A statistical approach to PVA validation: an example using diffusion approximation models

Updated with a few comments after talk

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Overview

- Different validation approaches
- Example: a cross-validation study of diffusion approximation PVAs
- Presenting uncertainty.

FOR MORE INFO...

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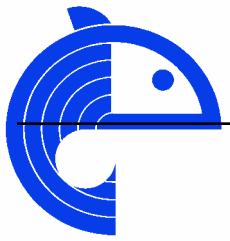
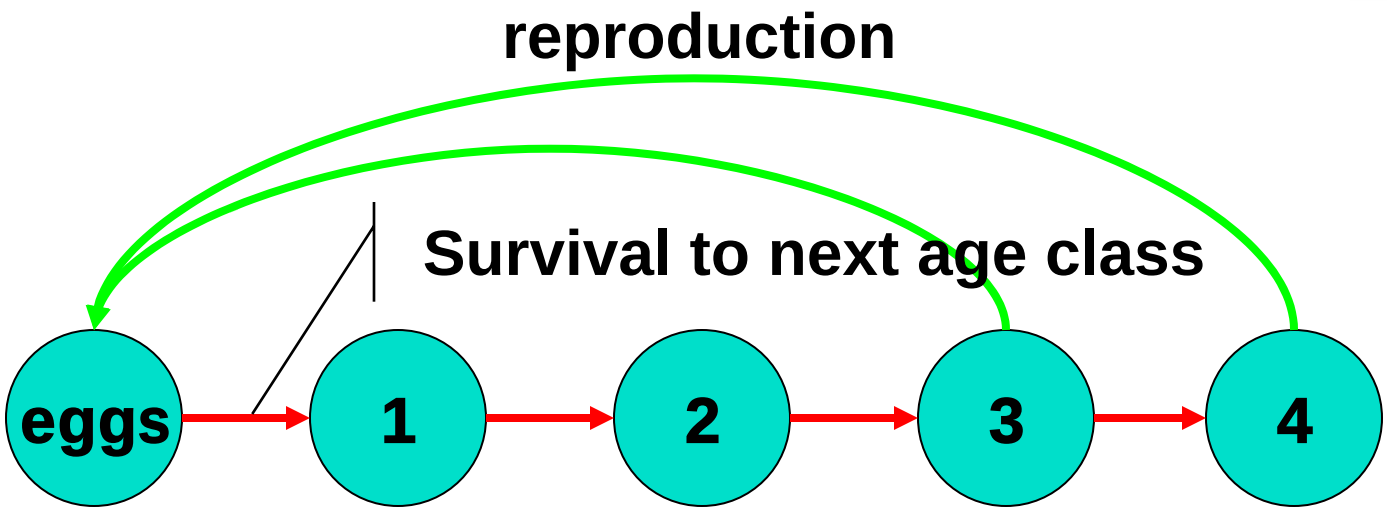
Methods for testing PVAs

from McCarthy et al. 2002. "Testing the Accuracy of PVA" Cons. Bio.

Compare mean or median predictions with observations	Subjective, ignores variability, single trajectories unlikely to be similar to mean
Compare observed vs predicted frequency of events	Only assesses average number or frequency of occurrences within a group, ignores variability
Compare probability distributions of population size or parameters	Assesses both the mean and variability, generally requires transformation of data to a standard variate, lots of data



Diffusion approximation PVA

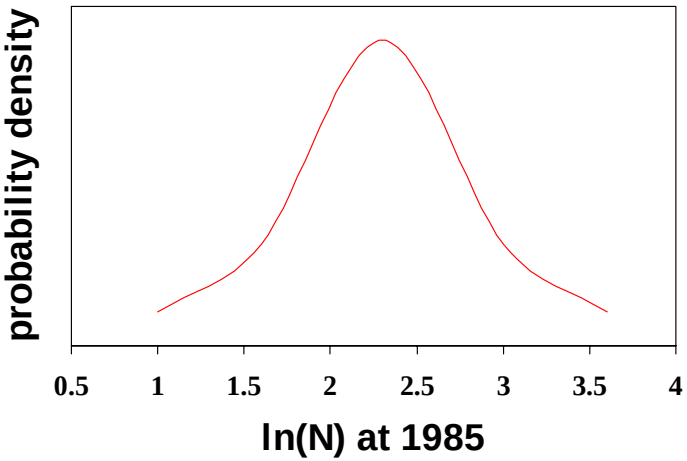


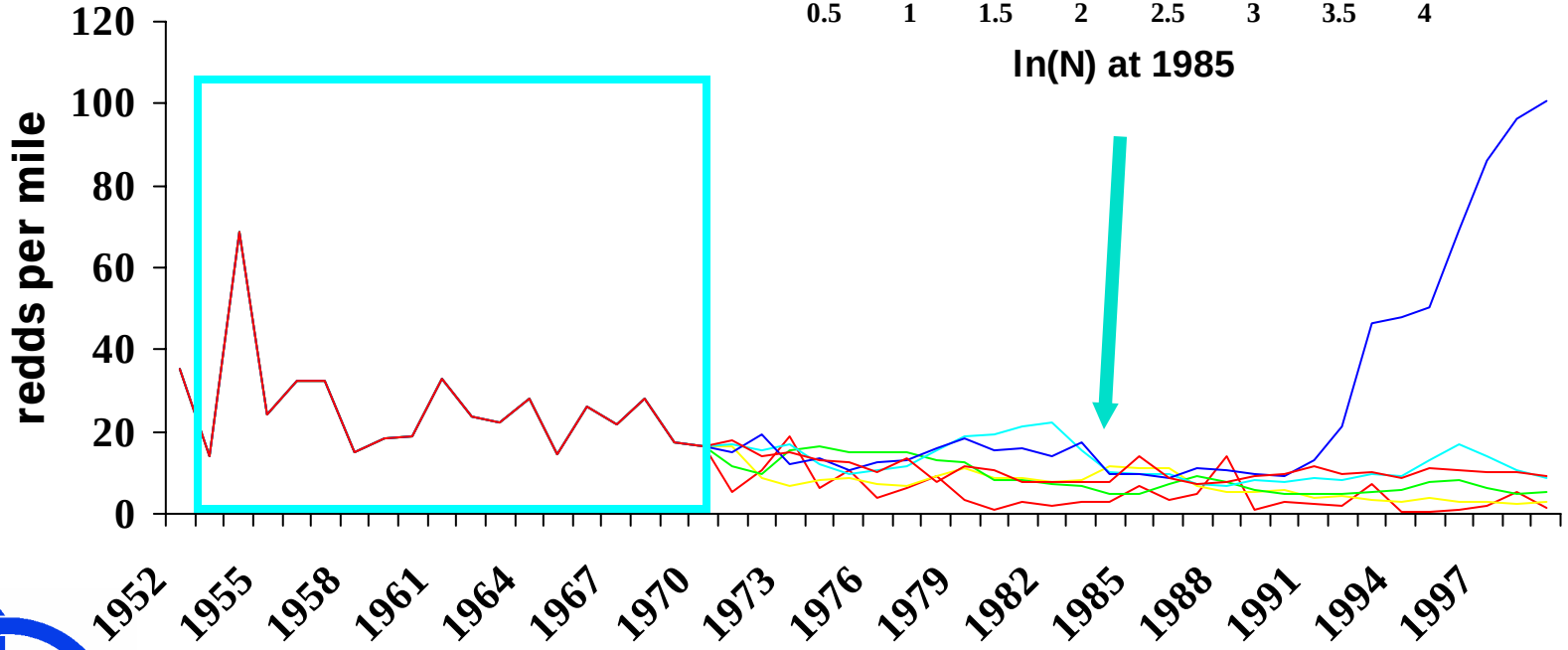
Let reproduction and survival vary yearly

