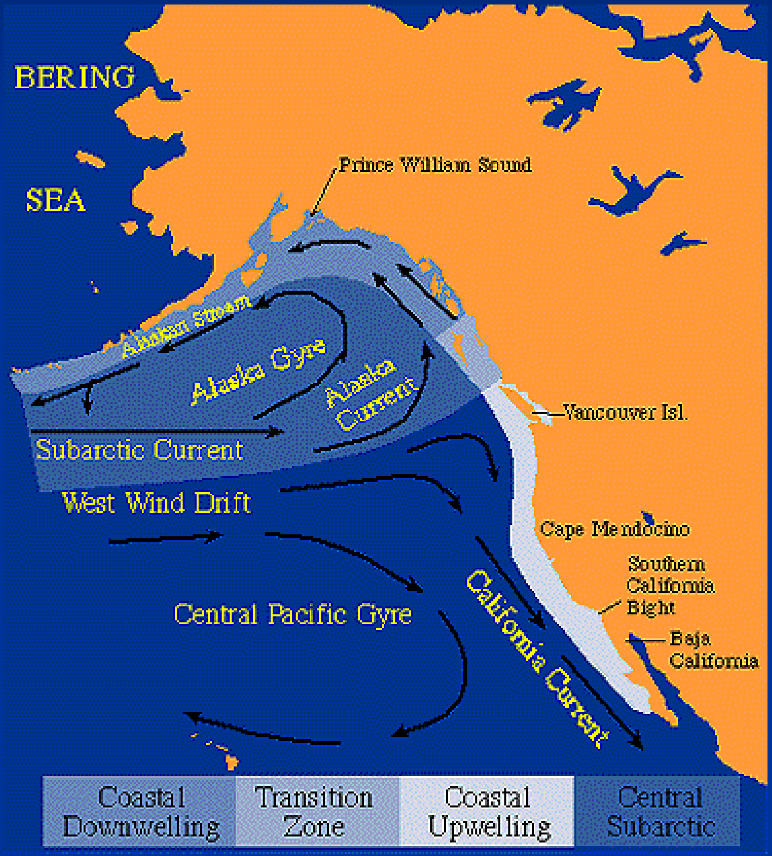
Testing Two Methods of Including Environmental Factors into Stock Assessments



Michael J. Schirripa
NOAA Fisheries
Northwest Fisheries Science Center

C. Phillip Goodyear
NOAA Fisheries
(Retired)

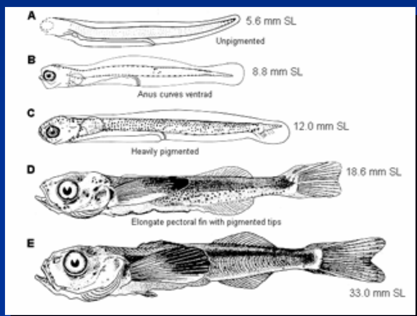
Richard Methot
NOAA Fisheries
Office of Science and Technology

NOAA FISHERIES SERVICE

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
- This all ties directly into the new PICES Science Program FUTURE

