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Searching for robust management procedures for Hecate Strait Pacific Cod (*Gadus macrocephalus*): a data-limited stock with highly uncertain dynamics

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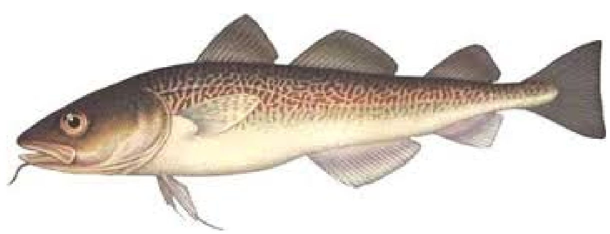

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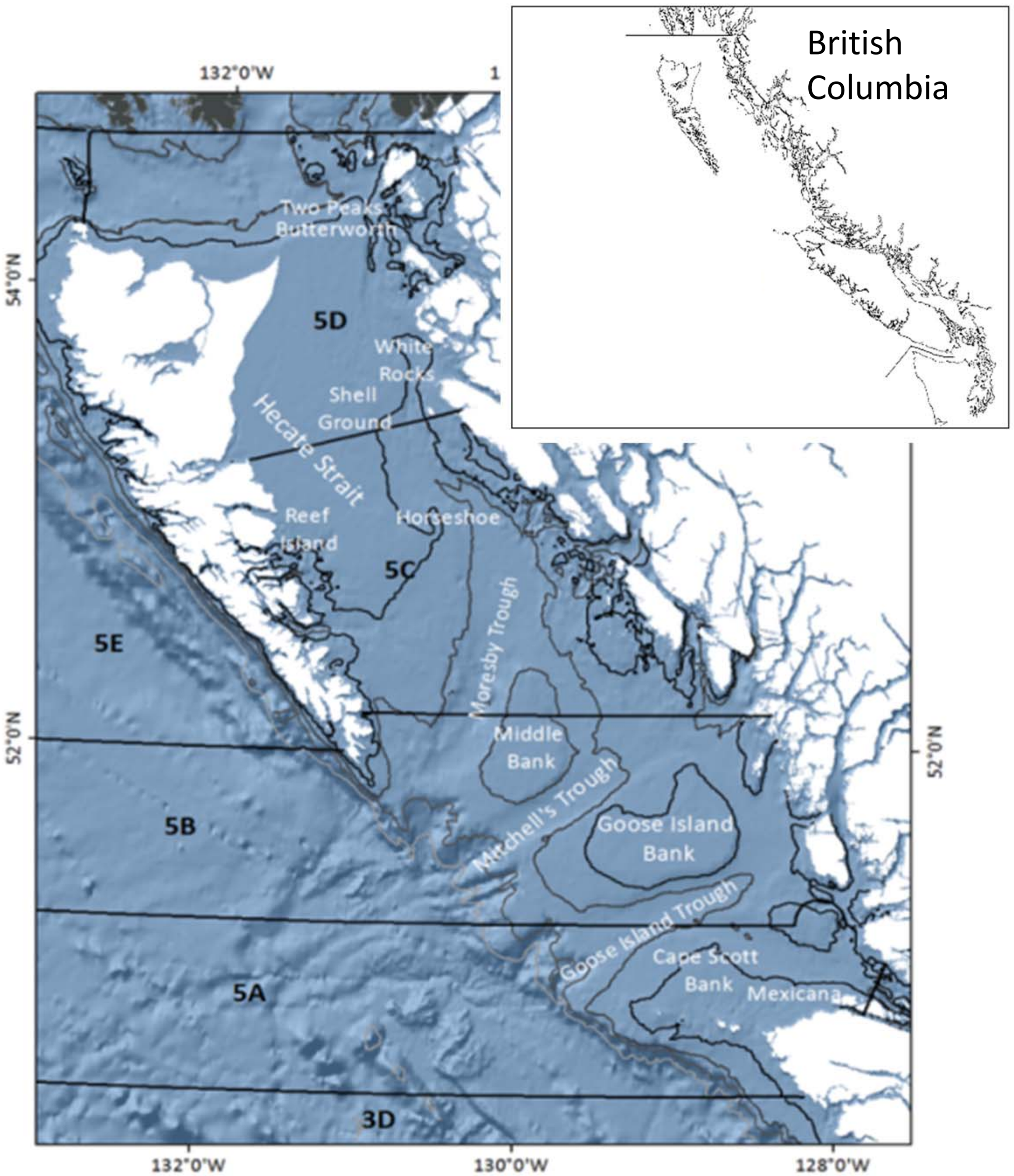
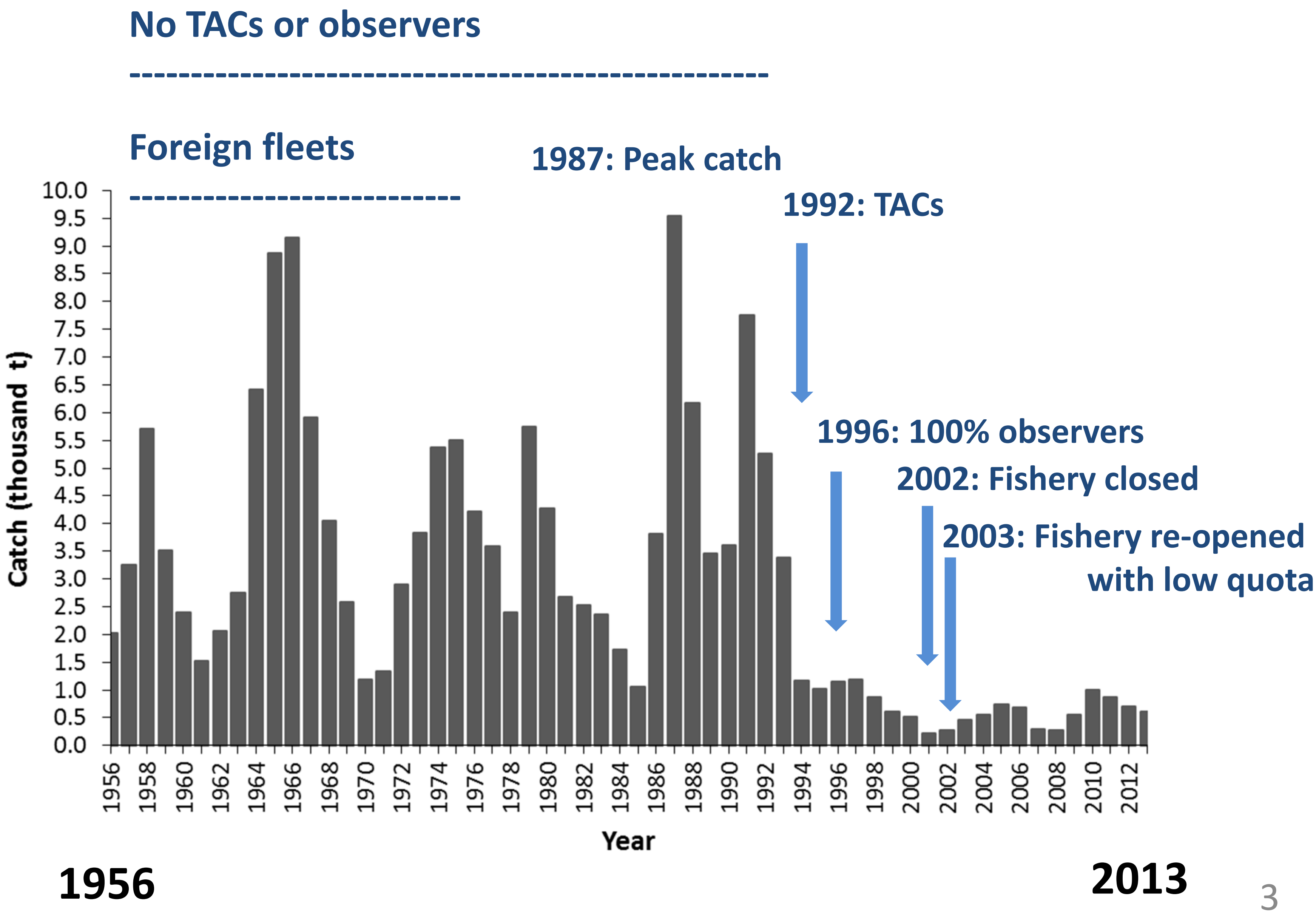
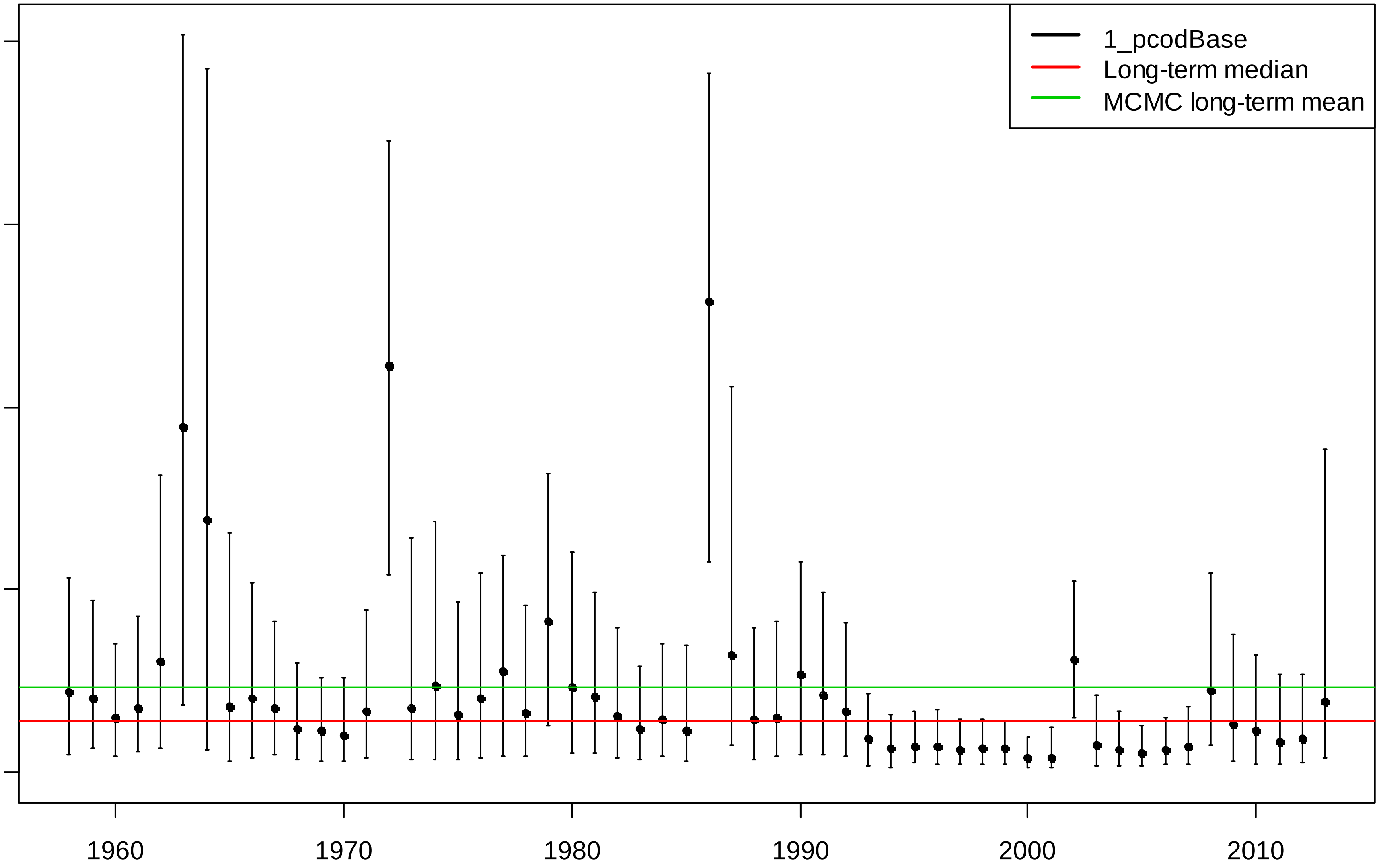
Pacific Cod (*Gadus macrocephalus*)



