Updated statistics and CPUE standardization of Pacific bluefin tuna from Korean coastal and offshore fisheries

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Introduction

Pacific bluefin tuna, *Thunnus orientalis* (PBF) has been caught by offshore large purse seine, set net, trawl, longline troll and others, and mostly by the offshore large purse seine fishery in Korean waters (Fig. 1). The main fishing ground of PBF of the offshore large purse seine 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 PBF migration patterns by season (NFRDI, 2002; Yoon et al., 2012).

In this study, we updated PBF catch statistics from Korean coastal and offshore fisheries up to 2017, and conducted CPUE (catch per unit effort) standardization of PBF caught by the offshore large purse seine fishery using Generalized Linear Model (GLM) to assess the proxy of the abundance index.

Data and Methods

PBF catch and effort data used in this study were obtained from Busan Cooperative Fish Market and Fisheries Cooperatives Radio Station, which contained fishing date, position (latitude and longitude), time (day and night), catch and effort (no. of hauls), etc.

The nominal PBF catch data span from 1975 to 2017, and the data from the period 2004-2017 were used in the CPUE standardizations. Data prior to 2004 were not used in this study as there was no information on catch and effort of PBF.

The relationship between PBF catch and sea surface temperature (SST) in the main fishing season was investigated to identify how SST affects the recent PBF catch in Korean waters.

We considered two cases of Generalized Linear Models (GLMs) for PBF CPUE standardization. The first case is using all data of whole area, where PBF was caught, for the GLM, and secondly, we explore the core area where PBF was mainly caught, and use data of the core area for the GLM. And we considered effects of year (Y), quarter (Q), latitude (Lat), longitude (Lon), PBF targeting (R) (Lee et al., 2018), moon phase in analyzing GLMs.

GLMs for the whole area and the core area are as follows, and the analysis was conducted by R packages.

Whole area: Ln(CPUE + c) ~ Y + Q + R + Lat + Lon + moon + error

Core area: Ln(CPUE + c) ~ Y + Q + R + 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)

Lat: effort of latitude (1 degree)

Lon: effort of longitude (1 degree)

R: effect of PBF catch ratio (2 cases: good, poor in PBF fishing)

moon: effect of the lunar illumination on the date of the set

error: error term

In addition, we analyzed the PBF length frequency caught by the Korean offshore large purse seine fishery.

Results and Discussion

In Korean waters, the annual catch of PBF showed less than 1,000 ton until the 1990s except 1997. The catch sharply increased to 2,401 ton in 2000 and recorded the highest of 2,601 ton in 2003, but the catch has decreased with a fluctuation thereafter. PBF in Korean waters has been caught by offshore large purse seine fishery which accounted for about 99% in total catch. The total catch was 743 ton in 2017, and of them, 734 ton came from the large purse seine fishery (Fig. 1).

Fig. 2 represents the nominal CPUE of PBF caught by offshore large purse seine fishery in Korean waters. It showed a decreasing trend in 2000s, but since 2012 it has shown an increasing trend, and showed the heighted of 3.9 ton/haul in 2017.

In recent years (2015-2017), PBF was mainly caught in January to March and the catch was highest in March (Fig. 3). As for the monthly catch from 2014 to 2017, the catch in March was high in all years and particularly higher in 2016 and 2017. The catches in other months were different by year (Fig. 4)

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 (Fig. 5). And in terms of fishing season, the catch was higher in quarter 1 and 2 than other seasons (Fig. 6).

Fig. 7 shows the distributions of SST in February to April from 2014 to 2016. The 15ºC isotherm further expanded north of 33 ºN in February 2016, March 2016, and April 2014 and 2016, the catch was also higher in those months.

We examined the relationship between response (catch of PBF) and predictor variables (Fig. 8). The catch was higher at latitude of 32°-33°, at longitude of 126°-128°, and in quarter 1 and 2. Hence the area of 32º-33ºN between 126ºE-128ºE was chosen as the core area for the PBF CPUE standardization.

Fig. 9 shows the standardized yearly CPUE trends of PBF for the whole and core areas with nominal CPUEs in real and relative scales. The standardized CPUE from 2004 to 2011, except 2010, showed a steady trend, and after 2012 it increased until 2014, but decreased in 2015 and in 2016 (Table 2). However, it again increased in 2017 and showed the highest level. Fig. 10 shows the standardized quarterly PBF CPUE trends for the whole and core areas. We examined the Akaike Information Criterion (AIC) which measures goodness of fit and complexity, and selected the CPUEs for the core area as the base model that showed the lower value. Table 1 shows results from the GLMs, which suggests that PBF ratio effect is the largest factor affecting the nominal CPUE. Fig. 11 shows diagnostic plots of the GLM.

