On the promises and pitfalls of including decadal scale climate forcing of recruitment in demersal fish stock assessment

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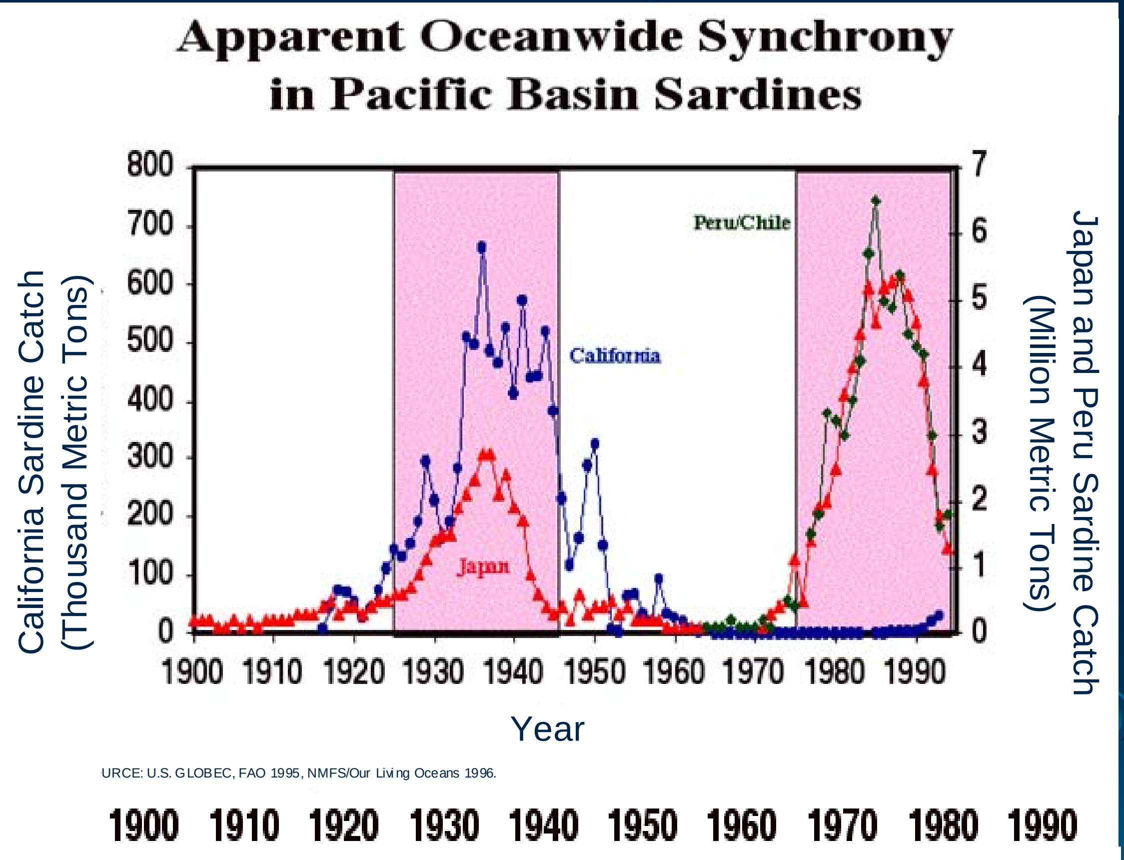
S8: Impact of climate variability on marine ecosystems: Understanding functional responses to facilitate forecasting

