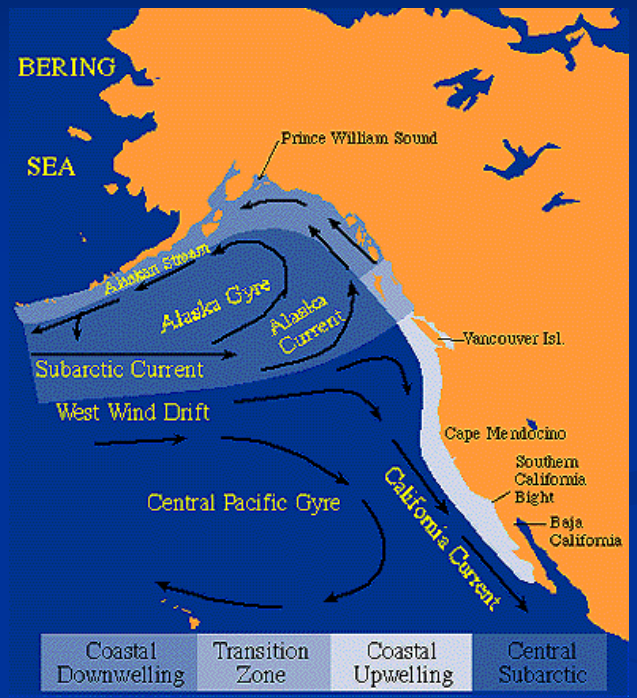
The Potential Effects of Including/Excluding Environmental Factors into Stock Assessments



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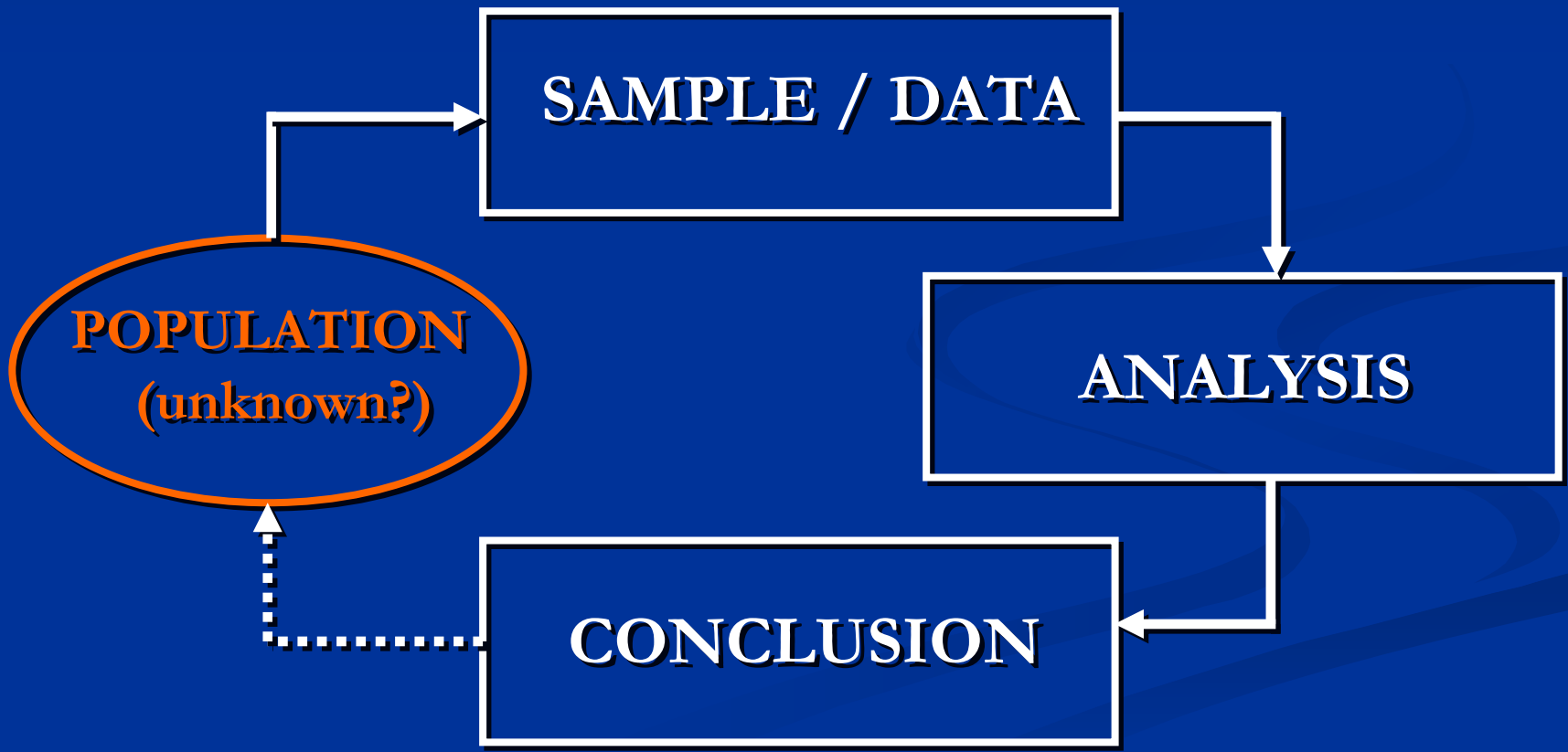
Basis of the Study

- The PICES Working Group 16 report on the impacts of climate and climate change concluded that climate is a major factor affecting the productivity of virtually all key commercial species
- However, nearly none of the stock assessments conducted on these species explicitly include climate effects in the assessment model
- The objective of this investigation is to evaluate the potential effects that omitting environmental variability in an assessment has on the estimation of recruitment parameters, stock status, and the conservation benchmarks used to manage a stock

Approach

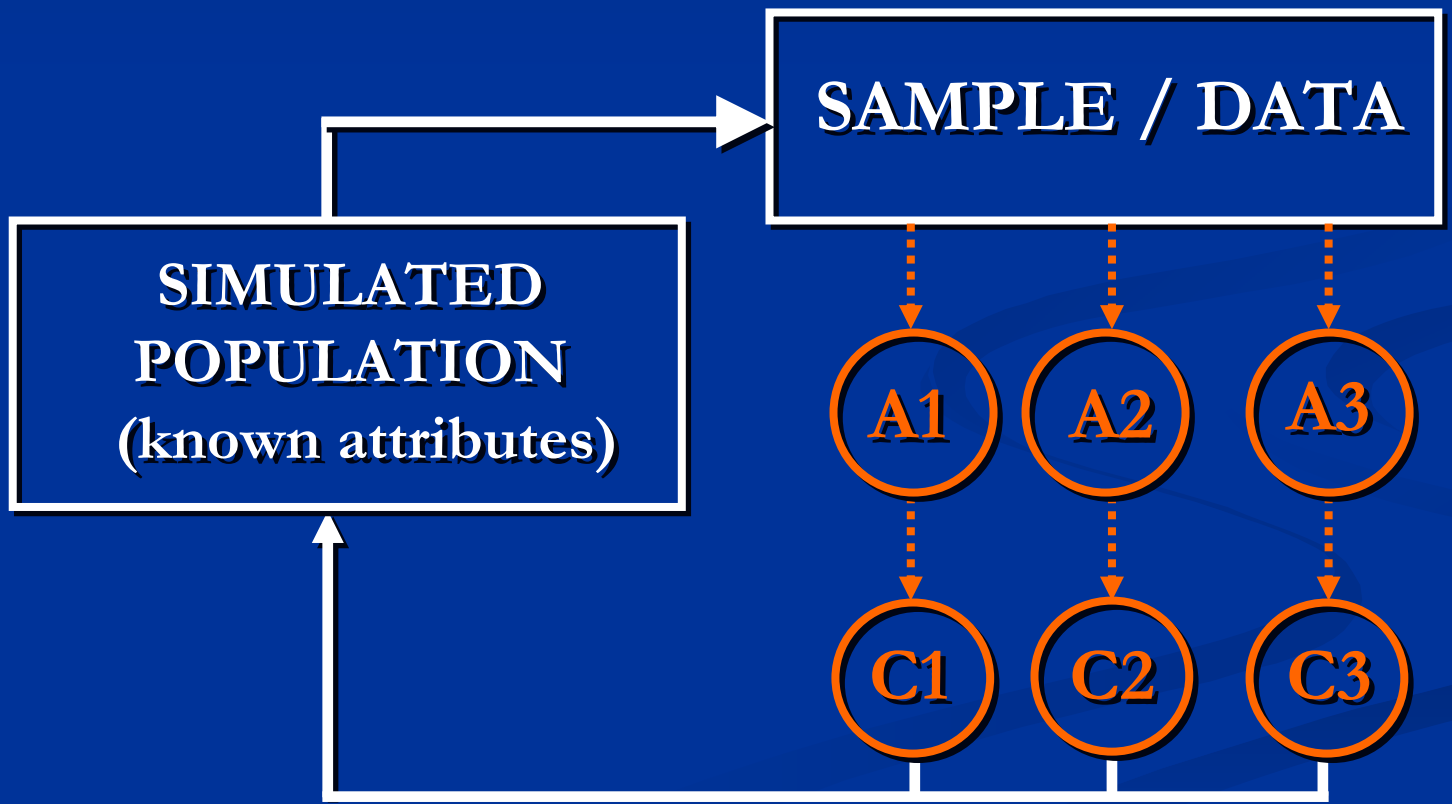
- MSY is estimated from spawner-recruitment time series by estimating the curvature of the relationship between recruitment and spawner abundance
- Good estimates can only be obtained if there are sufficient number of observations of recruitment over a reasonably broad range of spawner abundance and if there is not too much year-to-year variability in recruitment
- Inclusion of environmental information can help by allowing the analysis to factor out long-term trends in the environment that occur on the same time scale as changes in spawner abundance, and to explain some of the year-to-year variability in recruitment, thus allowing the underlying spawner effect to be seen more clearly

