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# **Standardized CPUE of Pacific saury (*Cololabis saira*) caught by the Japanese stick-held dip net fishery up to 2018**

Midori HASHIMOTO1, Miyako NAYA2, Shin-Ichiro NAKAYAMA3,

Taiki FUJI1, Satoshi SUYAMA2, and Kazuhiro OSHIMA1

1 *National Research Institute of Far Seas Fisheries, Japan Fisheries Research and Education Agency*

2 *Tohoku National Fisheries Research Institute, Japan Fisheries Research and Education Agency*

3 *National Research Institute of Fisheries Science, Japan Fisheries Research and Education Agency*

# **Summary**

We updated the standardized catch-per-unit-effort (CPUE) of Pacific saury caught by the Japanese stick-held dip net fishery up to 2018 for the stock assessment under the framework of NPFC. CPUE was explained by a generalized linear model (GLM) where explanatory variables such as year, month, fishing area, vessel size, and sea surface temperature were incorporated. Although the model selected by the values of BIC changed by a slight modification to the standardization procedure, year trend of standardized CPUE when using data up to 2018 was relatively similar with that for data up to 2017. The standardized CPUE in 2018 increased to the levels in 2013 and 2015 after the decrease in 2017.

# **Introduction**

The participants of the 4th meeting of Small Scientific Committee on Pacific Saury (SSC PS04) of the North Pacific Fisheries Commission (NPFC) agreed to update and improve CPUE indices for next PS stock assessment. Since catch data of Pacific saury (*Cololabis saira* hereafter PS) by the Japanese stick-held dip net (hereafter SHDN) fishery in 2018 has been collected, we updated the standardized CPUE up to 2018.

# **Method**

Standardization of CPUE for PS was conducted according to the standardization protocol (Annex D in NPFC- 2017-TWG PSSA02-Final Report) agreed in the 2nd meeting of Technical Working Group on Pacific Saury Stock Assessment (see **Appendix I**).

## Commercial fishery data sources

Catch data of Japanese SHDN fishery for PS was obtained by interviews with the chief radio operators or fishing masters of fishing vessels taken at major six landing ports. Procedure of the interviews and types of information in the obtained data were described in the previous working paper (Suyama et al, 2018). In 2018, interview data for 1,945 fishing operations were collected and their total catch in weight accounted for 49.0% of Japanese total landing.

Interview data includes information on date, fishing position (longitude and latitude), catch in weight (mt), number of hauls, *in situ* sea surface temperature (SST) measured using an on-board thermometer, and size of the fishing vessels (GRT). There was no data with zero catch, because fishing operations were conducted only when the fish schools were detected. CPUE was defined as catch in weight per number of hauls in a fishing operation. Incorrect records with CPUE value higher than its vessel size were newly eliminated from data during 1994 to 2017 (a total of 12 records). Fishing ground of Japanese SHDN fishery for PS was divided into five subareas based on oceanographic characteristics (**Fig. 1**). Features of each subarea are described by Suyama et al. (2018). Because fishing ground expanded eastward in 2018, total area of Area V slightly increased.

## Statistical method

i. Model specification

A generalized linear model (GLM) was used to standardize CPUE. Because there was no data with zero catch, logarithm of CPUE was used as response variable. Factors of year, month, fishing area, GRT of fishing vessels and SST were incorporated as explanatory variables. CPUE varied annually and monthly with its peak around October (**Fig. 2**). There observed differences in CPUE among categories for fishing area, vessel size and SST. The correlation matrix for these explanatory variables is shown in **Fig. 3**.

Full model was given as:

ln(*CPUE*) = Intercept + *Year* + *Month* + *Area* + *Grt* + *Sst* + two-way interactions + *ε,*

where *Year*, *Month* and *Area* are categorical variables, composed of 25 years (1994–2018), 5 months (August–December) and 5 subareas (I–V), respectively (**Table 1**). GRT was divided into 10 (*Grt1*) or 5 (*Grt2*) categories at intervals of 20 or 40 mt, respectively. SST was divided into 12 (*Sst1*) or 5 (*Sst2*) categories at intervals of 1 or 3 oC, respectively. Parameter *ε* denotes an error term with *ε* ~ *N*(0, *σ*2).

