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Update Standardization of CPUE for Chilean Jack Mackerel (*Trachurus murphyi*) from Chinese Trawl Fleet

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Gang Li, Xiaorong Zou, Yinqi Zhou, Lin Lei

College of Marine Sciences, Shanghai Ocean University, Shanghai, China

National Distant-water Fisheries Engineering Research Center,
Shanghai Ocean University, Shanghai, China

During the 10th SWG and its subgroup meeting held in Port Vila, Vanuatu, China submitted a report about CPUE standardization for Chilean jack mackerel based on catch and effort data of Chinese trawl fishery (SWG-10-JM-06). The Jack mackerel Sub Group noted that three environmental variables (Sea surface temperature, Sea surface temperature anomaly and El Niño effects) were likely to be highly correlated, so that the higher explained deviance by the GLM model was misleading. In order to resolve this problem and get the new standardized CPUE based on update catch and effort of Chinese trawl fishery, new environmental variables have been selected and general additive models (GAM) to standardize the nominal Chilean jack mackerel catch rate of the Chinese trawl fishery used to help the better understanding. .

Materials & Methods

Catch and effort data (2001-2011) were collected from the logbooks of the Chinese factory trawling fleets for Chilean jack mackerel. Effort was measured as haul times in hours, and CPUE was expressed as ton per hour. Therefore, monthly catch rate by vessel in the 0.5° × 0.5° cell was calculated as the ratio of the recorded catch to the total fishing hours.

Five environmental variables, Sea surface temperature (SST), Sea surface height (SSH), Chlorophyll-a concentration (Chl-a), Nino 3.4 index and El Niño-La Niña events (ELE) were used to build GAM models. Monthly SST (9 km resolution), SSH (0.2° resolution) and Chl-a (0.1° resolution) data were downloaded from Live Access Server (LAS) of NOAA OceanWatch (http://oceanwatch.pifsc.noaa.gov/las/servlets/dataset), and Nino 3.4 index was obtained from the NOAA Climate Prediction Center (http://www.cpc.ncep.noaa.gov). El Niño and La Niña events were expressed as 1 and −1, respectively, while in normal years, the value of monthly ELE was 0. SST, SSH and Chl-a data were averaged 0.5° grid cells to match the resolution of CPUE data.

Stepwise GAM was applied to the standardization of catch rate for Chilean jack mackerel from Chinese fleets in the SE Pacific Ocean from 2001 to 2011. A total of 10 factors were tested and selected one by one to add into GAM, including Year, Month, Vessel, Latitude, Longitude, ELE, Nino3.4 index, SST, SSH and Chl-a. For GAM analyses, temporal (Year and Month), spatial (Longitude and Latitude), fishing technological (Vessel code) and environmental factors are the explanatory variables, and the natural logarithm of the Chilean jack mackerel catch-rate +0.1 is the response variable. Constant 0.1 was added to deal with computational problem related to the undefined logarithm of zero (Maunder and Punt, 2004; Campbell, 2004; Su et al., 2008). Year, Month, Vessel code and ELE were the factors, whereas the remaining five factors were covariates in and GAMs. The full GAM was expressed as:

Ln(CPUE+0.1) ~ Year + Month + Vessel + ELE + s(Longitude) + s(Latitude) + s(SST) + s(SSH) + s(Chl-a) + s(Nino3.4 index)

Models were built by testing step by step, which is adding new variables one by one and observing the corresponding improvement on the fit with non-significant variables omitted. Alternative model structures (different choices on the explanatory variables) were compared using the Akaike Information Criterion (AIC), pseudo-coefficient of determination (pseudo-R^2), and adjusted pseudo-R^2 (Su et al., 2008). The optimum GAM was selected with the smallest AIC, largest pseudo-R^2 and adjusted pseudo-R^2:

$$\text{Pseudo-}R^2 = 1 - \frac{\text{Residual deviance}}{\text{null deviance}} \quad \text{Adjusted pseudo-}R^2 = 1 - \frac{\text{Residual deviance/degree of freedom}}{\text{null deviance/degree of freedom}}$$

Results

A total of 7313 data records were analyzed. Stepwise GAM building using the AIC, Pseudo R^2 and Pseudo adjusted R^2 showed all the explanatory variables were significant ($P < 0.05$, Table 1). The explanatory variables, one by one were tested and added to the GAM model, the residual deviance and AIC were significantly reduced, whereas the explained cumulative variance, Pseudo R^2 and Pseudo adjusted R^2 were increased consistently. Together these indicated that the final model with the 10 variables provided better fits to catch rate data.

