Standardization of CPUE of Japanese Anchovy Caught by Small to Medium-Scale Purse Seine Fisheries in Nagasaki Prefecture

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Summary

Data	Data from small to medium-scale purse seine fisheries operating along the coast of Nagasaki Prefecture (catch of Japanese anchovy per vessel per day), FRA-ROMS II reanalysis data (water temperature at 50 m depth, downloaded on July 15, 2022)
Units	Catch per vessel per day (kg/day・vessel)
Period of Available Data	2001 to 2021
Period Used for Standardization	2001 to 2021
Data Extraction for Standardization	In order to use standardized results as abundance indices of fish age 0 for VPA with tuning, we extracted non-zero catch data from April to December, and excluded data from January to March because the catch of fish age 1 and older is relatively higher in these months.
Statistical Software Packages	R (4.2.1). The functions used are glm, dredge, predict, expand.grid, and vif.
Statistical Model	Generalized linear model (lognormal distribution)
Explanatory Variables Applied in the Full Model	Year (category, fixed), month (category, fixed), area (category, fixed), water temperature at 50 m depth (category, fixed)
Selection Method for Final Model	Best subset regression based on BIC
Explanatory Variables Selected in the Final Model	Year (category, fixed), month (category, fixed), area (category, fixed), water temperature at 50 m depth (category, fixed)
Extraction Method for Yearly Trends	Yearly average of projected values for all combinations of each variable
Calculation Method for Estimated Errors and	Standardized CPUE (catch per unit effort) was calculated based on bootstrap sampled data and best model, and the calculations were

Confidence Intervals	repeated 1,000 times.
Standardization Results	The standardized CPUE, which was scaled by average, fluctuated following generally similar trends as the nominal CPUE, ranging between 0.5 and 1.1 from 2001 to 2013, and reaching a record high of 1.9 in 2014. After that, it fluctuated between 1.0 and 1.4 from 2015 to 2020, and it was 0.9 in 2021.
References	Ohshimo, S. and Kuroda, H. (2021) Analysis of CPUE of Japanese Anchovy Caught by Small to Medium-Scale Purse Seine Fisheries in Nagasaki Prefecture. FRA-SA2021-SC02-211

Introduction

The Tsushima current stock of Japanese anchovy is the schools distributed from the East China Sea to the Sea of Japan, and the main fishing grounds for Japanese fishing vessels are the coastal regions along the western Sea of Japan and the northwestern coast of Kyushu. Nagasaki Prefecture accounts for around half of the catch of this stock (Fig. 1). This species is usually sold as a dried and processed product rather than as raw fish, and it is mainly caught by small to medium-scale purse seine fisheries. The purpose of this report is to standardize the CPUE of Japanese anchovy caught by small to medium-scale purse seine fisheries in Nagasaki Prefecture.

Methods

We used data from small to medium-scale purse seine fisheries operating along the coast of Nagasaki Prefecture (Fig. 2). Catch per vessel was recorded by day and by area (Fig. 2). However, the fishing vessels did not track how many nets they used each day, so the CPUE units are catch (kg) per vessel per day. In order to use standardized results as abundance indices of fish age 0, which comprise the majority of catch in weight, we standardized data from April to December, and excluded data from January to March because the catch of fish age 1 and older is relatively higher in these months.

Because operations of small to medium-scale purse seine fisheries are focused on Japanese anchovy, targeting operations were not considered, and only data from non-zero catches was used for analysis (zero-catch data was excluded) (for reference, results which consider zero-catch data are presented in the Appendix). The percentage of non-zero catch data by year ranged from 29 to 43%. We constructed a model based on standardization documents from the previous fiscal year, which sets the response variable as the natural log converted CPUE, and sets the explanatory variables as year (Year), month (Month), ocean area (Area), and the water temperature at 50 m depth (Temp50m), and which assumes that model error follows a normal distribution. In the previous fiscal year, standardization used water temperature at 10 m depth, but in this year’s analysis we identified problems with multicollinearity so this was changed to water temperature at 50 m depth, categorized in increments of 1°C.

$$\log(CPUE) \sim f(Year)+f(Month)+ f(area)+f(Temp50m)$$

The best model was selected through a best subset approach based on the Bayesian Information Criterion (BIC). Dummy data was created for each variable in the selected best model, and projected values for CPUE were found using all combinations of each variable in evenly spaced increments. The average of projected CPUE values for each year was used as the standardized CPUE. The 95% confidence interval was found using the bootstrap method (1,000 simulations).