Standard Approach To Gaining Inference About a Population

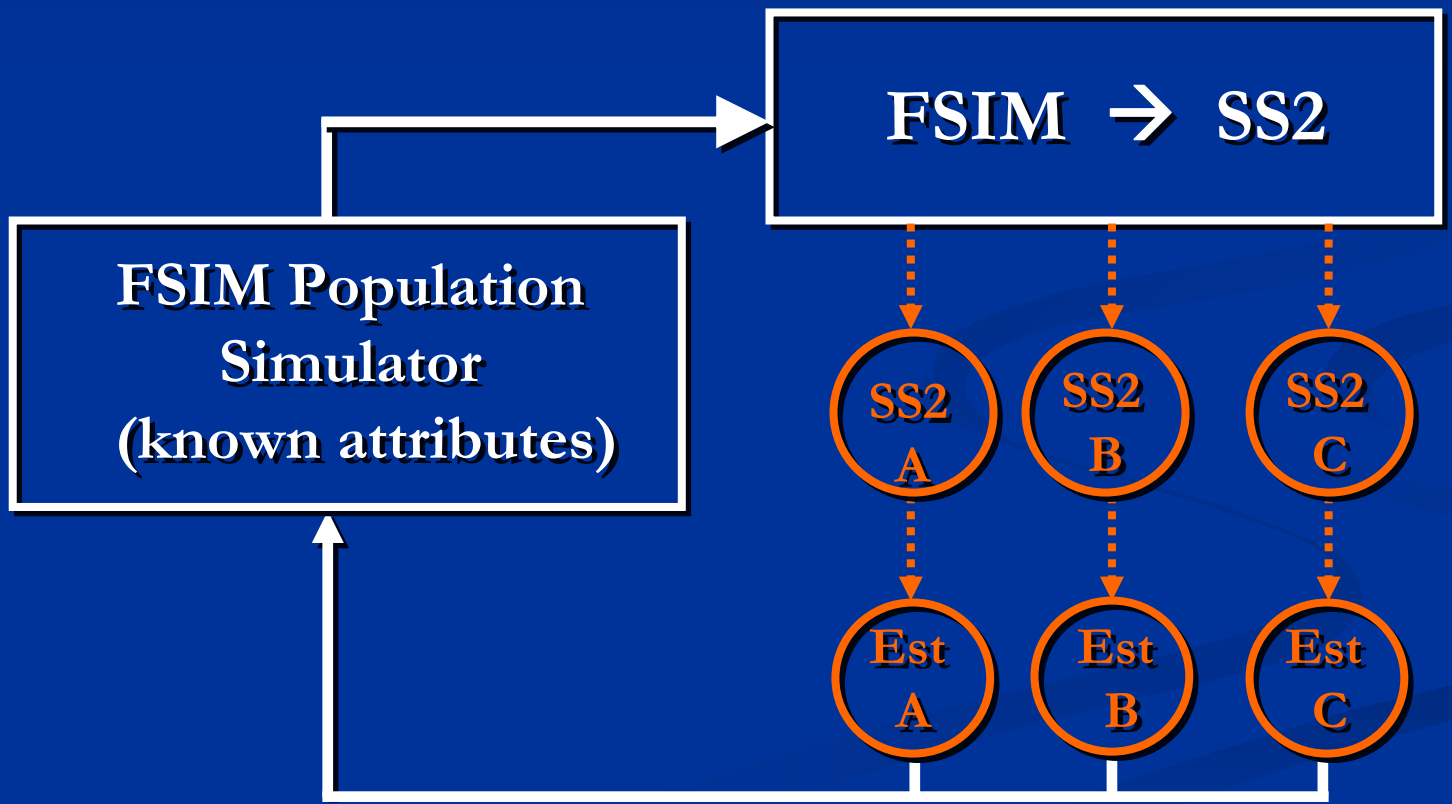


The Simulation Approach:

To find a solution you must first understand the problem

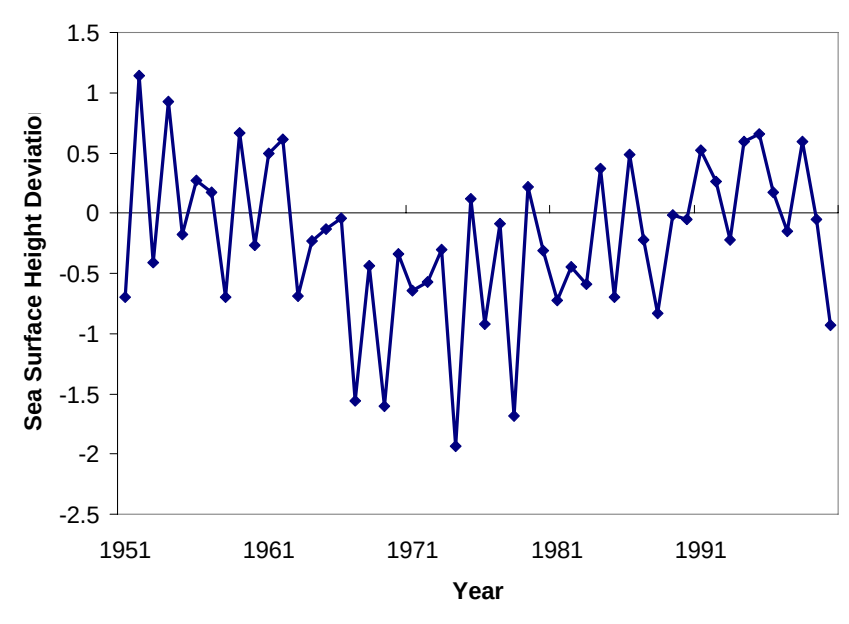


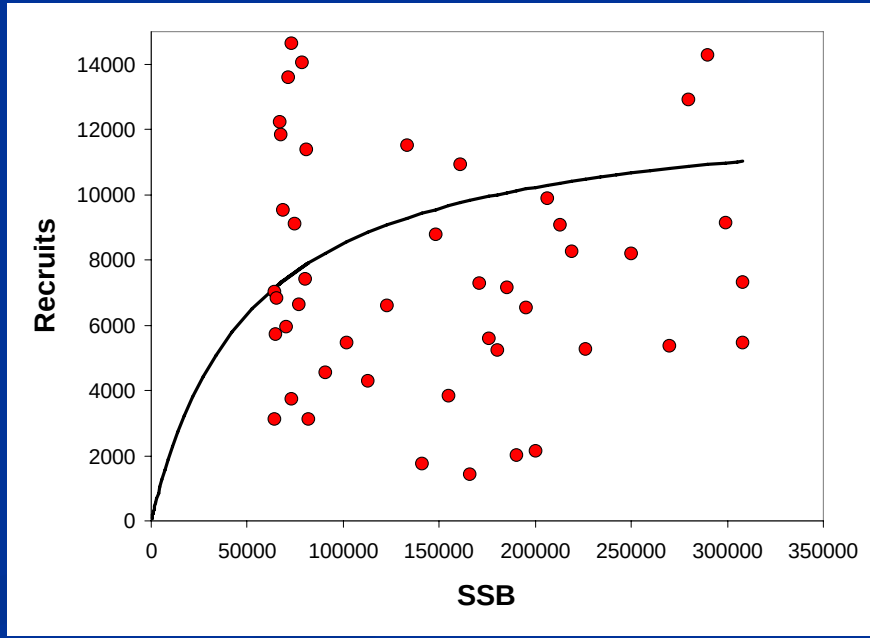
Using the Independent Platform FSIM to Generate Simulated Data for SS2 Analysis



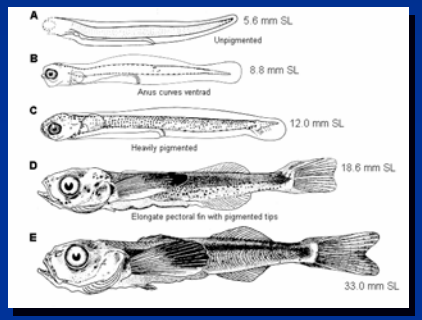
FSIM - Defined Biological Inputs

- Biological parameters (growth, fecundity, S/R relation, etc.)
- Fishery and Survey characteristics (selectivity, catchability, etc.)
- Samples of ages and lengths are collected from survey and fishery
- Recruit survival can be made a function of an environmental effect





Sablefish Recruitment: The Conceptual Model



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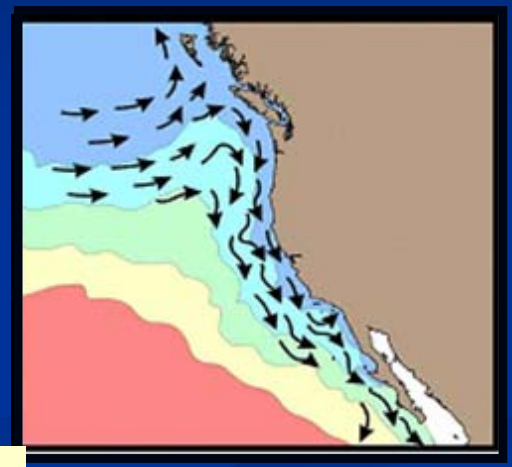
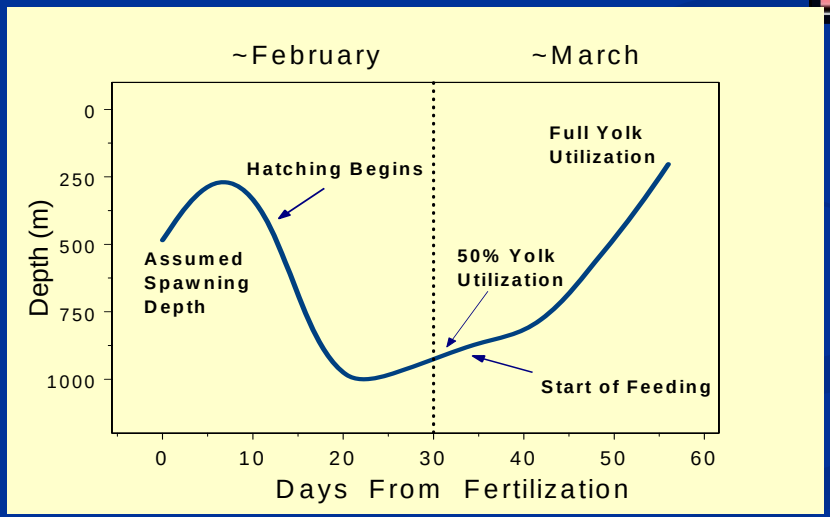




(Reproduced from McFarlane and Beamsih, 1992)

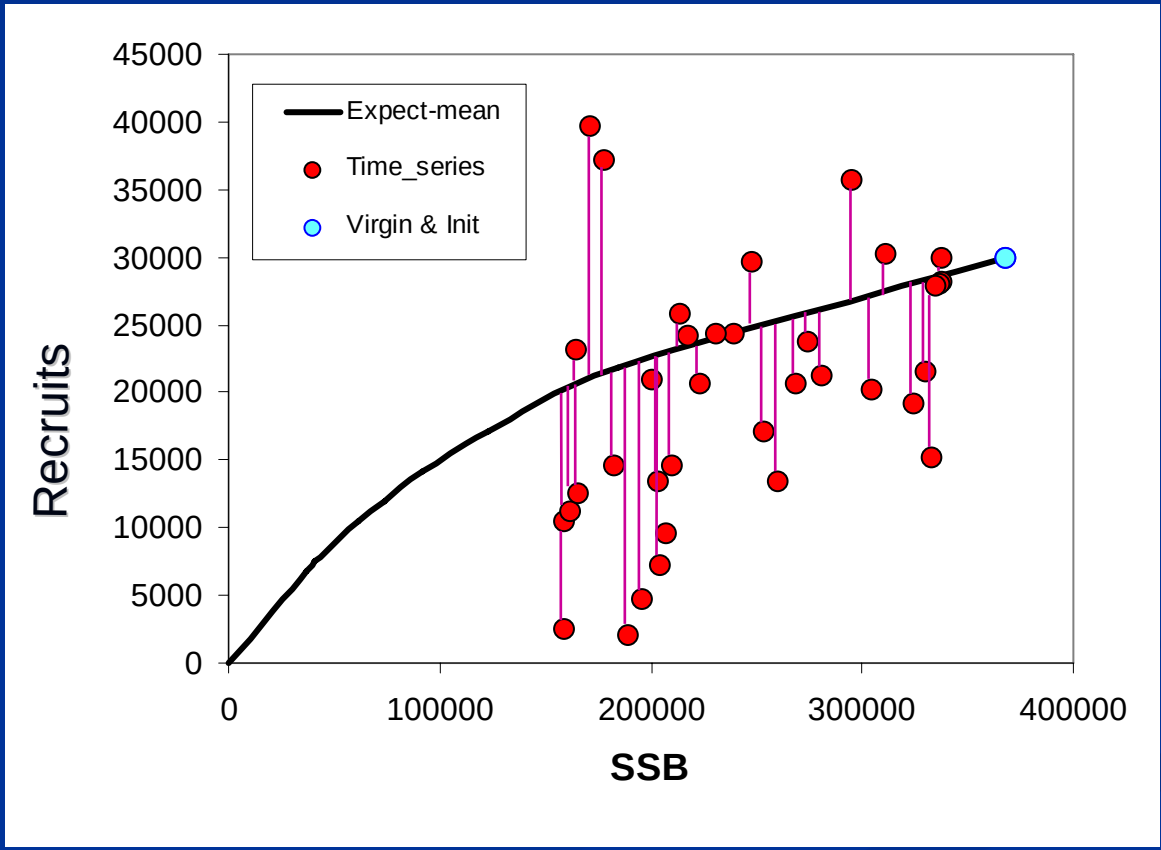
Annual Variation Accounted for by Spawning Stock Biomass

$$\hat{R}_y = \frac{4hR_0S_y}{S_0(1-h)+S_y(5h-1)}$$

Where the estimated parameters are:

- h = steepness*
- R_0 = virgin / initial recruitment*
- S_0 = virgin / initial spawning biomass
- S_y = Spawning stock biomass in year t

The Classic Problem: SSB Does Not Account for a Significant Portion of Total Variability in Recruitment



Environmental Effect Modifies the Initial Estimate

$$R_y = \hat{R}_y e^{(\beta E_y)} e^{-0.5\sigma_R^2} e^{\tilde{R}y}$$

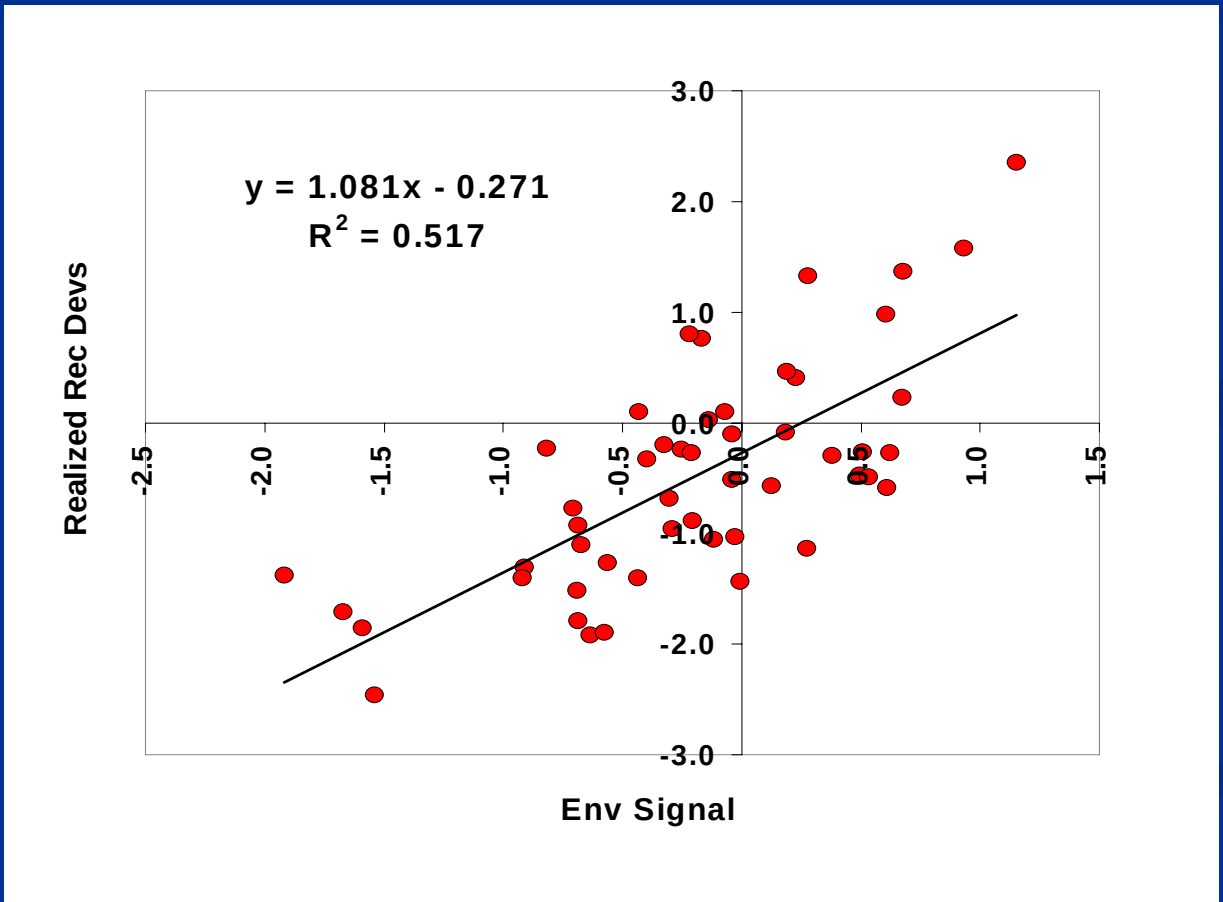
Where:

$e^{(\beta E_y)}$ **are the additional parameters that modify the initial estimate according to the environmental series**

$e^{-0.5\sigma_R^2}$ **is the bias correction for the lognormal distribution of recruits scaled by sigma-r**

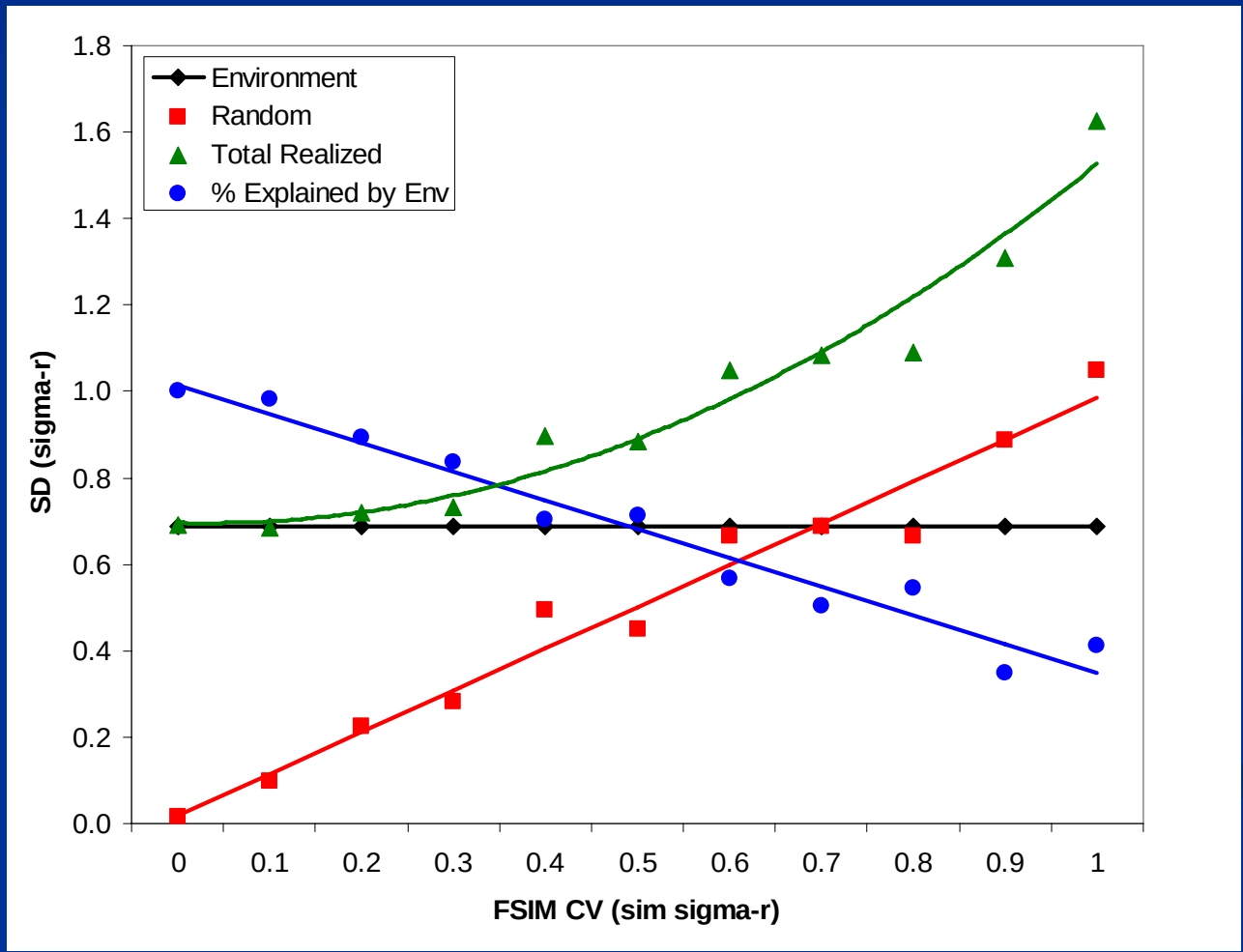
$e^{\tilde{R}y}$ **is the remaining lognormal deviation in year *y***

The R^2 is the Percent of the Deviation Accounted for by Env



Parsing Out the Recruitment Deviations

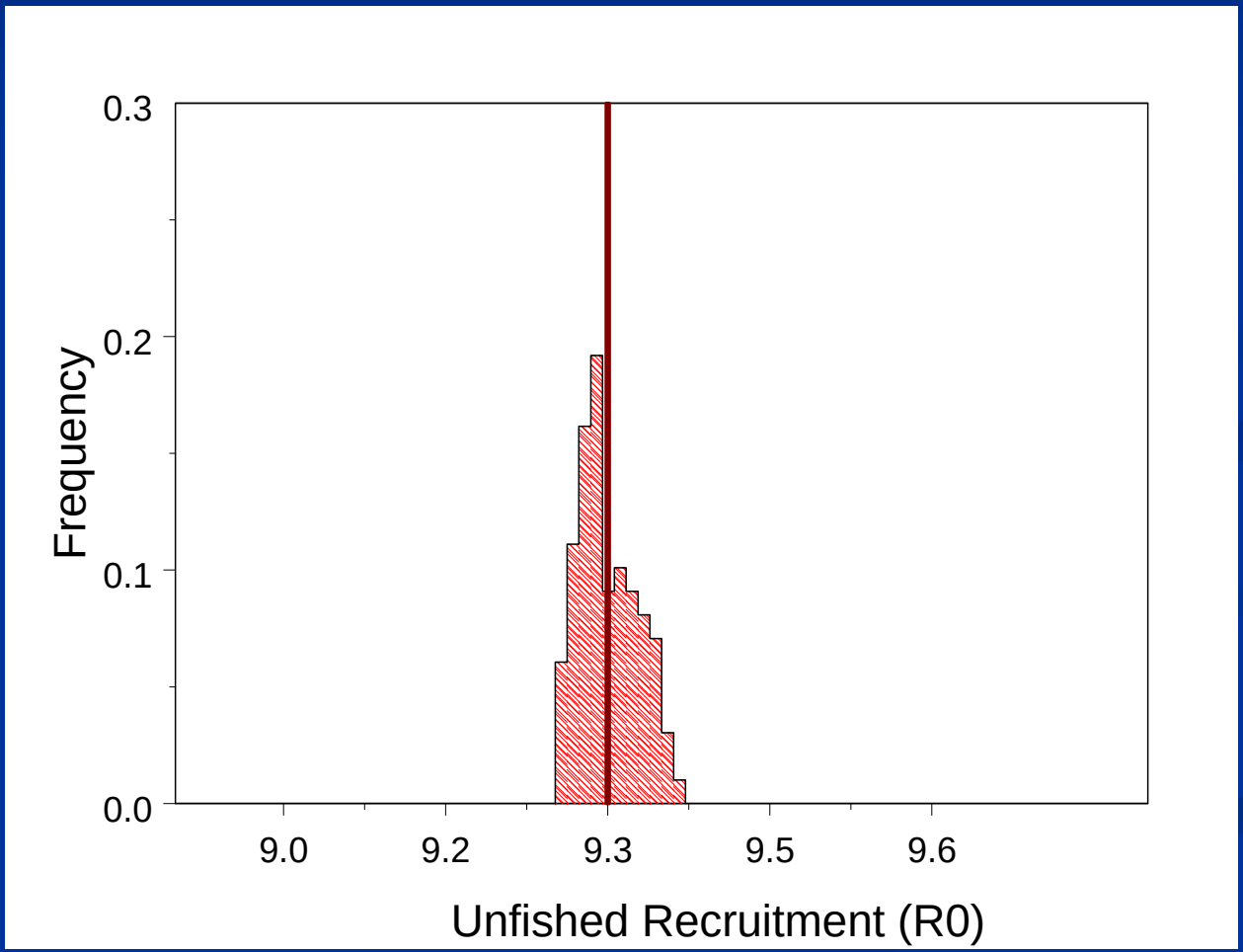
$$\sigma_{Total} = \sqrt{\sigma_{Env}^2 + \sigma_{Rand}^2}$$



