International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean

# Standardizing Catch and Effort Data of the Taiwanese Distant-Water Tuna Longline Fishery for Blue Marlin (*Makaira nigricans*) in the Pacific Ocean, 1967-2011[1]

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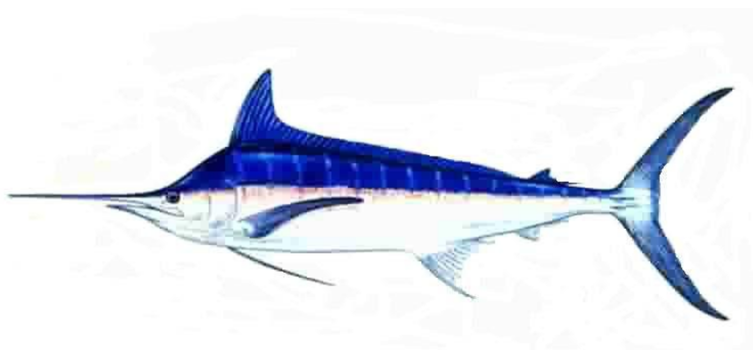

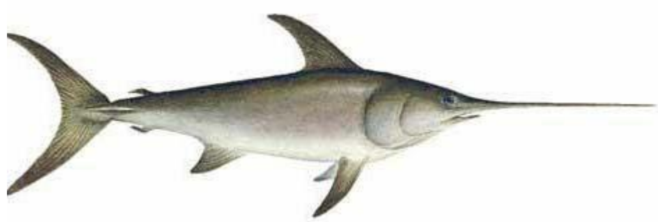

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# Standardizing catch and effort data of the Taiwanese distant-water tuna longline fishery for blue marlin (*Makaira nigricans*) in the Pacific Ocean, 1967-2011*


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## Abstract

The catch and effort data for blue marlin in the Taiwanese distant-water tuna longline fishery in the Pacific Ocean were standardized using generalized additive models. Task II data (aggregated into 5º×5º grid) for 1967-2011 and those with hooks per basket (HPB) information for 1995-2011 were used for the standardization of CPUE (catch per unit effort) in this study. The CPUE standardization were conducted by three periods, 1967-1978, 1979-1999, and 2000-2011, due to the changes in targeting species since 2000 and the fishing ground shift in early periods. Results show that the standardized CPUE of blue marlin were generally stable over 1979-1999, but noticeably increased thereafter. The effect of HPB was statistically significant in the CPUE standardization. However, the CPUE trend with HPB information included in the model for 2000-2011 was similar to those without HPB included. The standardized CPUEs of blue marlin derived from this study could be used as basic input data for the assessment of this stock.



**Keywords:** abundance index, generalized additive model, hooks per basket.


## Introduction

Blue marlin (*Makaira nigricans*) is a highly migratory species distributed throughout tropical and temperate waters of the Pacific Ocean (Su et al., 2011). A single stock of blue marlin in the Pacific Ocean has been assumed based on genetic analyses (Graves and McDowell, 2003) and fishery catch-rate data (Kleiber et al., 2003). This assumption is also supported by the results of tagging experiments, which have demonstrated that blue marlin migrate long distances (>8,000 km in some instances) and throughout the Pacific basin (Hinton, 2001).

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Blue marlin are the largest of the billfishes, attaining up to 450 cm in length and over 900 kg in weight, and are the most popular gamefish because of their size and fighting ability (Molony, 2008). They exhibit, however, sexual dimorphism in size, with males reaching a maximum size of 200 cm in length while females can grow to much more than this (Wilson et al., 1991). The sizes-at-maturity of blue marlin also differ between males and females, with estimated size at about 130 and 180 cm EFL (eye fork length) respectively (Sun et al., 2009). Therefore, the assessment method for blue marlin in the Pacific Ocean need to take account of sex structure to improve the stock assessment, as suggested by previous studies (e.g., Su et al., 2012).

