



Evaluation of possibility of estimating systematic changes in catchability in the state-space production model

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SUMMARY

The paper aims at evaluating possibility of estimation of systematic change in the catchability coefficient over time within the interim stock assessment model, BSSPM, used in Pacific saury stock assessment in the NPFC. For conditioning the simulation models, the parameters including in the time-varying catchability coefficient were firstly estimated according to the three base case scenarios agreed in the last stock assessment. The simulation data were then generated and applied to the BSSPM models. The results showed that such a dynamic change in catchability might be estimated well for some scenarios within their models if the assumption in the relative biomass is correct. However, if such an assumption is not correctly hold, there may be some potential bias in the estimation of catchability and biomass. This sort of exercise should be more paid attention before finalizing 2020 stock assessment. Otherwise, a safer option might be to exclude Japanese early CPUE from the assessment.

INTRODUCTION

In the previous stock assessment conducted for the Pacific saury, an assumption of time-varying catchability coefficient in the early time-series of Japanese CPUE (1980-1993) was employed for expressing possible changes in Japanese fishing technology during that period. The TWG meeting agreed to estimate such changes within the stock assessment models (as base case scenarios 1-3). The TWG also agreed other options without using such time series to assess the impact of the data to stock assessment results (as base case scenarios 4-6). Three stock assessment groups developed their own preferred models for the time-varying catchability coefficient. The results by the three groups consistently indicated that, although some difference in the biomass trajectory in 1980-1993 was observed between the two different treatment of catchability coefficient, the biomass dynamics after that period is not influenced by handling early Japanese CPUE but mostly driven by the assumption of relative bias in the Japanese biomass survey. Despite this result, use/non-use of Japanese early CPUE data brings different implication to the historical stock status, and therefore it is worth assessing the validity of those results.

The time-varying catchability coefficient was sometimes in the stock synthesis (SS3) to account for the difference in fishery pattern in different periods ("time block" and "time-varying"). The Pacific saury stock assessment eventually used "time block" option by splitting into two periods according to Japanese early/late CPUE series. But what is difference is, while SS3 normally assumes random changes in the catchability, the Pacific saury stock assessment assumed a parametric and systematically monotonic function for that. Also, the results of time-varying catchability were not very similar among three different stock assessment groups, and therefore a concern if time-varying catchability is estimated well is raised.

Here, in order to address this question, we conducted a simulation study based on the previous stock assessment specification particularly with focusing on the estimation performance in the catchability and the impact on the biomass estimates.

MATERIALS AND METHODS

Data set

The data sets included in this simulation were same as those used in the stock assessment (see the TWG03 report):

- 1) time series of total reported catch up to 2018
- 2) standardized CPUE indices by the following five Members (Table 1 and Fig 2)
 - China (2013-2017)
 - early Japan (1980-1993)
 - late Japan (1994-2017)
 - Korea (2001-2016)
 - Russia_only (1994-2017)
 - Chinese Taipei (2001-2017)
- 3) fishery-independent survey by Japan (2003-2018).

Specification of simulation

We first re-estimated parameters in the BSSPM for base cases 1-3 based on the same specification used in Chiba and Kitakado (2019). The model is same with the simulation model shown later. For each base case, we then randomly picked up 100 time series of biomass from MCMC samples as the true biomass series in the simulation.

