Bioeconomic analysis of small yellow croaker (*Larimichthys polyactis*) in the Republic of Korea

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Introduction

Small yellow croaker is one of the most popular commercial species in the Republic of Korea. In particular, the fish species accounts for about 9% of the total fish production amount in Korean coast, and as it accounts for approximately 40% of the total output of the offshore Gill-net fishery. But, the catch amount of small yellow croaker has been declining since 2011. Therefore, it seems that management plans are needed to restore the catch amount. For small yellow croaker, size limit and season limit have existed, but there is no TAC regulation. In this study, we use the Bayesian state-space surplus production model for assessing the resource status of small yellow croaker and deriving B_{MSY}. Besides, the biological and economic effects depending on the TAC scenarios are conducted for the setting of the annual TAC.

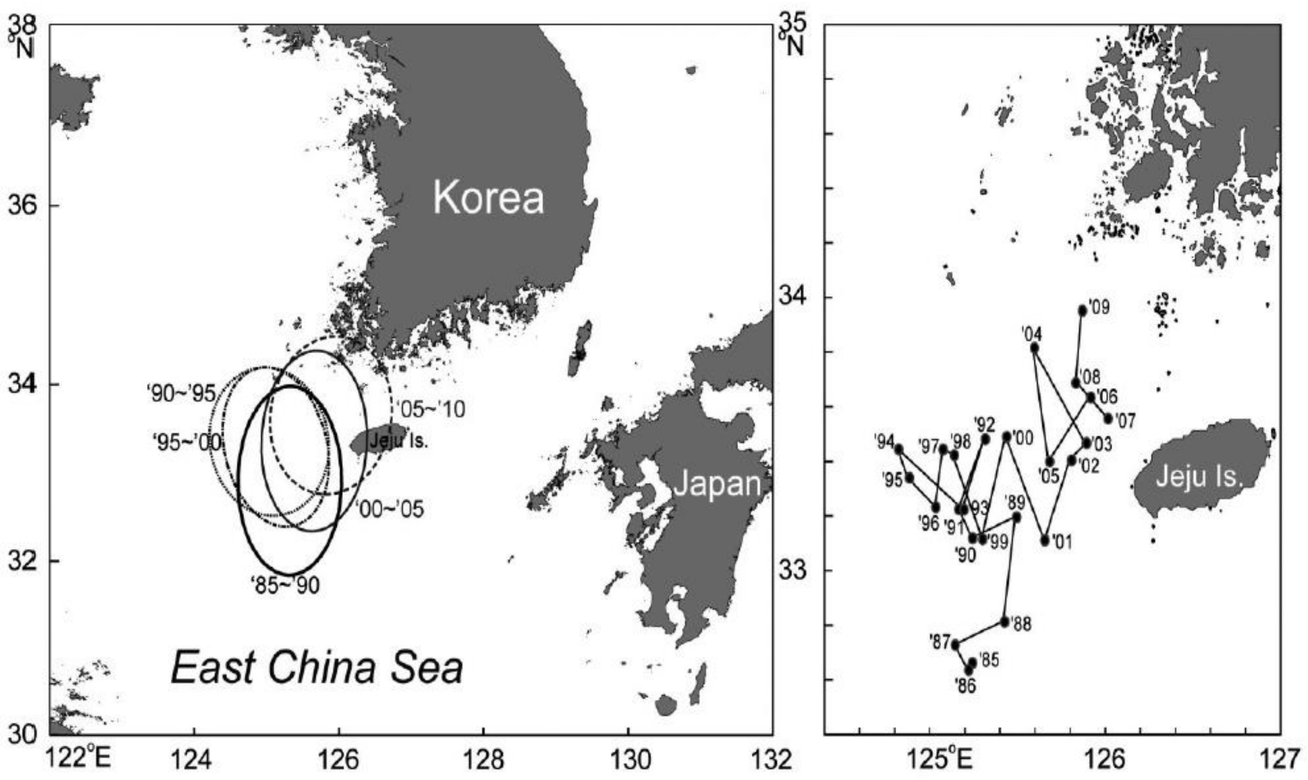
Materials and Methods

1. Materials

- Catch and effort data(1992-2018) of Gill-net, Stow-net, and Pair-net which account for approximately 85% of the total catch of small yellow croaker are used.

2. CPUE standardization

- Generalized linear model (GLM; Gavaris, 1980) is conducted to standardize CPUE.