$$N_t = N_0 \exp(\mu t + \varepsilon t)$$

where $\varepsilon \sim \text{Normal}(0, \sigma)$

Basic Idea of DA PVA





Parameters of a DA model

$N_t = N_0 * \exp(\mu t + \varepsilon t)$ where $\varepsilon \sim N(0, \sigma)$

Parameter that governs the median rate of decline.

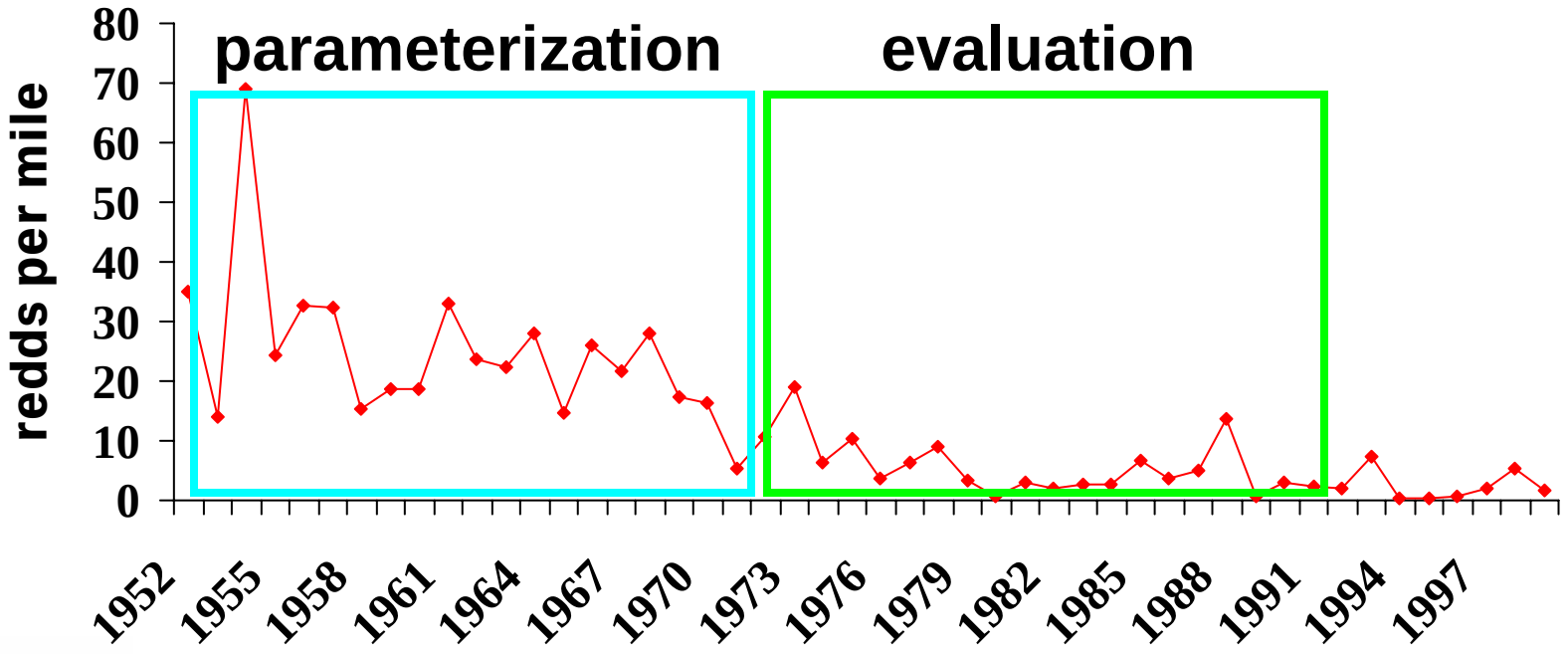
$\hat{\mu}$

"Process error": parameter that describes the long-term variability of the process.

