NPFC-2019-SSC PS05-WP05

#

# **Standardized CPUE of Pacific saury (*Cololabis saira*) for the Korean stick-held dip net fishery in Northwest Pacific during 2001 to 2018**

Seok-Gwan CHOI, Kyum Joon PARK, and Jung-Hyun LIM

*National Institute of Fisheries Science, Republic of Korea*

# **Summary**

We standardized catch-per-unit-effort (CPUE) of Korean stick-held dip net fishery for Pacific saury during 2001-2018. CPUE was modeled with generalized linear model (GLM) where factors such as year, month, fishing area, vessel size and sea surface temperature were incorporated as explanatory variables. The nominal CPUE and the standardized CPUE indicated a similar tendency and showed the second lowest at 2017, respectively.

# **Introduction**

Pacific saury (Cololabis saira) is widely distributed in the subarctic and subtropical areas of the North Pacific Ocean from inshore waters of Japan and Kuril Islands eastward to Gulf of Alaska and southward to Maxico (Parin 1960). The species migrates seasonally from the subtropical Kuroshio Current in winter to the Subarctic Oyashio Current in summer, for feeding on zooplankton (Shimizu et al., 2009, Taki, 2011). The preferred water temperature for Pacific saury is 13-18 ℃and the vertical distribution is from to close to surface down to around 230m (Eschmeyer et al. 1983, Syah et al. 2017). The highest cpue (catch per unit effort) of Pacific saury was found when the SST ranged from 14 to 16 ℃(Tseng et al. 2013).

After the first exploratory stick-held dip net fishing from Korea had been conducted in the Northwest Pacific Ocean in the 1960s, three commercial fishing vessels commenced saury fishing in the area in 1985 (Jo 2003). Since then, the Korean stick-held dip net fishery has grown rapidly year-by-year, and the largest catch, 50 thousand tons, was made in 1997. Korean’s pacific saury catch information has been managed by two organizations: Korea Overseas Fisheries Association (KOFA) and National Institute of Fisheries Science (NIFS). KOFA collected total catches and NIFS collects logbook data from fishing vessels as subsamples. The logbook contains daily catch and additional information such as light power (kw), amount of catch by size (M, L and XL). However, since September 2015 an electronic reporting system (ERS) was replaced the traditional logbook and has been collecting the catch data in near real-time. Accordingly, some of data categories have been changed after the introduction of the ERS (e.g. the catches by fish size were unified into the total catch, light power information was excluded).

# **Standardization of CPUE**

 The logbook information from 2001 to 2018 was used in the CPUE standardization process. We standardized the CPUE of Pacific saury derived from the Korean fishery according to the standardization protocol (NPFC - 2018 - TWG PSSA03 - Report Annex E) but GAM analysis has not tried.

## Commercial fishery data sources

Data used in this study were obtained from log books which reported to KOFA and NIFS from 2001 to early 2015 and electronic log books reported by ESR from late 2015 to 2018 including information on date, fishing location (longitude and latitude), catch in weight (mt), sea surface temperature (SST) measured using an on-board thermometer and GRT(gross tonnage) of the fishing vessels.

## Area definition

We divided the fishing ground of the Korean saury fishery into seven sea areas based on the combination of Chinese Taipei and Japanese, suggested at TWG-PSSA03 and categorized it. The other category what we used was gathered into three areas by concerning historical catch area (Fig. 1).

## Factors considered

The factors of year, month, fishing area, GRT of fishing vessels and SST what we used in previous study on CPUE standardization (NPFC-2018-SSC-PS03-WP07), were incorporated as explanatory variables in the CPUE standardization of this study (Table 1). The correlation matrix for the explanatory variables is shown in Fig. 2.

## Statistical methods for CPUE standardization

Generalized linear model (GLM) was used to standardize the CPUE. The CPUE used in this study was defined as catch per vessel per day.

The full model used in GLM analysis is given as:

ln(CPUE) = Intercept + Year + Month + Area1/Area2 + Sst1/Sst2 + Grt1/Grt2/Grt3 + interactions + ε,

where Year, Month and Area are categorical variables, composed of categories of 18 years (2001–2018), 7 months (May – December) and 7 areas (Area1), respectively (Table 1). The other area category was made of 7 areas gather to 3 areas (Area2) by EEZ, near EEZ and far EEZ. GRT, categorical variable of, has 3, 5 and 8 categories, which are divided at intervals of 300 ton (Grt1), 100 ton (Grt2) and 50 ton (Grt3), respectively. There are 4 and 12 categories of SST, which are divided at intervals of 1oC (Sst1) and 4oC (Sst2), respectively. The optimal categorizations regarding Area, GRT and SST were determined through model selections.