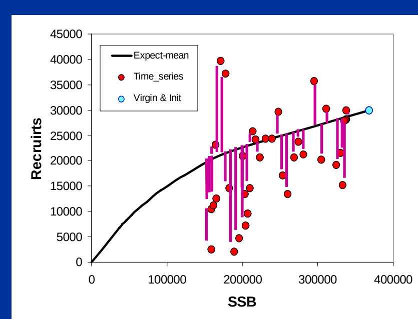
The Conceptual/Mathematical Model



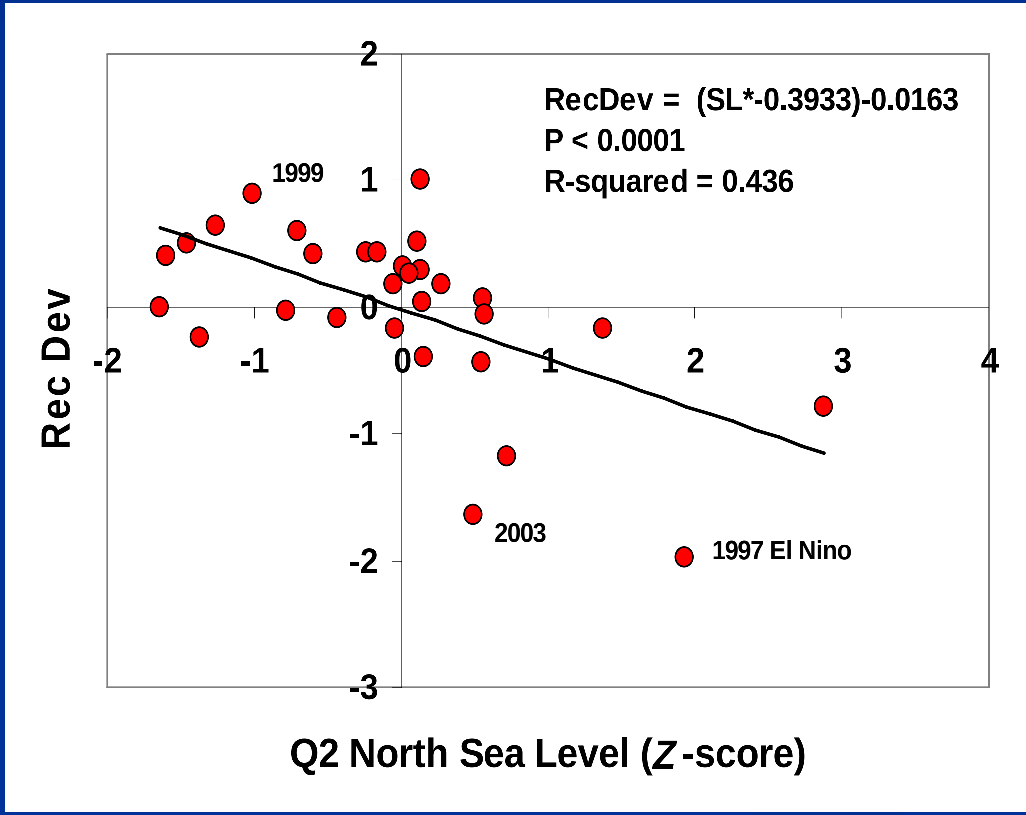
=

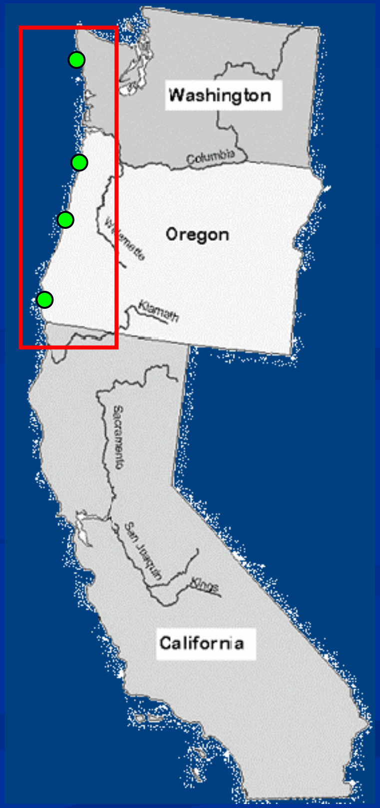
+

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



For sablefish, at Least Part of the Deviation Can Be Accounted for by Environment Effects; In This Case, Changes in Sea Level





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 into highly parameterized stock assessment models

Competing Method 1:
Direct calculation of expected recruitment

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

- Method 1: 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 deviations, so it is in addition to the variance "created" by the environmental effect; *Ey* is assumed to be measured without error

$\sigma_{Total} = \sqrt{\sigma_{Env} + \sigma_{Rand}}$

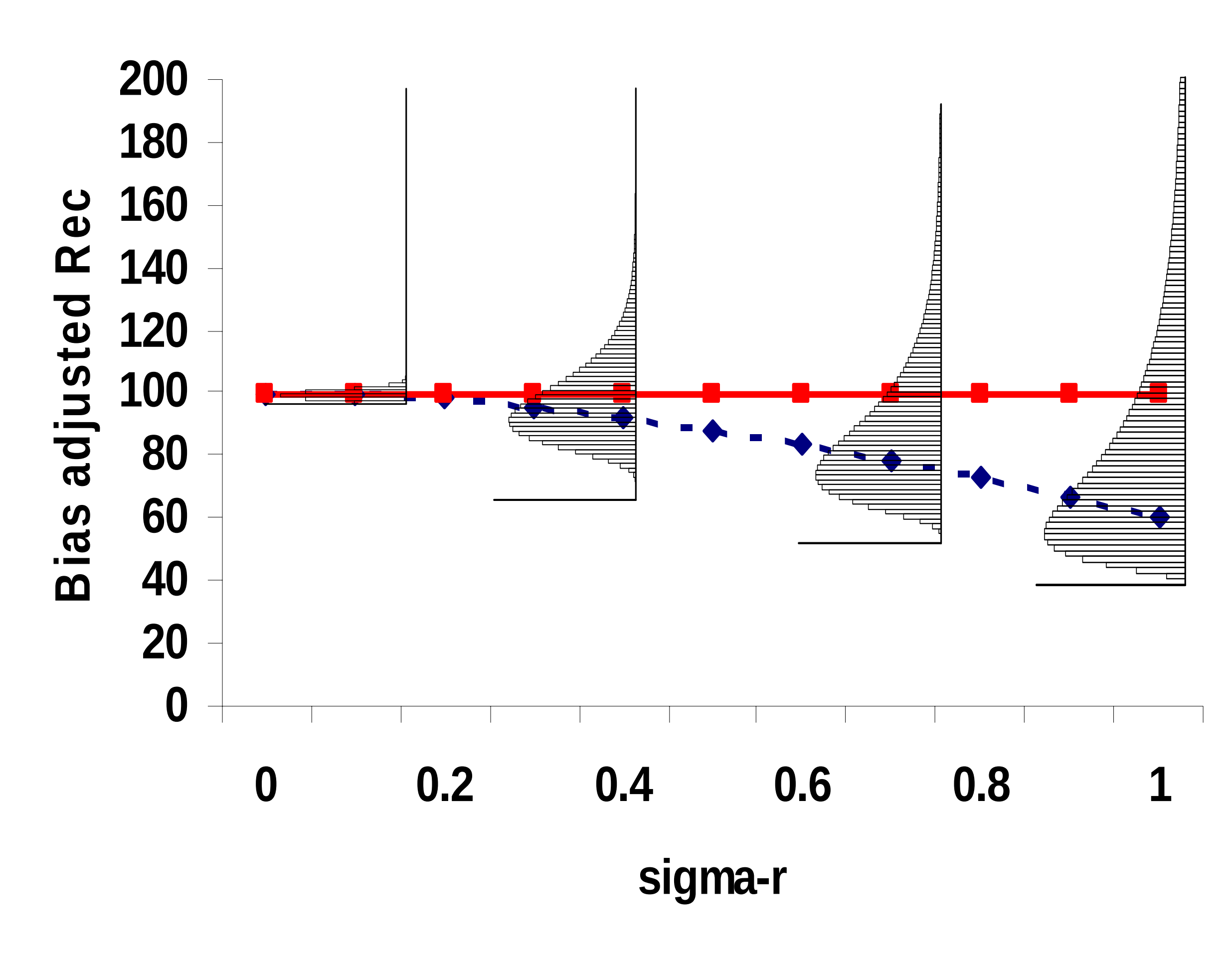
Modeling an Environmental effect on rec devs requires proper partitioning of total deviation

