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CPUE standardizations of Taiwanese PBF fisheries with/without geostatistical consideration

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Summary

PBF was an important seasonal target species to Taiwan offshore longline fishery, however only market landing data with small coverage of logbooks were available before 2010. Several alternative procedures were thus used to reconstruct catch and effort data since 2001 for the fishery, taking advantage of voyage data recorder (VDR) data, trip data and CDS data. The current work is an update to the work of ISC/18/PBFWG-1/02 with a revision of 2017 data and an addition of 2018 data. The CPUEs were standardized for north and south fishing grounds separately, as well as for all fishing grounds combined, using delta-generalized linear mix model (delta-GLMM). Two standardization models were designed: the first one was the same as previous without geostatistical component (residual of observed CPUE and interpolated CPUE from geostatistical ordinary kriging method) in the model and the second one included geostatistical component. Standardized CPUE series for the southern fishing ground from the first model is recommended for representing the abundance index of PBF in this region. Result of this analysis showed similar standardized CPUE trend as the previous work presented in the 2018 ISC PBFWG meeting for the southern fishing ground. In general, the standardized CPUE declined continuously from 2001 to 2012 and then started to increase slowly since 2014. The 2018 CPUE level was almost the same as the 2017 level, indicating the increasing trend might have paused.

Introduction

Pacific bluefin tuna (PBF) was seasonally targeted by Taiwanese offshore (small-scale) longline fishery during May to July. The fish was also caught as a bycatch species by other fishing gears like set net and gillnet in a small amount. The longline catch has been as high as 3,089 mt in 1999 but was continuously declined to the lowest record of 210 mt in 2012. Thereafter, the catch was slowly bounced back and stayed at the level of 400–550 mt during 2014–2017, with the peak of 552 mt in 2015. The 2018 catch was 380 mt, slightly decreased from 416 mt of 2017 due to decrease of fishing vessels.

PBF was traditionally caught in the southeastern waters off Taiwan (the South fishing ground, Fig. 1); less than 10% of annual catch was from the northeastern waters off Taiwan (the North fishing ground, Fig. 1) before 2008. The percentage of annual catch from the North fishing ground was gradually increased to 18%–26% during 2008–2012 and then jumped to about 45% in 2014 and 54% in 2015. Thereafter, the percentage gradually declined to 40% in 2017 and 11% in 2018.

PBF catch was composed mainly of 150–200 kg medium size fish (>60%) in the early 2000s. But following the decrease of available medium size fish, large fish of >200 kg became the majority during 2000 and 2014. However, since 2015, more medium size fish was observed in the catch and its ratio has reached or higher than 50%. Comparatively, more medium size fish was from the North fishing ground (Fig. 2, Shiao et al., 2017) and thus the average size of the catch was lower in the years when higher percentage of catch was from the North.

The PBF logbook information for Taiwanese offshore longline fishery was considered incomplete and insufficient to conduct CPUE analyses. To enhance the management on PBF fishery, Taiwan implemented specific regulations (catch documentation scheme, CDS) on the fishery since 2010. Thereafter many information on PBF fishery was available for retrospectively constructing the catch and effort data for the years before 2010. Document ISC/15/PBFWG-2/10 (Chang et al., 2015) has performed four major approaches for estimating 2001-2014 Taiwanese standardized PBF CPUE series. The work was refined in the PBFWG meetings of 2016 and 2017 [ISC/16/PBFWG-1/02(revised) and ISC/17/PBFWG-1/02] (Chang and Liu, 2016, 2017) and later published in Chang et al. (2017). The refined work standardized the CPUE separately by the South and the North fishing grounds, and the CPUE index of the South fishing ground was recommended to be used for the PBF stock assessment since 2016 PBFWG meetings.