Catch history



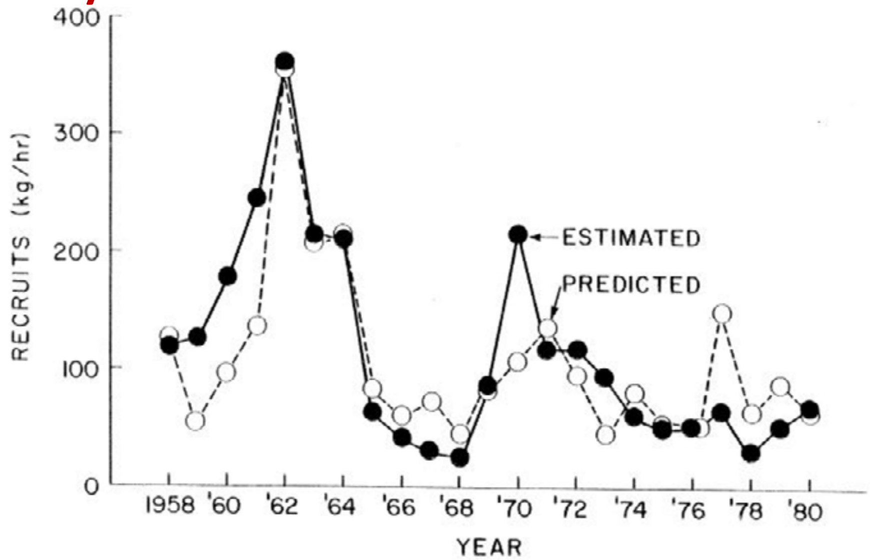
Recruitment estimates



*Forrest et al. 2013. Stock assessment. Delay Difference model.

Recruitment drivers: Hypotheses

Tyler and Westrheim 1986



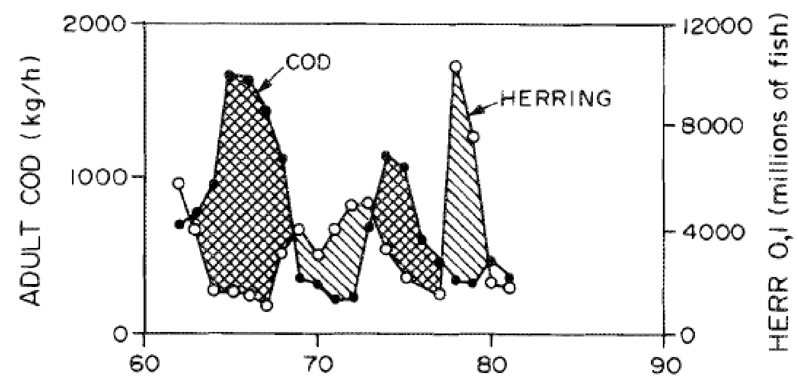
Fournier 1983

An Analysis of the Hecate Strait Pacific Cod Fishery Using an Age-structured Model Incorporating Density-dependent Effects

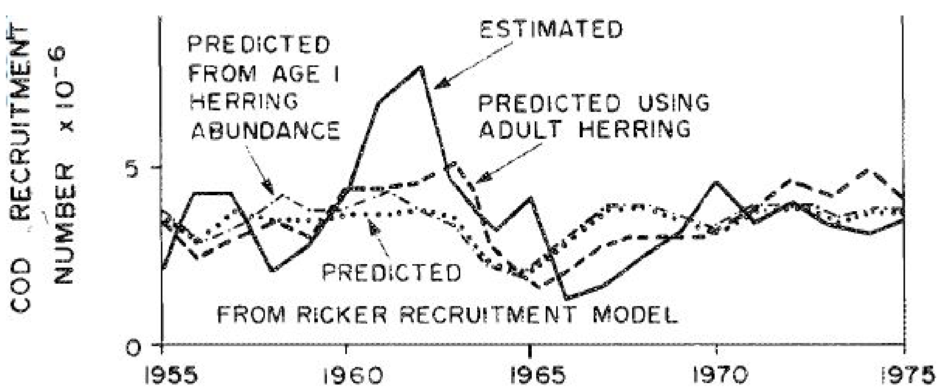
D. A. FOURNIER[1]

Department of Fisheries and Oceans, Resource Services Branch, Nanaimo, B.C.

Tyler and Crawford 1991



Walters et al. 1986



Sinclair and Crawford 2005

FISHERIES OCEANOGRAPHY *Fish. Oceanogr.* 14:2, 138–150, 2(

Incorporating an environmental stock–recruitment relationship in the assessment of Pacific cod (*Gadus macrocephalus*)

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of observations of both the fish stock and a number environmental factors that could possibly affect population dynamics. Careful analysis may rev candidate hypotheses; however, once identified, t hypotheses are subject to additional testing throu the accumulation of more observations. More oft

The Hypotheses

Exogenous factors

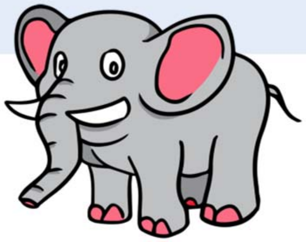
- Northward larval transport
  - Indicated by Prince Rupert Sea Level
- Availability of Age-0 herring as prey

