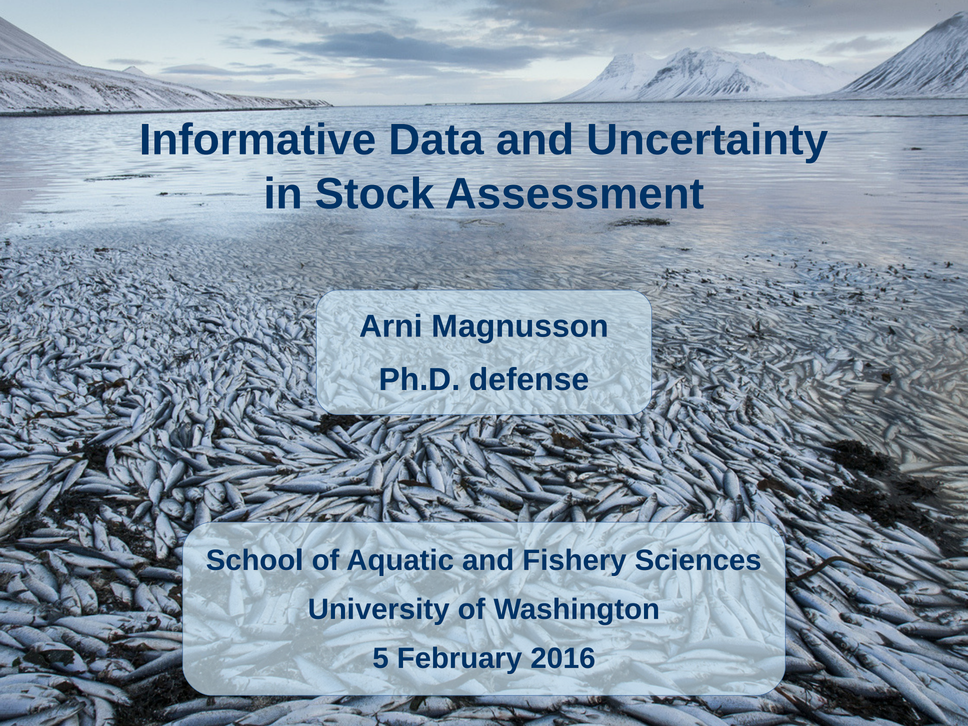

Informative Data and Uncertainty in Stock Assessment

Arni Magnusson

Ph.D. defense

School of Aquatic and Fishery Sciences

University of Washington

5 February 2016

Outline

Introduction

Uncertainty in stock assessment, research questions

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Papers 1 & 2 (simulation studies)

Informative data, stock status, key parameters

Delta method, bootstrap, MCMC

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Paper 3 (synthesis and case study)

Broader overview, application of methods to Icelandic saithe

Profile likelihood, retro, bivariate confidence region, HCR

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Profile likelihood, retro, bivariate confidence region, HCR

Conclusions

Summary of findings, general recommendations

Uncertainty in stock assessment

Fisheries management relies on stock assessment

Stock status, harvest rate, reference points, key parameters

Not just the most likely value, but a range of plausible values

Uncertainty in stock assessment

Fisheries management relies on stock assessment

Stock status, harvest rate, reference points, key parameters

Not just the most likely value, but a range of plausible values

Give advice that is robust to violated assumptions

Failure to incorporate uncertainty into the management advice
$\rightarrow$ suboptimal yields, fishery collapse

Research questions

What makes some datasets more **informative** than others?

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How reliable are **statistical methods** to measure uncertainty?

Research questions

What makes some datasets more **informative** than others?

How reliable are **statistical methods** to measure uncertainty?

What are **good practices** for confronting uncertainty?

Study design

Simulation studies [1-2]

Generate random datasets where the true values are known

Evaluate the performance of statistical methods

Typical groundfish data and age-structured model

Study design

Simulation studies 1-2

Generate random datasets where the true values are known

Evaluate the performance of statistical methods

Typical groundfish data and age-structured model

Review & case study 3

Review findings from simulation studies

Apply same methods to Icelandic saithe, interpret results

Demonstrate additional methods to confront uncertainty

Paper 1

FISH and FISHERIES, 2007, **8**, 337–358

What makes fisheries data informative?

