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An Example Management Strategy Evaluation Of A Model Free Harvest Control Rule.

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SUMMARY

KEYWORDS: Bluefin, Harvest Control Rule, FLR, Management Procedure, Management Strategy Evaluation, Model Free

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1. Introduction

A Harvest Control Rule (HCR) relates the recommended catch, or other fishery control measure, to the current value of selected control variables. A HCR may be empirical where control variables are directly measurable quantities (e.g., catch rate, size composition, tag recovery rate, survey estimates of abundance or species composition) or model based on using a statistical procedure (i.e. an estimator) that provides information on resource status and productivity from past resource monitoring data.

An empirical HCR has been adopted for Southern bluefin tuna *(Thunnus maccoyii)* (SBT) which sets the TAC using data solely from a fisheries dependent Catch Per Unit Effort (CPUE) index of adult abundance and a fisheries independent aerial survey of juveniles. The HCR is based on year-to-year changes and in the indices. Before the HCR can be implemented appropriate reference levels (e.g. based on historical catch, effort, CPUE and/or surveys) must be selected and the parameters tuned to meet management objectives using Management Strategy Evaluation (MSE). The HCR is therefore evaluated as part of a Management Procedure (MP), i.e. the combination of pre-defined data, together with an algorithm to which the data are input to provide a value for a TAC or effort control measure.

We first describe the empirical (i.e model free) HCRs used by CCSBT and then conduct an MSE for Atlantic bluefin tuna.

2. Management Strategy Evaluation

Data for use in the MP are sampled from the Operating Model (OM) via the Observation Error Model (OEM). Where the OM is a mathematicalstatistical model used to describe the actual resource dynamics in simulation trials and to generate resource monitoring data when projecting forward. The OM generates fishery-dependent and/or fishery-independent resource monitoring data for input to the MP. The aim of an MSE is to demonstrate through simulation trials the robust performance of feedback control rules in the presence of uncertainties.

2.1 Operating Model

The OM is based on the East Atlantic and Mediterranean BFT assessment Kell et al. (2012). The assessment was conducted using Virtual Population Analysis (VPA) in 2012 for two assumed historical catch levels and three future recruitment (i.e. six scenarios were considered). The two levels of catch corresponded to the **reported** and **inflated** levels; in the latter case catches were raised to 50,000 tonnes from 1998 to 2006 and to 61,000 tonnes in 2007 to allow for the possibility of actual catches being greater than those reported. Recruitment had varied over the historic period Kell et al. (2014) and so the three recruitment scenarios **low**, **high** and *medium* were based on recruitment over different historical periods.

2.11 Scenarios

The scenarios are given in **Table** 3.

2.2 Management Procedure

The MPs are based on the model free HCR developed by CCSBT. The TAC is an average of candidate TACs obtained from two harvest control rules. Here we run the two HCRs separately in order to compare their performance (**?**).

2.21 Harvest Control Rule I

The first HCR is based on a single index i.e.

$$TAC^1_{y+1} = TAC_y \times \begin{cases} 1 - k_1|\lambda|^\gamma & \text{for} \quad \lambda < 0 \\ \\ 1 + k_2\lambda & \text{for} \quad \lambda \geq 0 \end{cases} \tag{1}$$

where λ is the slope in the regression of $\ln B_y$ against year for the most recent n years, k_1 and k_2 are *gain* parameters.

giving 4 tunable parameters (**Table** 1)

2.22 Harvest Control Rule II

The second HCR uses both a biomass and a juvenile index i.e.

$$TAC_{y+1} = 0.5 \times \left(TAC_y + C^{\text{targ}}_y \Delta^R_y\right), \tag{2}$$

and

$$\begin{aligned} TAC^2_{y+1} &= 0.5 \times \left(TAC_y + C^{\text{targ}}_y \Delta^R_y\right), \\ C^{\text{targ}}_y &= \begin{cases} \delta \left[\dfrac{B_y}{B^*}\right]^{1-\varepsilon_b} & \text{for} \quad B_y \geq B^* \\ \delta \left[\dfrac{B_y}{B^*}\right]^{1+\varepsilon_b} & \text{for} \quad B_y < B^* \end{cases}, \\ \Delta^R_y &= \begin{cases} \left[\dfrac{\bar{R}}{\mathcal{R}}\right]^{1-\varepsilon_r} & \text{for} \quad \bar{R} \geq \mathcal{R} \\ \left[\dfrac{\bar{R}}{\mathcal{R}}\right]^{1+\varepsilon_r} & \text{for} \quad \bar{R} < \mathcal{R} \end{cases} \end{aligned} \tag{3}$$