ii. Model selection and diagnosis

We applied Akaike Information Criteria (AIC) and Bayesian information criterion (BIC) to measure the predictive ability and determined the selected model with the minimum AIC and BIC through the GLM analyses. For model diagnosis, the percent deviation explained was calculated in addition to Q-Q plot and histogram of residuals.

iii. Calculation of standardized CPUE

Time series of standardized CPUE were estimated using the selected models from the GLM analyses. The formula is given as;

$$\overbar{CPUE}\_{i}=\frac{1}{n\_{i}}×\sum\_{k=1}^{n\_{i}}CPUE\_{k}^{fitted}$$

Where, $\overbar{CPUE}\_{i}$ is CPUE indices in ith year, $n\_{i}$ is the observation number in ith year, $CPUE\_{k}^{fitted}$ is the kth fitted CPUE data in ith year.

# **Results and Discussion**

In the selected model from the GLM analysis, where deviance explained was 81.71%, vessel size and sea surface temperature were divided at intervals of 300 ton (Grt1) and those of 4oC (Sst1), respectively (Table 2). Analysis of deviance indicated that all explanatory variables were significant at the significant level of 0.05 in the selected model except Grt1 (Table 3). The Q-Q plot and the histogram of residuals for evaluating the assumption on error distribution are shown in Fig. 3. The CPUE were appropriately modeled using the explanatory variables which were selected through the GLM analysis and the changes of the CPUE by categorical variables were shown in Fig. 4.

We estimated annual standardized CPUE with 95% confidence intervals using he selected models from the GLM analyses (**Table 4**). The standardized CPUE and nominal CPUE indicated a similar tendency. Both of CPUEs were the second lowest at 2017 since 2001, respectively (Fig. 5).

Generalized additive model (GAM) will be used to standardize the nominal CPUE and compare to GLM derived standardized CPUE in further study.

# **References**

NPFC. (2018). NPFC-2018-SSC-PS03-WP07

NPFC (2018). NPFC - 2018 - TWG PSSA03 - Report Annex E

Parin, N.V. 1960. The range of the saury (*Cololabis saira* Brev.-Scombresocidae, Pices) and effects fo oceanographic features on its distribution. Proc. Acad. Sci. USSR 130(3):649-652.

Shimizu Y., Takahashi K., Ito S.I. Kakehi S., Tatebe H., Yasuda I., Kusaka A., et al. Transport of subarctic large copepods from the Oyashio area to the mixed water region by the coastal Oyashio intrusion, Fisheries Oceanography , 2009, vol. 18 (pg. 312-327)

Taki K. Distribution and population structure of *Thysanoessa inspinata* and its dominance among euphausiids off northeastern Japan, Journal of Plankton Research , 2011, vol. 33 (pg. 891-906)

Tseng, C-T., Su, N-J., Sun, C-L., Punt, A. E., Yeh, S-Z., Liu, D-C., and Su, W-C. 2013. Spatial and temporal variability of the Pacific saury (*Cololabis saira*) distribution in the northwestern Pacific Ocean. – ICES Journal of Marine Science, 70: 991–999.

Eschmeyer W. N., Herald E.S and Hamman H. 1983. A field guide to Pacific coast fishes of North America. Houghton Mifflin Company. 336pp.

Syah, A. F. Saitoh, S. I. Alabia, I.D., and Hirawaka, T. 2016. Predicting potential fishing zones for Pacific saury (*Cololabis saira*) with maximum entropy models and remotely sensed data. Fishery Bulletin, 114(3) 330-343.

Jo, H. S. 2003. Catch specification of Pacific Saury, *Cololabis saira*, caught by stick-held dip net fishery (Doctoral dissertation). Pukyong National University, Busan, Korea.

Akaike, H. 1974. A new look at the statistical model identification, IEEE Trans. Automat. Contr. 19(6):716-723.

Table 1 Summary of used explanatory variables in GLM analyses

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variables | Cases | Categorical | Detail | Note |
| Year | *Year* | 18 categories | 18 years from 2001 to 2018  |  |
| Month | *Month* | 7 categories | 7 months from June to December |  |
| AreaSea surface temperature | *Area1**Area2**Sst1**Sst2* | 3 categories7 categories4 categories12 categories | 1(EEZ), 2(Near EEZ), 3(Far EEZ)7 areas divided by previous meetingSst<10℃;10℃≦Sst＜14℃，14℃≦Sst≤18℃, 18℃<SstSst<10℃;10℃≦Sst＜11℃，11℃≦Sst＜12℃，…, 19℃≦Sst<20℃; 20℃≤Sst | at intervals of 4℃at intervals of 1℃ |
| Vessel tonnage | *Grt1**Grt2**Grt3* | 3 categories5 categories8 categories | Grt<300tons; 300≦Grt＜600; 600≤GrtGrt<300tons; 300≦Grt＜400;... 500≦Grt＜600; 600≤GrtGrt<300tons; 300≦Grt＜350;... 550≦Grt＜600; 600≤Grt | at intervals of 300 tonsat intervals of 100 tonsat intervals of 50 tons |