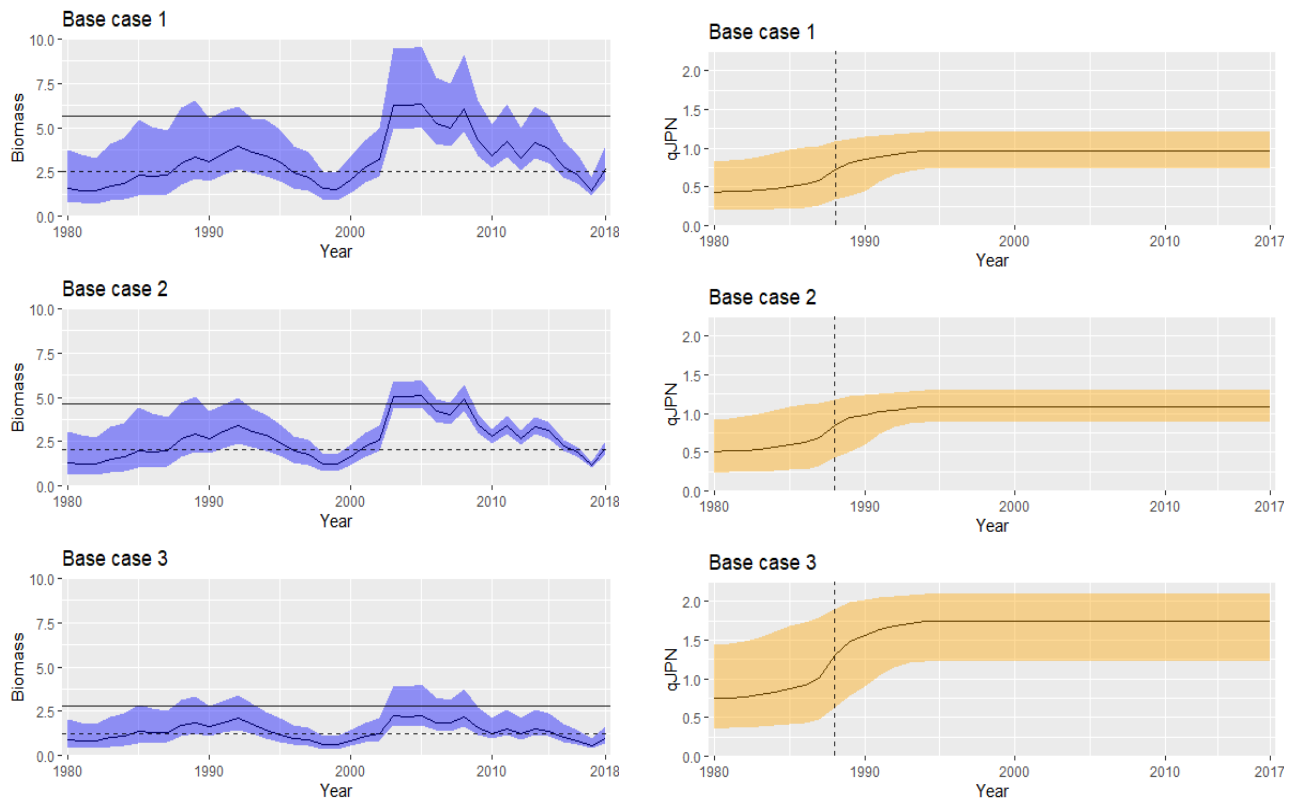


Figure 1. Estimated trajectories in biomass (left) and catchability change for Japanese fishery (right) for three base case scenarios. Color shaded envelopes show 80% credible intervals.

Table 1. Summary of parameter estimates (median) used in the simulation.

	Base case 1	Base case 2	Base case 3
r	0.865	0.927	1.193
K (million)	5.647	4.627	2.762
D1	0.294	0.305	0.338
shape	0.344	0.362	0.422
tau	0.329	0.328	0.319
sigma_Biomass	0.140	0.140	0.140
sigma_CPUE	0.343	0.344	0.344
qBio	0.829	1.000	2.283
qJPN2	0.967	1.084	1.739
qCHN	7.247	8.152	13.137
qKOR	4.501	5.032	8.007
qRUS	10.970	12.303	19.542
qCT	0.970	1.094	1.740
b	0.589	0.602	0.653
qq1	0.421	0.493	0.731
delta	0.524	0.586	0.918
alpha	3.912	3.990	3.997
beta	1988.078	1987.992	1987.969
MSY	0.535	0.501	0.437
BMSY (milion)	2.498	2.074	1.233
FMSY (milion)	0.211	0.236	0.348

Based on the conditioned models, simulation data set were generated for each biomass series in each scenario as follows:

Survey biomass:

$$I_{t,biomass} = q_{biomass} B_t e^{v_{t,biomass}}, \quad v_{t,biomass} \sim N(0, \sigma_{biomass}^2)$$

where I_t is the biomass observation in year t , and $q_{biomass}$ and $\sigma_{biomass}$ were respectively the median estimates for the relative bias in biomass survey and the standard deviation of survey.

CPUE series:

$$I_{t,f} = q_f B_t^b e^{v_{t,f}}, \quad v_{t,f} \sim N(0, \sigma_f^2)$$

where $I_{t,f}$ is the CPUE observation in year t for fishery f (China, Japan, Korea, Russia, Chinese Tapiei), and q_f and σ_f were respectively the median estimates for the catchability coefficient and the standard deviation in CPUE for fishery f , and b is the median estimate of hyperstability/hyperdepletion parameter. Note that “b” is not assumed for Japanese early CPUE as agreed in TWG03.

Particularly for the Japanese early CPUE, the following functional form was used.

$$q_{t,JPN1} = q_{1980,JPN1} + \delta \cdot \frac{1}{1 + e^{\alpha(\beta-t)}}$$

We then repeated the data generation and estimation in the simulation. In the estimation, we intentionally used three different models according to the three base cases for each simulation for each base case. The number of simulation replicas is 100 for each base case.

Prior distributions:

The prior distributions assumed in the BSSPM were same between conditioning and estimation in the simulation.

$$\begin{array}{lll}
 r \sim U(0.01,3), & K \sim U(0.01,20), & D1 \sim U(0.01,1), \\
 z \sim U(0.01,2), & \tau \sim U(0.01,2), & \sigma_{biomass} \sim U(0.01,2), \\
 q_{1980, JPN1} \sim U(0.001,2), & q_{CHN} \sim U(0.001,16), & q_{KOR} \sim U(0.001,10), \\
 q_{RUS} \sim U(0.001,20), & q_{CT} \sim U(0.001,2), & b \sim U(0.01,1), \\
 \alpha \sim U(0.01,10), & \beta \sim U(1980,1994), & \delta \sim U(0.001,3)
 \end{array}$$

RESULTS

Here, we give some of main results in this section, but most of results are shown in Appendix.