- 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 problem with this method is that the sigma-r is assumed to be the total sigma-r, even when a certain amount of the variation in recruitment is accounted for by the environmental link. Consequently, using the above equation will result in a sigma-r which causes an under-estimate of the bias adjustment, the median recruitment, and thus R0 and B0 (unfished levels)
- Env effect assumed measured without error

Consequences of the Problem: Increased sigma-r results in a decreased median recruitment due to bias adjustment



← Mean

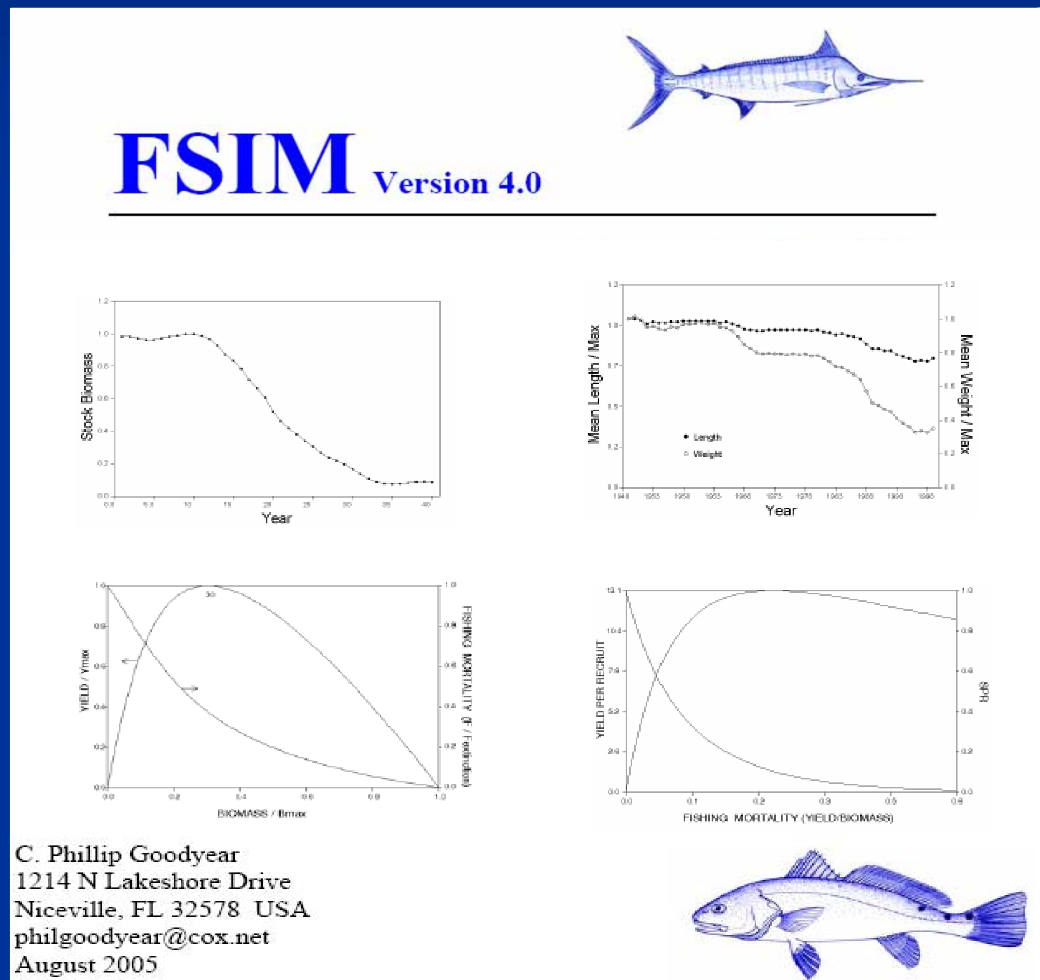
← Median (Bias adjusted) MaxLike tends to draw devs to this level

Competing Method 2: Use environmental data as an Age-0 Survey

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

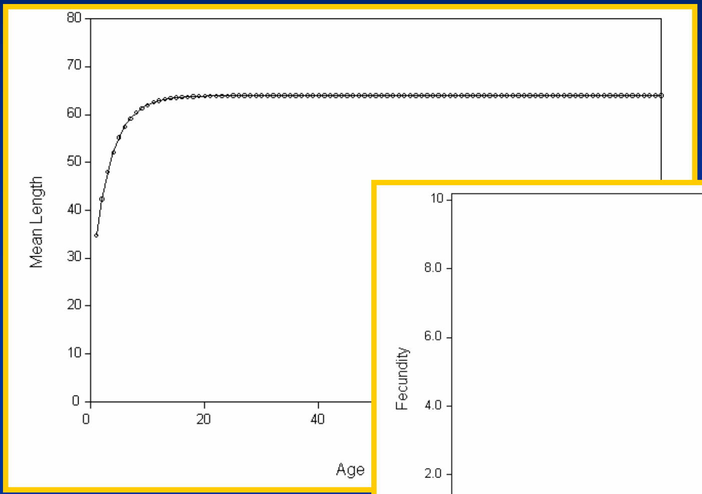
- Fit to the *Env* data is part of the objective function and thus contributes to the total likelihood of the model fit
- Allows *Env* data to have annual error associated with it
- *Env* effect is assumed to occur after any density dependence

