Future projections for the south coast rock lobster resource using Bayesian methodology

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Summary

A Bayesian approach is used to assess the south coast rock lobster resource based upon a model that allows for time-varying selectivity. Estimation precision appears good. Biomass projections and their uncertainties are compared for four different scenarios: two constant catch options, and simple empirically and model-based OMPs.

Introduction

This document reports future projections for the south coast rock lobster resource using Bayesian methods (i.e. MCMC).

Methods

The model which is used here to explore future projections is Model 2, described in RLWS/DEC05/ASS/7/2/3. This assessment model fits to catch-at-age data given full weight, assumes no effort saturation, and allows for time varying fishing selectivity.

Future assumptions

The following assumptions are made with respect to future projections of the resource:

i) Future recruitment
Future recruitment is assumed to follow the stock-recruit curve with stochastic residuals generated from $N(0,\sigma_R^2)$ where $\sigma_R = 0.4$.

ii) Future fishing selectivity functions
The future fishing selectivity functions allow for time variance as for the 1994-2003 period, in that the δ_y values are assumed to be $\sim N(0,\sigma_{sel}^2)$ where $\sigma_{sel} = 0.75$.

Summary statistics

The resource is projected ahead for a ten year period (2006-2015). The following summary statistics are produced:

i) C_{ave} – average catch

$$C_{ave} = \frac{\sum_{y=2006}^{2015} C_y}{10}$$

where

C_y is the total commercial catch in year y.

ii) AAV – average annual catch variation

$$AAV = \frac{\sum_{y=2006}^{2015} (C_y - C_{y-1}) / C_{y-1}}{10}$$

iii) Final depletion (FD)

$FD = B^{sp}_{2016} / K^{sp}$

iv) Relative depletions (RD)

$RD = B^{sp}_{2016} / B^{sp}_{2006}$

MCMC procedure

Model 2 is run using an MCMC algorithm to effect the Bayesian integration where 66 000 000 vectors of parameters are produced, and where every 12000th vector is saved for the projections (producing 5500 vectors) from which the posterior distributions are calculated. A 20% burn-in period was used. Median values are reported, along with the 5th and 95th percentiles (i.e. 90% probability intervals). Whilst complete convergence may not have occurred, sufficient convergence has been reached for the purposes of the illustrative nature of this analysis. The Appendix shows the traces of some of the model parameters and variables.

Constant Catches

Results are first produced by projecting the resource ahead assuming constant catch (CC) scenarios. The following scenarios have been explored:

Scenario 1: CC = 382 MT (current TAC value)
Future selectivity variability $\delta_y \sim N(0, \sigma^2_{sel})$

Scenario 2: CC = 325 MT
Future selectivity variability $\delta_y \sim N(0, \sigma^2_{sel})$

The 325 MT for Scenario 2 was selected so that the median final depletion B^{sp}_{2016} / K^{sp} was 0.40.

OMP development

<u>Future data generation</u>

The only future data that are generated are CPUE data, where:

$$CPUE^{fut}_y = qB^{\exp}_y e^{\varepsilon_y} \qquad \varepsilon_y \sim N(0, \sigma^2_{cpue})$$

and $\sigma_{cpue} = 0.141$ as estimated in the fit of Model 2 to the CPUE data.

Some simple OMPs are developed here. The first is a simple empirical OMP.

<u>Empirical OMP</u>

$$TAC_{y+1} = TAC_y (1 + \alpha\, slope)$$

where *slope* is the slope of a log-linear regression line fitted to the last three CPUE values.

Model-based OMP

This OMP involves fitting a Schefer model to CPUE and catch data and then setting the TAC as follows:

$$TAC_{y+1} = \Delta TAC_y + \frac{\hat{r}}{2}\hat{B}_y \beta$$

where

$\hat{r}$ is the Schaefer estimated *r* value

$\hat{B}_y$ is the Schaefer estimated biomass value in year *y*, and

Δ, β are control parameters.

For both OMPs, it is possible to specify a maximum interannual TAC increase and decrease. Here we have assumed both to be 20%, that is the maximum TAC change each year is constrained to be 20%. For the model-based OMP, Δ is set at 0.50.

Management Objectives

For this study, the provisional management objective for this resource is generally to aim for a final spawning biomass depletion relative to *K* of 0.40.

Results

Table 1 reports various output statistics from the Model 2 MCMC analysis. The posterior distributions for some of the key parameters and variables are illustrated in Figures 1a-f.

Table 2 reports results of summary statistics for four different future TAC setting options (two constant catch options, an empirically-based OMP and a model-based OMP.) Three of the four scenarios have been tuned so that the median B_{2016}^{sp} / K^{sp} is 0.40. Figures 2a-d illustrate the spawning biomass trajectories (median plus 90% probability intervals) for each of these future scenarios. Figures 2a and b show the catch trajectories for the two OMP scenarios. Figures 3a-c compare the catch and resource abundance performance statistics for these 10-year projections under alternative OMPs.

