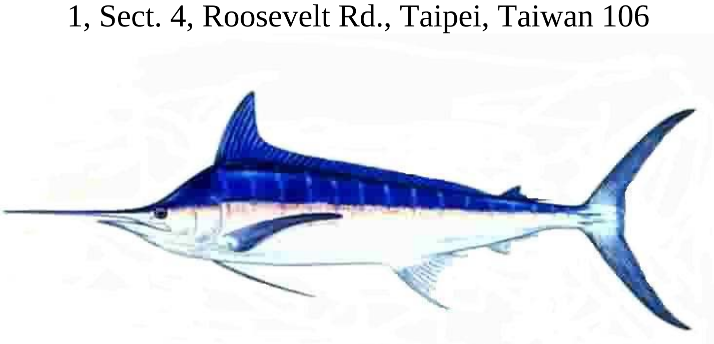
ISC/09/BILLWG-3/09

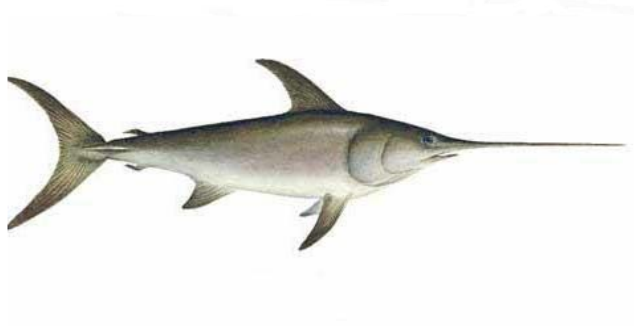
Stock structure of striped marlin, *Kajikia audax*, based on fishery information from Taiwanese longline fisheries in the Pacific Ocean

Chi-Lu Sun
National Taiwan University
Institute of Oceanography
1, Sect. 4, Roosevelt Rd., Taipei, Taiwan 106

Nan-Jay Su
National Taiwan University
Institute of Oceanography
1, Sect. 4, Roosevelt Rd., Taipei, Taiwan 106

Su-Zan Yeh
National Taiwan University
Institute of Oceanography
1, Sect. 4, Roosevelt Rd., Taipei, Taiwan 106





Working document submitted to the ISC Billfish Working Group Workshop, 30 November – 4 December 2009, Honolulu, Hawaii, USA. Document not to be cited without author's written permission.

Stock structure of striped marlin, *Kajikia audax*, based on fishery information from Taiwanese longline fisheries in the Pacific Ocean

Chi-Lu Sun, Nan-Jay Su, and Su-Zan Yeh

Institute of Oceanography, National Taiwan University
Taipei, Taiwan

Abstract

Catch and effort data with information on number of hooks per basket (HPB) of Taiwanese tuna longline fleet are available from 1995 to 2007. A generalized linear model (GLM) was applied to analyze the catch-rates of striped marlin in the Pacific Ocean. Main effects considered in the model included year, month, latitude, longitude, HPB, and two-way interactions among month, latitude, and longitude. ANOVA showed that all factors are statistically significant except for latitude. The catch-rates of striped marlin predicted by the model fit very well to the observed nominal catch-rates in spatial distribution. Base on the fishery information form Taiwanese tuna longline fishery, higher values of model-predicted catch-rates occurred in the North and East Pacific, which might suggest at least three stocks of striped marlin should be separated in the Pacific Ocean.

1. Introduction

Striped marlin (*Kajikia audax*) is the most widely distributed of the billfish species, throughout tropical, subtropical, and temperate waters of the Pacific Ocean (Nakamura 1985). Many countries fish for striped marlin since 1950s, but the bulk of the total catch is taken by Japan, and followed by Taiwan (Fig. 1). However, since the middle of 1960s the catch of striped marlin decreased gradually from more than 20000 metric tons to about 5000 metric tons in recent years. Striped marlin represent an important commercial and recreational resource, even though caught as bycatch by the pelagic tuna longline fisheries, However, as a bycatch species has resulted in a lack of basic information necessary for effective fishery management, for example the number of independent stocks and their boundaries. The objective of this study is to investigate possible stock structure of striped marlin in the Pacific Ocean through fishery catch-rate information from Taiwanese longline fisheries.