This document is to provide an update of CPUE series for the 2019 PBFWG meeting. Two types of standardization models were used. The first model was the same as that used in the 2018 PBFWG meeting. Same dataset was used with a revision of 2017 data and an addition of new 2018 data (2017 fishing season). The second model was a preliminary trial to include geostatistical component in the model to partially address the research priority identified in the 2018 PBFWG (ISC, 2018, Attachment 4) that to “improve Taiwanese index with focus on spatio-temporal change”.

Materials and Methods

The data used in this study was the same as those in ISC/16/PBFWG-1/02 (revised) and ISC/17/PBFWG-1/02 (Chang and Liu, 2017) with the following changes: (1) 2017 data (the last year data used in 2018 PBFWG) was slightly updated due to more complete VDR data is available for the estimation of fishing effort. (2) New 2018 data is added to the dataset. Size of PBF were obtained from the CDS in which the length and weight of almost every PBF fish were measured by independent inspectors.

Standardization method of the first model was the same as that used in 2018 PBFWG meeting. The major procedures are: (1) Estimating PBF catch in number from landing weight for 2001–2003, for which the catch number information was incomplete, based on a Monte Carlo simulation; (2) deriving fishing days for 2007–2009 from data of VDR based on an algorithm that taking advantage of the information of change of vessel direction calculated from VDR; (3) deriving fishing days for 2001–2006 from vessel-trip information from the Coast Guard Administration, based on linear relationships between fishing days and at-sea days in a trip, by vessel size and fishing port; and finally (4) standardizing the CPUE calculated from the reconstructed data of 2001–2018 using delta-generalized linear mix model (delta-GLMM) which separately estimates the proportion of positive PBF catches assuming a binomial error distribution (zero-proportion model), and the mean catch rate of positive catches by assuming a lognormal error distribution (positive-catch model). The standardized index is the product of these model estimated components. Akaike and Bayesian information criteria was used to determine the most favorable variable composition of standardization models. Detail of the procedures could be found in Chang and Liu (2016) and Chang et al. (2017).

Covariates considered in the GLMM included: year (2001 – 2018), month (May – July), fishing area (North and South fishing ground separated by 24.3°N), and vessel size (CT1 – CT4). Since the number of explanatory variables considered in the study was small (due to limitation in available information), simpler backward (decreasing variables) and forward (increasing variables) methods were applied when determining the variables to be included in the model (α=0.05). All the explanatory variables were included initially in the model and were determined in the final models through backward method. First order interactions of the explanatory variables were also considered for the model and were determined through forward method. The interaction of year and month was treated as random variable, while the others were treated as fix variables. Three standardization runs were performed: (1) that on the area-combined data (fishing ground effect was treated as a covariate in the model); (2) that on the data from the South fishing ground; and, (3) that on the data from the North fishing ground. Coefficient of Variation (CV) series were calculated through balanced bootstrap approach (Gleason, 1988) for 1,000 times.

The second standardization model included geostatistical component. CPUE data are usually highly spatially autocorrelated (Nishida and Chen, 2004). This study applied the geostatistical ordinary kriging method (Bailey and Gatrell, 1995) to interpolate minimum error-variance estimate of unsampled CPUE from the observed CPUEs based on the distance between points, which method tends to smooth out the details and extreme values of the original data set (MacKenzie et al., 2017). The spatial-autocorrection was modelled using the following four variogram models: exponential, spherical, Gaussian and Matern models. The model fitting was made annually and was based on the average of observed CPUE within 0.1-degree square area to avoid the effect of highly fluctuated daily-CPUE estimates caused by the patchy distribution of PBF. The best model of each year was decided simply by “eye-ball” selection for this preliminary study. The *gstat* R package was used for this geostatistical analysis.

Finally, the geostatistical residuals of the observed CPUE and the interpolated CPUE were used as a covariate (Geo_residual) to be included in the first standardization model to establish the second model. In the second model, the Geo_residuals and the vessel size were treated as continuous variables, and the rest variables were categorical. If vessel size was treated as categorical variable as in the first model, the model could not converge. Same variable selection methods as the first standardization model were used.