The objective of this study was to standardize the catch and effort data of the Taiwanese distant-water tuna longline fishery for blue marlin in the Pacific Ocean. The standardized abundance indices of blue marlin derived from this study could provide basic, necessary input data for stock assessments of this species.

## Materials and methods

*Fishery data*

Task II data of the Taiwanese distant-water tuna longline fishery in the Pacific Ocean for blue marlin, including catch (in number of fish) and fishing effort (in number of hooks) for 1967-2011 and those with hooks per basket (HPB) information from 1995 to 2011, were obtained from the Oversea Fisheries Development Council (OFDC, Taiwan). This data set contains information on time (year and month) and location (latitude and longitude) which were aggregated in 5º by 5 º grid and month. CPUE is expressed as the number of fish caught per 1000 hooks in this study.

*Statistical model*

Generalized additive models (GAMs) are a standard and commonly used approach for standardizing catch and effort data, assuming that the expected value of a response variable is related to a linear combination of exploratory variables (Maunder and Punt, 2004). GAMs were thus used to standardize the catch and effort data of the Taiwanese distant-water tuna longline fishery for blue marlin in the Pacific Ocean. The full GAM model is expressed as follows:

$$\mathbf{BUM \sim Year + s(Month) + s(Lat) + s(Lon) + s(Lat{:}Lon) + s(HPB)} \qquad (1)$$

where BUM is the nominal CPUE of blue marlin, added with a constant;

Year is the factor for year;
Month is the month effect;
Lat is the latitude effect;
Lon is the longitude effect;
Lat:Lon is the interaction between latitude and longitude;
HPB is the hooks per basket information; and
s(X) denotes a spline smoother function of the covariate X.

*Diagnostic analysis*

Diagnostic plots (i.e., distribution of residuals and quantile-quantile (Q-Q) plot) were used to assess the assumed error distribution (log-normal distribution). The deviance analysis, the $\chi^2$ test, and AIC (Akaike Information Criterion) values were also used to examine the model fitting.

**Results and discussion**

There are in total 21,350 catch and effort records in 5º by 5 º grids for the Taiwanese distant-water tuna longline fishery in the Pacific Ocean for 1967-2011. However, the number of catch and effort observations with HPB information reduced substantially, because the HPB information is only available since 1995. In general, high nominal CPUEs of blue marlin occur in tropical waters of the Pacific Ocean for the Taiwanese distant-water tuna longline fishery (Fig. 1). The catches of blue marlin in Taiwan, from various fisheries, have increased gradually since the 1960s, most of which came from the offshore longline fishery (Sun et al., 2011). Annual catches of blue marlin from the Taiwanese distant-water tuna longline fishery were low before 2000, but have increased substantially to more than 1,000 mt afterward (Fig. 2).

The residual distributions based on a lognormal error distribution appear normal in the GAM analysis (Figs. 3 and 4), which confirms the assumption of error models for lognormal distribution to standardize catch and effort data of the Taiwanese tuna longline fishery, except for the early period due to limited data points. According to the Q-Q plot, this assumption is also suitable to model the CPUE of Pacific blue marlin for this fleet, even when HPB information was included in the standardization (Figs. 3 and 4). Therefore, the CPUE standardization for blue marlin in this study was consequently based on the lognormal error distribution.

The effects considered in the GAM models were all statistically significant based on the $\chi^2$ test ($p < 0.01$) and the AIC values, including year, month, latitude, longitude, and the interaction between latitude and longitude, as well as the HPB effect (Table 1). The deviance explained by the model for standardizing the blue marlin CPUE was 32.1% (1967-2011), while the deviance explained by the model that included the HPB information was reduced to 30.4% (based on different data sets for 1995-2011). The proportion of total deviance explained by the additional HPB factor was 5.5%, which increased the $R^2$ from 0.288 to 0.304.