Density dependent processes

- Density-dependent mortality (depensatory)
- Density-dependent growth

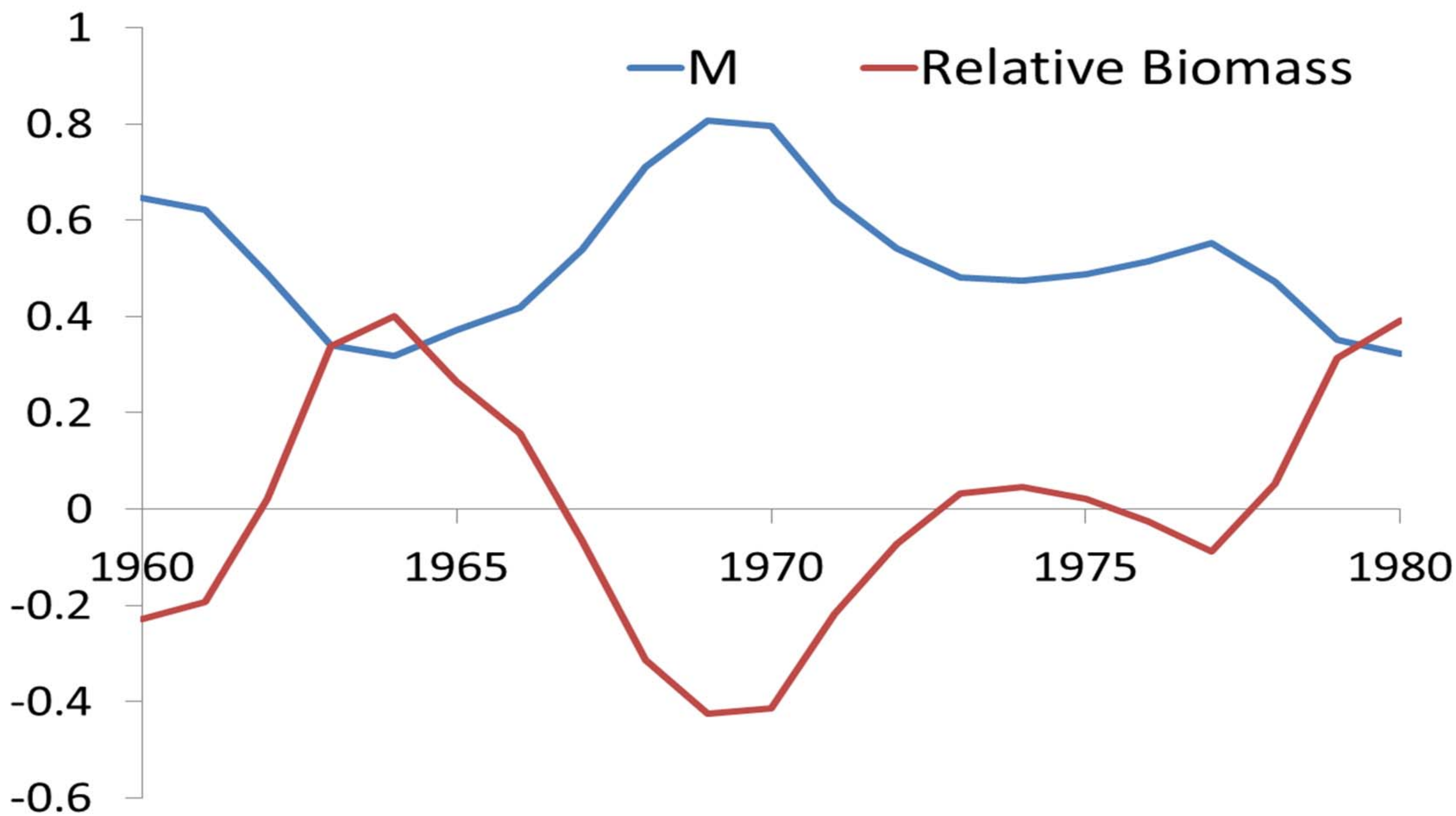
The elephant in the room

- Stock structure

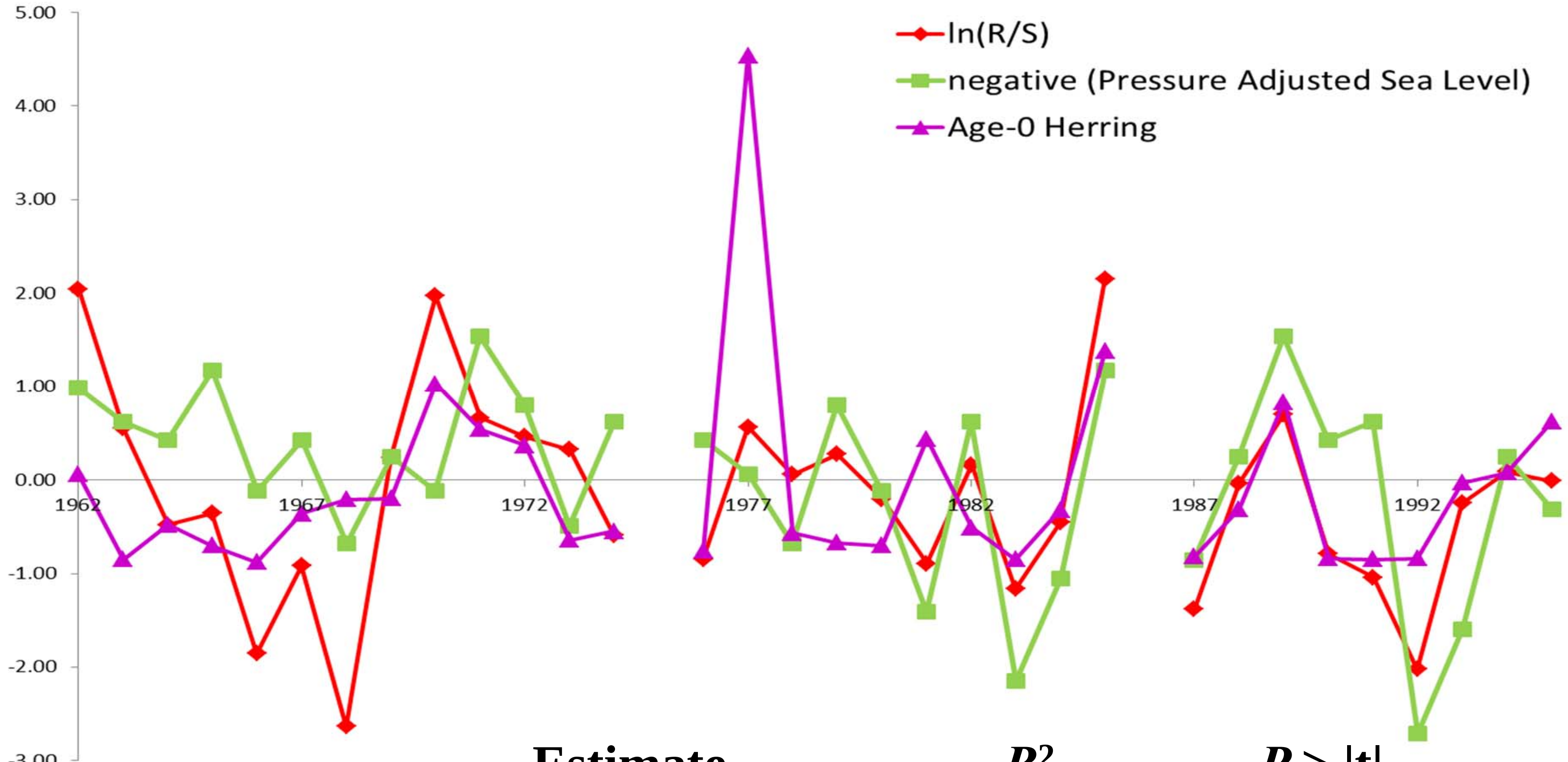


Density Dependent Natural Mortality

- Depensatory: As biomass decreases mortality increases (Fournier 1983)



Environmental causes: Sinclair &Crawford 2005



	Estimate	R^2	$P > \|t\|$
$\beta_{Spawning\ Biomass}$	-0.46	0.20	0.01*
$\beta_{Sea\ Level}$	-0.57	0.28	0.00*
$\beta_{Age\ 0\ Herring}$	0.49	0.22	0.01*

Sinclair, A.F., and Crawford, W.R. 2005. Incorporating an environmental stock recruitment relationship in the assessment of Pacific cod (*Gadus macrocephalus*). Fish. Oceanogr. 14

Questions

Q 1.