Results and Discussion

Catch and effort (total number of vessels) from April to December is shown in Fig. 3. Catch remained around 21,000 to 27,000 tons from 2001 to 2008, and then declined sharply to 16,000 tons in 2009. After that, it remained around 16,000 to 23,000 tons up to 2014, and reached a record high of 27,000 tons in 2015. Since 2016, it has been in an decreasing trend, and was 13,000 tons in 2021. Effort has been in a decreasing trend while fluctuating in cycles. The reason for the sharp decline in catch from 2008 to 2009 is not clear, but the high price of crude oil in 2008 is thought to have led to avoidance of fishing, because large amounts of fuel oil are required for drying processing and vessel operations. Accordingly, there is a possibility that catch strategies up to 2008 were different than those used in 2009 and onwards.

The relationship between the explanatory variables and logarithmized catch used in this report is shown in Fig. 4. Catch tended to be lower in September and onwards compared to earlier months. According to interviews with fishermen, it is common to avoid fishing of Japanese anchovy because they make decisions about operations in consideration of the spawning season and the fattiness of the fish, and in autumn and onwards, the fattiness of the fish makes them unsuitable for drying. Catch in the Tsushima area was relatively lower than in other areas.

A summary of the generalized linear model used in this summary is shown in Appendix Fig. 1 and Appendix Table 1. The full model was selected based on BIC results.

We confirmed that there were no problems with multicollinearity when using GVIF as an index in the selected model.

Projected values for CPUE were found using all combinations of each year, each month, each area, and each water temperature at 50 m depth, and the average for each year was used as the standardized CPUE. Yearly changes in results for standardized CPUE and the 95% confidence interval are shown in Fig. 5. The standardized CPUE, which was scaled by average, fluctuated following generally similar trends as the nominal CPUE, ranging between 0.5 and 1.1 from 2001 to 2013, and reaching a record high of 1.9 in 2014. After that, it fluctuated between 1.0 and 1.4 from 2015 to 2020, and then it decreased to 0.9 in 2021. Residuals of explanatory variables from the best model are plotted in Fig. 6. We confirmed that distribution of residuals generally averaged around 0.

Up to 2021, operations small to medium-scale purse seine fisheries in Nagasaki Prefecture mainly targeted Japanese anchovy, but in 2022, operations targeted age 0 Japanese pilchard that were recruited unexpectedly. Fishing conditions in 2022 were different than in typical years, therefore, there is a possibility that CPUE standardization will need to consider the target of operations in the next fiscal year and onwards.

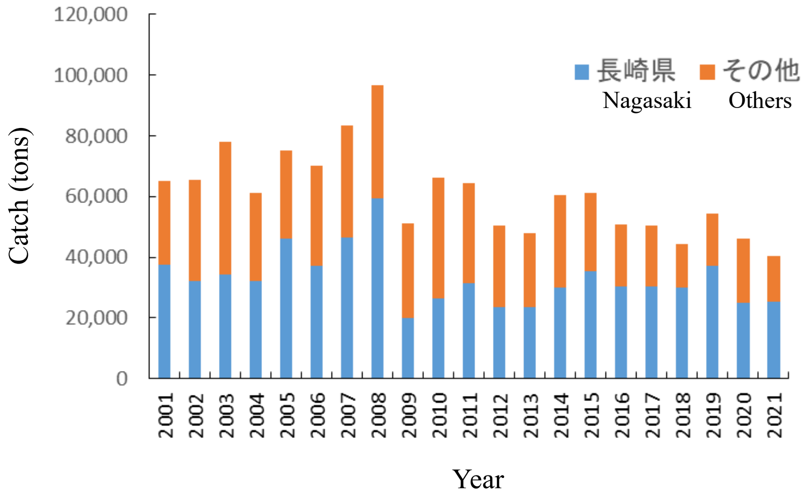


Fig. 1. Yearly changes in catch of the entire Tsushima current stock of Japanese anchovy and Japanese anchovy caught in Nagasaki Prefecture (2001 and onwards). Nagasaki Prefecture accounted for around 54% of the catch of this stock from 2001 to 2021.

