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Trial application of JABBA to Pacific saury stock assessment

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Abstract

JABBA (Just Another Bayesian Biomass Assessment) is an open-source software to conduct stock assessment based on Bayesian state-space surplus production model (BSSPM). This software is easy to share among the NPFC members owing to its openness and to modify its code to meet stock assessment model specification. We tried to mimic the latest stock assessment results of Pacific saury (PS) completed by the Technical Working Group on Pacific Saury Stock Assessment (TWG-PSSA) using the JABBA variant where the model specifications of the PS stock assessment were incorporated. The JABBA variant showed similar stock assessment results of the latest stock assessment. JABBA can be one of the candidates of shared stock assessment model on PS in the SSC-PS.

Introduction

The Small Scientific Committee decided to apply Bayesian state-space surplus production model (BSSPM) to the preliminary stock assessment on Pacific Saury (SSC-PS, 2016). The Technical Working Group on Pacific Saury Stock Assessment (TWG-PSSA) agreed the Pacific saury (PS) stock assessment results and current stock status at the third meeting (TWG-PSSA, 2019). The 4th Meeting of the TWG-PSSA agreed to use the current stock assessment models (BSSPM) as a benchmark and continue to improve them. At this meeting, the participants reaffirmed the importance of the model code sharing, which would enable more effective stock assessment works.

JABBA (Just Another Bayesian Biomass Assessment) is an open-source software to conduct stock assessment based on BSSPM (Parker et al., 2018; Winker et al., 2018). At the 4th TWG-PSSA meeting, Russia reported an alternative PS stock assessment using JABBA, where the biomass was estimated for 1994 to 2017 using two types of abundance indices such as a nominal joint CPUE and the biomass estimates from the Japanese fisheries-independent survey (Russia, 2019). JABBA is easy to share because of its openness and to enable the code modification to meet particular model specification of stock assessments. Therefore, we addressed to mimic the PS stock assessment conducted in 2019 using JABBA where a part of the specifications of the current PS stock assessment was incorporated.

Data

The 3rd meeting of the TWG-PSSA agreed the data set and the model specifications applied for the stock assessment of PS using BSSPM (TWG-PSSA, 2018). In this study, the same data set were applied to mimic the stock assessment results conducted by the TWG-PSSA (TWG-PSSA, 2019).

Methods

We applied JABBA to conduct the mimic stock assessment of PS. The JABBA software can be downloaded via https://github.com/jabbamodel/JABBA. Winker et al. (2018) described features of JABBA and illustrated application results of JABBA to South Atlantic swordfish.

In JABBA, the surplus production at year t SP_t is formulated based on Pella-Tomlinson model as follows:

$$SP_t = \frac{r}{m-1} B_t \left(1 - \left(\frac{B_t}{K}\right)^{m-1}\right), \quad (1)$$

Where r, K, B and m demote intrinsic rate of population increase, carrying capacity, stock biomass and shape parameter determining B/K ratio where the surplus production attains MSY, respectively. It should be noted that although eq. 1 is apparently different from that used in the current PS stock assessment, which is expressed as:

$$SP_t = rB_t \left(1 - \left(\frac{B_t}{K}\right)^{z}\right), \quad (2)$$

these parameterizations show essentially same dynamics

In this study, the specifications of the current stock assessment model of PS for the base cases of 4-6 (B4-B6) (**Table 1**) were reflected. Because the time-varying catchability setting for early JPN CPUE has not been completed, the base cases of 1-3 (B1-B3) were not performed. To mimic the current PS stock assessment and to be consistent with its manner, the following modifications were applied to the jags code of JABBA:

1. Change of assumption of prior distribution for relative bias from biomass of the Japanese fishery-independent survey q_JPNbio and catchability of CPUE from commercial fishery q_CPUE:
   i. q_JPNbio ~ U(0.1, 1), 1 or U(0.1, 3),
   ii. q_CPUE ~ U(0.00001, 0.0002);
2. Treatment for variance component: variance of CPUEs were set at fivefold one of JPNbio;
3. Estimation of the hyper stability parameter b representing nonlinear relationship between

biomass and CPUEs: $b \sim U(0, 1)$

4. Estimation on the shape parameter *m*;

Because the parameter *m* was not estimated in the original JABBA, the modified version of JABBA was called as "JABBA variant". 10000 MCMC samples were taken for each base case. Parameters to estimate through the MCMC runs are listed in **Table 2**.