Discussion

The Bayesian posteriors (Table 1, Figures 1 and 2) suggest relatively well determined parameter values for the model. Interestingly, the 95% probability interval for MSY [307, 448] MT is much narrower than the likelihood profile estimate of [112, 428] MT for the RC model reported in RLWS/DEC05/ASS/7/2/3. A probably reason is the better fit that Model 2 achieves to the CPUE data by admitting the possibility of changes in selectivity over time.

The performance statistics for the four initial OMPs are of interest in showing the trade-off between maintaining the current catch level and securing some increase in abundance and hence CPUE. The empirically-based OMP achieves its target abundance level in 2016 with only slightly better precision than the constant catch equivalent, and with the cost of relatively high interannual catch variability. Behaviour of the model-based OMP is poorer, but the control rule used certainly has scope for refinement.

Table 1: Bayesian estimated output statistics for Model 2. The median is reported, with the 5th and 95th percentiles in brackets.

Statistics	Median (5th and 95th percentile)
K	7756 (7378; 8254)
M	0.120 (0.106; 0.135)
$a50$	10.17 (9.81; 10.51)
$a95$	12.26 (10.67; 12.88)
h	0.853 (0.639; 0.974)
MSY	378 (307; 448)
B^{sp}_{2006}	2363 (1996; 3027)
B^{sp}_{2006} / K^{sp}	0.305 (0.257; 0.382)
B^{exp}_{2006} / K^{exp}	0.282 (0.213; 0.442)
$B^{exp}_{2006} / B^{exp}_{msy}$	1.372 (0.854; 2.530)

Table 2: Projection results from Bayesian estimated output statistics for Model 2. The median is reported, with the 5th and 95th percentiles in brackets. Values in **bold** are chosen tuning targets.

	CC =382	**CC = 325**	**Empirical OMP** $\alpha = 1.0$	**Model-based OMP** $\beta = 0.395$
C_{ave}	382 (382, 382)	325 (325, 325)	319 (267, 385)	309 (267, 386)
AAV	0 (0, 0)	0.01* (0.01, 0.01)	0.12 (0.07, 0.16)	0.16 (0.09, 0.20)
B^{sp}_{2006} / K^{sp}	0.34 (0.21, 0.50)	**0.40** (0.27, 0.56)	**0.40** (0.29, 0.54)	**0.40** (0.21, 0.59)
$B^{sp}_{2016} / B^{sp}_{2006}$	1.09 (0.71, 1.57)	1.29 (0.91, 1.78)	1.30 (0.93, 1.79)	1.30 (0.72, 1.85)
$B^{exp}_{2015} / B^{exp}_{msy}$	1.15 (0.73, 3.22)	1.83 (0.92, 3.75)	1.84 (1.02, 3.68)	1.91 (0.85, 4.00)

* This reflects the TAC change for the first year.

Figure 1a: Estimated posterior distribution for *K* in MT.

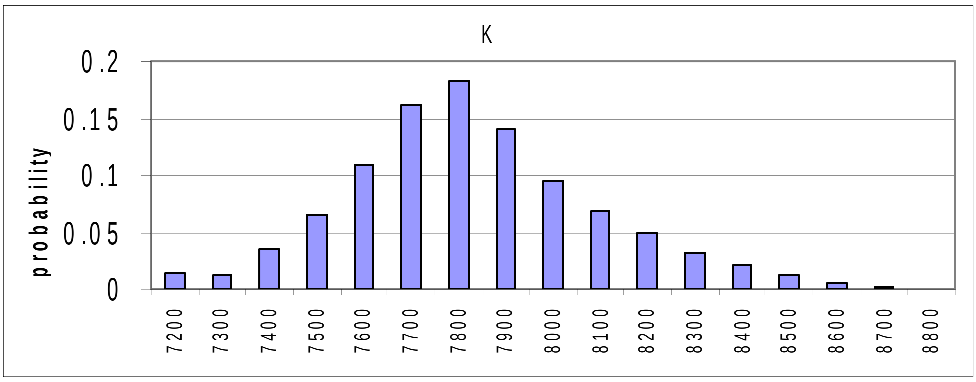


Figure 1b: Estimated posterior distribution for *M* in yr^{-1}.

