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CPUE standardization of Pacific bluefine tuna caught by Korean offshore large purse seine fishery (2003-2016)

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Introduction

Pacific bluefin tuna, *Thunnus orientalis* (PBF) has been mostly caught by the Korean offshore large purse seine fishery (KOPS) in Korean waters. The main fishing ground of Pacific bluefin tuna of this fishery is around Jeju Island, however, it expands to the west to the Yellow Sea, north to coastal of Busan and east to the East Sea depending on Pacific bluefin tuna migration patterns by season (NFRDI, 2002; Yoon et al., 2012).

In Korean waters, the annual catch of Pacific bluefin tuna caught by the offshore large purse seine fishery showed less than 1,000 mt until the 1990s except for 1997. The catch sharply increased to 2,401 mt in 2000 and recorded the highest of 2,601 mt in 2003, but the catch has generally decreased with a fluctuation thereafter. The catch in 2016 was 1,024 mt, which was higher than in 2015 and lower than in 2014 (Fig. 1).

In this study, CPUE (catch per unit effort) standardization of Pacific Bluefin tuna caught by Korean offshore large purse seine fishery in Korean waters (2003-2016) was conducted using Generalized Linear Model (GLM) to assess the proxy of the abundance index.

Data and Methods

Data used in this study for the CPUE standardization of Pacific bluefin tuna were obtained from Busan Cooperative Fish Market and Fisheries Cooperatives Radio Station, which contained fishing date, fishing position (latitude and longitude), fishing time (day and night), effort (no. of hauls), catch and so on. As the effort and catch data were the total amount fished for a day, in case of data aggregated two operations for a day, the catch were divided by the effort. However, most of fishing vessels operated once a day.

Data from the period 2003-2016 were used in the CPUE standardizations. Data prior to 2003 were not used in this study as there was no information on catch of Pacific bluefin tuna (PBF).

Dates were converted to months and quarters, and to identify moon phase.

PBF catch ratio per set (haul) can be a significant factor for the CPUE standardization of Pacific bluefin tuna caught by Korean offshore large purse seine fishery, because the fishing vessels have targeted small pelagic fishes such as chub mackerel in Korean waters and have

caught PBF temporarily around the east of Jeju Island (Shin et al., 2018). We examined the proportion of PBF catch in total catch by set through time in order to investigate whether the fishing condition of Pacific bluefin tuna was good or poor.

To identify the best GLM model several cases were considered. Generalized Linear Models (GLM) for CPUE standardization of Pacific bluefin tuna were fitted as follows, and the analyses were conducted by R packages.

Case 1: Ln(CPUE + c) ~ Y + Q + R + Lon + error
Case 2: Ln(CPUE + c) ~ Y + Q + R + Lat*Lon + error
Case 3: Ln(CPUE + c) ~ Y + Q + R + Lon + moon + error

where, CPUE: catch in weight (kg) per haul
c: 10% of average overall nominal CPUE
Y: effect of year
Q: effect of quarter (4 quarters)
Lon : effort of longitude (1 degree)
*Lat*Lon : interaction term between latitude and longitude*
R: effect of PBF catch ratio (2 cases: good, poor)
moon : effect of the lunar illumination on the date of the set
error: error term

Results and Discussion

Fig. 1 shows the nominal CPUE of Pacific bluefin tuna caught by by the Korean offshore large purse seine fishery (KOPS) in Korean waters. It decreased from 2003 to 2011, since 2012 it has increased with a big jump in 2014 and is showing an average of 1.6 in recent years (2015-2016).

The patterns of proportion of PBF catch in total catch were not significantly different through time, but based on the PBF ratio of 20%, we could define above 20% as good condition and below 20% as poor condition (Fig. 2).

The fishing areas of PBF by Korean offshore large purse seine fishery were mainly formed around Jeju Island, and widely expanded to the Yellow Sea and the East Sea (Figs 3 and 5). In terms of season, the catch was concentrated in Q1 and Q2 (Fig. 4).

We examined the relationship between response (catch of PBF) and predictor variables (Fig. 6). The catch was higher at latitude of 32°-33°, at longitude of 126°-129°, and during quarter 1-2.