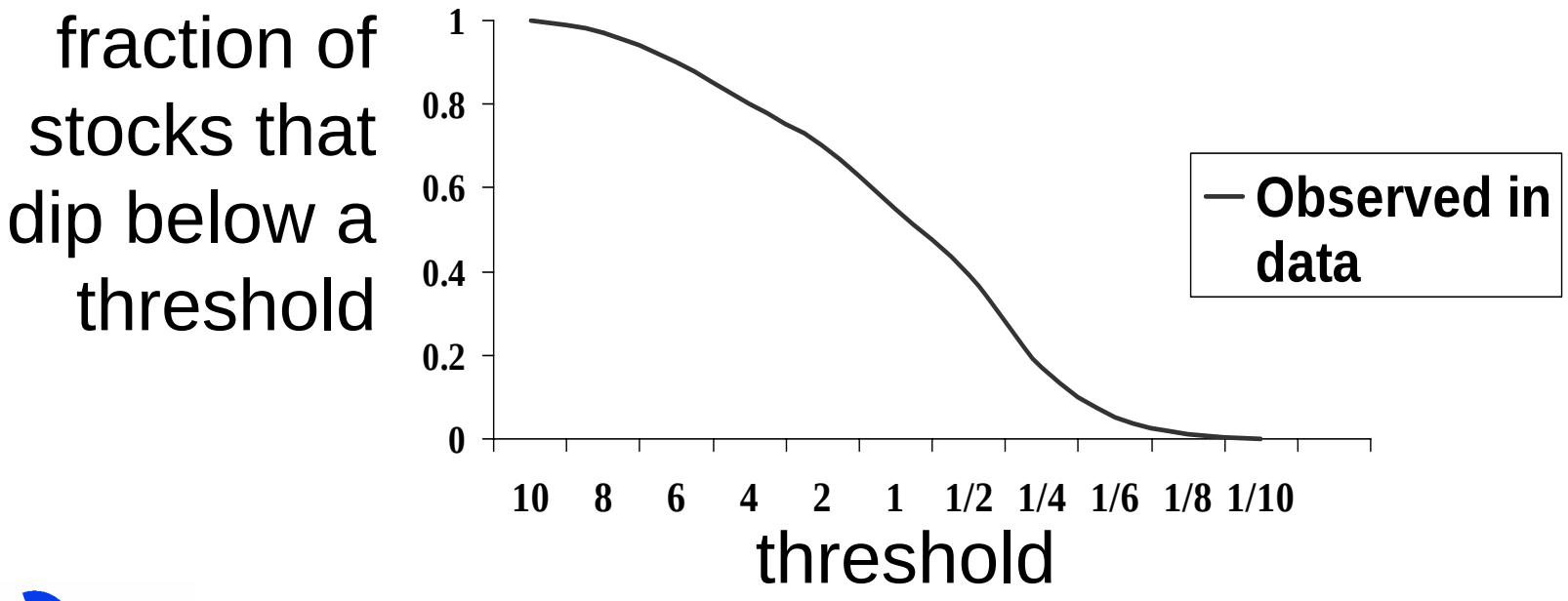
$\hat{\sigma}$

Cross-validation

- 147 chinook and 42 steelhead 30-70 year time series from ESUs in WA, OR, and CA

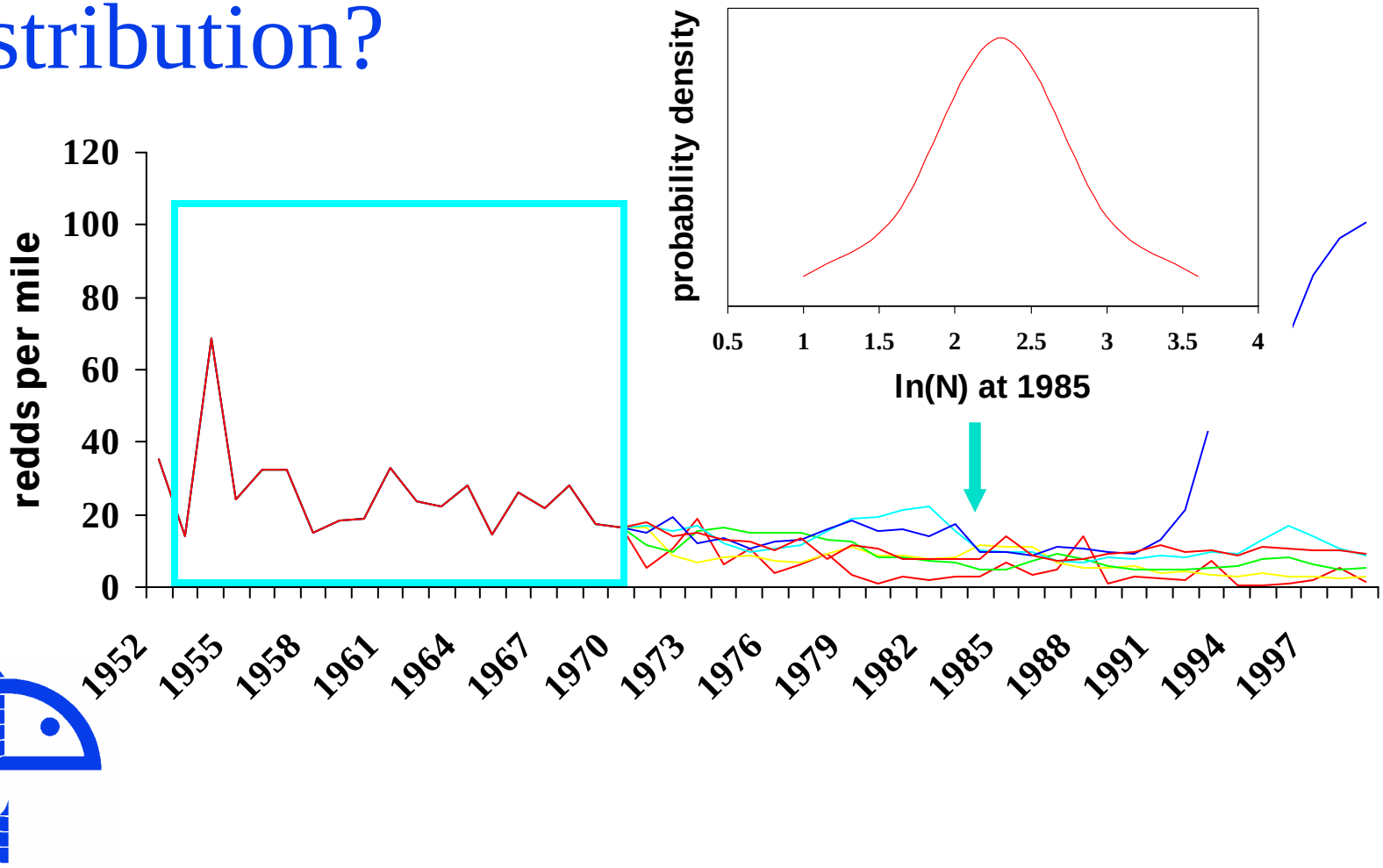


Does the DA model predict the frequency of actual declines?



(rel. to size at the start of the eval. period)

Do the projected population sizes follow the expected theoretical distribution?