The final GAM explained 29.31% of the variance in nominal CPUE (Table 1). The temporal factor Month was the most influential effect which explained 15.04% of the deviance in Chilean jack mackerel CPUE, followed by Vessel (6.00%), Year (4.16%), Latitude (1.40%), Longitude (1.08%), SST(0.49%), ELE(0.38%), SSH(0.34%), Nino3.4 index(0.32%) and Chl-a(0.01%).

The impacts of the same variables (Year, Month, Vessel, ELE, Latitude, Longitude, SST and Nino3.4 index) on CPUE by the two time series catch and effort data (2001-2010/2001-2011) showed the same trends (Fig.1), and Month, Vessel and Year (ranked by explained deviance) were always the first important three factors.

The impact of Month on CPUE was the foremost factor, contributing to 51.3% of the total reduction in deviance. The intra-annual seasonality in CPUE was evident from the Month effect. CPUE was lower at the beginning of the fishing season, with a peak in autumn and winter and continuously decreases after October (Fig.1). These indicated that April to July was the most favorable fishing season for Chilean jack mackerel off central-southern Chile. Monthly catches and CPUE (ton per day) of Chilean jack mackerel by European Union vessels showed similar seasonal trends (Corten and Janusz, 2010).

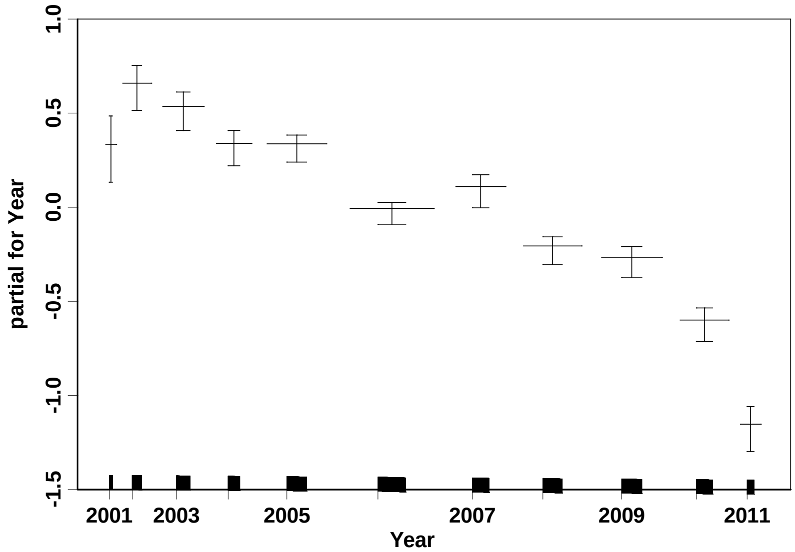
The estimated Year effect showed a declining trend in CPUE from 2002 and 2011, except for a small increase in 2007. The CPUE declined to the lowest level in 2011 (Fig.1). The estimated year effect in

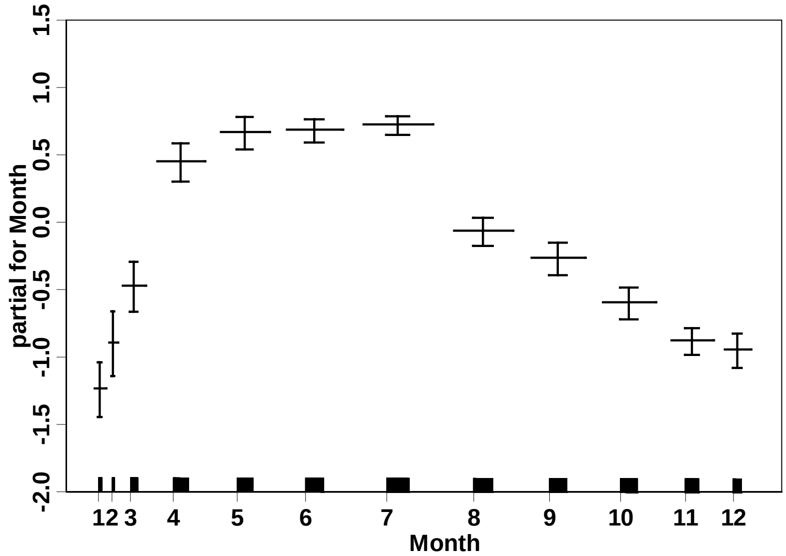
2001 was biased due to the small sample size of catch rate data, which were retrieved from three trawlers operating brokenly during the second half-year of 2001. Compared to the nominal CPUE and GAM-standardized CPUE showed obvious annual variations in the lower standardized indices. During the last three years, all the 3 indices reflected the same decreasing trend (Fig.2).