Results and Discussions

CPUE on trip basis were calculated for the whole series of 2001–2018. For the first standardization run, three delta-GLMM runs were performed on data of southern area, northern area, and whole combined area. The best explanatory variable combinations were shown in Table 1. In general, all the best models include key variables of year, month, and year*month interaction (random variable). As the works of previous years, vessel size variable does not have significant effect. The diagnostic residual plots for these GLMM runs in Fig. 3 indicated the appropriateness of the two-stage delta lognormal model for evaluation of the factors that influence the PBF catch rate. The resulted relative CPUEs are shown in Table 2 (along with their CVs) and Fig. 4.

Although AICs and BICs of the southern and northern areas in Table 1 cannot be directly combined to compare with those of the combined whole area, from the large difference between them (AIC=29426.6 for area-separated standardization and 29709.6 for area-combined one), the area-separated standardization with much smaller AIC/BIC was likely to be a statistically significant improvement. The overall-R^2 (Chang et al. 2017) or the bootstrap-R^2 (Chang et al. 2019) can be calculated to compare fitting performance between area-separated and area-combined standardizations, and the results suggested that the area-separated one has better statistical performance (0.262 over 0.234, Table 3). The North fishing ground was basically a new fishing ground; as mentioned above, historically this area composed less than 10% of the annual catch before 2008 and less than 30% before 2013. With these considerations and that the South fishing ground was the traditional fishing ground with higher proportion of historical catch, as previous studies, this study recommended to use the series of the southern area as the representative of Taiwanese PBF CPUE series.

With addition of only one-year data and no model revision, the new CPUE series from the first standardization model for the South fishing ground (TLS_2019) is almost identical to the previous one (TLS_2018) that used in the 2018 PBFWG meeting (Fig. 4). In general, the standardized CPUE declined continuously from 2001 to 2012 and then started to increase slowly since 2014. The 2018 CPUE level was almost the same as the 2017 level, indicating the increasing trend might have paused.

For the second standardization run, in addition to year, month and year*month variables, both vessel size and geostatistical residuals variables were mostly significant ($p<0.05$). The best variable combinations of the models were shown in Table 4 and the diagnostic residual plots were shown in Fig. 5. Comparing Fig. 3 with Fig. 5, it seems inclusion of geostatistical component (the second model) apparently has no improvement. The second model has produced smaller bootstrap-R^2 than the first model (Table 3, e.g., 0.208 to 0.263 for the area-separated run), indicating that inclusion of geostatistical component did not improve the model fitting. However, for this model, the area-combined run has higher bootstrap-R^2 (0.213 to 0.208) and smaller mean square error (MSE) (0.189 to 0.192) than the area-separated run. Therefore, with geostatistical component in the model, there might not be necessary to consider performing standardization separately by fishing grounds and removing information from the North fishing ground. However, in an overall view, in terms of bootstrap-R^2, the first standardization model without geostatistical component has higher statistical performance and its results were recommended to be used for stock assessment, although the CPUE trends of both models (Fig. 6) were very similar.

Comparatively, the second model has smaller MSE but also smaller bootstrap-R^2 than the first model (Table 3), suggesting that inclusion of geostatistical component could have higher accuracy but lower precision. The second model was still preliminary without thorough consideration about the appropriateness to include geostatistical residuals in the model (indirect consideration of the spatial effect) and so needs further improvements.

The standardization approach to incorporating spatial autocorrelation into the model as did by Nishida and Chen (2004) might be worth for a trial.

References

Bailey, T.C., A.C. Gatrell. 1995. Ordinary Kriging. *In*: Interactive spatial data analysis. Chap.5.5. Longman Scientific & Technical, New York.

Chang, S.-K. and H.I. Liu. 2016. Update of Standardized PBF CPUE Series for Taiwanese Longline Fishery. Pacific Bluefin Tuna Working Group Intersessional Workshop of the ISC, La Jolla, USA, 29 February – 11 March 2016. ISC/16/PBFWG-1/02 (revised).