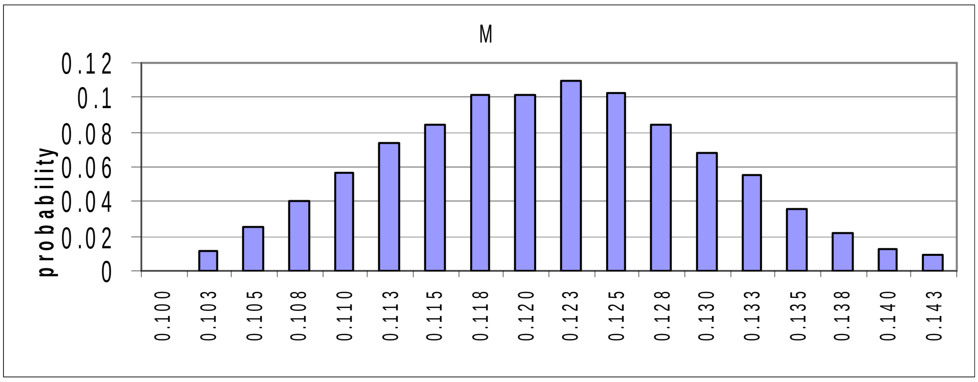


Figure 1c: Estimated posterior distribution for *a*50 in yrs.

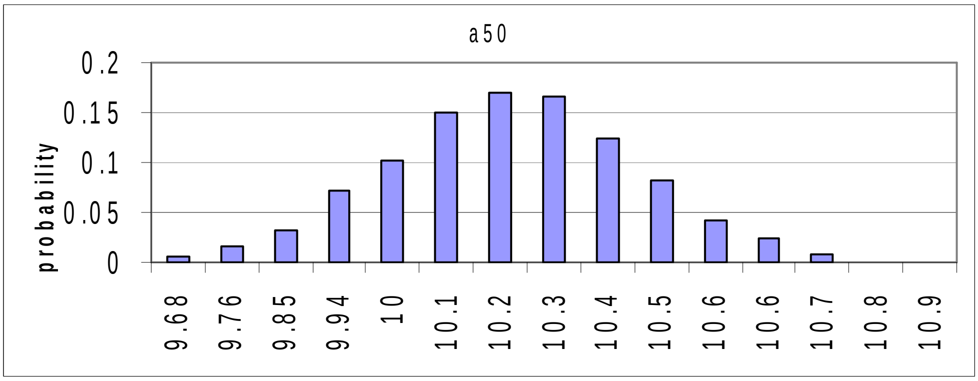


Figure 1d: Estimated posterior distribution for *h*. The bar at *h* = 0.65 reflects values ≤0.65.

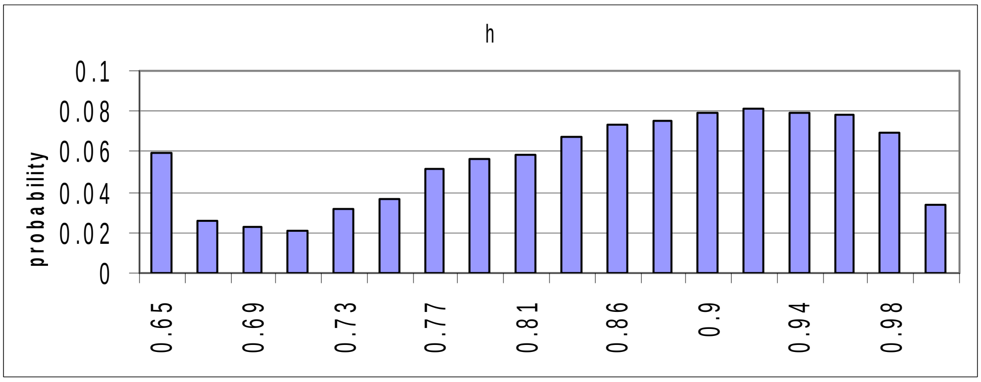


Figure 1e: Estimated posterior distribution for MSY in MT.

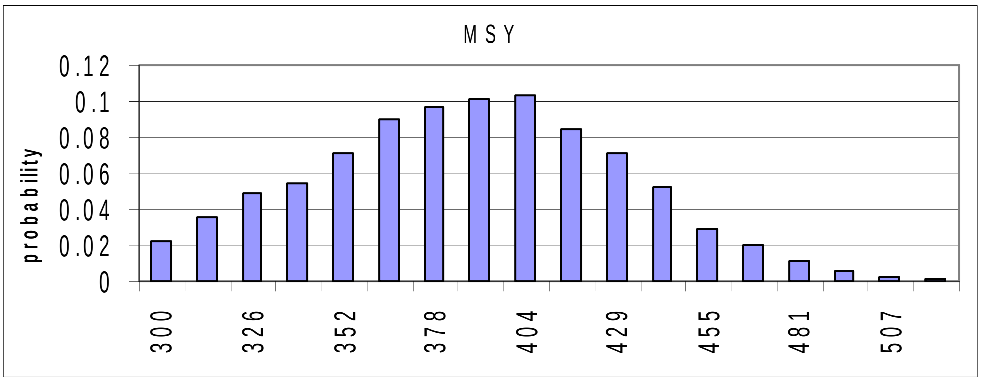


Figure 1f: Estimated posterior distribution for B^{sp}_{2006}/K .