Fisheries SIMulator (FSIM)
An Independent Platform

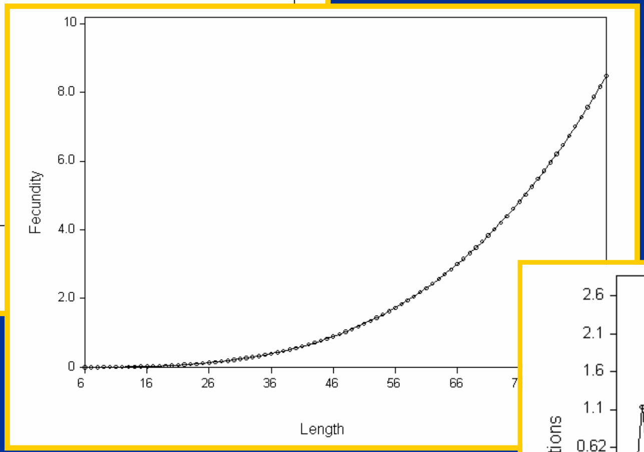

FSIM Version 4.0

C. Phillip Goodyear
1214 N Lakeshore Drive
Niceville, FL 32578 USA
philgoodyear@cox.net
August 2005

FSIM - Defined Biological Inputs

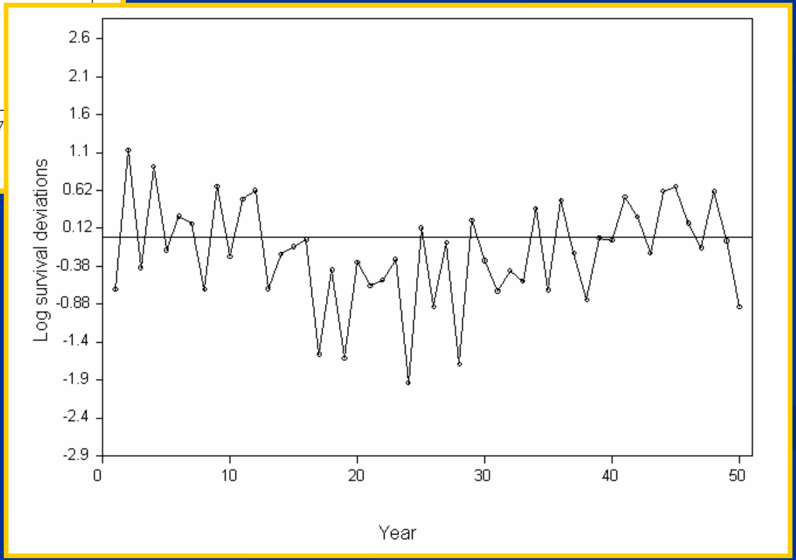


Growth



Fecundity

FISHERY DEFINED
- Selectivity
- Seasonality
- Min-max size
- Quota



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

Environmental Effect

Approach

- **Level 1** – Demonstrate that FSIM and SS2 can arrive at the same answers given relatively error free data.
- **Level 2** – Simulate environmental forcing and use the S/R function to model the effect (competing Model 1)
- **Level 3** – Simulate environmental forcing and use the environmental data as a survey, fix final selectivity at correct value (competing Model 2)
- **Level 4** – Simulate environmental forcing and use the environmental data as a survey, estimate final selectivity

Simulation uses sablefish biological parameters from last assessment

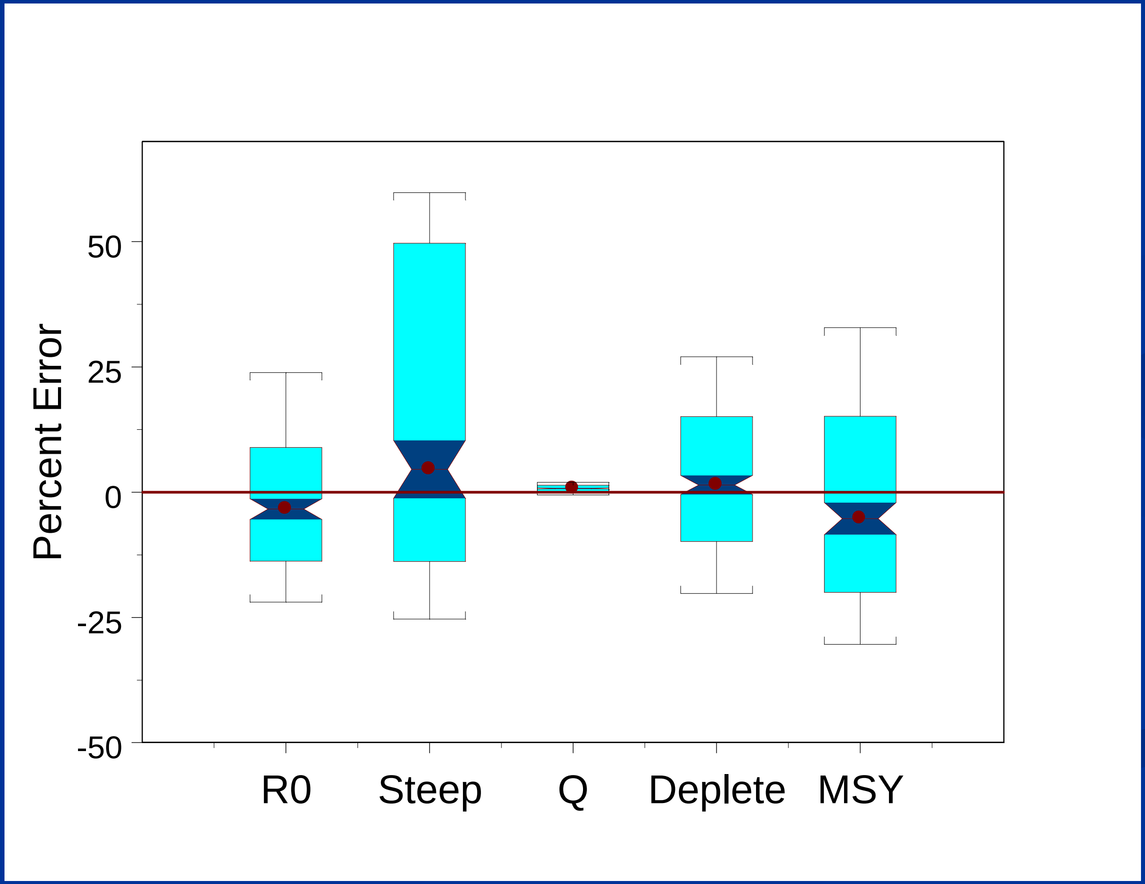
- Total of 100 ages and 100 platoons (growth morphs)
- FSIM seasonally adjusted to fit SS2 assumptions
- M = 0.07
- One fishery, one survey; Length/ages randomly sampled (5000 survey, 500 fishery per year)
- B-H type recruitment steepness = 0.61, ln(*R0*) = 9.33

