ISC/22/ALBWG-02/06

Standardized CPUE for North Pacific albacore caught by the Japanese pole and line by Geostatistical method[1]

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This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 6-12 December 2022, held at the Fisheries Resources Institute, Japan Fisheries Research and Education Agency, Kanagawa, Japan.

Summary

This document is a summary of a trial to calculate a geostatistical standardized CPUE (i.e., relative abundance index) for north Pacific albacore caught by Japanese pole-and-line (JPPL). CPUE were calculated based on four different models, that include two models with/without the Quarter effect, and two models with/without consideration of spatial effects. Based on the WAIC (Widly-Applicable Information Criterion) results, the CPUE calculated with the model considering both Quarter and spatial effects was selected. Standardized CPUE showed the opposite trend to nominal CPUE, varying between 0.5-1.7.

Introduction

JPPL fishery operates targeting albacore (Thunnus alalunga) and skipjack (Katsuwonus pelamis). Albacore are usually caught in the second and third quarters of the year. Therefore, the catch data in first and fourth quarters are basically reported as zero. In addition, since JPPL targets both albacore and skipjack, in case they catch only skipjack, the catch of albacore is reported as zero. Therefore, the catch data of albacore are often reported as zero in a logbook.

Also, in recent years, the number of JPPL vessels has been decreasing year by year, and fishing grounds have been shrinking, resulting in a decrease in the number of data available from previous years. CPUE for JPPL fishery has been submitted as input data in albacore stock assessments, but zero catches and shrinking fishing grounds make it difficult to create a reliable JPPL CPUE.

Previous CPUE for the JPPL has been calculated by delta-lognormal model that considers latitude/longitude and vessel effects as fixed effects. However, the effect of latitude/longitude should inherently have a higher autocorrelation at closer distances. Also, vessel effect for standardization of CPUE is not constant because fishing master or the devices such as sonar and fish finder were changed annually. Therefore, we attempted to calculate a standardized geostatistical CPUE that incorporates vessel effect as a random effect. Also, in order to solve the zero-catch problem, we attempted to standardize the CPUE using a tweedie distribution instead of a delta-lognormal distribution.

Data and Methods

Logbook data were used to calculate standardized CPUE as same as previous CPUE. Logbook data contains daily catch, vessel ID, number of poles, vessel size (grt), and latitude and longitude from 1972-2021. Filtering process for logbook data was the same as previous CPUE as follows (Matsubara et al. 2020).

DWPL for CPUE data was extracted by

- Gross register tonnage (>199 t) and types of fishery (“Enyo”) for extracting DWPL
- Vessels that has searching devices (bait tank, NOAA receiver, bird radar)
- Operational areas (5°× 5° in 30-45N, 140-180E)
- Operational seasons (quarters 2 and 3)
- Sufficient operational days (>10 days in each year) AND operational years (>five years)

CPUE Standardization

The INLA package in R was used in this analysis, which is the package for the approximate Bayesian inference for Latent Gaussian Models. This approach is useful for understanding spatial trends in CPUE, and the structured form of the model allows for minimizing effects that may be included and directly related to spatial effects.

The model equation for CPUE standardization that was finally adopted is as follows

CPUE = exp(year + quarter + f(Vessel ID, model="iid")+ f(w,model=spde))~ tweedie

The other model equation for CPUE standardization is shown in **Table 1**. To standardize the

CPUE, year, quarter (fixed effects), vessel ID (random effects), and latitude and longitude were introduced as covariates. For ship random effects, iid (Independent and identically distributed Gaussian random effect) was used as the model. For spatial effects, SPDE (Stochastic Partial Differential Equations) or iid was applied as a model.
In order to cope with zero data, we attempted to standardize the data by using a tweedie distribution. WAIC, which is recommended for use in hierarchical models, was used for model selection (Watanabe and Opper 2010).

Results and Discussion

The calculations of the standardized CPUE have successfully converged in all the models selected for this analysis. The WAIC for each model is shown in Table 1, and the results for both the quarter and spatial effect were selected based on the WAIC results.

CPUE trends

The selected standardized CPUEs are shown in **Fig. 1**. It basically showed the opposite trend to the nominal CPUE, fluctuating between 0.5-1.7; from 1970-1990, observed around 1.0-1.7, then decreased until 2002, followed by a gradual increase until 2021. In recent years (2019-2021), CPUE has been varied, 1.6 in 2019, while in 2020 it decreased to about 0.7 and then increased to 1.3 in 2021.

