Standardized CPUE of striped marlin for the Taiwanese distant-water tuna longline fishery in the western and central North Pacific Ocean*

Chi-Lu Sun[1], Nan-Jay Su[2], and Su-Zan Yeh[1]

[1] Institute of Oceanography, National Taiwan University, Taipei, Taiwan

[2] Department of Environmental Biology and Fisheries Science, National Taiwan Ocean University, Keelung, Taiwan

Abstract

Catch and effort data for the Taiwanese distant-water tuna longline fisheries in the North Pacific Ocean were obtained from OFDC, and the CPUE (catch per unit effort) of striped marlin for the western and central North Pacific Ocean (WCNPO) stock was standardized using the generalized linear models (GLMs). Year, quarter, latitude, longitude, and the two-way interaction between latitude and longitude were included as predictors in the standardization models. Information on hooks per basket (HPB) has been available since 1995, and was thus incorporated in the CPUE standardization model for 1995-2013. All the factors considered in the models were statistically significant. The standardized CPUE of striped marlin derived from various models showed very similar abundance trends for this stock. In general, the standardized CPUE of striped marlin decreased gradually in the 1990s, but showed an obviously increasing trend from 2001 with a peak occurring during 2004-2005, and then decreased but increased again from 2009 until recent years.

Keywords: striped marlin, GLM, CPUE, standardization, tuna longline fishery

Introduction

Striped marlin (*Kajikia audax*) are widely distributed throughout tropical, subtropical, and temperate waters of the Pacific and Indian Oceans (Nakamura, 1985). They occasionally occur in the Atlantic Ocean near the Cape of Good Hope (Penrith and Cram, 1974), and are both recreationally and commercially important resources (McDowell and Graves, 2008). Most of striped marlin are caught as a bycatch in the pelagic longline fisheries targeting tunas (Hinton and Maunder, 2003). Based on the

---

* A working paper submitted to the Intercessional Workshop of the Billfish Working Groups of ISC, 13-20 January 2015, Honolulu, Hawaii, USA. Document not to be cited without author's written permission.

results of genetic studies and the larvae distribution of striped marlin occurring in spatially discrete regions in the Pacific Ocean in the same season, there were four possible stocks of striped marlin in the Pacific Ocean (McDowell and Graves, 2008). Striped marlin are highly abundant in the central North Pacific and the eastern tropical Pacific, but less abundant in the southern and western Pacific, as inferred from data from longline fisheries including the Japanese and Taiwanese fleets (Ueyanagi and Wares, 1975; Lien et al., 2014). The objectives of this study were to standardize catch and effort data of the Taiwanese distant-water tuna longline fishery for striped marlin of the WCNPO (western and central North Pacific Ocean) stock, which could be used as basic, necessary input data for stock assessment of this important resource.

Materials and methods

Fishery data

Catch and effort data of the Taiwanese distant-water tuna longline fishery in the North Pacific Ocean, including striped marlin catch (in number of fish caught) and fishing effort (in number of hooks employed) for 1974-2013 and those with hooks per basket (HPB) information from 1995 to 2013, were obtained from the Oversea Fisheries Development Council (OFDC) of Taiwan. This data set, aggregated by month and by 5º by 5º grid cell, contains information on time (year and month) and location (latitude and longitude), but was separated at 140˚W into the WCNPO and EPO (Eastern Pacific Ocean) stocks in the North Pacific Ocean as defined by ISC. CPUE (catch per unit effort) is expressed as the number of fish caught per 1000 hooks in this study.

Statistical model

Generalized linear models (GLMs) are a standard and commonly used approach for standardizing catch and effort data, assuming that the expected value of a transformed response variable is related to a linear combination of exploratory variables (Maunder and Punt, 2004). We thus applied GLMs to standardize catch and effort data of the Taiwanese distant-water tuna longline fishery for the WCNPO stock of striped marlin in the North Pacific Ocean.

