

**Measuring uncertainty in age-structured
fisheries stock assessment models using
delta, bootstrap, and MCMC methods**

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Why measure uncertainty

Fisheries managers would like to know the status of the resource and expected consequences of alternative actions

- Current biomass, absolute or relative
- Future biomass, given catch level x

Not only the most likely value, but a range of likely values

- Confidence interval

What's the problem

“Very unlikely” things keep happening in fisheries

- Our methods underplay the real uncertainty
- A 90% confidence interval should contain the true value 90% of the time

Scientists use a variety of methods, not knowing which methods are more reliable than other

- Using delta method, bootstrap, or MCMC can lead to different management advice

Which method works best?

Punt and Butterworth (1993)

- Delta - Jackknife - Bootstrap
- Schaefer~SCA, data=hake
- Equally good, if bootstrap is done right

Restrepo et al. (2000)

- Delta - Bootstrap - MCMC
- VPA~SCA, data=contrast
- Delta and bootstrap are best, with bias correction

My plan

Magnusson and Punt (in prep.)

- Delta - Bootstrap - MCMC
- SCA~SCA, data=contrast

Procedure

- Generate simulated datasets where true parameter values and reference points are known
- Run datasets through estimation model
- Apply different methods to quantify uncertainty about reference points
- Check how often confidence intervals contain true value

Limitations

In real assessments, the uncertainty is much greater than is captured in a simulation study

Mantra of simulation studies

- If a method doesn't work in laboratory conditions, it's probably not going to work in nature

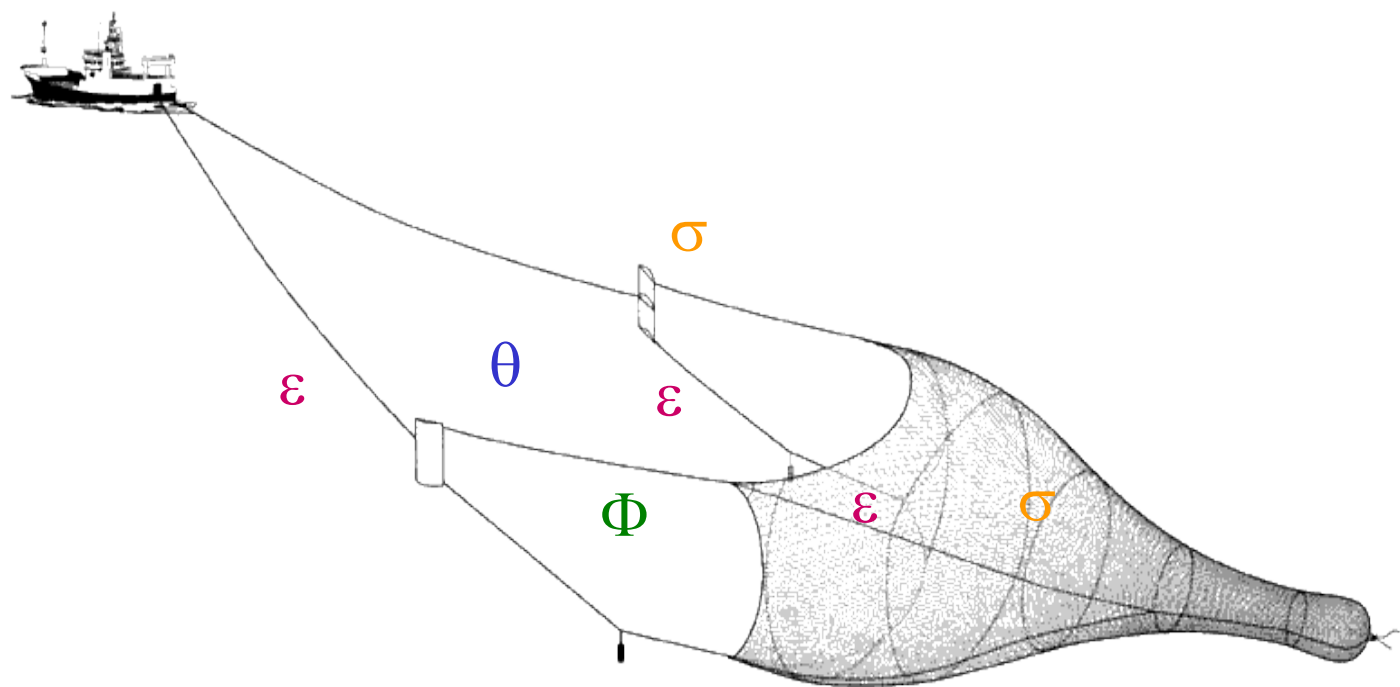
Hypothesis

For all methods, the empirical performance is expected to match the claimed uncertainty