Results and discussion

The JABBA variant runs for the base cases 4-6 of the PS stock assessment, as a whole, succeeded to mimic the current stock assessment results such as *F* and *B* ratios and Kobe plots (**Figs 1 and 2**).

All parameter estimations were converged, because all Rhat were smaller than 1.1 (**Table 3**). Prior and posterior distribution of all parameters are shown in **Fig. 3**. Although median of *q*_JPNbio exceeded 1 under a prior distribution of U(0.1, 3), it was 1.041, close to 1. The parameter estimates were not sensitive for the assumption on *q*_JPNbio and did not show inconsistency relative to the parameters estimated through the current stock assessments by Members (**Fig. 4**).

In the latest stock assessment conducted by China, Japan and Chinese Taipei, some assumptions regarding the time-varying *q* for JPN_early CPUE were made (Chiba and Kitakado, 2019; China, 2019; Hsu et al., 2019). Because the JABBA variant has not included a function of the time-varying *q* at the present stage, it should be incorporated in future.

The TWG-PSSA specified the items required to be listed in summary table of reference points (TWG-PSSA, 2018). Although the JABBA variant does not provide all the required items at the present stage, it can be modified according to further requests.

JABBA has advantages in code sharing and modification and can contribute to conduct a joint work on stock assessment. It can be one of the candidates of shared stock assessment model on PS in the Scientific Committee on Pacific Saury (SSC-PS).

References

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Table 1 Model specification for the Bayesian state-space surplus production model used in the Pacific saury stock assessment agreed in the 3rd meeting of the TWG-PSSA (TWG-PSSA, 2019).

	Base case (B1-B3)	**Base case (B4-B6)**	**Sensitivity case (S1-S6)**
Initial year	1980	1980	1980
Relative bias in biomass estimate	U(0.1, 1), 1, U(0.1, 3) forJPNbio(2003-2018)	U(0.1, 1), 1, U(0.1, 3) forJPNbio(2003-2018)	U(0.1, 1), 1, U(0.1, 3) forJPNbio(2003-2018)
CPUE	CHN(2013-2017) JPN_early(1980-1993) with assumptions of time-varying q JPN_late(1994-2017) KOR(2001-2016) RUS(1994-2017) CT(2001-2017)	CHN(2013-2017) JPN_late(1994-2017) KOR(2001-2016) RUS(1994-2017) CT(2001-2017)	Two sets as on the left
Variance component	Variances of CPUEs are assumed to be common and 6 times of that of biomass	Variances of CPUEs are assumed to be common and 5 times of that of biomass	Variances are assumed to be free parameters
Hyper-depletion/ stability	A common parameter for all fisheries but JPN_early, with a prior distribution, b ~ U(0, 1) but [b_JPN_early=1]	A common parameter for all fisheries with a prior distribution, b ~ U(0, 1)	No (b=1)
Prior	Own preferred options	Own preferred options	Own preferred options

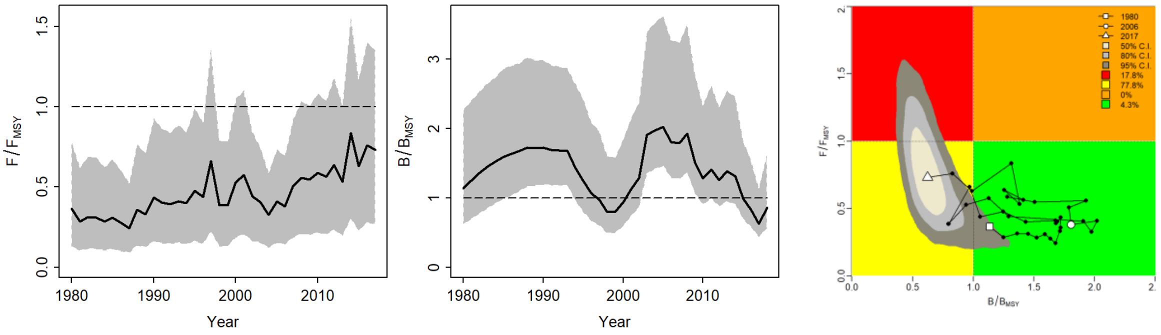
Table 2 Parameters to estimate through the MCMC runs and those descriptions.

