Testing Two Methods of Including Environmental Factors into Stock Assessments

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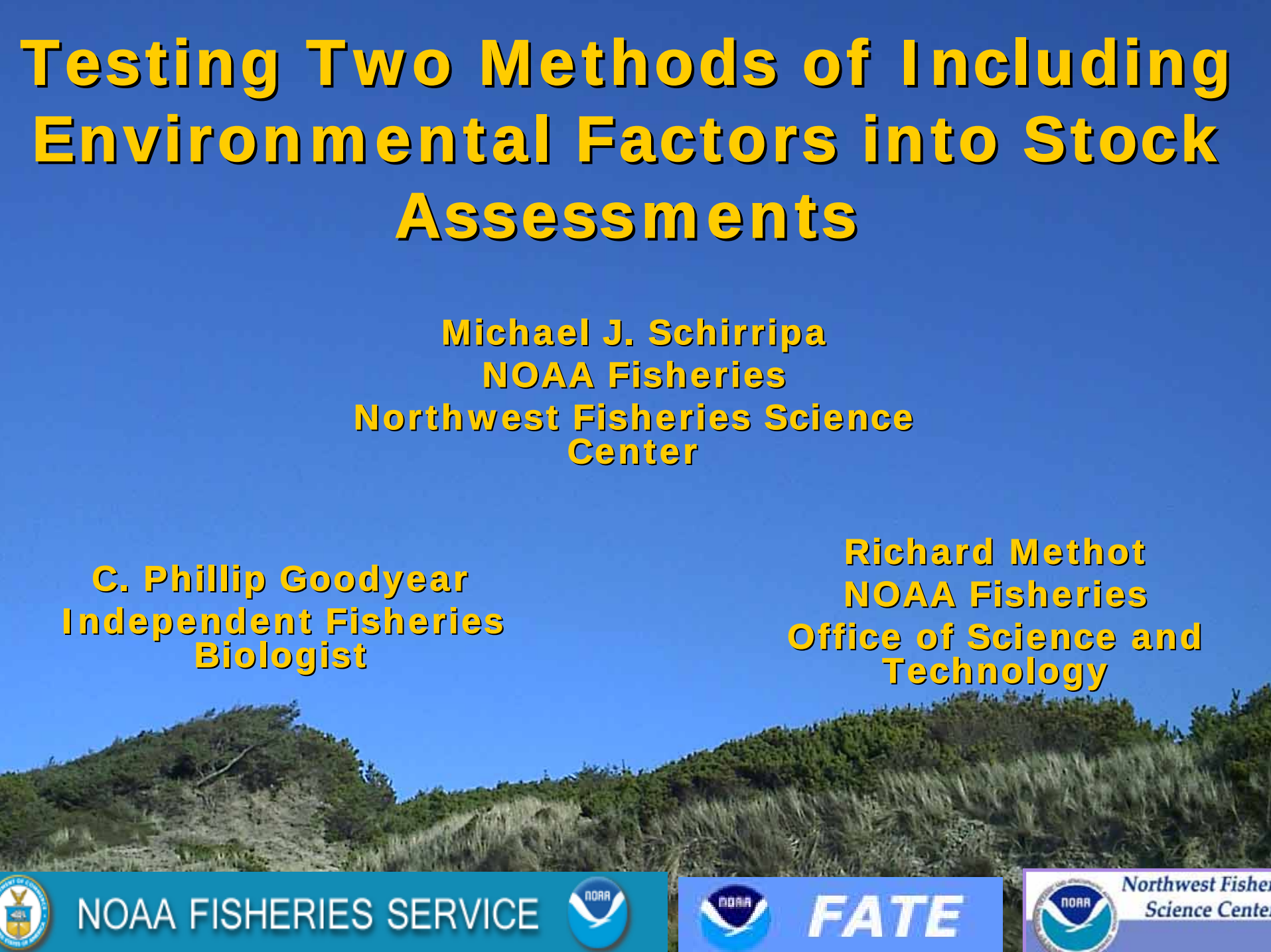
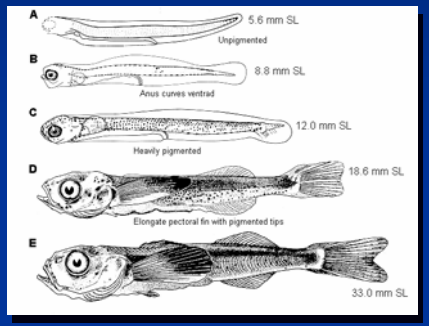


Motivation For the Study

- Recent finding on climate change has prompted the question of how changes in the ocean environment will effect our fisheries and exploited fish stocks
- This has lead to a great deal of research on which environmental indicators might be used to more completely/holistically assess the status of these stocks
- Now that we have some of these indicators we need to evaluate the best methods of incorporating environmental data into our current stock assessments models