Arni Magnusson[1,2] & Ray Hilborn[1]

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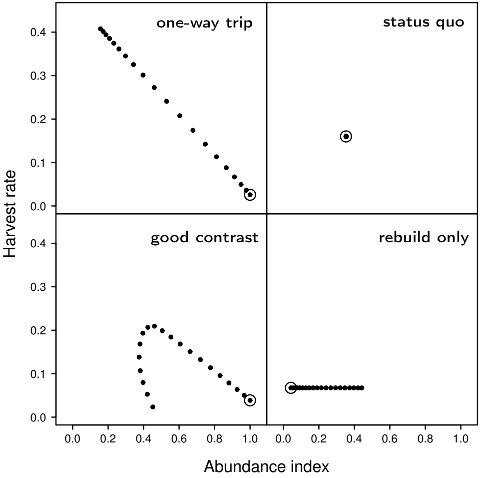
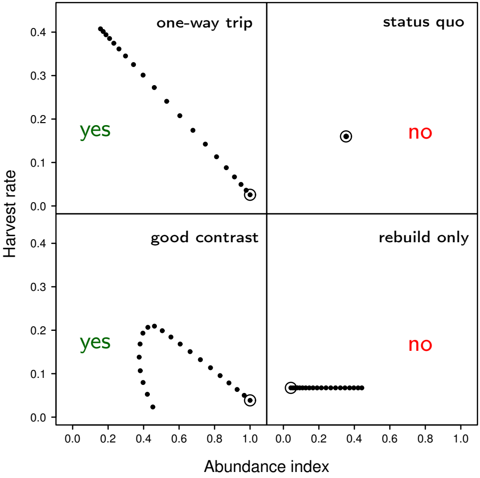
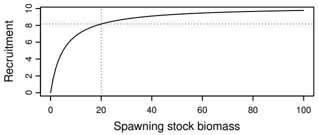
Informative fishing history?



Informative fishing history?

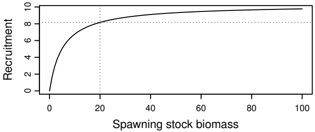


Key parameters: h, M, r



h : stock-recruitment steepness

Key parameters: h, M, r



h : stock-recruitment steepness

only if data include very low *SSB*

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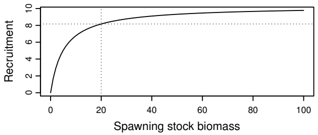

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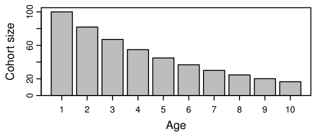
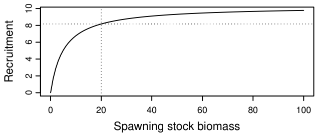


M : natural mortality rate

Key parameters: h, M, r



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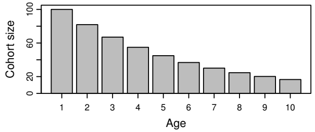

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only if data include high & low *F*

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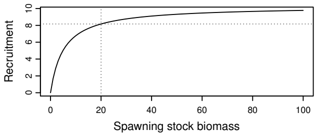

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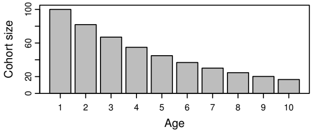

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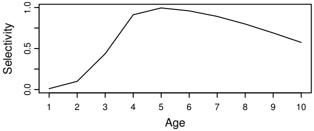
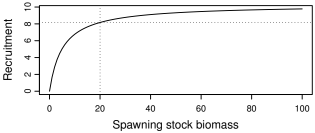


r : right-hand selectivity

Key parameters: h, M, r



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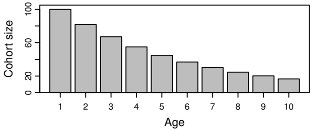

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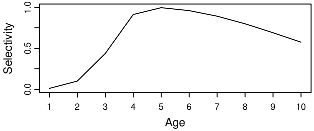

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Paper 2

FISH and FISHERIES, 2013, **14**, 325–342

Measuring uncertainty in fisheries stock assessment: the delta method, bootstrap, and MCMC

Arni Magnusson[1,2], André E Punt[1] & Ray Hilborn[1]