Two-way interactions for all combinations of explanatory variables were incorporated in the full model. In Japanese SHDN fisheries, no fishing operation in December was occurred in some years and spatial allocation of fishing efforts has varied across years as shown in **Appendix II**. Re-stratification was therefore conducted for explanatory variables other than year used in interaction terms (*Month.int*, *Area.int*, *Grt.int*, and *Sst.int*) in order to avoid no observation in any stratum (**Table 2**). Although this treatment had conducted to derive standardized CPUEs after model selection in the previous report (Hashimoto et al. 2018), here it was carried out before model selection in order to use exactly the same best model for deriving standardized CPUEs.

ii. Model selection and diagnostics

We employed a Bayesian information criterion (BIC) to measure the predictive ability and select the best model. The optimal categorizations regarding GRT and SST were also determined through model selections. For model diagnostics, the percent deviation explained was calculated in addition to Q-Q plot and residual plots.

iii. Calculation of standardized CPUE

Time series of standardized CPUE was estimated using the best GLM. We first generated a data that was composed of all combinations of explanatory variables included as main effects in the best GLM, and then predicted annual values of ln(*CPUE*) for area *a* (ln(*CPUE*)*y,a*). Finally annual standardized CPUE were calculated as the area-weighted mean of (*CPUE*)*y*,*a*:

CPUE*y* = Σ*a*{ exp(ln(*CPUE*)*y,a*) $×$ (*Aa* / Σ*A*) },

where *Aa* indicates an areaof area *a*. Coefficient of variation and 95% confidential intervals were calculated by bootstrap resampled residuals with 1000 replications. The standardized CPUE was compared with nominal CPUE and the previous result when using catch data up to 2017 (Hashimoto et al. 2018).

# **Results and discussion**

## Model selection

Following model was selected as the best GLM:

ln(*CPUE*) = Intercept + *Year* + *Month* + *Grt1* + *Sst2* + *Year:Month.int* + *Year:Area.int* + *Year:Grt.int* + *Month.int:Area.int* + *Month.int:Grt.int* +*Area.int:Grt.int* + *ε.*

Main effect of area dropped and interaction terms of *Year:Grt.int* and *Month.int:Grt.int* were newly selected, comparing with the previous best GLM when using data up to 2017, due to the change of timing for re-stratification of explanatory variables in interaction terms. BIC value and percent deviance explained were 87,123 and 50.5%, respectively. Analysis of deviance (Type III tests) indicated that all selected explanatory variables were significant at a significant level of <0.05 (**Table 3**). Q-Q plot and residuals distribution indicated residuals were distributed normally around 0, even though long tails were observed at the both ends (**Fig. 4**). Furthermore, there found no tendencies in residuals across years. It is concluded that CPUE were appropriately modeled using the selected explanatory variables.

## Year trend of standardized CPUE

Annual standardized CPUE derived from the best GLM showed a similar trend with nominal CPUE and the previous result up to 2017 (**Fig. 5**). Slight differences from the previous result in 2006 and 2007 were derived by interaction terms *Year:Month.int* and *Year:Grt.int* in the best model, respectively. The CPUE in the terminal year increased to the levels in 2013 and 2015 after the decrease in 2017.

# **References**

Hashimoto M, Suyama S, Nakayama S, Fuji T, Naya M and Oshima K (2018) Update of standardized CPUE of Pacific saury (*Cololabis saira*) caught by the Japanese stick-held dip net fishery during 1994 to 2017. NPFC-2018-TWG PSSA03-WP10.

Suyama S, Kidokoro H, Naya M, Hashimoto M and Vijai D (2018) Standardization of CPUE data of Pacific saury (*Cololabis saira*) caught by the Japanese stick-held dip net fishery during 1994 to 2017. NPFC-2018-SSC PS03-WP05.