Chang, S.-K. and H.I. Liu. 2017. Standardized PBF CPUE series for Taiwanese longline fishery up to 2016. Pacific Bluefin Tuna Working Group Intersessional Workshop of the ISC, La jolla, USA, 15 – 20 February 2017. ISC/17/PBFWG-1/02.

Chang, S.-K., H.-I. Liu, H. Fukuda and M.N. Maunder. 2017. Data reconstruction can improve abundance index estimation: An example using Taiwanese longline data for Pacific bluefin tuna. PLoS ONE 12, e0185784.

Chang, S.-K., H.I. Liu. and Y.-W. Fu. 2015. Estimation of standardized CPUE series on Pacific bluefin tuna for Taiwanese longline fishery under incomplete data. Pacific Bluefin Tuna Working Group Intersessional Workshop of the ISC, Kaohsiung, Taiwan, November 18-25, 2015. ISC/15/PBFWG-2/10.

Chang, S.-K., T.-L. Yuan, S.-P. Wang, Y.-J. Chang and G. DiNardo. 2019. Deriving statistically reliable abundance index from landing data: an application to Taiwanese coastal dolphinfish fishery with multi-species feature. Transactions of the American Fisheries Society 148, 106-122.

Gleason, J. 1988. Algorithms for balanced bootstrap simulations. American Statistician 42(2), 263-266.

ISC. 2018. Report of the Pacific Bluefin Tuna Working Group Intersessional Workshop. ANNEX 9 of the 18th Meeting of the International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean. ISC/18/ANNEX/09.

MacKenzie, D.I., J.D. Nichols, J.A. Royle, K.H. Pollock, L. Bailey, J.E. Hines. 2017. Occupancy Estimation and Modeling: Inferring Patterns and Dynamics of Species Occurrence (second ed.), Elsevier, New York, New York, USA.

Nishida, T., D.-G. Chen. Incorporating spatial autocorrelation into the general linear model with an application to the yellowfin tuna (*Thunnus albacares*) longline CPUE data. Fisheries Research 70, 265–274.

Shiao, J.-C., H.-B. Lu, J. Hsu, H.-Y. Wang, S.-K. Chang, M.-Y. Huang, T. Ishihara. 2017. Changes in size, age, and sex ratio composition of Pacific bluefin tuna (*Thunnus orientalis*) on the northwestern Pacific Ocean spawning grounds. ICES Journal of Marine Science 74, 204-214.

Table 1. Best variable combinations of the delta-lognormal mixed models for the first standardization and the Akaike information criterion (AIC) and Bayesian information criterion (BIC). (ZPM: zero-proportion model; PCM: positive-catch model)

Model type	Final model formulation	n	AIC	BIC
South fishing ground				
ZPM:	Year+Month+Year*Month	180	517.6	521.5
PCM:	Year+Month+Year*Month	8085	22512.7	22516.7
North fishing ground				
ZPM:	Year+Month+Year*Month	133	556.0	559.7
PCM:	Year+Month+Year*Month	2393	5840.3	5843.5
Combined South and North fishing grounds				
ZPM:	Year+Month+Year*Month	313	1011.1	1015.0
PCM:	Year+Month+Area+Year*Month	10478	28698.5	28702.5

Table 2. Relative CPUE series from the first standardization run of this study and from the PBFWG-2018. '2018 est.' is the series that was provided to PBFWG-2018. 'This study' and 'CV' are the relative CPUEs and their CVs estimated from this study. The relative CPUEs and CVs are obtained from 1,000 bootstrap runs.