The standardized CPUEs of blue marlin for the Taiwanese distant-water longline fishery in the Pacific Ocean were generally stable over 1980-2000, although nominal CPUEs of blue marlin varied largely for a few of the years (Fig. 5). The CPUE trend of blue marlin substantially increased in recent 10 years (since 2000), probably due to the change in targeting species from albacore tuna (*Thunnus alalunga*) to bigeye tuna (*Thunnus obesus*). However, the CPUE trend of blue marlin with HPB information included in the CPUE standardization was similar to that standardized without HPB information in the model (Fig. 5). This may imply that the change in targeting cannot be quantified well in the CPUE standardization owing to a lack of more informative operational data, such as hooks-at-depth and bait types.

Given the changes in targeting species of the fishery from albacore to bigeye tuna since 2000, as well as the fishing ground shift from the South Pacific Ocean to the whole Pacific Ocean since the 1980s, the CPUE standardization of blue marlin in the Taiwanese distant-water longline fishery were conducted by three periods, 1967-1978, 1979-1999, and 2000-2011, to account for the temporal effect. The factors considered in the three CPUE standardizations were all statistically significant based on the $\chi^2$ test ($p < 0.01$) and the AIC values (Table 2). In general, the standardized CPUE series were consistent with those based on the single time period, but it appears that the three separate standardized CPUE series fit the observed data (nominal CPUE) better than the single time period CPUE series (Fig. 6).

The effect of HPB was statistically significant in the CPUE standardization of blue marlin. However, the CPUE trend with HPB information included in the model for 2000-2011 was almost identical to that without HPB included. The standardized CPUE series with HPB included in the model were considered (by the working group) the best available scientific information from the fishery owing to additional deviance explained by HPB, compared with the one without HPB. Therefore, the working group agreed to use these abundance indices, as well as the CPUE series in early two periods, in the coming stock assessment for Pacific blue marlin in 2013.

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Table 1. Deviance tables for the models selected to standardize the CPUE of blue marlin caught in the Taiwanese distant-water longline fishery in the Pacific Ocean.

(a) 1967-2011 (without HPB)

| **Predictor variable** | **Residual deviance** | **Deviance explained** | **% of deviance explained** | **AIC** | $\boldsymbol{P(\chi^2)}$ |
|---|---|---|---|---|---|
| NULL | 24304 | | | | |
| +Year | 21367 | 2936.3 | 37.7 | 61430 | < 0.01 |
| +s(Month) | 20857 | 510.2 | 6.5 | 60913 | < 0.01 |
| +s(Latitude) | 17431 | 3426.4 | 44.0 | 57036 | < 0.01 |
| +s(Longitude) | 16855 | 575.8 | 7.4 | 56323 | < 0.01 |
| +s(Latitude:Longitude) | 16511 | 343.5 | 4.4 | 55905 | < 0.01 |
| $R^2$ | **0.321** | | | | |

(b) 1995-2011 (with HPB)

| **Predictor variable** | **Residual deviance** | **Deviance explained** | **% of deviance explained** | **AIC** | $\boldsymbol{P(\chi^2)}$ |
|---|---|---|---|---|---|
| NULL | 24750 | | | | |
| +Year | 23616 | 1134.3 | 15.1 | 59762 | < 0.01 |
| +s(Month) | 23288 | 327.9 | 4.4 | 59492 | < 0.01 |
| +s(Latitude) | 18830 | 4458.4 | 59.2 | 55306 | < 0.01 |
| +s(Longitude) | 18217 | 612.8 | 8.1 | 54666 | < 0.01 |
| +s(Latitude:Longitude) | 17626 | 591.1 | 7.8 | 54056 | < 0.01 |
| +s(HPB) | 17215 | 410.9 | 5.5 | 53602 | < 0.01 |
| $R^2$ | **0.304** | | | | |

Table 2. Deviance tables for the models selected to standardize the CPUE of blue marlin caught in the Taiwanese distant-water longline fishery in the Pacific Ocean.