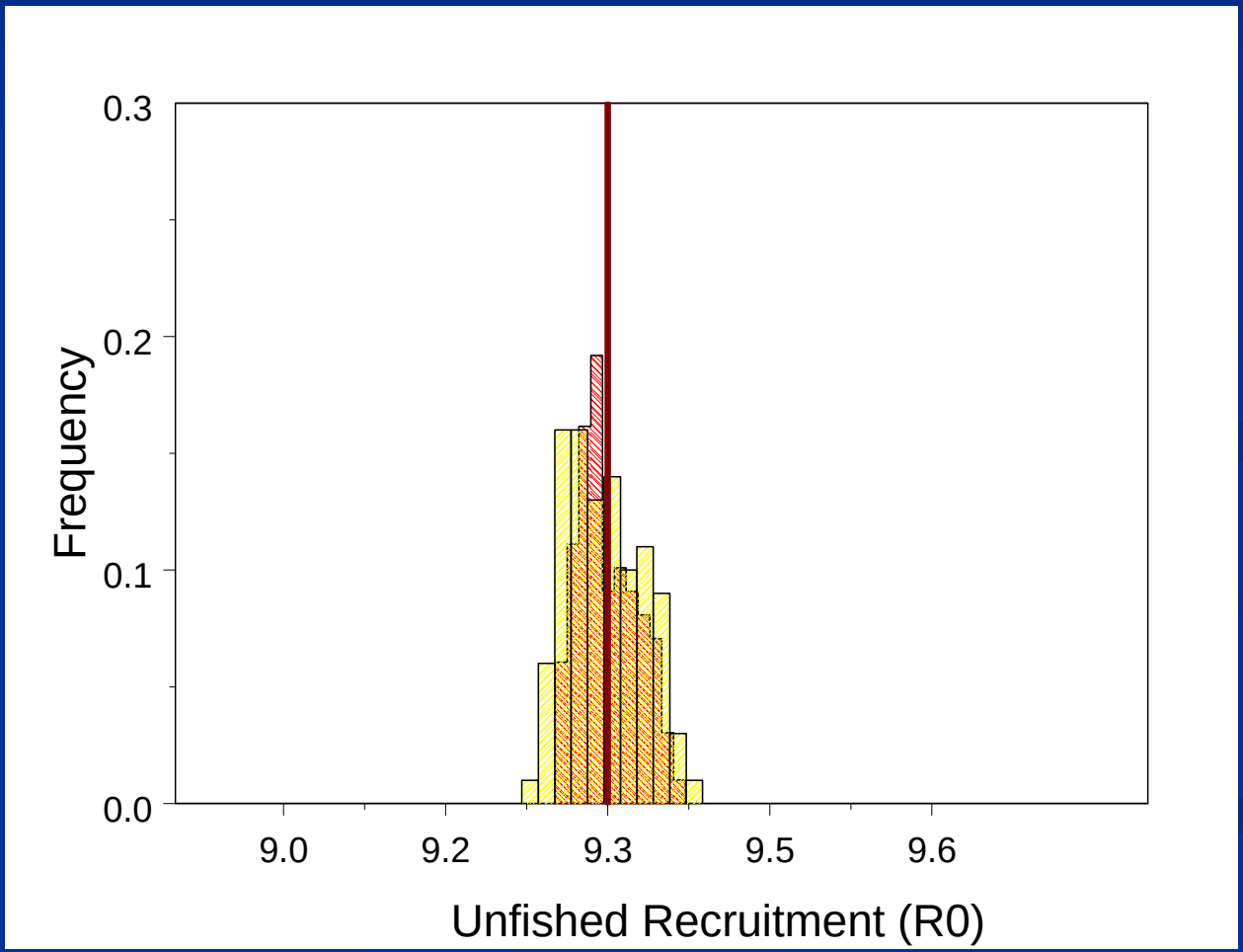
Step 1: Ensure the Two Models were Capable of Unbiased Agreement

- The first step was to ensure that SS2 was capable of reproducing unbiased estimates of FSIM parameter values
- This was accomplished by starting with mostly fixed/correct parameter values in SS2 and requiring increased levels of fitting
- Assumed no environmental effect and the annual recruitment deviation was kept low (sigma-r = 0.20)

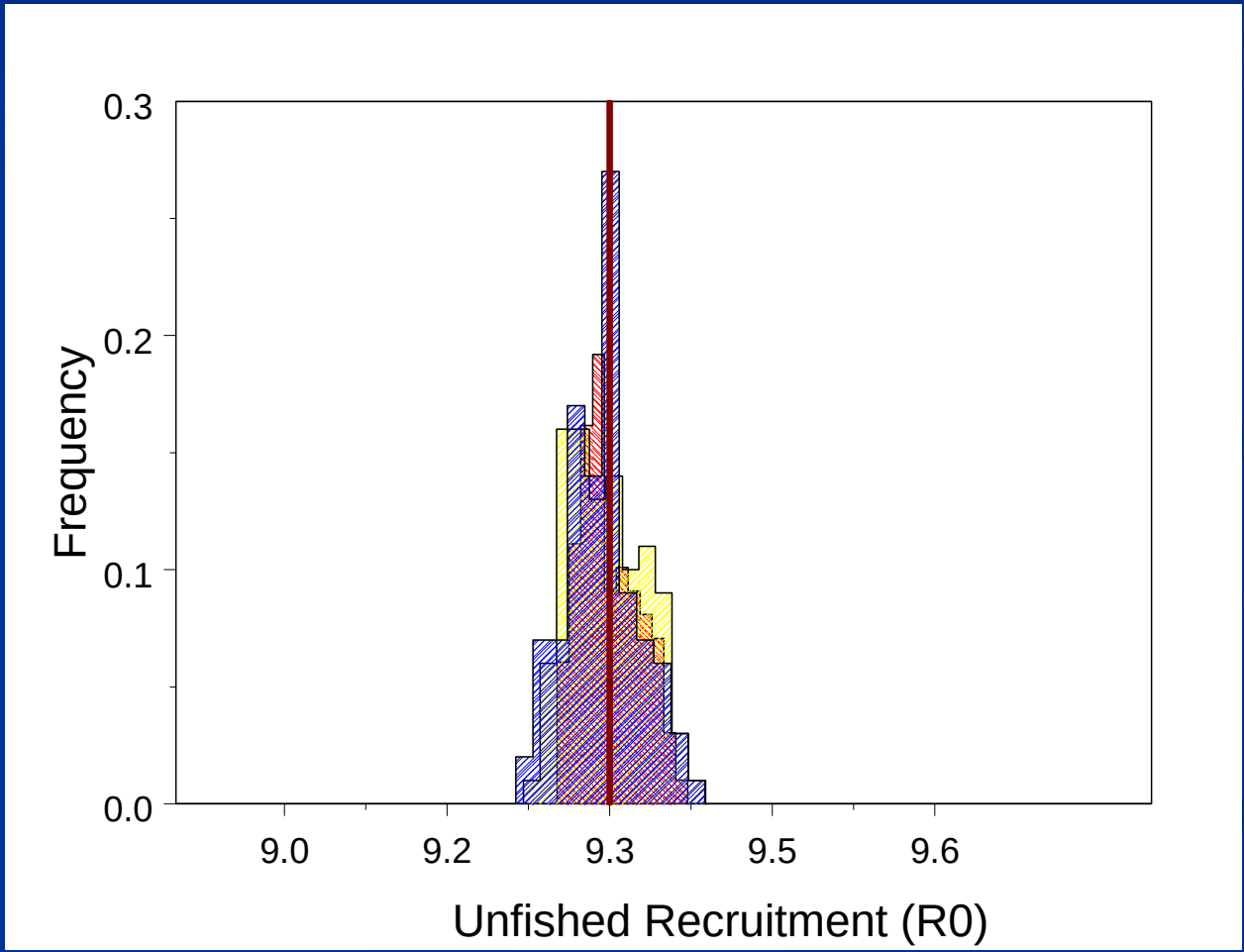
Along with Annual Recruitments Devs, Estimate only *R0*



Along with Annual Recruitments Devs, Estimate *R0* and Steepness



Along with Annual Recruitments Devs, Estimate *R0*, Steepness, and Survey *Q*



Step 2: Add Simulated Env Effect and Biologically Realistic Variability

1. Annual recruitment deviation was increased to a more realistic level (sigma-r = 0.85)
2. An env effect was added to account for ~62% of the total recruitment variation (then increased to ~70%)
3. The effect of omitting env effect

   (sigma-r = 0.85, env link = 0)