Fig. 12 represents the frequency of fork length of PBF caught by Korean offshore large purse seine fishery, which showed the modes of large size since 2014.

References

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

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

(a) Whole area

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	21.717487	4.876484	4.454	0.00000853
year	-0.016152	0.002485	-6.499	8.4E-11
lat1	-0.018867	0.010601	-1.78	0.0751
lon1	0.080601	0.006896	11.689	< 2e-16
qtr	-0.097421	0.006503	-14.981	< 2e-16
targ	3.120581	0.032083	97.266	< 2e-16
moon	-0.111336	0.023924	-4.654	0.0000033

(b) Core area

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	25.643	5.575	4.600	4.29E-06
year	-0.013	0.003	-4.768	1.89E-06
qtr	-0.153	0.007	-20.596	< 2e-16
targ	3.060	0.033	93.390	< 2e-16
moon	-0.125	0.027	-4.589	4.51E-06

Table 2. The standardized Pacific bluefin tuna (PBF) CPUE for the core area

Year	CPUE	SE
2004	0.519	0.020
2005	0.490	0.019
2006	0.507	0.018
2007	0.381	0.017
2008	0.441	0.016
2009	0.549	0.016
2010	0.851	0.018
2011	0.446	0.017
2012	0.695	0.018
2013	0.820	0.020
2014	1.663	0.023
2015	0.665	0.023
2016	0.602	0.026
2017	1.797	0.029

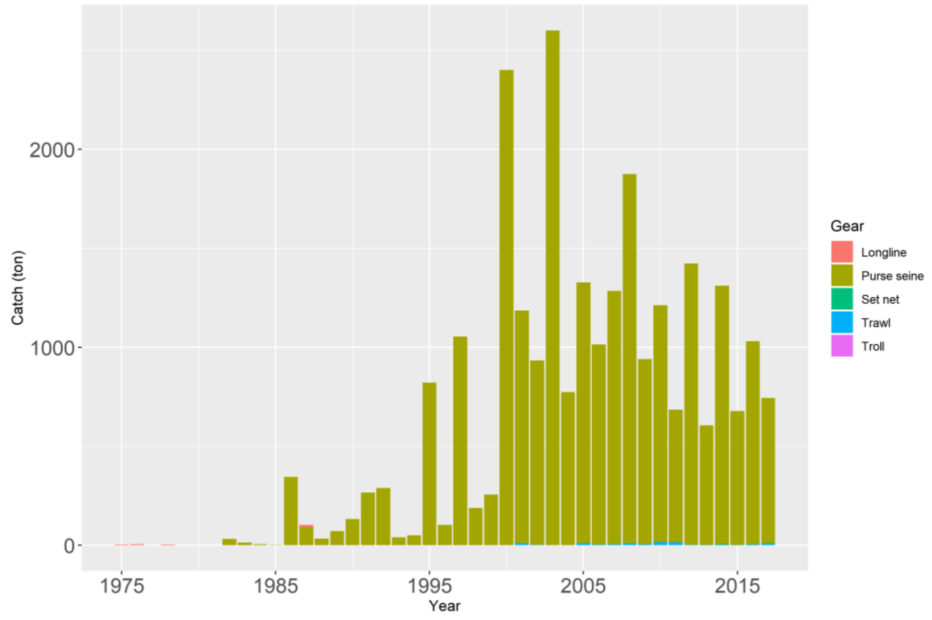


Fig. 1. Annual catch of PBF by fisheries in Korean waters, 1975-2017 (Data source: ISC database).

