Management Strategy Evaluation and the Gulf of Alaska walleye pollock fishery: incorporating climate variability

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18 May 2008

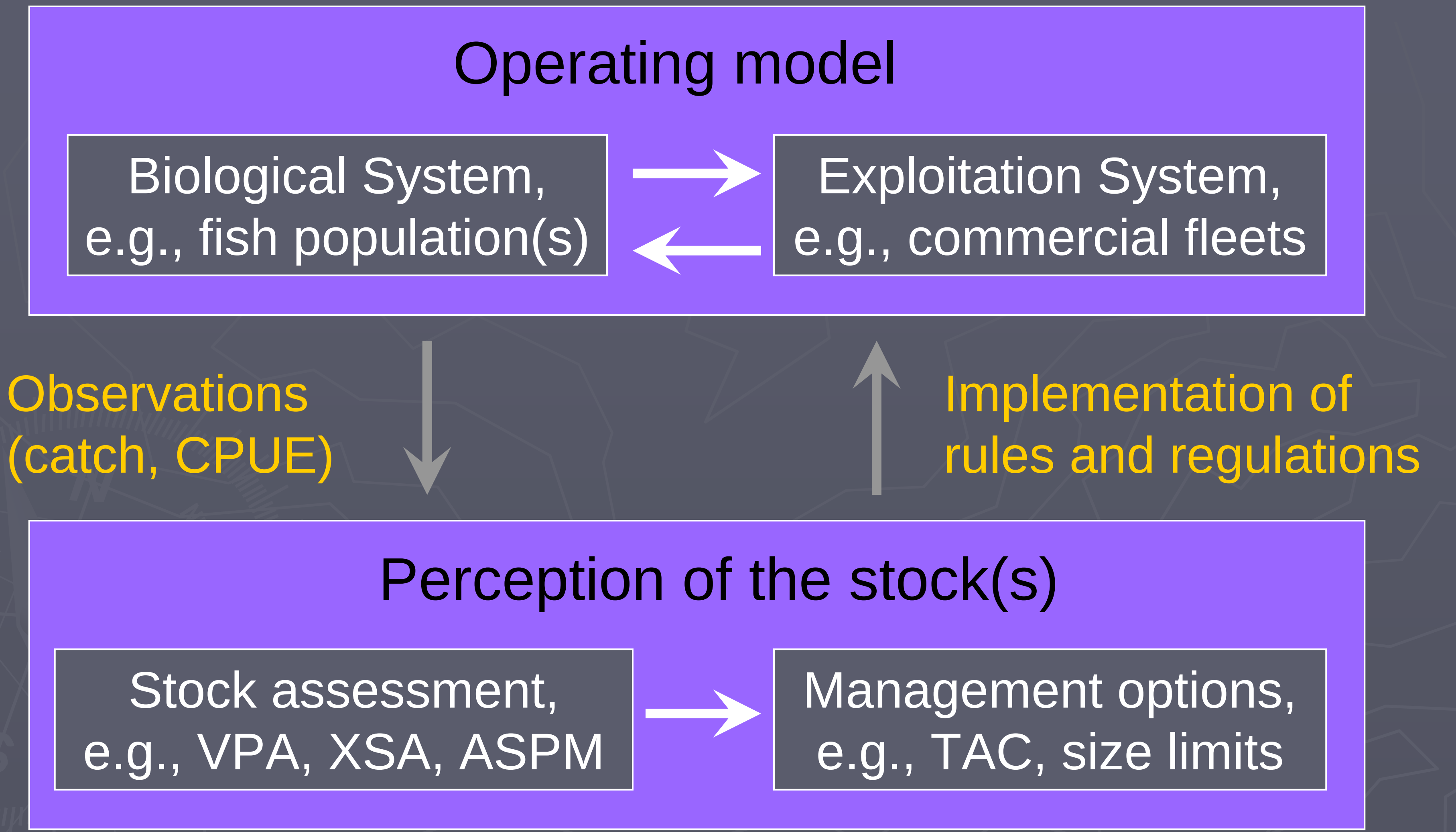
Outline

- Management Strategy Evaluation
- The Gulf of Alaska walleye pollock fishery
- The MSE for the GOA pollock fishery
- Simulation scenarios
- Results when including environmental variability

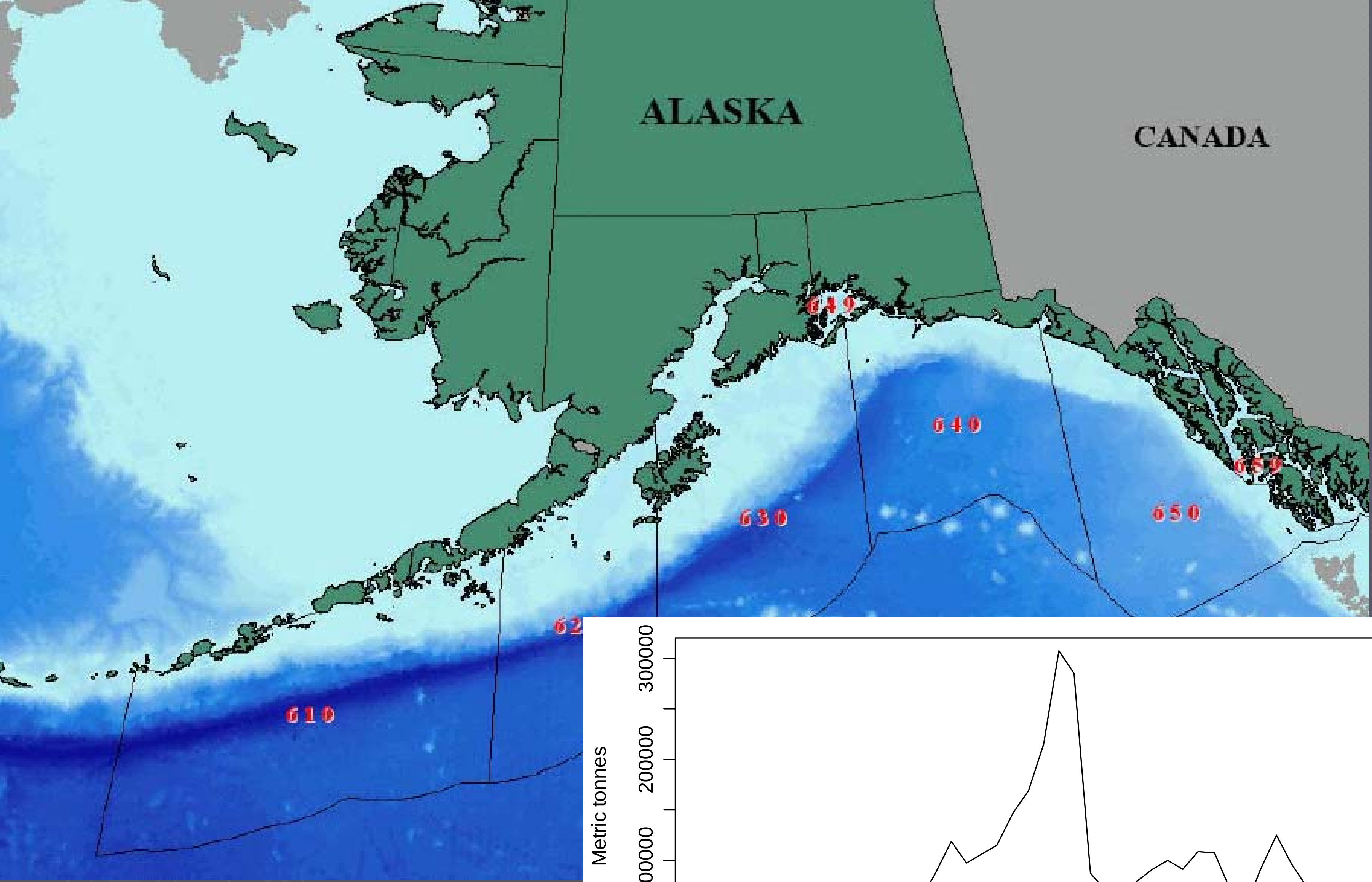
Management Strategy Evaluation

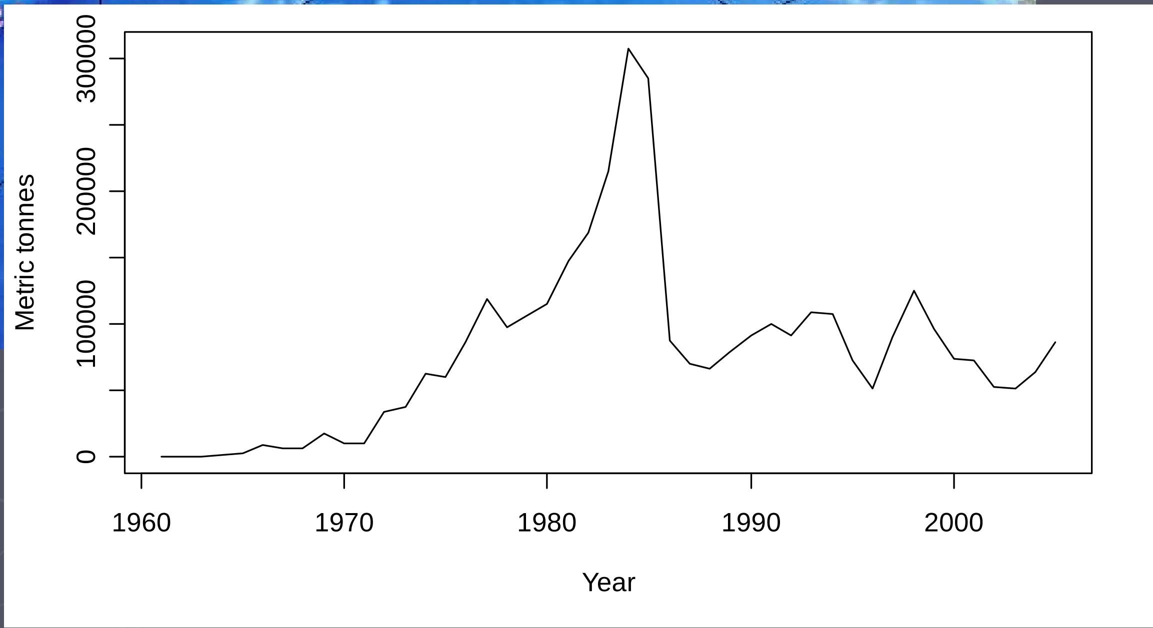
- Simulation testing of a management strategy with feedback
  - Can account for process, observation, model, and implementation uncertainty
- Why perform an MSE?
  - Assess the impact of error and uncertainty on the ability to achieve management goals and objectives
- This method is used in other countries, IWC

MSE Framework



From Fromentin and Kell, 2007


ALASKA
CANADA
649
640
630
659
650
610


Metric tonnes
0
100000
200000
300000
1960
1970
1980
1990
2000
Year

The GOA walleye pollock fishery

- Directed fishing since 1964; fully domestic since 1989
- Managed by the NPFMC, with scientific advice provided by NOAA Fisheries - AFSC
- Current management strategy used since 2001
- Certified by the MSC in 2005