(a) 1967-1978 (without HPB)

| **Predictor variable** | **Residual deviance** | **Deviance explained** | **% of deviance explained** | **AIC** | $\boldsymbol{P(\chi^2)}$ |
|---|---|---|---|---|---|
| NULL | 2739.7 | | | | |
| +Year | 2708.3 | 31.4 | 22.6 | 11076 | < 0.01 |
| +s(Month) | 2685.5 | 22.8 | 16.4 | 11043 | < 0.01 |
| +s(Latitude) | 2641.7 | 43.9 | 31.6 | 10978 | < 0.01 |
| +s(Longitude) | 2639.3 | 2.3 | 1.7 | 10976 | < 0.01 |
| +s(Latitude:Longitude) | 2601.0 | 38.3 | 27.6 | 10920 | < 0.01 |
| $R^2$ | **0.05** | | | | |

(b) 1979-1999 (without HPB)

| **Predictor variable** | **Residual deviance** | **Deviance explained** | **% of deviance explained** | **AIC** | $\boldsymbol{P(\chi^2)}$ |
|---|---|---|---|---|---|
| NULL | 7328.4 | | | | |
| +Year | 7005.3 | 323.1 | 13.5 | 20024 | < 0.01 |
| +s(Month) | 6449.2 | 556.1 | 23.2 | 19454 | < 0.01 |
| +s(Latitude) | 5405.2 | 1044.0 | 43.6 | 18224 | < 0.01 |
| +s(Longitude) | 5062.0 | 343.2 | 14.3 | 17777 | < 0.01 |
| +s(Latitude:Longitude) | 4933.9 | 128.1 | 5.3 | 17617 | < 0.01 |
| $R^2$ | **0.327** | | | | |

(c) 2000-2011 (with HPB)

| **Predictor variable** | **Residual deviance** | **Deviance explained** | **% of deviance explained** | **AIC** | $\boldsymbol{P(\chi^2)}$ |
|---|---|---|---|---|---|
| NULL | 23346.6 | | | | |
| +Year | 22899.0 | 447.6 | 6.5 | 56847 | < 0.01 |
| +s(Month) | 22588.7 | 310.3 | 4.5 | 56510 | < 0.01 |
| +s(Latitude) | 18038.1 | 4550.6 | 66.4 | 56265 | < 0.01 |
| +s(Longitude) | 17374.8 | 663.3 | 9.7 | 52124 | < 0.01 |
| +s(Latitude:Longitude) | 16875.8 | 499.0 | 7.3 | 51445 | < 0.01 |
| +s(HPB) | 16489.5 | 386.3 | 5.6 | 50938 | < 0.01 |
| $R^2$ | **0.294** | | | | |