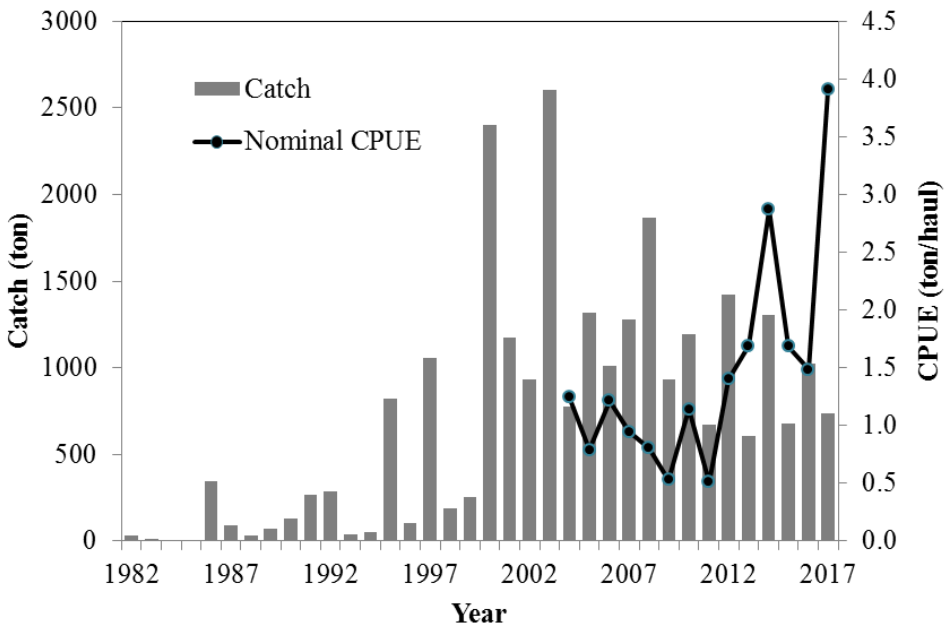


Fig. 2. Annual catch of PBF and its nominal CPUE caught by offshore large purse seine fishery in Korean waters, 1982-2017.

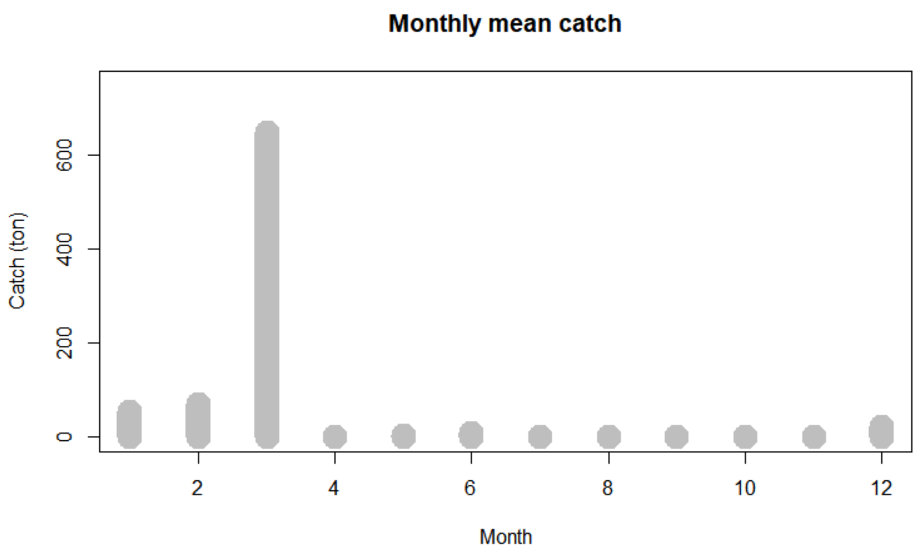
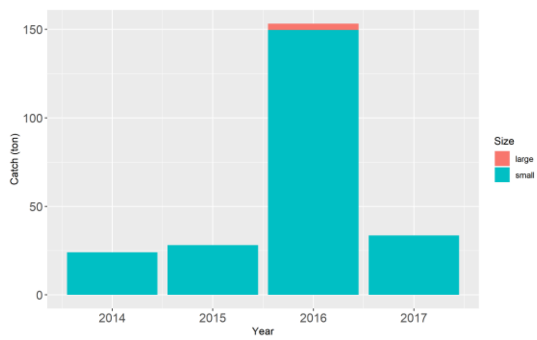
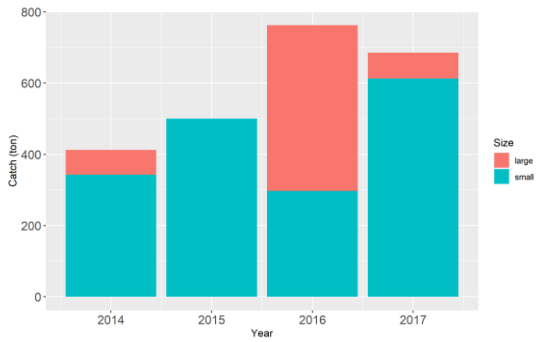


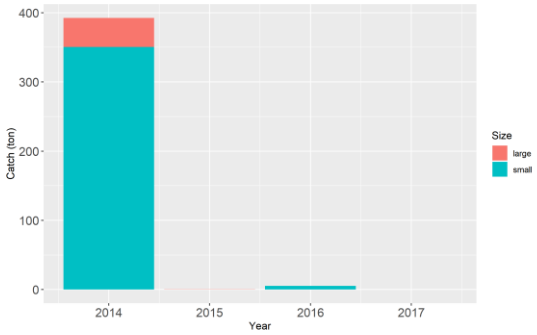
Fig. 3. Monthly mean catch (2015-2017) of PBF in Korean waters.



(a) February



(b) March



(c) April

Fig. 4. Monthly catch of PBF in February to April.