Figs 2 and 3 show the mesh of SPDE model used in this analysis and the latent spatial field obtained from the analysis. JPPL effort was spread from the offshore of Japan to the east distant water and was less around 30N and 45N (Fig. 2). Latent spatial field values were high in the eastern direction from around 37N and 145E. High values of latent spatial field were observed in the west of 160E and north of 40N, which is presumed as due to the influence of high catch of albacore in the 1970s and 1980s. However, the catch in the area in north of 40N has decreased since 1990s. Therefore, it is more appropriate to apply the temporal spatial field for standardized CPUE of JPPL to incorporate temporal changes of the areas in the calculation.

The Mattern correlation of the model calculated from the analysis is shown in **Fig. 4**, which shows that the correlation was observed up to about 1,200 km and converges to 0 after that. The Mattern correlation is around 30% in the max edge of mesh with 600 km. From these results of Mattern correlation, we determined that an appropriate SPDE mesh has been created.
The residuals for standardization of CPUE in each year is shown in **Fig. 5**. The calculated random quantile residuals in each year tended to be stable around 0.

In summary, the standardized CPUE was successfully calculated. However, the results of the latent spatial field suggested some necessary improvement, such as the application of spatial-temporal effects. A statistical comparison between the previous CPUE and the new CPUE with geostatistical standardization will also be needed to compare their accuracy.

Reference

Matsubara, N., Aoki, Y. and Kiyofuji,H. (2020) Standardized CPUE for North Pacific albacore caught by the Japanese pole and line from 1972 to 2018. ISC/20/ALBWG-01/02.

Watanabe, S. and Opper, M., 2010. Asymptotic equivalence of Bayes cross validation and widely applicable information criterion in singular learning theory. Journal of machine learning research, 11(12).

Table 1. Summary of CPUE standardization for each model.

ID	Model name	Formula	WAIC
1	Qtr+ Spatial (SPDE)	CPUE = exp(year + quarter + f(Vessel ID, model="iid") + f(w,model=spde))~ tweedie	-155336
2	Spatial (SPDE)	CPUE = exp(year + f(Vessel ID, model="iid") + f(w,model=spde))~ tweedie	-155270
3	Qtr+ Spatial (iid)	CPUE = exp(year + quarter + f(Vessel ID, model="iid")+ f(latlon5,model=iid))~ tweedie	-155307
4	Spatial (iid)	CPUE = exp(year + Vessel ID + f(latlon5,model=iid))~ tweedie	-155201

Figure 1. Relative abundance index of NPALB caught by Japanese distant water pole and line (JP DWPL) from 1972 to 2021. Dashed line showed nominal CPUE (ID 1).