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

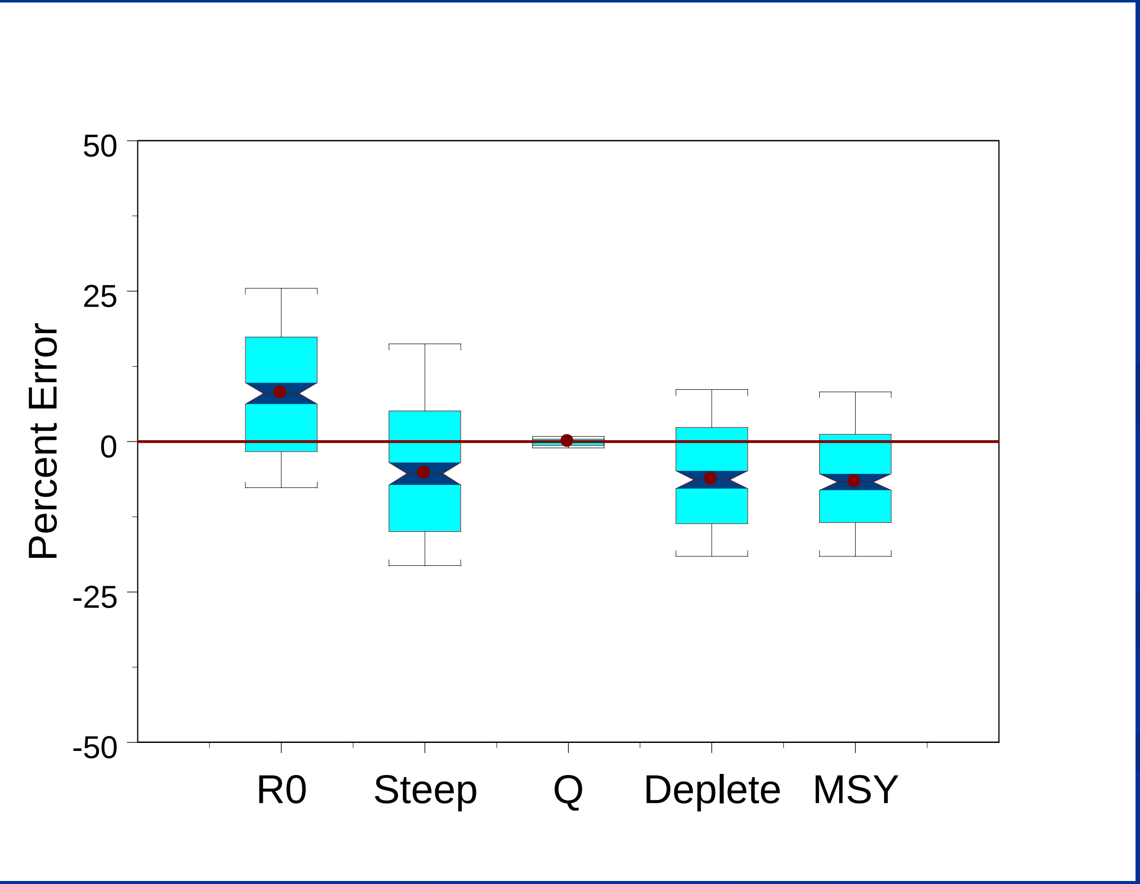
Level 1 - Calibration

FSIM and SS2 are capable of agreement given low error data



Level 2 – S/R Model

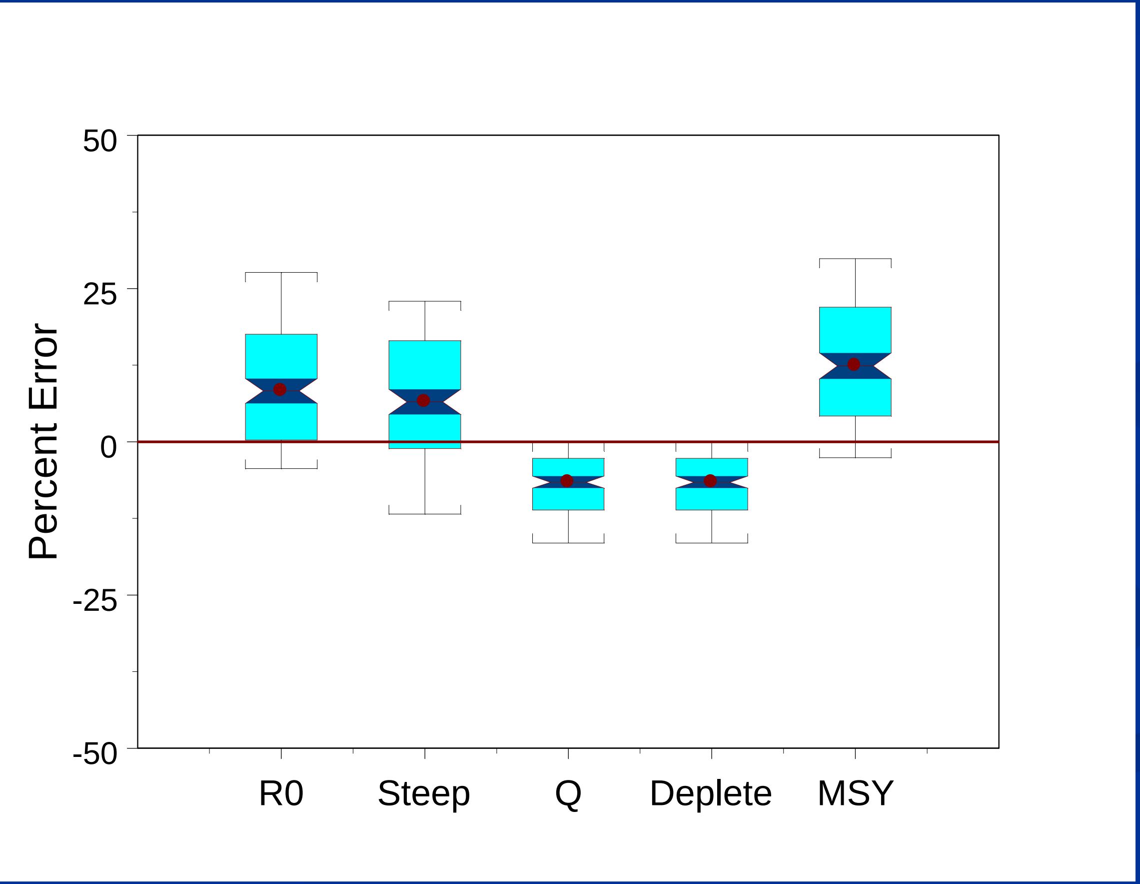