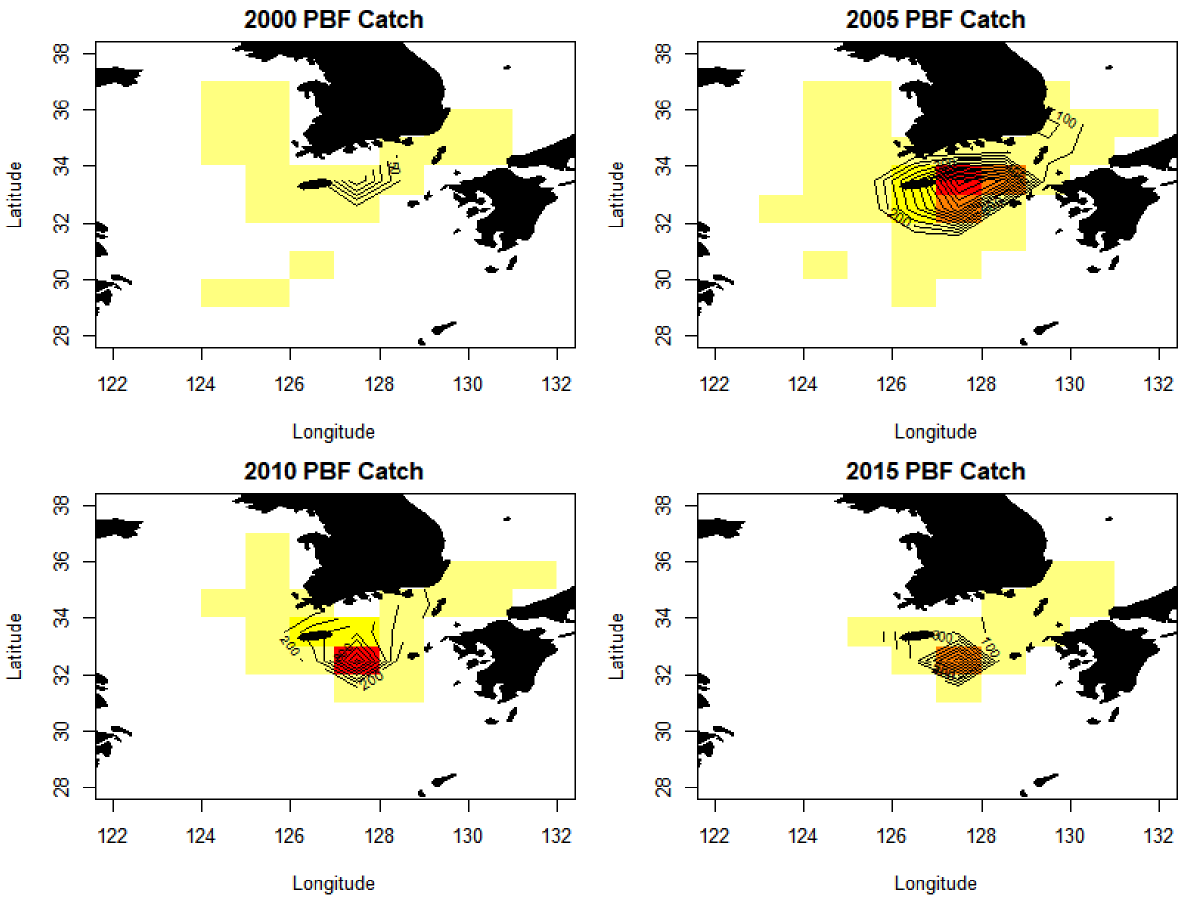


Fig. 5. Map showing the fishing areas of PBF of Korean offshore large purse seine fishery, aggregated by 5-year period. Red color indicates higher catch.