	South fishing ground			North fishing ground		All fishing ground	
Year	2018 est.	This study	CV	This study	CV	This study	CV
2001	2.562	2.595	0.030	0.519	0.119	2.570	0.028
2002	1.059	1.068	0.057	1.280	0.011	1.063	0.064
2003	1.862	1.884	0.041			1.967	0.035
2004	1.949	1.978	0.031			2.055	0.031
2005	1.366	1.392	0.039	1.248	0.126	1.372	0.039
2006	1.432	1.453	0.029	1.006	0.044	1.371	0.027
2007	1.022	1.038	0.042	0.499	0.026	0.872	0.035
2008	0.873	0.888	0.049	0.929	0.034	0.846	0.051
2009	0.820	0.834	0.035	1.018	0.038	0.829	0.030
2010	0.409	0.420	0.055	0.560	0.038	0.398	0.053
2011	0.395	0.402	0.048	0.625	0.052	0.407	0.033
2012	0.349	0.355	0.052	0.451	0.062	0.328	0.039
2013	0.363	0.371	0.077	0.782	0.047	0.392	0.058
2014	0.552	0.565	0.055	1.783	0.029	0.708	0.046
2015	0.625	0.638	0.040	1.507	0.023	0.738	0.036
2016	0.624	0.631	0.033	1.949	0.027	0.754	0.028
2017	0.738	0.746	0.033	1.301	0.028	0.712	0.030

2018	0.740	0.049	0.544	0.054	0.617	0.045

Table 3. The bootstrap-R^2 and mean square error, and their 95% confidence intervals, for the first (same as the one used in 2018 PBFWG meeting) and the second (additionally included geostatistical component) standardization models, based on 1,000 balanced bootstrap runs. "Area-combined" run standardized all the data from the North and the South fishing grounds, and "Area-separated" run standardized the data from the North and the South fishing grounds separately.

		Bootstrap-R^2		**MSE**	
		Mean	**95% C. I.**	**Mean**	**95% C. I.**
First standardization model	Area-combined	0.234	0.222 - 0.246	0.208	0.206 - 0.210
	Area-Separated	0.262	0.250 - 0.275	0.204	0.202 - 0.206
Second standardization model	Area-combined	0.213	0.201 - 0.224	0.189	0.187 - 0.190
	Area-Separated	0.208	0.198 - 0.219	0.192	0.191 - 0.194

Table 4. Best variable combinations of the delta-lognormal mixed models for the second standardization and the Akaike information criterion (AIC) and Bayesian information criterion (BIC). (ZPM: zero-proportion model; PCM: positive-catch model)

Model type	**Final model formulation**	**n**	**AIC**	**BIC**
South fishing ground				
ZPM:	Year+Month+Vessel_size+ Geo_residual+Year*Month+	8707	81116.0	81117.9
PCM:	Year+Month+Vessel_size+ Geo_residual+Year*Month	8106	21855.0	21859.0
North fishing ground				
ZPM:	Year+Month + Geo_residual+Year*Month	4089	23846.7	23850.4
PCM:	Year+Month+ Geo_residual+Year*Month	2372	4959.9	4963.2
Combined South and North fishing grounds				
ZPM:	Year+Month+Area+Vessel_size+ Geo_residual+Year*Month+	12796	116975.8	116977.8
PCM:	Year+Month+Area+ Geo_residual+Year*Month+	10478	27239.5	27243.4