2. Materials and methods

2.1. Data used

Catch (number of striped marlin caught) and effort (number of hooks employed) data for 1995-2007 were provided by Oversea Fisheries Development Council (OFDC, Taiwan) for the Taiwanese tuna longline fleets in the Pacific Ocean. Information on gear configuration (number of hooks per basket, HPB; Fig. 2) is available from daily logbook data since 1995, and was also provided by OFDC. Data set was aggregated into monthly 5°×5° latitude and longitude grids for each year and HPB if available. Catch-rates (CPUE, catch in number per unit of effort) were expressed as the number of fish caught per 1000 hooks for striped marlin.

2.2. Statistical model

The catch and effort data of Taiwanese tuna longline fleet in the Pacific Ocean were analyzed for striped marlin by applying the generalized linear model (GLM; Nelder and Wedderburn, 1972), with assuming a lognormal error distribution. GLM is the most commonly used approach for analyzing catch and effort data (Maunder and Punt, 2004), assuming that the expected value of a transformed response variable is related to a linear combination of exploratory variables (Guisan et al., 2002). Year, month, latitude, longitude, gear configuration (i.e. HPB), and two-way interaction among month, latitude, and longitude were considered in the modeling analysis as main explanatory variables. The GLM model is expressed as follows:

$$
\begin{aligned}
MLS \sim\ & Year + Month + Latitude + Longitude + HPB + Month{:}Latitude \\
& + Month{:}Longitude + Latitude{:}Longitude;
\end{aligned}
$$

where MLS is the catch-rate of striped marlin with a constant being added to avoid taking the logarithm of zero.

Two diagnostic plots, i.e. the distribution of residuals and the quantile-quantile (Q-Q) plots, were used to assess the error distribution (here assuming lognormal distribution) as well as the model fitting for analyzing the catch-rates of striped marlin caught by Taiwanese longline fleet. The change in residual deviance for each model is expressed as: pseudo-$R^2 = 1 - $ (residual deviance/null deviance). The catch-rates of striped marlin were predicted using the GLM model for which data of 5 by 5 blocks are available to conduct a geographic maps in order to investigate possible stock structure of striped marlin in the Pacific Ocean.

3. Results and discussion

There are total 15344 catch-effort records with information on gear configuration available for 1995-2007 for Taiwanese longline fisheries in the Pacific Ocean. The residual distribution from lognormal error distribution based on the GLM analysis appears normal (Fig. 3). This has also been confirmed to the greatest extent with the lognormal assumption according to the Q-Q plot for the analysis approach (Fig. 4). Therefore, analyzing catch-rates of striped marlin based on the lognormal error distribution in this study are appropriate.

All of the main explanatory variables and two-way interactions considered in the modeling are statistically significant, except for latitude (Table 1; latitude was kept as the interactions are significant). The pseudo-R^2 based on the GLM analysis derived from analyzing 1995-2007 dataset for striped marlin are around 0.188 (Table 2).

Striped marlin were taken throughout entire Pacific Ocean for the Taiwanese longline fisheries (Fig. 5). However, most of striped marlin catch appear mainly in the eastern tropical waters and the north and south central Pacific Ocean. This is probably because the Taiwanese longline fleets operated mostly in those areas for targeting bigeye and albacore tunas (Fig. 6). Unlike catch distribution of striped marlin and effort distribution for Taiwanese longline fleet, there is no distinct spatial pattern for the catch-rates of striped marlin in the Pacific Ocean (Fig. 7).

Relative high CPUEs of striped marlin appeared sparsely in the north central and eastern tropical Pacific Ocean. However, the catch-rates predicted by the GLM model showed an obvious spatial pattern for the striped marlin. This fishery information derived with Taiwanese longline fleet suggested that striped marlin are more abundant in the north central and the eastern tropical Pacific Ocean (Fig. 8; green squares). However, some extremely high catch-rates of striped marlin were found in waters off Chile and Philippines (Fig. 8; red and orange squares in eastern and western Pacific Ocean respectively), probably resulted from coastal and offshore fisheries.