where δ is the *target* catch; B^* the *target* CPUE (i.e. the mean observed CPUE corresponding to some multiple of a biomass reference point such as B_0 or M_{MSY}) and $\bar{R}$ is the average recent juvenile biomass i.e.

$$\bar{R} = \frac{1}{\tau_R} \sum_{i=y-\tau_R+1}^{y} R_i, \tag{4}$$

$\mathcal{R}$ is a "limit" level derived from the mean recruitment over a reference period;
while $\varepsilon_\bullet \in [0, 1]$ actions asymmetry so that increases in TAC do not occur at the same level as decreases.

There are therefore 5 tunable parameters, **Table** 2

In our example we use reference periods to set δ as well as $\mathcal{R}$.

The MP operates every three years, i.e.

1. In year t historical data up to and including $t - 1$ are sampled from the OM by the OEM
2. These data are then used by the MP to set a quota for 3 years starting in years $t + 1$.
3. repeat step 1 for year $t + 4$

2.3 Observation Error Model

A simple OEM was constructed to generate two unbiased abundance indices corresponding to the adult biomass and numbers of recruits. A log normal random error of 30% was added to these time series.

3. Results and Discussion

Catch, fishing mortality, recruitment and SSB are summarised in **Figure** 1 for the 2 HCRs and 6 OM Scenarios. Worm plots (i.e. single iterations) for yield, fishing mortality, recruits and SSB are shown in **Figures** 5, 4, 3 and 2.

The HCR parameters were not tuned to achieve the best performance but ran with default values. This was because the intention of the study was to provide a simple example of model free HCRs.

To conduct a full MSE involves a number of steps (Punt and Donovan, 2007) i.e.

- identification of management objectives and mapping these to performance measures in order to quantify how well they have been achieved.
- selection of hypotheses about system dynamics.
- conditioning of OMs on data and knowledge and possible rejecting and weighting the different hypotheses.
- identifying candidate management strategies and coding these up as MPs
- projecting the OMs forward using the MPs as feedback control procedures; and
- agreeing the MPs that best meet management objectives.

The next steps will be to compare the performance of empirical HCRs to model based ones, such as those documented in Kell et al. (2013a,b). This will require a number of scenarios to be considered that reflect the uncertainty about resource dynamics (e.g. Fromentin et al., 2014; Leach et al., Accepted; Kell.L.T., 2014; Kell et al., 2014).

References

J.-M. Fromentin, S. Bonhommeau, H. Arrizabalaga, and L. L. Kell. The spectre of uncertainty in management of exploited fish stocks: the illustrative case of atlantic bluefin tuna. *Marine Policy*, 47: 8–14, 2014.

L. Kell, S. Bonhommeau, J.-M. Fromentin, M. Ortiz, and J. Walter. Projections for east atlantic mediterranean bluefin tuna. *ICCAT Collect. Vol. of Sci. Pap.*, 64:x:xx–xxx, 2012.

L. Kell, G. Merino, P. De Bruyn, J. Ortiz de Urbina, H. Arrizabalaga, J. Santiago, and H. Murua. An example of a management procedure based on a biomass dynamic stock assessment model. *ICCAT Collect. Vol. Sci. Pap.*, 69(33):xxx–xxx, 2013a.

L. Kell, G. Merino, P. De Bruyn, J.-M. Ortiz de Urbina, H. Arrizabalaga, J. Santiago, and H. Murua. An example management strategy evaluation of a harvest control rule. *ICCAT Collect. Vol. Sci. Pap.*, 69(35):xxx–xxx, 2013b.

L. Kell, J.-M. Fromentin, and C. Szuwalski. Which came first? the chicken, the egg or the tortilla. *ICCAT Collect. Vol. of Sci. Pap.*, 66:x:xx–xxx, 2014.