Reduced σ_R did indeed result in an over estimation of *R0*



Level 3 – Env as a Survey

Final Selectivity Fixed

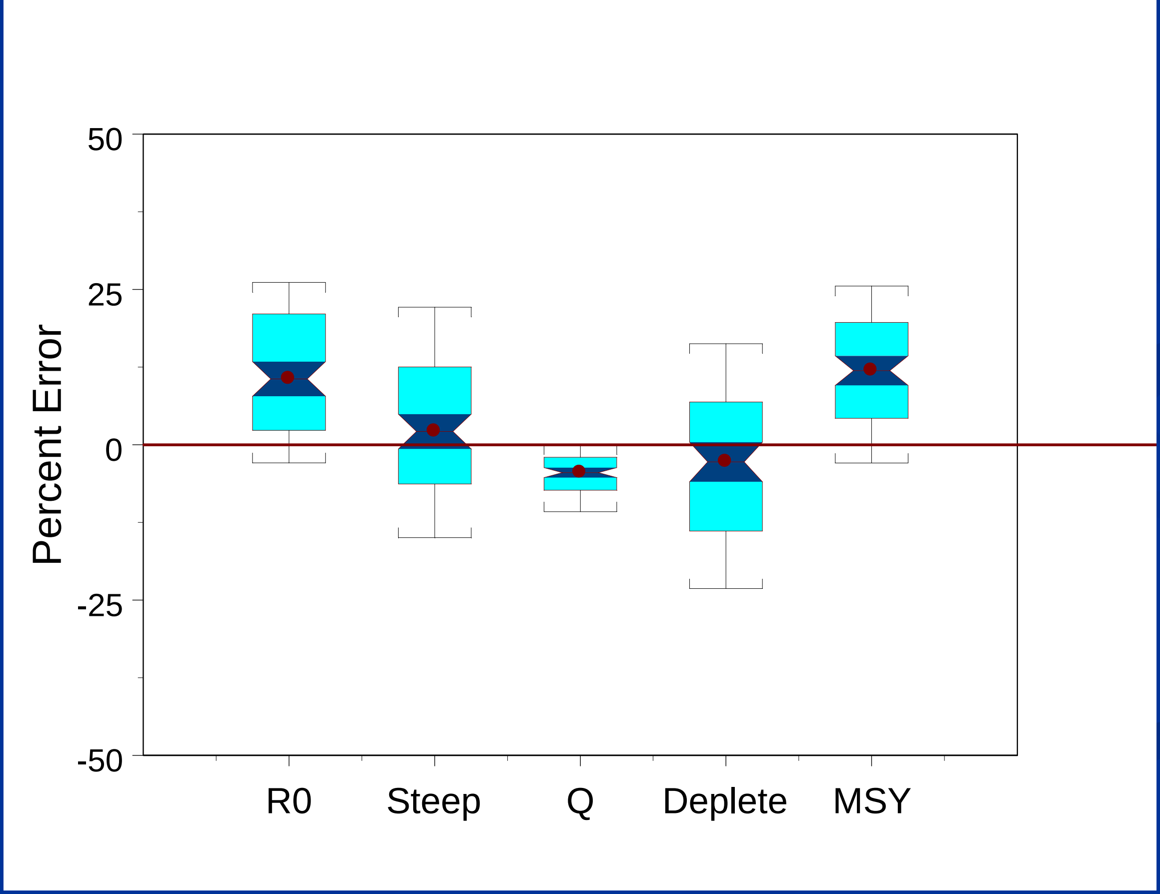
Bias was merely relocated to another parameter (i.e. either selectivity or *Q*)