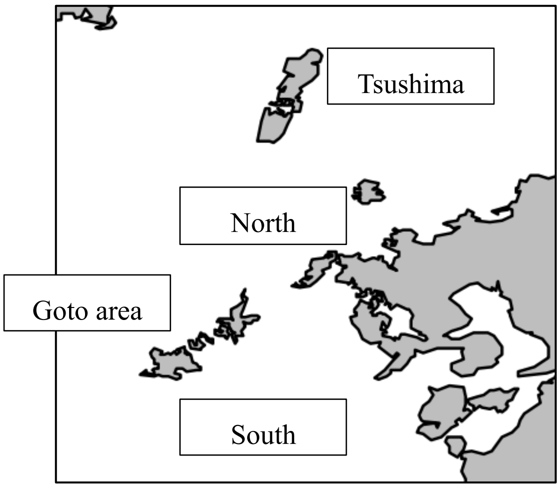


Fig. 2. Small to medium-scale purse seine areas in Nagasaki Prefecture

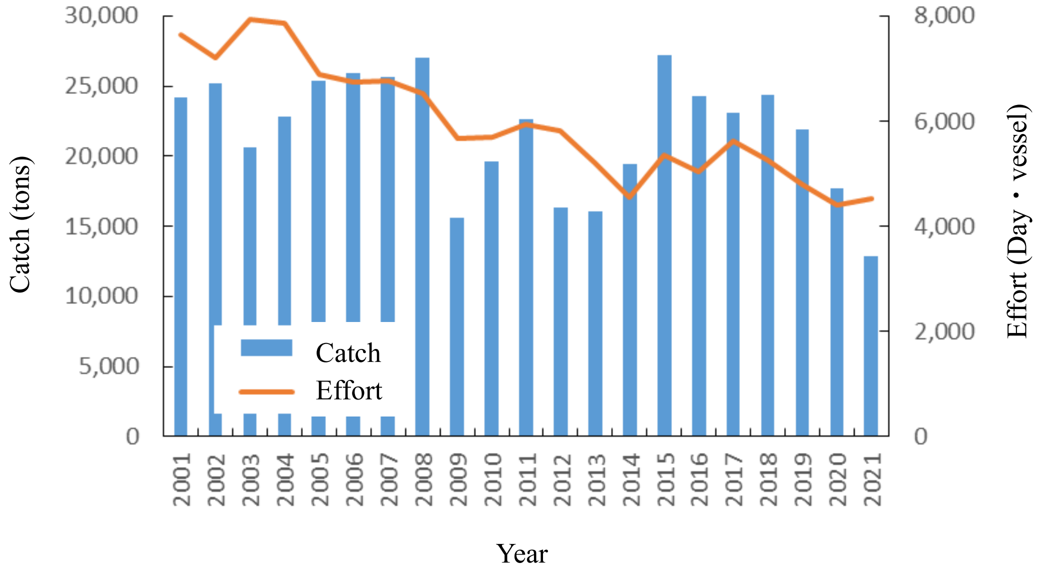


Fig. 3. Catch (tons) and effort (vessels per day) for Japanese anchovy caught by small to medium-scale purse seine fisheries in Nagasaki Prefecture from April to December