Components of the GOA pollock MSE

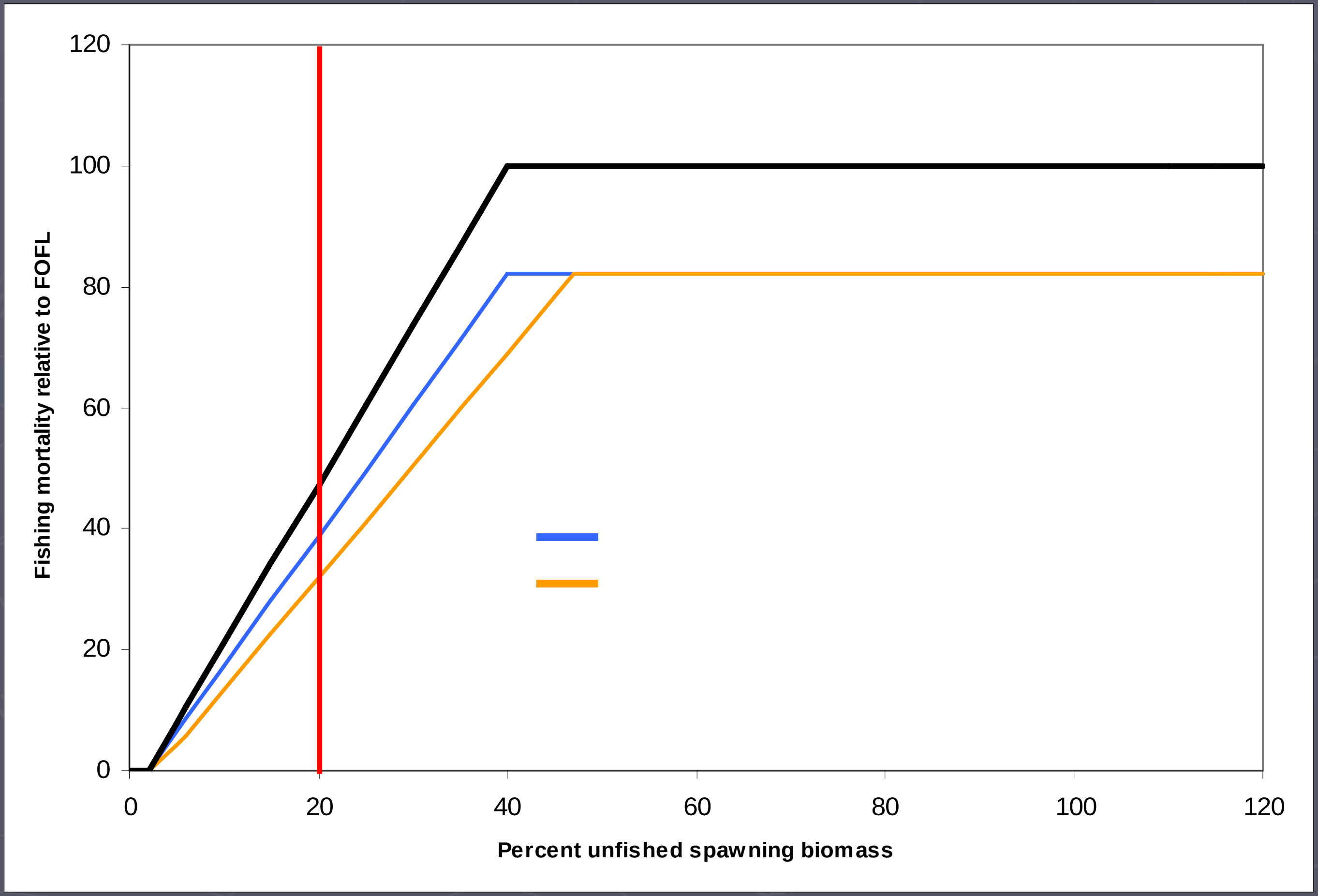
- The operating model
  - represents the “true” state of nature
  - applies management decisions to the “true” stock
- The stock assessment model
  - represents the “perceived” state of the stock
  - estimates stock status and biological reference points
- The decision rule
  - determines management decisions based on the results of the stock assessment
- The performance measures
  - statistics that quantify management goals and objectives

The models

- Statistical catch-at-age population dynamics models
- Fit fishery, survey, and biological data
- Estimate biological reference points
- Main difference is the age range
- Operating model
  - Estimates and projects process, observation, and model error

GOA pollock fishery management strategy

Annual stock assessment estimates $F_{40\%}$, $SB_{40\%}$, and current spawning biomass

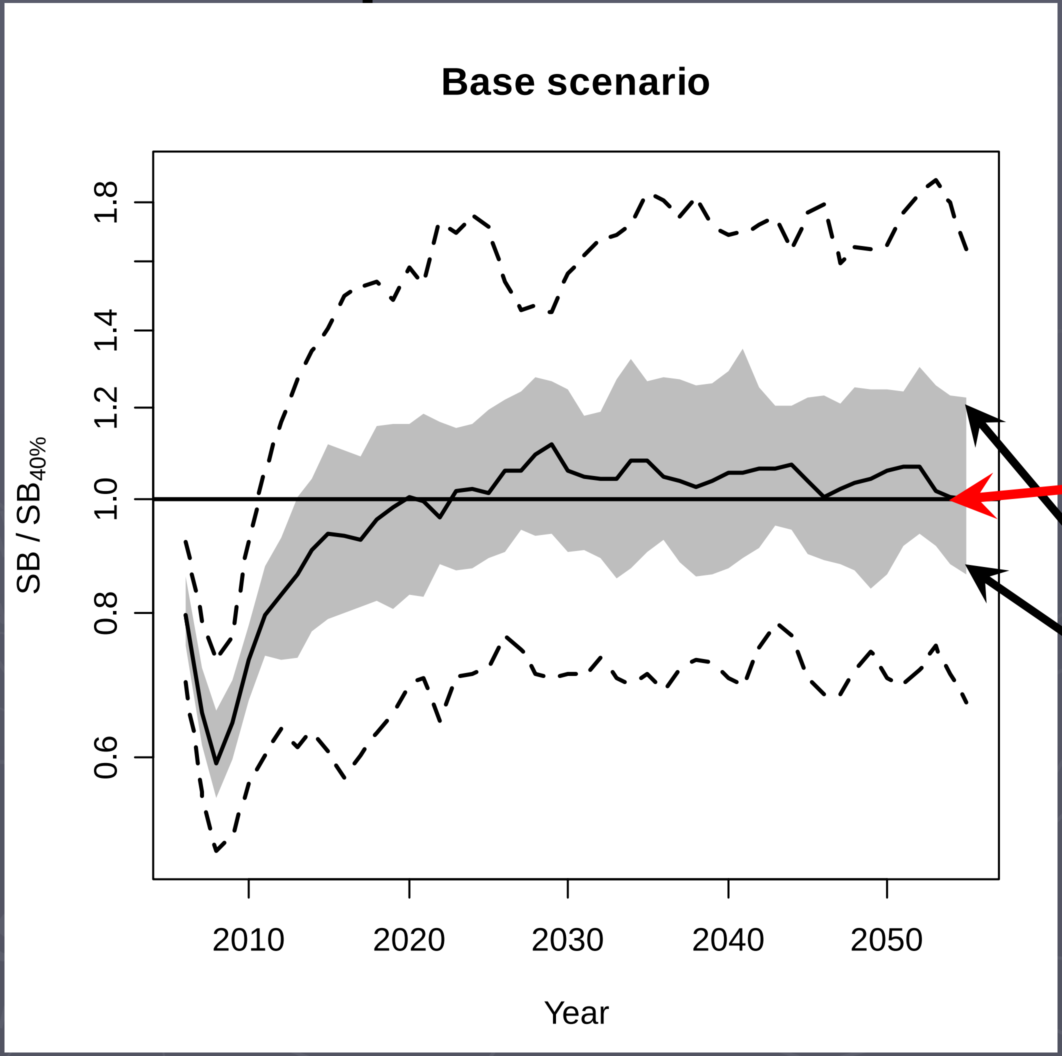


Some results

Simulation scenarios

- Base scenario
  - 50 years, 2006 – 2055
  - No environmental or ecosystem forcing
- Regime shifts
  - 50 years, 2006 – 2055
  - Changes in average level of recruitment
- Environmental variability
  - 45 years, 2006 – 2050
  - Climate indices affect annual recruitment

Base scenario – management performance: $SB/SB_{40\%}$



Is the spawning biomass near the target level?

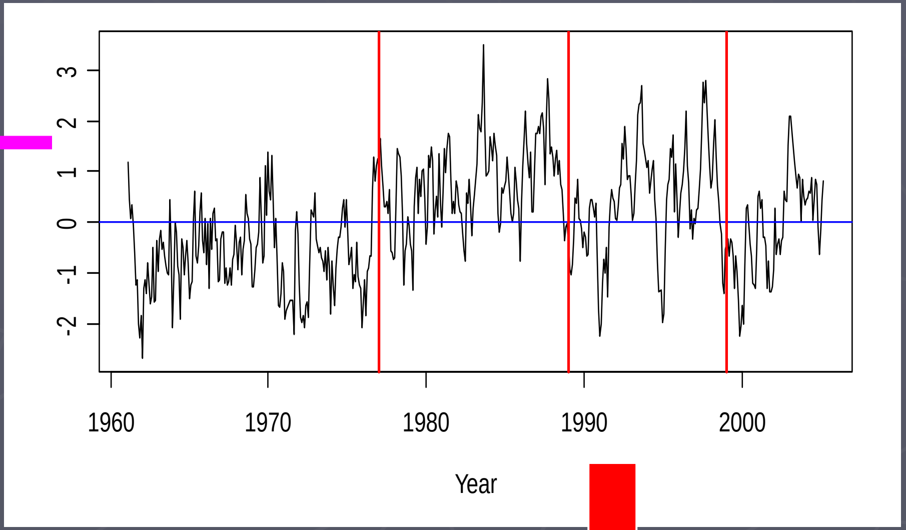
Target level

Inter-simulation quantiles

The stock is close to the target level on average

Environmental forcing

Climate indices



Age-structured operating model

Link to recruitment

Data

TAC

Management Strategy

Climate Decision rule

Years for defining the current regime

Environmental effects

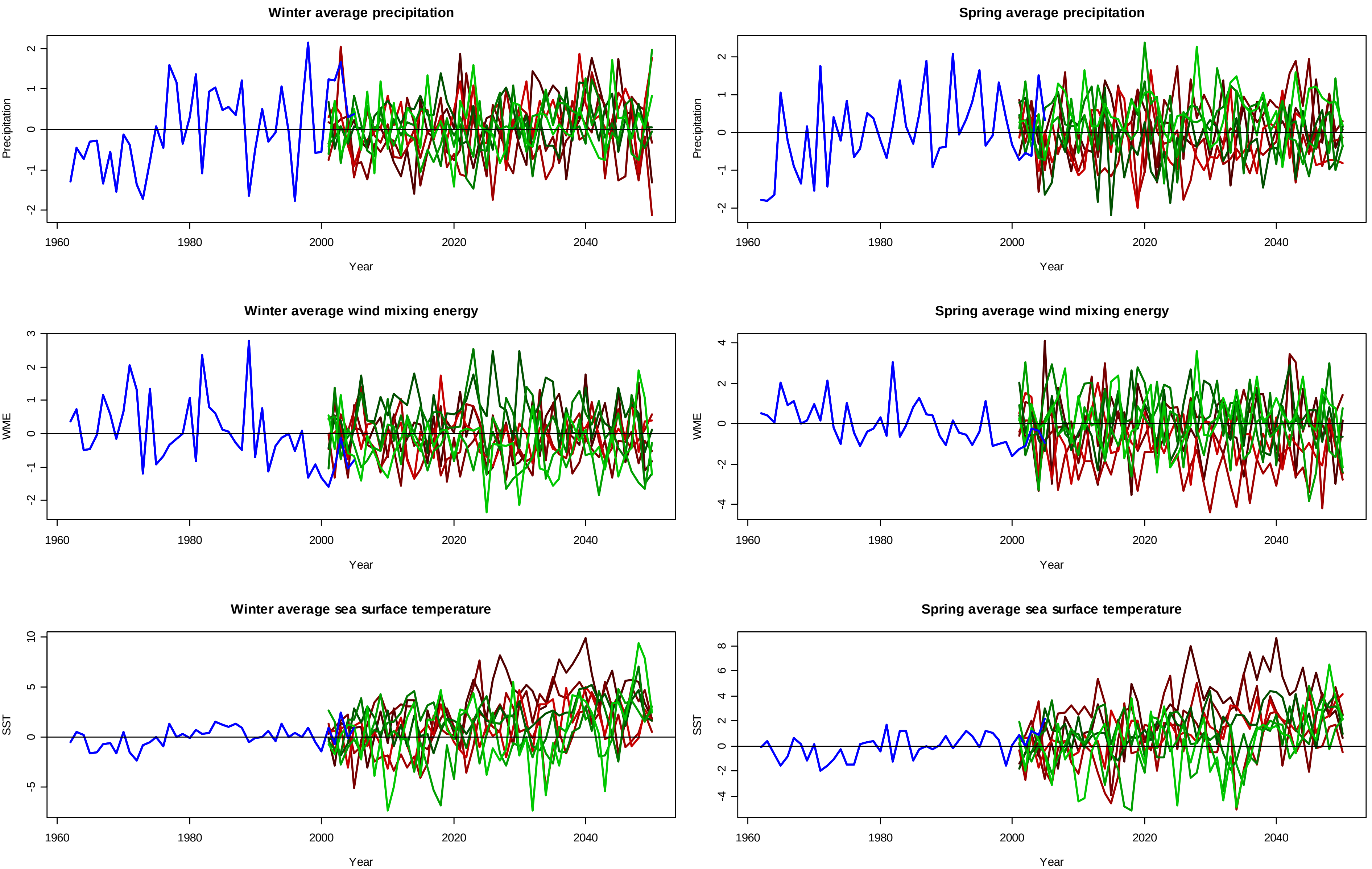
Mechanism	Index	Season	Source/Citation
Primary production	Precipitation	Winter	Bailey *et al*. 2005
Primary production	Wind mixing energy	Winter	Bailey *et al*. 2005
Concentration of prey and larvae	Eddy formation due to freshwater input – Precipitation	Spring	FOCI
Concentration of prey and larvae	Upwelling and transport – Wind mixing energy	Spring	FOCI
Stage duration	Temperature	Spring	FOCI
Water column turbulence, eddies, transport, advection, upwelling	Precipitation	Spring	Ciannelli *et al*. 2004, Bailey *et al*. 2005
Water column turbulence, eddies, transport, advection, upwelling	Wind mixing energy	Spring, Summer	Bailey and Macklin 1994, Ciannelli *et al*. 2004, Bailey *et al*. 2005
Temperatures affect amount of prey and amount of pelagic habitat for juveniles and age-0 animals	Sea surface temperature (may interact with other environmental factors)	Summer, Autumn	Bailey 2000, Bailey *et al*. 2005