We examined the Akaike Information Criterion (AIC) which measures goodness of fit and complexity, and selected case 3 as the best model that showed the lowest the AIC.

Fig. 7 shows the standardized CPUE trends of PBF with nominal CPUE in real and relative scales. The standardized CPUE from 2004 to 2011, except for 2003 and 2010, showed a steady trend, and since then it had increased until 2014, but decreased in 2015 (Table 2). And the CPUE in 2016 was higher than in 2015. Fig. 8 shows the standardized quarterly PBF CPUE trend.

Table 1 shows results from the GLMs, which suggests that PBF ratio effect is the largest factor affecting the nominal CPUE. Fig. 8 shows diagnostic plots of the GLM.

References

NFRDI. 2002. Fishing gear of Korea. Hangeul Graphics Publ. Co. 579pp.

Shin A., S. C. Yoon, S. I. Lee, H. W. Park and S. Kim. 2018. The relationship between fishing characteristics of Pacific bluefin tuna (*Thunnus orientalis*) and ocean conditions around Jeju Island. Fisheries and Aquatic Sciences, 21:1.

Yoo, J. T., Kim, Z. G. Lee, S. I., Yean, I. J., Yoon, S. C. and Lee., D. W. 2012. Recent update of Pacific bluefin tuna catch in Korean waters. ISC/12-1/PBFWG/19.

Table 1: Results from lognormal (CPUE + c) GLMs

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	23.303	5.002	4.658	3.22E-06
Y	-0.019	0.003	-7.324	2.58E-13
Q	-0.102	0.006	-16.535	< 2e-16
R	3.126	0.032	96.513	< 2e-16
Lon	0.079	0.006	13.299	< 2e-16
moon	-0.110	0.024	-4.600	4.27E-06

Table 2. The standardized CPUE of PBF

Year	CPUE	SE
2003	1.086	0.024
2004	0.495	0.019
2005	0.467	0.019
2006	0.445	0.017
2007	0.353	0.017
2008	0.393	0.016
2009	0.391	0.017
2010	0.636	0.018
2011	0.367	0.017
2012	0.678	0.019
2013	0.631	0.020
2014	1.169	0.022
2015	0.375	0.023
2016	0.502	0.024

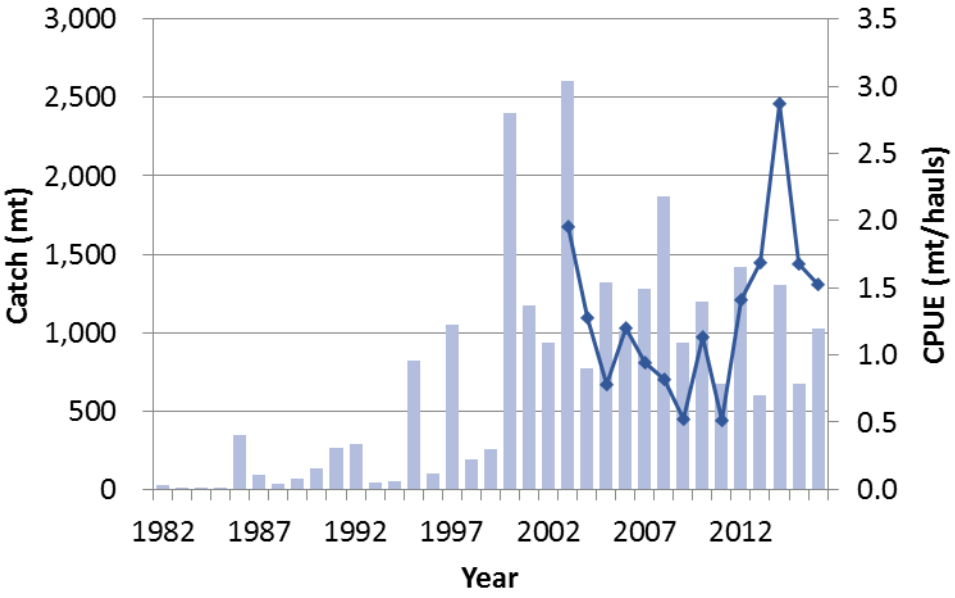

Fig. 1. Annual catch of Pacific bluefine tuna (PBF) and its nominal CPUE caught by Korean offshore large purse seine fishery in the Korean waters, 1982-2016 (Data source: ISC database).