Figure 2 showed a comparison between the true and estimated catchability change under three different estimation models (base cases 1-3) for each of three true conditioned models (base bases 1-3). These pieces of results suggested that the assumption of relative bias in the biomass survey might influence to the estimation performance in changes in catchability coefficient.

Figure 3 showed biases in the biomass, which indicated some propagation of bias in Japanese catchability coefficients when the assumption of relative bias in survey is violated. However, the impact of the bias was softened because the Japanese CPUE is less influential (1/6 contribution relative to that of the biomass estimates), and this is not only due to less precision of catchability changes rather because of misspecification of model in survey bias.

Conclusion

The results showed that the dynamic change in catchability might be estimated well for some scenarios if the assumption in the relative biomass is correct. However, if such an assumption is not correctly hold, there may be some potential bias in the estimation of catchability, which also causes the bias in biomass estimate. The current work is still preliminary, but this sort of exercise should be more paid attention before finalizing 2020 stock assessment. Otherwise, a safer option might be to exclude Japanese early CPUE from the assessment.

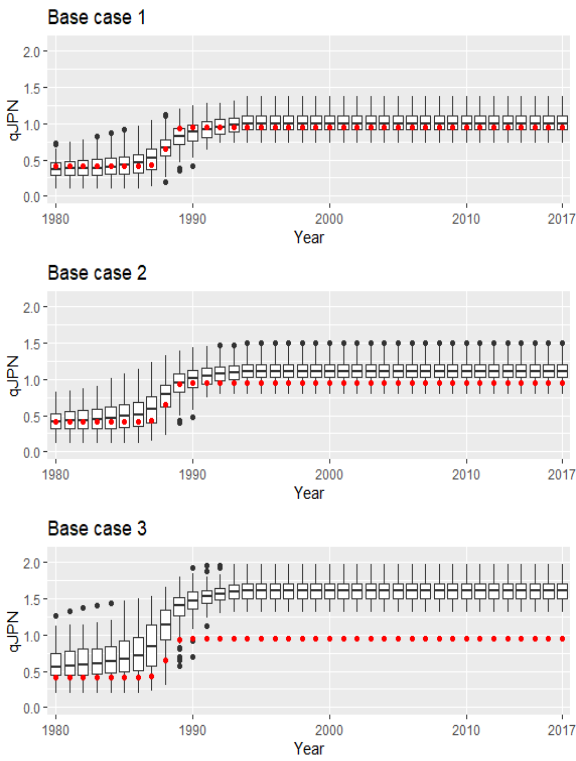
References

Natsuko Chiba and Toshihide Kitakado (2019) Outcomes of the stock assessment for the Pacific saury - 2019 update with the BSSPM-. NPFC-2019-TWG PSSA04-WP10 (Rev. 1)

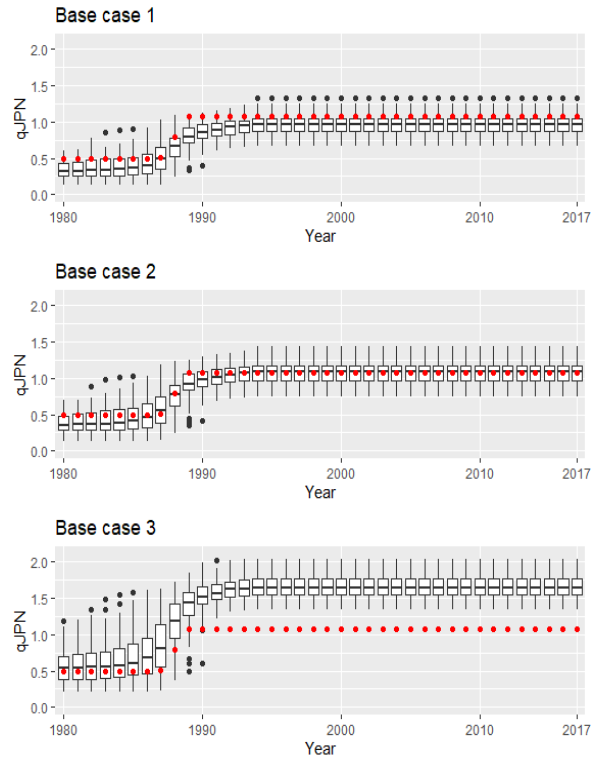
NPFC (2018) Report of the TWG-PSSA 03.

NPFC (2019) Report of the TWG-PSSA 04.