Level 4 – Env as a Survey

Final Selectivity Estimated

Bias in R0 was not removed as expected by using environmental data as a survey



Conclusions

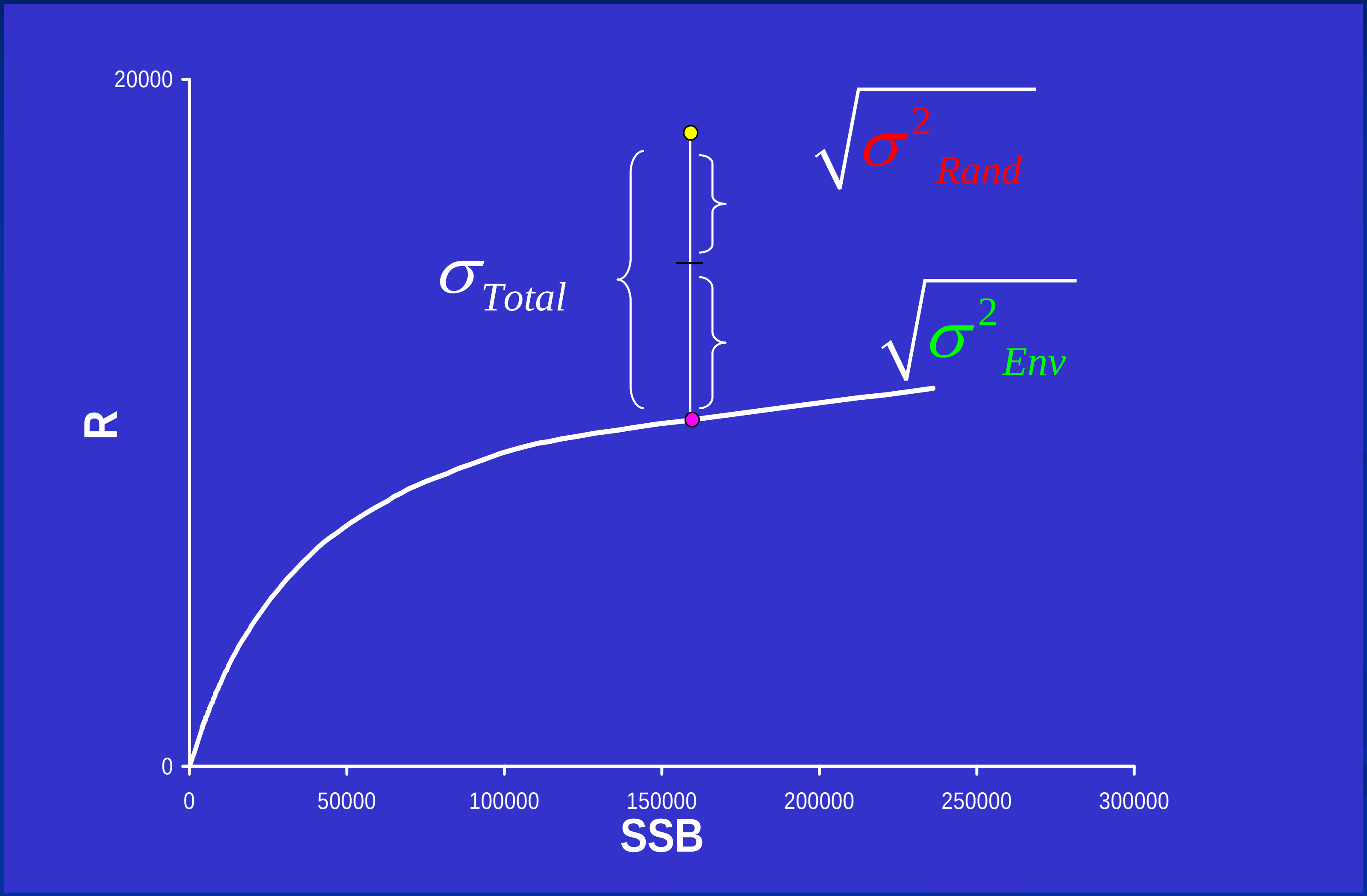
- The FSIM simulator is a viable tool for testing the SS2 stock assessment model
- The importance of incorporating environmental data into the stock assessment is directly proportional to the strength of the signal and amount of recruitment variability that can be attributed to environmental effect
- While a stock assessment model can be written to utilize environmental data, careful consideration must be given to the resulting behavior of the other standard parameter estimates
- For now, this (ongoing) work should be viewed more specific than general. Each situation should be simulated on it's own to capture the specific details of the potential biases and errors inherent in that modeling exercise. Don't assess it if you can't simulate it.

There are at least 3 situations that can benefit from environmental input:

- Environmental variability causes a large deviations in recruitment, but conventional fishery and survey data are not good enough to see this variability clearly, so including environmental data helps the model estimate the correct time series of recruitment. On the other hand, the environmental data are just redundant if the fishery and survey age comp data already allow good estimation of the recruitment time series
- Fish recruit to the fishery at a young age, but there are no surveys of young fish to estimate the recent levels of recruitment
- There is a long-term signal in the environment that affects recruitment, but this trend is confounded with a one-way trip in the spawning biomass. So including environmental data helps the model estimate the correct S-R relationship (steepness).