Environmental variability

- Climate indices
  - precipitation (on Kodiak Island)
  - wind mixing energy (Shelikof Strait)
  - sea surface temperature (Shelikof Strait)
  - North Pacific PDO anomaly

- Jan 1962 – Dec 2005 (historical data)
- Jan 2001 – Dec 2050 (data from IPCC model output)

Climate indices



Incorporating climate indices

$$R_{y+1} = \bar{R}_1 \exp\left(\sum_{i=1}^{n} a_i I_{i,y}\right) e^{\varepsilon_y - \sigma_R^2/2}; e_y \sim N(0, \sigma_R^2)$$

- Multiple scenarios for climate forcing on age-1 recruitment
  - Model selection using AIC
- Accounts for some of the process error using the climate indices
  - σ_R decreased from 1.0 to 0.6
- Two management strategies were evaluated

Operating models

- Model 1
  - Winter precipitation
    - +0.339 (0.119)
  - Spring SST
    - -0.833 (0.180)
  - Summer precipitation
    - -0.140 (0.095)
  - Summer SST
    - +0.570 (0.187)
  - Autumn SST
    - -0.405 (0.130)

- Model 2
  - Winter precipitation
    - +0.310 (0.117)
  - Spring SST
    - -0.776 (0.176)
  - Summer SST
    - +0.531 (0.185)
  - Autumn SST
    - -0.394 (0.130)

Match existing hypotheses

Management strategies

$$SB_{40\%} = SBPR(F = F_{40\%}) * \bar{\mathrm{R}}_y$$

- Current management strategy

$$\bar{R}_y = \frac{1}{y-1978} \sum_{y'=1978}^{y-1} N_{y',1}$$

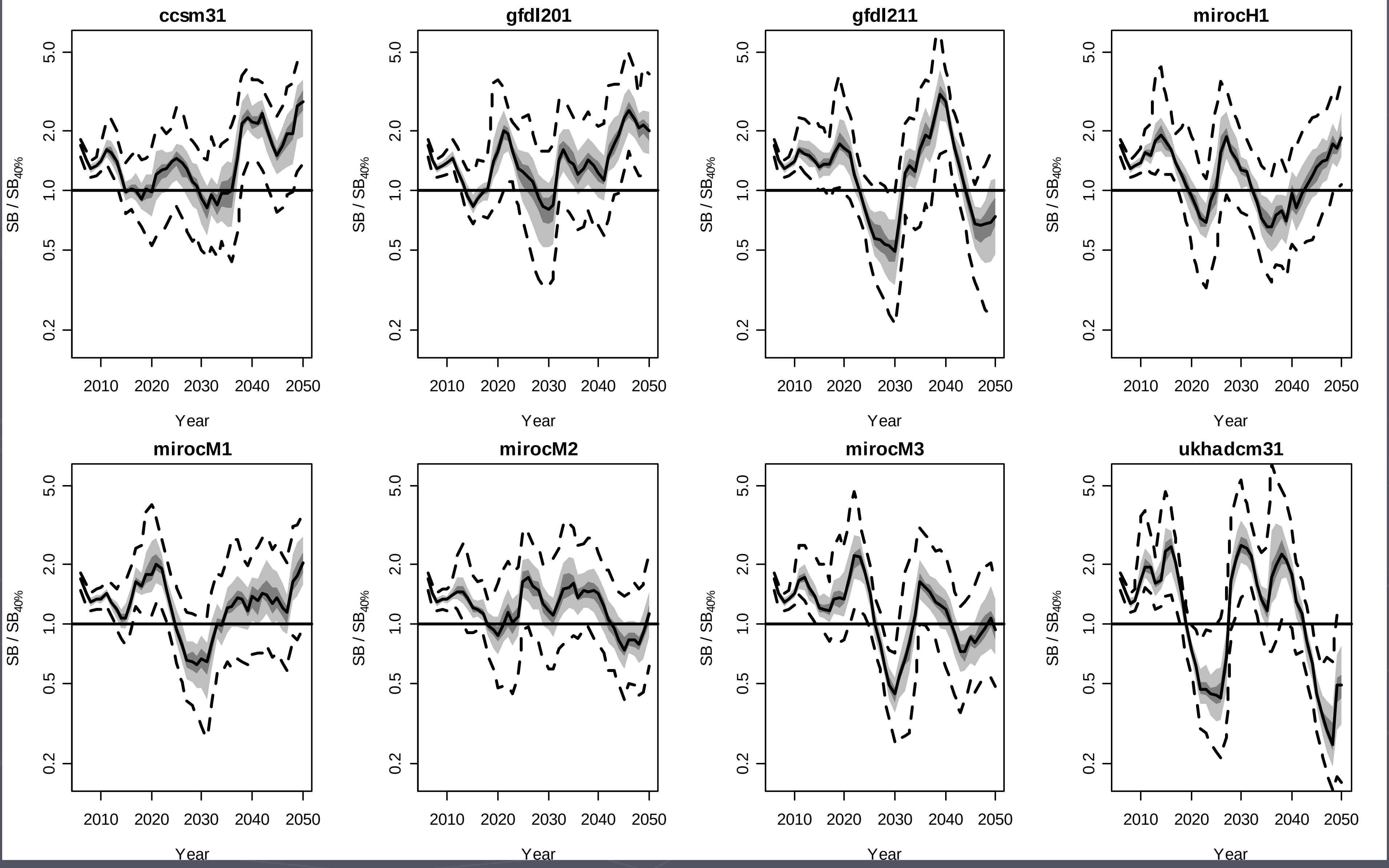
- Dynamic B_0 management strategy

$$\bar{R}_y = \sum_{a=1}^{15} m_a w_a N_{y-a,1} / \sum_{a=1}^{15} m_a w_a$$

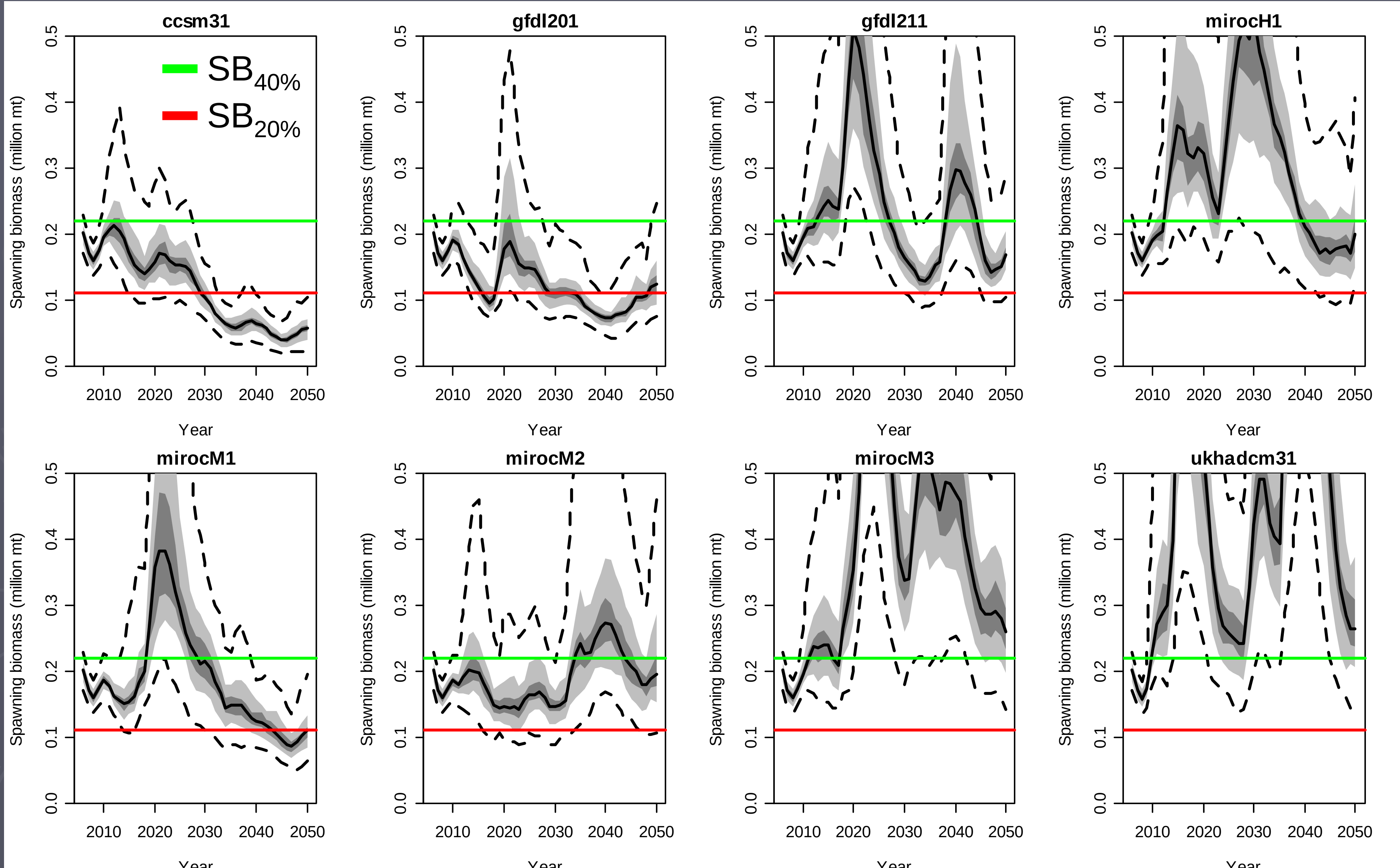
- CPA algorithm management strategy

$$\bar{R}_y = \frac{1}{y-\mathrm{RegimeYear}} \sum_{y'=\mathrm{RegimeYear}}^{y-1} N_{y',1}$$