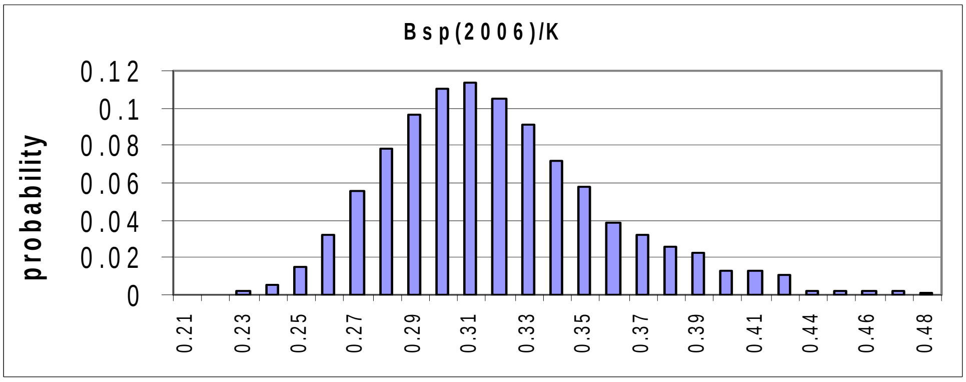


Figure 2a: Spawning biomass trajectory – future constant TAC = 382 MT (median and 90% probability intervals shown).

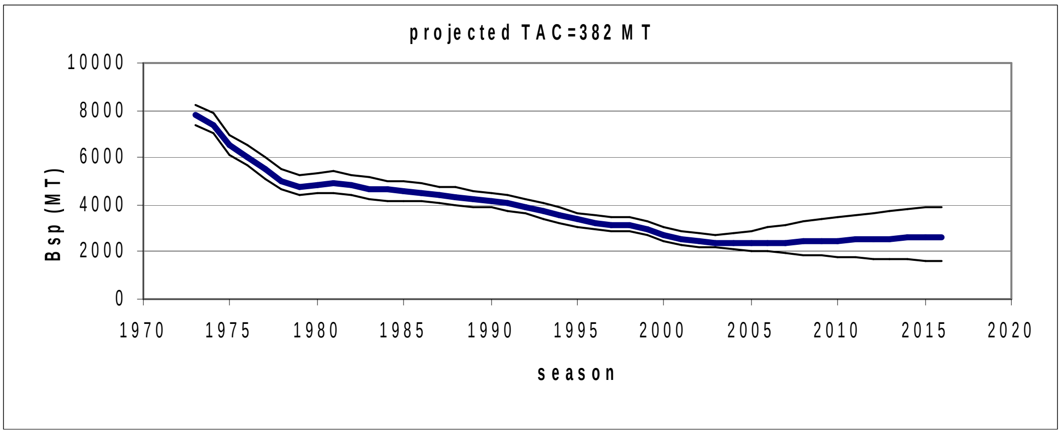


Figure 2b: Spawning biomass trajectory – future constant TAC = 325 MT (median and 90% probability intervals shown).

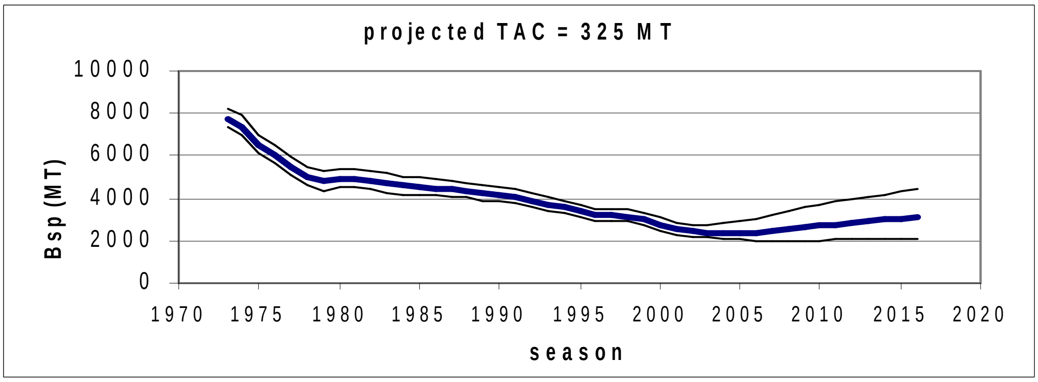


Figure 2c: Spawning biomass trajectory – future TAC from empirically-based OMP (median and 90% probability intervals shown).