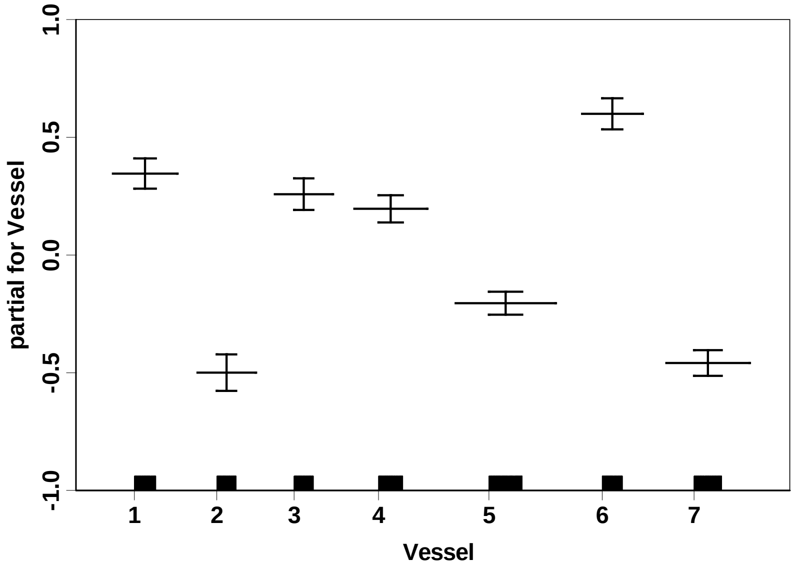
The GAM plot of SSH showed a U-shaped curve. The lowest catch rate was found when SSH was about 10cm. The CPUE decreased when SSH ranged from -15cm to 10cm and increased when SSH ranged from 10cm to 45cm. Higher catch rate values were observed in two SSH range: -10 – 0cm and 30 – 40cm (Fig.1). Although Chl-a explained 0.01% of the total deviance only, however, its impacts on CPUE was significant ($P<0.05$, Table 1). Most the fishing activities were occurred in a narrow range of chlorophyll-a concentration (0.05-0.26mg/m^3), and higher CPUE was found when SSH ranged from 0.10 to 0.15 mg/m^3 (Fig.1).

Table 1 Stepwise GAM building for influencing factors of the Chilean jack mackerel catch rate of Chinese factory trawl fishing fleets (2001-2011)

Added terms	d.f.	Deviance	Resid. d.f.	Resid. dev.	*p*	Cumulative explained dev. %	AIC	Pseudo adj. R^2	Pseudo R^2
null	1	9547.65	7312	-	-	-	-	-	-
+Year	9	9150.64	7302	397.01	0.0000	4.16	22416.75	0.040	0.042
+Month	11	7714.85	7291	1435.78	0.0000	19.20	21190.59	0.190	0.192
+Fleet	6	7142.43	7285	572.42	0.0000	25.19	20638.81	0.249	0.252
+ELE	2	7105.86	7283	36.57	0.0000	25.57	20605.27	0.253	0.256
+s(Longitude)	1	7002.31	7279	103.56	0.0000	26.66	20499.91	0.263	0.267
+s(Latitude)	1	6869.08	7275	133.22	0.0000	28.05	20361.43	0.277	0.281
+s(SST)	1	6821.88	7271	47.20	0.0000	28.55	20313.01	0.281	0.285
+s(SSH)	1	6789.21	7267	32.67	0.0000	28.89	20279.90	0.285	0.289
+s(Chl-a)	1	6779.85	7263	9.36	0.0412	28.99	20271.81	0.285	0.290
+s(Nino3.4)	1	6748.92	7259	30.93	0.0000	29.31	20240.38	0.288	0.293