Background

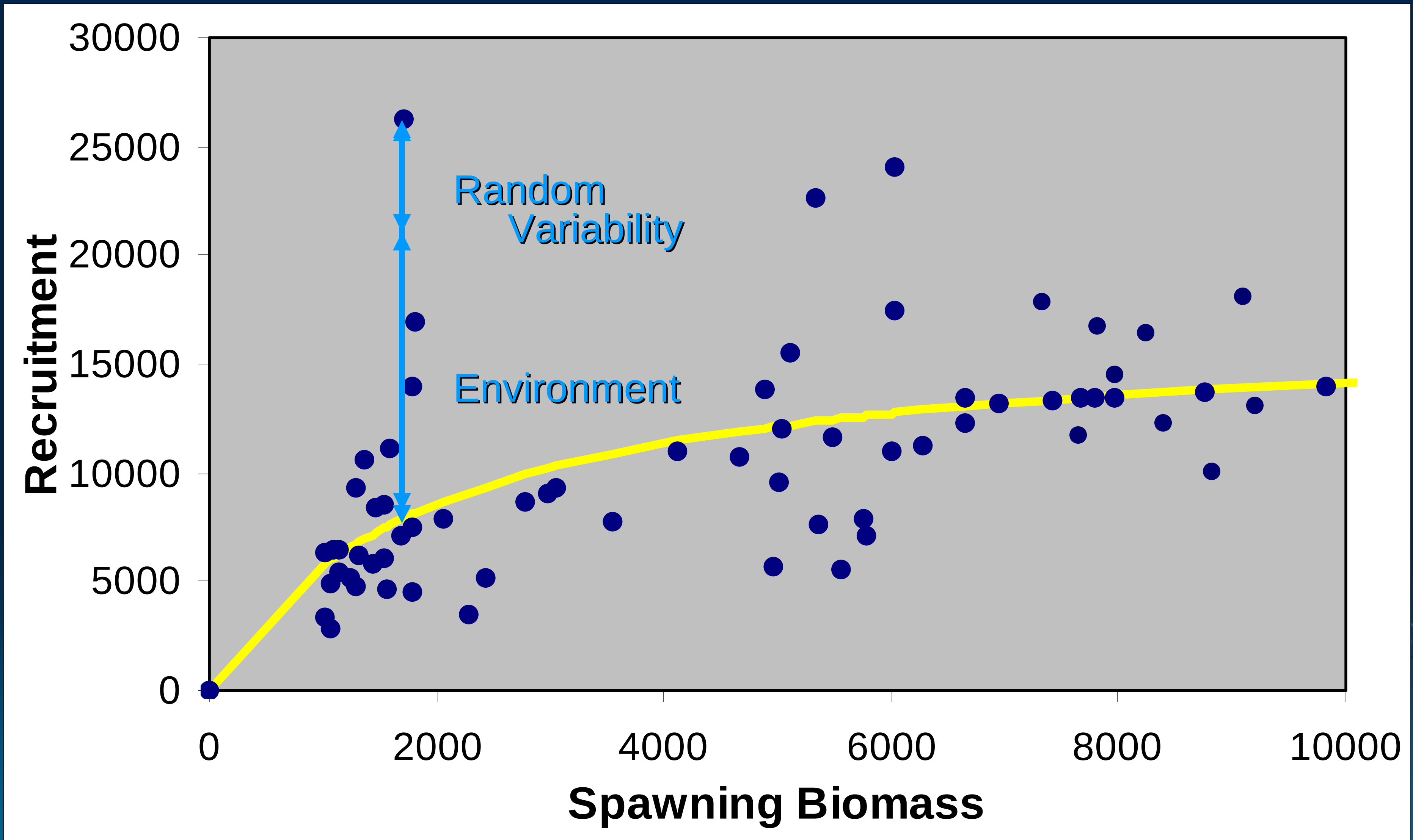
- Evidence for climate-driven changes in marine populations
  - Across trophic levels
  - Synchronous recruitment
  - Shifts in production



Francis, Sibley. 1991

- Population processes
  - Natural mortality
  - Growth
  - Movement/Migration
  - Recruitment