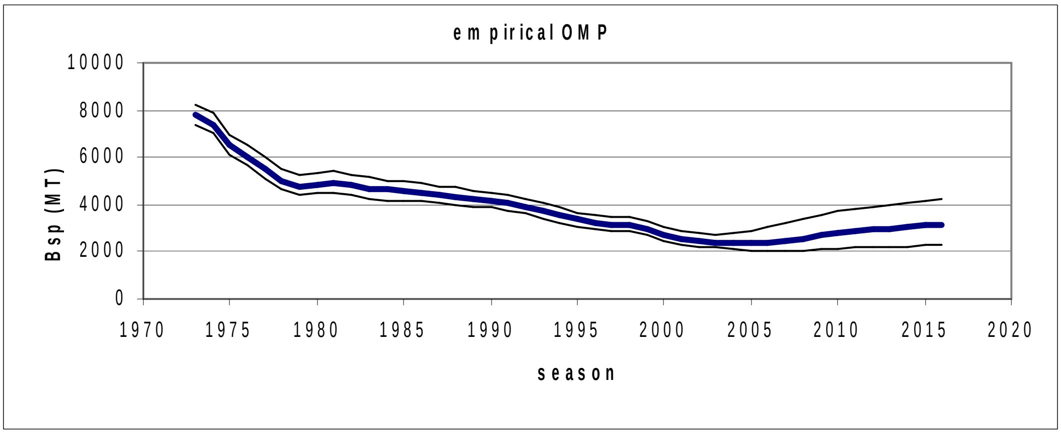


Figure 2d: Spawning biomass trajectory – future TAC from model-based OMP (median and 90% probability intervals shown).

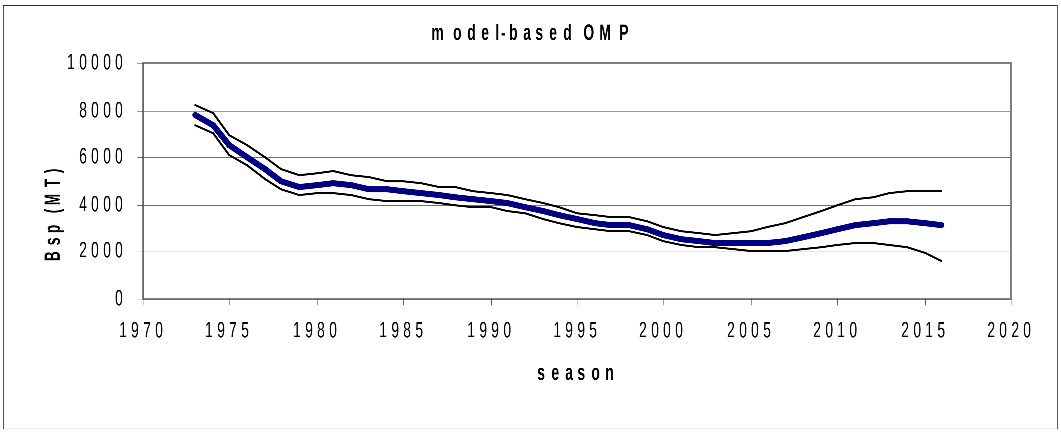


Figure 2a: Catch trajectory for the empirically-based OMP.

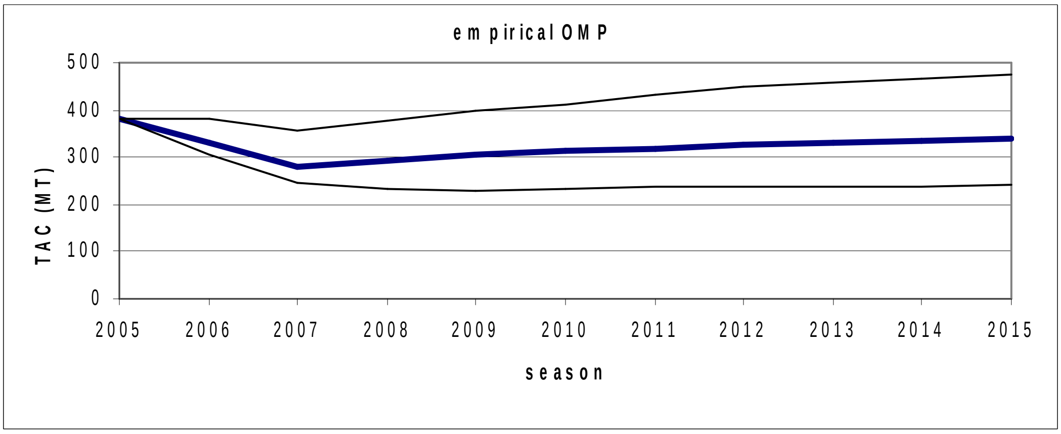


Figure 2b: Catch trajectory for the model-based OMP.