* Lim et al.(2014)

Fig. 1. Fishery ground ellipses computed using the CPUE distribution of small yellow croaker by the three fisheries by each period range (left panel) and the center of fishing grounds by each fishing year (right panel).

- It was researched that main fishing area of small yellow croaker had been moved.

$$\log(CPUE_{ijk}) = Intercept + Year_i + Gear_j + Move_k + Gear * Move_{jk} + Error_{ijk}$$

$$Error_{ijk} \sim N(0, \sigma^2)$$

- $MOVE_1$: 1992~1999, $MOVE_2$: 2000~2004, $MOVE_3$: 2005~2018

3. Stock assessment

- Bayesian state-space surplus production model is applied to assess the status of small yellow croaker's biomass.

$$P_1|\sigma^2 = e^{u_1}$$

$$P_t|P_{t-1}, K, r, \sigma^2 = \left(P_{t-1} + rP_{t-1}(1 - P_{t-1}) - \frac{C_{t-1}}{K}\right)e^{u_t}, \quad t = 2, \dots, N$$

$$I_t|P_t, q, \tau^2 = qKP_t e^{v_t}, \quad t = 1, \dots, N$$

$$p(K, r, q, \sigma^2, \tau^2, P_1, \dots, P_N, I_1, \dots, I_N) =$$

$$p(K)p(r)p(q)p(\sigma^2)p(\tau^2)p(P_1|\sigma^2) \times \prod_{i=2}^{N} p(P_t|P_{t-1}, K, r, \sigma^2) \prod_{i=1}^{N} p(I_t|P_t, q, \tau^2)$$

$$\left(P_t = \frac{B_t}{K}, B_t = biomass, K = carrying\ capacity, r = intrinsic\ growth,\right.$$

$$\left.C_t = catch, \sigma^2 = process\ error, \tau^2 = observation\ error\ I_t = CPUE\right)$$

$$u_t \sim N(0, \sigma^2) \quad v_t \sim N(0, \tau^2)$$

- Posterior distributions of model parameters are formed by 10,000 samples.
- 250,000 iterations after discarding the initial 50,000 samples (burn-in period) are used to reduce the influence of the initial value.
- Every 25th sample are extracted to avoid autocorrelations of samples.

4. Economic analysis

- The average market prices of the recent 5 years from Gill-net and Stow-net were applied.

$$TR_j = C_j \cdot price_j$$

- The average costs per standardized vessel for catching small yellow croaker are calculated by the business situation survey (average of the recent 5 years).