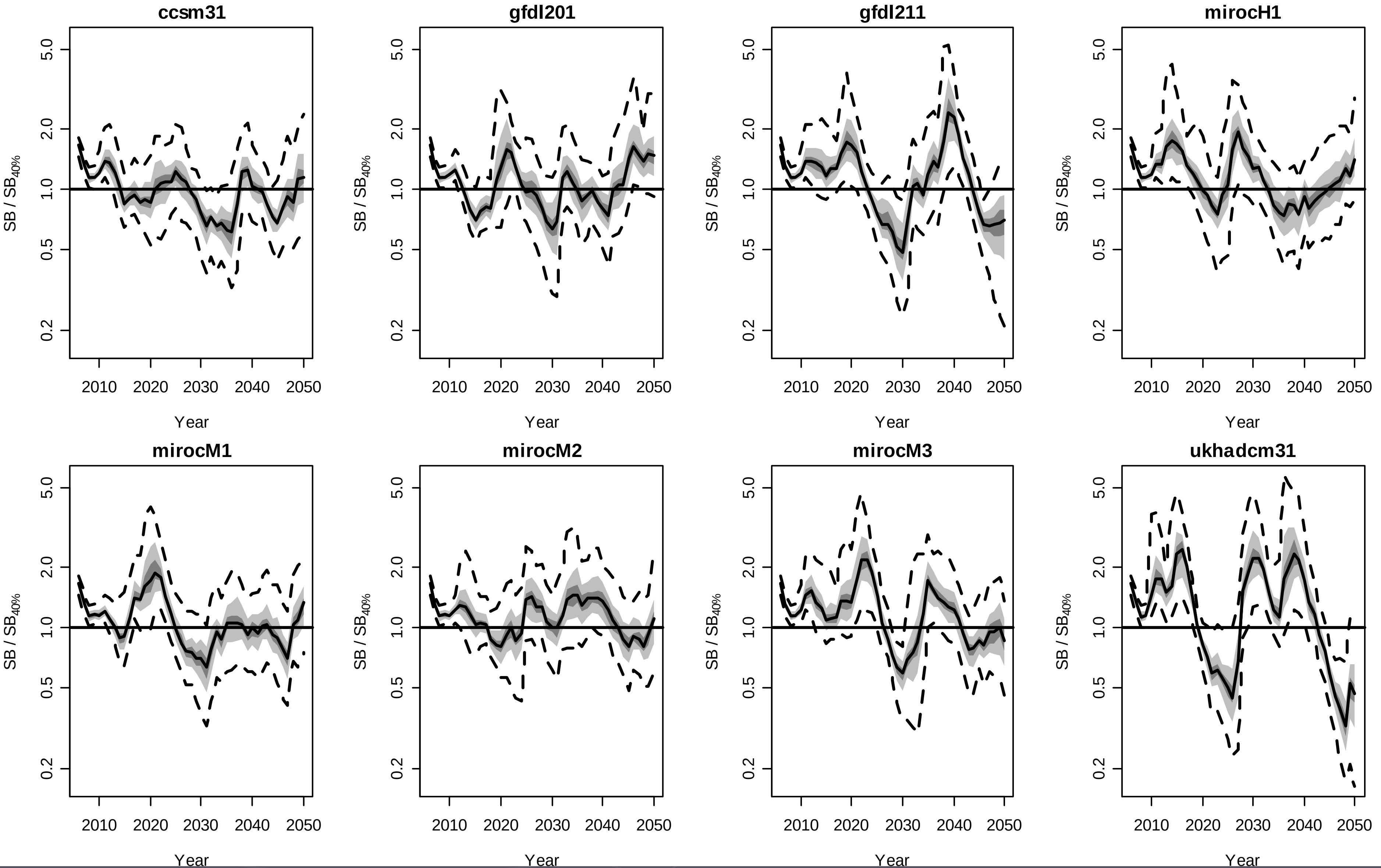
Current MS – $SB/SB_{40\%}$



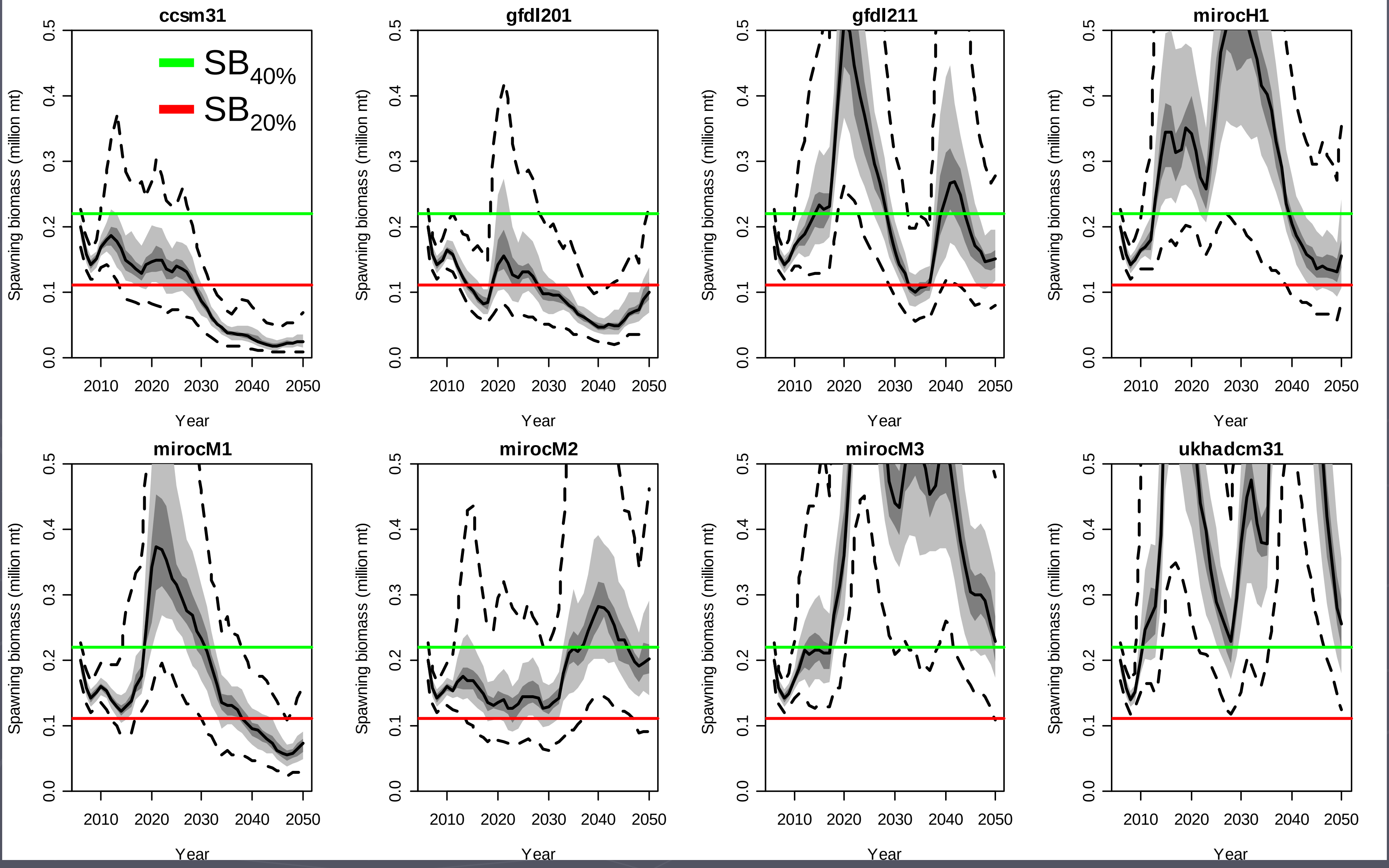
Current MS – spawning biomass



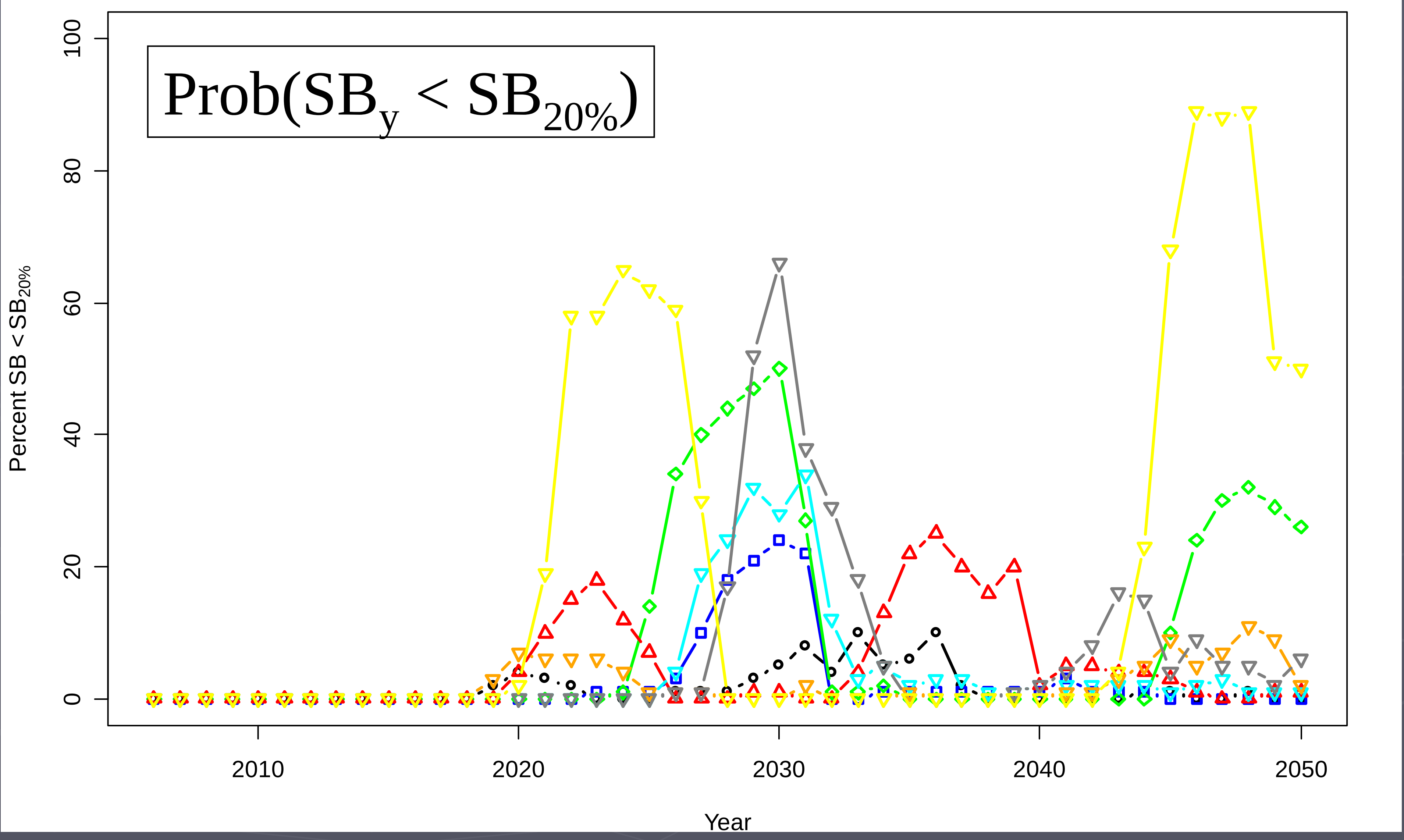
Dynamic B_0 MS – $SB/SB_{40\%}$



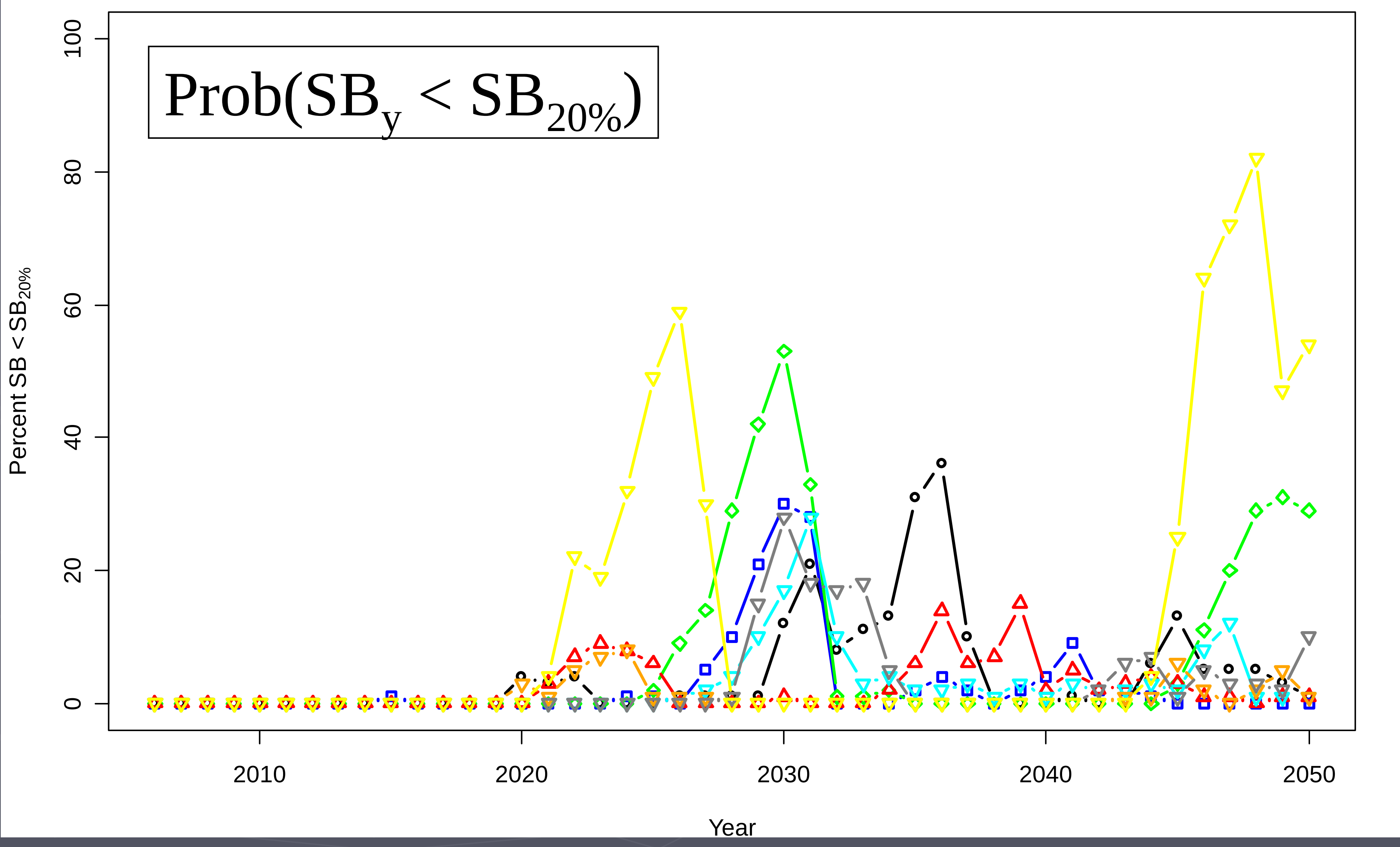
Dynamic B_0 MS – spawning biomass



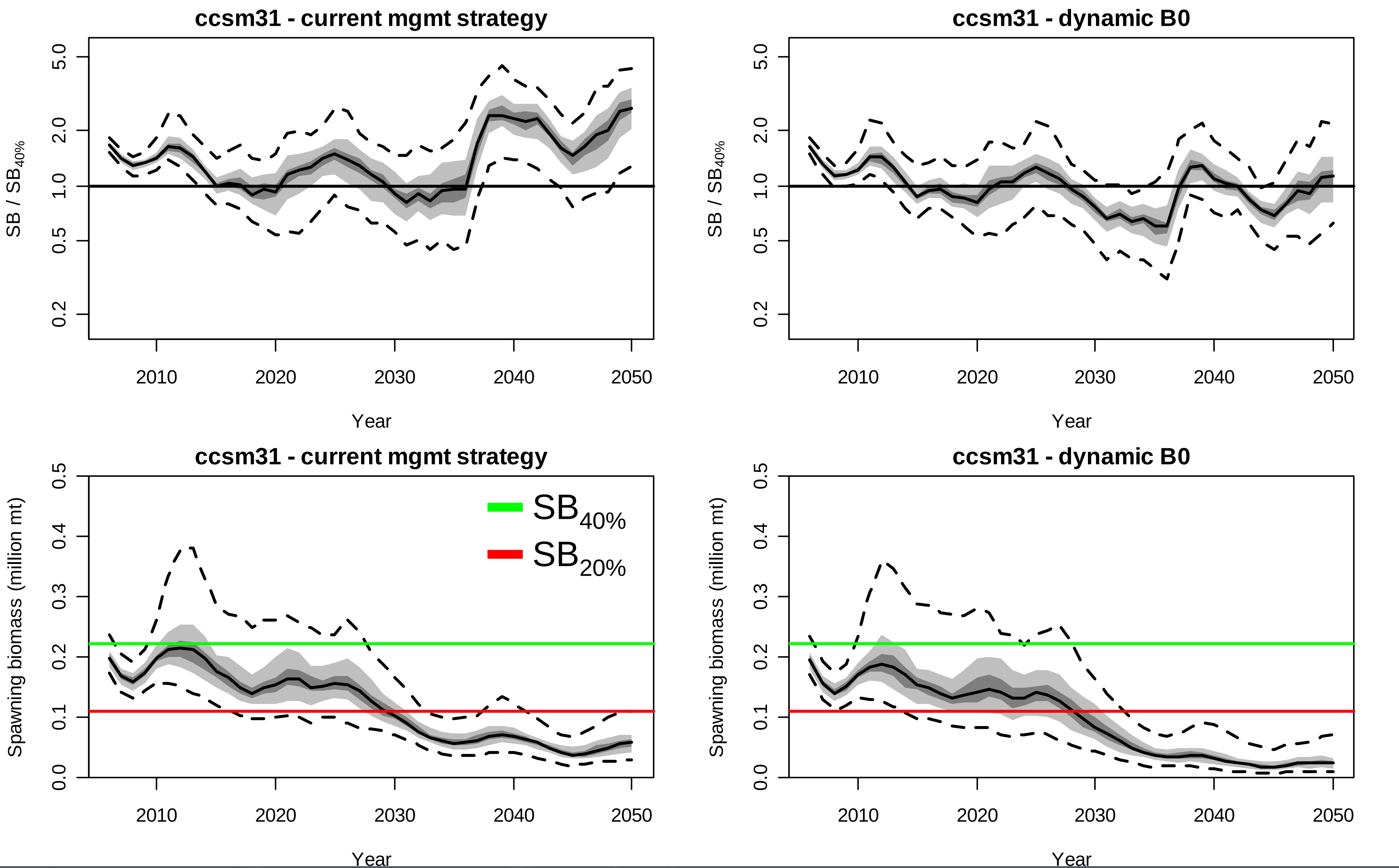
Current mgmt strategy



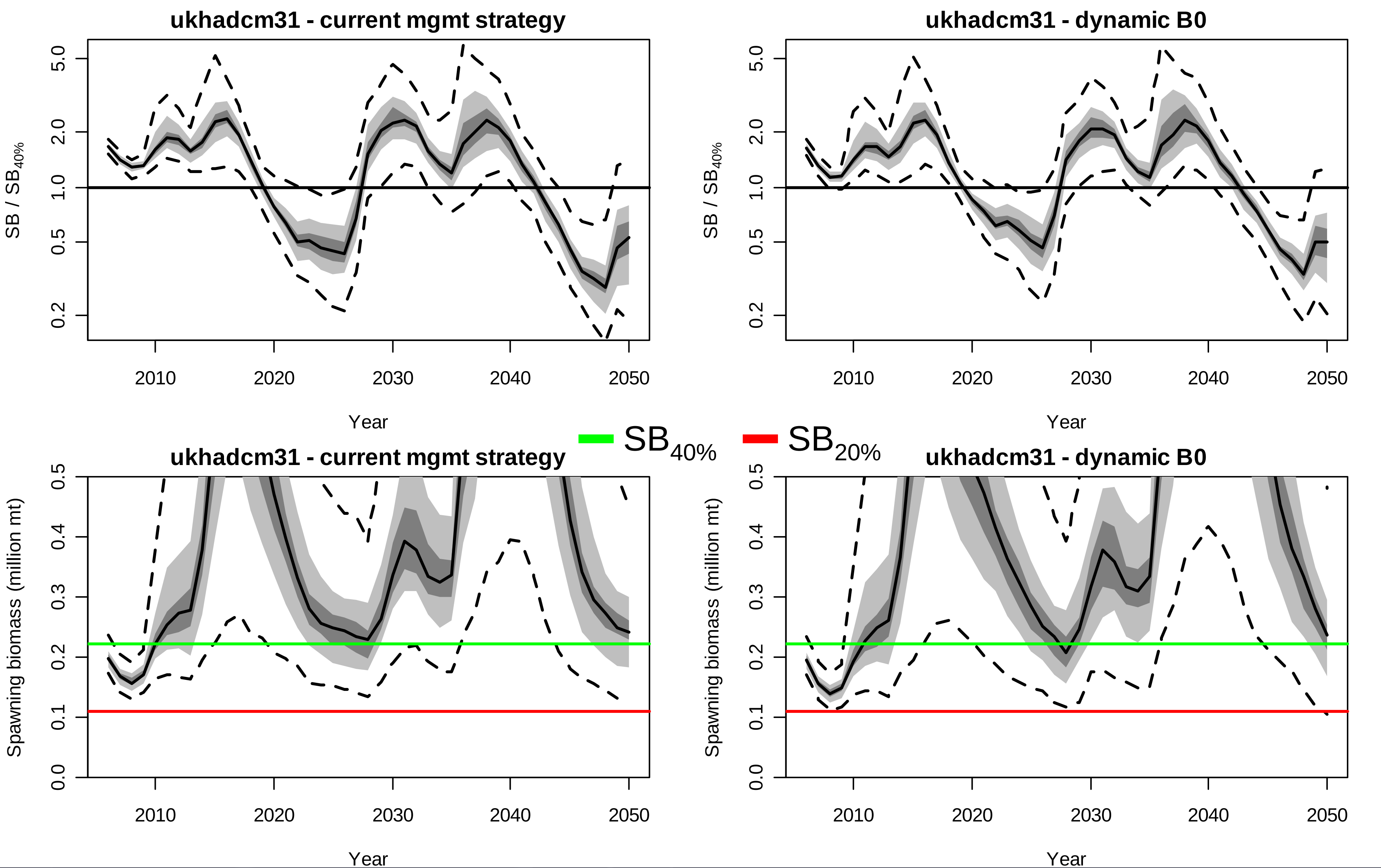
Dynamic B_0 MS