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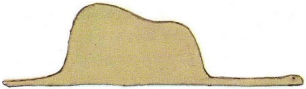


Uncertainty methods: delta, boot, mcmc

	Procedure	Interval
Delta method	$\widehat{\mathrm{SE}}_{\hat{g}} = \sqrt{\sum_i \sum_j \widehat{\mathrm{Cov}}\left(\hat{\theta}_i, \hat{\theta}_j\right)\left(\frac{\partial g}{\partial \theta_i}\right)\left(\frac{\partial g}{\partial \theta_j}\right)}$	$\left[\hat{g} - z_{1-\alpha/2}\widehat{\mathrm{SE}}_{\hat{g}},\ \ \hat{g} + z_{1-\alpha/2}\widehat{\mathrm{SE}}_{\hat{g}}\right]$
Bootstrap	simulate datasets *y**	$\left[\frac{\alpha}{2} \text{ quantile from } {}_{\mathrm{BC}}\vec{\hat{\theta}}^{\star},\ \ \left(1-\frac{\alpha}{2}\right) \text{ quantile from } {}_{\mathrm{BC}}\vec{\hat{\theta}}^{\star}\right]$
MCMC	simulate parameter values	$\left[\frac{\alpha}{2} \text{ quantile from } \vec{\theta},\ \ \left(1-\frac{\alpha}{2}\right) \text{ quantile from } \vec{\theta}\right]$

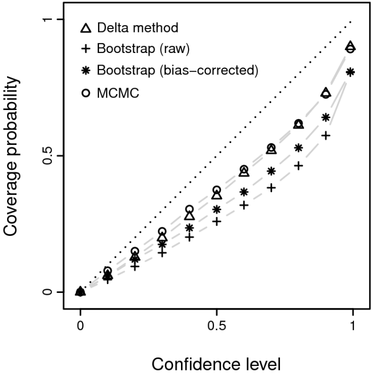
Uncertainty methods: delta, boot, mcmc

Delta method

Bootstrap

MCMC

Performance



Uncertainty methods: delta, boot, mcmc

Performance

Delta method	All methods produce too narrow intervals	Better than bootstrap	
Bootstrap			
MCMC		Better than bootstrap	Best in terms of worst-case performance

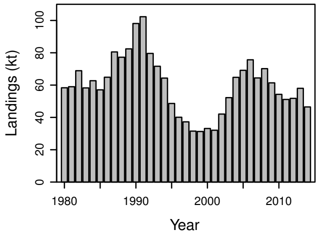
Paper 3

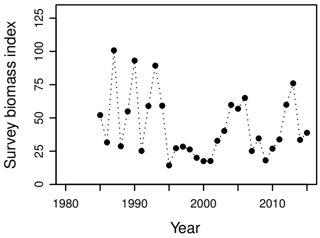
Confronting Uncertainty in Stock Assessment

Paper 3

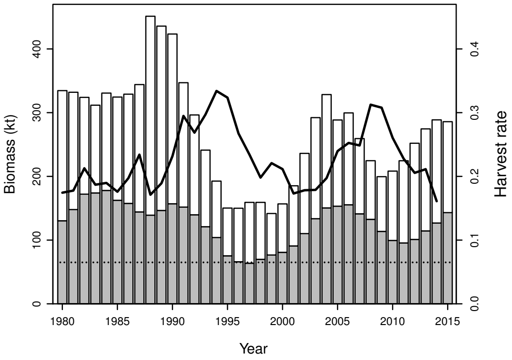
Confronting Uncertainty in Stock Assessment