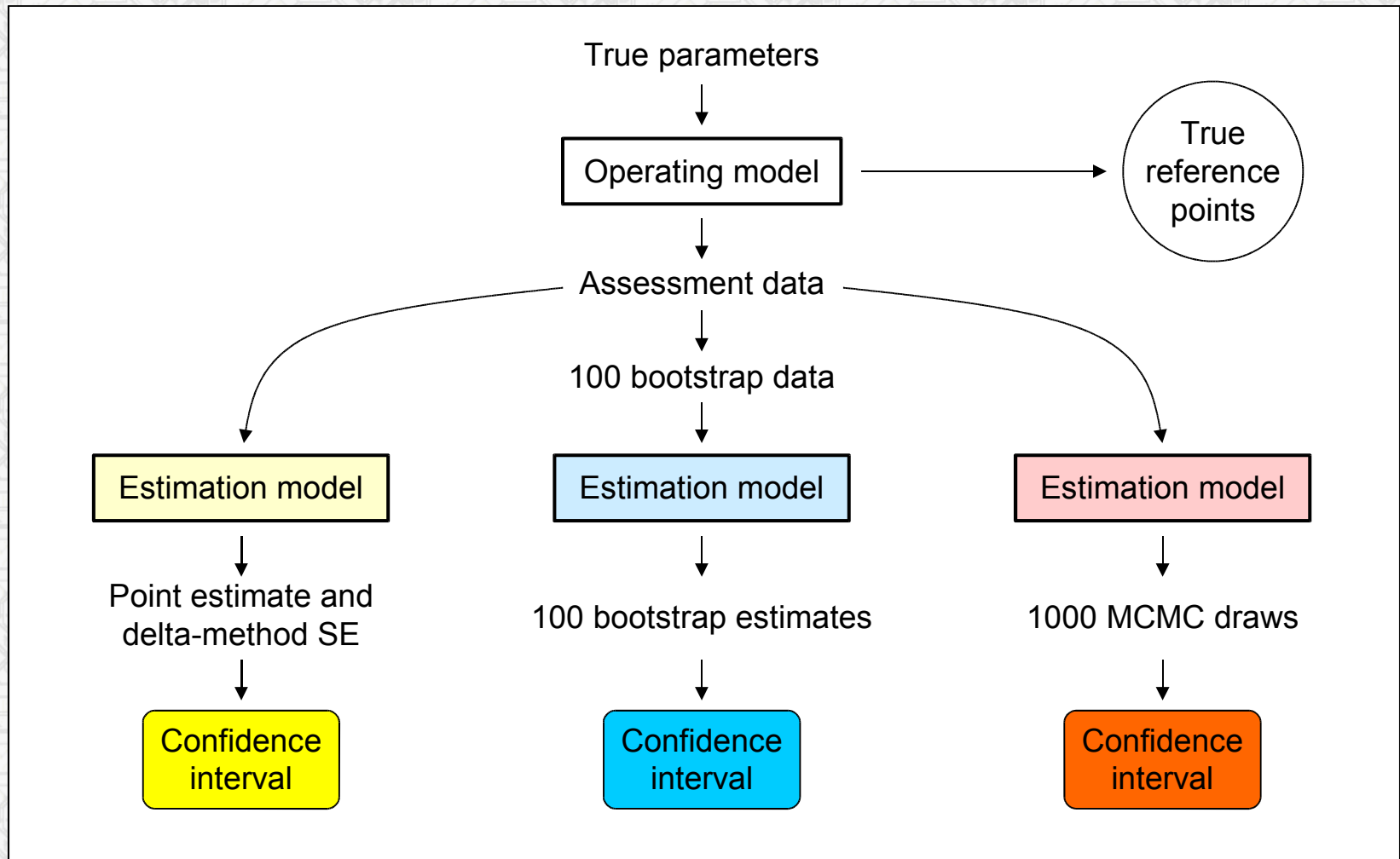
- Delta
- Bootstrap
- MCMC

Main emphasis on confidence limits, but bias and variance will also be looked at

Methods



Simulation flowchart



Operating model

Simple version of Coleraine, implemented in R

- Constant M , q , and selectivities

Biology and fishery based on Atlantic cod

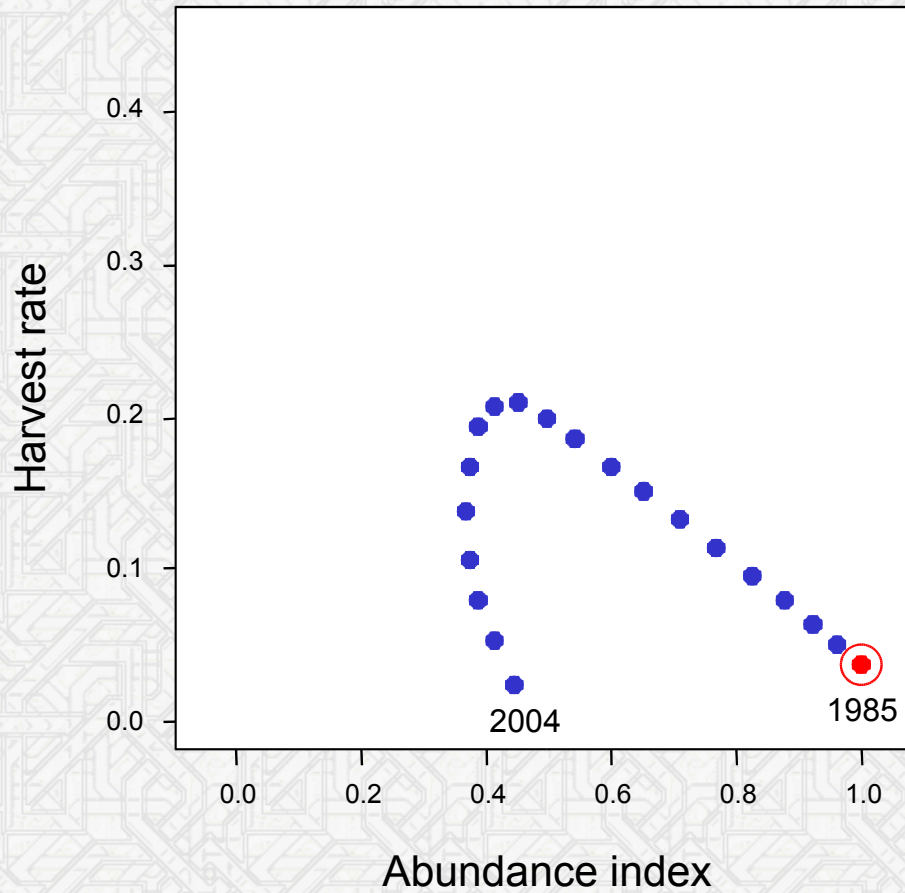
- 10 ages, $M=0.2$, Bev-Holt recruitment
- 20 years of data, one fleet, one survey, asymptotic selectivities

Simulated datasets

- Recruitment variability $\sigma_R=0.6$
- Observation noise $\sigma_I=0.2$, $n=50$

Scenario

Contrasted fishing history



Estimation model

Coleraine, given the exact

- model structure
- σ_R , σ_I , n
- annual catch, weight and maturity at age

Estimating

- R_0 , h , M , q , dome-shaped selectivities
- u_{init} , R_{init} , R_{plus} , recruitment deviates

Objective function

- $survIndex + survCA + comCA + penalties$