1.0
0.5
0.0
-0.5
-1.0
-1.5
partial for Year
2001
2003
2005
2007
2009
2011
Year


1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
partial for Month
1 2 3 4 5 6 7 8 9 10 11 12
Month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0.5
0.0
-0.5
-1.0
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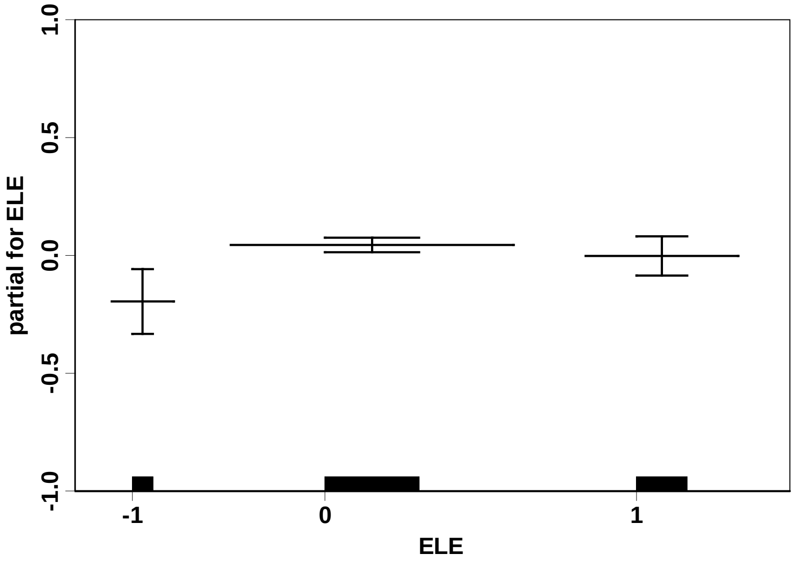
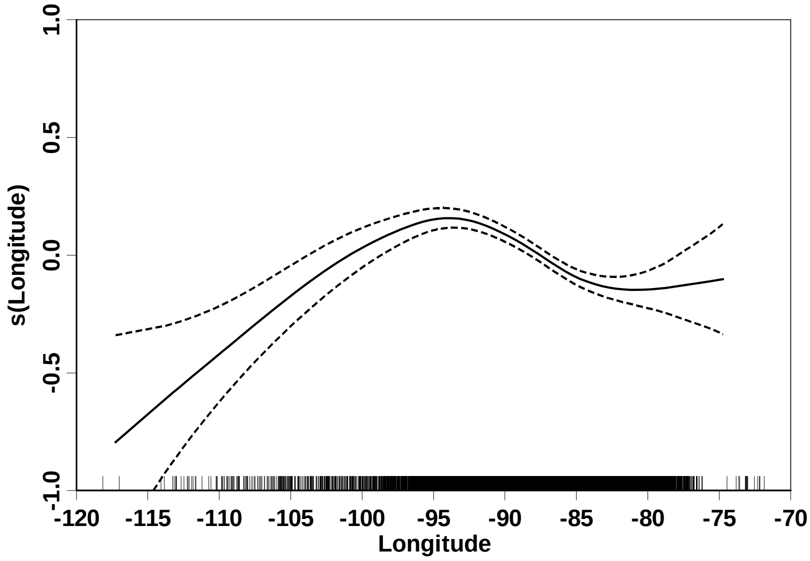
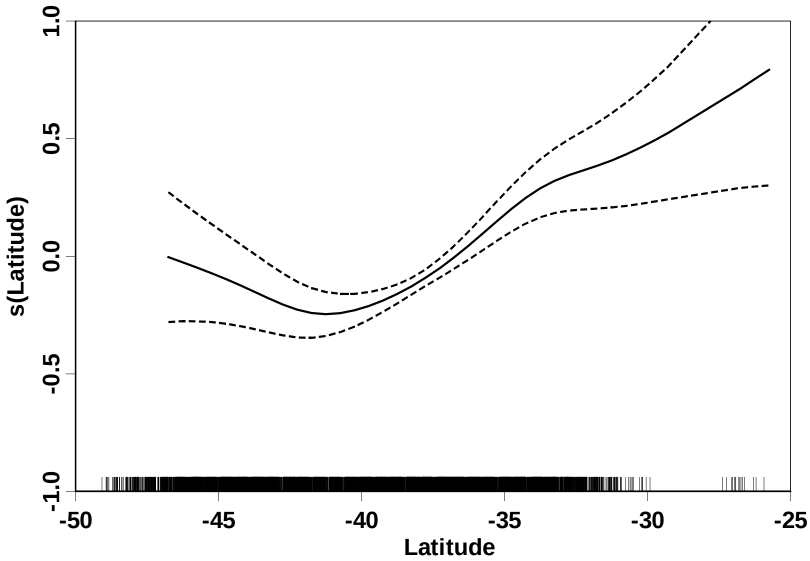
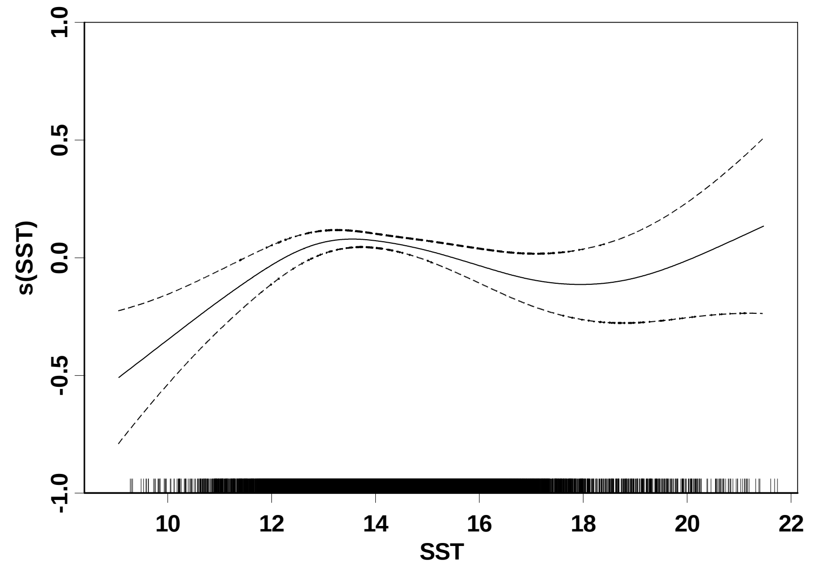
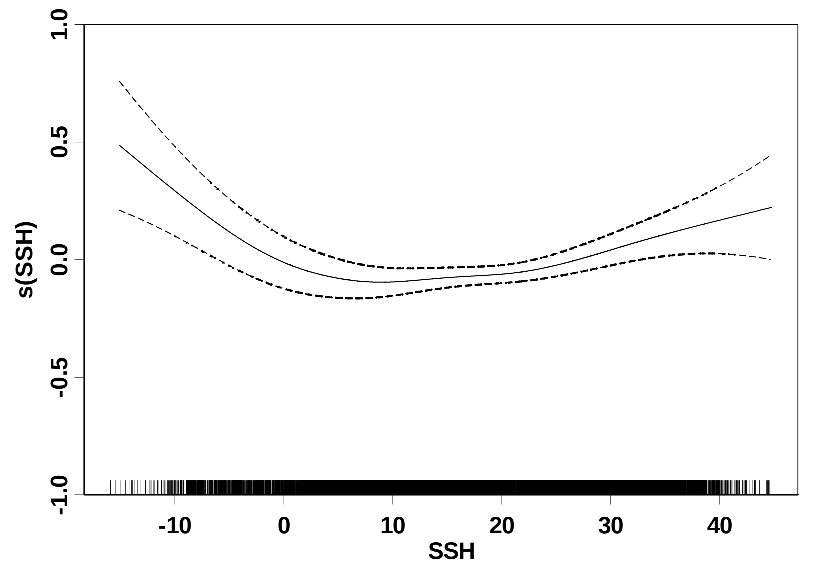
1 2 3 4 5 6 7
Vessel