Three standardization models were developed respectively in this study for an entire period (1974-2013) and two different periods of 1989-2013 and 1995-2013, due to the development of this fishery in this area and the availability of HPB information since 1995. Although the catch record of striped marlin started from 1974, this fishery has caught striped marlin constantly and regularly since 1989 (Fig. 1). The full GLM is expressed as follows:

MLS ~ Year + Quarter + Latitude + Longitude + Latitude:Longitude + HPB (1)

where MLS is the log-transformed CPUE of striped marlin, with a constant added;
Year is the factor for year;
Quarter is the factor for quarter;
Latitude is the factor for latitude;
Longitude is the factor for longitude;
Latitude:Longitude is the interaction between latitude and longitude;
HPB is hooks per basket information available since 1995.

Diagnostic analysis

Diagnostic plots (i.e., distribution of residuals and quantile-quantile (Q-Q) plot) were used to assess the assumed log-normal error distribution. The deviance analysis, the R^2, the χ^2 test, and AIC (Akaike Information Criterion) values were used to examine the model fitting for standardizing CPUE of striped marlin.

Results and discussion

Most of striped marlin were caught in the WCNPO for the Taiwanese distant-water tuna longline fishery, while small amount of the catches were taken from the EPO (Fig. 1). The catch of striped marlin from the WCNPO increased substantially from the late 1990s to near 250 mt in 2004, and then decreased to less than 100 mt during 2007-2013 (Fig. 1).

For the Taiwanese distant-water tuna longline fishery, high nominal CPUE of striped marlin for the WCNPO stock generally occurred in sub-tropical waters of the central North Pacific Ocean around 15ºN~25ºN, while striped marlin CPUE of the EPO stock from this fishery was high in waters close to the coast of Central America (Fig. 2, upper panel). Similar patterns can be found when plotting the nominal CPUE distribution of striped marlin with the data that HPB information is available (Fig. 2, lower panel). Latitude and longitude in 5º (and its interaction) were thus treated as spatial factors in the GLM analysis.

The residual distributions for both models of 1974-2013 and 1989-2013 based on a lognormal error distribution appear normal in the GLM analysis, which confirms the assumption of error models for lognormal distribution to standardize catch and effort data of the Taiwanese tuna longline fishery for striped marlin (Fig. 3). However, the residual distributions for the models that include HPB information (Fig. 3d) or not (Fig. 3c) appeared slightly skew comparing with normal distributions.

According to Q-Q plots, this assumption of lognormality is suitable to model the striped marlin CPUE for the WCNPO stock in the North Pacific Ocean for the Taiwanese distant-water longline fishery, although results from diagnostic analyses were less than ideal when data with HPB information were used to model striped marlin CPUE for 1995-2013 (Fig. 4). The CPUE standardization of striped marlin was consequently based on the lognormal error distribution in this study.

The factors considered in the three GLM models, including year, quarter, latitude, longitude, and the two-way interaction, were all statistically significant based on the χ^2 test (Table 1). Addition of HPB information into the model (1995-2013) also produced statistically significant effect and lower AIC values (Table 2). The deviance explained by the models of 1974-2013 and 1989-2013 were 22.1% and 21.1% respectively (Table 1). However, HPB only explained a small proportion of deviance (about 2.5% of total deviance explained) in the model of 1995-2013 for the WCNPO stock of striped marlin, which increased R^2 from 0.159 to 0.163 (Table 2).

The standardized CPUE of striped marlin for WCNPO stock from the four models generally all follow similar trends of nominal CPUE for the Taiwanese distant-water tuna longline fishery in the North Pacific Ocean, except for the early period in the 1970s for the model of 1974-2013 (Fig. 5). This is probably because the sample size of catch and effort data is small for years before 1989, while the sample size of observation increased substantially thereafter. However, the standardized CPUE of striped marlin derived from various models showed very similar abundance trends for this stock during 1995-2013 (Fig. 6).