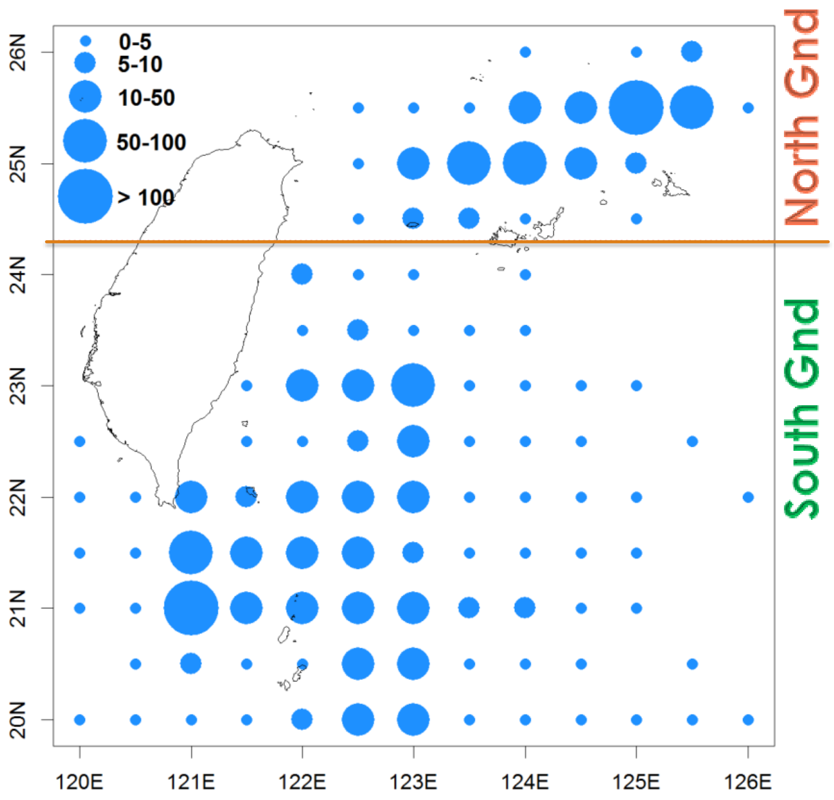


Fig. 1. Average PBF catch distribution off Taiwan for 2010–2015. The line splits the fishing grounds into southern ground and northern ground by 24.3°N.