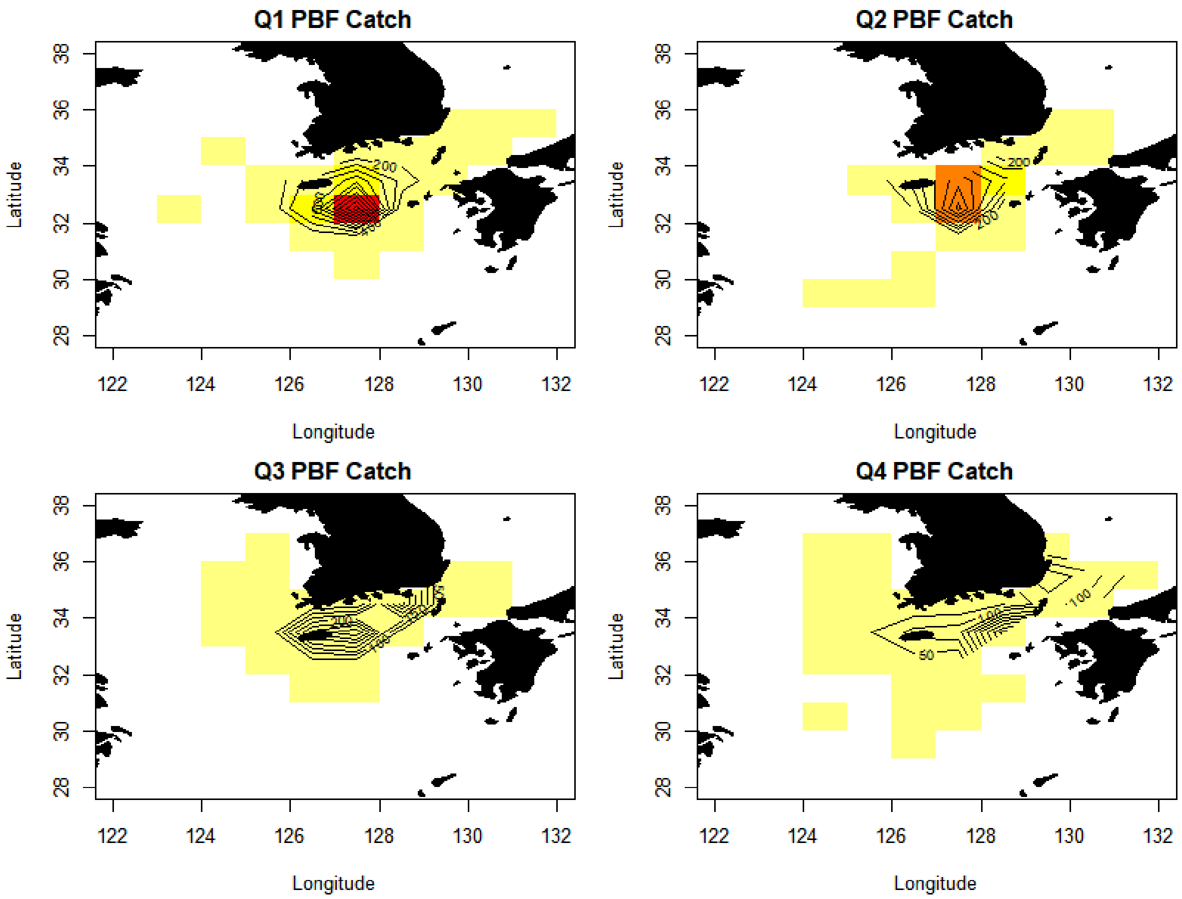


Fig. 6. Map showing the fishing areas of PBF of Korean offshore large purse seine fishery, aggregated by quarter. Red color indicates higher catch.