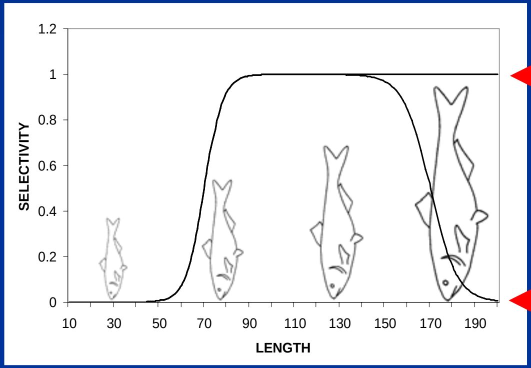
Thank you!

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



Gear Selectivity & Catchability

1. *Selectivity* – The proportion of fish, by length or age, that are susceptible to the gear



Asymptotic

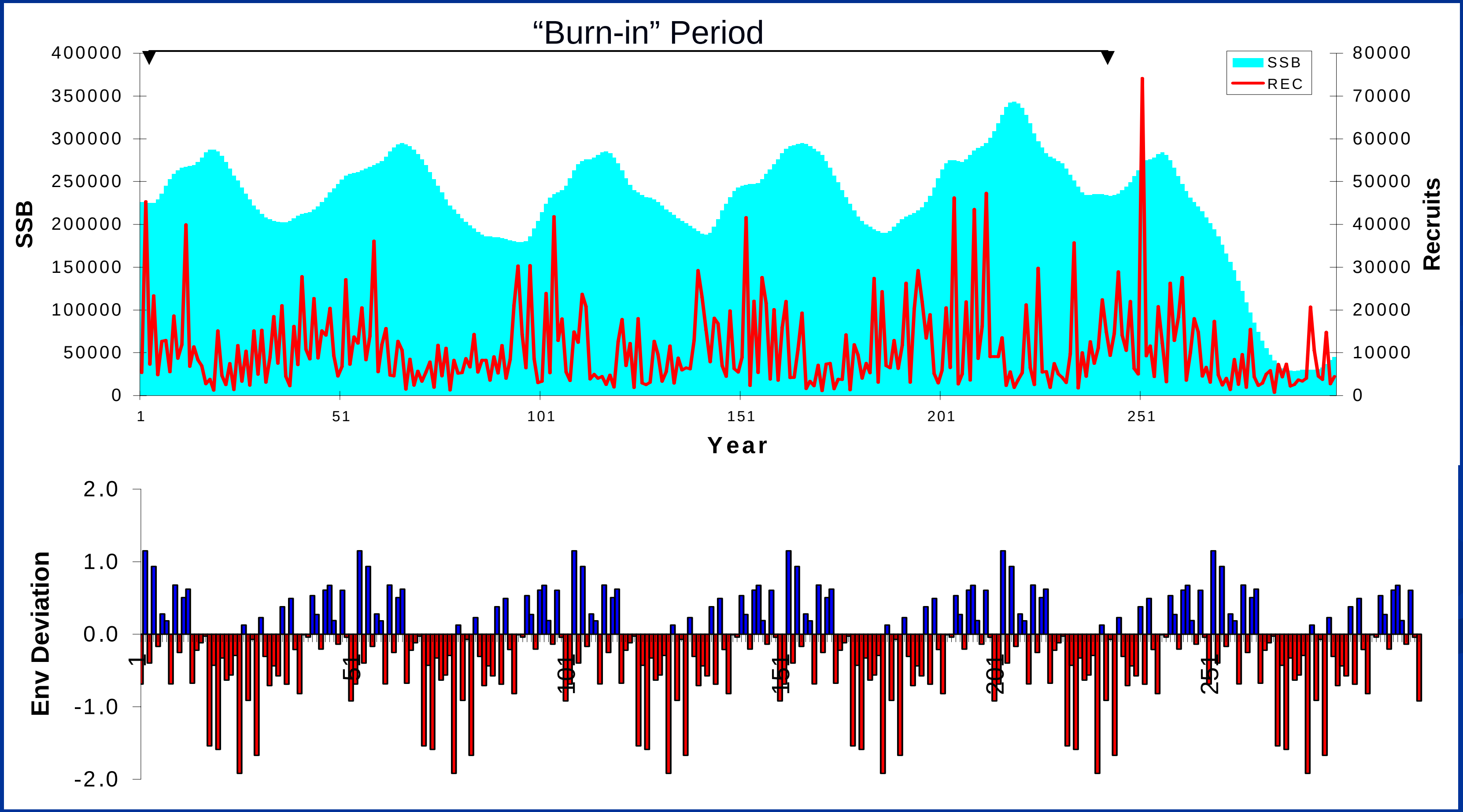
"Dome-shaped"

2. *Catchability (Q)* – The efficiency of the gear

*Catch = q * Biomass*

3. Selectivity and Catchability dictate estimated stock size and are ***highly correlated***

Typical simulated time series that includes an environmental effect



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*
- Dynamic *R0* and *B0* = mean of assessment time series values in the absence of fishing. Not as accurate as FSIM values as they are dependent on SS2 parameter value estimates
- 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

Level 4 – Same as Level 1 except estimate *R1*

- FSIM *ENV* link = off, $\sigma_R = 0.89$
- SS2 *ENV* link = off, σ_R fixed at 0.89
- Estimate *R1*
- All ages in survey fully selected
- Fitted response variables: (growth), *R0*, steepness, *Q*, recruit devs, some fishery selectivity parms; compare to true values
- Compare various *R0*/*B0* calculations to the *R0*/*B0* from the burn-in period

Parsing out the source of variation in the recruitment deviations

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