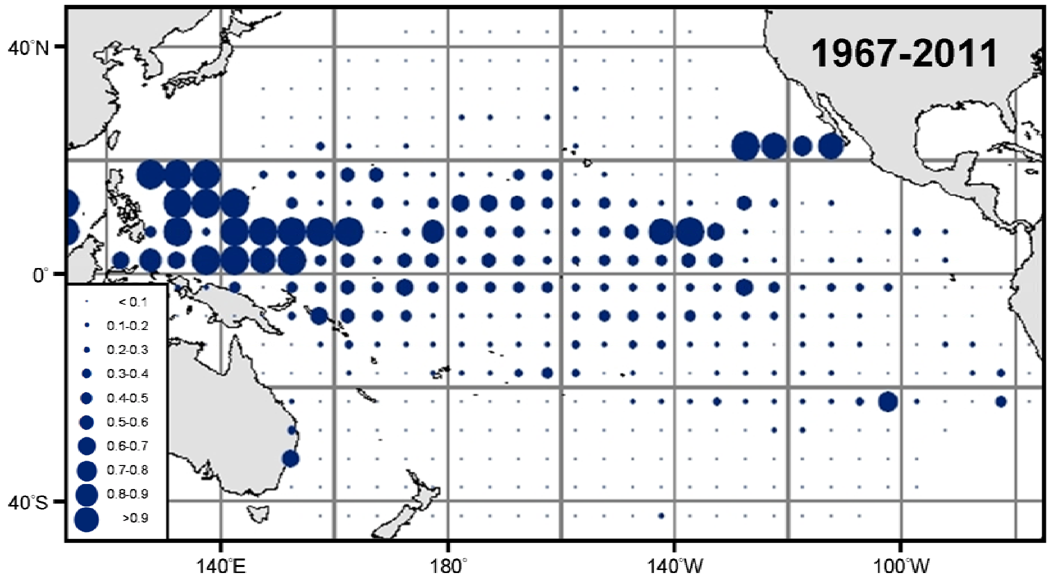


Fig. 1. Distribution of nominal CPUE (number of fish caught per 1000 hooks) for blue marlin caught in the Taiwanese distant-water longline fishery in the Pacific Ocean for 1967-2011.

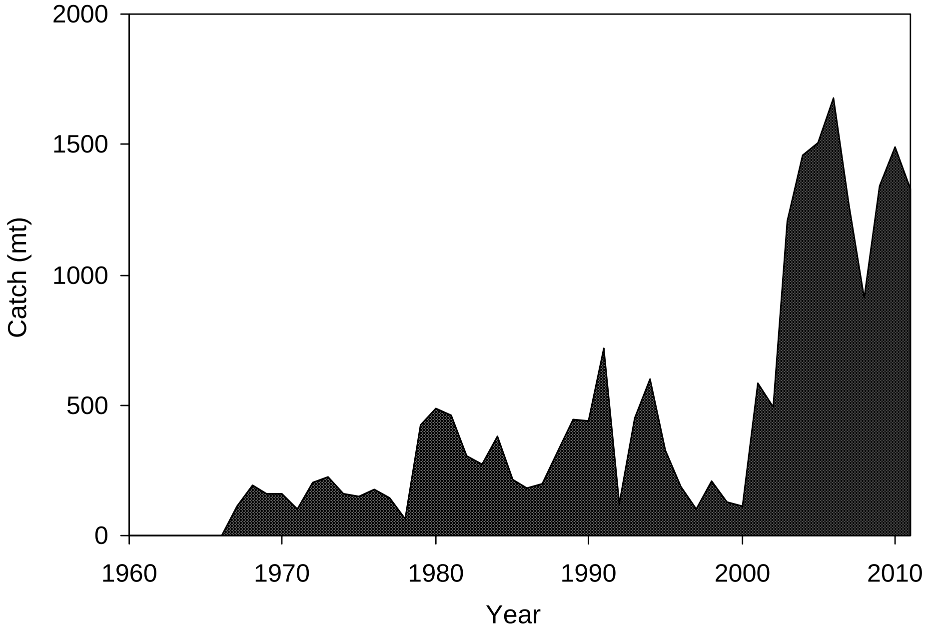


Fig. 2. Annual catches of blue marlin caught in the Taiwanese distant-water longline fishery in the Pacific Ocean for 1967-2011.