Parameter	**Description**	**Prior**
*K*_million	Carrying capacity (million ton)	*K*_million ~ LogNormal(log(10)-σ_K^2/2, σ_K^2); CV_K=0.3
r	Intrinsic rate of population increase	*r* ~ LN(log(0.5)-σ_r^2/2, σ_r^2); CV_r=0.3
q.1	Catchability of the Japanese fishery-independent survey (JPNbio)	*q*.1 ~ U(0.1,1)/1/U(0.1,3)
q.2	Catchability of CHN CPUE	*q*.2 ~ U(0.00001, 0.0002)
q.3	Catchability of JPN_late CPUE	*q*.3 ~ U(0.00001, 0.0002)
q.4	Catchability of KO CPUE	*q*.4 ~ U(0.00001, 0.0002)
q.5	Catchability of RU CPUE	*q*.5 ~ U(0.00001, 0.0002)
q.6	Catchability of CT CPUE	*q*. 6 ~ U(0.00001, 0.0002)
psi	Initial depletion rate	psi ~ LN(log(0.5)-σ_r^2/2, σ_r^2); CV_r=0.3
sigma2	Variance of process error	1/sigma2 ~ Gamma(4,0.1)
tau2.1	Variance of observation error for JPNbio	1/tau2.1 ~ Gamma(4,0.1)
tau2.2	Variance of observation error for CPUEs	1/tau2.2 ~ Gamma(4,0.1)
m	Shape parameter	*m* ~ U(0.1,2)
*b*2	Hyper-stability coefficient	*b*2 ~ U(0,1)

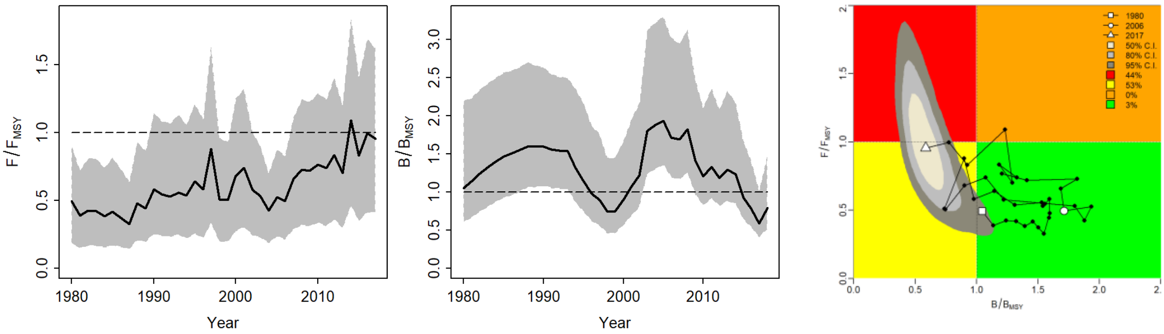
Table 3 Median of estimated parameters and those 95% confidence intervals and Rhat.