Kell.L.T. Identification of the major sensitivities in the east atlantic and mediterranean bluefin assessment. *ICCAT Collect. Vol. of Sci. Pap.*, 66:x:xx–xxx, 2014.

A. Leach, P. Levontin, J. Holt, L. Kell, and J. Mumford. Identification and prioritization of uncertainties for management of eastern atlantic bluefin tuna (*Thunnus thynnus*). *Marine Policy*, x(xx):xxx–xxx, Accepted.

A. Punt and G. Donovan. Developing management procedures that are robust to uncertainty: lessons from the international whaling commission. *ICES Journal of Marine Science: Journal du Conseil*, 64 (4):603–612, 2007.

4. Tables

Parameter	default
k_1	1.5
k_2	3
γ	1
n	-

Table 1: HCR 1 tunable parameters

Parameter	BP
ε_b	0.25
ε_r	0.75
δ	-
τ_B	7
B^*	-
τ_r	5

Table 2: HCR 2 tunable parameters

Factor	Levels	ΣN	Values
Historic Catch	2	2	Reported, Inflated
Recruitment	2	4	Low,Medium,High
HCR	2	8	1,2

Table 3: OM options

5. Figures

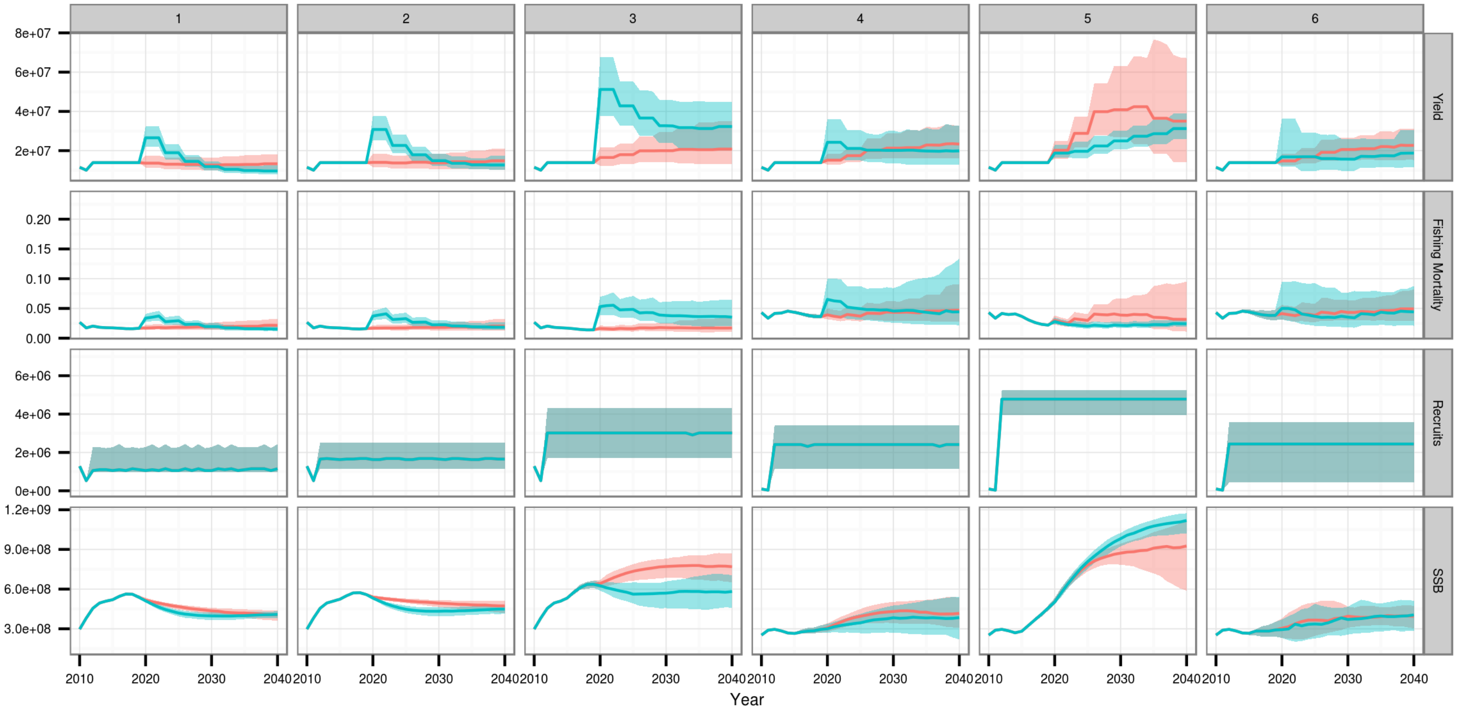

Figure 1: Inter-quartiles (shaded area) and medians (lines) for time series of catch, SSB, recruits and fishing mortality for the 2 HCRs (colour) and OM Scenario (col).

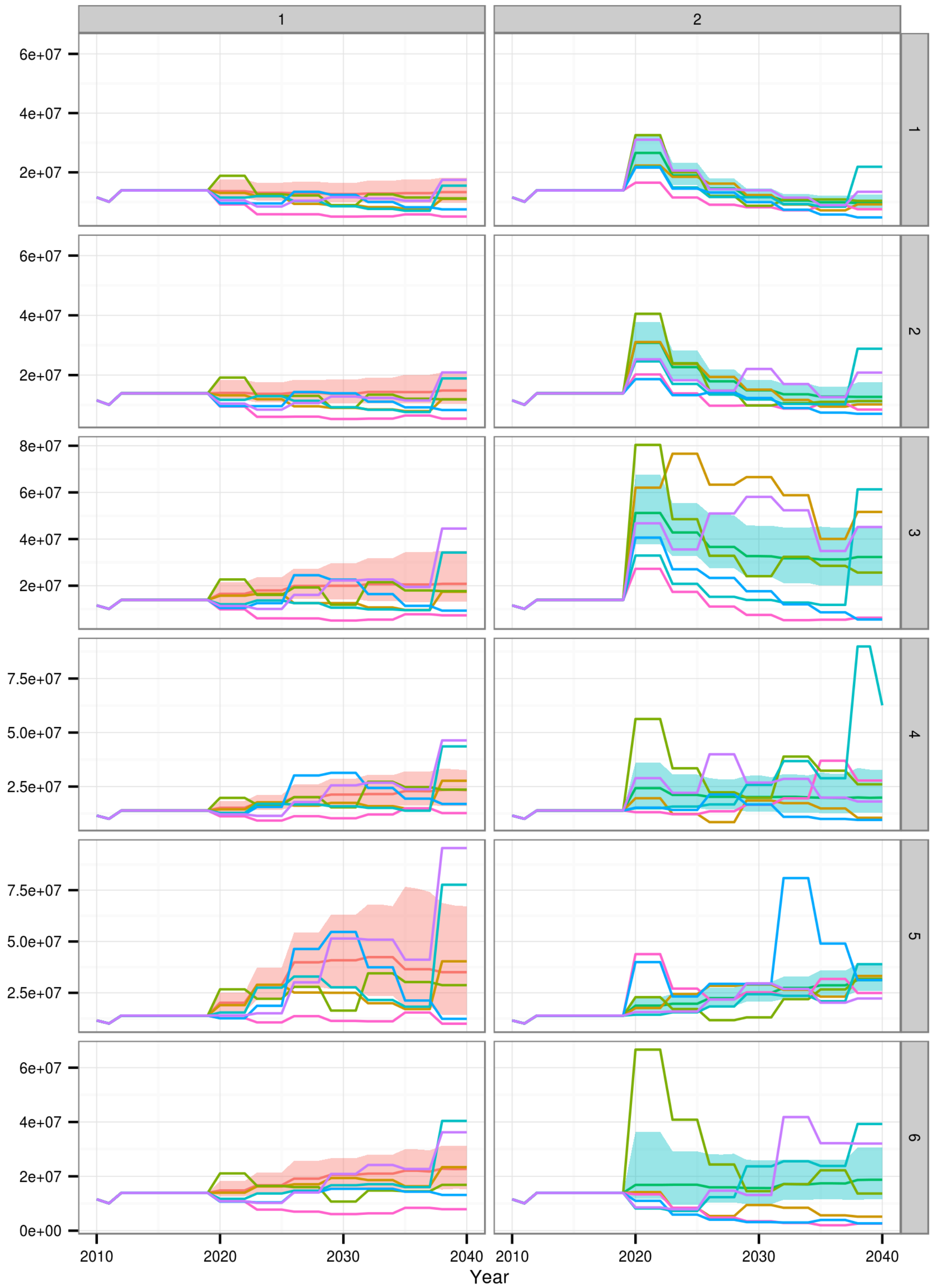

Figure 2: Worm plots for catch by HCR (row) and OM Scenario (col).