Recruitment 101

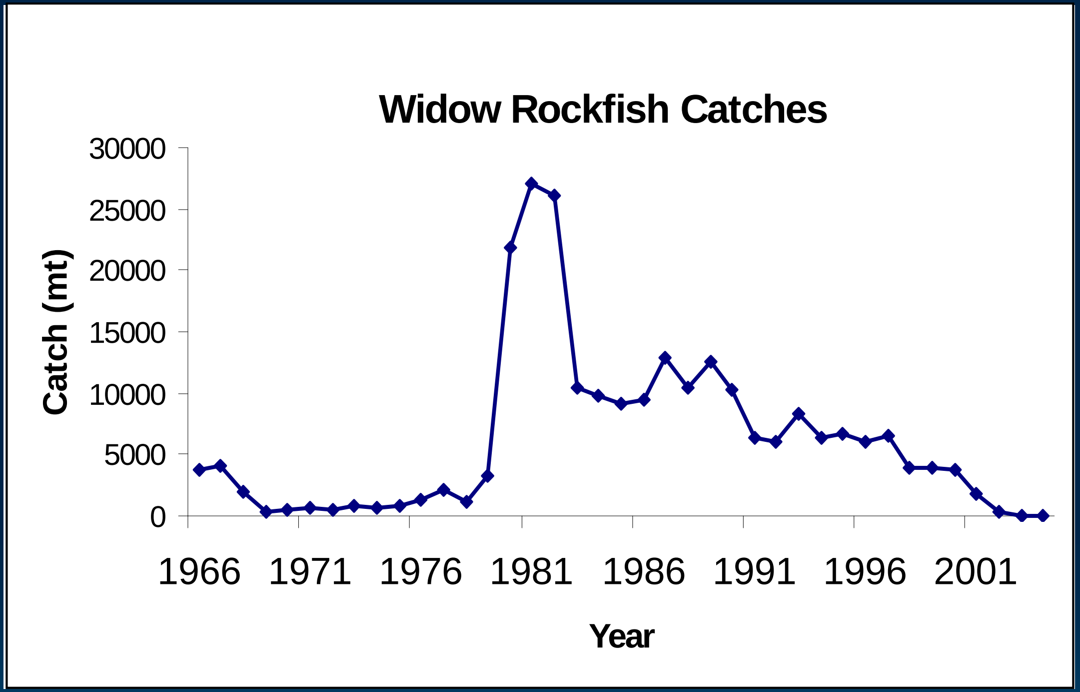


Background

- Current stock assessment models don't typically include climate – recruitment relationships.
- Can stock assessment models discriminate among hypotheses regarding resource changes related to human-induced stresses (fishing) and inter-annual climate variability?

The Context: West Coast Groundfish

- Concurrent low frequency climate forcing and increasing fishing effort.
- Stock declines over the past few decades due to a shift in productivity or fishing effort?



- Stock assessments assume the stock-recruitment relationship does not change over time
- Current harvest policies which appear sustainable may not be sustainable given environmentally forced recruitment.