Reference points

B_{2005}

current spawning biomass

Depletion

$$B_{2005}/B_0$$

MSY

avg long-term catch at optimal u_{MSY}

B_{2005}/B_{MSY}

current abundance relative to B_{MSY}

Surplus

$$Y_{2004} + (VB_{2005} - VB_{2004})$$

Measuring uncertainty

Delta

ADMB output (.cor)

Bootstrap

add parametric noise to CA and Index, 100 datasets

MCMC

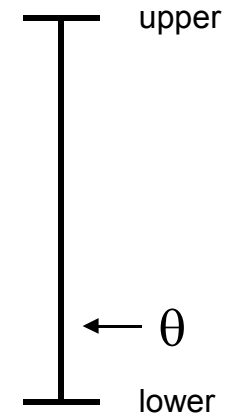
ADMB output (.psv), million iterations, 1000 draws

All methods benefit from knowing $\sigma_i=0.2$ and $n=50$

Performance

Compare

- $\text{CONFINT}_{\text{delta}}$
- $\text{CONFINT}_{\text{boot}}$
- $\text{CONFINT}_{\text{mcmc}}$



to the true value of a reference point

If we look at one thousand 90% confidence intervals for MSY, we expect around 900 out of 1000 to contain the true value

Initial results

300 assessment datasets

Recruitment pattern #1

- 100 x observation noise

C4hmr-01-001.txt

...