In general, the standardized CPUE of striped marlin decreased gradually in the 1990s, but showed an obviously increasing trend from 2001 with a peak occurring during 2004-2005, and then decreased but increased again from 2009 until recent years (Fig. 6). Because the model of 1989-2013 can explain more deviance (21.1%) than the model of 1995-2013 with HPB included (16.3%), with better diagnostic results (Figs. 3-4), we suggest using the abundance index from the 1989-2013 model, as part of the basic input data for conducting the assessments of striped marlin in the western and central North Pacific Ocean (Table 3).

References

Hinton, M.G., Maunder, M.N. (2003). Status of striped marlin in the eastern Pacific Ocean in 2002 and outlook for 2003–2004. Report 4. Inter-American Tropical Tuna Commission, La Jolla, Calif.

Lien, Y.H., Su, N.J., Sun, C.L., Punt, A.E., Yeh, S.Z., Dinardo, G. (2014). Spatial and environmental determinants of the distribution of striped marlin (*Kajikia audax*) in the western and central North Pacific Ocean. Environmental Biology of Fishes, 97: 267-276.

Maunder, M.N. Punt, A.E.(2004). Standardizing catch and effort data: a review of recent approaches. Fisheries Research, 70: 141-159.

McDowell, J.R., Graves, J.E. (2008). Population structure of striped marlin (*Kajikia audax*) in the Pacific Ocean based on analysis of microsatellite and mitochondrial DNA. Canadian Journal of Fisheries and Aquatic Sciences, 65: 1307-1320.

Nakamura, I. (1985). FAO species catalogue. Vol. 5. Billfishes of the world. An annotated and illustrated catalogue of marlins, sailfishes, spearfishes and swordfishes known to date. FAO Fisheries Synopses 125, Rome, Italy.

Penrith, M.J., Cram, D.L. (1974). The Cape of Good Hope: a hidden barrier to billfishes. In Proceedings of the International Billfish Symposium Kailua–Kona, Hawaii, 9–12 August 1972. Part 2. Edited by R.S. Shomura and F. Williams. National Marine Fisheries Service, Seattle, Wash. NOAA Tech. Rep. NMFS SSRF-675. pp. 175–187.

Ueyanagi, S., Wares, P.G. (1975). Synopsis of biological data on striped marlin, *Tetrapturus audax* (Philippi, 1887). In Proceedings of the International Billfish Symposium, Kailua–Kona, Hawaii, 9–12 August 1972, Part 3. Species synopses. Edited by R.S. Shomura and F. Williams. National Marine Fisheries, Service, Seattle, Wash. NOAA Tech. Rep. NMFS SSRF-675. pp. 132–159.

Table 1. Deviance tables for the models selected to standardize striped marlin CPUE of the WCNPO stock for the Taiwanese distant-water tuna longline fishery in the North Pacific Ocean.

(a) 1974-2013

Predictor	Residual D.F.	Residual Deviance	Deviance Explained	R^2	χ^2 test *p*-value	AIC
NULL	3805	4057.7				11049
+Year	3774	3845.2	212.5	0.052	<0.01	10906
+Quarter	3771	3765.3	79.9	0.072	<0.01	10832
+Latitude	3763	3442.7	322.7	0.152	<0.01	10507
+Longitude	3746	3335.4	107.2	0.178	<0.01	10421
+Latitude:Longitude	3635	3161.6	173.8	0.221	<0.01	10439

(b) 1989-2013

Predictor	Residual D.F.	Residual Deviance	Deviance Explained	R^2	χ^2 test *p*-value	AIC
NULL	3489	3373.7				9790
+Year	3466	3217.9	155.9	0.046	<0.01	9671
+Quarter	3463	3150.3	67.6	0.066	<0.01	9603
+Latitude	3455	2917.1	233.3	0.135	<0.01	9350
+Longitude	3438	2832.3	84.8	0.160	<0.01	9281
+Latitude:Longitude	3328	2662.7	169.6	0.211	<0.01	9286

Table 2. Deviance tables for the models selected to standardize striped marlin CPUE of the WCNPO stock for the Taiwanese distant-water tuna longline fishery in the North Pacific Ocean. HPB information is included in the final model for 1995-2013.