Promise of Including Climate Data in Models

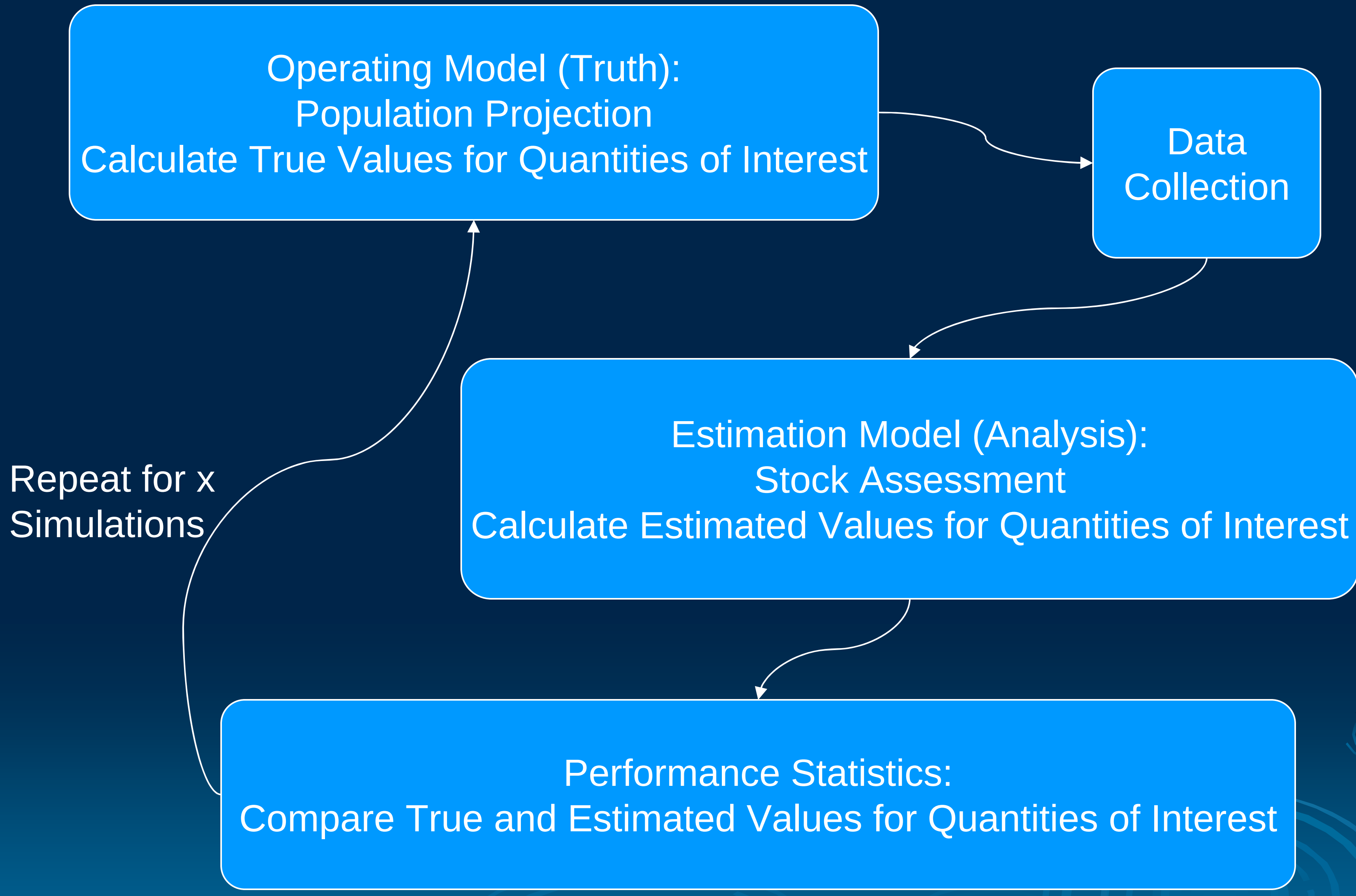
- Better estimates of recent recruitments
- Gain understanding of past and future stock dynamics by hindcasting and conducting future projections of likely recruitments under similar climate conditions

Pitfalls of including climate variability / environmental data in models

- Relationships that do not persist through time
- Hindcasts and forecasts may be wrong if extrapolated beyond the observed range
- Using auto-correlated estimates of spawning biomass and recruitment can lead to spurious correlations
- Few successful management applications

How to Test Climate-Recruitment Relationships?

- Empirical Observations Often Lack:
  - Long time series of field data
  - Replicates - scale of the system is to large
- Simulation Modeling:
  - Allows for hypothesis testing via experimentation
  - Replication


Operating Model (Truth):
Population Projection
Calculate True Values for Quantities of Interest
Data
Collection
Estimation Model (Analysis):
Stock Assessment
Calculate Estimated Values for Quantities of Interest
Repeat for x
Simulations
Performance Statistics:
Compare True and Estimated Values for Quantities of Interest

Objectives

- Can stock assessment methods correctly detect climate variability / forcing in recruitment?