The fishery information derived form Taiwanese longline fisheries suggested that at least three stocks of striped marlin should be considered and separated in the Pacific Ocean. However, more effort placed on incorporating the information from other fisheries as well as alternative researches, e.g. genetic studies, is needed for integrating all the knowledge available for striped marlin to effectively manage the striped marlin population and the fisheries that use this resource.

References

Guisan, A., T.C. Edwards Jr, T. Hastie (2002). Generalized linear and generalized additive models in studies of species distributions: setting the scene. Ecol. Model., 157: 89-100.

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.

Nelder, J.A., R.W.M. Wedderburn (1972). Generalized linear models. J. R. Stat. Soc. A, 135: 370-384.

Table and figures

Table 1. ANOVA table for fitting the GLM model for striped marlin caught by Taiwanese fleet in the Pacific Ocean for 1995-2007.

Predictor	df	F	p-value
Year	12	16.873	<0.001
HPB	25	7.004	<0.001
Month	11	1.927	0.032
Latitude	16	1.273	0.204
Longitude	32	1.547	0.025
Month:Latitude	167	2.167	<0.001
Month:Longitude	322	1.613	<0.001
Latitude:Longitude	336	1.993	<0.001
			$R^2 = 0.188$

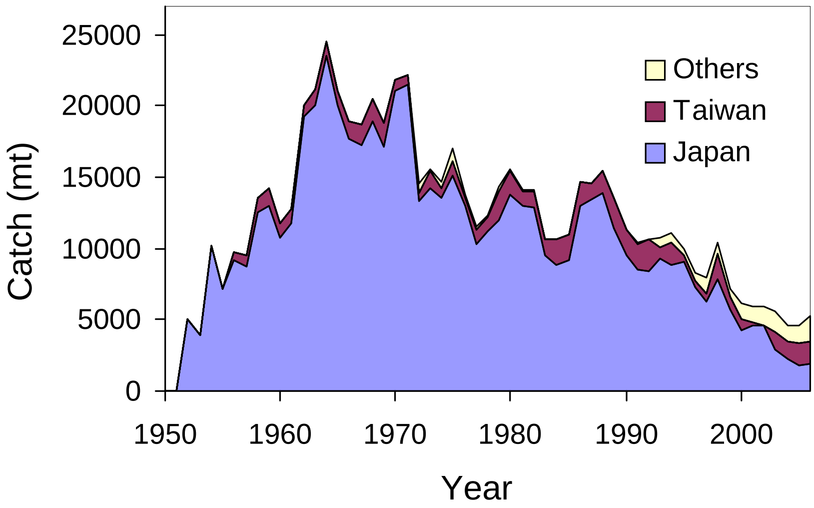


Fig. 1. Historical catch of striped marlin caught by Japanese, Taiwanese, and the other fleets in the Pacific Ocean.

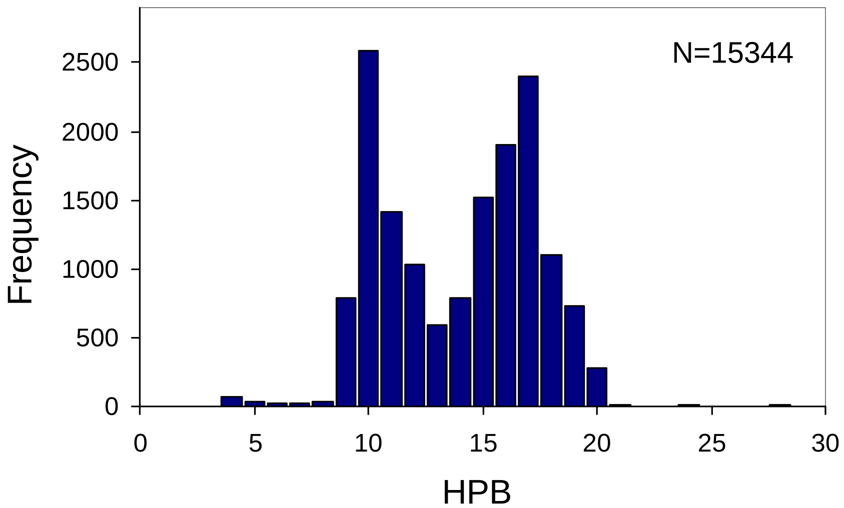


Fig. 2. Distribution of HPB (hooks per basket) in the catch-effort data set for the Taiwanese fleet in the Pacific Ocean.