Predictor	Residual D.F.	Residual Deviance	Deviance Explained	R^2	χ^2 test *p*-value	AIC
NULL	6231	4432.0				15565
+Year	6213	4233.2	198.8	0.045	<0.01	15315
+Quarter	6210	4174.9	58.2	0.058	<0.01	15235
+Latitude	6202	4018.1	156.8	0.093	<0.01	15013
+Longitude	6180	3926.6	91.5	0.114	<0.01	14913
+Latitude:Longitude	6061	3729.2	197.4	0.159	<0.01	14829
+HPB	6050	3711.2	17.9	0.163	<0.01	14821

Table 3. Standardized CPUE and CV of striped marlin caught in the Taiwanese distant-water tuna longline fishery for the WCNPO stock in the North Pacific Ocean.

(a) 1989-2013 (without HPB)			(b) 1995-2013 (with HPB)		
Year	**CPUE**	**CV**	**Year**	**CPUE**	**CV**
1989	0.052	15.2			
1990	0.051	19.2			
1991	0.091	18.6			
1992	0.052	28.4			
1993	0.077	21.5			
1995	0.082	12.2	1995	0.165	14.1
1996	0.063	10.0	1996	0.124	11.6
1997	0.054	11.0	1997	0.104	12.0
1998	0.053	12.9	1998	0.066	14.4
1999	0.062	9.8	1999	0.113	10.7
2000	0.056	7.9	2000	0.107	11.5
2001	0.049	6.8	2001	0.108	8.5
2002	0.071	8.1	2002	0.126	8.5
2003	0.068	7.6	2003	0.112	8.6
2004	0.095	5.7	2004	0.163	8.1
2005	0.095	6.1	2005	0.165	8.2
2006	0.067	6.7	2006	0.130	8.1
2007	0.062	6.8	2007	0.117	8.4
2008	0.054	7.4	2008	0.105	8.6
2009	0.046	7.6	2009	0.094	8.7
2010	0.056	7.6	2010	0.114	8.8
2011	0.061	6.7	2011	0.109	8.6
2012	0.061	7.5	2012	0.117	9.1
2013	0.071	7.5	2013	0.134	9.4

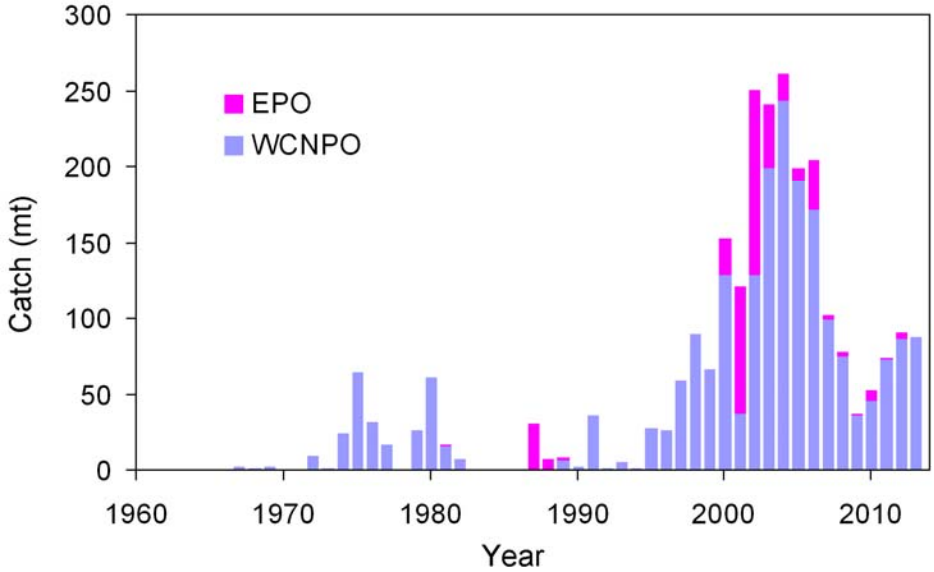

Fig. 1. Annual catches of striped marlin caught in the Taiwanese distant-water tuna longline fishery for the WCNPO and EPO stocks in the North Pacific Ocean.