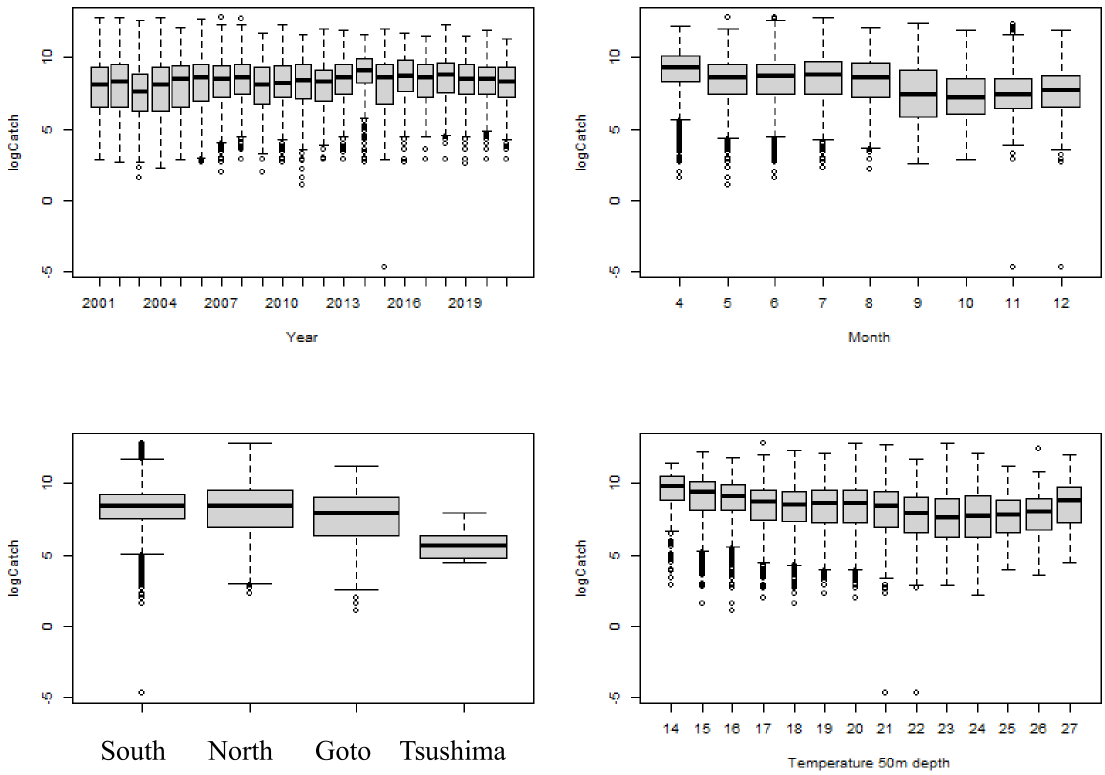


Fig. 4. Relationship between explanatory variables and logarithmized catch

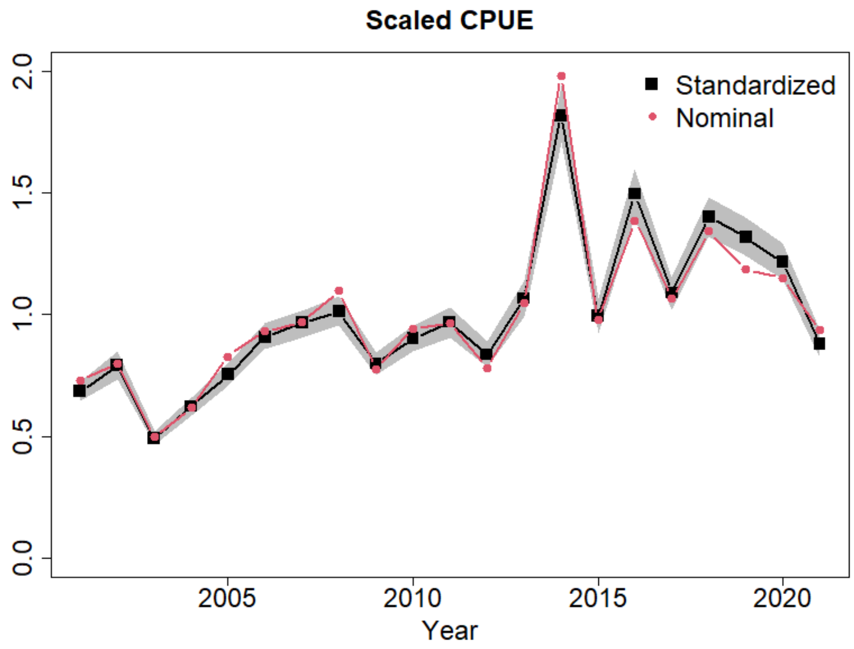


Fig. 5. Scaled standardized CPUE (■) and nominal CPUE (●) (right)

*The shaded area indicates the 95% confidence interval for scaled standardized CPUE