(a) Results under true base case 1



(b) Results under true base case 2



(c) Results under true base case 3

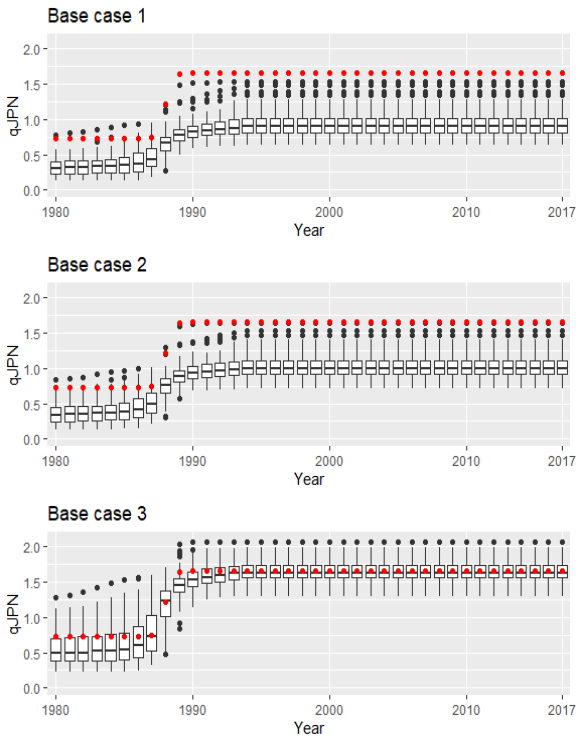
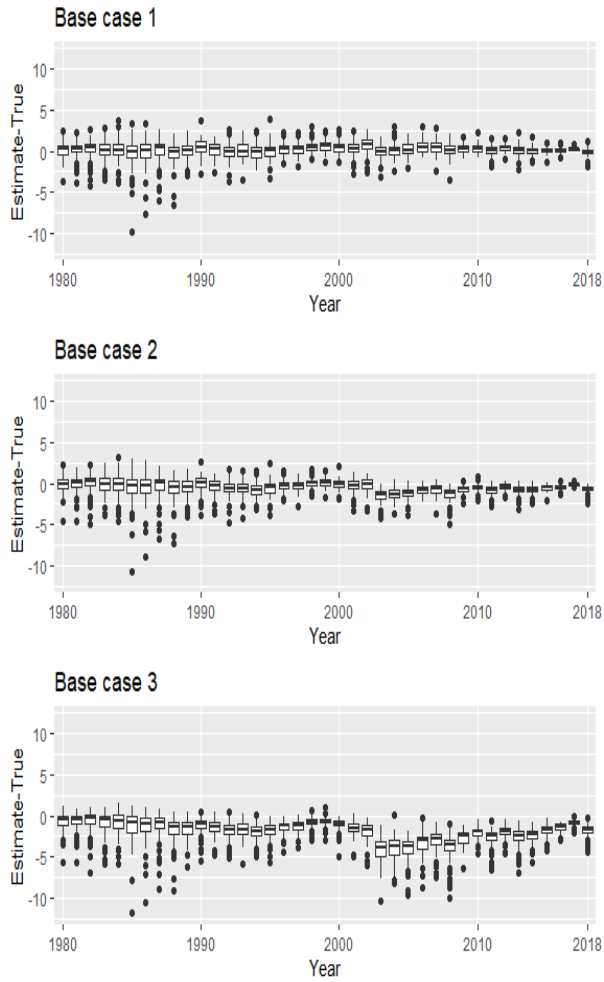


Figure 2. Trajectories of true catchability (red circles) with box plots for the estimates under three different estimation models (base cases 1-3) for each of the three true conditioned models (base bases 1-3).