Do previously-identified significant relationships hold up with new data?

Q 2.

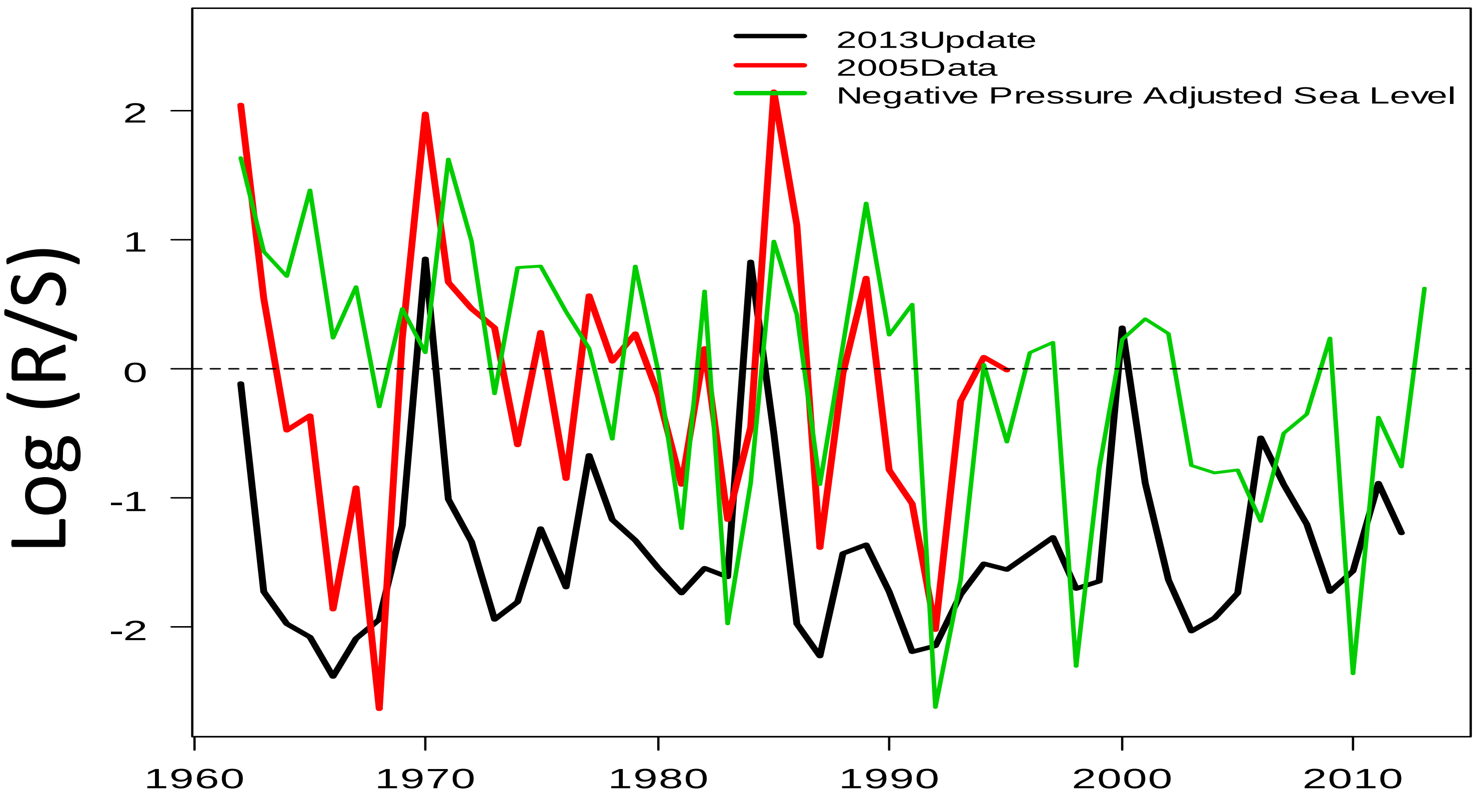
Can we distinguish among hypotheses with available data?

Q 3.

How should we proceed with management?

- What harvest strategies are robust to uncertainty in productivity drivers?