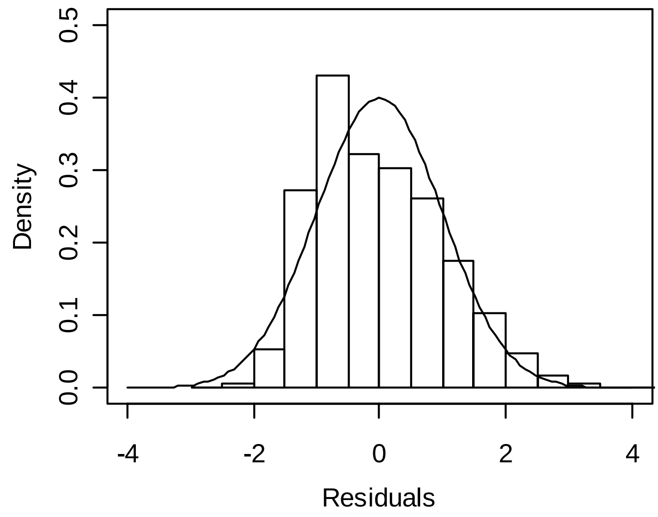


Fig. 3. Distribution of residuals from fitting the GLM model.

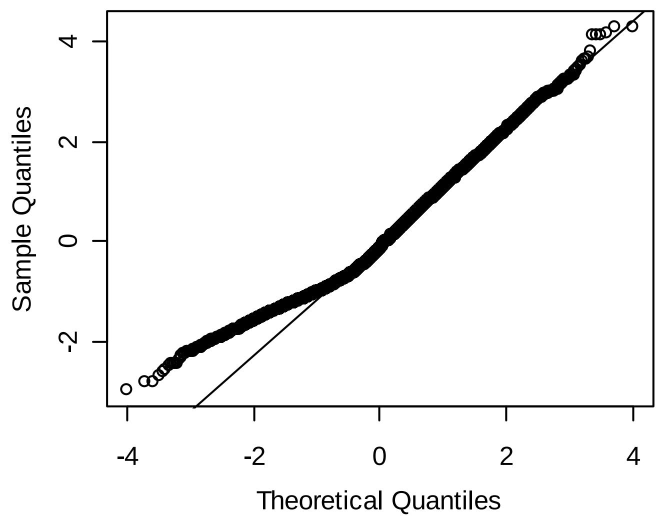


Fig. 4. The Q-Q plot for fitting the GLM model.