Results for Model 2 – ccsm31



Results for Model 2 – ukhadcm31



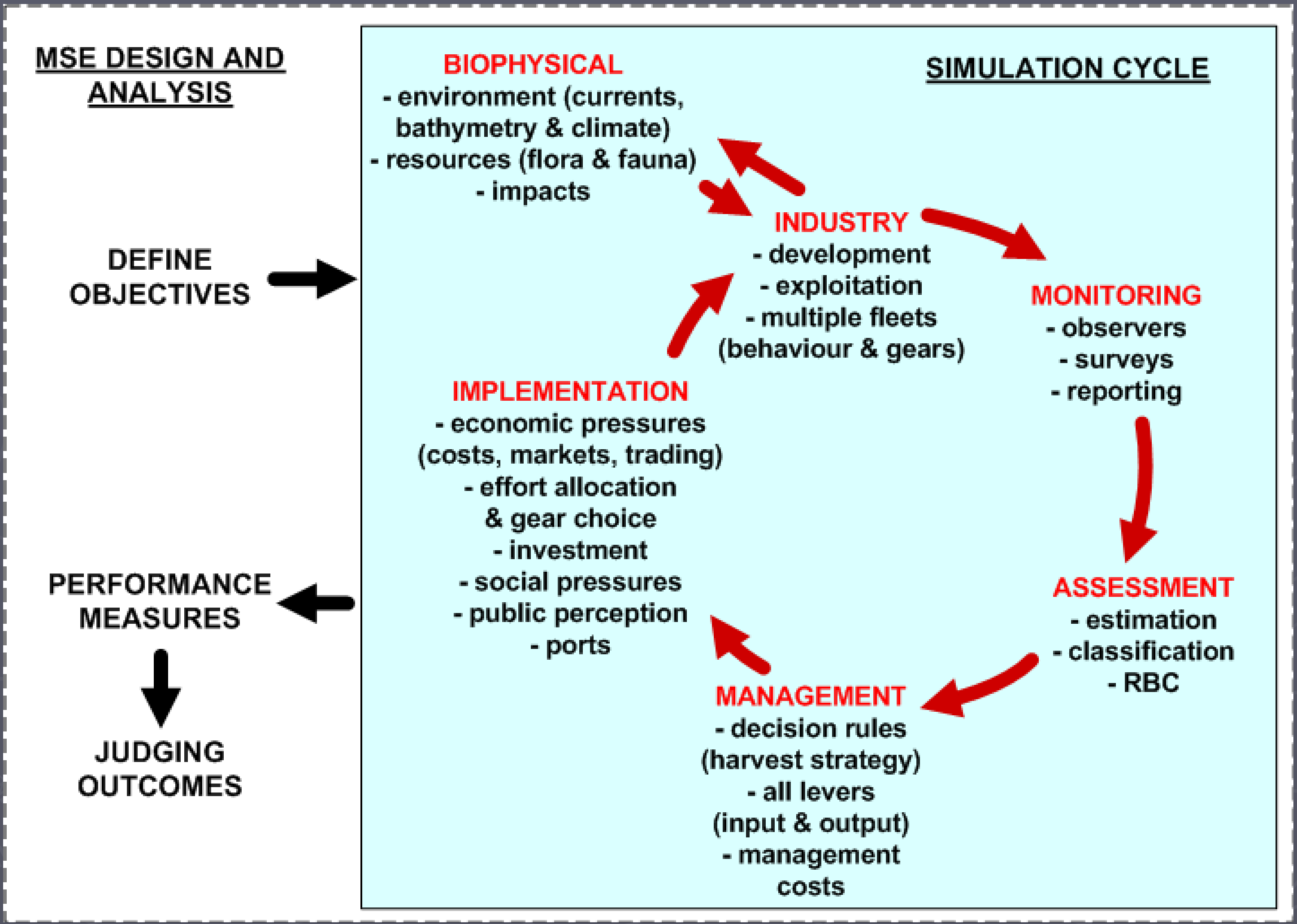
Conclusions

- The current management strategy meets management goals
- The current management strategy has uneven performance when regime shifts or climate variability are incorporated
- The dynamic B_0 management strategy has better performance for regime shifts, but significant tradeoffs for climate variability