The Conceptual / Mathematical Model



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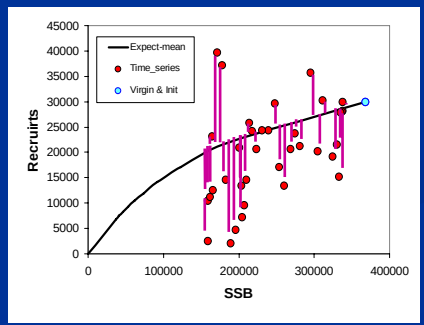
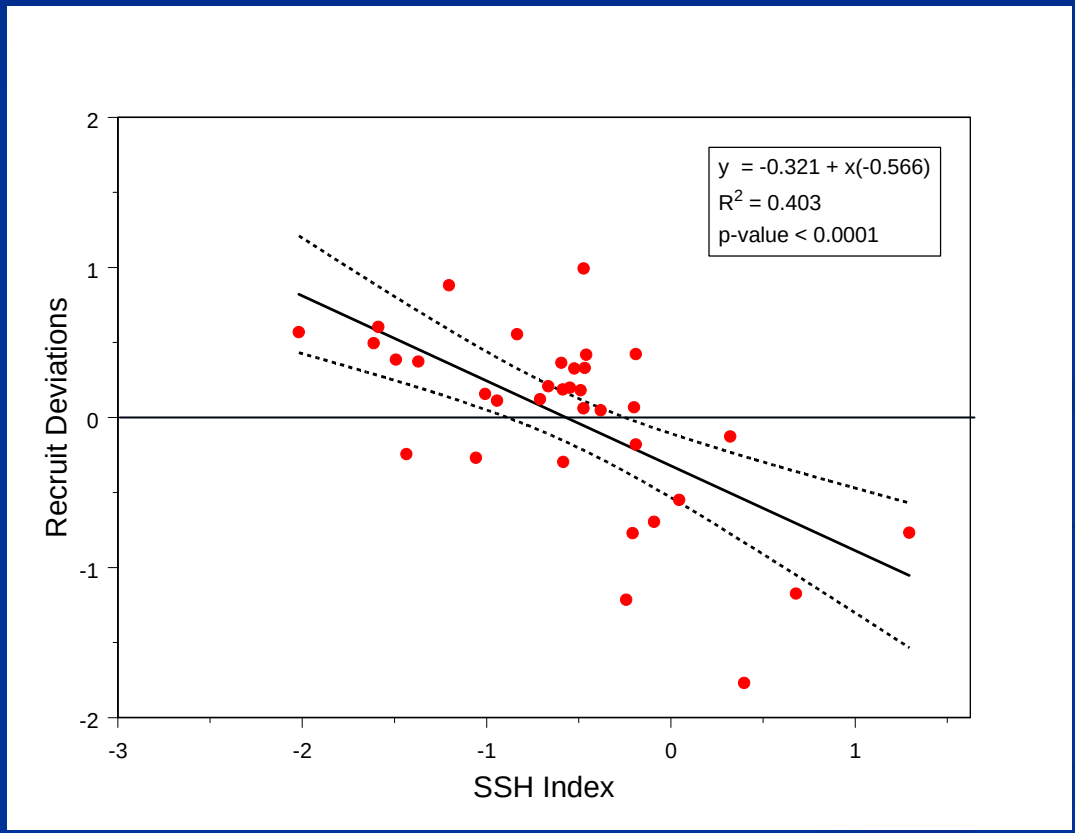
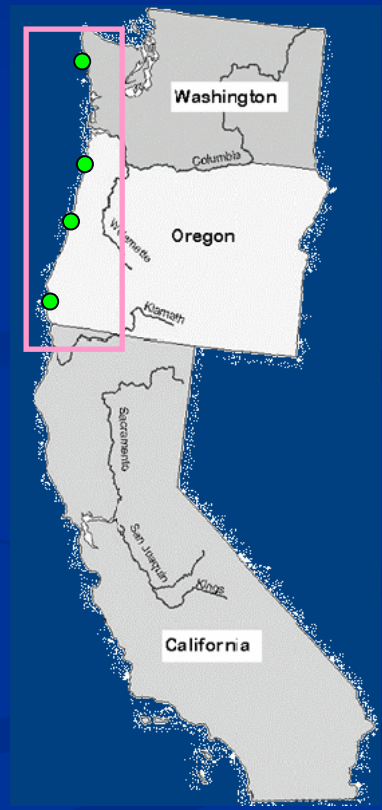
$$\hat{R}_y = \left(\frac{4hR_0S_y}{S_0(1-h) + S_y(5h-1)} \right) e^{\varepsilon} \quad *e^{\beta Ey}$$



For sablefish, part of the deviation can be explained by changes in Sea Surface Height





Objective of the Study

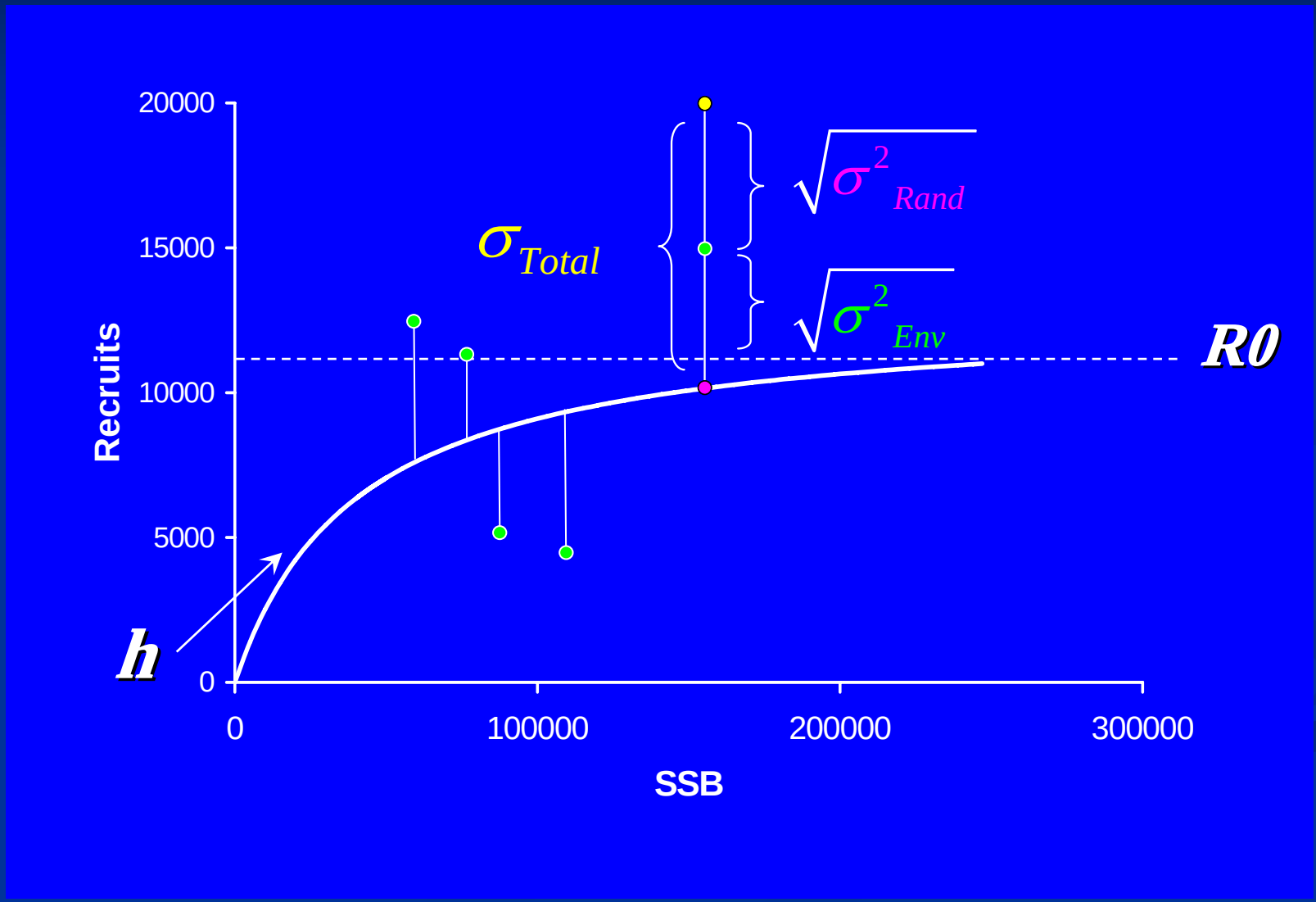
- Evaluate the usefulness of including our new environmental data into our stock assessments
- Objectively evaluate several modeling alternatives to include this data into our existing stock assessment framework and models, Stock Synthesis II (SS2)
- Identify and quantify any bias or error that might be associated with including environmental data

Competing Method 1: "Model" Method

$$\hat{R}_y = f(SSB_y) * e^{\beta Ey} * e^{\varepsilon y - 0.5\sigma_R^2}$$

- Use the environmental data to modify the annual working value of recruitment estimated within the stock-recruitment model
- Sigma-r is the variability of the remaining deviations, so it is in addition to the variance "created" by the environmental effect