Table 2 Selected GLM models based on AIC and BIC values

|  |  |  |  |
| --- | --- | --- | --- |
| Best model in GLM analysis | AIC | BIC | % deviance explained |
| Ln(CPUE)~*Intercept*+*Year*+*Month*+*Area2t+Sst1+Grt1+Month:Area2+Month:Sst1+Year:Area2+Year:Grt1+ε* | 41468.67 | 42631.95 | 81.71 |

Table 3 Analysis of deviance for the selected model in GLM

Signif. codes: ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Df | Deviance | F. | Pr(>F) | Signif. codes |
| Year | 17 | 1393.59 | 143.9744 | < 2.2e-16 | \*\*\* |
| Month | 6 | 315.77 | 92.4325 | < 2.2e-16 | \*\*\* |
| Area2 | 6 | 136.89 | 40.0716 | < 2.2e-16 | \*\*\* |
| Grt1 | 2 | 2.12 | 1.8652 | 0.154896 |  |
| Sst1 | 3 | 11.32 | 6.63E+00 | 0.00018 | \*\*\* |
| mon:area2 | 18 | 94.34 | 9.2048 | < 2.2e-16 | \*\*\* |
| mon:sst1 | 16 | 60.19 | 6.61E+00 | 3.28E-15 | \*\*\* |
| year:area2 | 62 | 358.27 | 10.149 | < 2.2e-16 | \*\*\* |
| year:grt1 | 17 | 25.95 | 2.6807 | 0.000203 | \*\*\* |

Table 4. Nominal and standardized CPUE of Korean stick-held dip net fishery in Pacific from 2001 to 2018

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Year | Nominal CPUE | SD of Nominal CPUE | Standardized CPUE | SD of Standardized CPUE | 95% CI |
| 2001 | 9.44 | 7.77 | 7.15 | 1.06 | 7.10 | 7.21 |
| 2002 | 11.46 | 9.42 | 8.58 | 1.59 | 8.50 | 8.66 |
| 2003 | 17.75 | 14.37 | 12.78 | 3.71 | 12.59 | 12.96 |
| 2004 | 12.21 | 10.03 | 9.04 | 2.35 | 8.91 | 9.17 |
| 2005 | 18.62 | 14.21 | 14.16 | 4.94 | 13.87 | 14.44 |
| 2006 | 16.76 | 12.63 | 13.47 | 6.36 | 12.78 | 14.16 |
| 2007 | 15.73 | 12.05 | 12.39 | 5.85 | 11.87 | 12.90 |
| 2008 | 20.97 | 14.27 | 16.65 | 5.83 | 16.18 | 17.12 |
| 2009 | 11.61 | 10.49 | 8.69 | 3.19 | 8.49 | 8.89 |
| 2010 | 16.58 | 12.85 | 11.94 | 3.05 | 11.62 | 12.26 |
| 2011 | 13.08 | 11.93 | 8.97 | 1.53 | 8.78 | 9.16 |
| 2012 | 11.28 | 10.89 | 8.12 | 1.82 | 7.94 | 8.29 |
| 2013 | 11.69 | 9.26 | 8.84 | 1.57 | 8.76 | 8.93 |
| 2014 | 19.22 | 14.25 | 14.22 | 2.92 | 14.05 | 14.39 |
| 2015 | 7.90 | 6.42 | 6.35 | 1.55 | 6.26 | 6.44 |
| 2016 | 12.20 | 10.00 | 9.20 | 1.46 | 9.12 | 9.28 |
| 2017 | 7.49 | 6.52 | 6.03 | 1.79 | 5.93 | 6.12 |
| 2018 | 9.08 | 5.80 | 7.67 | 0.85 | 7.63 | 7.71 |



Fig. 1. Distribution of fishing effort (fishing day) for Korean stick-held dip net fishing vessels from 2001 to 2018.



Fig. 2. Correlation matrix of used explanatory variables.

 

Fig. 3. Q-Q plot and histogram of residuals for the selected model in GLM analysis.

 

  

Fig. 4. Relationship between standardized CPUE and each factor (Year, Month, Area2, Grt1 and Sst1).

Fig. 5. Annual nominal CPUE and GLM estimated standardized CPUE of Korean stick-held dip net fishing vessels in Northwest Pacific.