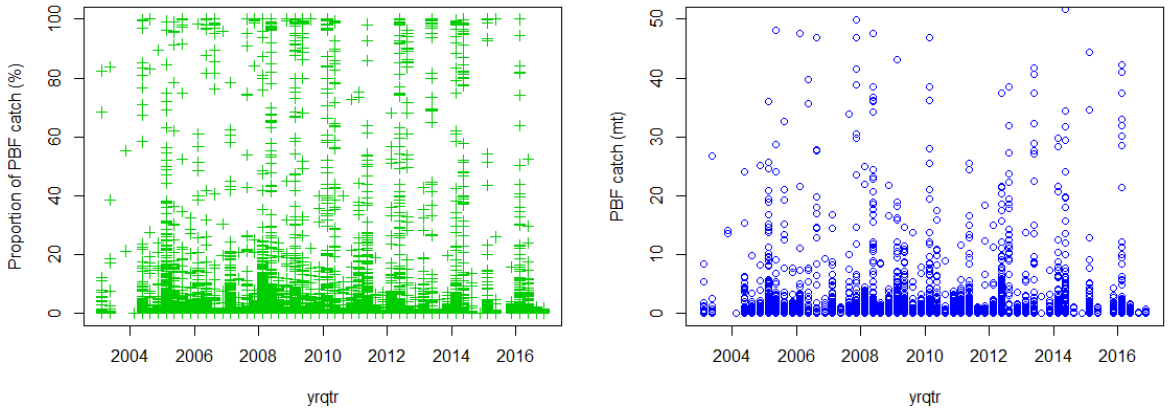

Fig. 2. Proportion of PBF catch in total catch (left) and the total PBF catch (right) through time. Catches of more than 50 mt are not shown in this figure.