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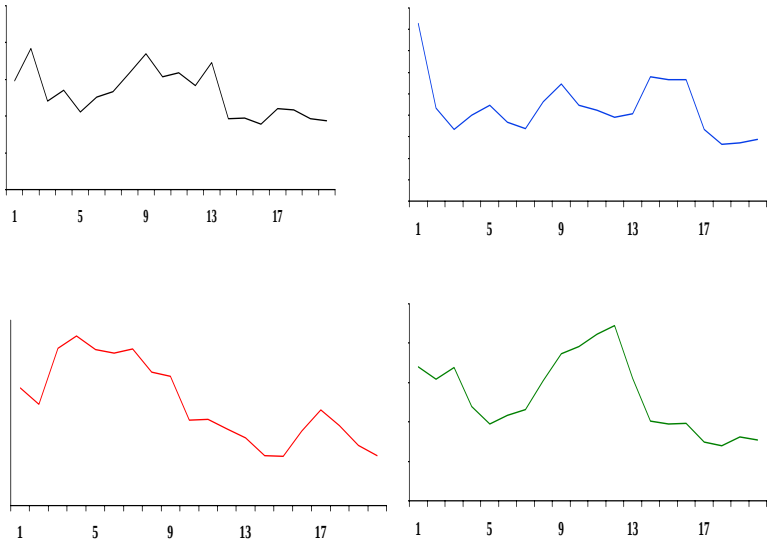
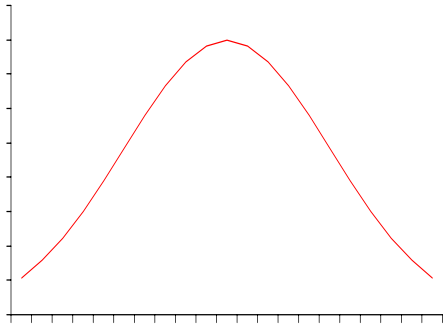
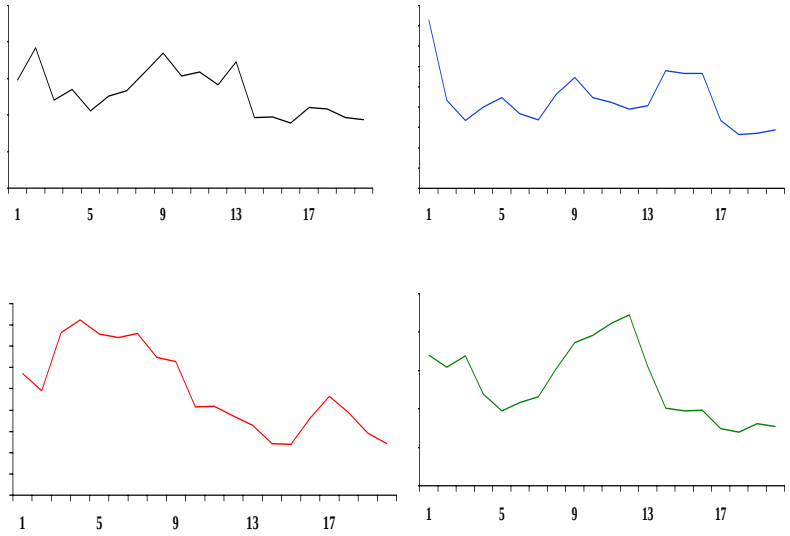


dist. of $\hat{\mu}$

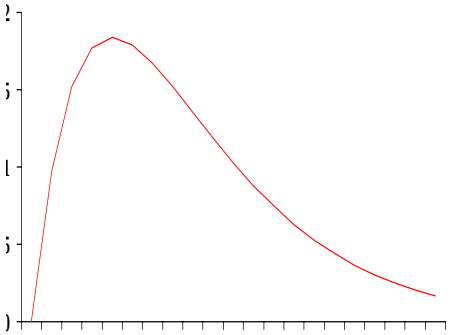


$\hat{\mu}$

Do my estimates of σ follow the expected theoretical distribution?



dist. of $\hat{\sigma}$



$\hat{\sigma}$

Transforming data to a common currency

- **Problem: don't view the same population process over and over**
- **Actual data: many different processes with different underlying parameters (growth rates and variability)**
- **Solution: transform data to a standardized metric that has the same statistical distribution for all processes**

For other examples see McCarthy et al. 2002. Conservation Biology

Standardized $\ln(N_{t+15}/N_t)= \psi$ distribution

$$\frac{(\psi_p - \psi_e)}{\sqrt{\frac{df_{slp}\hat{\sigma}_p^2 + df_{slp}\hat{\sigma}_e^2}{2df_{slp}}\left(\frac{1}{n_p - L} + \frac{1}{n_e - L}\right)}} \sim \frac{1}{\sqrt{\nu}} t_{2df_{slp}}$$