Acknowledgements

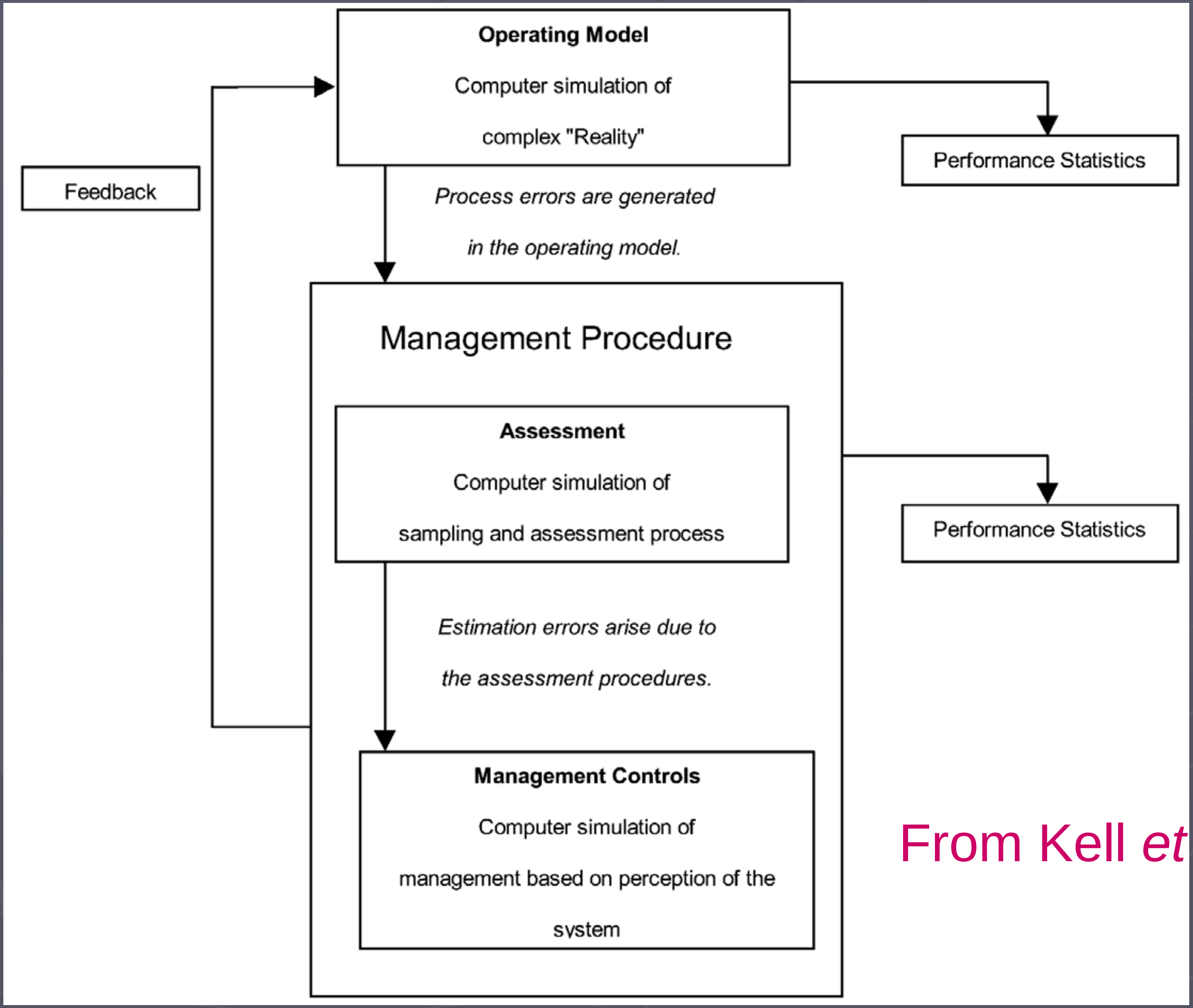
- Funding through NOAA Fisheries
- Anne Hollowed and Jim Ianelli
- Allen Macklin, Nick Bond, Phyllis Stabeno, Muyin Wang, Kevin Bailey, and Jim Overland (NOAA/PMEL)
- The Punt lab
- UW QERM and SAFS

MSE Framework



From Fulton *et al.*, 2007

MSE Framework



From Kell *et al.*, 2003

Schematic of the framework

Stock assessment

MCMC process

Projections

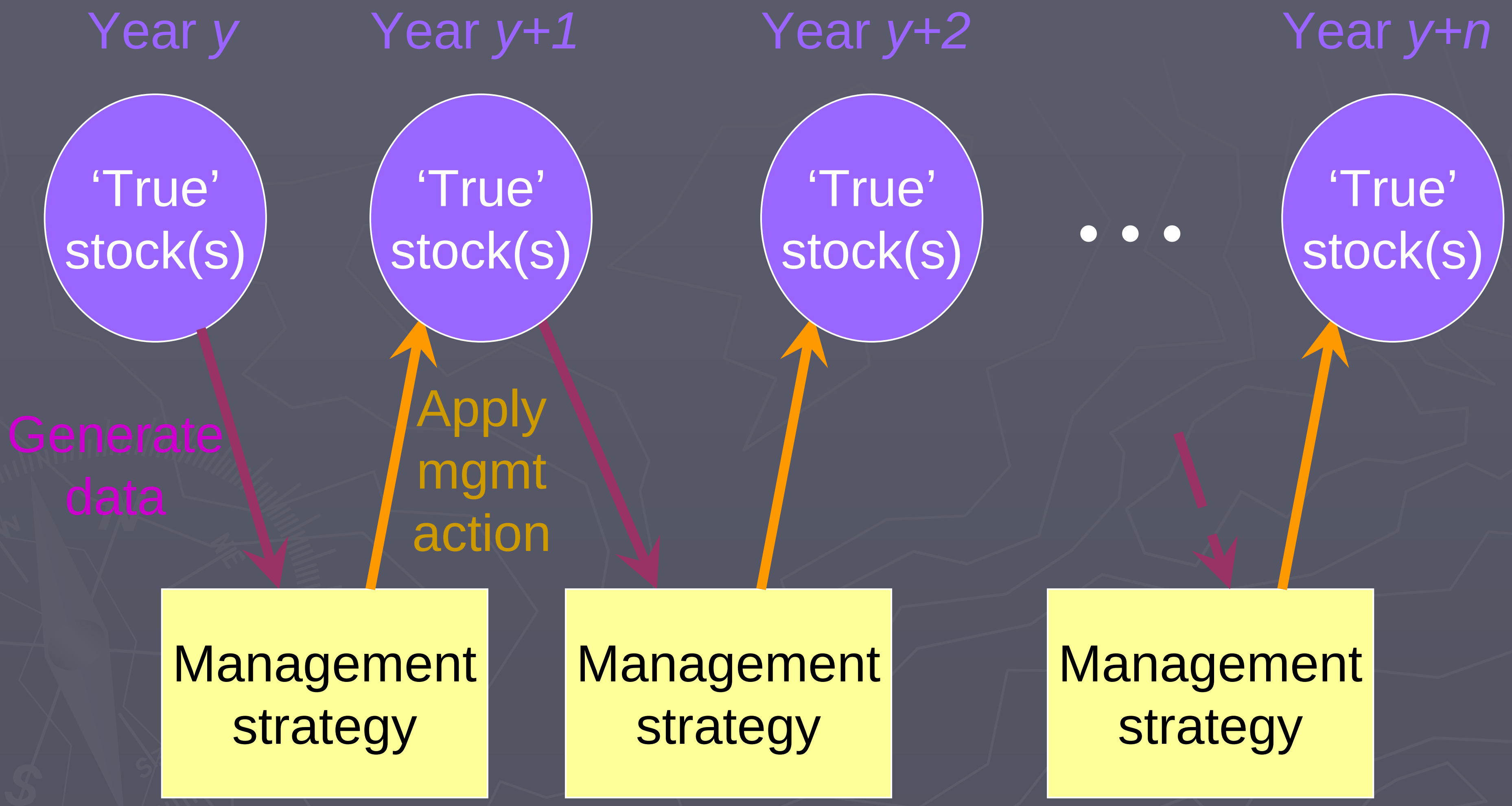
Estimate current state of population

Project population *i* forward with management strategy

• • •

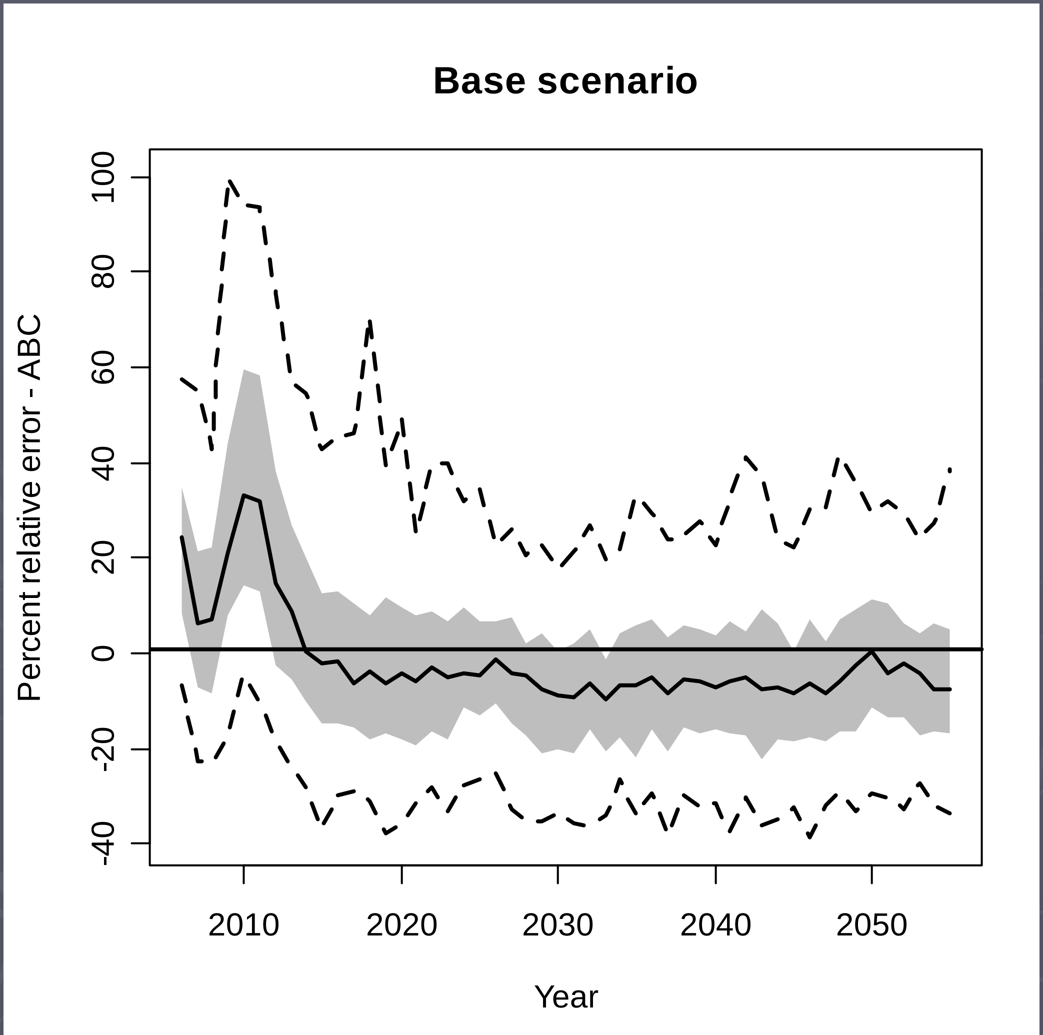
Each MCMC parameter vector represents a simulated population