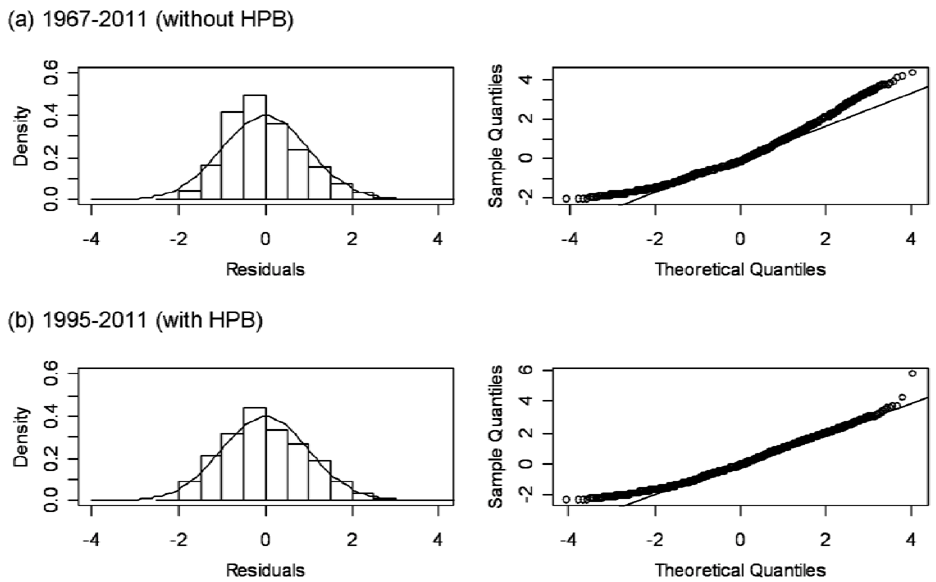


Fig. 3. Residual distributions and diagnostic Q-Q plots for the models selected to standardize the CPUE of blue marlin caught in the Taiwanese distant-water longline fishery in the Pacific Ocean for (a) 1967-2011 (without HPB information) and (b) 1995-2011 (with HPB information).

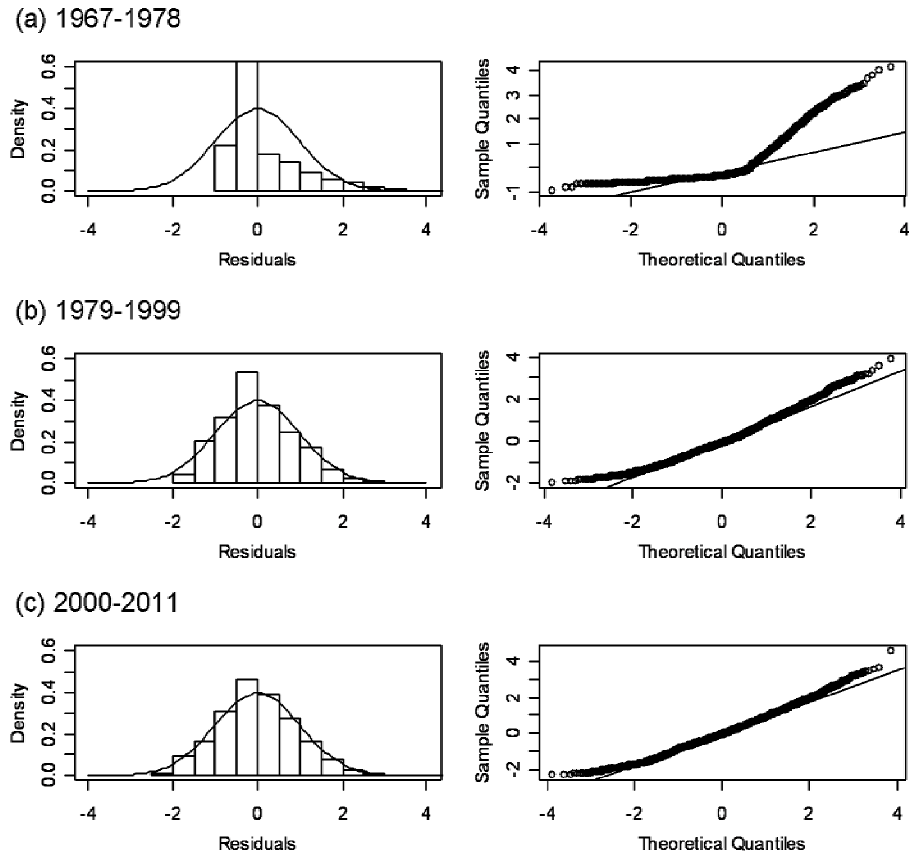


Fig. 4. Residual distributions and diagnostic Q-Q plots for the models selected to standardize the CPUE of blue marlin caught in the Taiwanese distant-water longline fishery in the Pacific Ocean for (a) 1967-1978 (without HPB information), (b) 1979-1999 (without HPB information), and (c) 2000-2011 (with HPB information).