Icelandic saithe





Biomass and harvest rate



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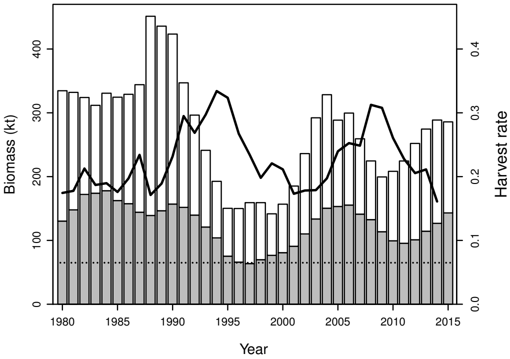
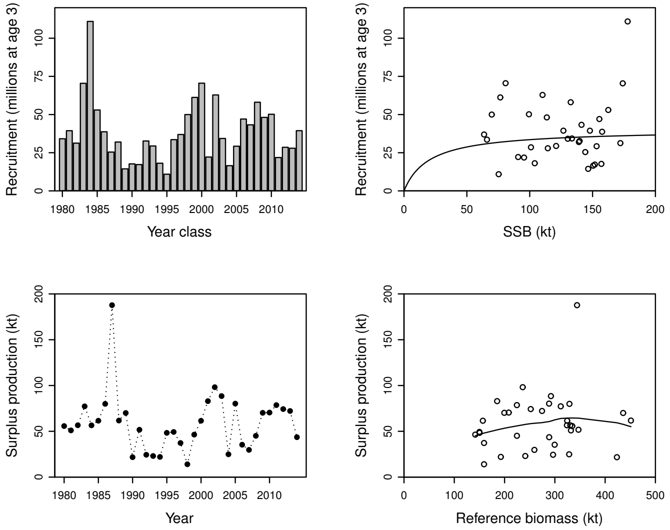
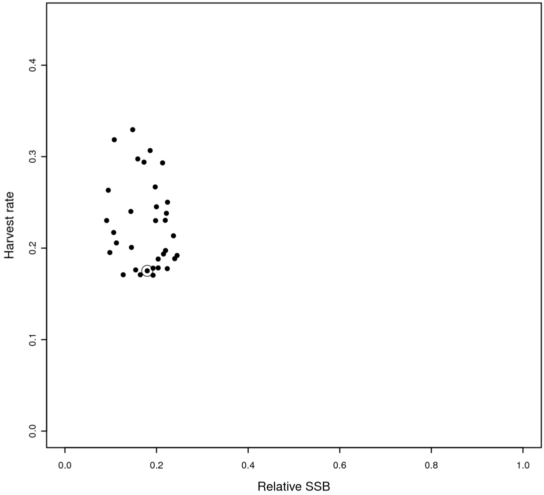


20% HCR: $$TAC_t = \frac{0.20 B_{t,\mathbf{4}+} + TAC_{t-\mathbf{1}}}{2}$$

Recruitment and surplus production



Fishing history



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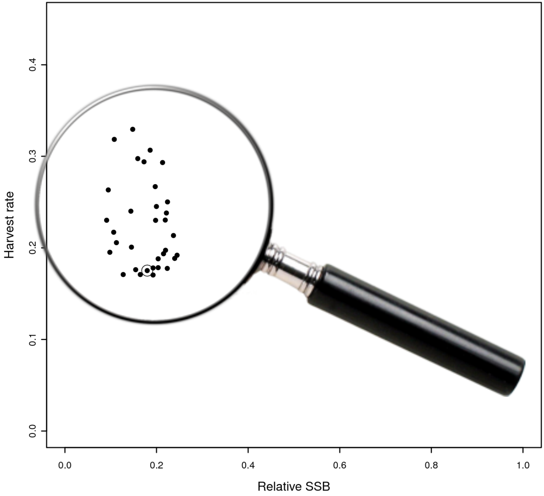

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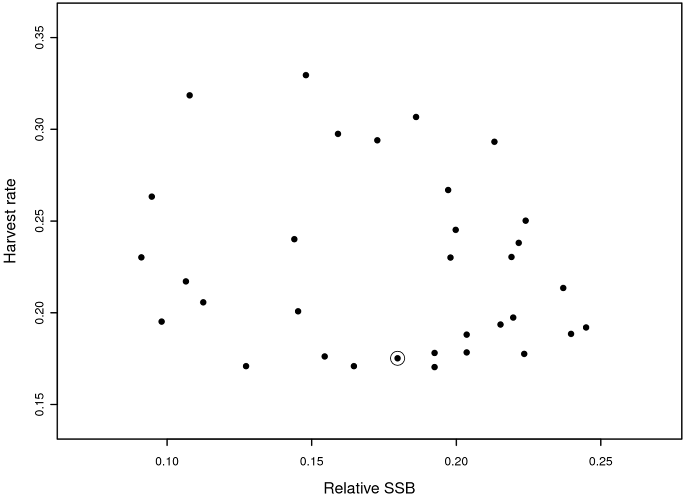