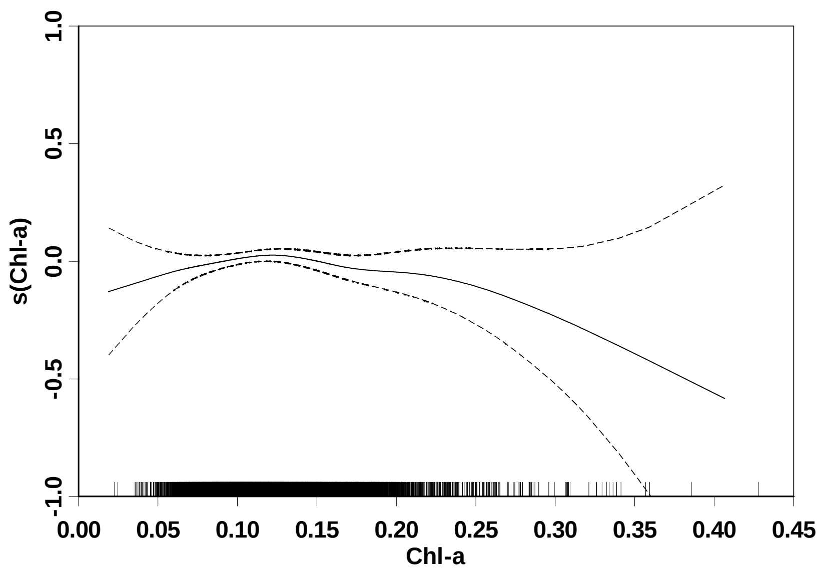

1.0
0.5
0.0
-0.5
-1.0
partial for ELE
-1
0
1
ELE


1.0
0.5
0.0
-0.5
-1.0
s(Longitude)
-120
-115
-110
-105
-100
-95
-90
-85
-80
-75
-70
Longitude