-0

no trend

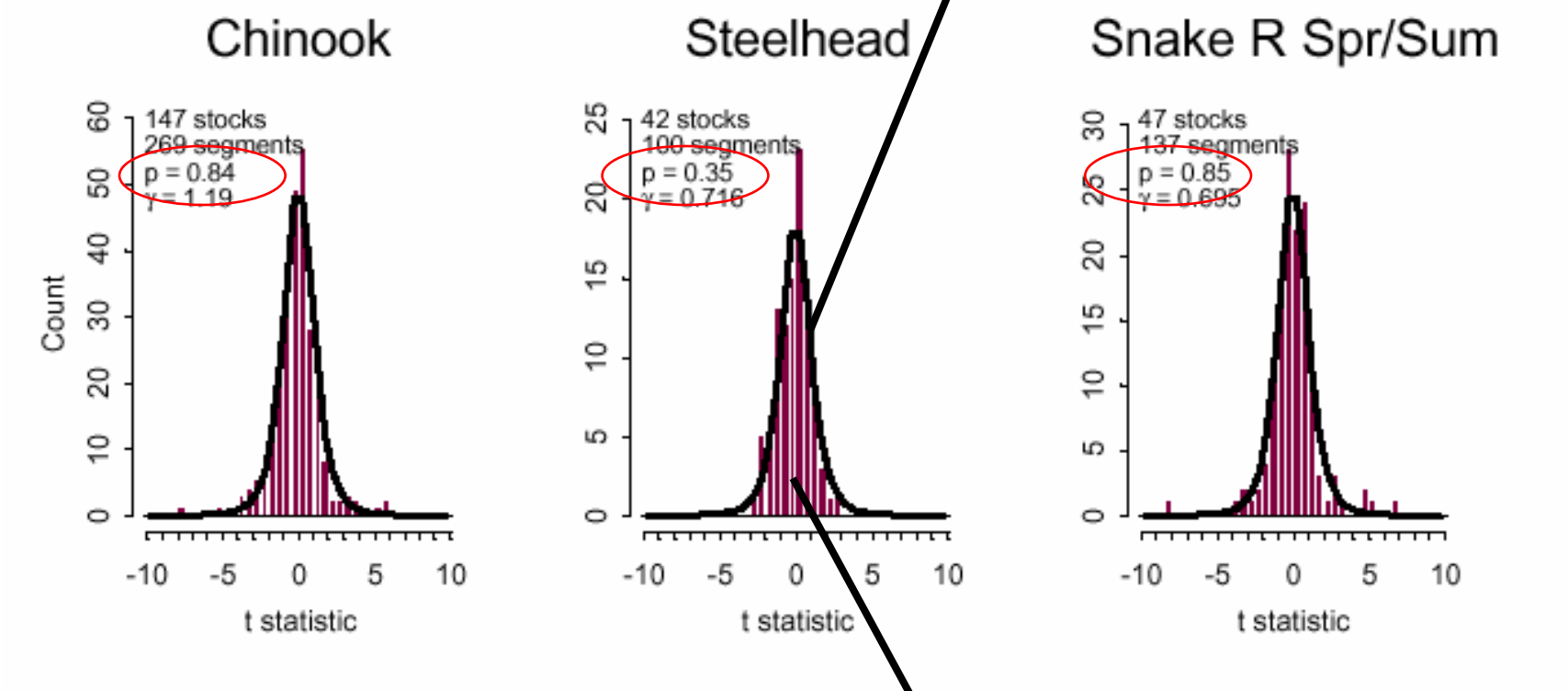
$\hat{\mu} \sim$ Normal – like

no bias in estimate

degrees of freedom

of $\mathrm{var}(\hat{\mu}) \sim \chi^2_{df_{slp}}$ – like

Results for population distribution



Predicted t distribution

Histogram of actual t statistics

Trend in the rate of decline?

- Fluctuating or declining stocks
  - No significant trend
- Rapidly increasing stocks
  - Significant negative trend
  - Estimate of μ lower for bigger population size

Standardized σ distribution

$$\left(\hat{\sigma}_e^2 / \hat{\sigma}_p^2\right) \sim F(df_{slp}, df_{slp})$$

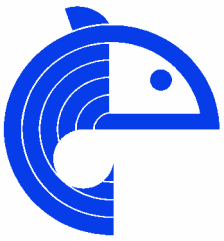
x 1

$\hat{\sigma}^2 \sim \chi^2$ – like

degrees of freedom

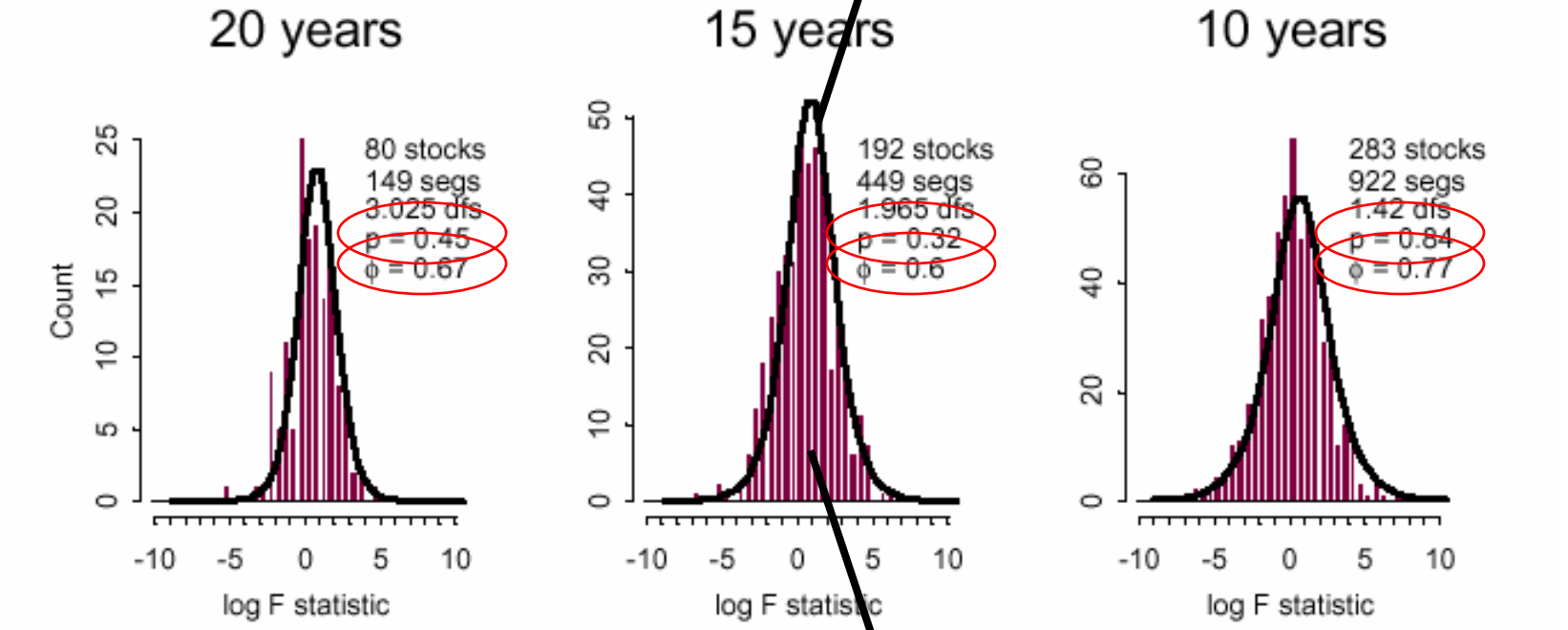
no trend

of $\hat{\sigma}_p^2$ is df_{slp}



Results for σ

Predicted F distribution



Histogram of actual F statistics

Trend in σ?

- Estimate of σ was higher when counts were really small
  - Demographic stochasticity?
  - Sampling effect?