(a) Results under true base case 1



(b) Results under true base case 2

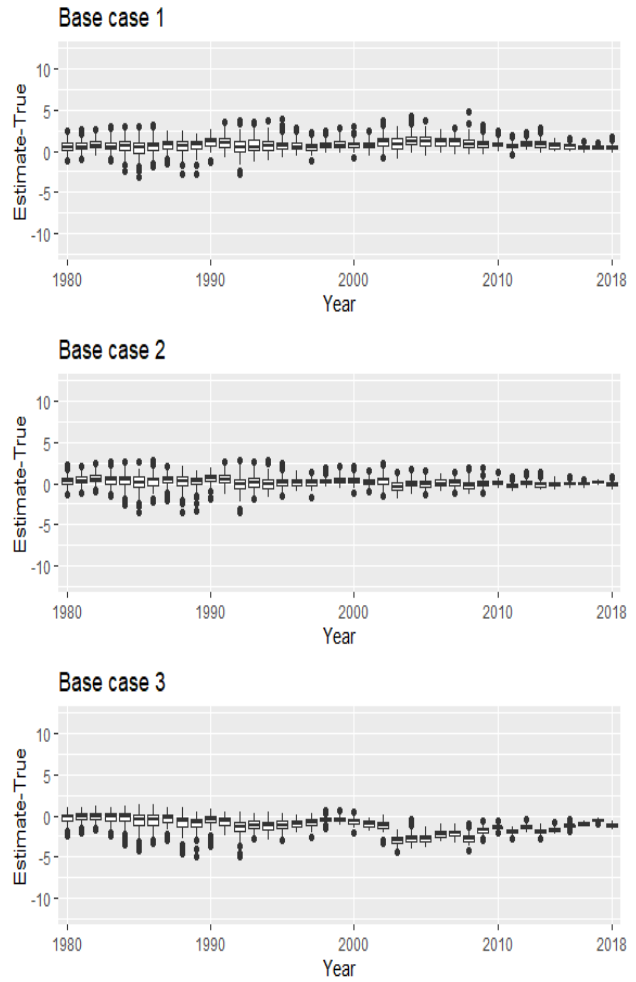


Figure 3. Biases in the estimates of biomass (estimate-true value, in million tons) based on the three estimation models under each of the three true conditioned models.

(c) Results under true base case 3

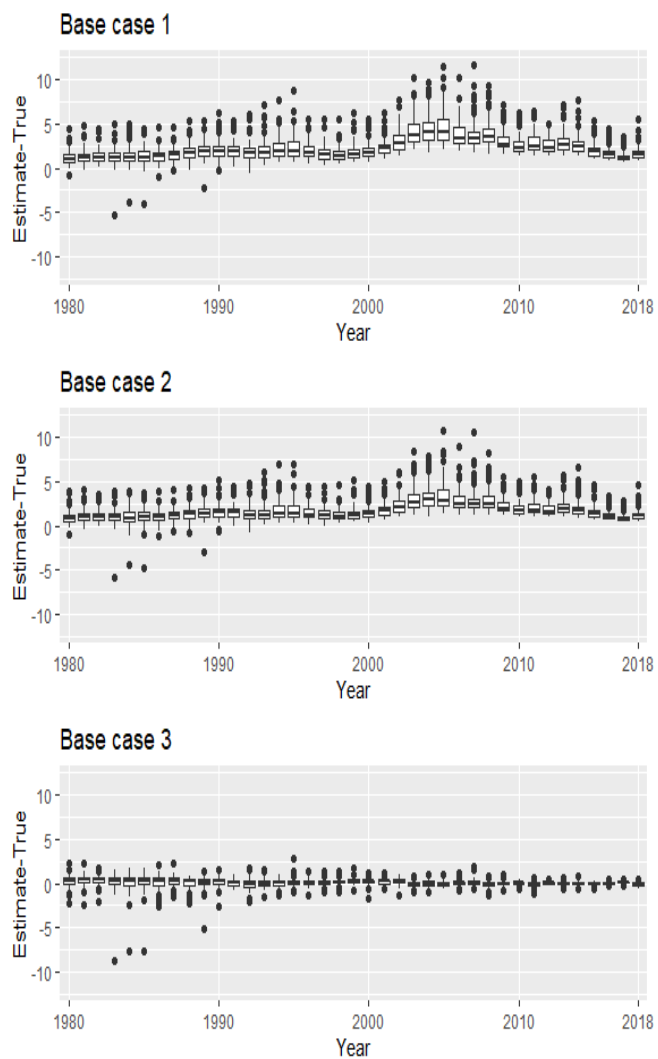
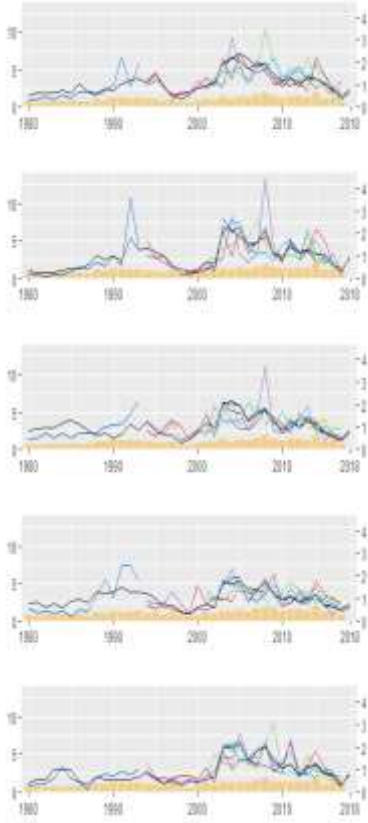


Figure 3. (continued)