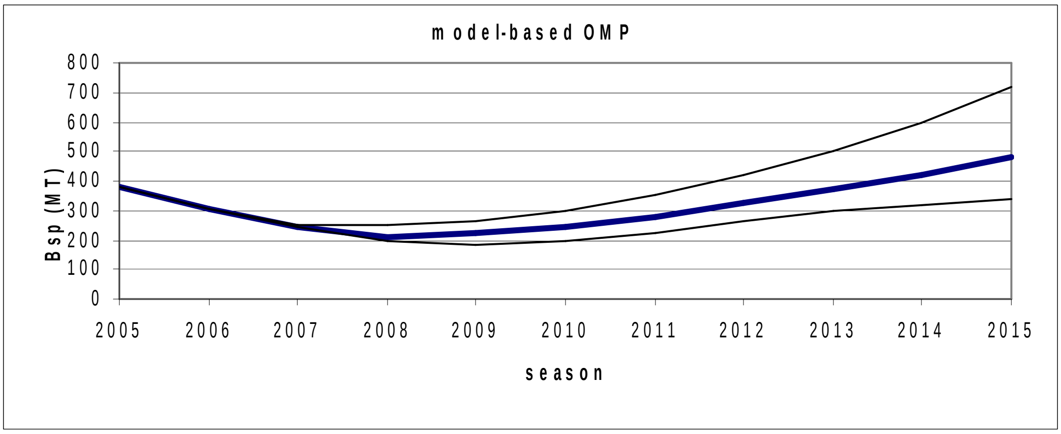
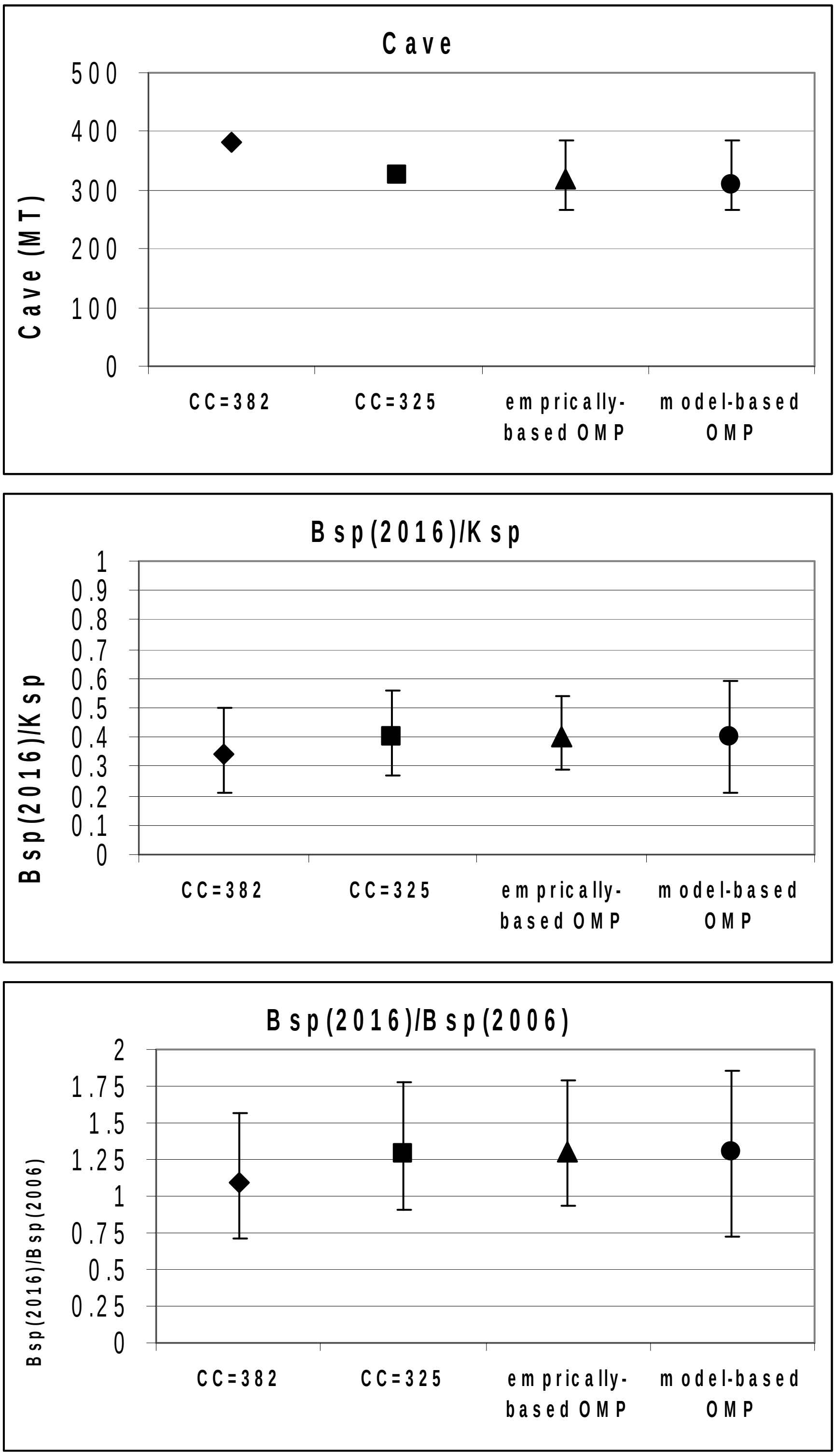