$$TC_j = cost_j \cdot std.vessels_j$$

Results and Discussion

1. Generalized linear model

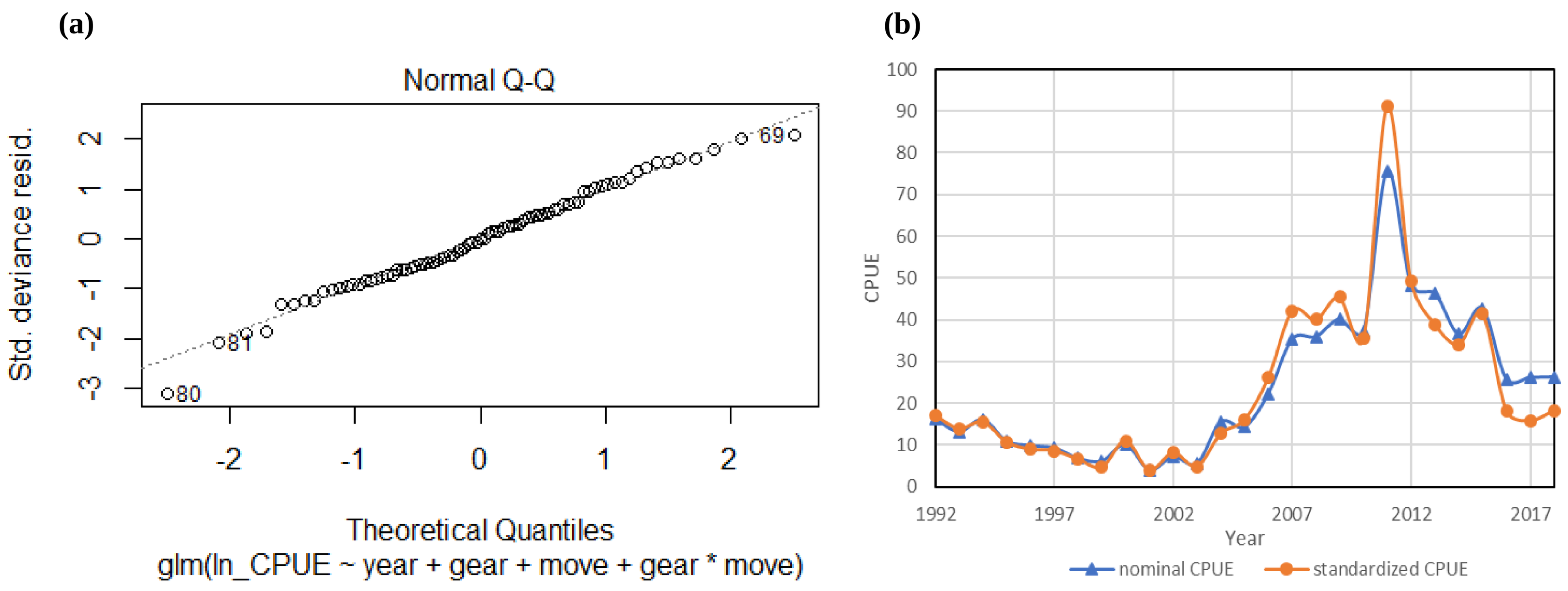


Fig. 2. Quantile-quantile plot of the standard residuals (a) and year trends of standardized CPUE and nominal CPUE (b) for small yellow croaker.