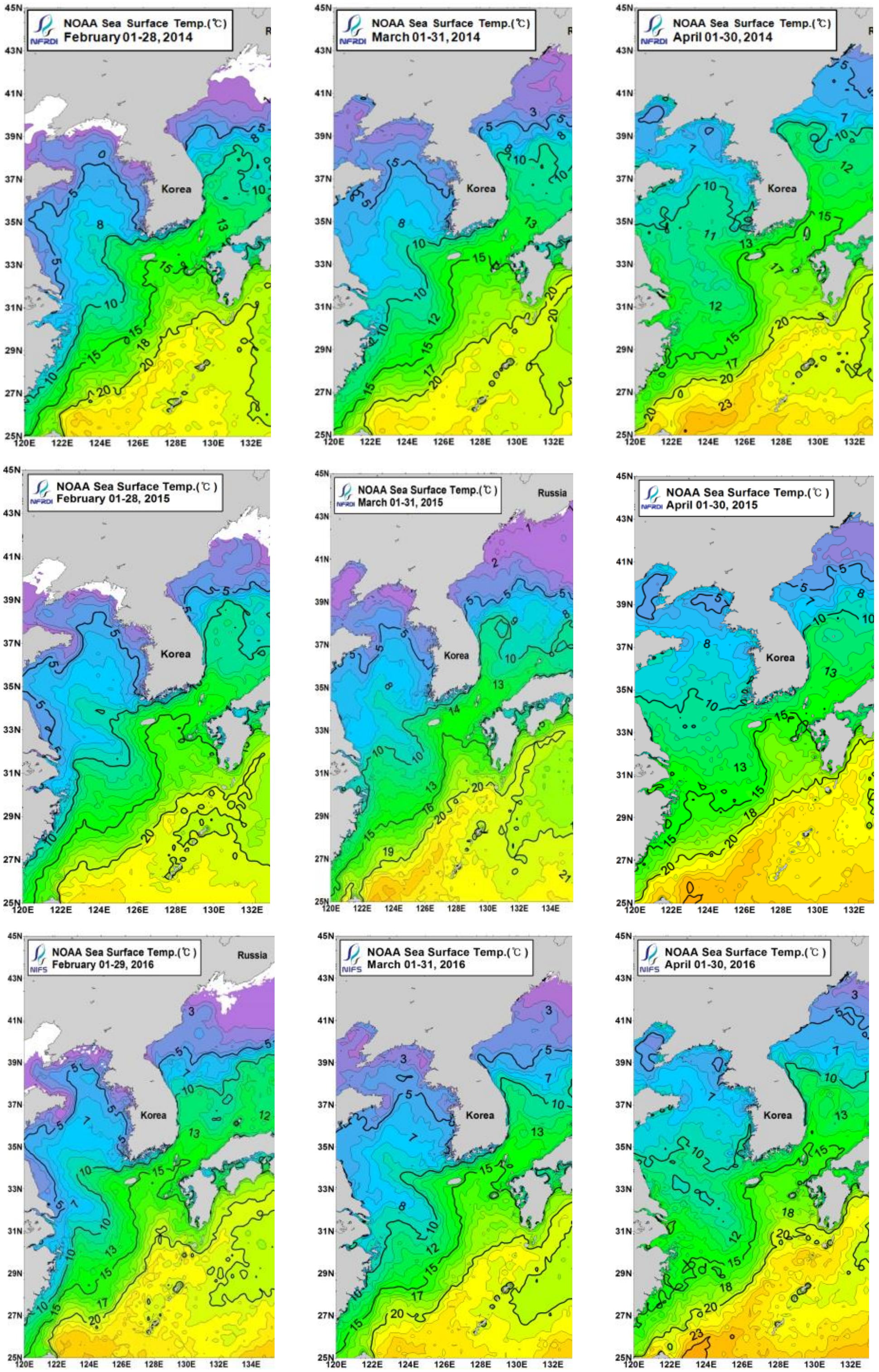


Fig. 7. The distributions of sea surface temperature (SST).

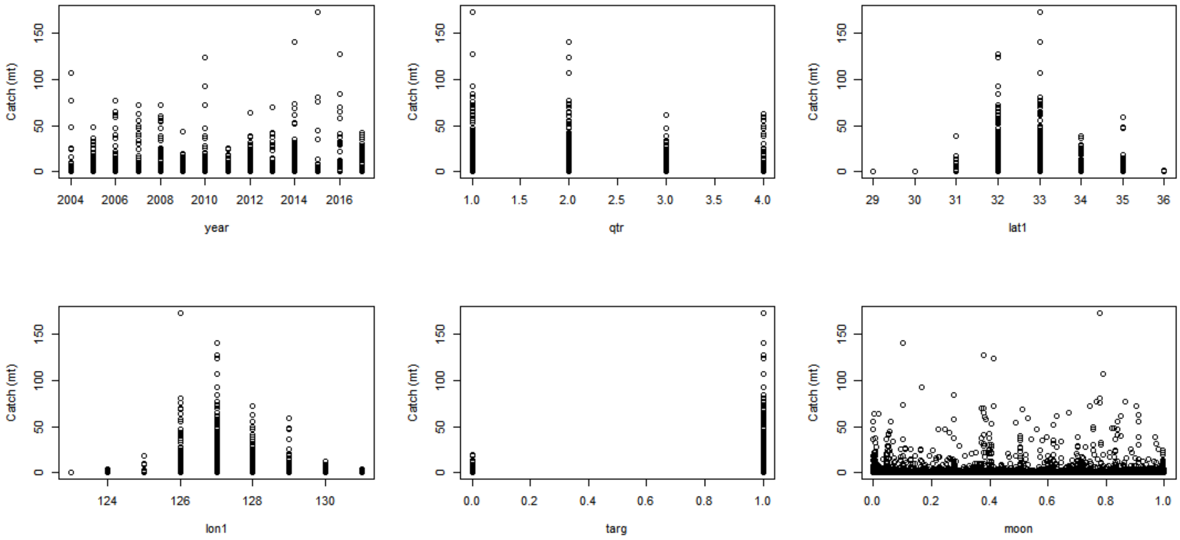


Fig. 8. Response (catch of PBF) versus predictor variables.