Stock Size (*R0*) and Productivity (*h*)



Requirement of proper partitioning of total deviation

Total sigma-r should reflect the deviation due to the environment plus the deviation due to other random noise as:

$$\sigma_{Total} = \sqrt{\sigma^2_{Env} + \sigma^2_{Rand}}$$

The model method accounts for environment

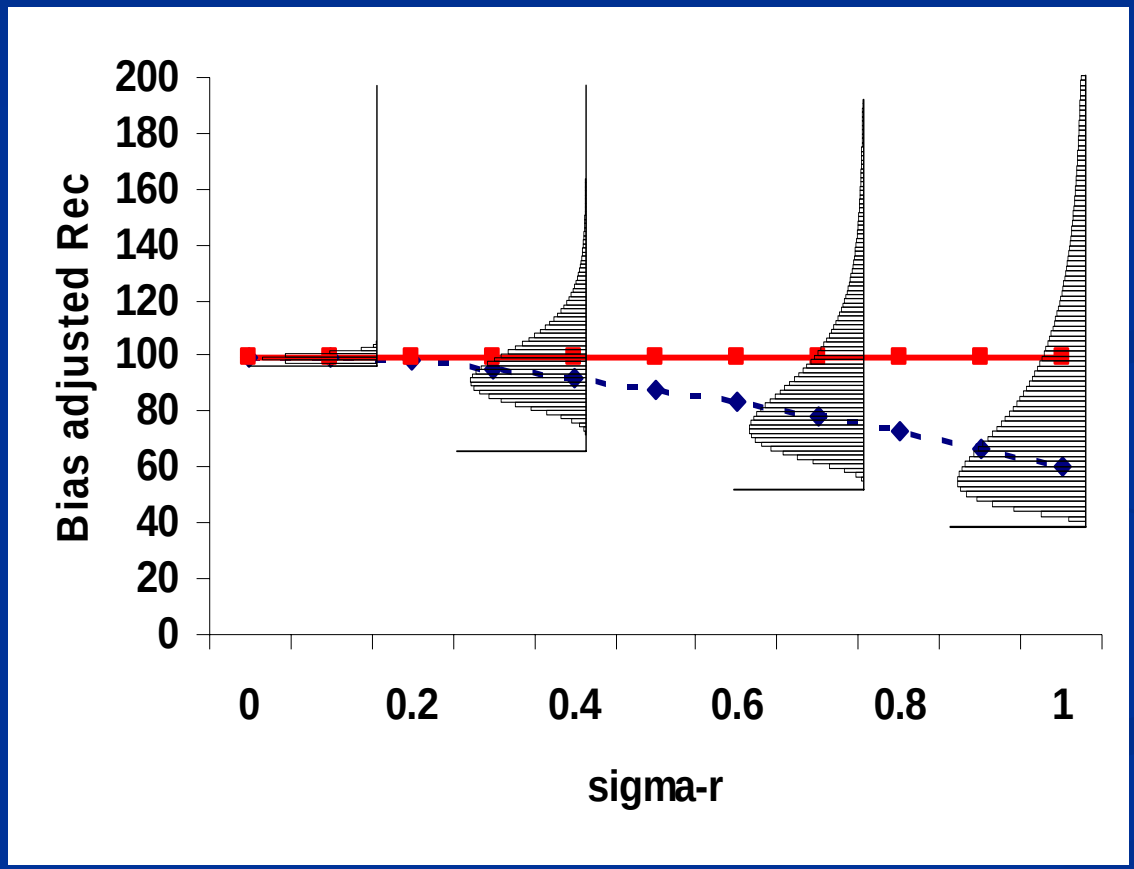
$$\sigma_{Total} = \sqrt{0_{Env} + \sigma^2_{Rand}}$$

But sigma-total does NOT equal sigma-rand

$$\sigma_{Total} \neq \sqrt{\sigma^2_{Rand}}$$

Consequences of the Problem:

Decreased sigma-r results in an increased median recruitment due to bias adjustment

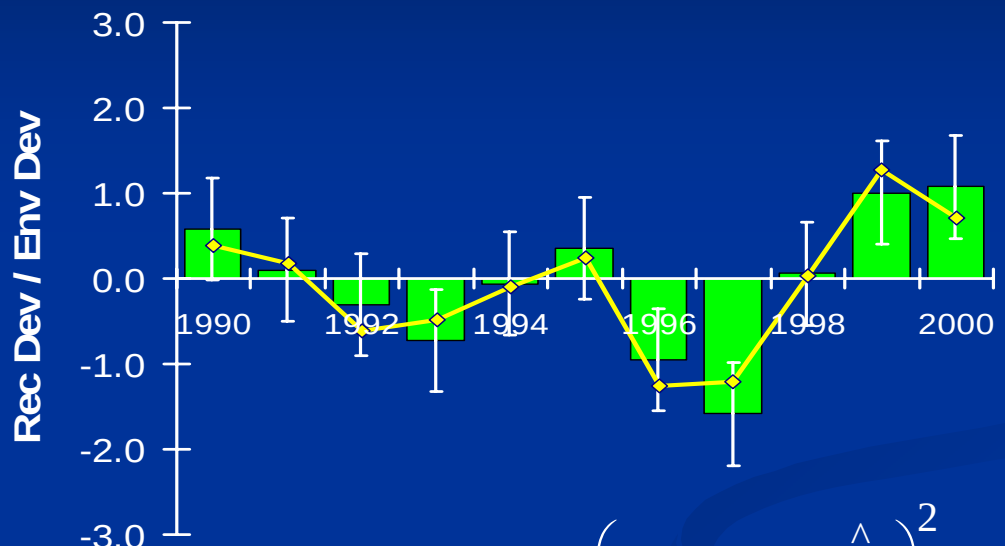


← Mean

← Median (Bias adjusted)

MaxLike tends to draw devs to this level

Competing Method 2: "Data" Method
Use environment as an Age-0 "Survey"

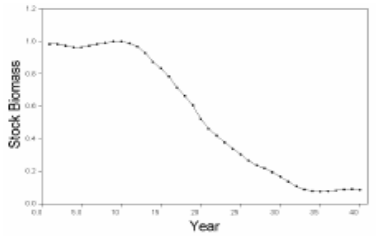


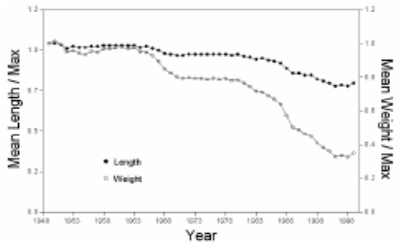
$$Likelihood = 0.5\sum_{t}\left(\frac{\ln(A_t)-\ln(\hat{A}_t)}{\sigma_t}\right)^2$$