1. Do previously-identified significant relationships hold up with new data? No and Yes. Maybe.

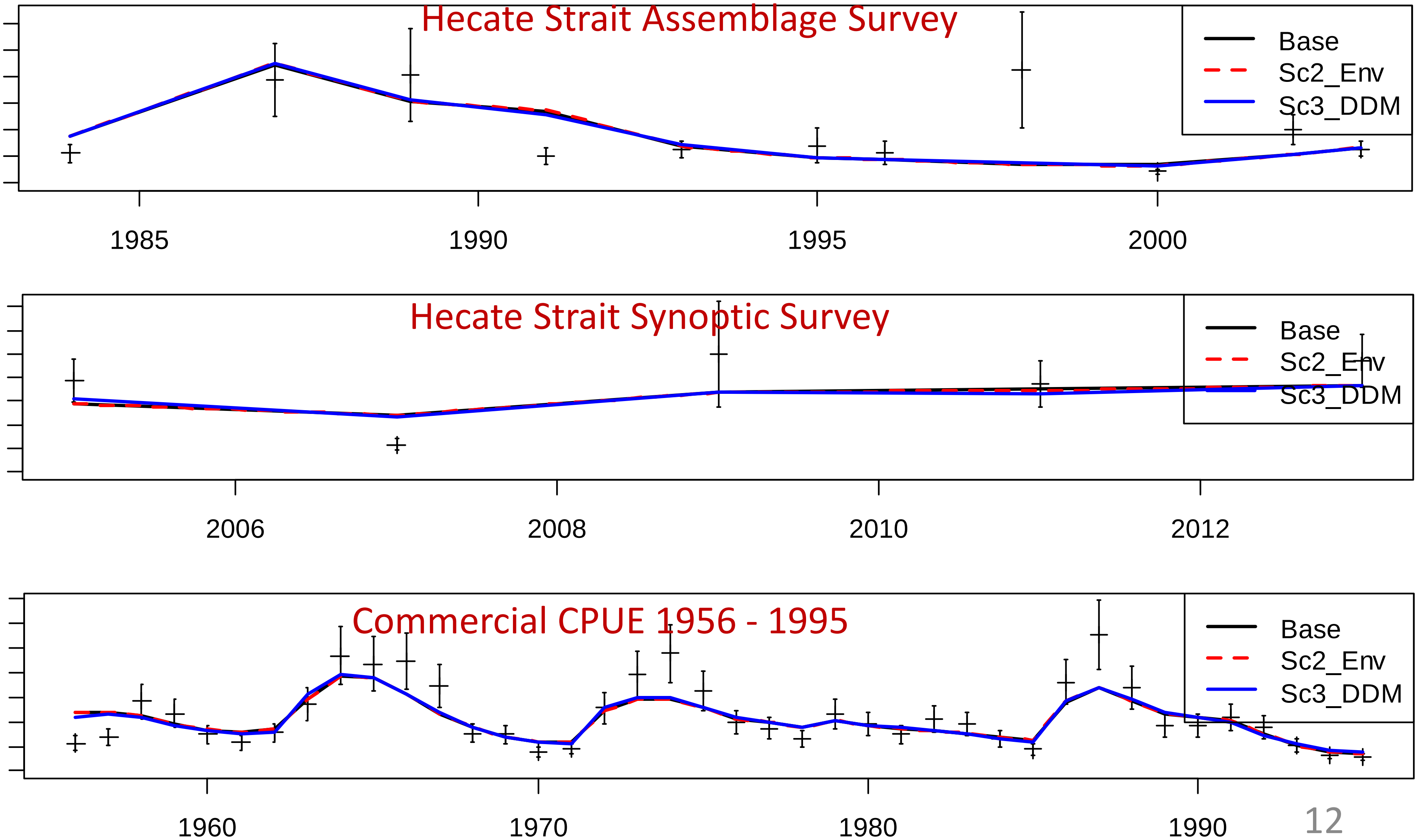


	Estimate	R^2	$P > \|t\|$
$\beta_{Spawning Biomass}$	-0.26	0.15	0.00*
$\beta_{Sea\ Level}$	-0.09	0.02	0.37
$\beta_{Age\ 0\ Herring}$	0.21	0.10	0.03*

Recruits and Spawning Biomass are not data

- Not a simple case of an environmental correlation breaking down over time
- The dependent variable ln(Recruits/Spawner) is a model output
  - Model estimates of abundance and productivity are highly dependent on structural model assumptions (e.g., selectivity)
  - Past estimates of abundance and productivity are often revised once new data are added
  - Estimates of recruitment since ~1996 influenced by large changes in management and fishing behaviour

2. Can we distinguish among hypotheses with available data? Not in this stock assessment model.



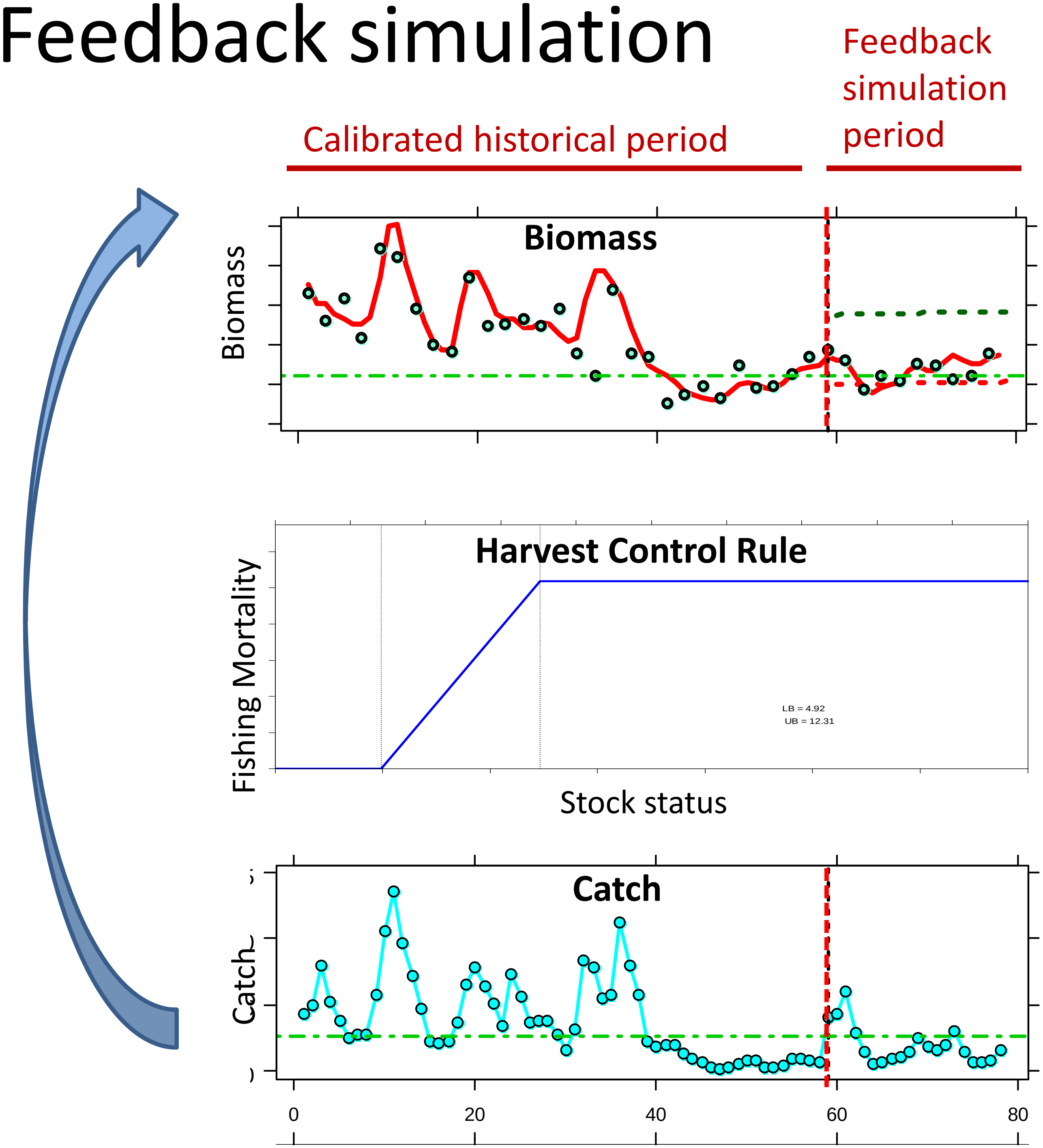
3. How should we proceed with management?

- What harvest strategies are robust to uncertainty in productivity drivers?