C4hmr-01-100.txt

Recruitment pattern #2

- 100 x observation noise

C4hmr-02-001.txt

...

C4hmr-02-100.txt

Recruitment pattern #3

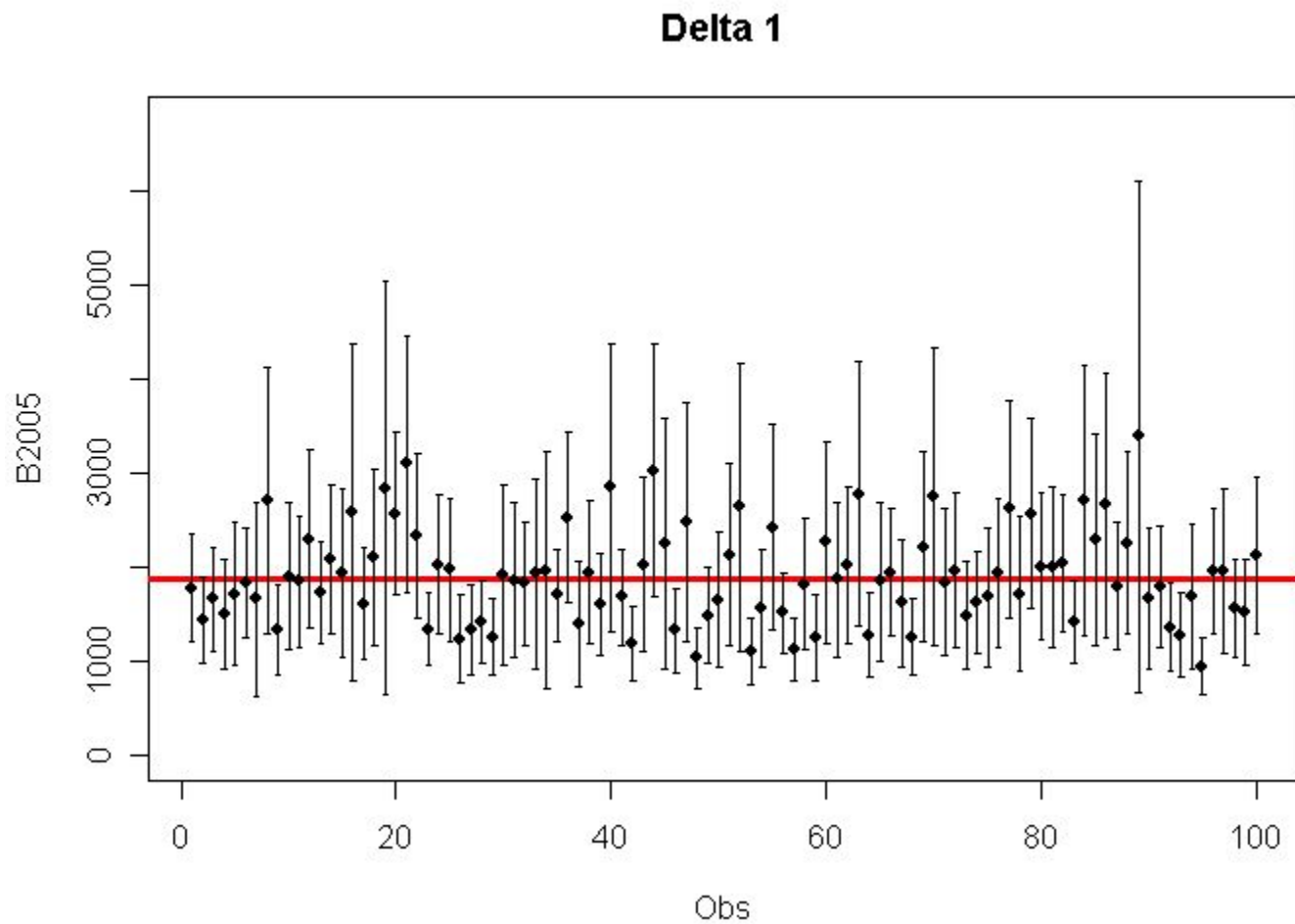