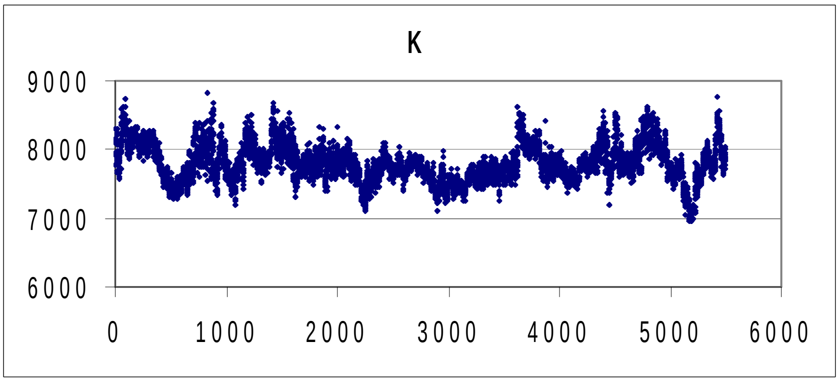
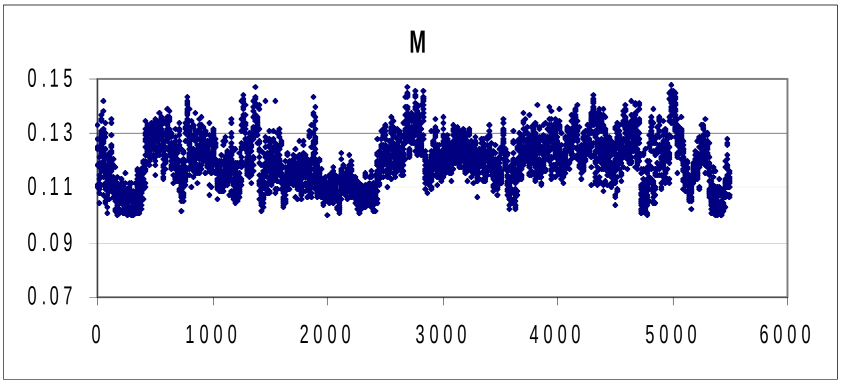