- Feedback simulation approach

- Feedback simulation is the only way to test the performance of the assessment and the harvest control rule simultaneously

Feedback simulation



1. Operating model ("true" state of nature)

2. Generate data with random error

3. Pass data to assessment model

4. Estimate stock size and reference points

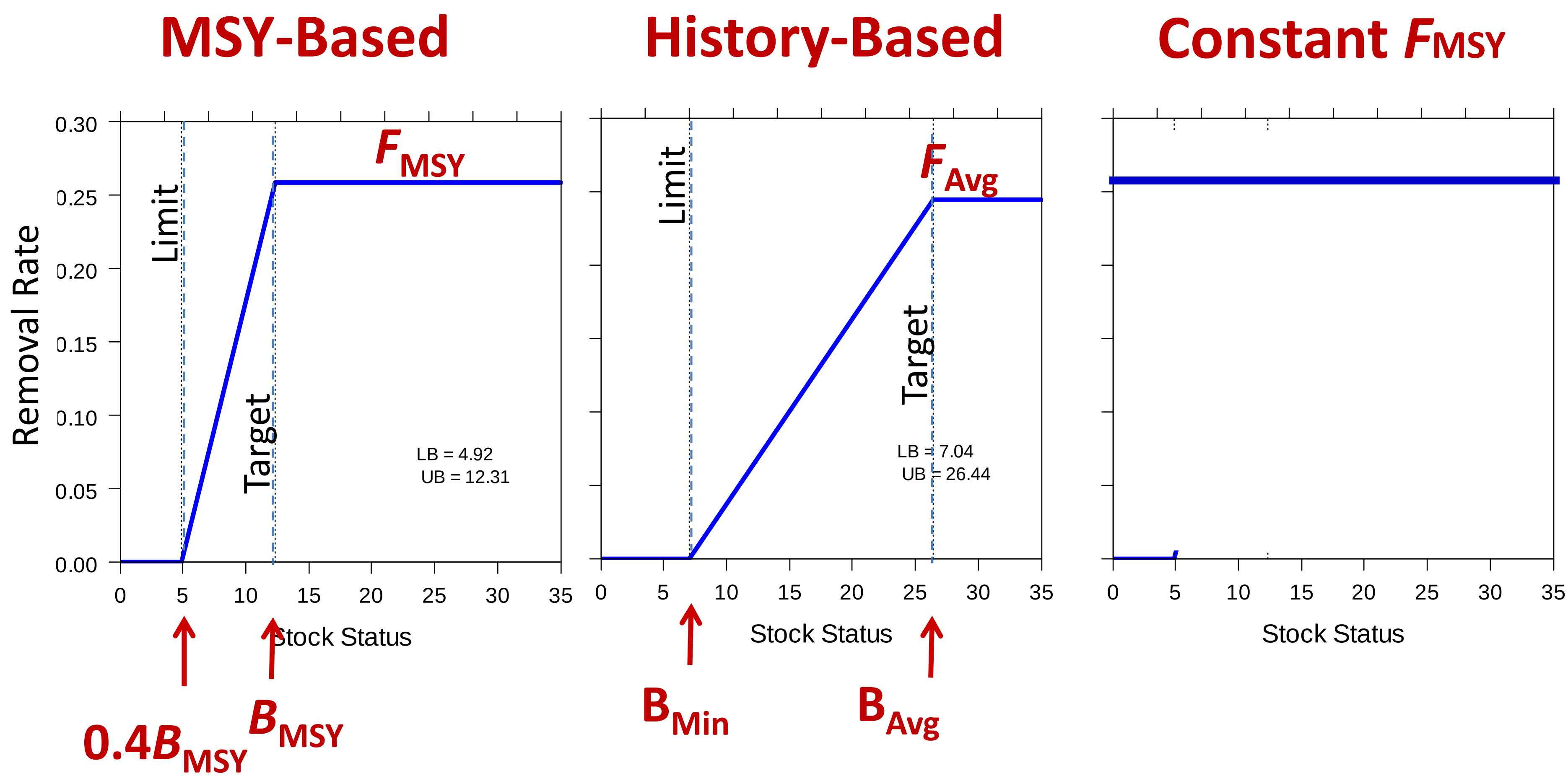
5. Apply harvest control rule to determine catch