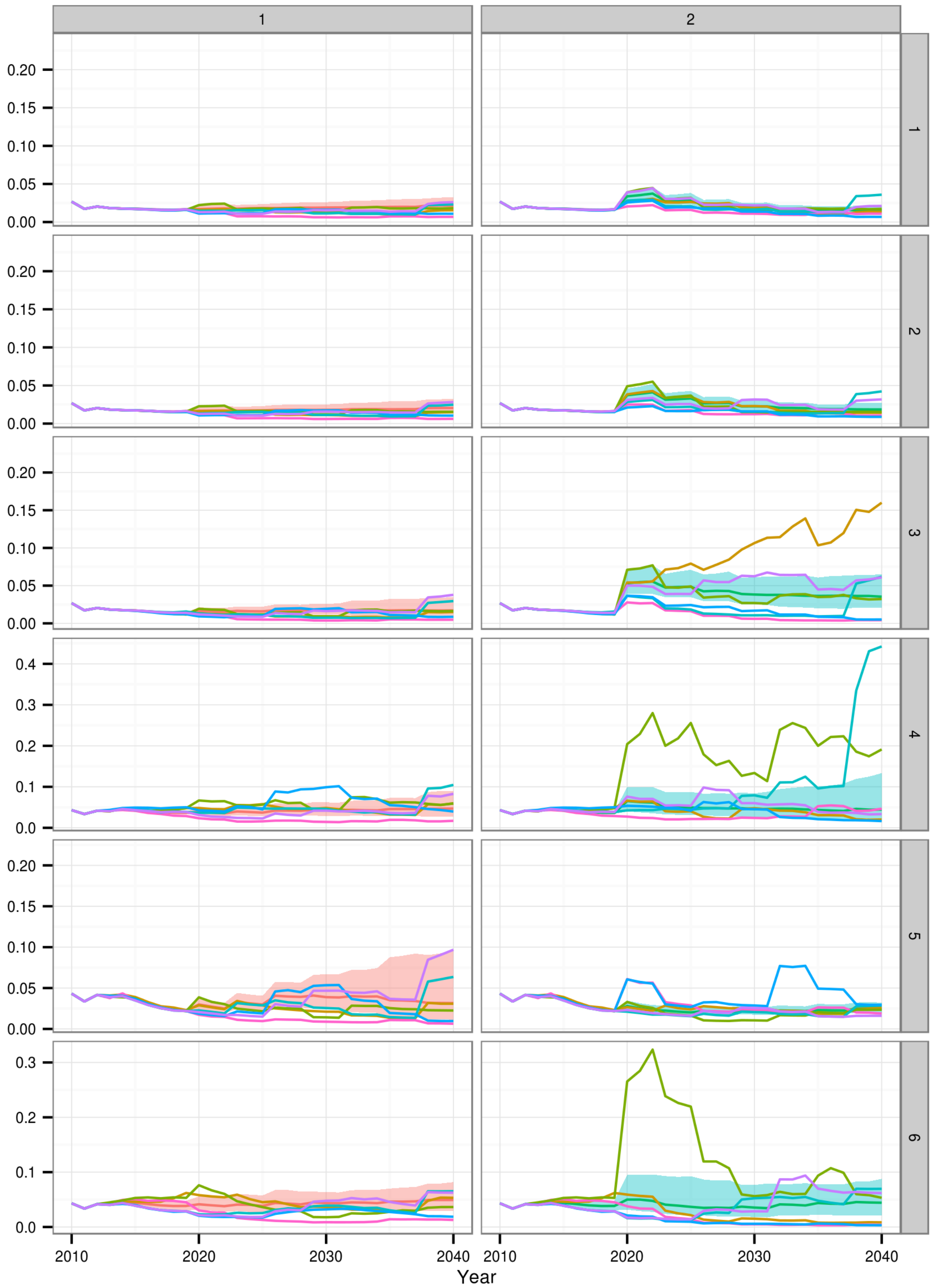

Figure 3: Worm plots for F by HCR (row) and OM Scenario (col).