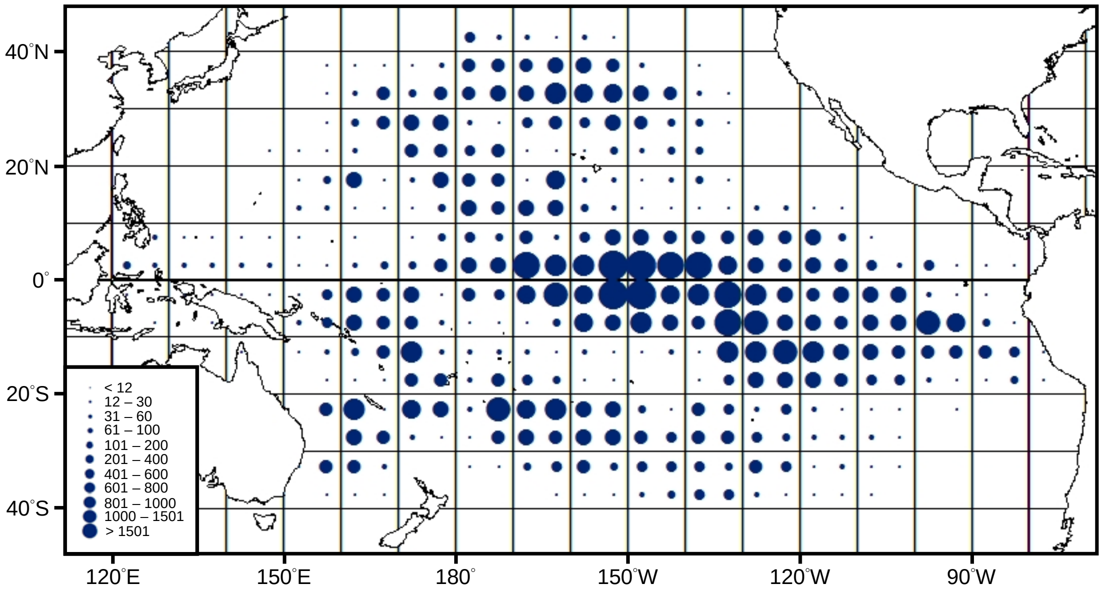


Fig. 5. The catch distribution of striped marlin (in number) caught by Taiwanese fleet in the Pacific Ocean for 1995-2007.

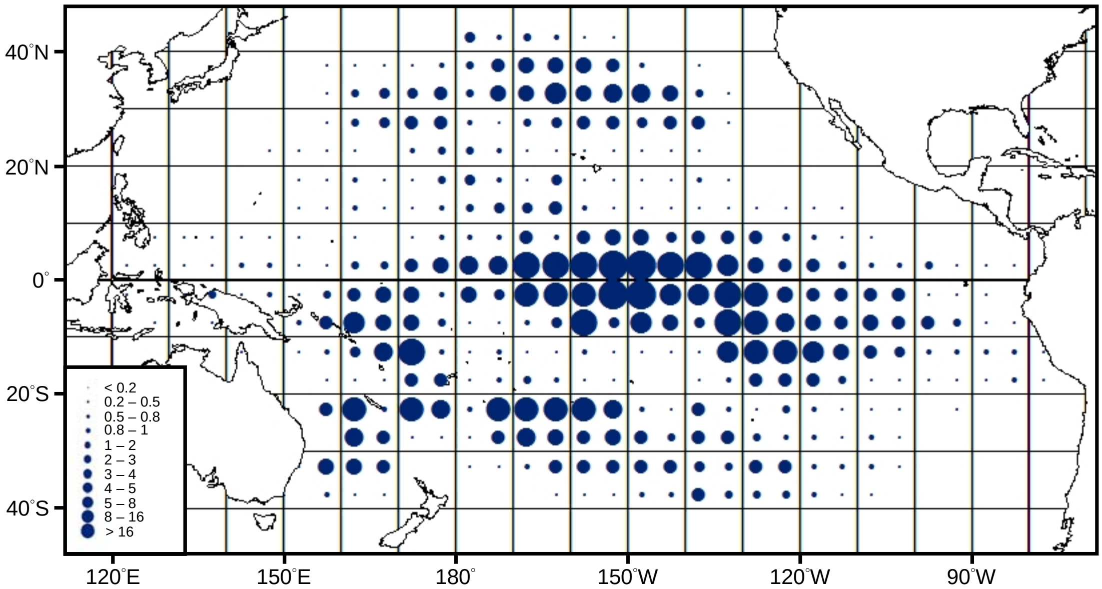


Fig. 6. The distribution of fishing effort (10^6 hooks) for Taiwanese fleet in the Pacific Ocean for 1995-2007.