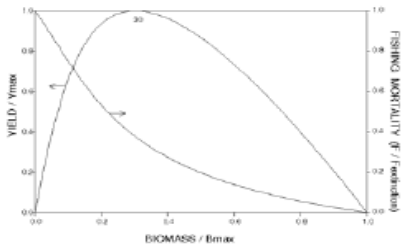
- Fit to the *Env* data is part of the objective function
- Allows *Env* data to have error associated with it

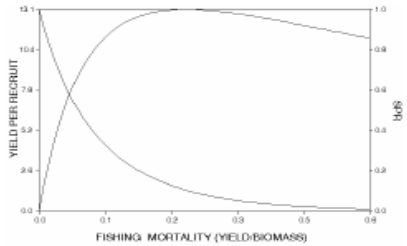
Fisheries SIMulator (FSIM)
An Independent Platform

FSIM Version 4.0









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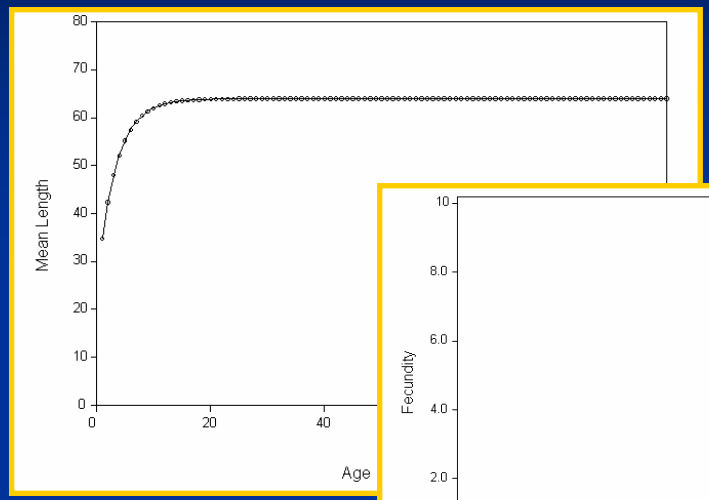
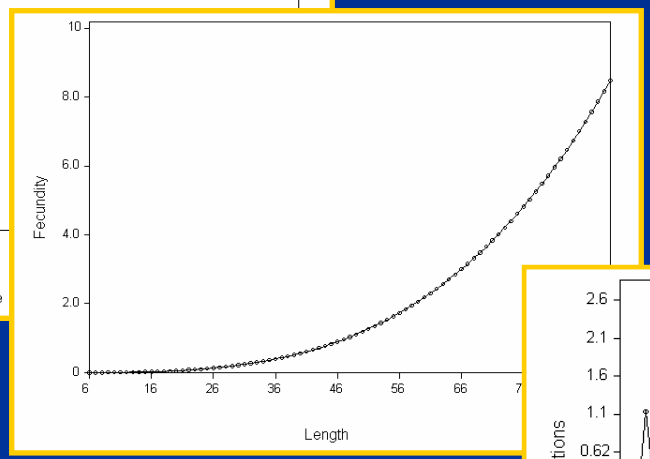
FSIM Data Simulator