	True Condition	
	No Environmental Forcing of Recruitment	**Environmental Forcing of Recruitment**
Positive Test Result	Spurious Correlation (Type I Error)	Correct
Negative Test Result	Correct	Failure to Detect (Type II Error)

- How is the estimation of biological reference points (BRPs) used to make management decisions impacted by Type I and Type II errors?

Alternative Estimation Methods

Stock Assessment Model	Stock-Recruitment Model	Climate-Recruitment Deviation Model	Modeling Approach	Simulation Performance Metric
M_0	Outside	Outside	U.S. North Pacific	α = 5%
M_{SR}	Inside	Outside	U.S. West Coast	α = 5%
M_{SRE}	Inside	Inside	Maunder and Watters (2003)	Likelihood Ratio Test

- Overall Performance Metric

  The proportion of trials that fail to correctly detect the recruitment deviation-climate relationship.

Results: The proportion of trials that FAIL to correctly detect climate forcing in recruitment

Life History ***Method***	**Spurious Correlation (Type I Error)**		**Failure to Detect (Type II Error)**
	Random Recruitment	Autocorrelated Recruitment	Climate Forcing
Rockfish			
M_0	0.79	1.00	0.04
M_{SR}	0.66	1.00	0.00
M_{SRE}	1.00	1.00	0.00
Flatfish			
M_0	0.89	1.00	0.57
M_{SR}	0.84	1.00	0.17
M_{SRE}	1.00	1.00	0.04
Hake			
M_0	0.86	0.99	0.38
M_{SR}	0.99	1.00	0.40
M_{SRE}	1.00	1.00	0.20

Objective 2

- Does making a type I or II error impact the estimation of biological reference points
  - How to calculate BRPs?
  - What assessment method is best?

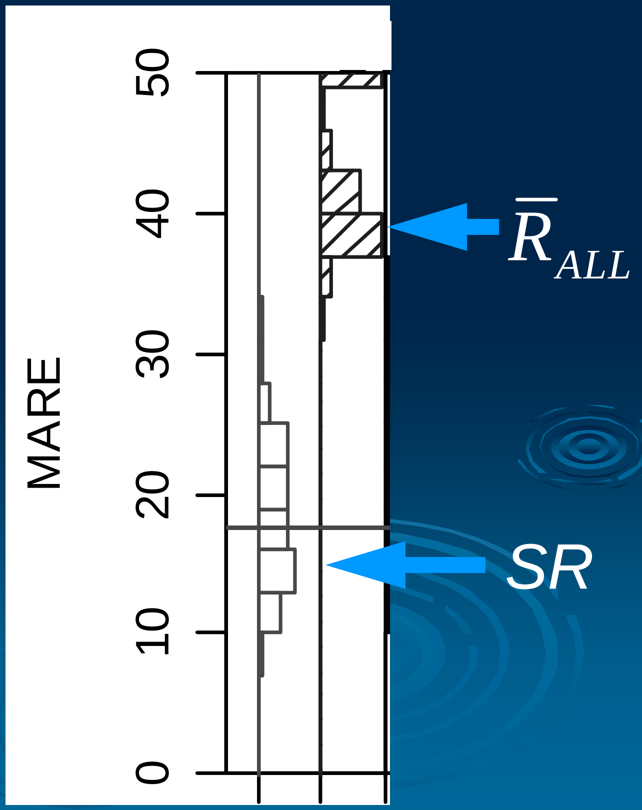
- 2 general ways to estimate BPRs depend upon:
  - Average Recruitment
  - Stock-Recruitment relationship

Results: Random Recruitment

- Spuriously including climate-recruitment deviation has small impact on estimation of BRPs if estimators with lowest MAREs chosen

The MAREs for all simulations that detected (*D*) and failed to detect (*FD*) environmental forcing

Estimator	$D\text{-}M_{SR}$	$FD\text{-}M_{SR}$
$\bar{R}_{ALL}$	15.0	14.9
SR	7.3	7.8