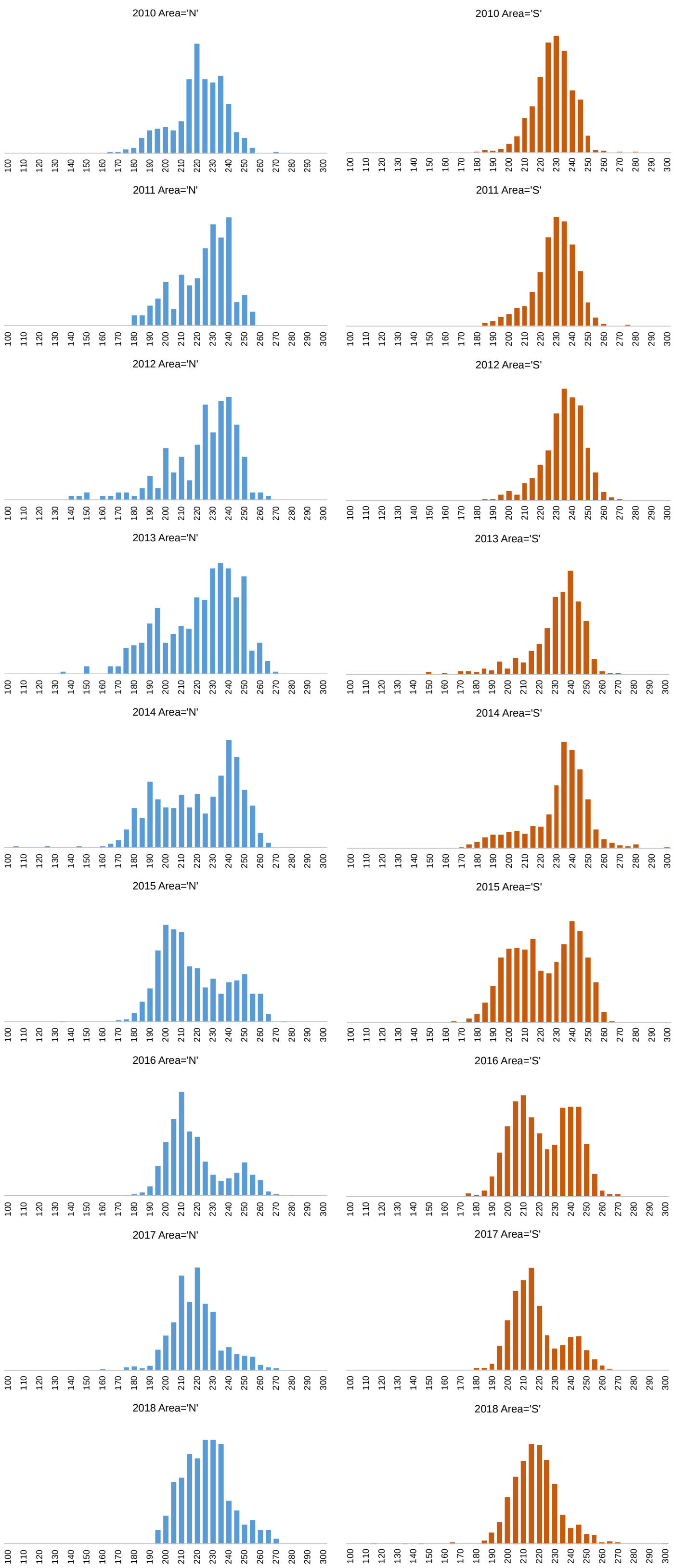


Fig. 2. PBF length distribution of Taiwanese longline fishery, by area (North in the left panels and South in the right panels) and by year (2010–2018).

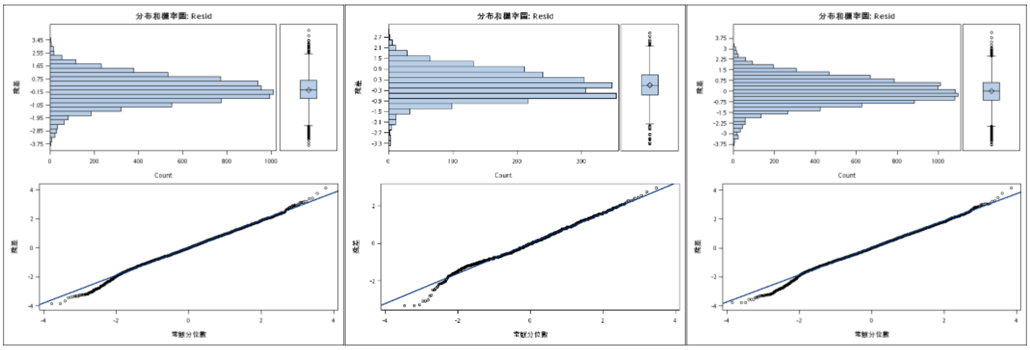
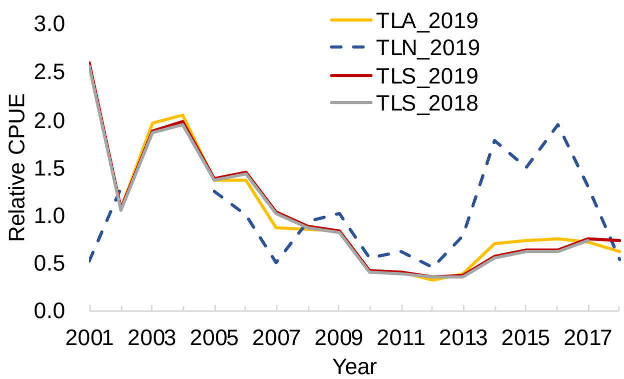


Fig. 3. Diagnostic residual plots for the delta-GLMM of the first PBF CPUE standardization model. From left to right shows residual plot for the standardization run on the South, the North and the whole fishing grounds.