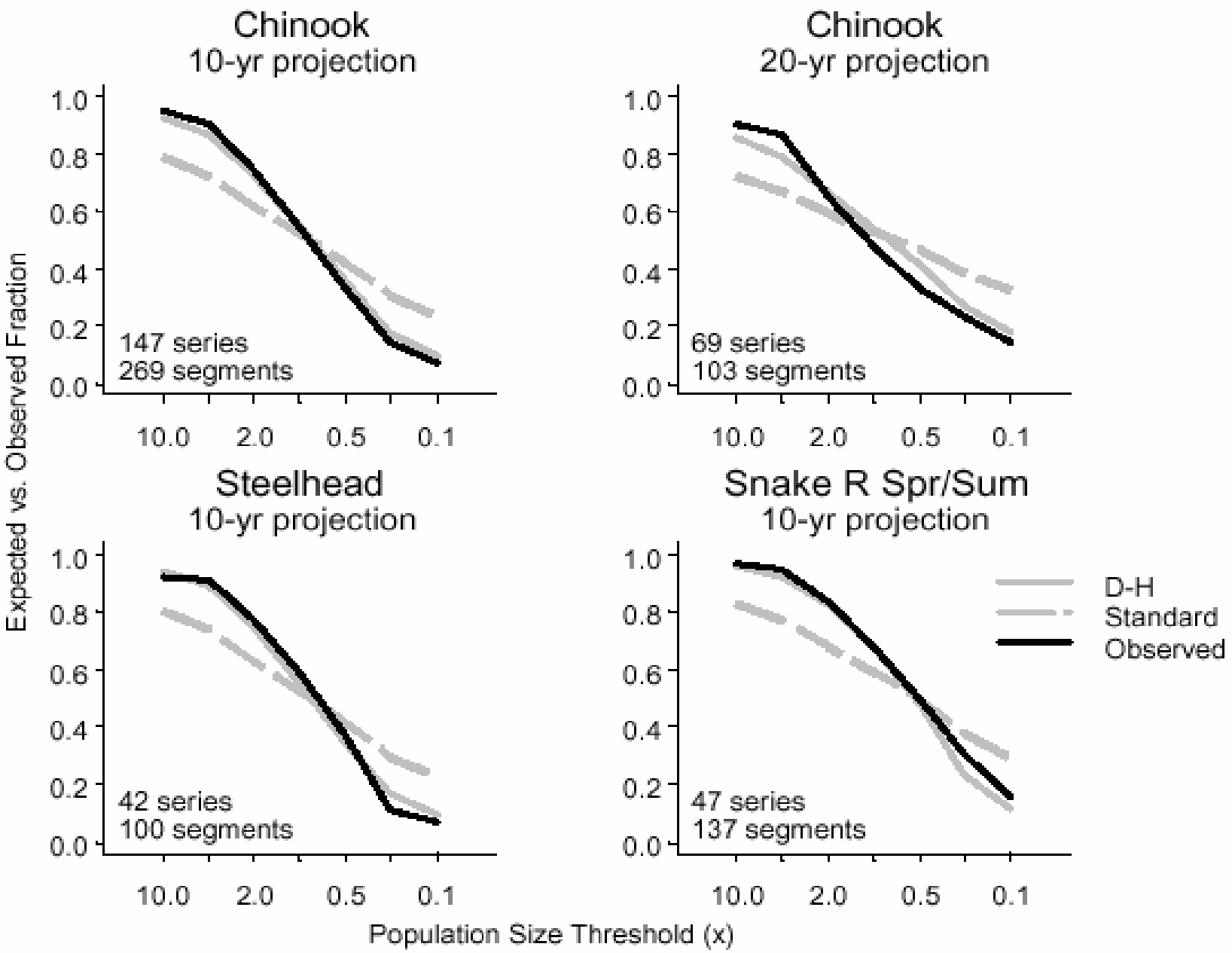
    Estimate of σ sensitive to percent of sampling error in the observation

    Percent error tends to be larger when counts are small

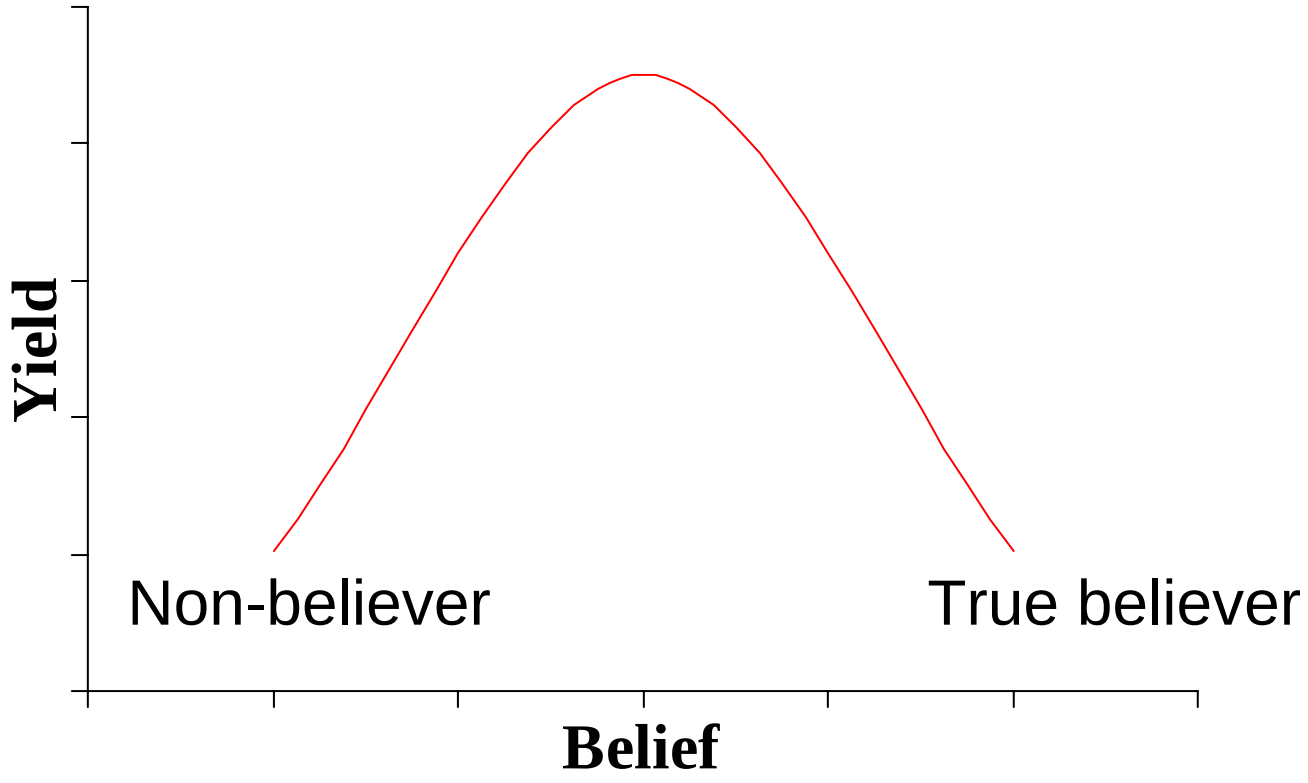
    e.g. Dunham and Rieman. 2001. Sources and magnitudes of sampling error in redd counts for Bull Trout. *North American Journal of Fisheries Management* 21:343–352