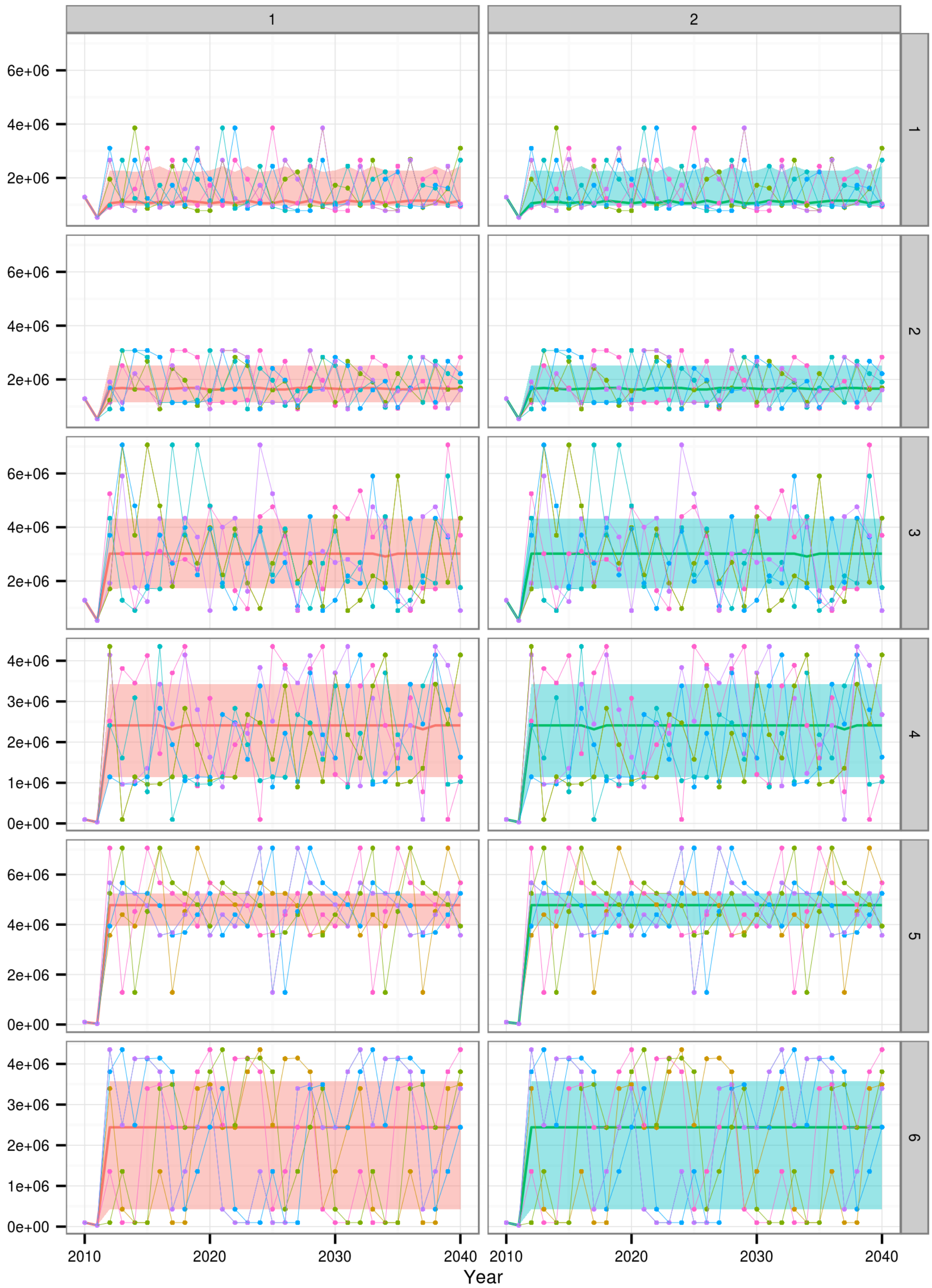

Figure 4: Worm plots for recruits by HCR (row) and OM Scenario (col).