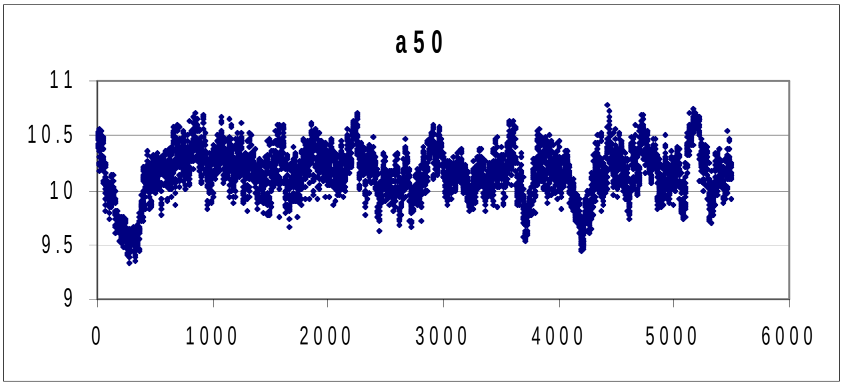
Figure 3: Comparative plots between the four future scenarios showing relative performance for three summary statistics. Medians and the 90% confidence intervals are shown.

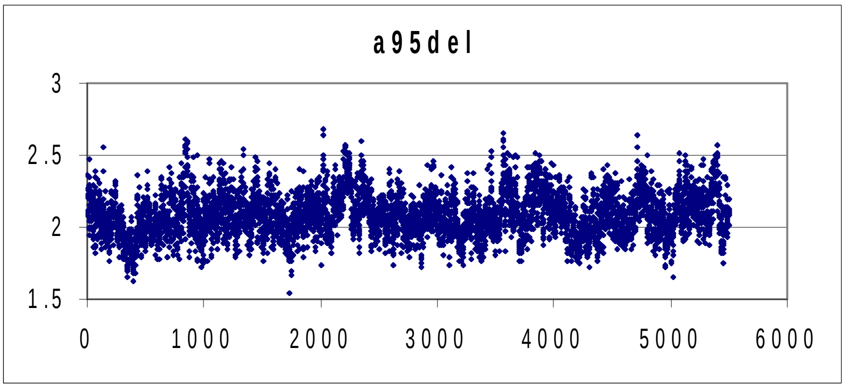


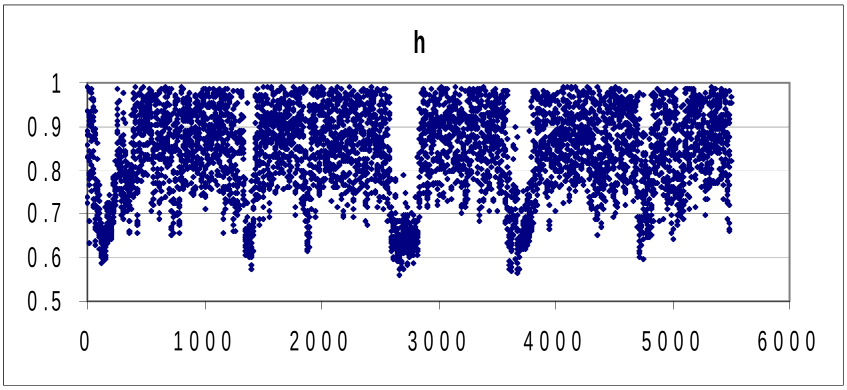
Appendix: MCMC traces of various model parameters and variables.

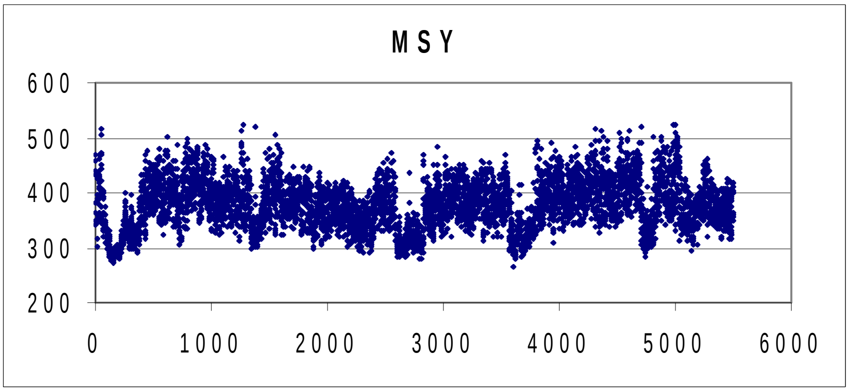


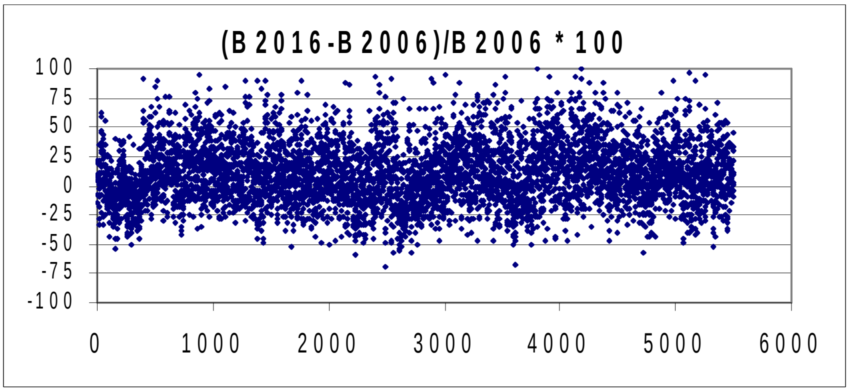


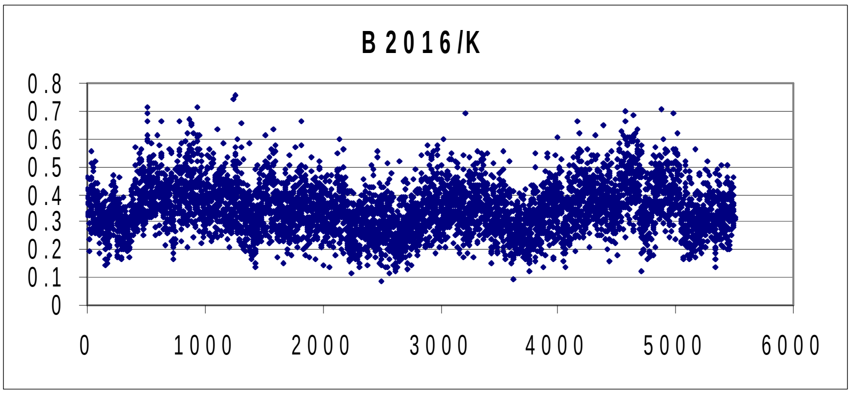





h
1
0.9
0.8
0.7
0.6
0.5
0
1000
2000
3000
4000
5000
6000


MSY
600
500
400
300
200
0
1000
2000
3000
4000
5000
6000


(B2016-B2006)/B2006 * 100
100
75
50
25
0
-25
-50
-75
-100
0
1000
2000
3000
4000
5000
6000


B2016/K
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1000
2000
3000
4000
5000
6000