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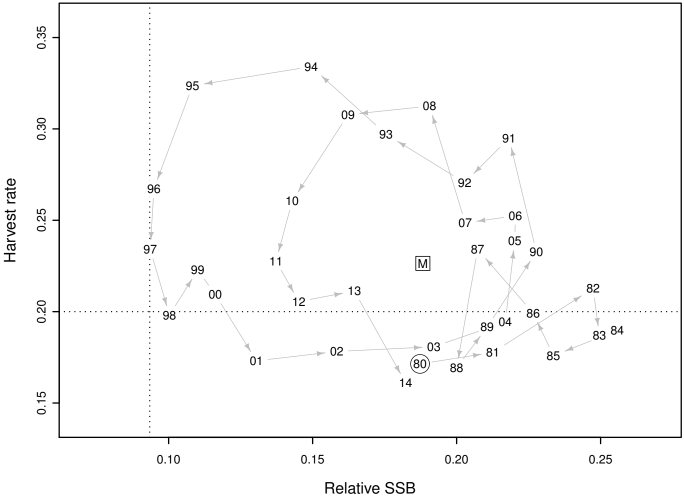
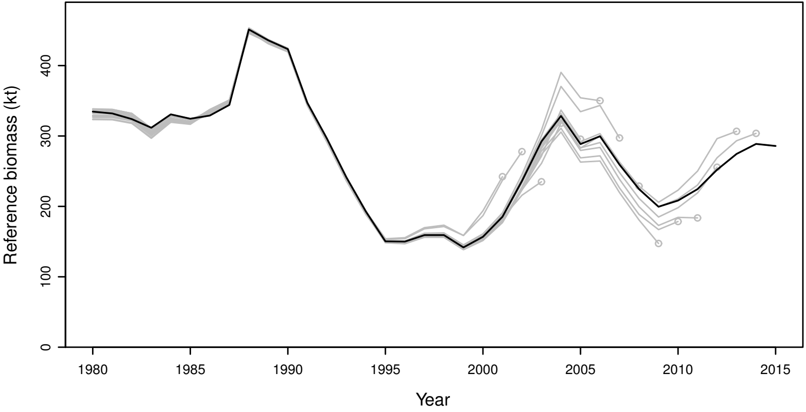
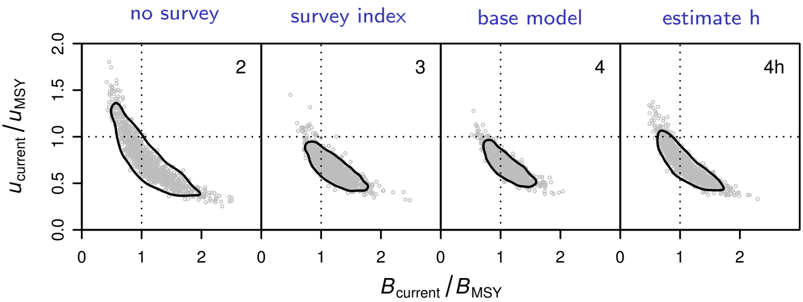