Results: Auto-correlated Recruitment

- All trials failed
- Choice of assessment model can decrease errors

The MAREs for all simulations that detected (*D*) and failed to detect (*FD*) environmental forcing

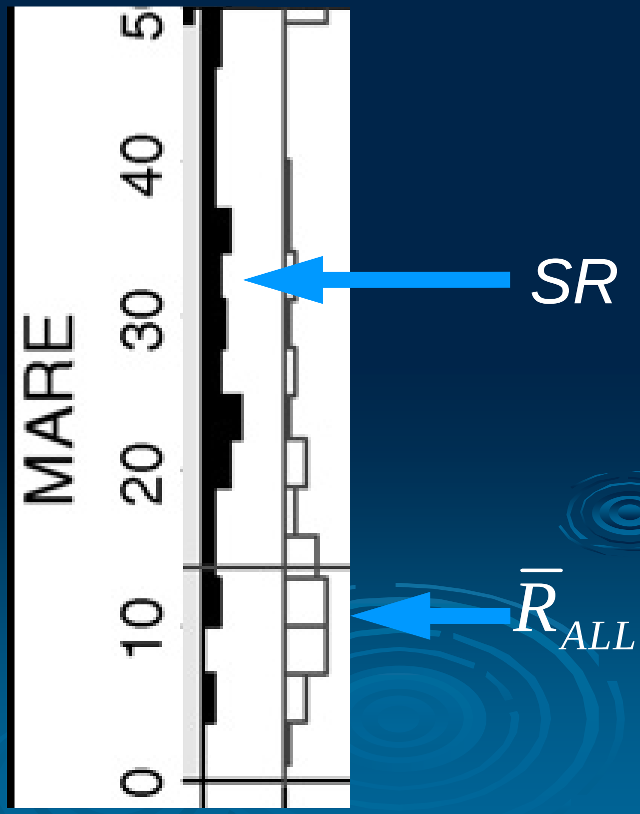
Life history	$D\text{-}M_0$	$FD\text{-}M_0$	$D\text{-}M_{SR}$	$FD\text{-}M_{SR}$	$D\text{-}M_{SRE}$	$FD\text{-}M_{SRE}$
Rockfish	16.7	NA	16.1	NA	**15.9**	NA
Flatfish	**16.3**	NA	18.1	NA	18.0	NA
Hake	24.0	NA	*30.4*	NA	*30.1*	NA

Results: Climate Forced Recruitment

- Correctly including the climate-recruitment deviation relationship improves BRP estimation

The MAREs for all simulations that detected (*D*) and failed to detect (*FD*) environmental forcing

Life history	$D\text{-}M_{SR}$	$FD\text{-}M_{SR}$
Flatfish	13.0	*34.9*
Hake	13.6	23.4



Conclusions: Advice for forecasting stock dynamics and catches given climate variability

- Strong tradeoff between the two types of errors.
- Low frequency auto-correlated recruitment
  - If the wrong climate data set is chosen and it shows low frequency periodicity there will nearly always be a problem with spurious correlation.
- Method M_{SRE} minimizes the total error rate for hake.
- Methods M_0 and M_{SR} minimize the total error rate for rockfish and flatfish.
- The impact of type I errors while estimating reference points can be minimized by choosing an appropriate combination of assessment method (M_{SR} & M_{SRE}) and reference point estimators.
- The estimation of reference points is always improved in the absence of type II errors.

Conclusions: Advice for forecasting stock dynamics and catches climate variability

- Base BRPs on the fit of the stock-recruitment relationship if:
  - No environmental forcing of recruitment
  - If the catch/survey time series are shorter than the period of the environmental forcing

- Base BRPs on average recruitment if:
  - Low frequency forcing of recruitment
  - If catch/ survey time series are at least as long as the period of the environmental forcing

- The method used to calculate BRPs has a larger impact on estimation ability than the configuration of the stock assessment models evaluated.

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