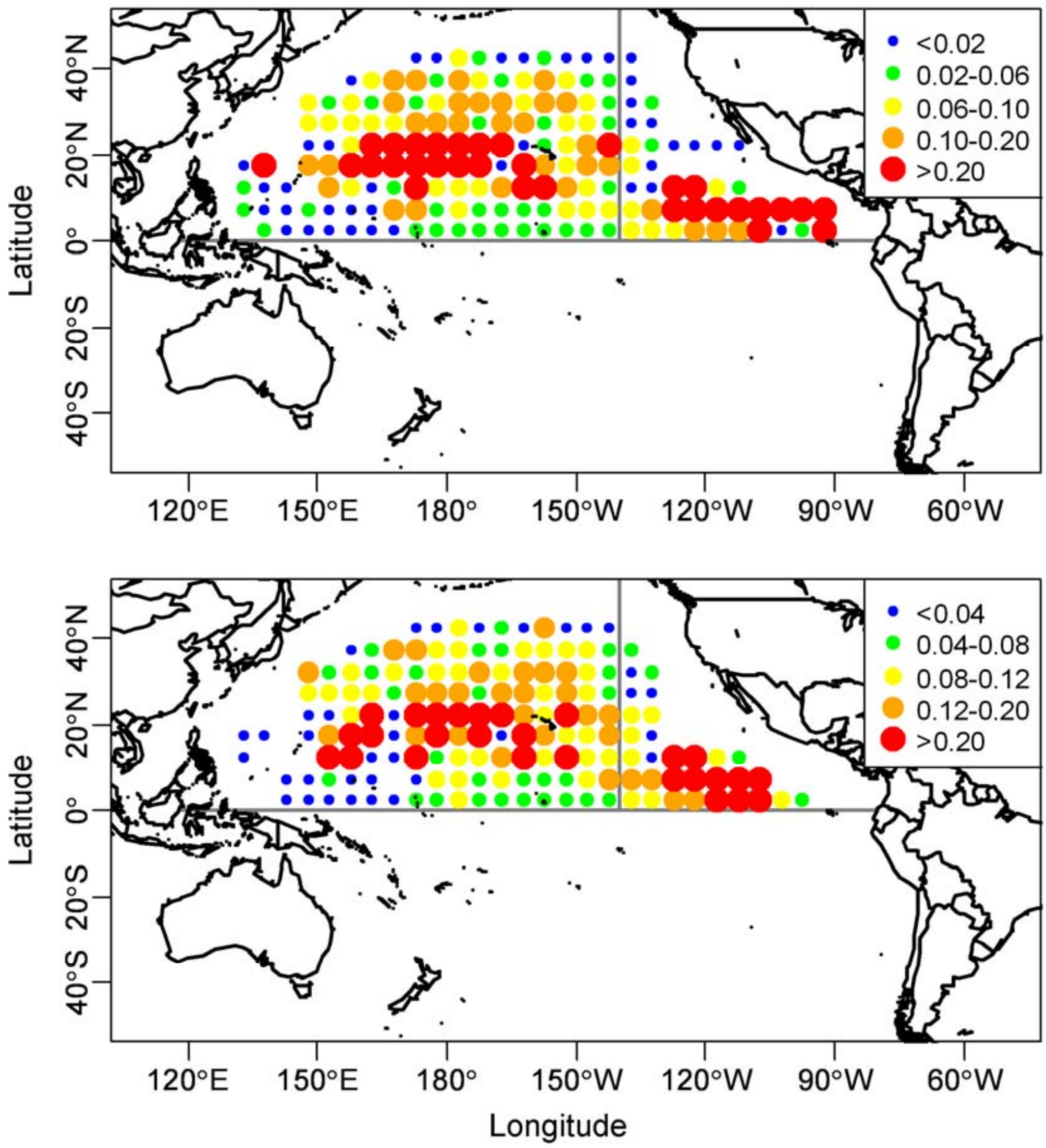

Fig. 2. Distributions of nominal CPUE (number of fish caught per 1000 hooks) of striped marlin caught in the Taiwanese distant-water tuna longline fishery in the North Pacific for 1974-2013 (upper panel) and 1995-2013 (lower panel, with HPB information included).