Projections for simulation *i*



The 'true' and estimated values are stored by year and simulation

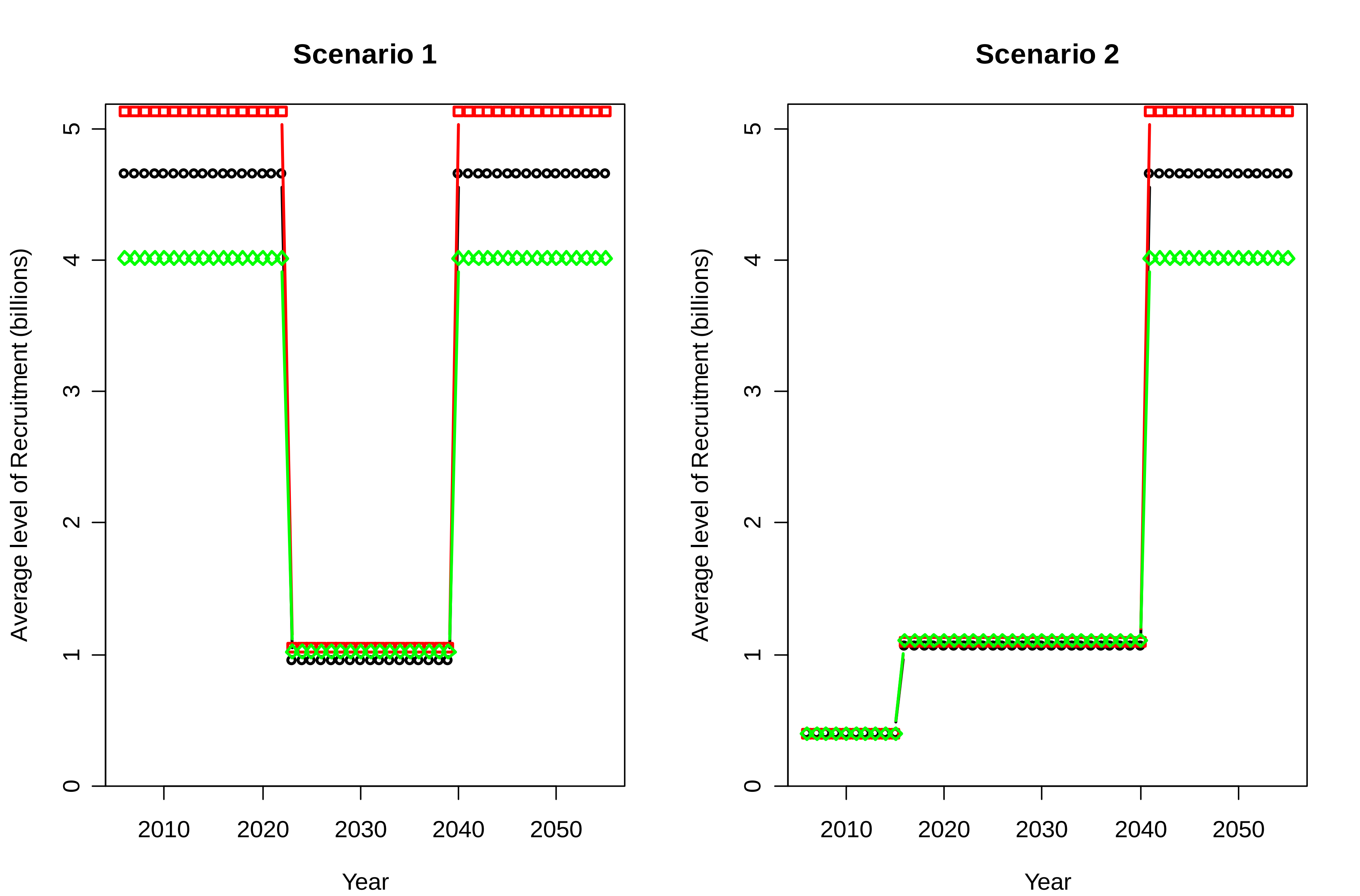
Base scenario – estimation performance: ABC



Annual management decision based on assessment results and decision rule

$$\text{Error}_y = 100(\text{Est}_y - \text{True}_y)/\text{True}_y$$

Regime shifts



Regime shifts

- All forcing is on age-1 recruitment

- Fixed regime shifts
  - the average level of recruitment changes in specific years during the projection period
- Random regime shifts
  - probability of an annual change in the average level of recruitment and recruitment variability
  - modelled using a homogeneous Markov process
- Four management strategies were evaluated

Management strategies

$$SB_{40\%} = SBPR(F = F_{40\%}) * \bar{R}_y$$

- Current management strategy

$$\bar{R}_y = \frac{1}{y - 1978} \sum_{y'=1978}^{y-1} N_{y',1}$$

- Dynamic B_0 management strategy

$$\bar{R}_y = \sum_{a=1}^{15} m_a w_a N_{y-a,1} \Big/ \sum_{a=1}^{15} m_a w_a$$

- Sliding window management strategy

$$\bar{R}_y = \frac{1}{25} \sum_{y'=y-25}^{y-1} N_{y',1}$$

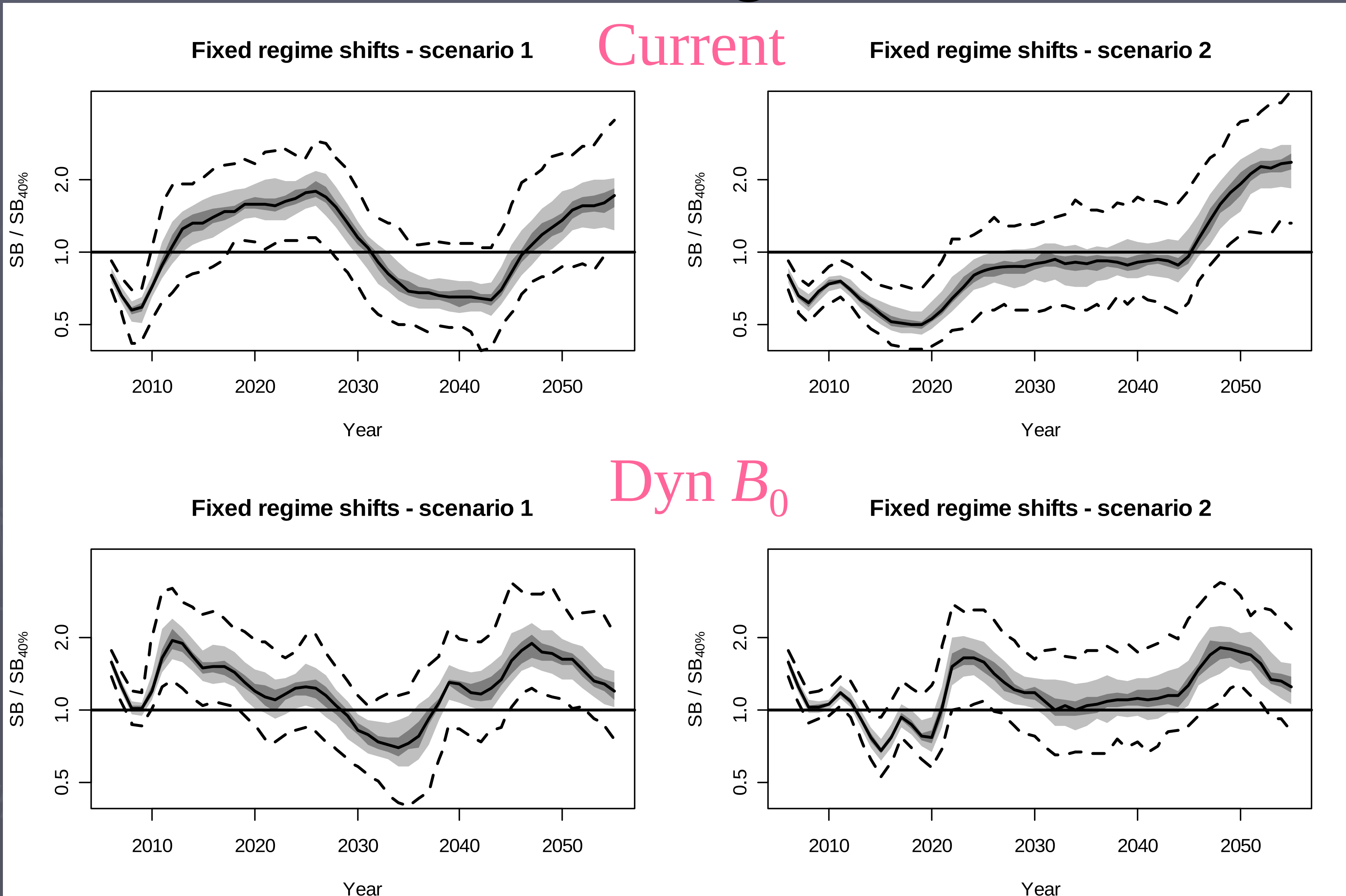
- CPA algorithm management strategy

$$\bar{R}_y = \frac{1}{y - \text{RegimeYear}} \sum_{y'=\text{RegimeYear}}^{y-1} N_{y',1}$$

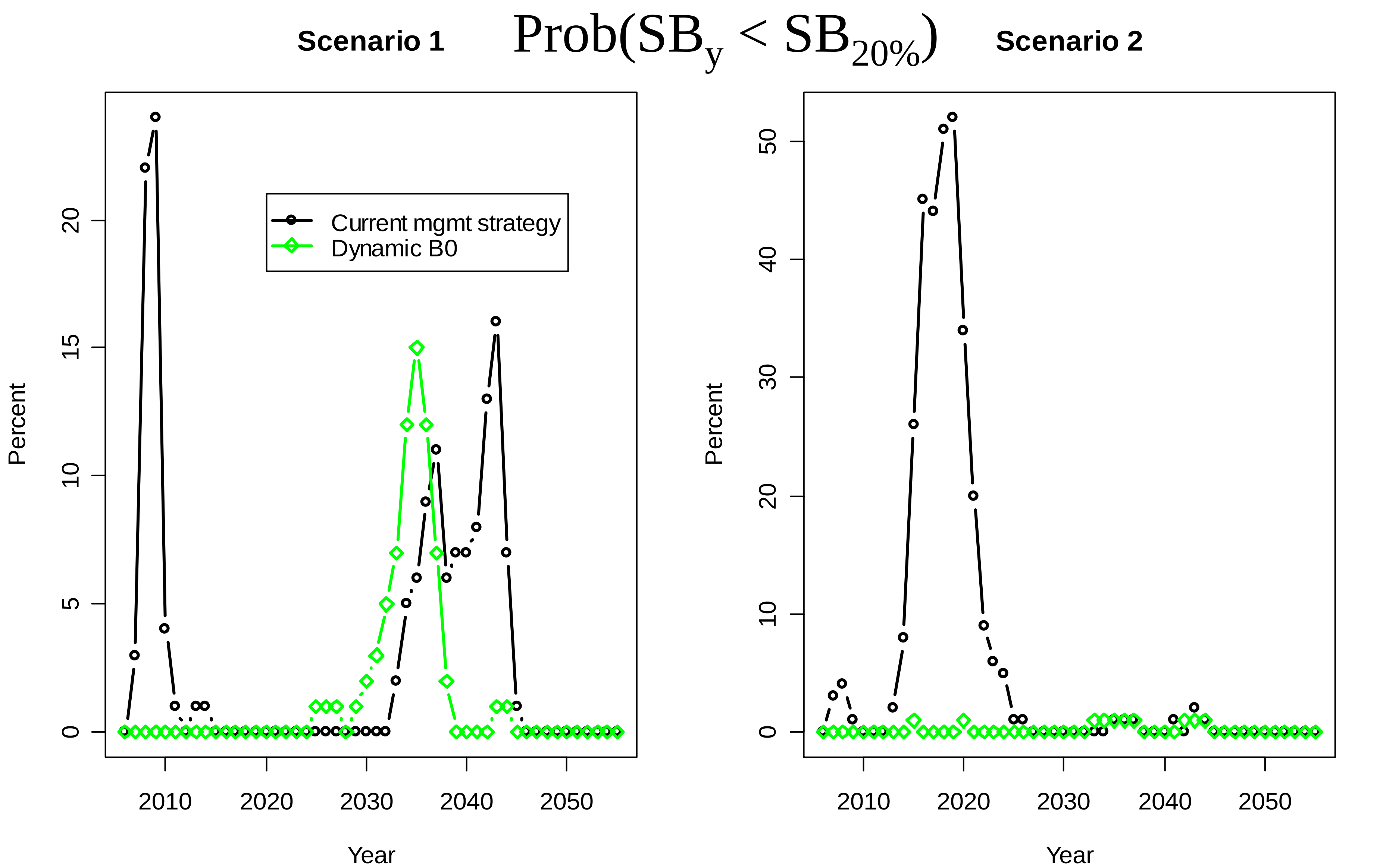
Results for regime shift scenarios

- Current management strategy and dynamic B_0 management strategy performed similarly
- The sliding window MS and the CPA algorithm MS did not perform as well
- Catches
  - dynamic B_0 MS > current MS during periods of lower productivity
  - dynamic B_0 MS < current MS during periods of higher productivity