Can the model predict actual declines?

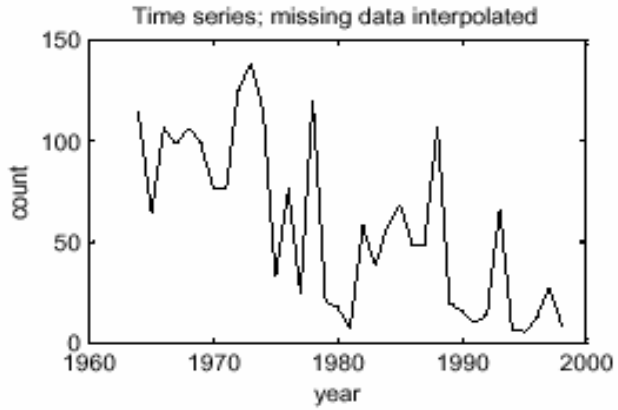
- Simple model makes many simplifying assumptions
  - density-independence
  - no environmental correlation
  - no trends
  - diffusion approximation of age-structured population


Chinook
10-yr projection
147 series
269 segments
Chinook
20-yr projection
69 series
103 segments
Steelhead
10-yr projection
42 series
100 segments
Snake R Spr/Sum
10-yr projection
47 series
137 segments
Expected vs. Observed Fraction
1.0
0.8
0.6
0.4
0.2
0.0
10.0
2.0
0.5
0.1
Population Size Threshold (x)
D-H
Standard
Observed