6. Remove catch from population in operating model

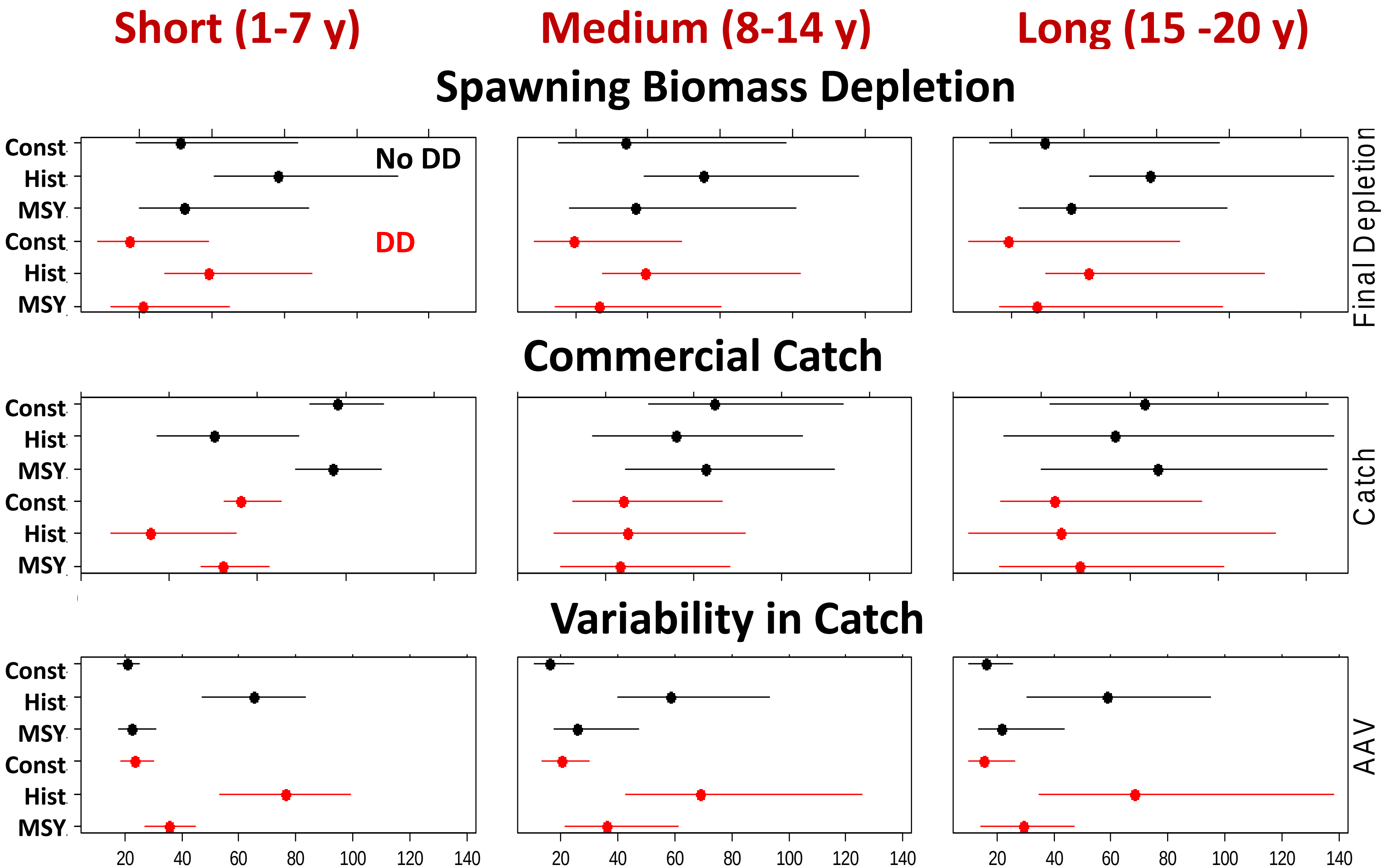
7. Repeat for 20 years

8. Repeat whole procedure 50 times

Harvest control rules



Performance after 20 y: Catch-Age model



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Trade-offs

- Historical reference points out-performed MSY-Based reference points in terms of depletion for both scenarios in all time periods … at the cost of

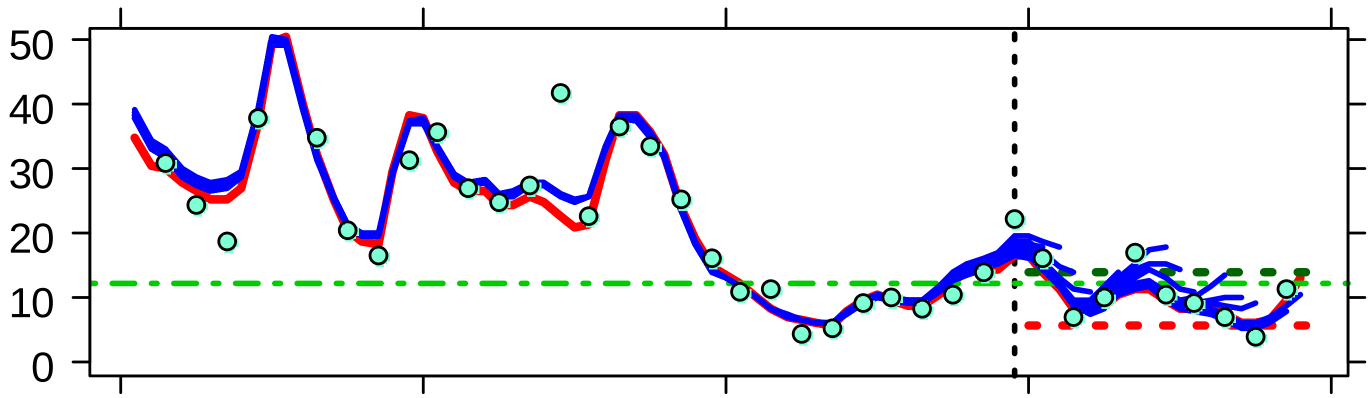
- … Catch in the short-term, but not in the long-term … but

- … Catch variability was high due to catch reductions when stock frequently estimated to be “on the ramp”

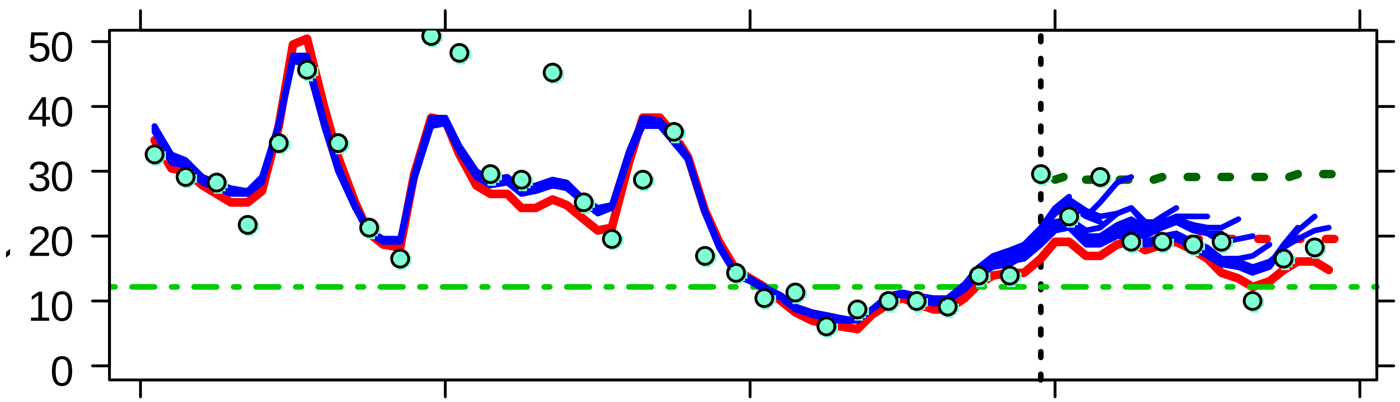
- Constant F_{MSY} had the most stable catches under both scenarios in all time periods, at the cost of depletion, especially when mortality was density-dependent

Assessment Bias and Reference Points

No Density Dependence, MSY-based



No Density Dependence, History-based



A framework

- Simple examples illustrate framework for testing management procedures in the face of uncertainty
- Many types of management procedures currently being proposed to account for climate change impacts, e.g.,
  – dynamic reference points
  – accounting for non-stationary parameters
  – decision-making frameworks that account for regime shifts …
- Feedback simulation allows for visualisation of trade-offs associated with alternative management recommendations

Concluding comments

- Different mechanisms can give rise to similar observations
  - especially for data-poor fisheries
- Consider multiple hypotheses
  - Density dependent mortality and growth can interact with environmental effects and fishing to give rise to complex dynamics
- Search for robust management strategies
  - Operating models can be made very complex and are relatively cheap to build!

Acknowledgements

- Kendra Holt, Sean Cox and Rob Kronlund
- Gordon Kruse and Jackie King
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- Maria Surry
- Kate Rutherford
- Chris Grandin