Parameters	Base case 4				Base case 5				Base case 6			
	Median	**LCI**	**UCI**	**Rhat**	**Median**	**LCI**	**UCI**	**Rhat**	**Median**	**LCI**	**UCI**	**Rhat**
*K*_million	6.77523	5.04351	11.21439	1.004	5.55641	4.62383	7.32096	1.001	5.50464	3.39622	9.93623	1.003
r	0.28245	0.18118	0.43183	1.003	0.28393	0.18023	0.43398	1.001	0.28754	0.18015	0.44444	1.003
q.1	0.79432	0.45123	0.98946	1.004	1	1	1	-	1.04142	0.5171	2.08617	1.004
q.2	0.00013	0.00008	0.00018	1.001	0.00013	0.00008	0.00018	1.001	0.00013	0.00008	0.00019	1.001
q.3	0.00002	0.00001	0.00002	1.001	0.00002	0.00001	0.00002	1.001	0.00002	0.00001	0.00002	1.001
q.4	0.00007	0.00005	0.0001	1.002	0.00007	0.00005	0.0001	1.001	0.00007	0.00005	0.0001	1.001
q.5	0.00018	0.00012	0.0002	1.001	0.00018	0.00012	0.0002	1.001	0.00018	0.00012	0.0002	1.001
q.6	0.00002	0.00001	0.00002	1.001	0.00002	0.00001	0.00002	1.001	0.00002	0.00001	0.00002	1.001
psi	0.50009	0.28401	0.84798	1.028	0.46104	0.27234	0.84226	1.015	0.46578	0.28242	0.85044	1.031
sigma2	0.03663	0.02162	0.04478	1.001	0.03584	0.02063	0.04453	1.001	0.03587	0.02049	0.0444	1.001
tau2.1	0.02677	0.01973	0.03722	1.002	0.02672	0.01974	0.03682	1.001	0.0267	0.01975	0.03727	1.001
tau2.2	0.13384	0.09863	0.1861	1.002	0.13358	0.09872	0.18408	1.001	0.13348	0.09873	0.18636	1.001
m	1.62342	0.5525	1.98258	1.001	1.62011	0.5904	1.98334	1.001	1.60474	0.55769	1.9848	1.001
b.2	0.77547	0.74485	0.80457	1.003	0.7877	0.77151	0.81231	1.001	0.79146	0.75175	0.83448	1.004
F_{MSY}	0.187	0.113	0.474	-	0.186	0.114	0.433	-	0.191	0.112	0.451	-
B_{MSY}	3.02562	1.64825	5.1228	-	2.51472	1.44315	3.47015	-	2.44152	1.19499	4.62913	-
MSY	0.57651	0.36689	1.04896	-	0.47134	0.32881	0.70691	-	0.46233	0.31019	0.90072	-

Base case 4



Base case 5



Base case 6

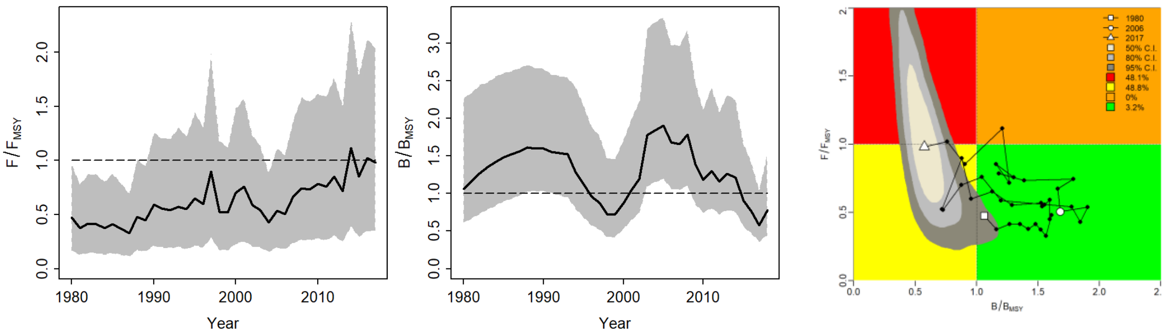


Fig. 1 Estimated trajectories of *B* and *F* ratios and Kobe plots outputted through the JABBA variant for base cases 4-6 of the PS stock assessment. Left, center and right panels show *B* and *F* ratios and Kobe plots, respectively. Gray-shaded areas in left and center panels denote 95% credible intervals.