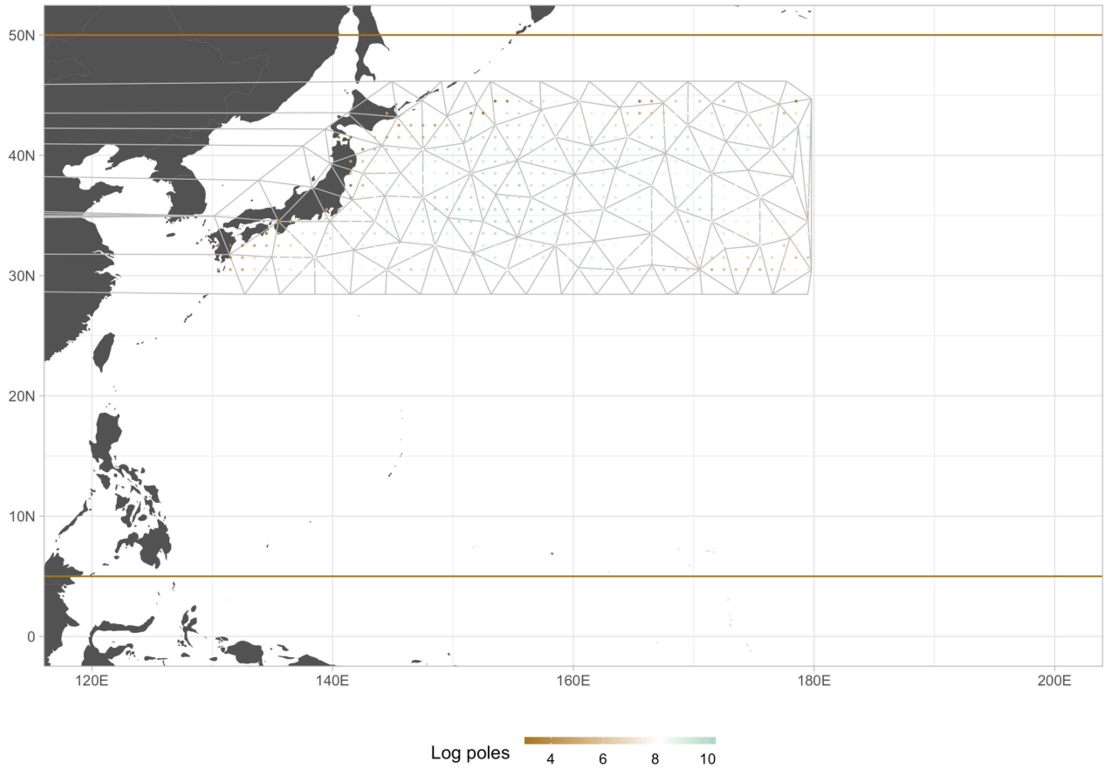

Figure 2. Mesh for SPDE model with effort of JPPLDW (ID 1)

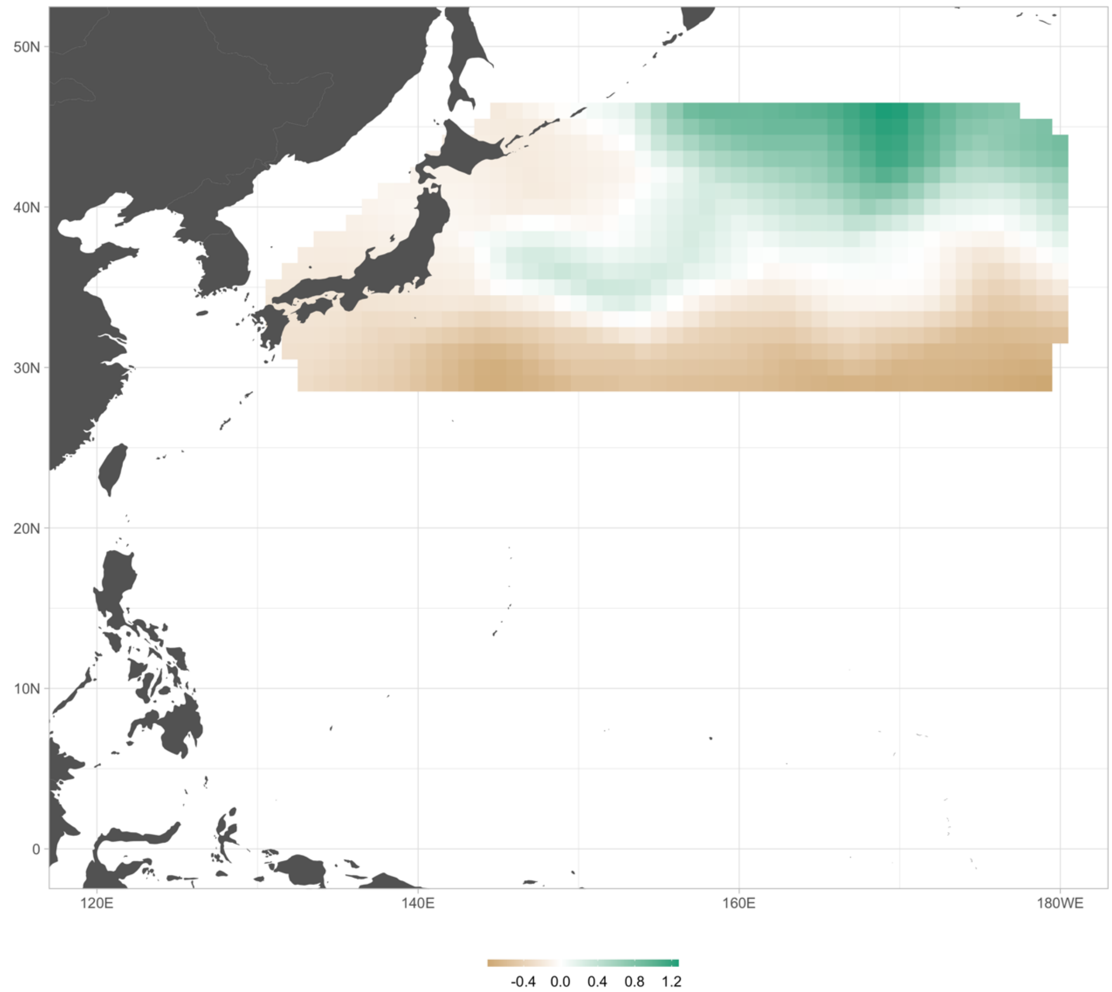

Figure 3. Latent spatial field for JPN PL (ID 1)