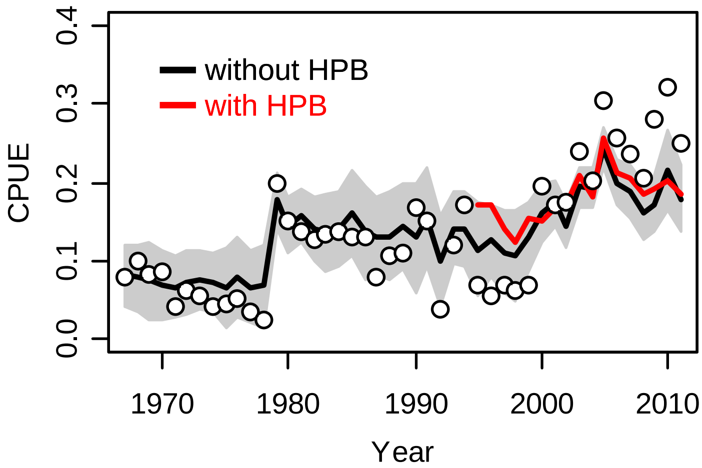


Fig. 5. Nominal (open circles) and standardized (black line: without HPB; red line: with HPB) CPUE of blue marlin caught in the Taiwanese distant-water longline fishery in the Pacific Ocean. CPUE is expressed as the number of fish caught per 1000 hooks. The shadows indicate point-wise standard errors for the standardized CPUE of blue marlin.

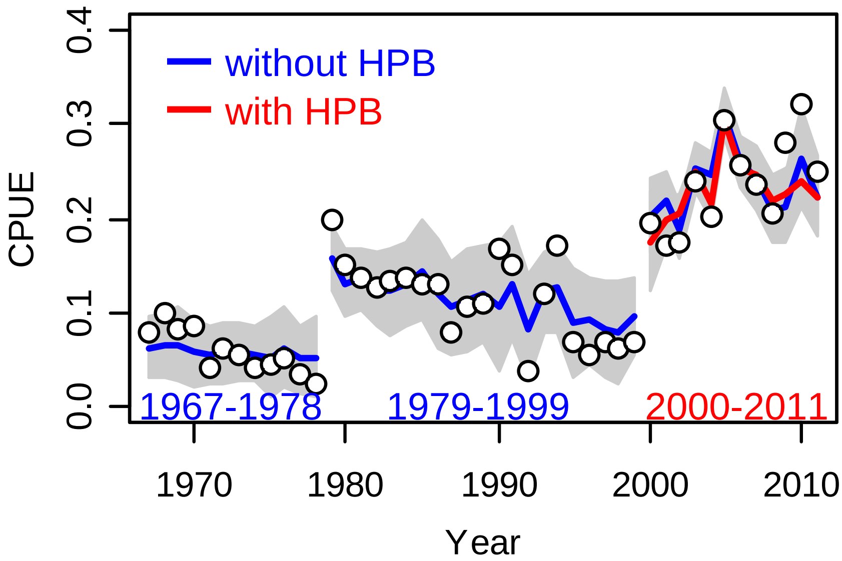


Fig. 6. Nominal (open circles) and standardized (blue line: without HPB; red line: with HPB) CPUE of blue marlin caught in the Taiwanese distant-water longline fishery in the Pacific Ocean for three time period 1967-1978, 1979-1999, and 2000-2011. CPUE is expressed as the number of fish caught per 1000 hooks. The shadows indicate point-wise standard errors for the standardized CPUE of blue marlin.