Defined Biological Inputs



Growth



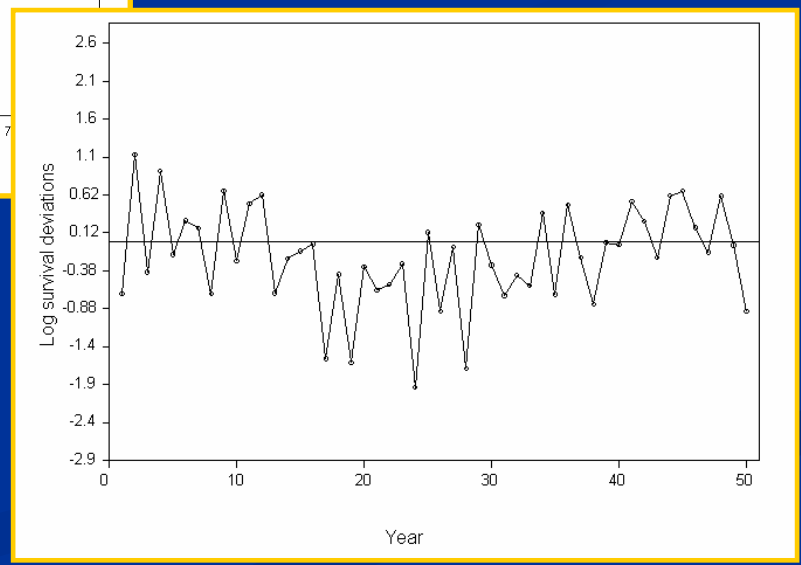
Fecundity

FISHERY DEFINED

- Selectivity
- Seasonality
- Min-max size
- Quota

SURVEY DEFINED

- Selectivity
- Seasonality
- Q
- Numbers / Wt
- Fishery Association

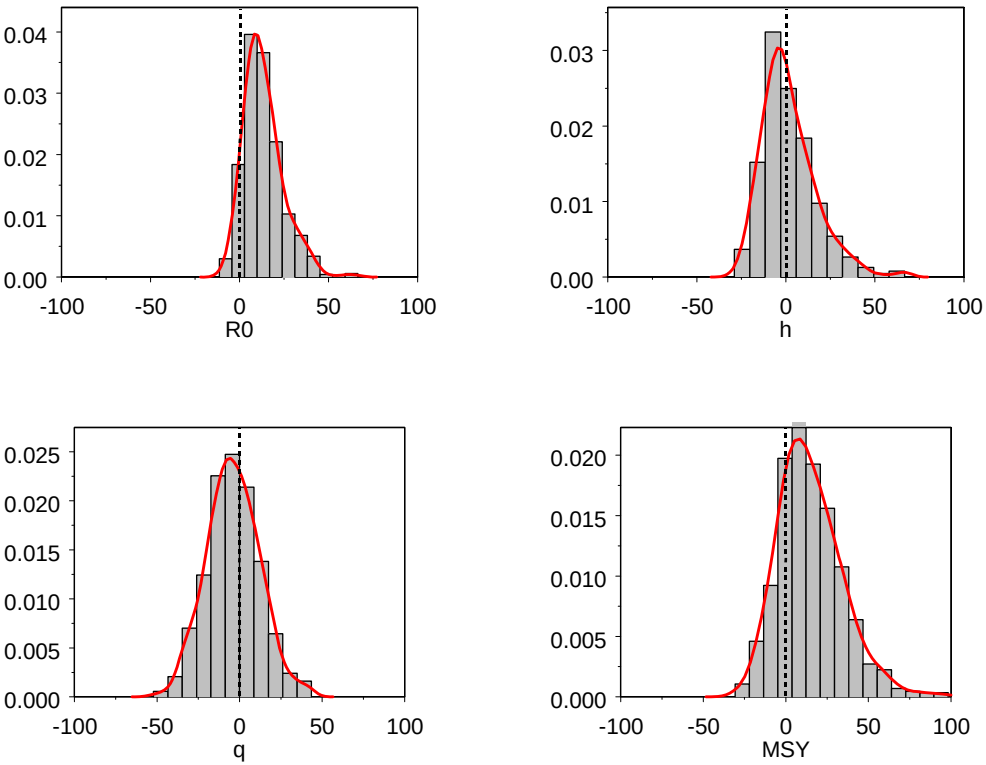


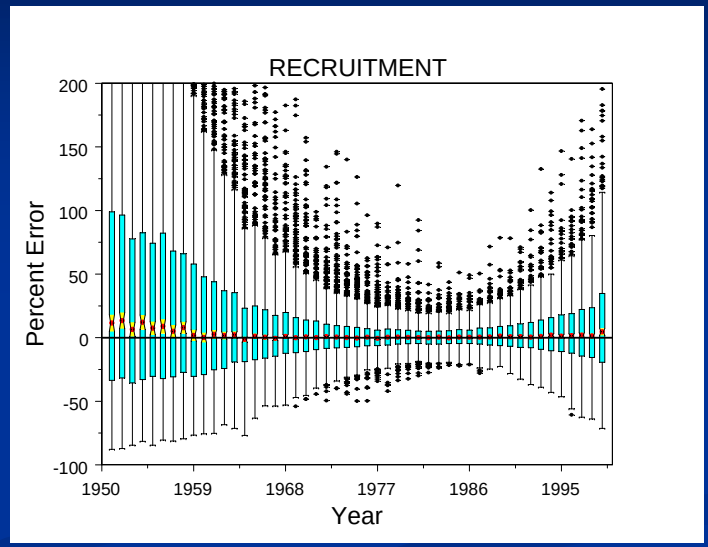
Environmental Effect

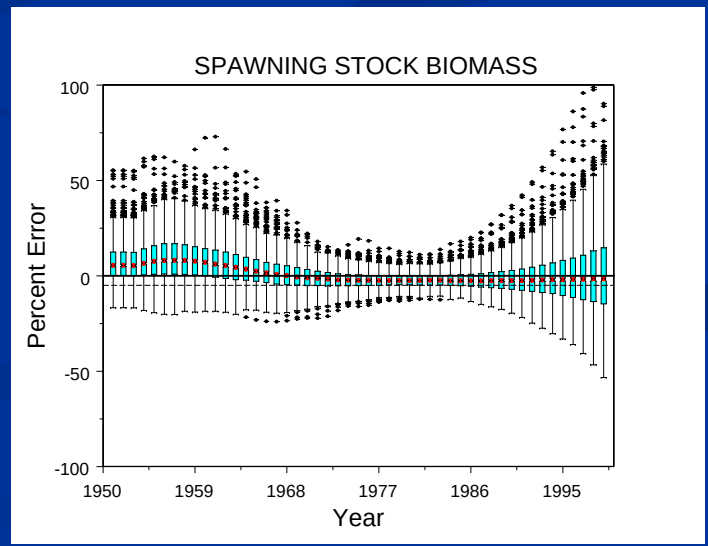
Approach & Methods

- All simulations/env run 1950-2000, all data run 1990-2000
- Method 1 – Isolate the effect of the shortened data series by simulating with no ENV effect
- Method 2 – Simulate environmental forcing in FSIM but make no attempt to explicitly account for it in SS2
- Method 3 – Simulate environmental forcing and use the Model Method
- Method 4 – Simulate environmental forcing and use the Data Method