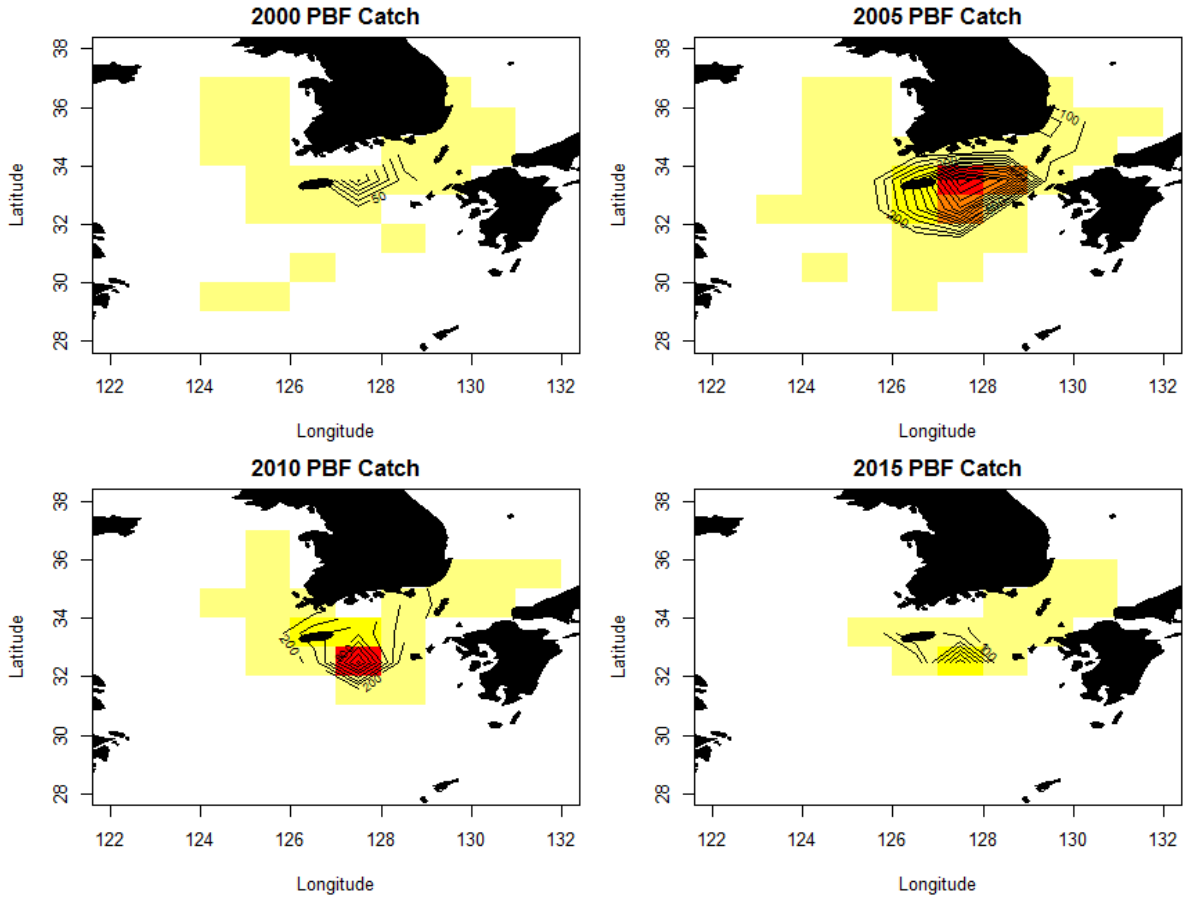

Fig. 3. Map showing the fishing areas of PBF of Korean offshore large purse seine fishery, aggregated by 5-year period. Red color indicates higher catch.