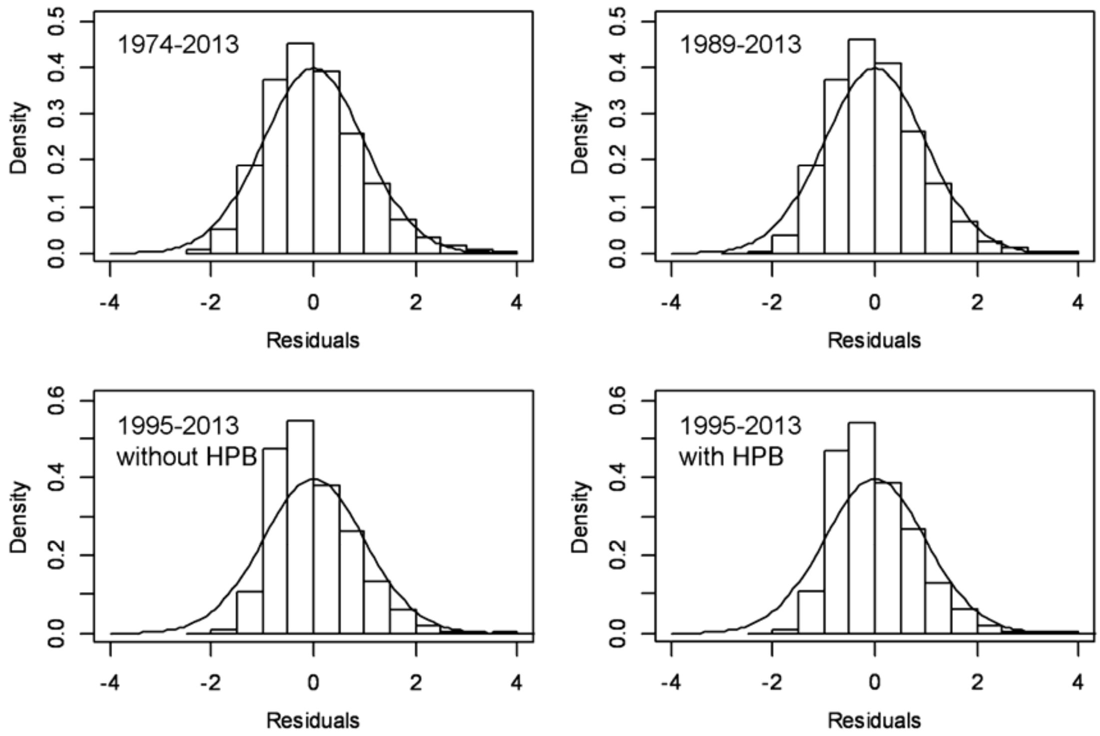

Fig. 3. Residual distributions for the models selected to standardize CPUE of striped marlin caught in the Taiwanese distant-water tuna longline fishery for the WCNPO stock in the North Pacific Ocean for (a) 1974-2013, (b) 1989-2013, (c) 1995-2013 without HPB, and (d) 1995-2013 with HPB.