2. Bayesian state-space surplus production model

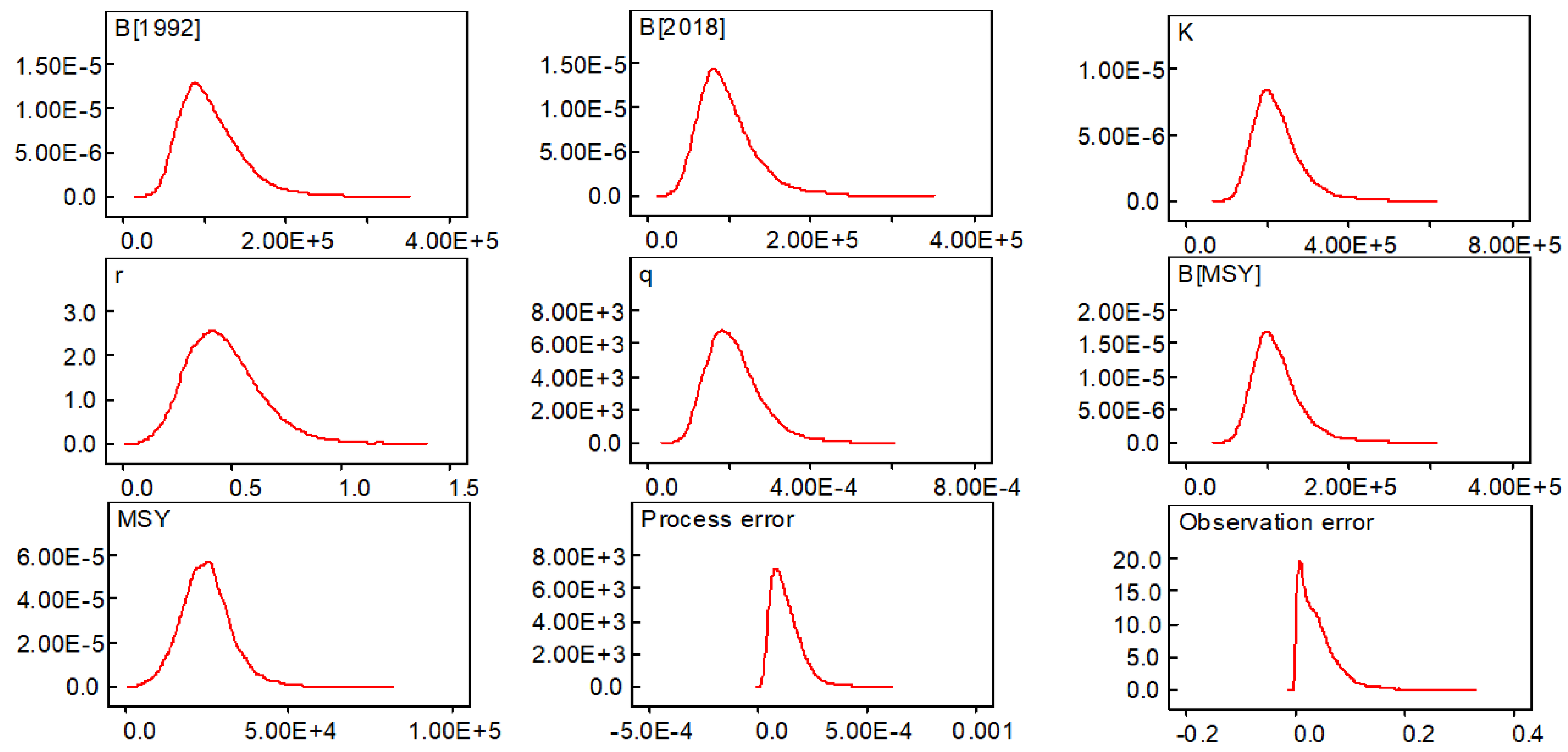


Fig. 3. Posterior densities of model parameters: Biomass(1992), Biomass(2018), Carrying capacity (K), Intrinsic growth rate (r), Catchability coefficient (q), B_{MSY}, MSY, Process error, and Observation error.

Table 1. 2.5th, 97.5th percentiles and median of model parameters from posterior distributions

Parameter	Bayesian state-space model		
	2.5%	Median	97.5%
K(ton)	139,700	214,100	361,000
r	0.20	0.45	0.83
q	1.13E-04	2.03E-04	3.63E-04
B_{1992}(ton)	54,730	101,500	194,200
B_{2018}(ton)	48,030	91,230	176,800
B_{MSY}(ton)	69,830	107,000	180,500
MSY(ton)	11,240	23,920	41,310

3. Biological and economic effects depending on the TAC plans

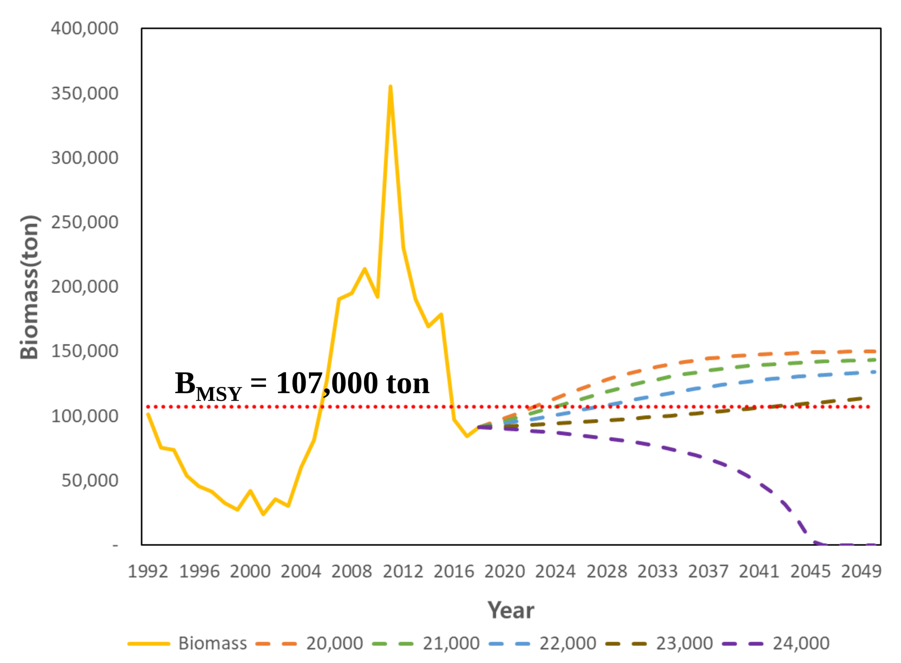


Fig. 4. Forecasting the future biomass of small yellow croaker depending on the TAC plans.

Table 2. Economic analysis of Gill net and Stow net depending on the TAC plans of small yellow croaker

TAC (ton)	Gill net (won/vessel)	Stow net (won/vessel)	Biomass (ton)
23,000	285,358	74,749	116,800
21,000	214,167	51,157	106,644
19,000	142,976	27,566	96,487
17,000	71,786	3,974	86,331
16,663	59,794	0	84,620
15,000	595	(19,618)	76,174
13,000	(70,596)	(52,808)	66,017

Summary and conclusion

- According to the Bayesian state-space surplus production model, the biomass of small yellow croaker is recently decreasing.
- If the amount of TAC is set as 24,000 tons per year, the biomass of small yellow croaker could be decreased. However, if the quantity of TAC is set as 23,000 tons per year, the biomass could be sustainable.
- From the economic analysis, it seems the annual TAC could be set over 16,663 tons and the biomass should be managed over 84,620 tons for ensuring the positive profits of Gill net and Stow net fisheries.

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