(A)



(B)

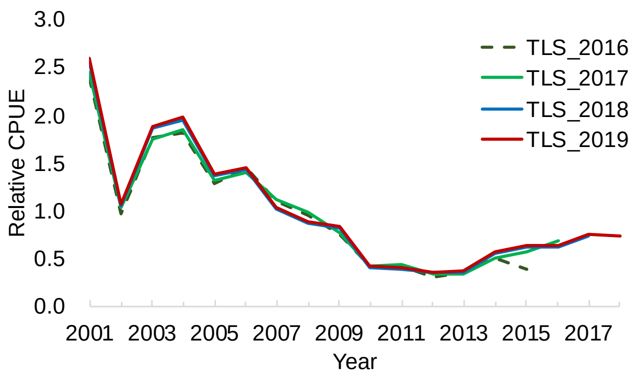


Fig. 4. Standardized CPUE series for Taiwanese PBF longline fishery for the first standardization model. (A) TLS_2018 is for south fishing ground adopted from ISC/18/PBFWG-1/02. TLS_, TLN_ and TLA_2019 are the standardized CPUE series of the South, North and All fishing grounds obtained from this study. (B) Comparisons of relative CPUE series of the South fishing ground from 2016 to 2019 analyses.

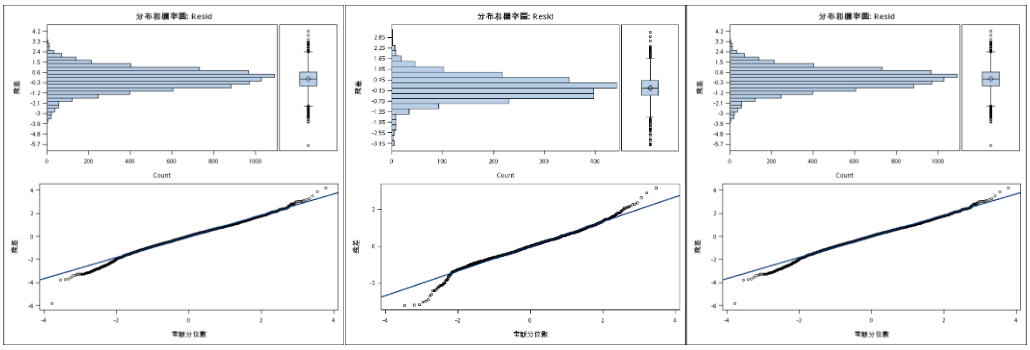


Fig. 5. Diagnostic residual plots for the delta-GLMM of the second PBF CPUE standardization model (including geostatistical component). From left to right shows residual plot for the standardization run on the South, the North and the whole fishing grounds.

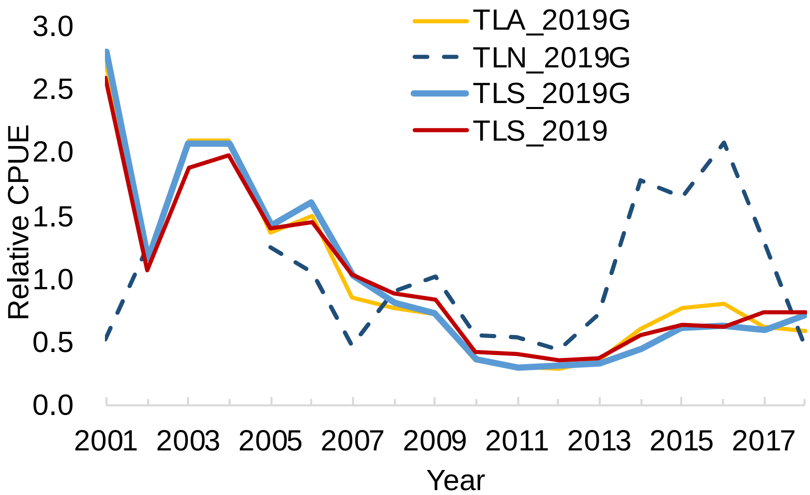


Fig. 6. Standardized CPUE series for Taiwanese PBF longline fishery for the second standardization model (including geostatistical component). TLS_2019 is for south fishing ground from the first standardization model. TLS_, TLN_ and TLA_2019G are the standardized CPUE series of the South, North and All fishing grounds with consideration of geostatistical component.