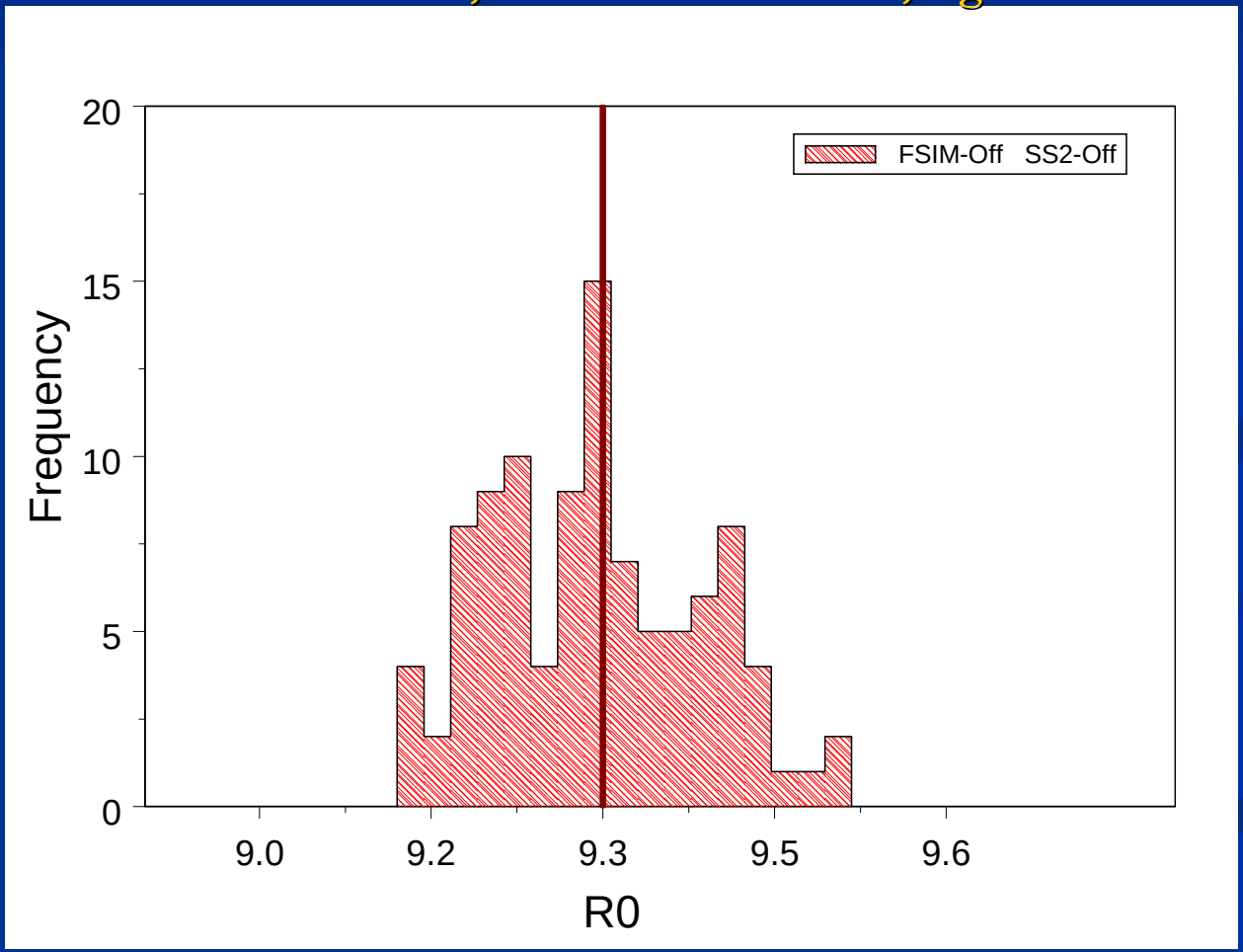
   versus explicitly modeling the env effect

   (sigma-r = 0.76, env link = estimated)

   on estimates of *R0* and steepness was evaluated

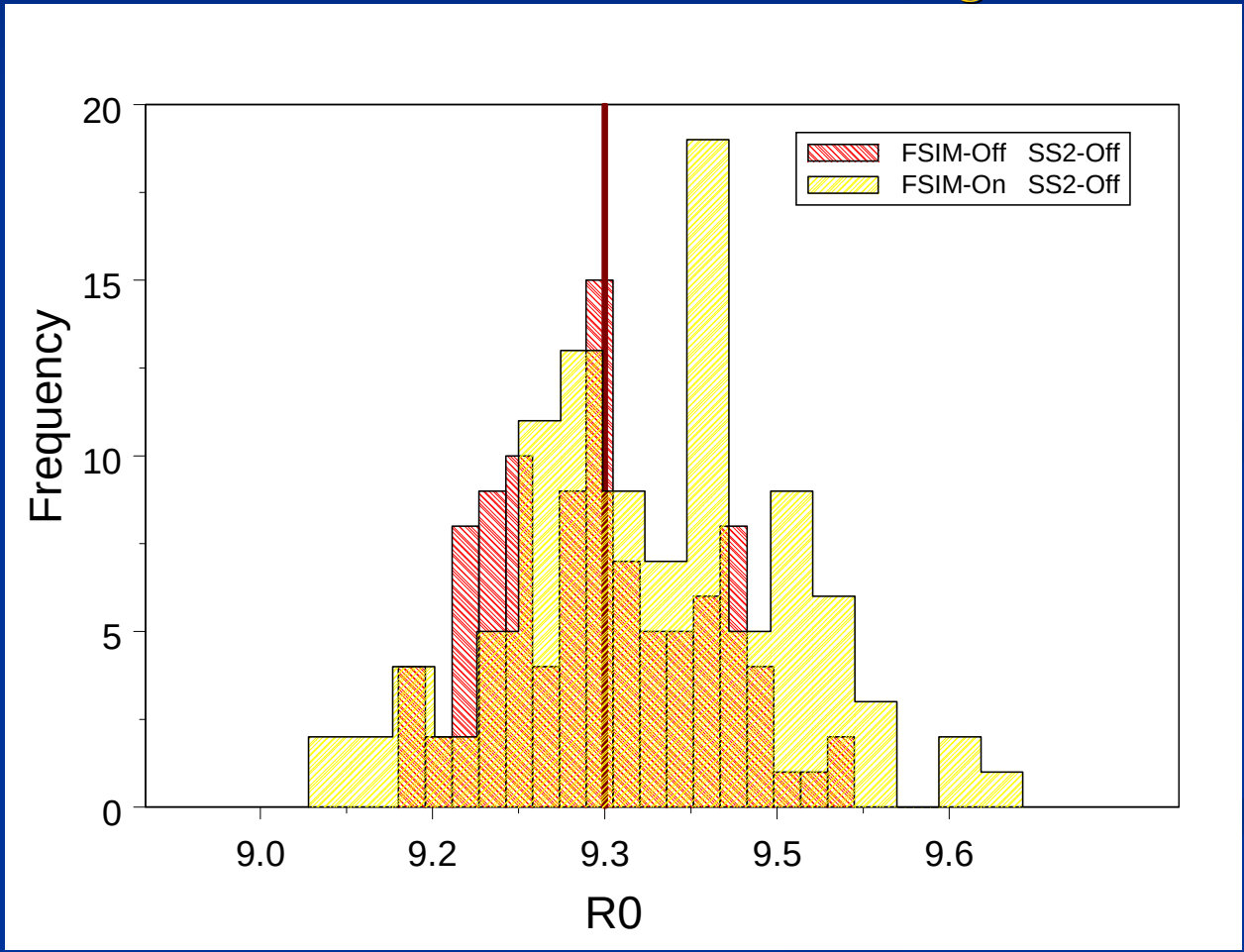
Omitting the Env Effect from Both Models Resulted in Good Agreement

FSIM Env Effect=Off, SS2 Env Effect=Off, sigma-r = 0.85



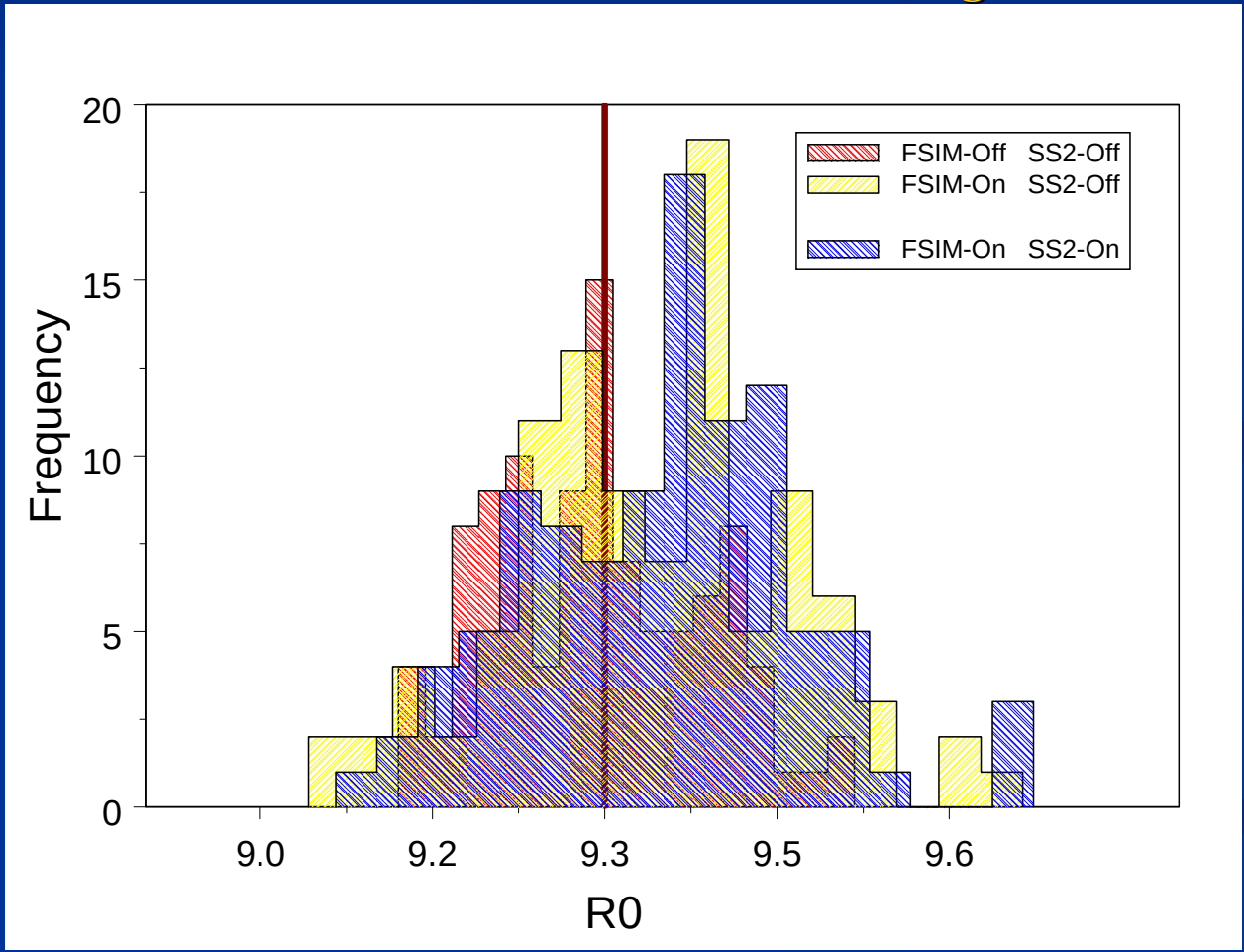
Adding the Env Effect to FSIM But Not SS2 Resulted in Poor Agreement