- 100 x observation noise

C4hmr-03-001.txt

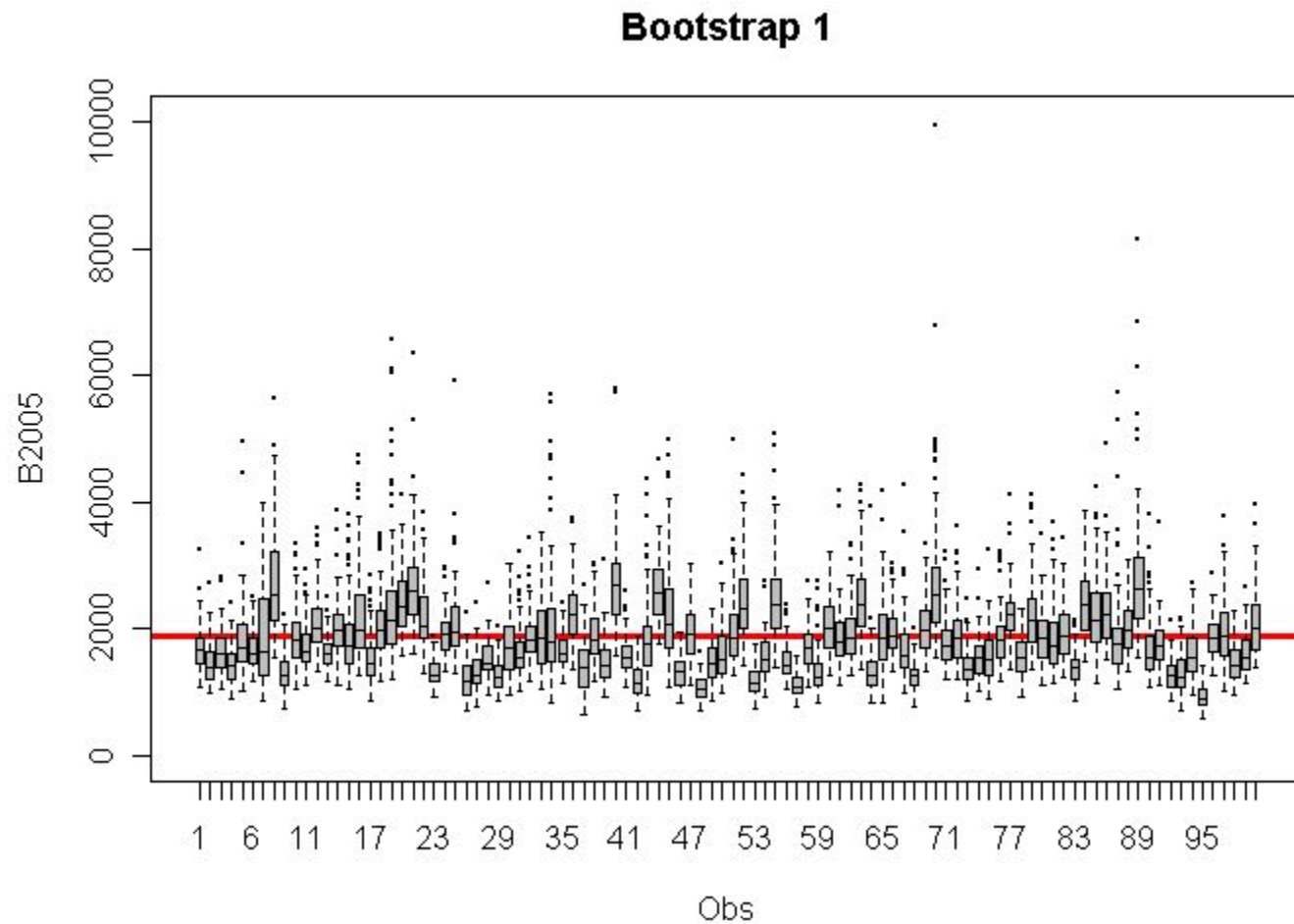
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C4hmr-03-100.txt