1.0
0.5
0.0
-0.5
-1.0
s(Latitude)
-50
-45
-40
-35
-30
-25
Latitude


s(SST)
1.0
0.5
0.0
-0.5
-1.0
10
12
14
16
18
20
22
SST


s(SSH)
1.0
0.5
0.0
-0.5
-1.0
-10
0
10
20
30
40
SSH


s(Chl-a)
1.0
0.5
0.0
-0.5
-1.0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
Chl-a

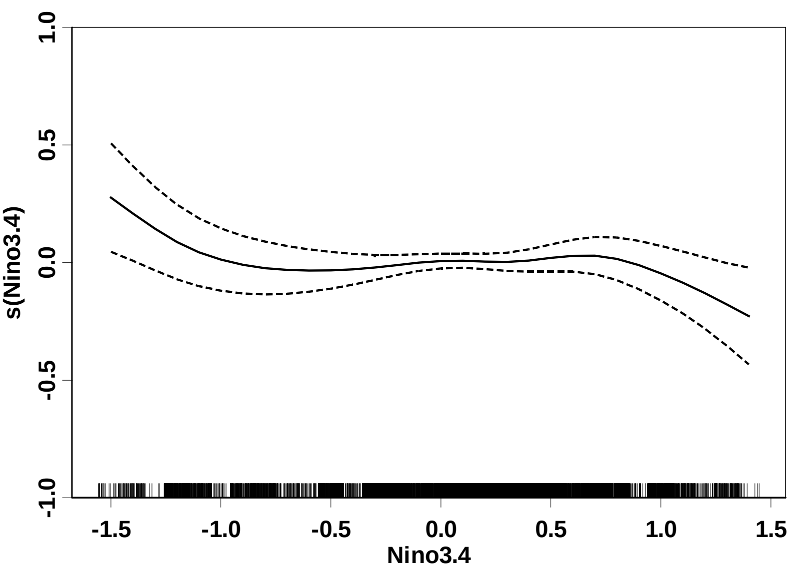


Fig.1 GAM-estimated impact of the main effects on log-transformed catch rate of Chilean jack mackerel (2001-2011).

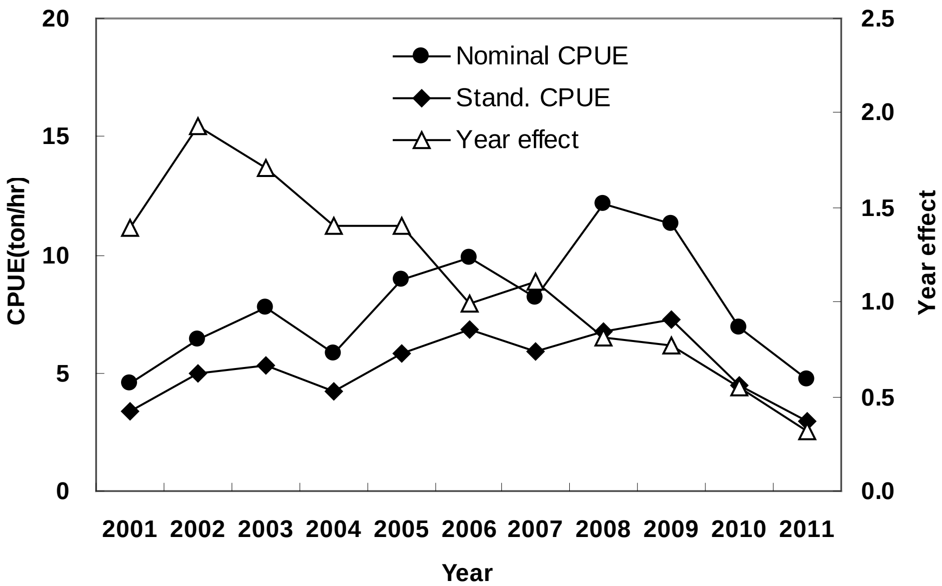


Fig.2 Nominal CPUE, GAM-standardized CPUE, and year effects on CPUE estimated by GAM analysis.

Reference

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