FSIM Env Effect=On, SS2 Env Effect=Off, sigma-r = 0.85



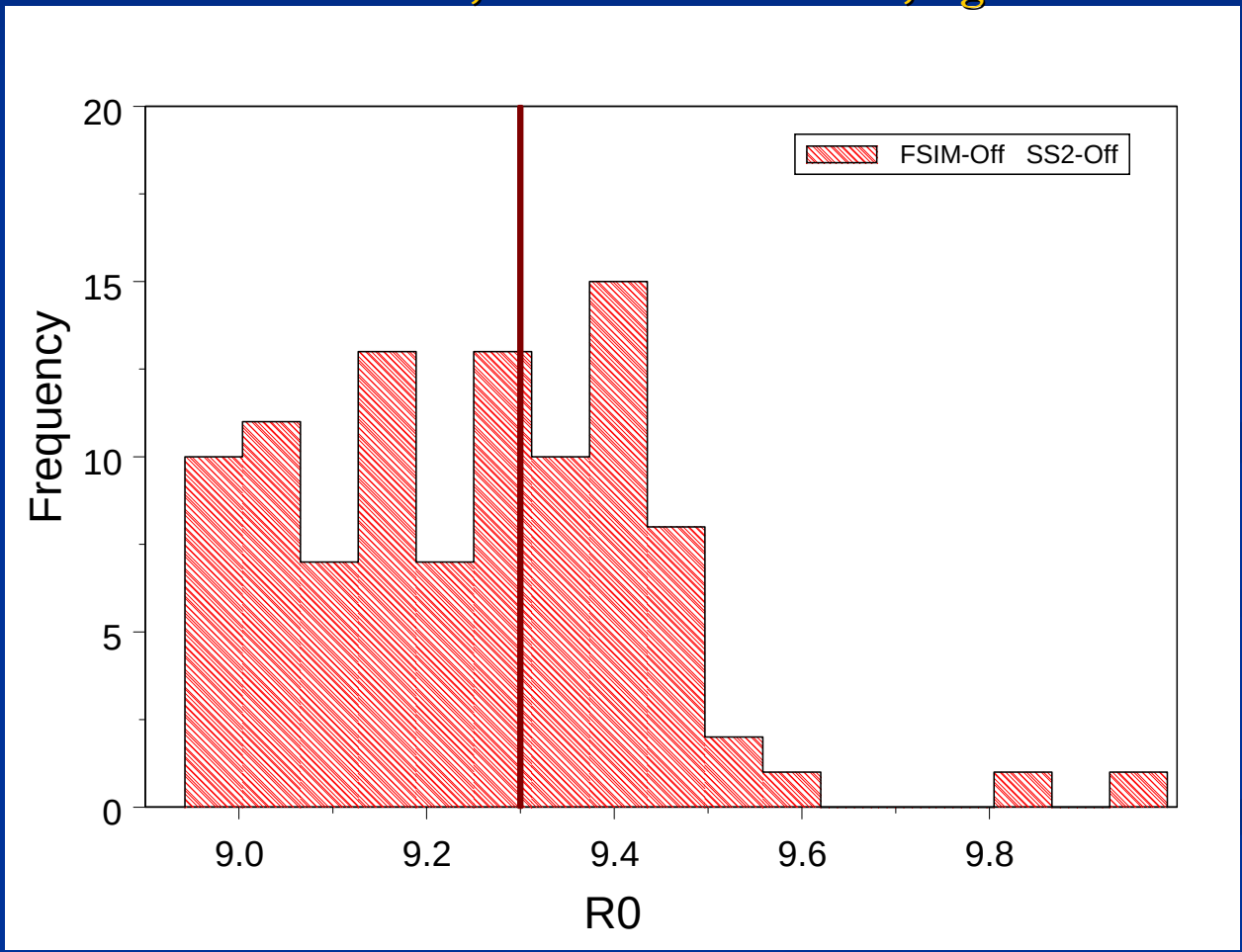
Adding the Env Effect to FSIM and SS2 still Resulted in Poor Agreement

FSIM Env Effect=On, SS2 Env Effect=On, sigma-r = 0.76



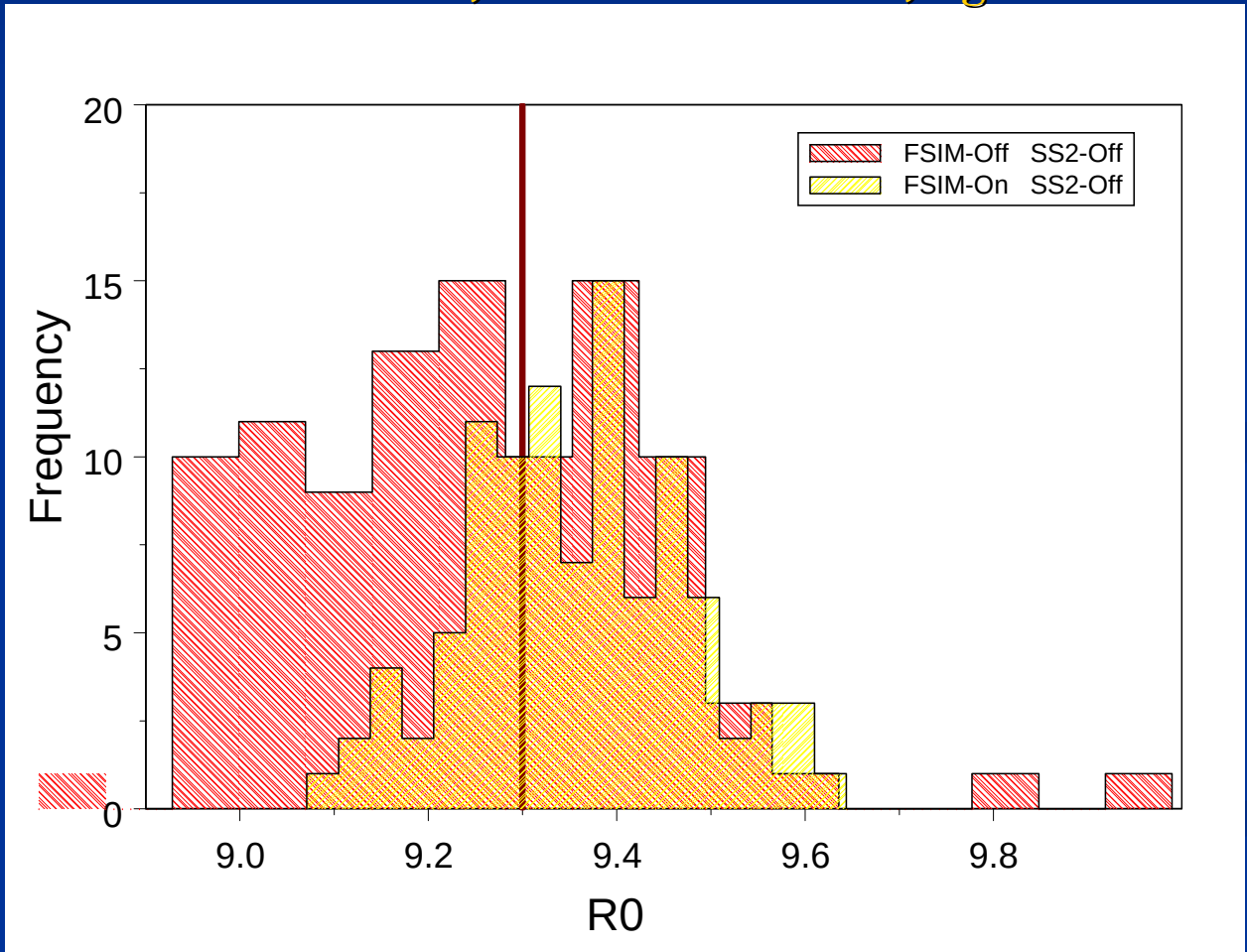
Increase Env accounting to ~70%

FSIM Env Effect=Off, SS2 Env Effect=Off, sigma-r = 0.89



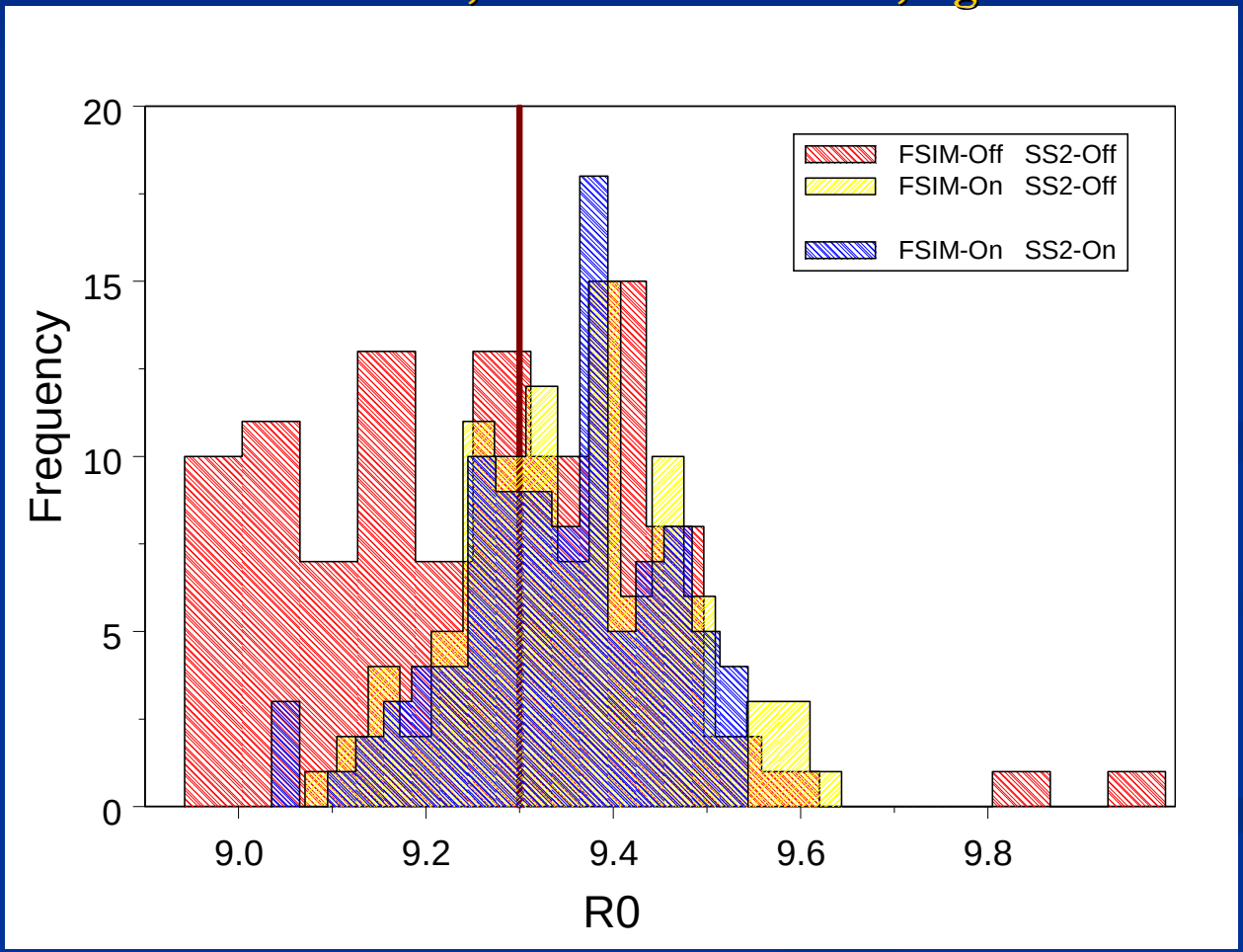
With FSIM ENV on and SS2 off R0 over-estimated