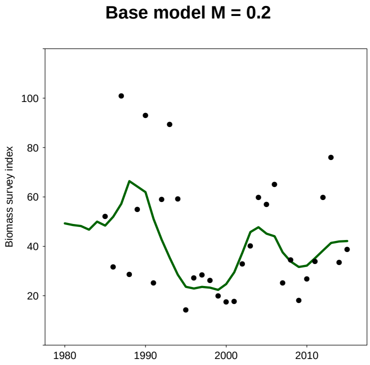
Retrospective analysis

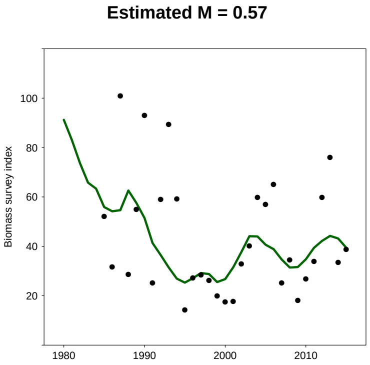


Bivariate confidence region

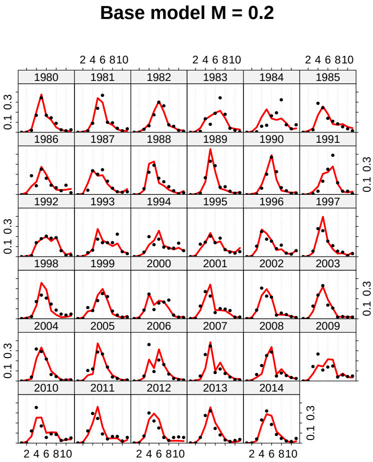


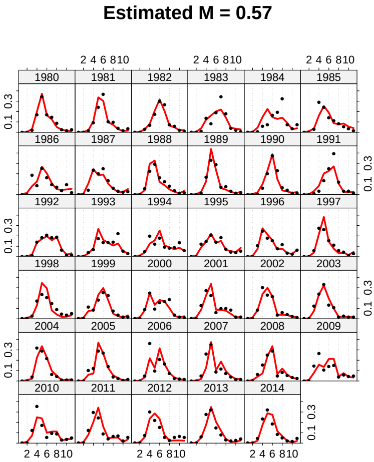
Estimating M





Estimating *M*





Estimating h and M

Stock-recruitment steepness

$h = 0.90$ in base model

Point estimate is 0.99

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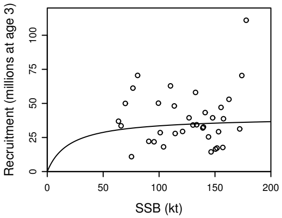

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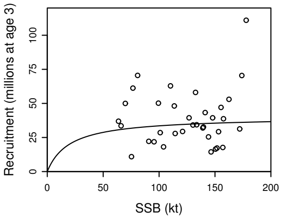

Natural mortality rate

$M = 0.20$ in base model

Point estimate is 0.57

Estimating h and M

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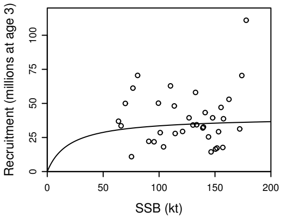

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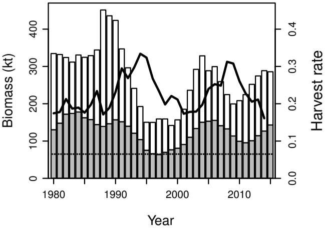

Summary of findings

Fishing history

One-way-trip proved no less informative than good contrast

'the more fish you catch, the better you know how many there were'

Key parameters

h : data must include years with very low SSB

M : data must include high and low F

r : confounded with M

Uncertainty methods

MCMC, delta method, profile likelihood more reliable than bootstrap

General recommendations

1. Use more than one method to evaluate uncertainty.
2. Keep in mind that the real uncertainty is greater than the analytical confidence intervals indicate.
3. Use more than one model and variations of models to evaluate how sensitive the main conclusions are to alternative assumptions.
4. Use retrospective analysis to evaluate uncertainty from an empirical viewpoint.

General recommendations

5. Use simulation analysis to evaluate the performance of the estimation model, which parameters can be estimated reliably, and which uncertainty methods work best.

6. Examine the fishing history to evaluate whether the data are likely to be informative about the stock status and key parameters like h and M.

7. Consider ways to reduce uncertainty by generating informative data via management (e.g., applying different fishing mortalities between years) and research (e.g., design a dedicated survey for a given stock, sample age data).

8. Harvest control rules can be a practical way to incorporate uncertainty into management advice.

Value

Comprehensive **overview** and **evaluation**

of methods to analyze uncertainty

Value

Comprehensive **overview** and **evaluation**

of methods to analyze uncertainty

Checklist of **recommendations**

for stock assessment practitioners

Acknowledgements

Committee: **Ray**, **André**, Jim, John, Christine

Staff: Amy, Machelle

ADMB friends: Dave, Hans, Johnoel, Jim, Mark, Anders, John

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NZ friends: Allan, Trevor, Vivian, Brandon, Paul

New friends: Punt lab, Hilborn lab, Branch lab, Essington lab

Icelandic mentors: Gunnar, Jakob, Björn

Family here today: Kristbjörg, Steini, Johannes, Sylvia

Family home: **Steffí**, **Emma**, Sigga, Þórunn, Magnús, Dedda, Sverrir

Thank you!