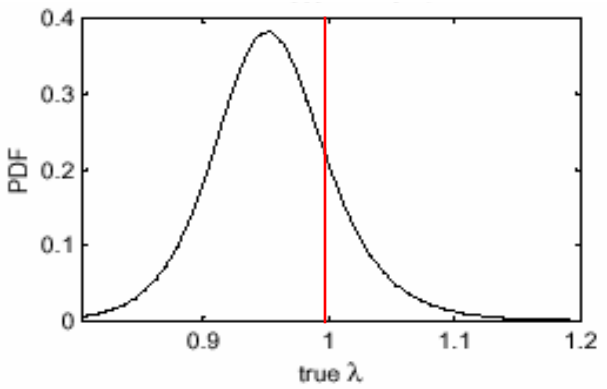
Maximum yield relationship for modeling



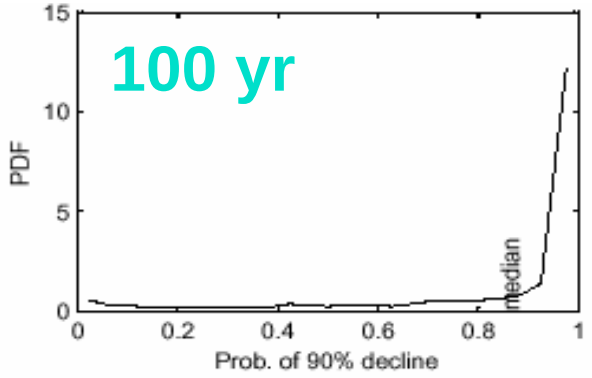
Lostine River 1964-1998

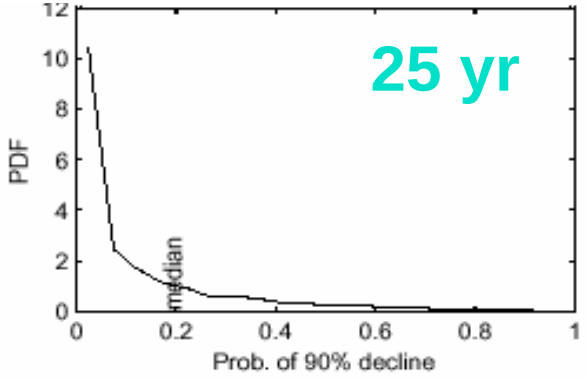


support for different λ's

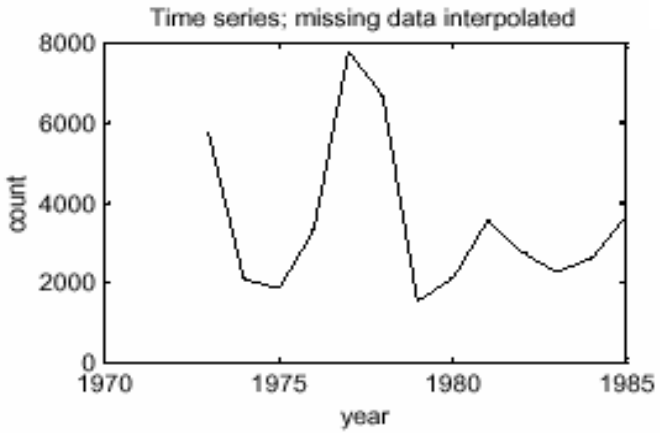


support for different probs of 90% decline

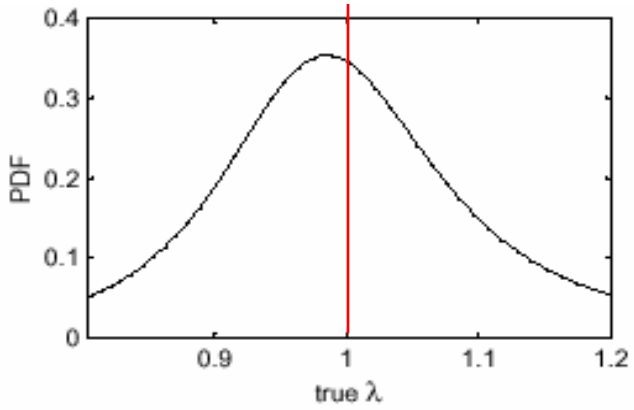




Clearwater River 1973-1985



support for different λ's



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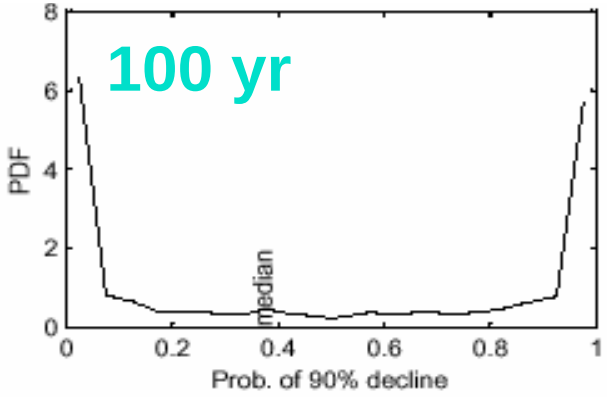
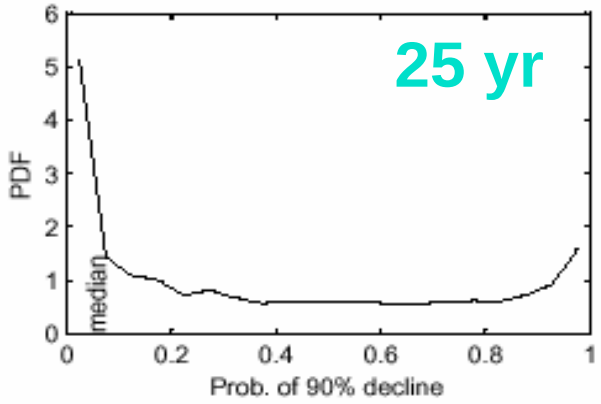
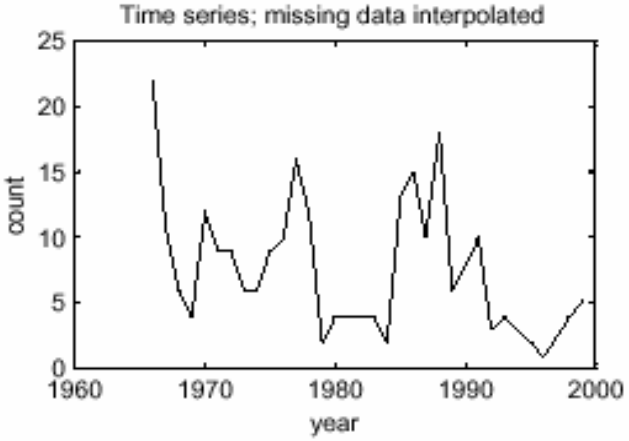




Camp Creek 1966-1999



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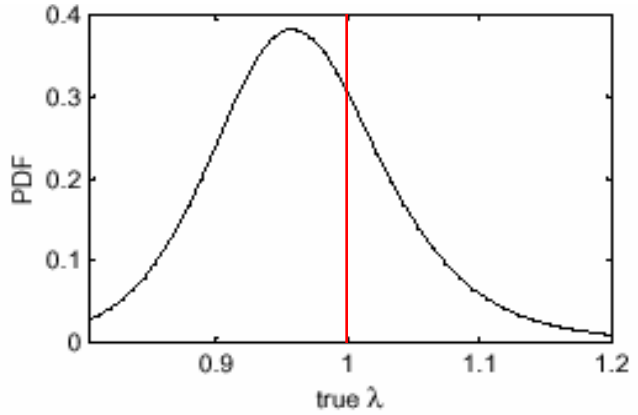

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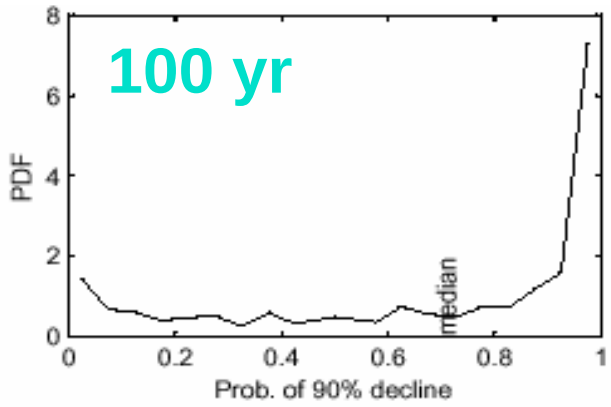
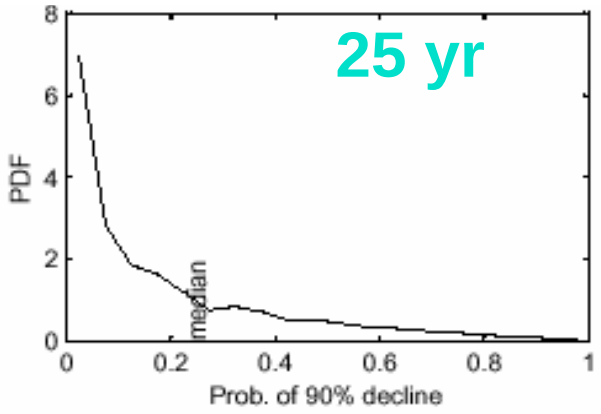




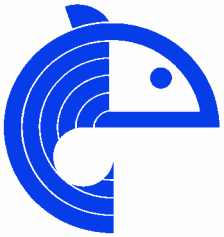
FOR MORE INFO...

A variety of matlab and Splus code for DA PVAs is at faculty.washington.edu/eeholmes

Holmes, E. E. 2001. Estimating risks in declining populations with poor data. Proceedings of the National Academy of Science 98: 5072-5077.

Holmes and Fagan. 2002. Validating population viability analysis for corrupted data sets. Ecology in press.

Holmes, E. E. Beyond theory to application and evaluation: diffusion approximations for population viability analysis.



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