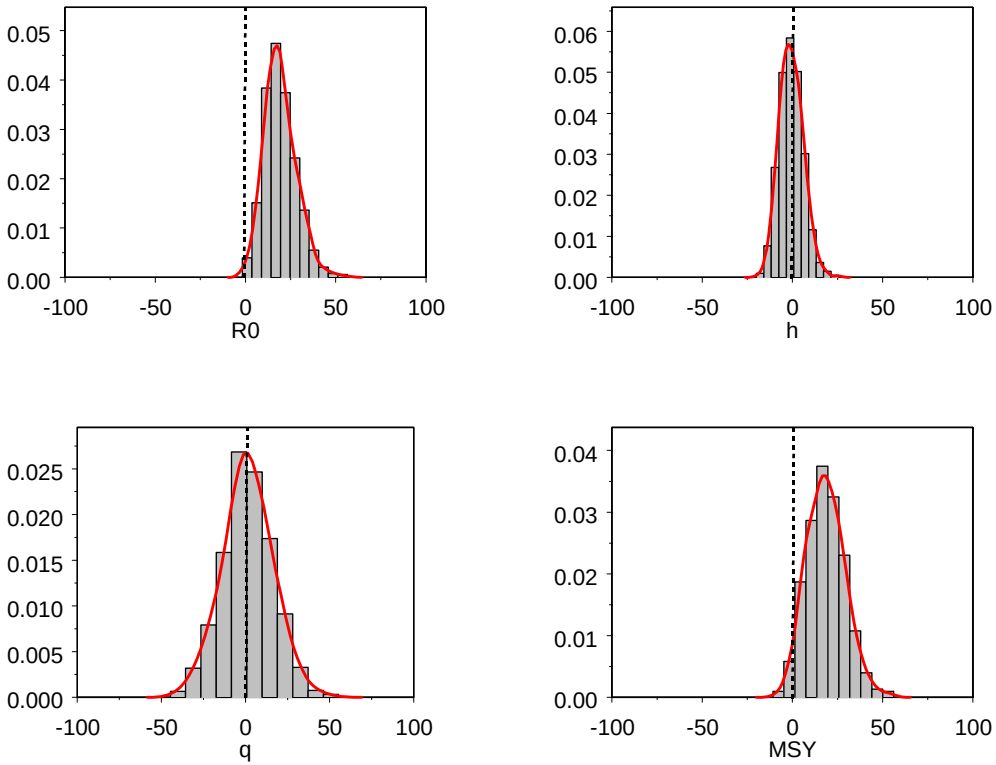
Method 1 – No environment; No method

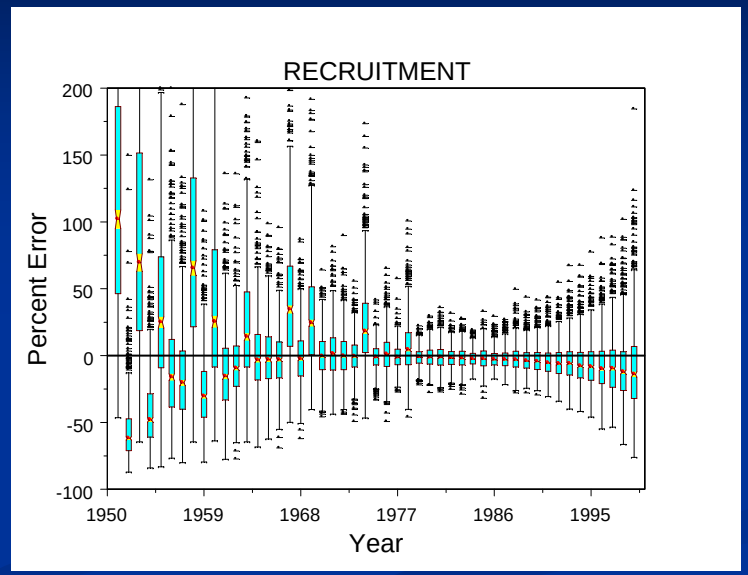


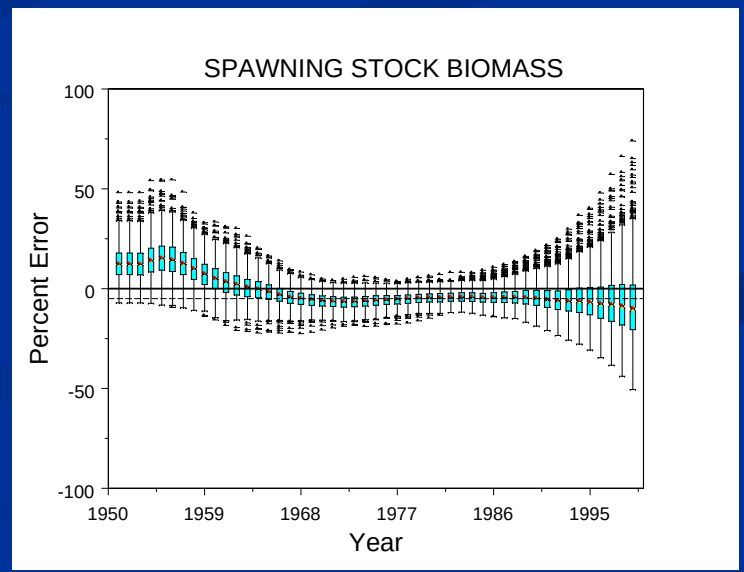




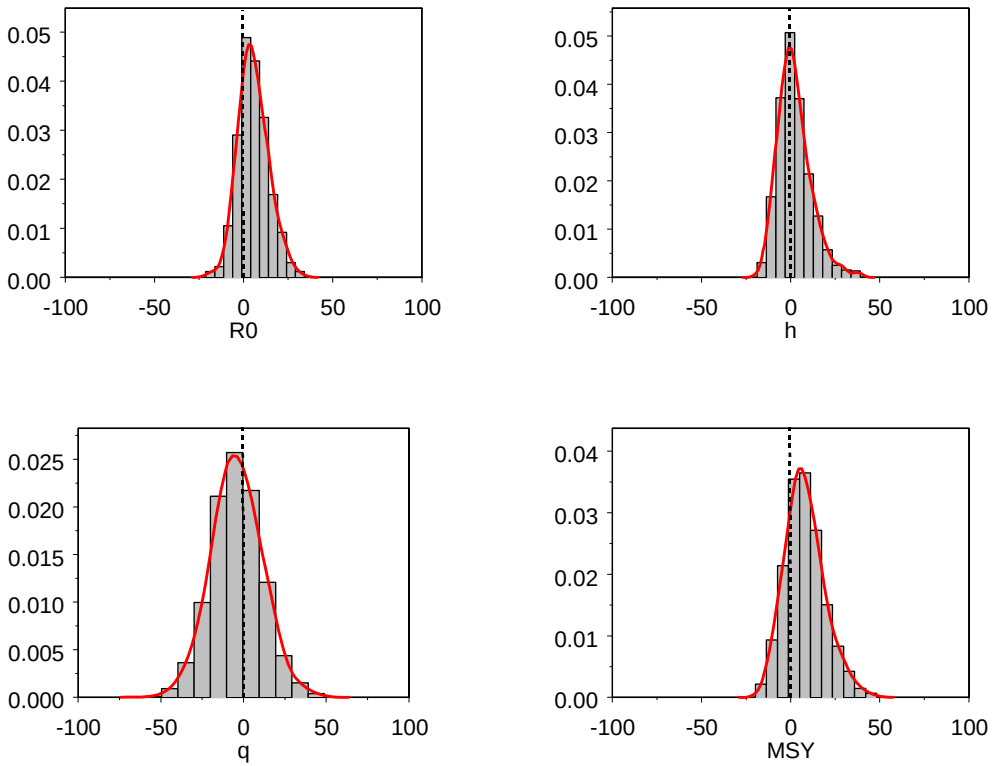
Method 2 – Add environment; No method

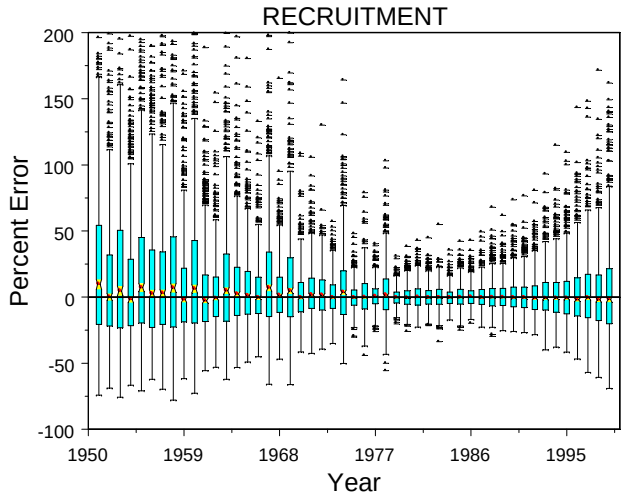


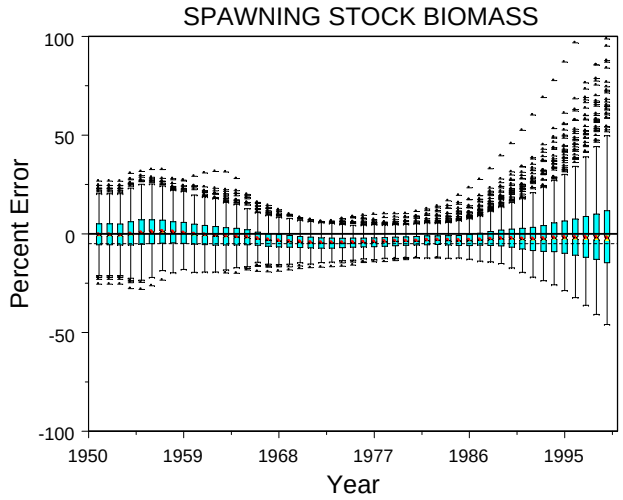




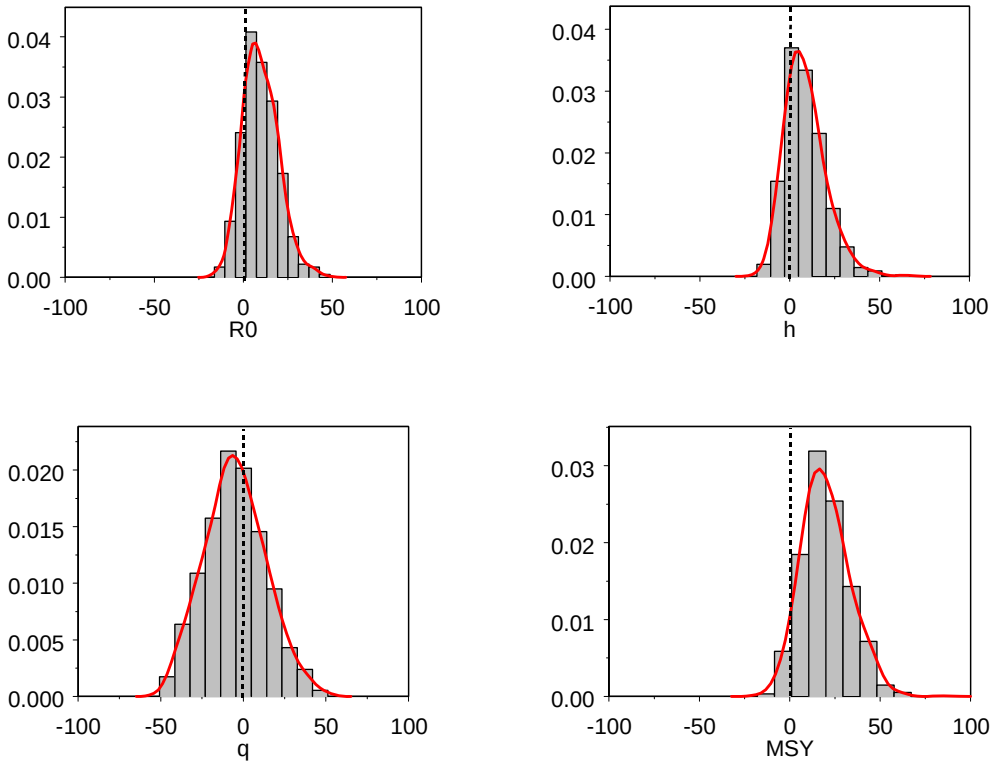
Method 3 – Use the Model method

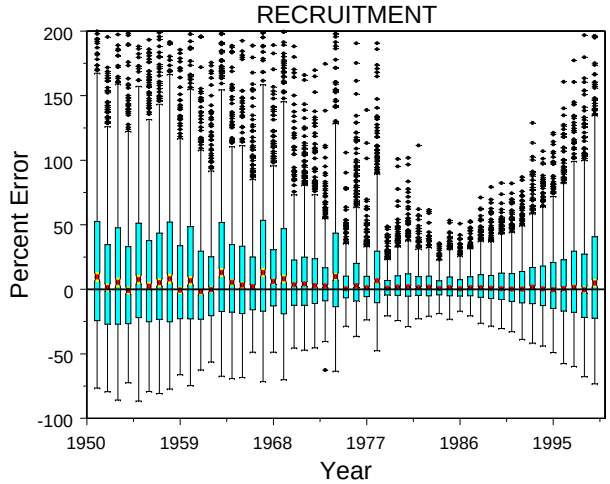


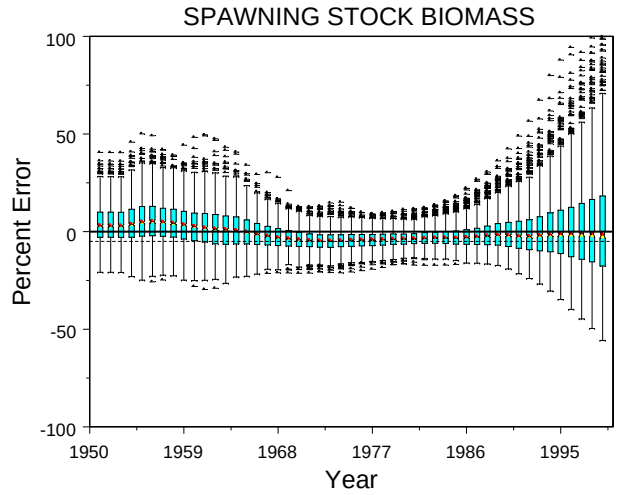




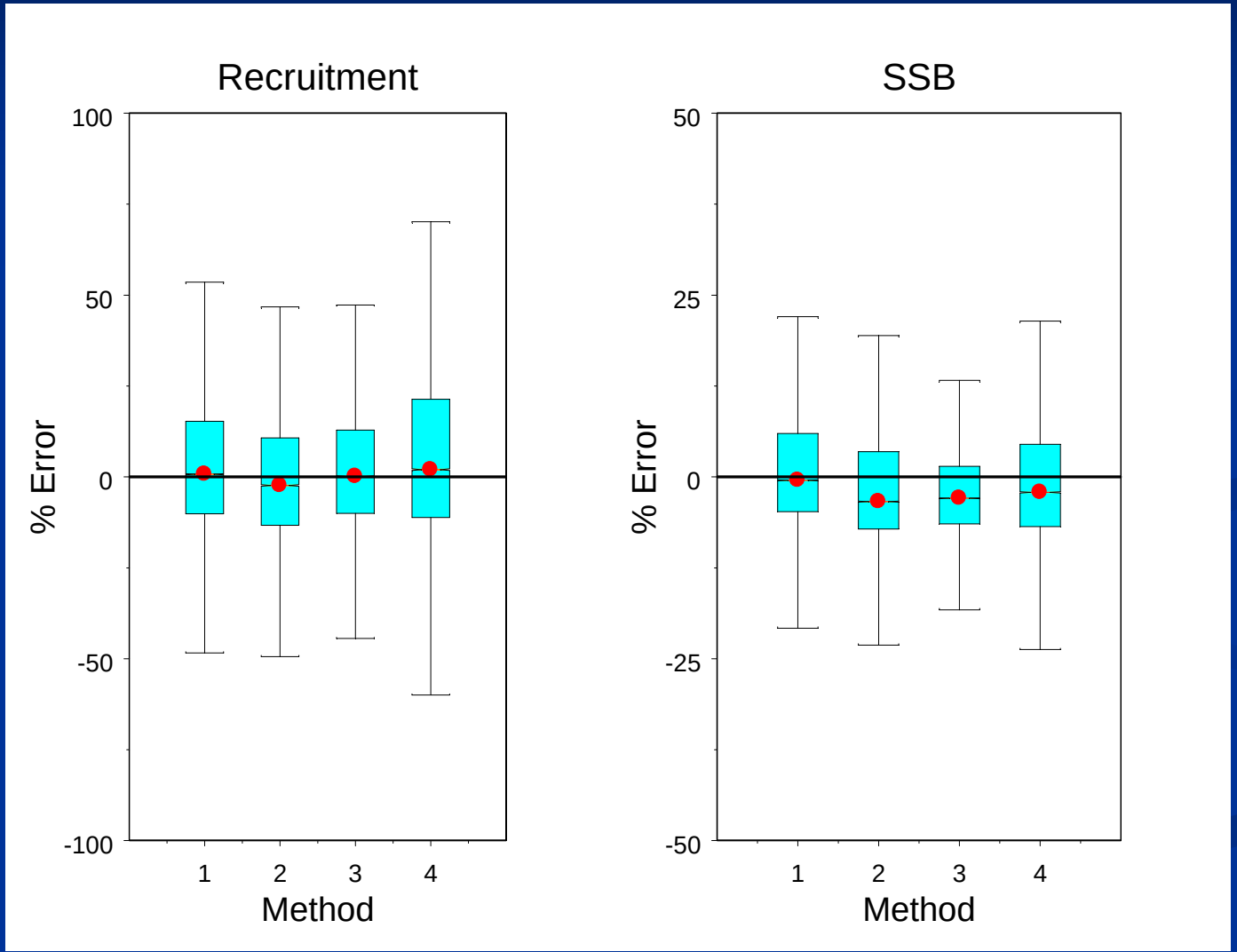
Method 4 - Data method







Percent Error Across Methods



Conclusions

- If an environmental influence is indeed present, either method performed better than not using any method at all, however, these results suggest the “model” method may be the better approach
- The “data” method is more correct when there are years with missing environmental data. As such, the best choice may be based on the available data rather than the available model

Conclusions