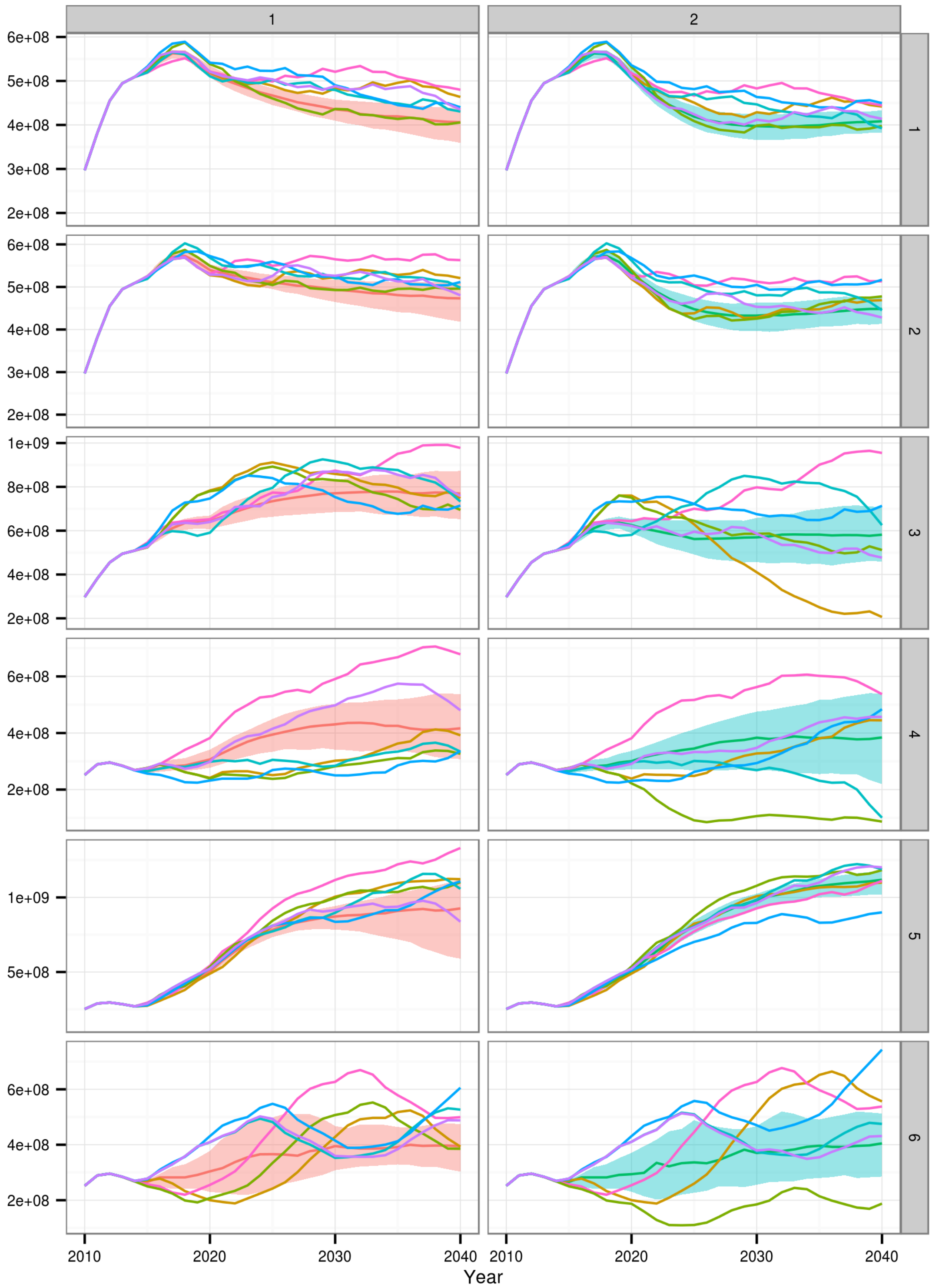

Figure 5: Worm plots for SSB by HCR (row) and OM Scenario (col).