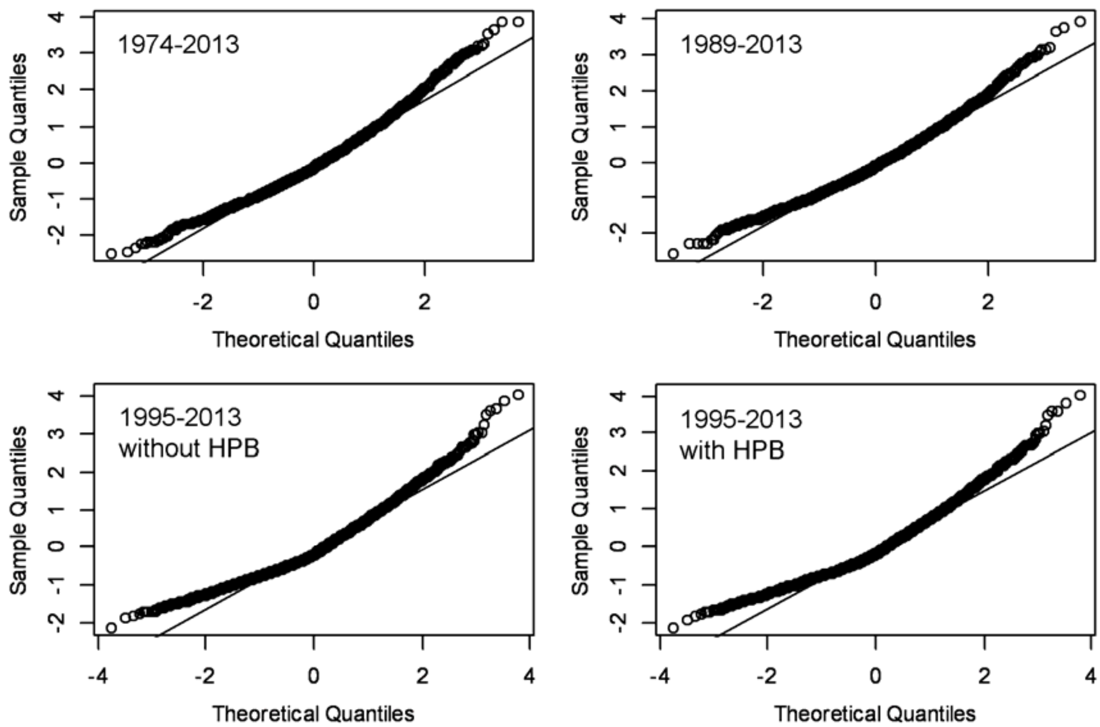

Fig. 4. Diagnostic Q-Q plots for the models selected to standardize CPUE of striped marlin caught in the Taiwanese distant-water tuna longline fishery for the WCNPO stock in the North Pacific Ocean for (a) 1974-2013, (b) 1989-2013, (c) 1995-2013 without HPB, and (d) 1995-2013 with HPB.