- The “model” method allows for an objective way to evaluate the inclusion of environmental data into the assessment (via an AIC, BIC type criteria)
- Although the ‘data” method assumes *a priori* that a relation exists one can do hypothesis testing by estimating the Q and/or the SD of the survey

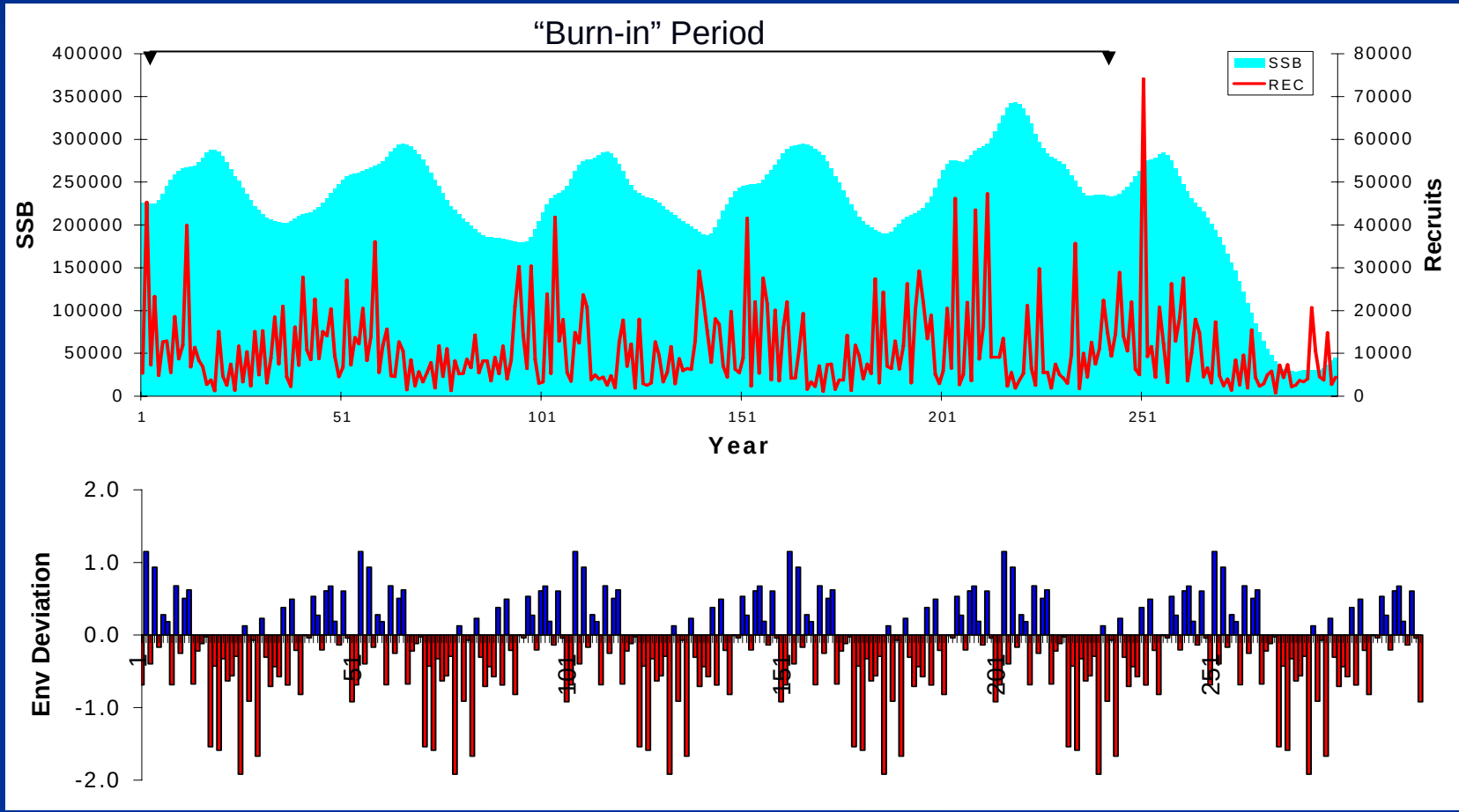
Future Direction

- Develop decision tables that explicitly consider possible (especially directional) changes in the California Current System as the various “States of Nature”
- Fish are FOOD, and we need to start preparing for how climate change is going effect this part of the world food supply in the next decade and beyond.
- Determine just how accurate/precise our forecasts of the environment need to be in order to be helpful to stock projections

An Autocritique

- This study is not definitive as the results may be dependent on the specific growth and environmental pattern modeled
- Why didn't we see the expected over-estimation of R0 with the model method?
- Does the data method penalize recruit devs twice, once for the deviating from the S/R function and again for deviating from the "survey" data?

Typical simulated time series that includes an environmental effect



Simulation uses sablefish biological parameters from last assessment

- Total of 100 ages and 100 platoons (growth morphs)
- FSIM seasonally adjusted to fit SS2 assumptions
- M = 0.07
- One fishery, one survey; Length/ages randomly sampled (500 survey, 500 fishery per year)
- B-H type recruitment steepness = 0.60, ln(*R0*) = 9.30

Recruit deviations can be driven in part by actual SSH data (50 years) and can be explicitly accounted for in SS2

- Each run (n=300) independent from all others within a level

B0 Calculations

- FSIM R0 = mean of the burn-in recruitment

  Considered the True *R0*

- FSIM B0 = mean of the burn-in SSB

  Considered the True *B0*

- SS2 *R0* and *B0* values taken from the forecast file with

  R0 = estimated parameter of SR function

  B0 = *R0* * SPR in the absence of fishing