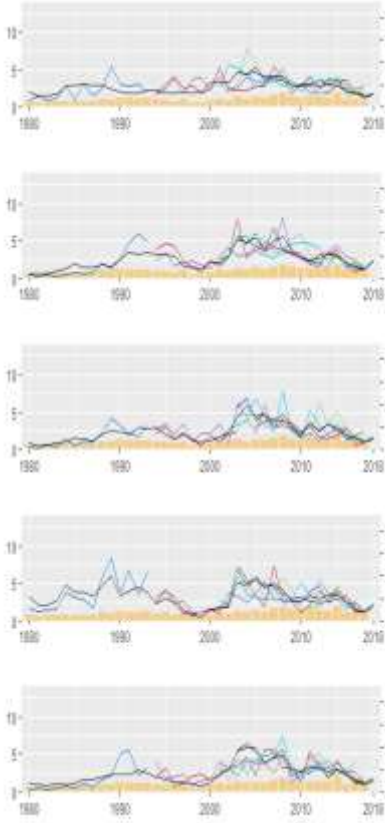
APPENDIX: five example plots of simulation data and associated results

1. Example plots of data

True model is base case 1



True model is base case 2



True model is base case 3

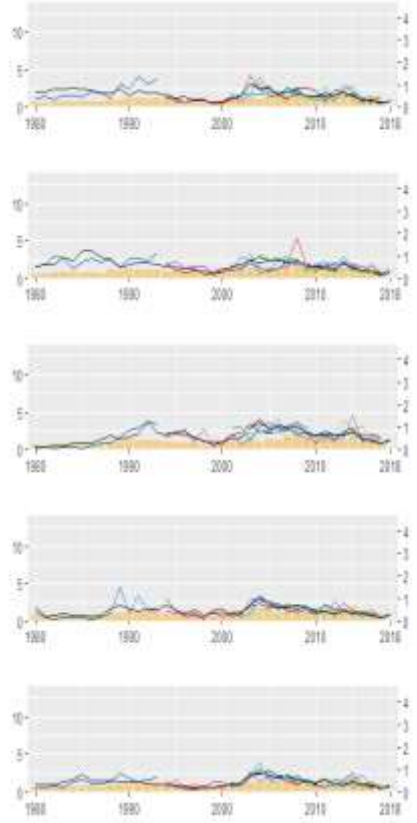


Figure A1. Example plots of simulated data (five randomly selected) under the three base case models.

