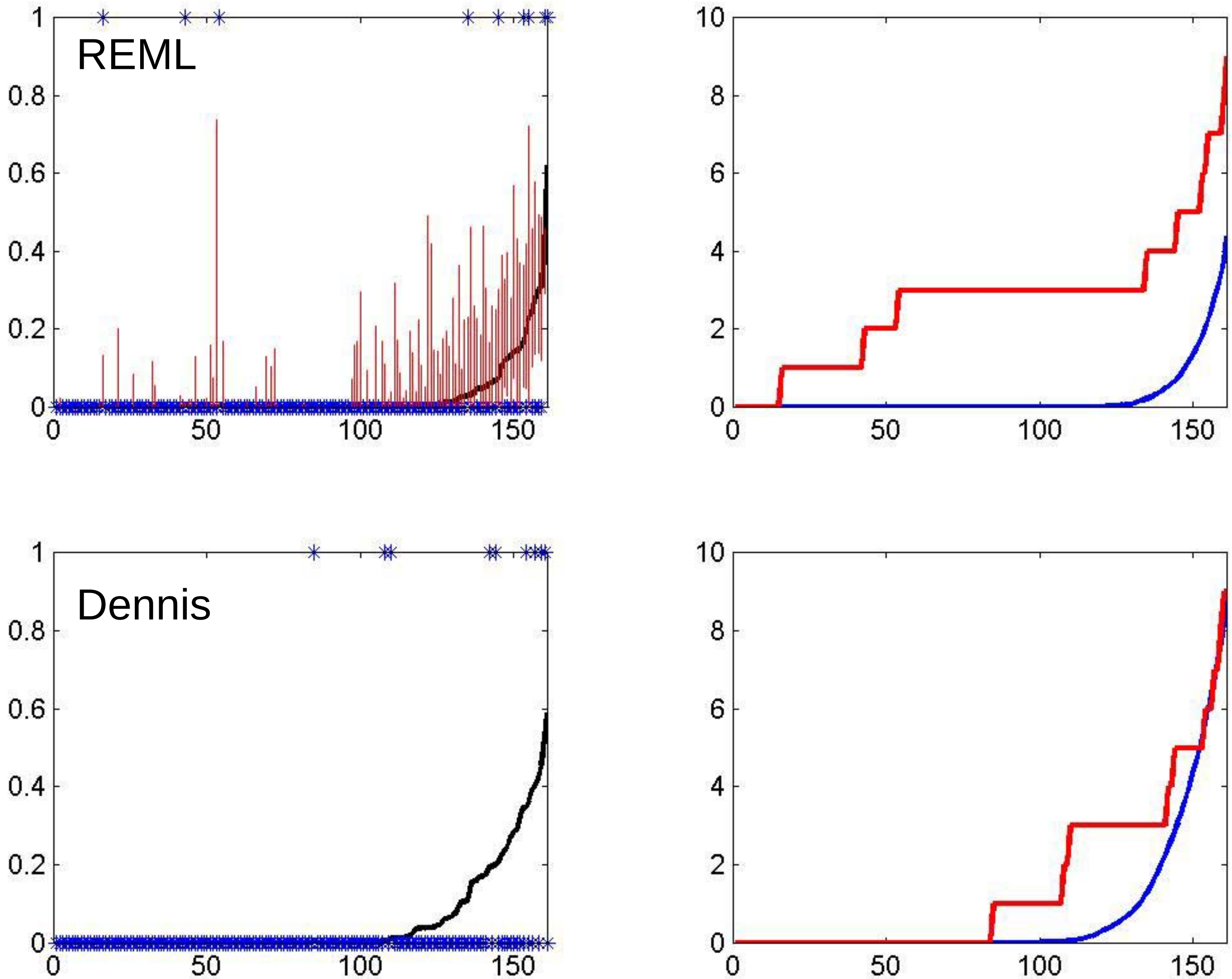
Estimated 75% decline risk vs actual 75% decline

Predicted accumulated 75% declines versus actual



Estimated 90% decline risk vs actual 90% decline

Predicted accumulated 90% declines versus actual



In conclusion….

- Separation of process error and non-process error appears challenging for some types of monitoring data
  - Still a lot of improvement to be done
- This problem does not appear pervasive in data on species of conservation concern
- There appears to be a trade-off between precision of estimates versus bias