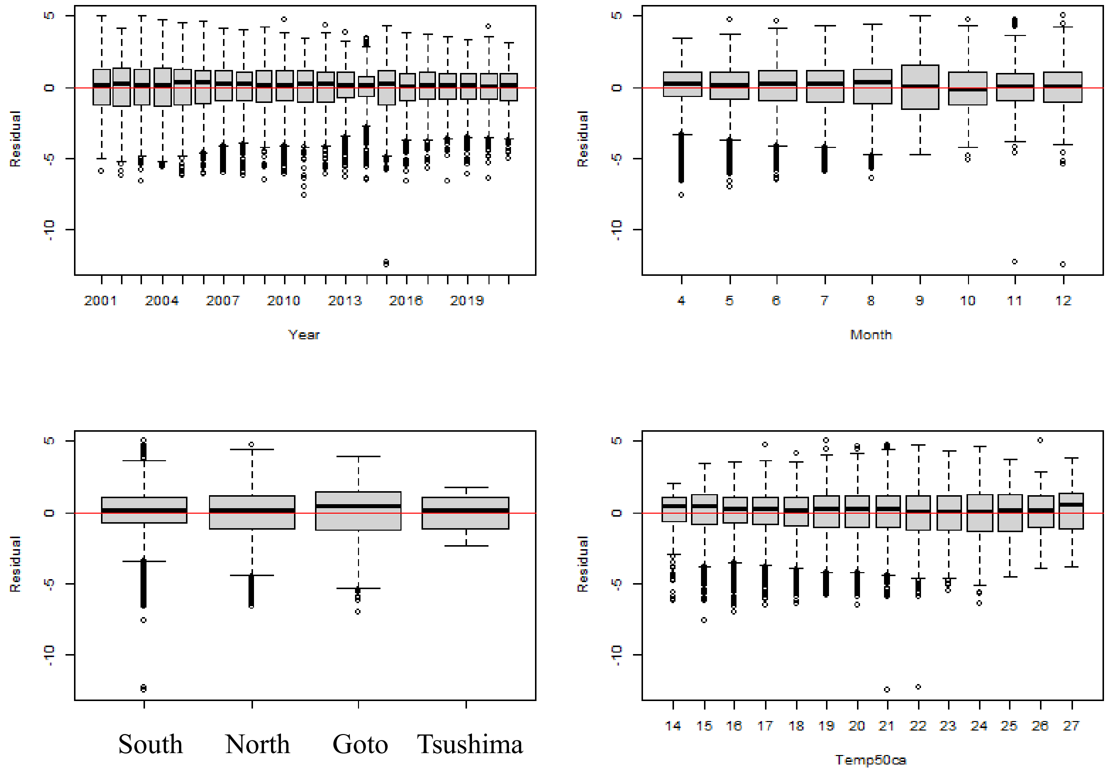
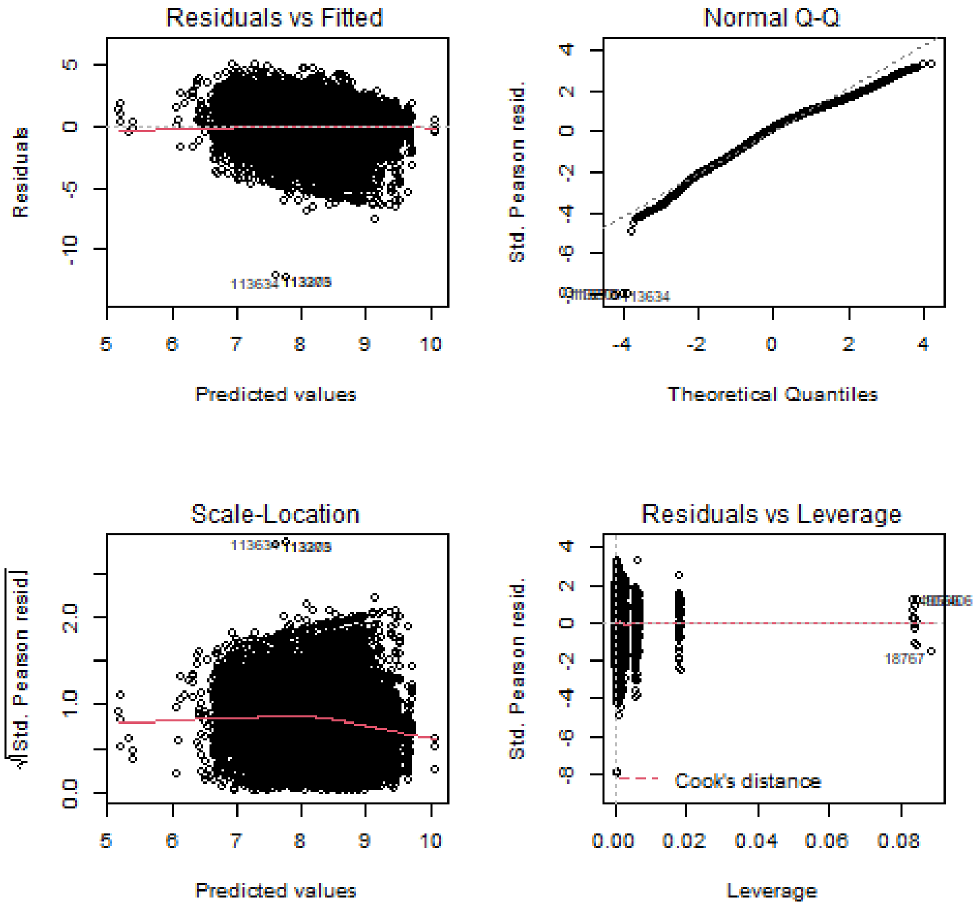