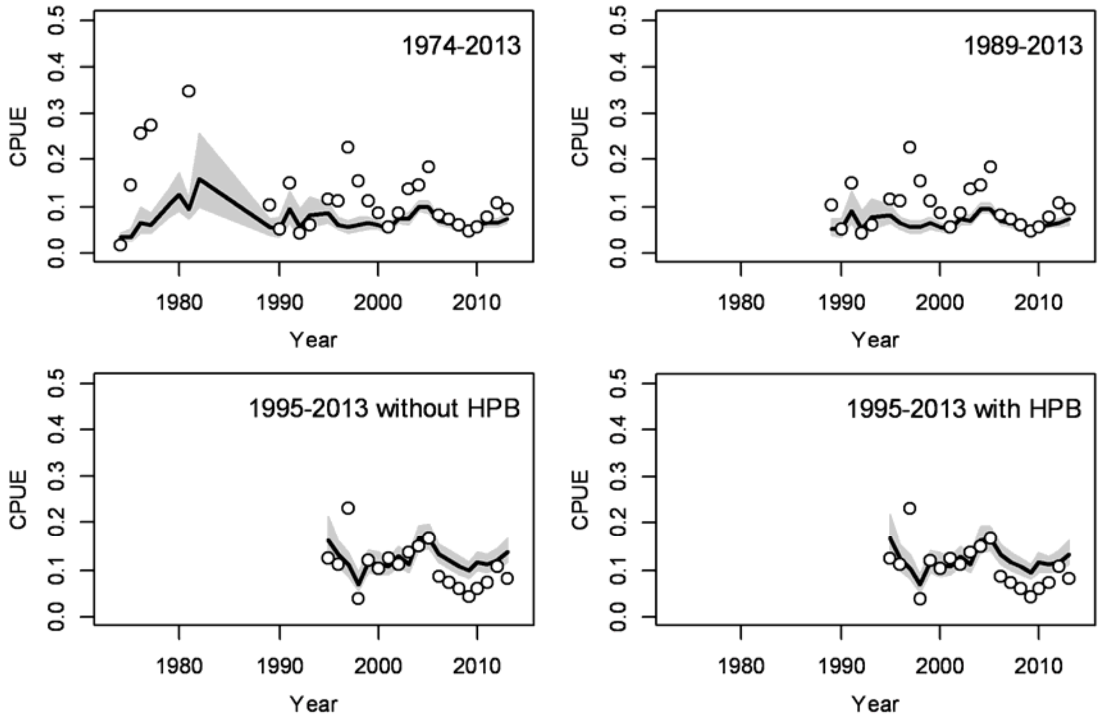

Fig. 5. Nominal (open circles) and standardized CPUE (solid lines, by model of different periods) of striped marlin caught in the Taiwanese distant-water tuna longline fishery for the WCNPO stock in the North Pacific Ocean. CPUE is expressed as the number of fish caught per 1000 hooks. Shadows behind the lines indicate point-wise standard errors for the standardized CPUE of striped marlin.

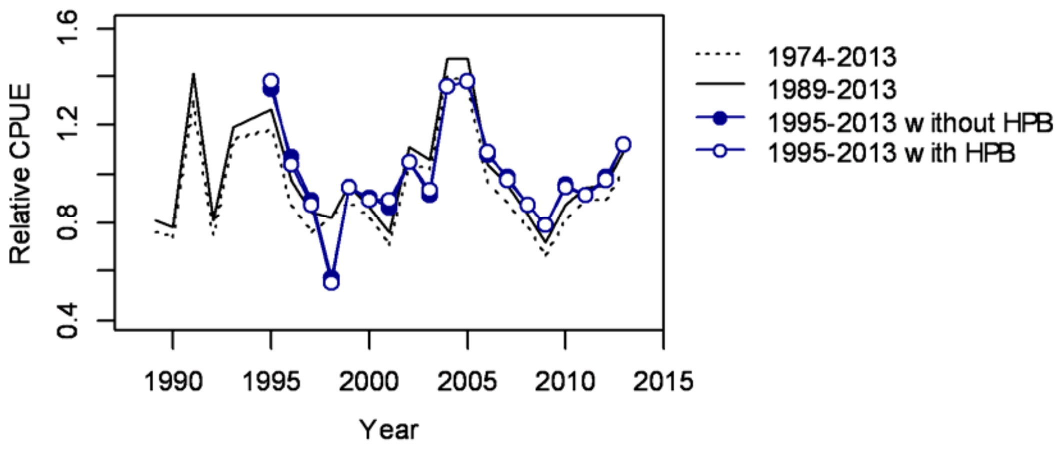

Fig. 6. Comparison of standardized CPUE by model of different periods for striped marlin of the WCNPO stock caught in the Taiwanese distant-water tuna longline fishery in the North Pacific Ocean. Standardized CPUE before 1989 from the 1974-2013 model are omitted for clarity.