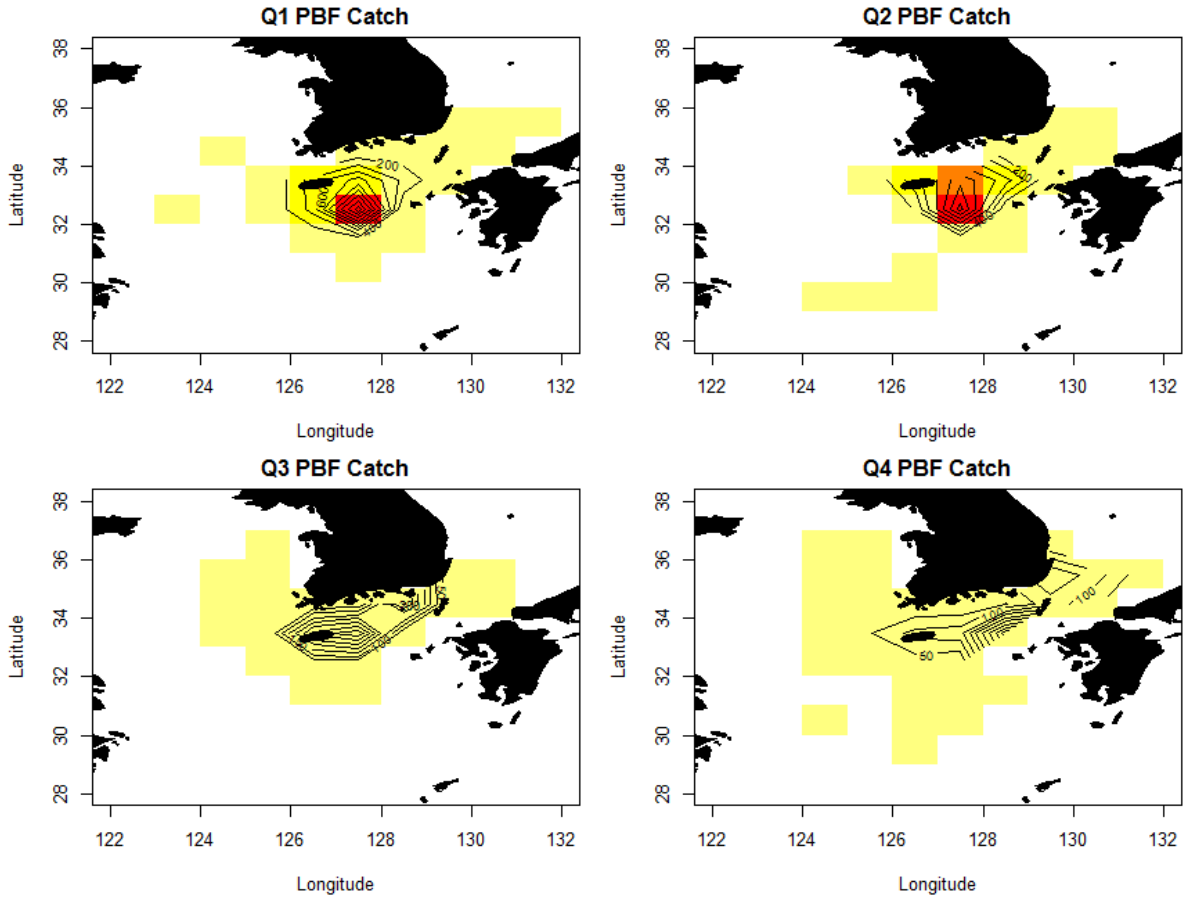

Fig. 4. Map showing the fishing areas of PBF of Korean offshore large purse seine fishery, aggregated by quarter. Red color indicates higher catch.

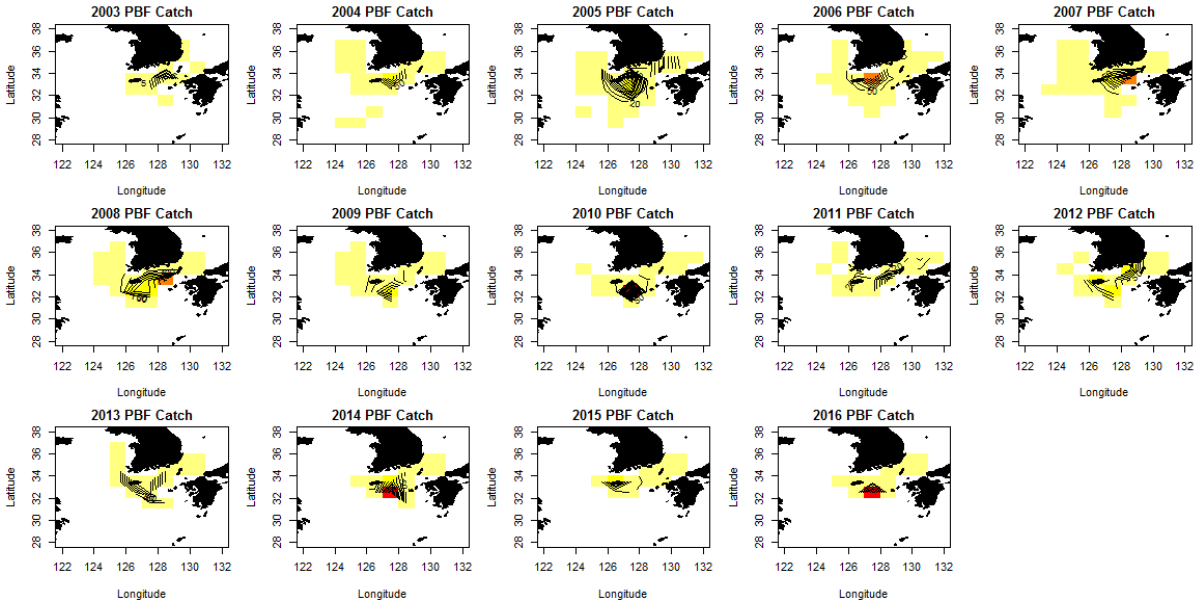

Fig. 5. Map showing the fishing areas of PBF of Korean offshore large purse seine fishery by year. Red color indicates higher catch.