Technical Working Group on Pacific Saury Stock Assessment (2017) 2nd Meeting Report. NPFC- 2017-TWG PSSA02-Final Report. 24 pp. (Available at www.npfc.int)

# **Tables and Figures**

**Table 1** Summary of explanatory variables in GLM.

|  |  |  |  |
| --- | --- | --- | --- |
| Variables | Number of categories  | Detail | Note |
| Year | *Year* | 25 | 1994–2018 | 　 |
| Month | *Month* | 5 | August–December | 　 |
| Fishing area | *Area* | 5 | I–V | *see* Fig. 1 |
| Vessel size | *Grt1* | 10 | *Grt*＜20, 20≦*Grt*＜40, ..., 180≦*Grt*＜200 tons | at intervals of 20 tons |
| *Grt2* | 5 | *Grt*＜40, 40≦*Grt*＜80, ..., 160≦*Grt*＜200 tons | at intervals of 40 tons |
| Sea surface temperature | *Sst1* | 12 | *Sst*＜10, 10≦*Sst*＜11, ..., 20 oC≦*Sst* | at intervals of 1oC |
| *Sst2* | 5 | *Sst*＜10, 10≦*Sst*＜13, ..., 19 oC≦*Sst* | at intervals of 3oC |

**Table 2** Summary on explanatory variables aggregated for interaction terms.

|  |  |  |
| --- | --- | --- |
| Variables | Number of Categories | Detail |
| *Month.int* | 4 | Aug, Sep, Oct, Nov + Dec |
| *Area.int* | 3 | I+V, II+IV, III |
| *Grt.int* | 3 | *Grt.int*＜80, 80≦*Grt.int*＜160, 160≦*Grt.int*＜200 tons |
| *Sst.int* | 4 | *Sst.int*＜13, 13≦*Sst.int*＜16, 16≦*Sst.int*＜19, 19 oC≦*Sst.int* |

**Table 3** Analysis of deviance table (Type III tests) for the best GLM with smallest BIC.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 　 | SS | Df | F | Pr(>F) | Signif. codes |
| Year | 453.8 | 24 | 39.35 | < 2.2e-16 | \*\*\* |
| Month | 117.3 | 1 | 244.06 | < 2.2e-16 | \*\*\* |
| Grt1 | 265.9 | 7 | 79.03 | < 2.2e-16 | \*\*\* |
| Sst2 | 51.1 | 4 | 26.60 | < 2.2e-16 | \*\*\* |
| Year:Month.int | 1067.4 | 72 | 30.85 | < 2.2e-16 | \*\*\* |
| Year:Area.int | 296.3 | 48 | 12.85 | < 2.2e-16 | \*\*\* |
| Year:Grt.int | 258.6 | 48 | 11.21 | < 2.2e-16 | \*\*\* |
| Month.int:Area.int | 45.4 | 6 | 15.734 | < 2.2e-16 | \*\*\* |
| Month.int:Grt.int | 33.5 | 6 | 11.624 | 4.74E-13 | \*\*\* |
| Area.int:Grt.int | 39.4 | 6 | 13.651 | 1.50E-15 | \*\*\* |
| Residuals  | 19277.7 | 40113 |  |  |  |
| Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1 |