FSIM Env Effect=On, SS2 Env Effect=Off, sigma-r = 0.50



With FSIM ENV on and SS2 on R0 Still Over-Estimated

FSIM Env Effect=On, SS2 Env Effect=On, sigma-r = 0.50



Omitting the Env Effect from Both Models Resulted in Bounded Steepness

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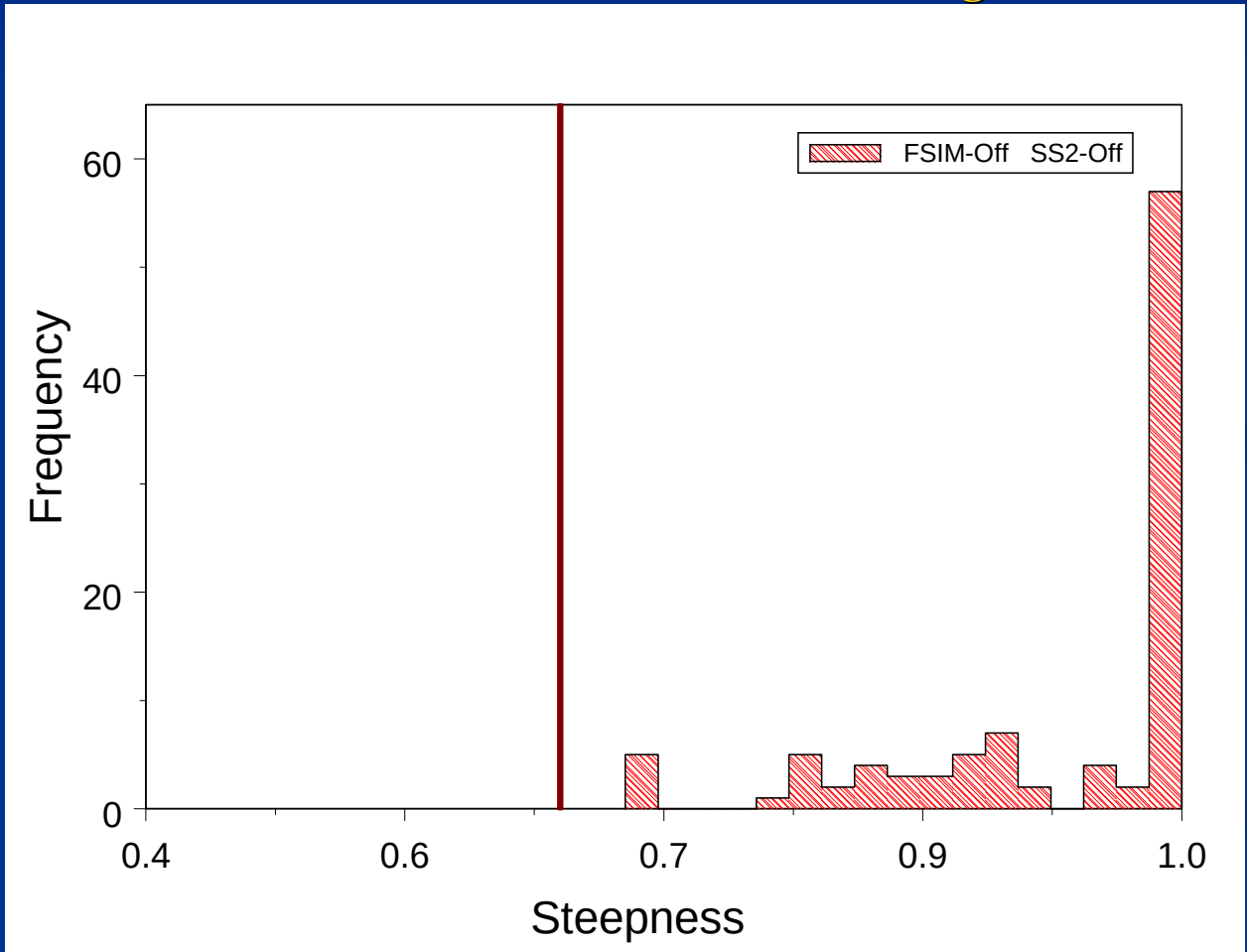
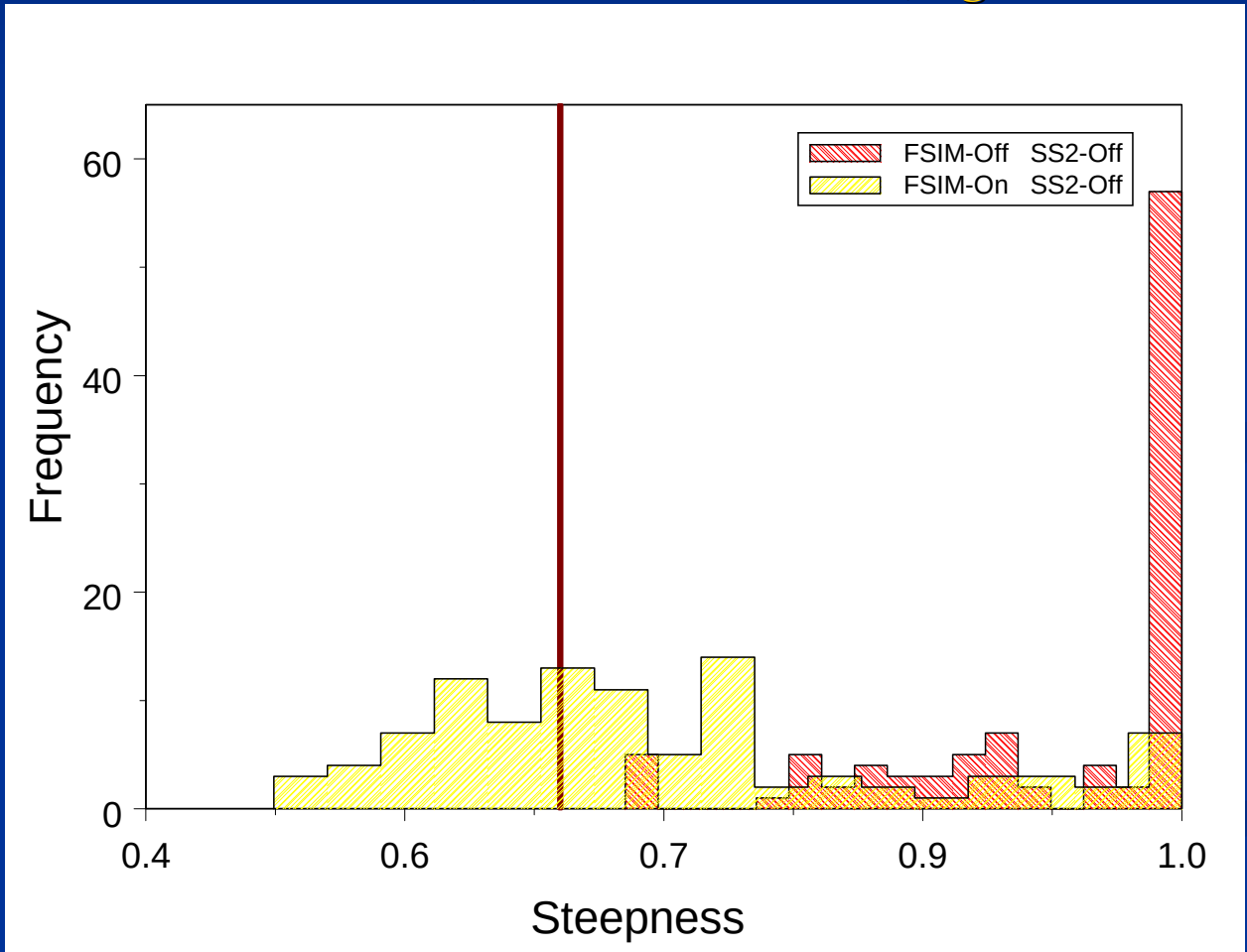


Adding the Env Effect to FSIM But Not SS2 Improved Agreement

FSIM Env Effect=On, SS2 Env Effect=Off, sigma-r = 0.85



Adding the Env Effect to FSIM and SS2 still Resulted in Poor Agreement

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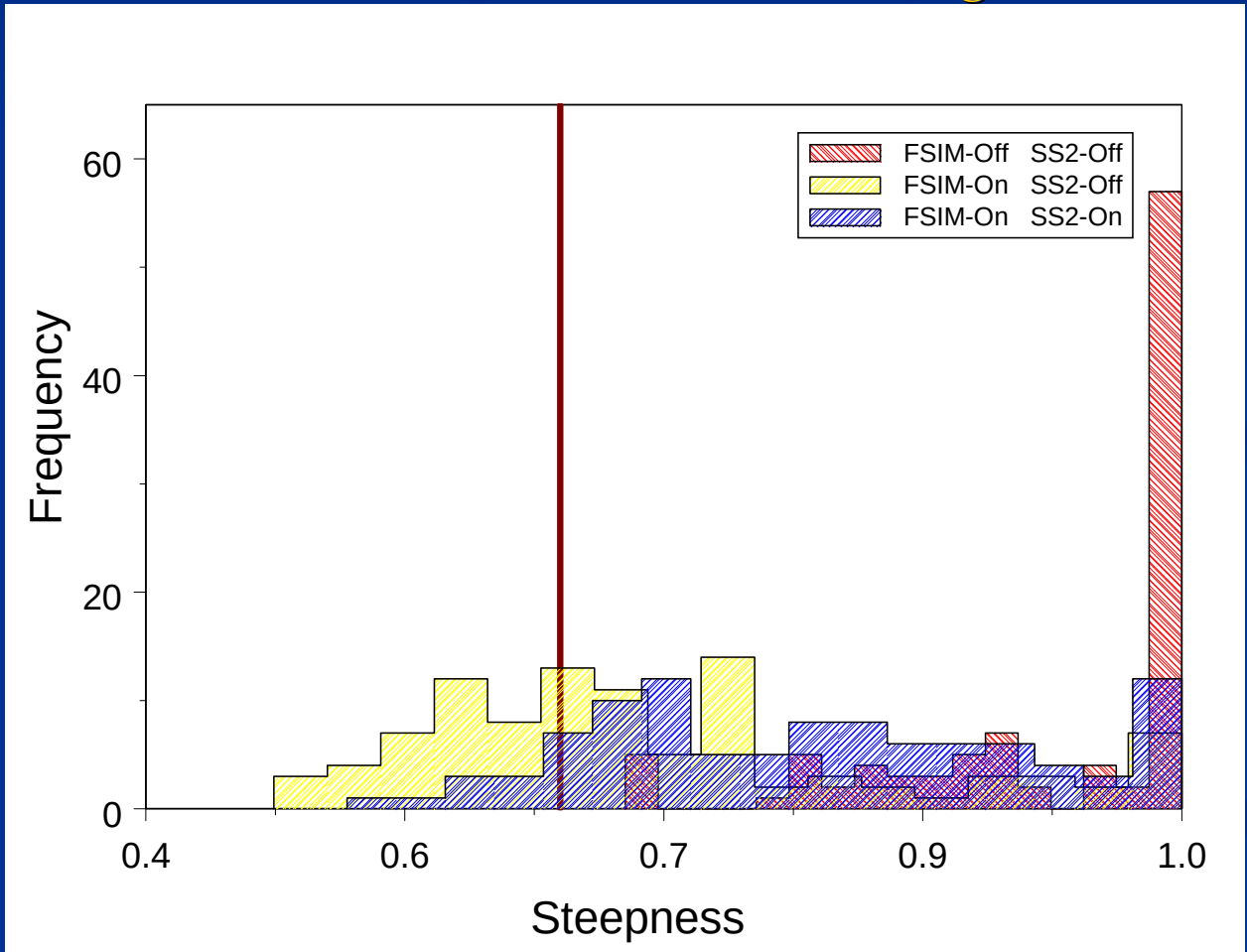