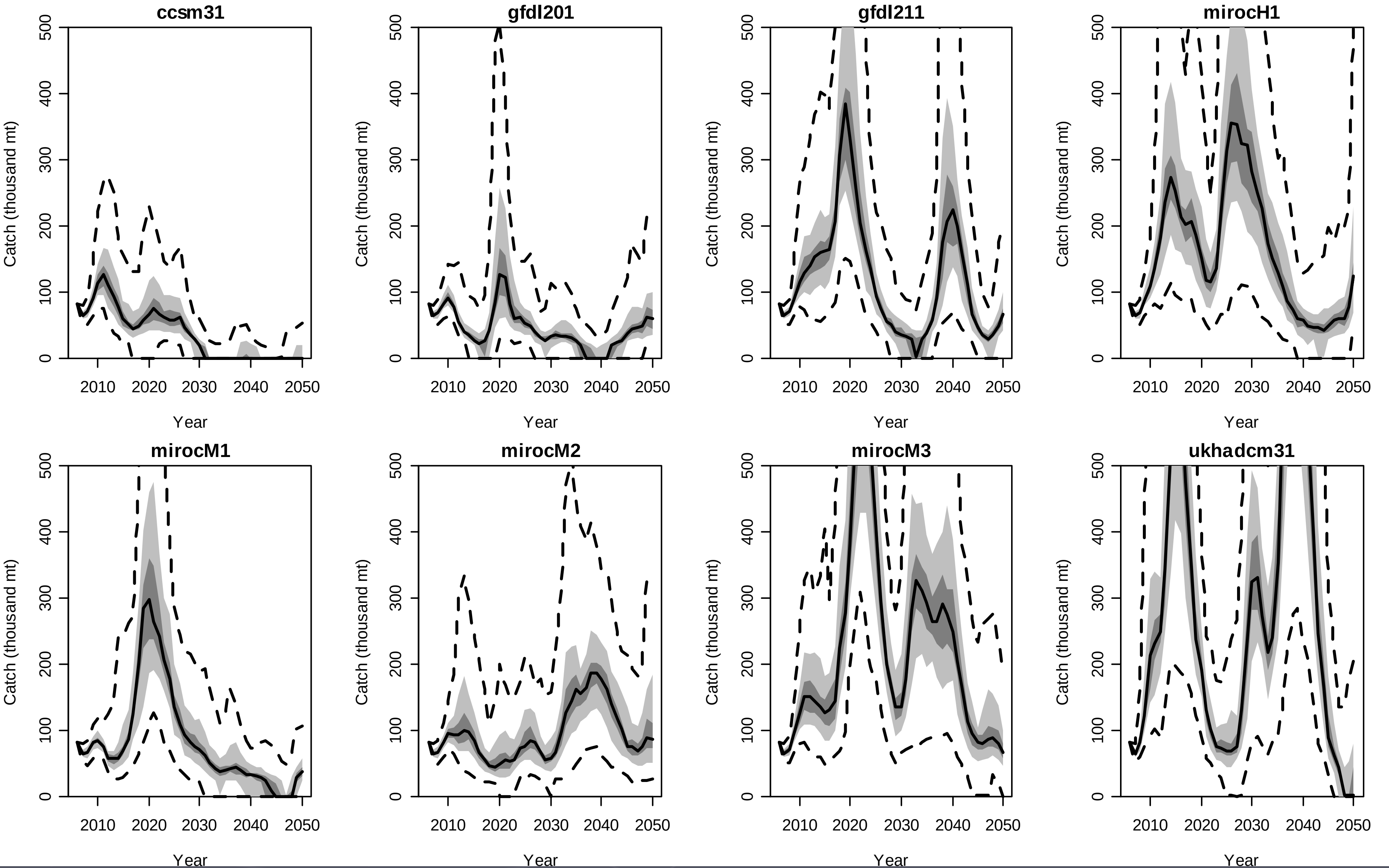
Results for regime shifts



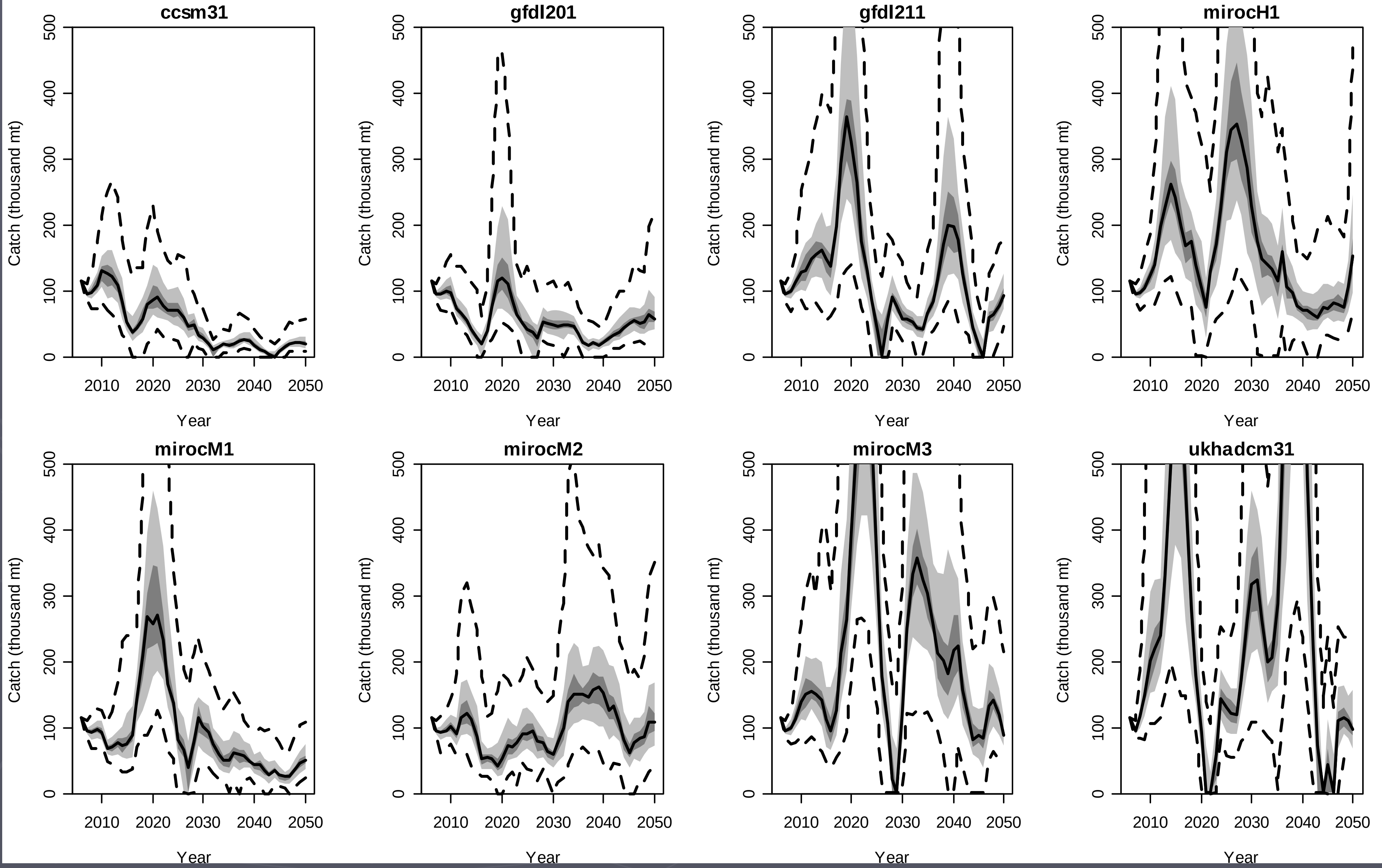
Results for regime shifts



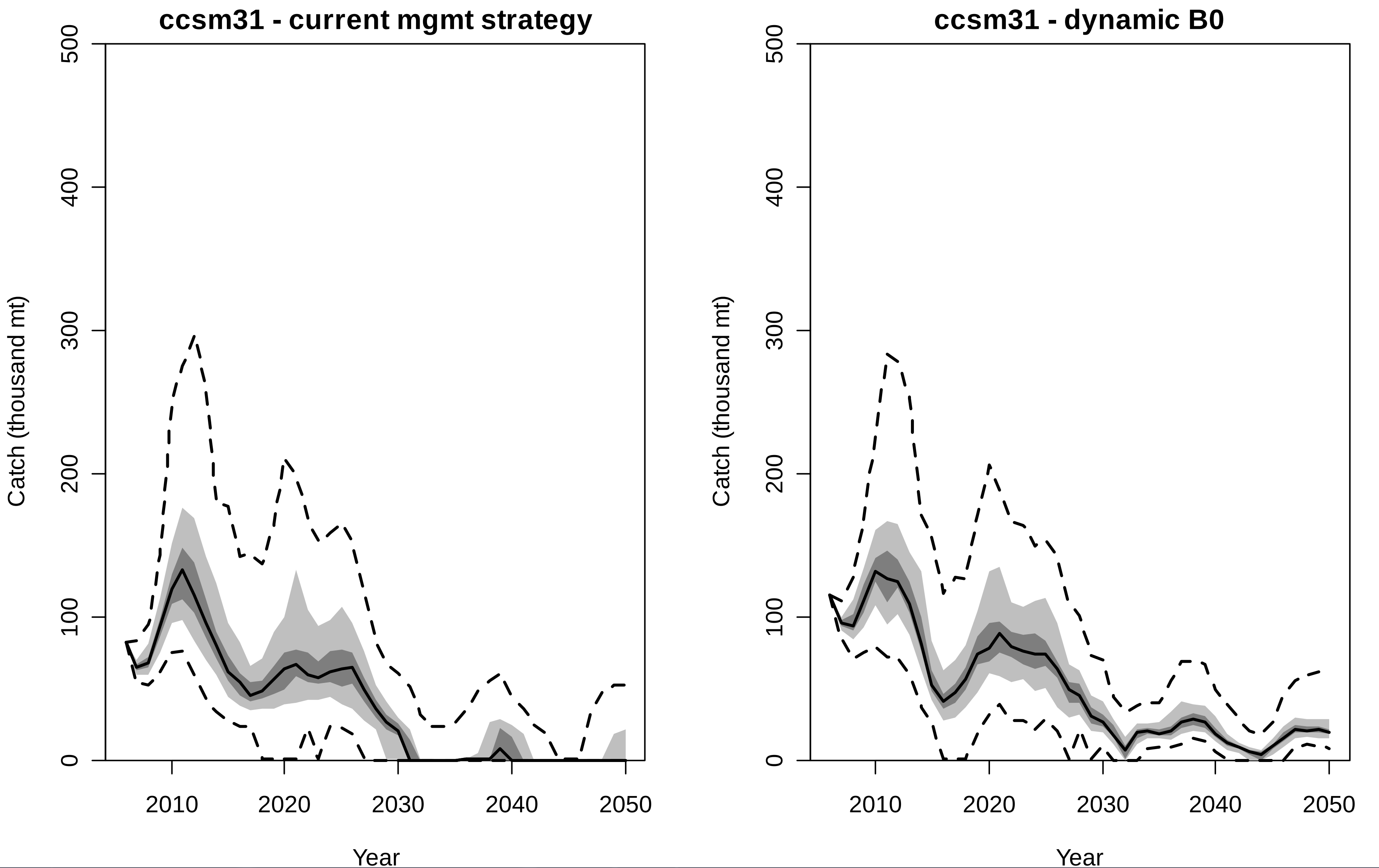
Current MS – Catch applied



Dynamic B_0 – Catch applied



Model 2 – ccsm31



Model 2 – ukhadcm31