**Table 4** Nominal and standardized CPUE of Japanese stick-held dip net fishery for Pacific saury from 1994 to 2018.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Year | Nominal CPUE(metric ton / hauls) | Standardized CPUE | CV(%) | 95% CI |
| Lower | Upper |
| 1994 | 5.38 | 2.93 | 3.53 | 2.74 | 3.14 |
| 1995 | 4.41 | 2.16 | 6.53 | 1.90 | 2.44 |
| 1996 | 2.40 | 1.62 | 4.69 | 1.48 | 1.77 |
| 1997 | 4.77 | 3.58 | 12.93 | 2.79 | 4.63 |
| 1998 | 1.44 | 1.02 | 3.86 | 0.94 | 1.09 |
| 1999 | 1.45 | 0.75 | 3.97 | 0.70 | 0.81 |
| 2000 | 2.18 | 1.37 | 4.38 | 1.26 | 1.49 |
| 2001 | 3.18 | 2.06 | 5.64 | 1.84 | 2.32 |
| 2002 | 1.93 | 1.15 | 5.66 | 1.02 | 1.29 |
| 2003 | 3.21 | 2.17 | 4.27 | 2.01 | 2.37 |
| 2004 | 3.65 | 2.51 | 3.95 | 2.33 | 2.71 |
| 2005 | 6.63 | 4.38 | 4.05 | 4.03 | 4.72 |
| 2006 | 6.03 | 3.93 | 4.30 | 3.61 | 4.28 |
| 2007 | 7.81 | 4.05 | 4.31 | 3.73 | 4.40 |
| 2008 | 7.81 | 4.93 | 4.06 | 4.56 | 5.31 |
| 2009 | 4.60 | 3.58 | 4.43 | 3.29 | 3.92 |
| 2010 | 2.73 | 1.49 | 3.66 | 1.37 | 1.59 |
| 2011 | 4.45 | 2.36 | 4.01 | 2.19 | 2.55 |
| 2012 | 3.65 | 2.31 | 4.31 | 2.12 | 2.52 |
| 2013 | 3.04 | 1.43 | 3.88 | 1.33 | 1.55 |
| 2014 | 5.42 | 2.49 | 3.64 | 2.32 | 2.67 |
| 2015 | 2.65 | 1.34 | 4.43 | 1.23 | 1.46 |
| 2016 | 2.82 | 1.50 | 5.94 | 1.33 | 1.68 |
| 2017 | 1.40 | 1.08 | 4.23 | 1.00 | 1.17 |
| 2018 | 2.96 | 1.40 | 3.91 | 1.30 | 1.52 |

**Fig. 1** Area definition applied for CPUE standardization in this study.



**Fig. 2** Relationship between CPUE and each factor (Year, Month, Area, vessel size and SST).

**Fig. 3** Correlation matrix of used explanatory variables.



**Fig. 4** Q-Q plot, histogram of residuals and residual plots across years for the best GLM.

**Fig. 5** Scaled nominal CPUE and annual scaled standardized CPUE when using catch data up to 2017 and 2018. Gray zone indicates 95% confidence intervals of standardized CPUE up to 2018.

# **Appendix I** Checklist for the CPUE standardization protocol.

|  |  |  |
| --- | --- | --- |
| (1) | Conduct a thorough literature review to identify key factors (i.e., spatial, temporal, environmental, and fisheries variables) that may influence CPUE values; | Yes(*see* previous working paper, Suyama et al. (2018)) |
| (2) | Determine temporal and spatial scales for data grouping for CPUE standardization; | Yes (*see* Table 1) |
| (3) | Plot spatio-temporal distributions of fishing efforts and catch to evaluate spatio-temporal patterns of fishing effort and catch;  | Yes (*see* Appendix II) |
| (4) | Calculate correlation matrix to evaluate correlations between each pair of those variables; | Yes (*see* Fig. 3) |
| (5) | Identify potential explanatory variables based on (1)-(4) to develop full model for the CPUE standardization; | Yes (*see* Table 1) |
| (6) | Make statistical assumptions on the full models and fit the data to the assumed statistical models (i.e., GLM, GAM, Delta-lognormal GLM, Neural Networks, Regression Trees, Habitat based models, and Statistical habitat based models); | Yes (GLM) |
| (7) | Select and evaluate the models using methods such as likelihood ratio, AIC, BIC or cross validation; | Yes (BIC) |
| (8) | Evaluate if distributional assumptions are satisfied and if there is a consistent spatial/temporal distribution of residuals in CPUE standardization modeling;  | Yes (*see* Fig. 4) |
| (9) | Determine the optimal model to estimate yearly standardized CPUE and their associated uncertainty. | Yes (*see* Table 4) |
| (10) | Plot nominal and standardized CPUEs over time. | Yes (*see* Fig. 5) |

# **Appendix II** Annual changes in monthly fishing ground of Japanese stick-held dip net fishery for Pacific saury from 1994 to 2018.