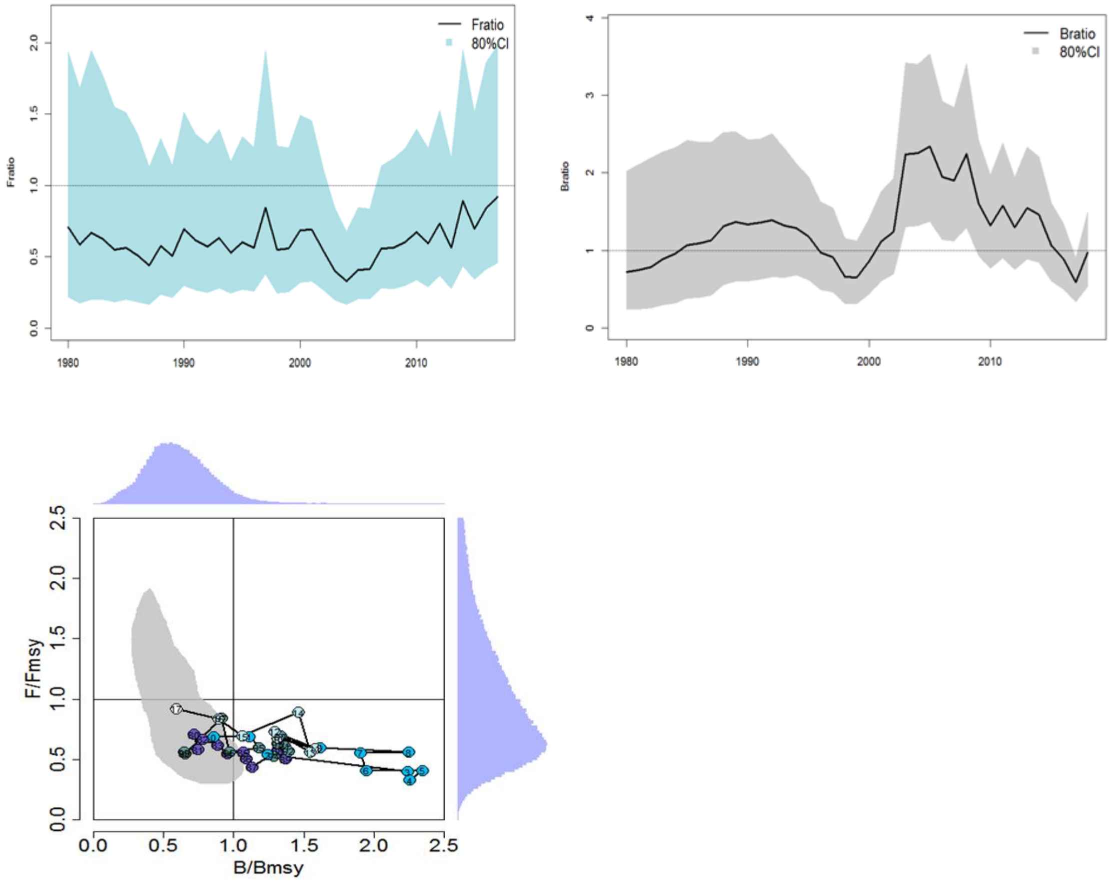


Fig. 2 Trajectories of *F* (top left) and *B* (top right) ratios and Kobe plot (bottom) from the current stock assessment results provided by the TWG-PSSA (2019). 80% confidence intervals for *F* and *B* ratios are colored in blue and gray, respectively. Gray area in bottom panel denote 80% credible interval for terminal year (2017).