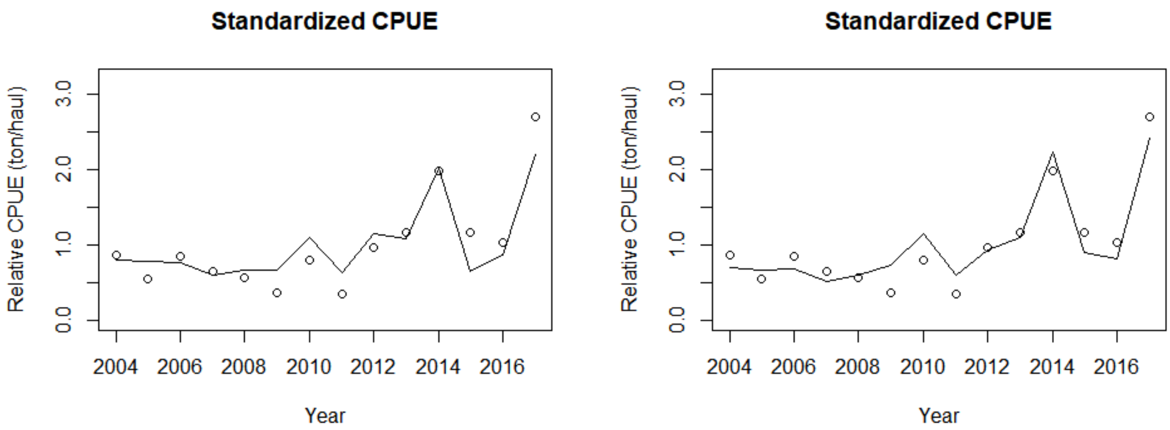


Fig. 9. The standardized yearly PBF CPUE indices for the whole (left) and the core (right) area.

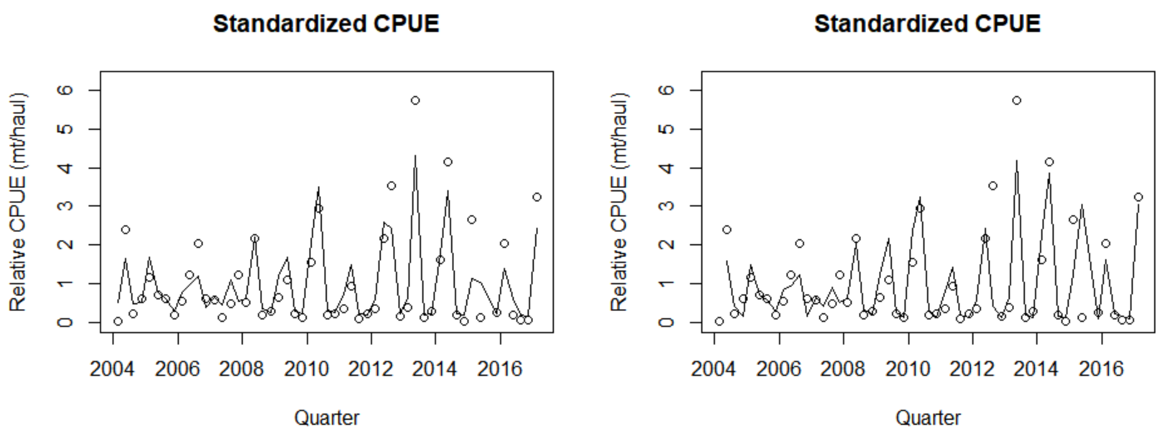


Fig. 10. The standardized quarterly PBF CPUE indices for the whole (left) and the core (right) area.