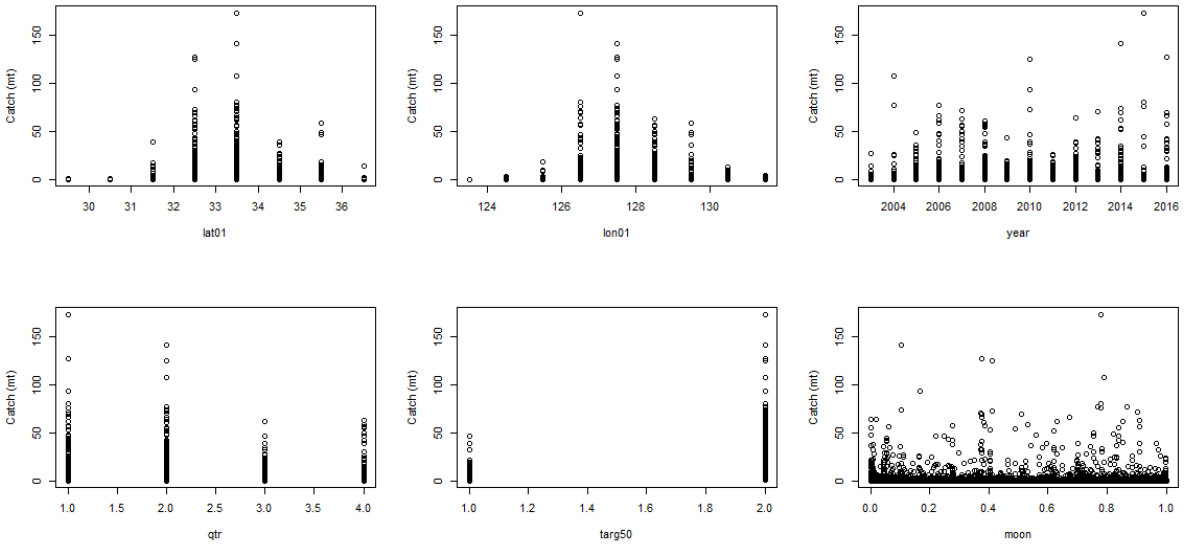

Fig. 6. Response (catch of PBF) versus predictor variables.

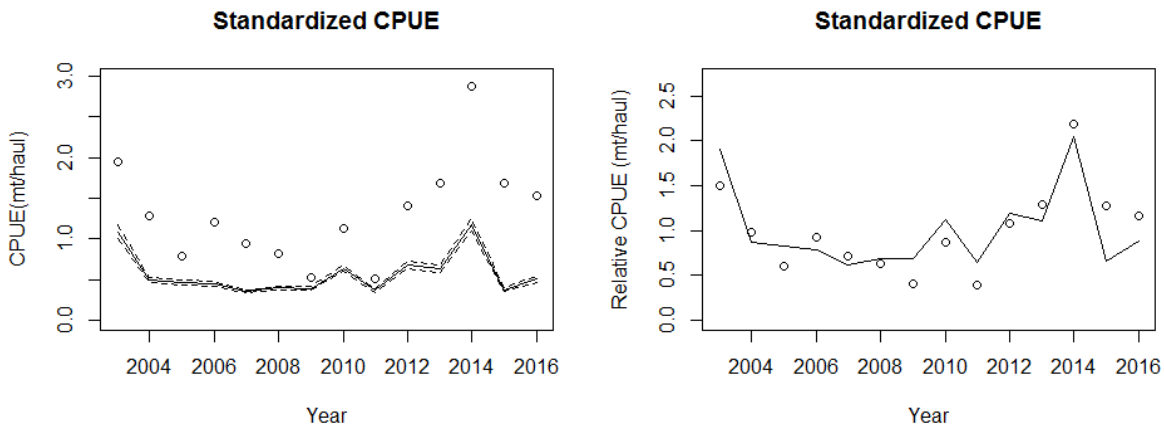

Fig. 7. Unstandardized (circle) and standardized (line) CPUE indices of PBF by year.