Base case 4

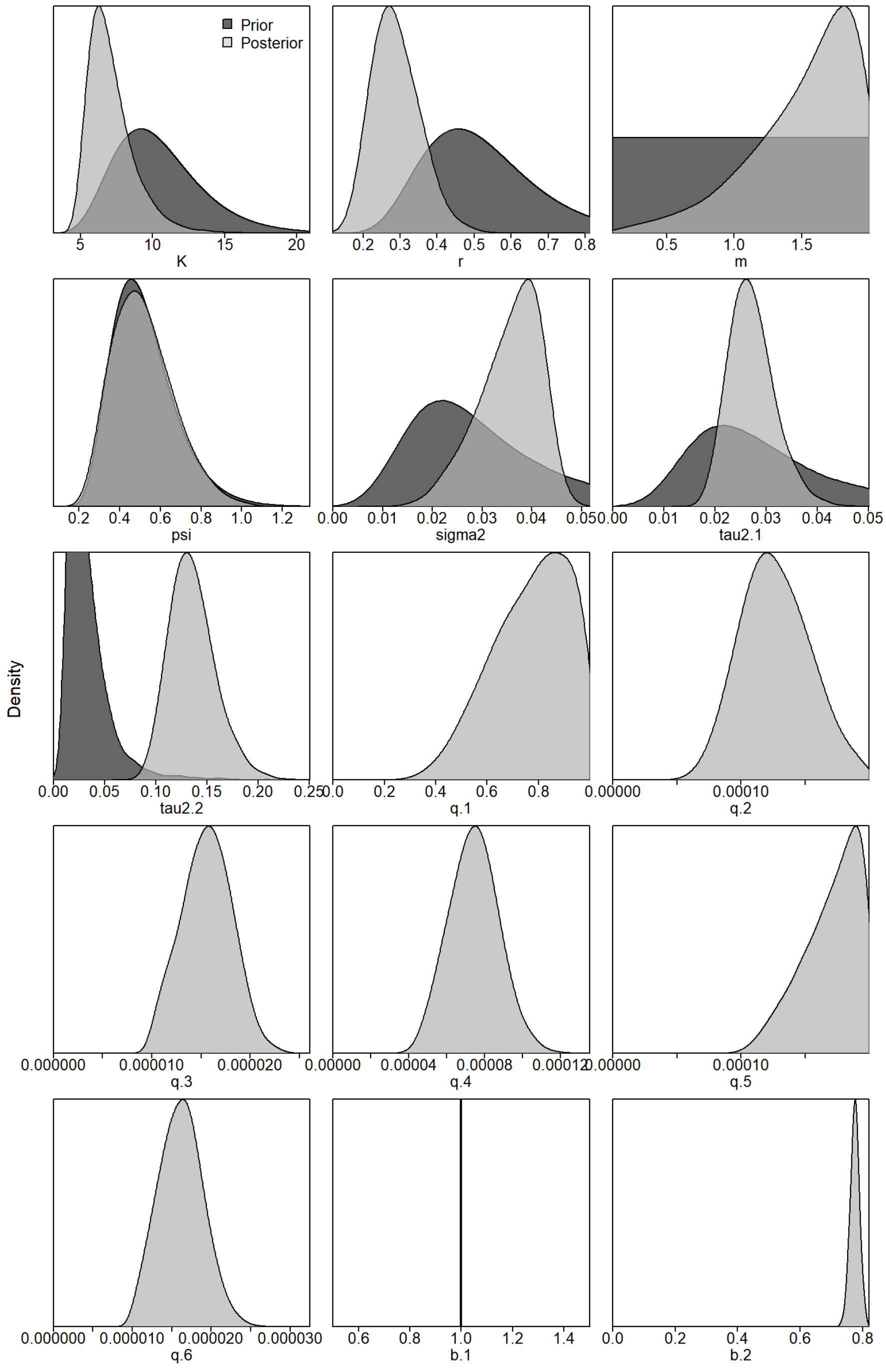


Fig. 3 Prior and posterior distributions parameters to estimate through MCMC runs of base cases of 4-6.