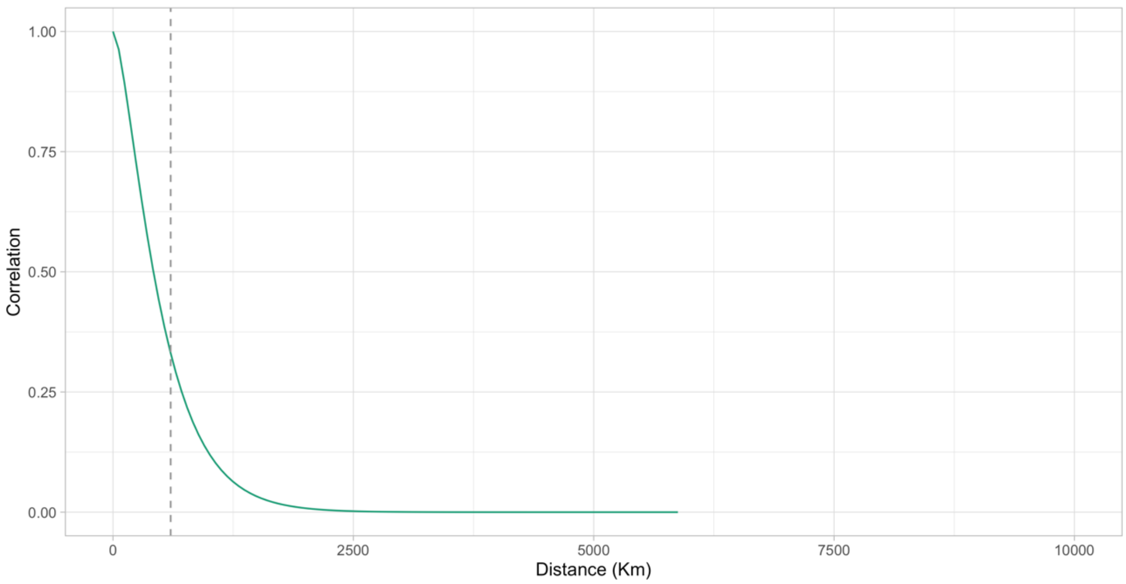

Figure 4. Mattern correlation for standardization of CPUE (ID 1). The grey vertical dashed line indicated the max edge of mesh with 600 km.

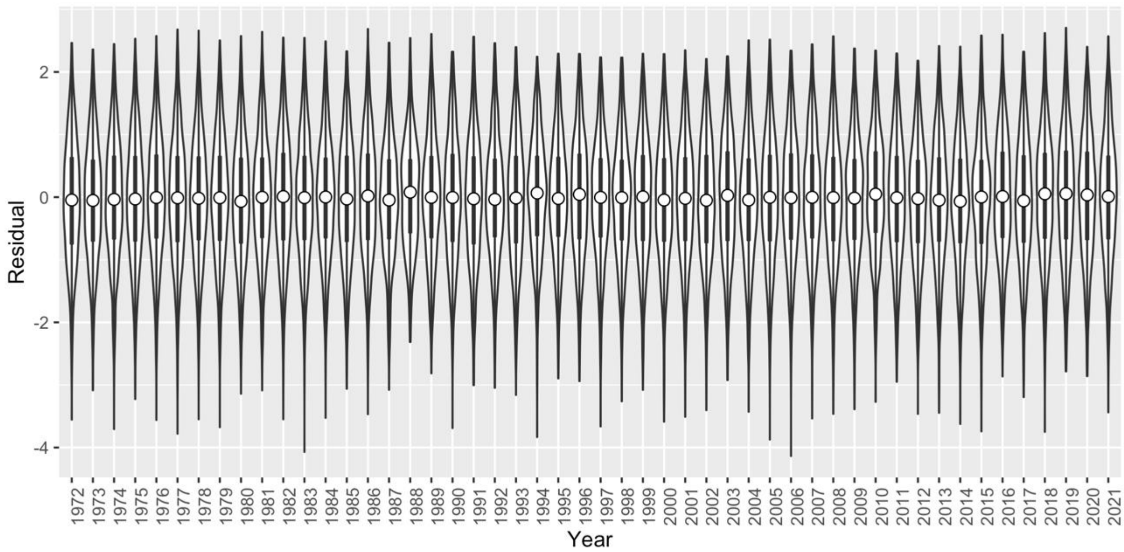

Figure 5. Random Quantile Residuals for standardization of CPUE in each year (ID 1)