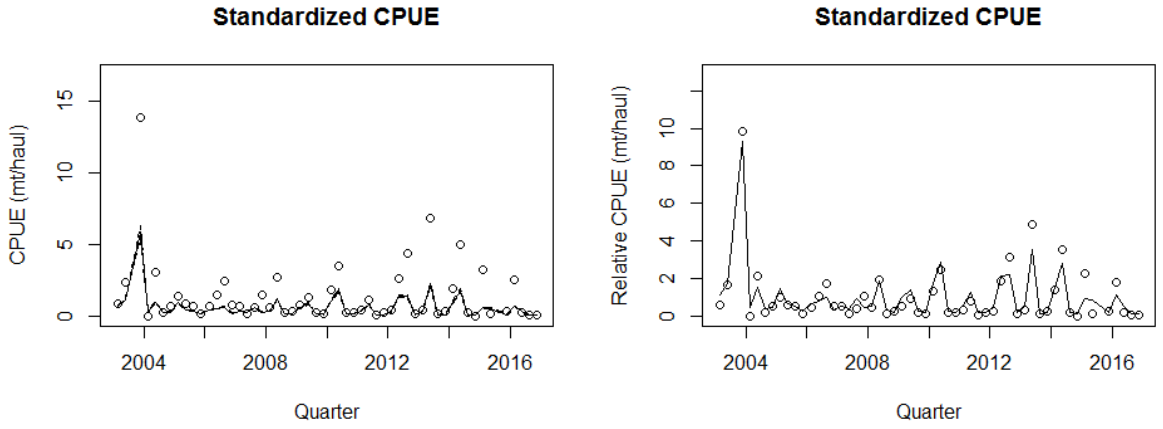

Fig. 8. Unstandardized (circle) and standardized (line) CPUE indices of PBF by quarter.

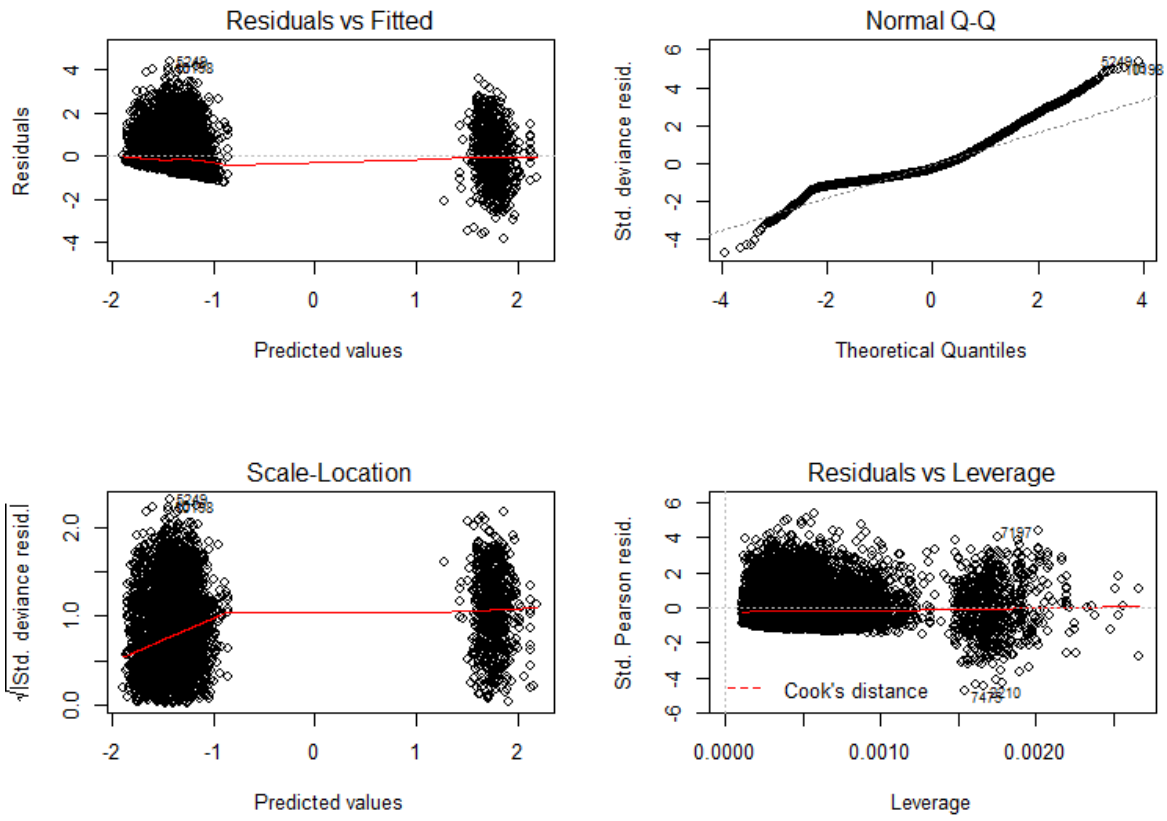

Fig. 9. GLM diagnostic plots for PBF.