Base case 5

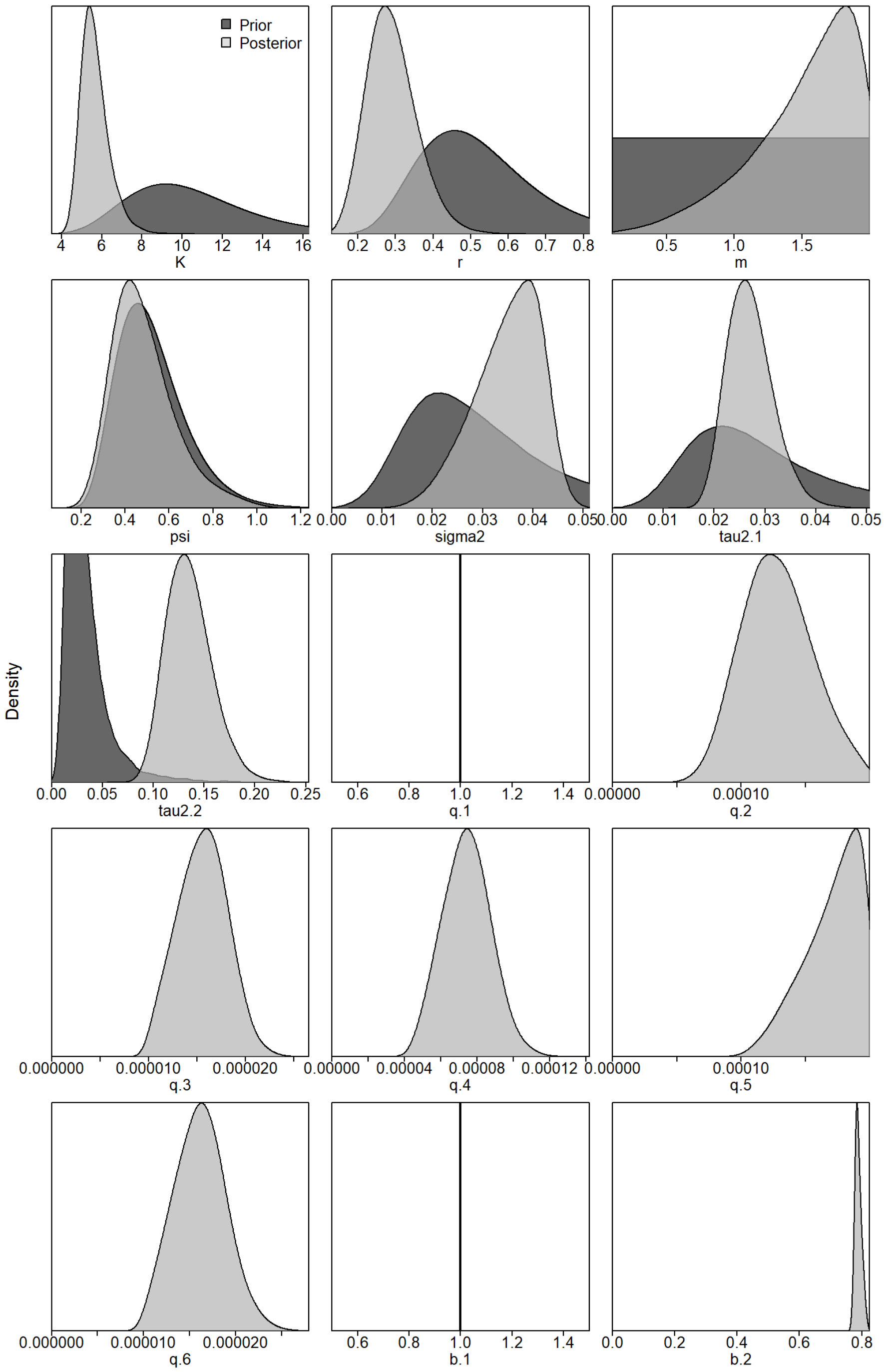


Fig. 3 *Continued.*

Base case 6

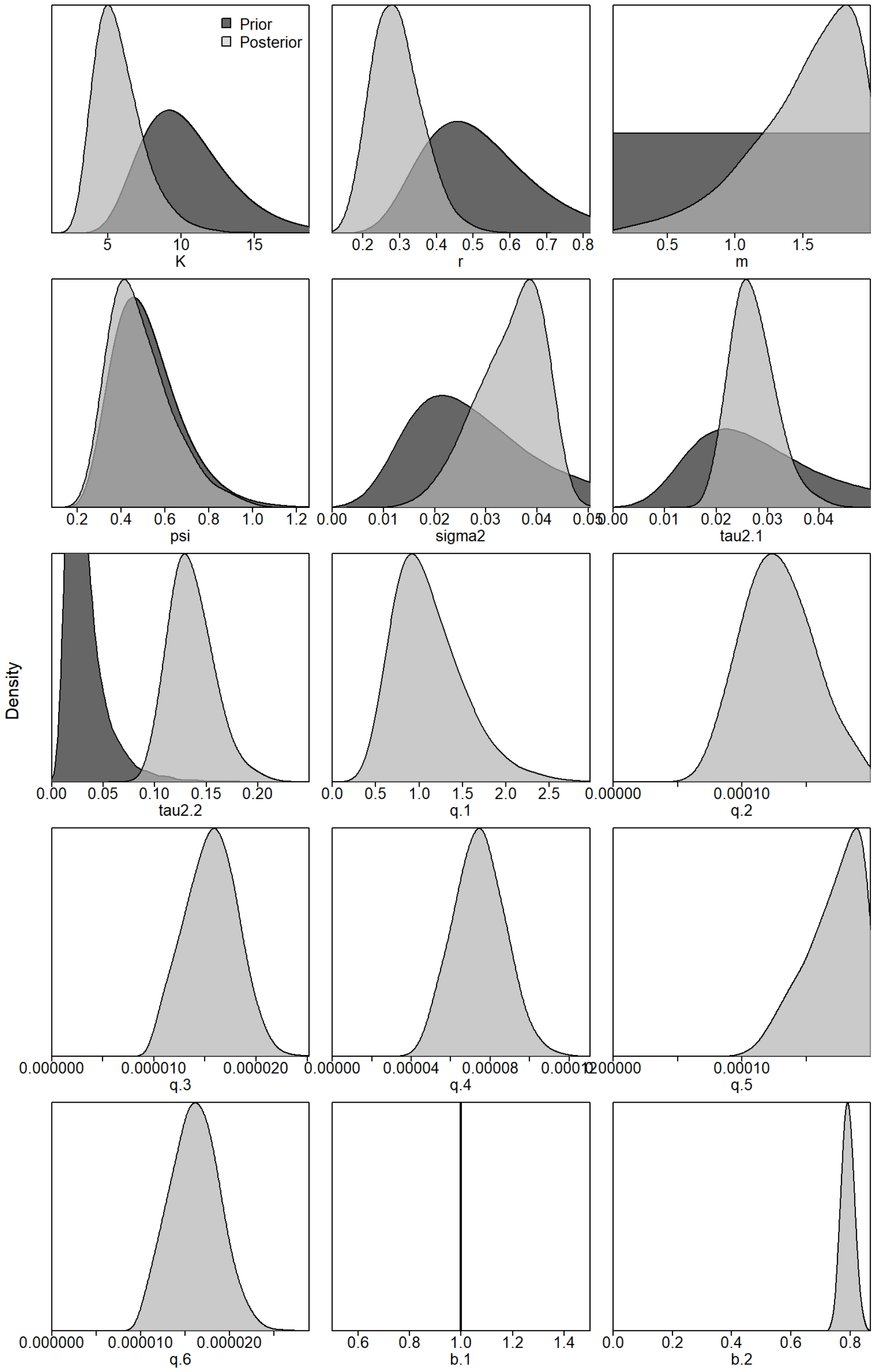


Fig. 3 *Continued.*

Fig. 4 Comparison of median of key parameter estimates of base cases 4-6 obtained in this study (denotes as JABBAv) with those from the stock assessment results provided by China, Japan and Chinese Taipei (Chiba and Kitakado, 2019; China, 2019; Hsu et al., 2019). Because, in JABBA, the shape parameter m is given as $m - 1$ in the surplus production function of BSSPM, one was subtracted from m to compare with others.