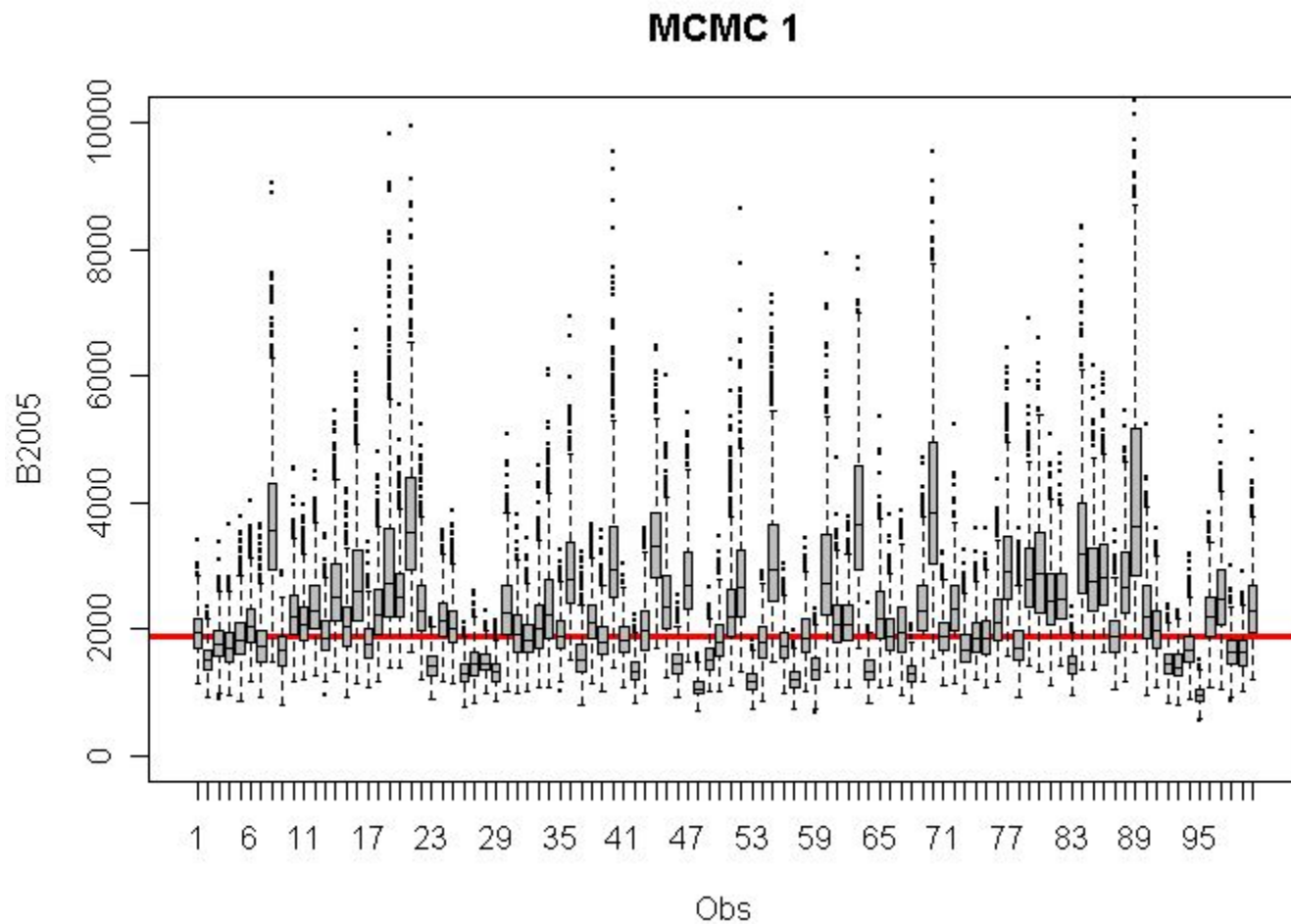
Initial results



Initial results



Initial results



Discussion

Operating model

- constant M and sel, linear $I=qB$
- ...

Estimation model, maybe we'd like to explore a model that

- underplays uncertainty
- overplays uncertainty
- ...

Discussion

Likelihood profiling

Does ADMB apply the delta method with a bias correction? Should I be using bias correction and/or variance acceleration in my bootstrap analysis?

Performance (something other than conf. int.)

Theoretical differences, how to interpret conf. int.