2. Example plots of true and estimated biomass (true is base case 1)

Estimation model is base case 1

Estimation model is base case 2

Estimation model is base case 3

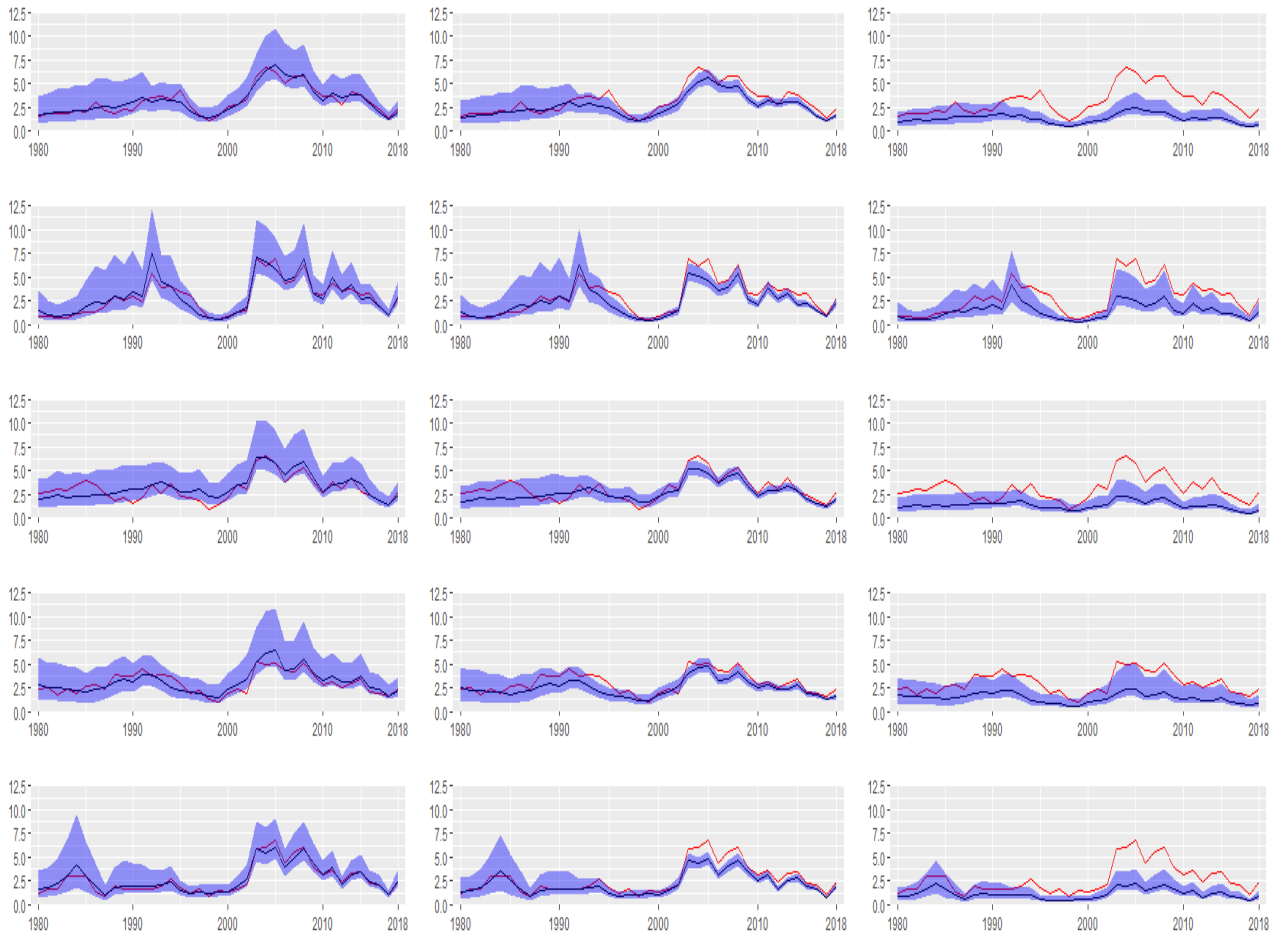


Figure A2. Example plots of true (red) and estimated biomass (black line for the median with 80% credible intervals) when the true is the model conditioned with base case 1. The data in each row are same among the three estimation models.

3. Example plots of true and estimated biomass (true is base case 2)

Estimation model is base case 1

Estimation model is base case 2

Estimation model is base case 3

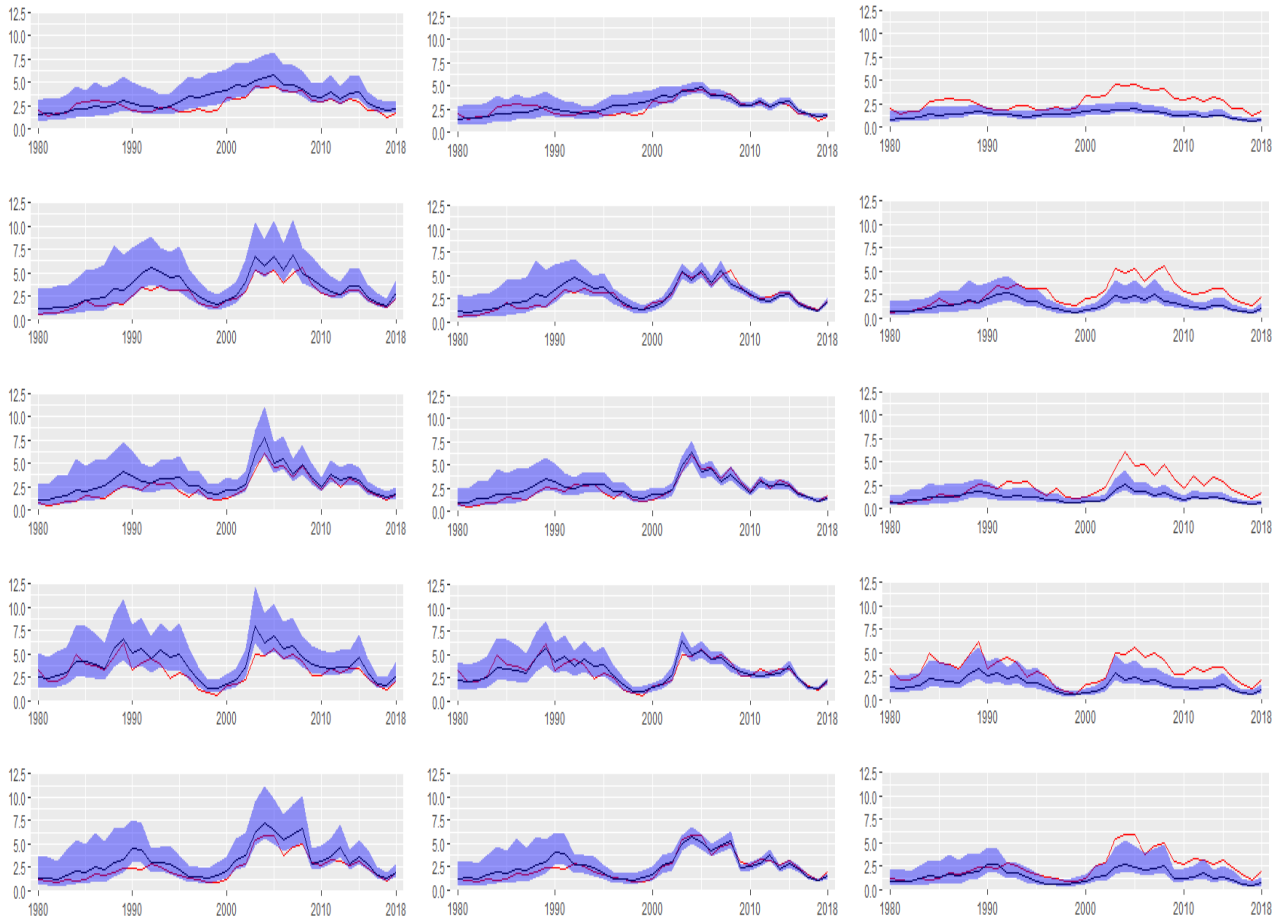


Figure A3. Example plots of true (red) and estimated biomass (black line for the median with 80% credible intervals) when the true is the model conditioned with base case 2. The data in each row are same among the three estimation models.