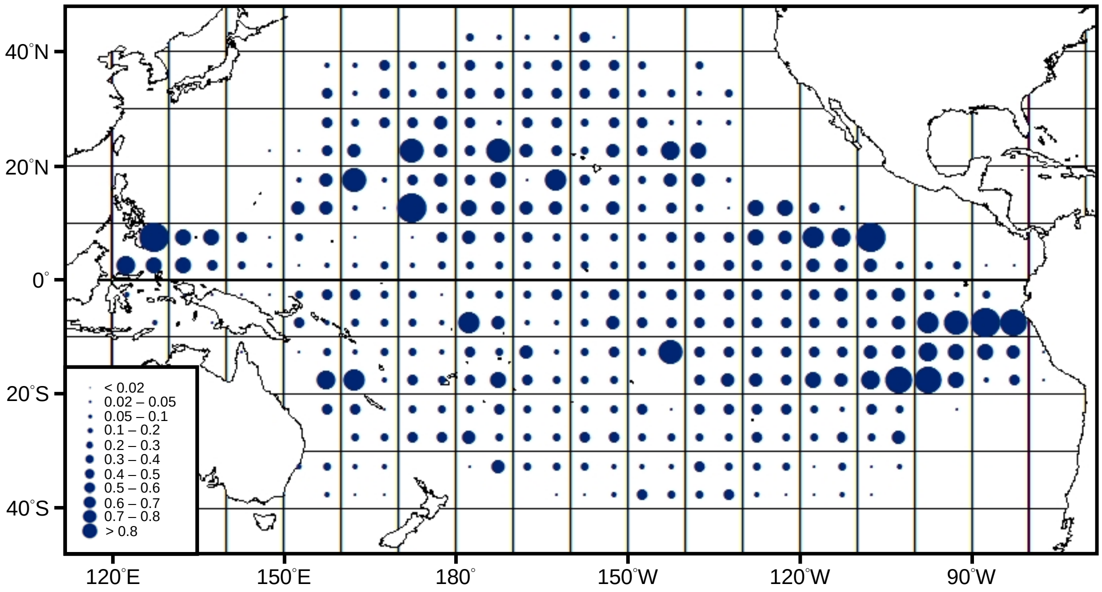


Fig. 7. The distribution of nominal CPUE (1995-2007) for striped marlin caught by Taiwanese fleet in the Pacific Ocean.

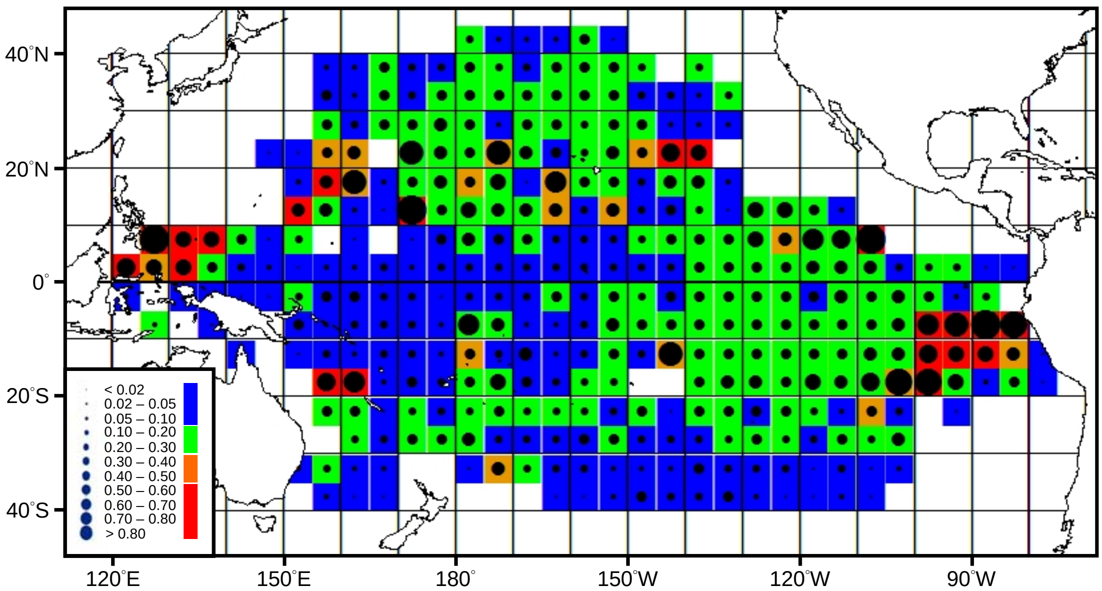


Fig. 8. The distribution of model-predicted CPUE (squares) and observed nominal CPUE (dots) for striped marlin caught by Taiwanese fleet in the Pacific Ocean.