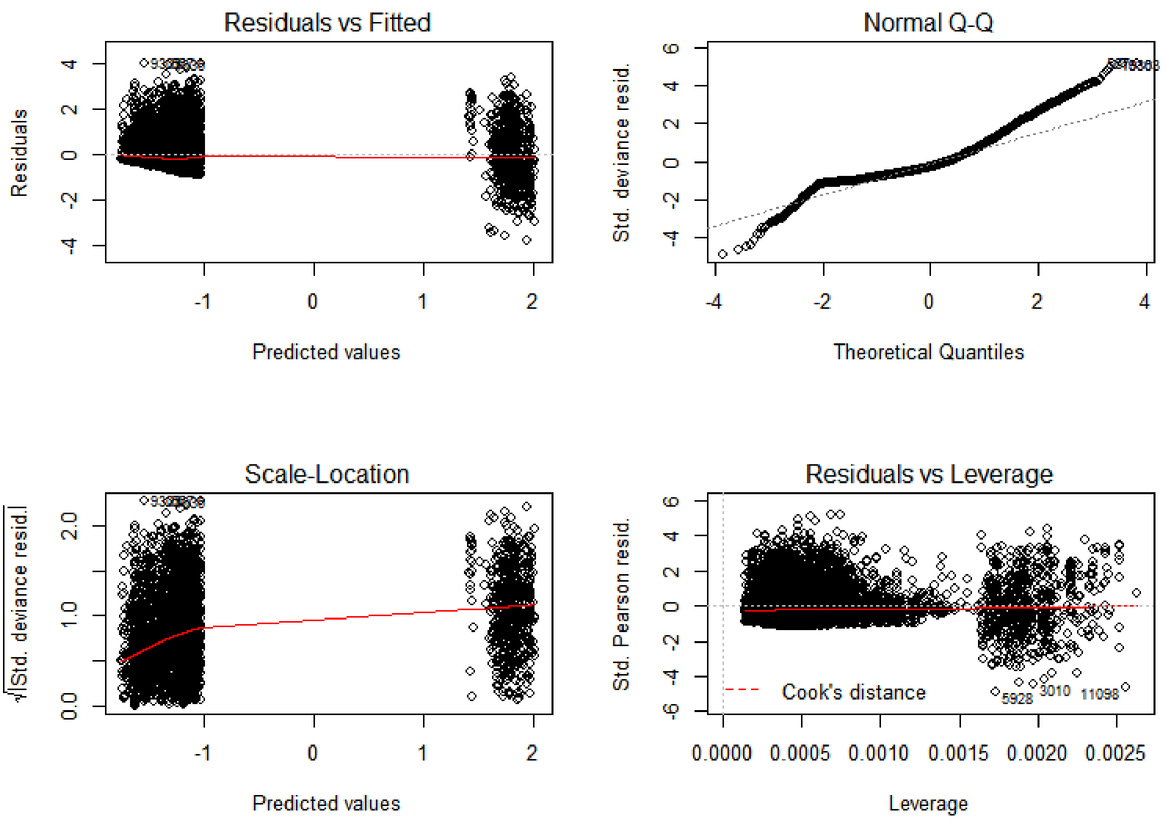


Fig. 11. GLM diagnostic plots for the core area.

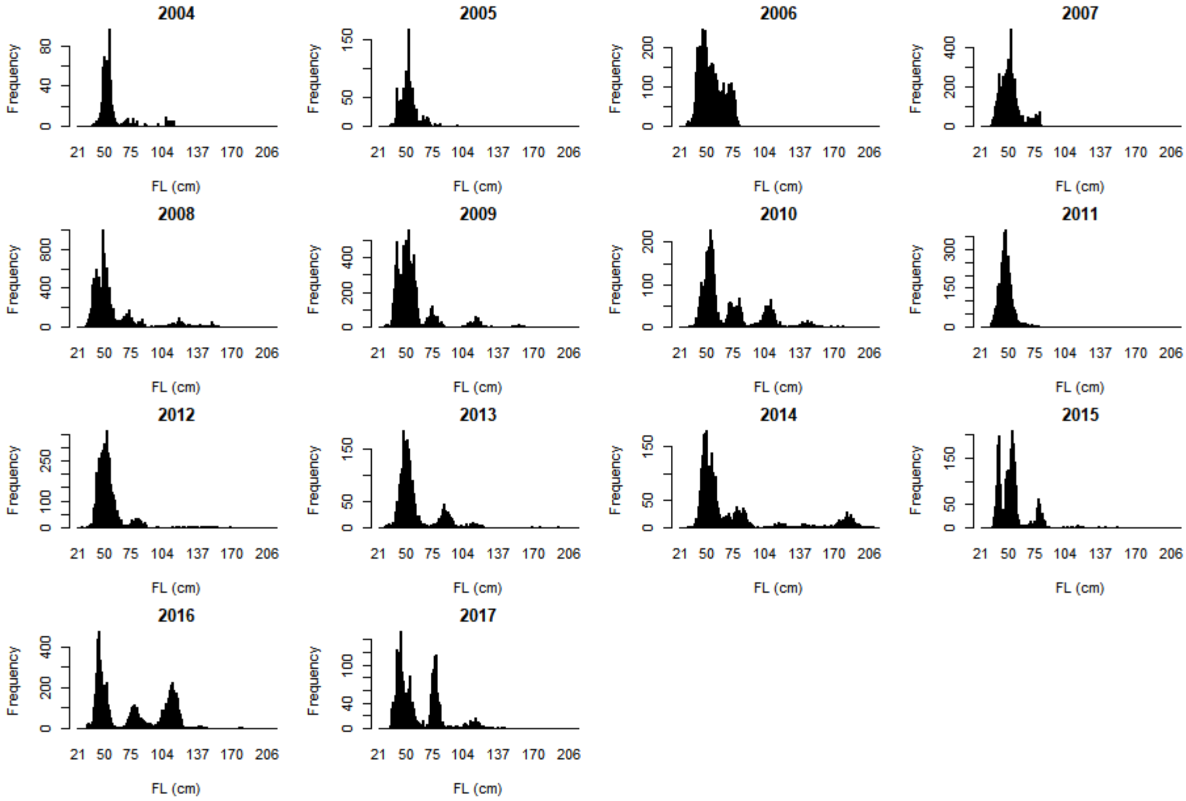


Fig. 12. The distributions of fork length of PBF caught by the Korean offshore large purse seine fishery.