4. Example plots of true and estimated biomass (true is base case 3)

Estimation model is base case 1

Estimation model is base case 2

Estimation model is base case 3

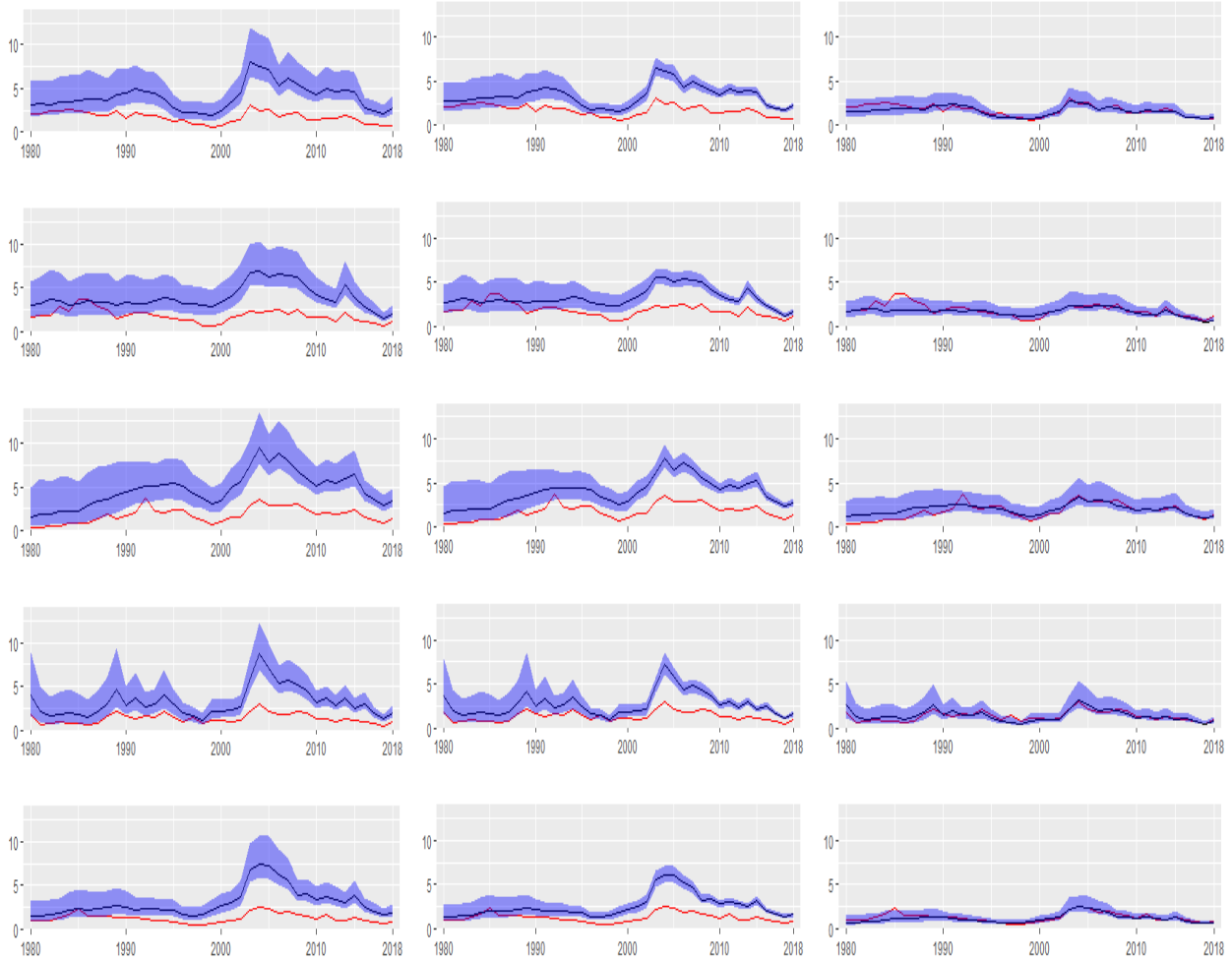


Figure A4. Example plots of true (red) and estimated biomass (black line for the median with 80% credible intervals) when the true is the model conditioned with base case 3. The data in each row are same among the three estimation models.