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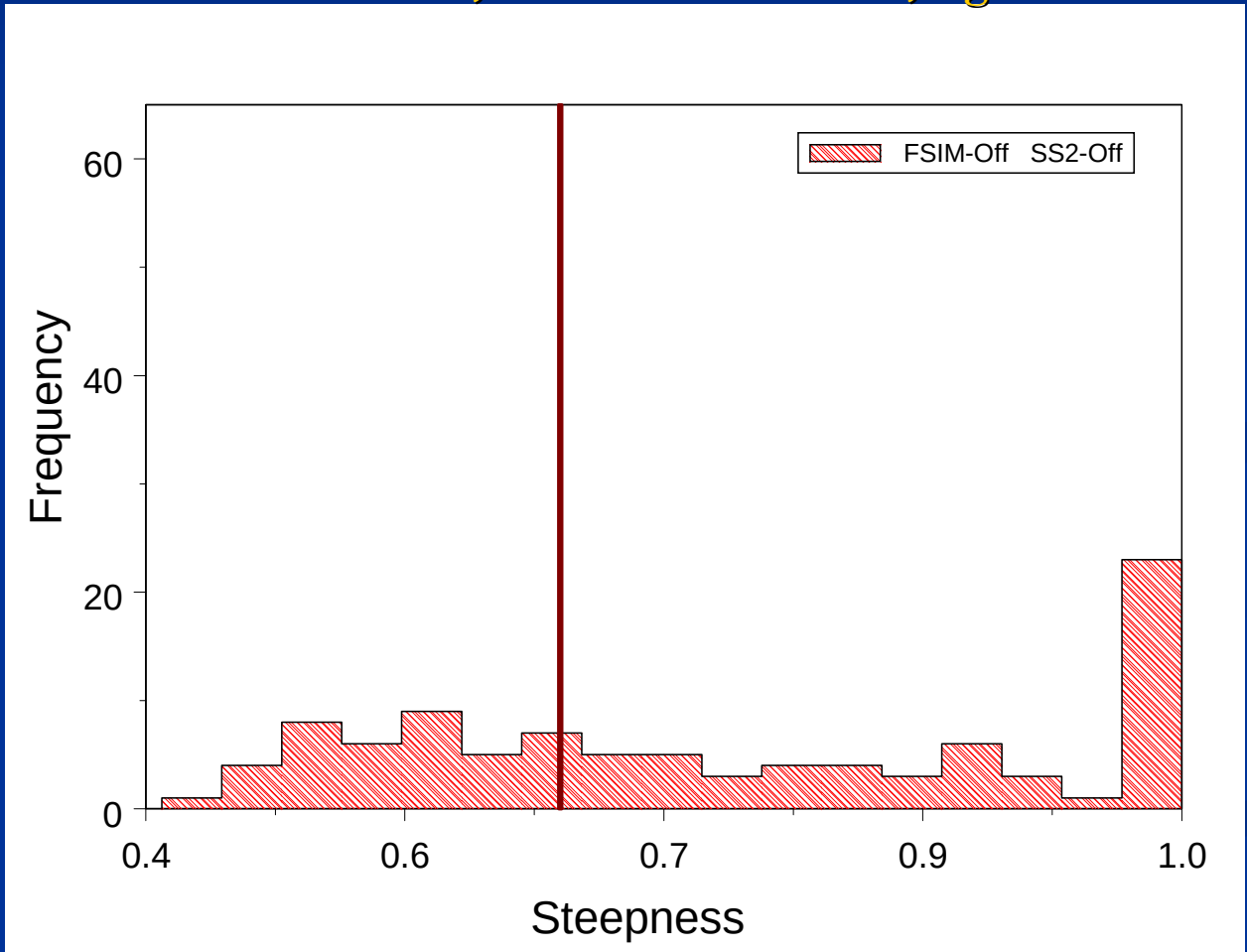

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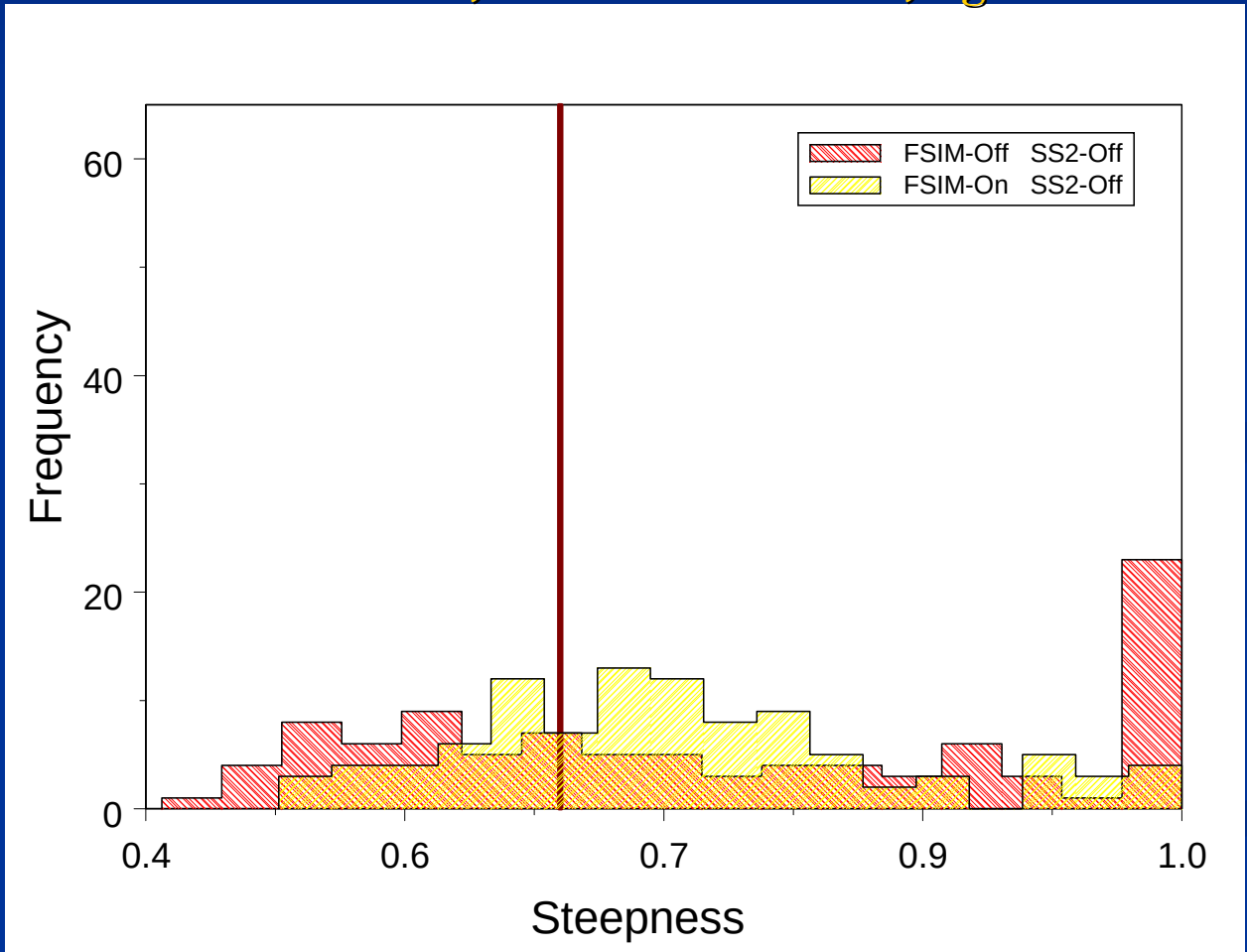
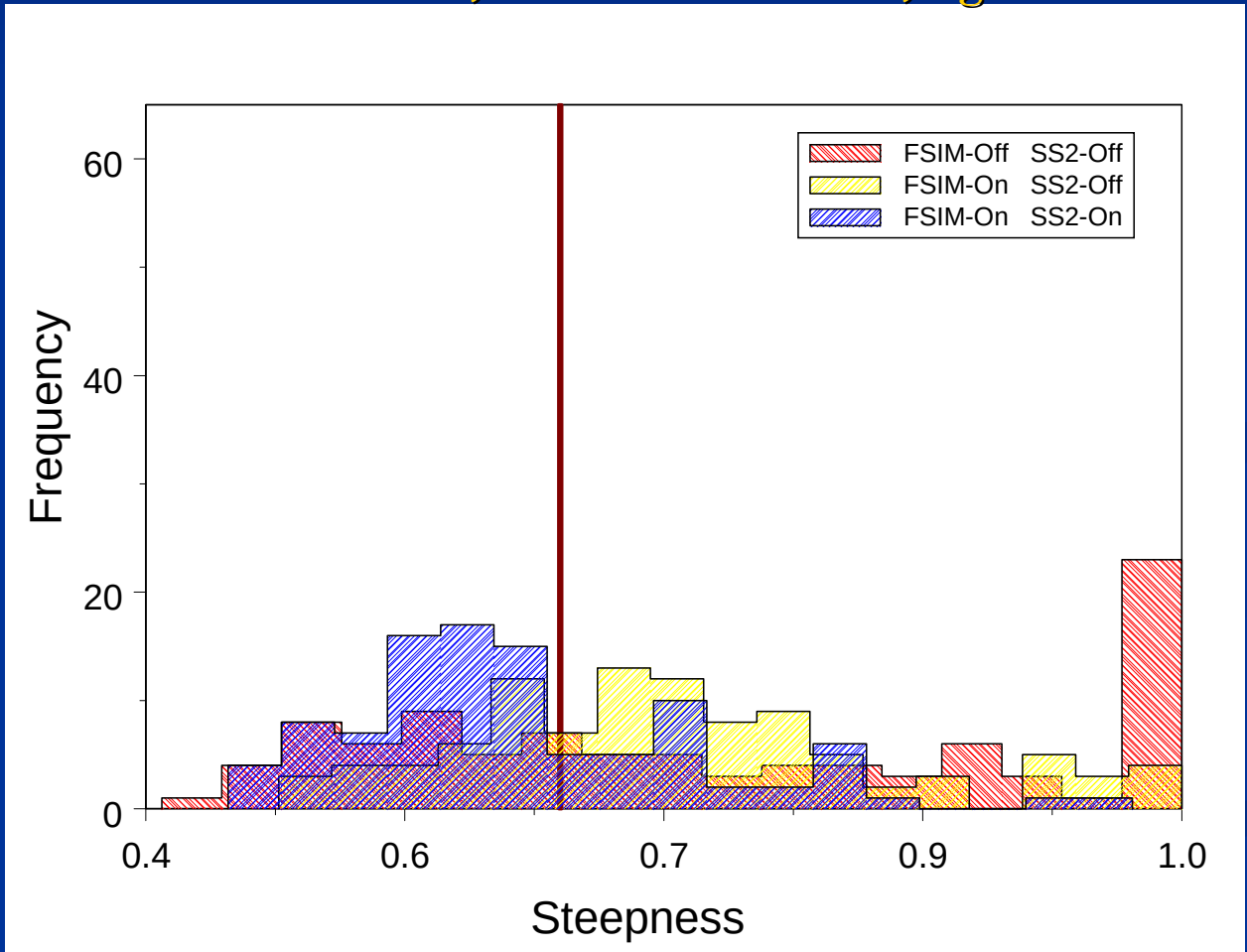


Adding the Env Effect to FSIM and SS2 Resulted in Under-Estimate

FSIM Env Effect=On, SS2 Env Effect=On, sigma-r = 0.50



What Have We Learned So Far?

- This simulation approach seems to offer sound instruction on how to better model environmental effects within our stock assessments
- Large amounts of variation in recruitment are probably going to be difficult to deal with no matter what we do
- With the current SS2 model configuration, estimates of recruitment prior to estimating recruitment deviations remain uncorrected for bias, which effects estimates of *B0* and thus current levels of depletion

Focus of Future Work

- Continue with current method but attempt to correct for some statistical inconsistencies
- Use the environmental variable to directly modulate age-0 natural mortality via *M*
- Use the environmental series as a recruit deviation index, much like a survey, thus allowing for error in the observations and the need to fit other observation data
- Proper evaluation of the "improvement" to the stock assessment by the inclusion of env data
- How to best utilizing env data in stock assessment forecasts

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