Fig. 6. Residuals of explanatory variables from the best model

Table 1. Results of model selection (yellow highlight indicates the selected model)

```
> select_anchovy
Global model call: glm(formula = log(X22) ~ factor(Year) + factor(Month) + factor(Area) +
    factor(Temp50ca), family = gaussian, data = pos.data)
---
Model selection table
   (Int) fct(Are) fct(Mnt) fct(T50) fct(Yer) df    logLik      BIC   delta weight
16 9.453        +        +        +        + 46 -88387.57 177270.8    0.00      1
12 8.703        +        +                 + 33 -88513.55 177382.7  111.89      0
15 9.239                 +        +        + 43 -88521.42 177506.2  235.38      0
11 8.583                 +                 + 30 -88653.54 177630.3  359.55      0
4  9.067        +        +                   13 -89271.49 178683.1 1412.29      0
```



Appendix Fig. 1. Summary Graphs of Generalized Linear Models

Appendix Table 1. Summary Table of Best Models

```
> summary(cpue_YMAT)

Call:
glm(formula = log(X22) ~ factor(Year) + factor(Month) + factor(Area) + 
    factor(Temp50ca), family = gaussian, data = pos.data)

Deviance Residuals: 
     Min        1Q    Median        3Q       Max  
-12.3890   -1.0147    0.2044    1.1452    5.0805  

Coefficients:
                     Estimate Std. Error t value Pr(>|t|)    
(Intercept)           9.45294    0.12631  74.839  < 2e-16 ***
factor(Year)2002      0.14408    0.04385   3.286  0.00102 ** 
factor(Year)2003     -0.33095    0.04036  -8.200 2.46e-16 ***
factor(Year)2004     -0.09383    0.04117  -2.279  0.02268 *  
factor(Year)2005      0.09618    0.04229   2.274  0.02294 *  
factor(Year)2006      0.28430    0.04184   6.795 1.10e-11 ***
factor(Year)2007      0.34481    0.04169   8.270  < 2e-16 ***
factor(Year)2008      0.39259    0.04262   9.212  < 2e-16 ***
factor(Year)2009      0.15488    0.04590   3.375  0.00074 ***
factor(Year)2010      0.27575    0.04443   6.206 5.48e-10 ***
factor(Year)2011      0.34924    0.04393   7.950 1.91e-15 ***
factor(Year)2012      0.20063    0.04430   4.529 5.93e-06 ***
factor(Year)2013      0.44464    0.04868   9.135  < 2e-16 ***
factor(Year)2014      0.97814    0.05160  18.955  < 2e-16 ***
factor(Year)2015      0.37469    0.04348   8.617  < 2e-16 ***
factor(Year)2016      0.78328    0.04716  16.608  < 2e-16 ***
factor(Year)2017      0.46555    0.04402  10.577  < 2e-16 ***
factor(Year)2018      0.71692    0.04394  16.317  < 2e-16 ***
factor(Year)2019      0.65558    0.04497  14.577  < 2e-16 ***
factor(Year)2020      0.57476    0.04616  12.451  < 2e-16 ***
factor(Year)2021      0.25111    0.04956   5.067 4.06e-07 ***
factor(Month)5       -0.25388    0.03987  -6.368 1.93e-10 ***
factor(Month)6       -0.07969    0.04804  -1.659  0.09718 .  
factor(Month)7       -0.01905    0.05527  -0.345  0.73035    
factor(Month)8       -0.28437    0.06183  -4.599 4.26e-06 ***
factor(Month)9       -1.09579    0.06756 -16.219  < 2e-16 ***
factor(Month)10      -1.34557    0.06660 -20.203  < 2e-16 ***
factor(Month)11      -1.21738    0.06297 -19.334  < 2e-16 ***
factor(Month)12      -1.02412    0.05678 -18.035  < 2e-16 ***
factor(Area)県北海域  -0.08203    0.01877  -4.371 1.24e-05 ***
factor(Area)五島海域  -0.75621    0.04812 -15.714  < 2e-16 ***
factor(Area)対馬海域  -2.14522    0.44520  -4.819 1.45e-06 ***
factor(Temp50ca)15   -0.64405    0.13137  -4.903 9.48e-07 ***
factor(Temp50ca)16   -0.68764    0.12714  -5.408 6.39e-08 ***
factor(Temp50ca)17   -1.06373    0.12889  -8.253  < 2e-16 ***
factor(Temp50ca)18   -1.22254    0.13194  -9.266  < 2e-16 ***
factor(Temp50ca)19   -1.16992    0.13410  -8.724  < 2e-16 ***
factor(Temp50ca)20   -1.07478    0.13573  -7.919 2.45e-15 ***
factor(Temp50ca)21   -1.01967    0.13705  -7.440 1.02e-13 ***
factor(Temp50ca)22   -1.00341    0.13934  -7.201 6.07e-13 ***
factor(Temp50ca)23   -0.96159    0.14100  -6.820 9.22e-12 ***
factor(Temp50ca)24   -0.98164    0.14426  -6.805 1.03e-11 ***
factor(Temp50ca)25   -1.11705    0.15831  -7.056 1.74e-12 ***
factor(Temp50ca)26   -1.07461    0.18425  -5.832 5.51e-09 ***
factor(Temp50ca)27   -0.30794    0.25309  -1.217  0.22372    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 2.36621)

    Null deviance: 129224  on 47799  degrees of freedom
Residual deviance: 112998  on 47755  degrees of freedom
AIC: 176867

Number of Fisher Scoring iterations: 2
```

Appendix Standardization of CPUE Using the Delta Two-Step Method

Results of trial calculations for standardization of CPUE with consideration of zero-catch data are shown here. We used an occupancy model which assumes binomial distribution, and the lognormal distribution model for non-zero catch data.

Occupancy model

$r \cong Bin(1,p)$

$\log[p/(1-p)] = factor(Year) + factor(Month) + factor(Area) + factor(Temp50)$

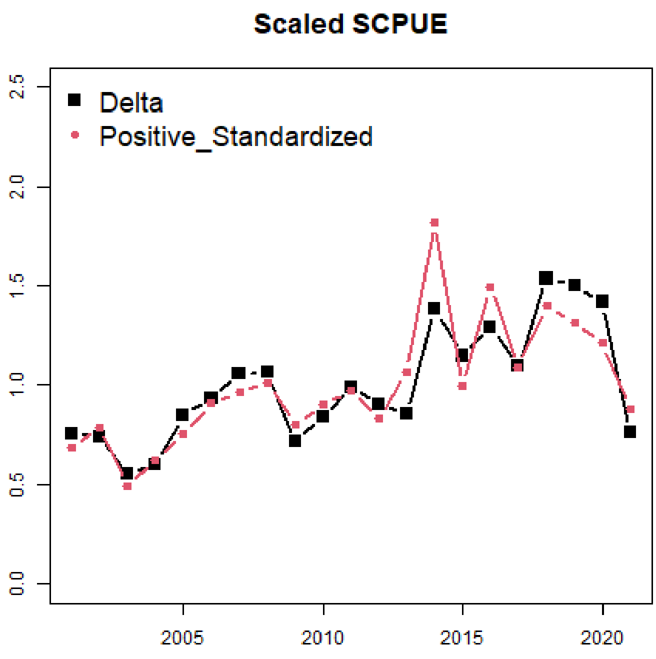
In this model, r is the response variable, p is the probability of occupancy, and Bin is the binomial distribution.

Lognormal distribution model

$Lcpue \cong N(\mu,\sigma^2)$

$\mu = factor(Year) + factor(Month) + factor(Area) + factor(Temp50)$

In this model, lcpue, μ, and σ^2 are the logarithm, average, and variance of CPUE, respectively. The selection of explanatory variables was determined using BIC. After model selection using BIC, both full models were selected. CPUE results are shown in Appendix Fig. 2. CPUE which was standardized using the delta two-step method fluctuated following generally similar trends as the standardized non-zero catch CPUE.



Appendix Fig.2 CPUE standardized using delta two-step method (■), standardized non-zero catch CPUE (●) (scaled by average)