# CPUE standardization of stripe marlin caught by Taiwanese distant-water longline fishery in the Western and Central North Pacific Ocean during 1995 – 2020

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**Abstract**

This report provides the standardized catch rate of striped marlin caught by Taiwanese distant-water tuna longline fishery (DWLL) during 1995 – 2020 in the Western and Central North Pacific Ocean (WCNPO). Catch rates were standardized using the Vector-Autoregressive Spatio-Temporal model with year, quarter, vessel, spatial, and spatio-temporal effects as explanatory variables. Results indicated that the standardized catch rate of the DWLL for the WCNPO striped marlin has fluctuated overtime, and recently increased from 2018 to 2020.

**Introduction**

We acknowledged that the North Pacific striped marlin is experiencing overfishing and is overfished (ISC, 2019) and noted that the ISC BILLWG work plan for 2022 includes completing a benchmark North Pacific striped marlin assessment. In preparation for the next stock assessment of striped marlin in the Western and Central North Pacific Ocean (WCNPO; west of 150°W and north of the equator) in 2022, the objective of this paper is to provide the standardized CPUE index as necessary input data. We applied a Vector-Autoregressive Spatio-Temporal Model (i.e., VAST, Thorson, 2019) to standardize the North Pacific striped marlin catch rate data from the Taiwanese distant-water tuna longline fishery (DWLL). The standardized indices of the North Pacific striped marlin derived from this study could provide basic and necessary input data for stock assessments of this species.

**Materials and methods**

*Fishery data*

Operational logbook data of Taiwanese distant-water longliners (DWLL) in Western and Central North Pacific Ocean during 1964 – 2020 was provided by Oversea Fisheries Development Council, including time (year and month) and location (longitude and latitude aggregated by 5° by 5° grid). Quarter was assigned to each data with definition as follows: January – March (quarter 1), April – June (quarter 2), July – September (quarter 3), and October – December (quarter 4). CPUE is expressed as the number of fish caught per 1,000 hooks in this study. This paper presents standardizations of the DWLL dataset from 1995 - 2020, due to the better quality and quantity of the dataset.

*Statistical model*

The approach we used here is adapted from the *R* package VAST (https://github.com/James-Thorson-NOAA/VAST) developed by Thorson et al. (2015). VAST uses Gaussian random fields to model spatial correlation and spatio-temporal autocorrelation with the Matérn covariance function (Thorson, 2019). Correlation of the spatial and spatio-temporal effects is estimated using previously defined knots (*s*) through *k*-mean analysis. The appropriate knot number for striped marlin in WCNPO was explored and 100 was found to be the most appropriate. VAST is a delta-generalized linear mixed model that calculates the probability distribution with two components:

Encounter rate component (binominal distribution):

$$\text{logit}(p_i) = \beta_1(t_1) + \omega_1(s_1) + \varepsilon_1(s_i, t_i) + \delta_1(v_i) + \sum_{k_1=1}^{n_{k_1}} \lambda_1(k_1) Q(i, k_1)$$

Positive catch rate component (log-normal distribution):

$$\log(q_i) = \beta_2(t_i) + \omega_2(s_i) + \varepsilon_2(s_i, t_i) + \delta_2(v_i) + \sum_{k_2=1}^{n_{k2}} \lambda_2(k_2) Q(i, k_2)$$

where $\beta(t_i)$ is the fixed effect intercept of year $t$ ; $\omega(s_i)$ is the time-invariant spatial auto-correlated variation for knot $s$; $\varepsilon(s_{i,}t_i)$ is the time-varying spatial-temporal auto-correlated variation for knot $s$ in year $t$; $\delta(v_i)$ is the random variation in catchability for vessel $v$; $Q(i,k)$ are the fixed effects for seasonal effects (e.g. seasonal effect based on quarters, $n_{k1} = n_{k2} = 1$).

*Derived abundance index*

The area-weighted abundance ($d(t,q)$) of the WCNPO striped marlin for year $t$ and quarter $q$ except for the vessel effect is estimated as follows (Grüss et al., 2019):

$$d(t,q) = \sum_{s=1}^{n_s} A(s) \times \text{logit}^{-1}\left(\beta_1(t) + \omega_1(s) + \varepsilon_1(s,t) + \lambda_1(q)\right) \times \exp\left(\beta_2(t) + \omega_2(s) + \varepsilon_2(s,t) + \lambda_2(q)\right)$$

where $\lambda(q)$ is the seasonal effect; $A(s)$ is the surface area (in km²) of knot $s$.

Annual CPUEs of the WCNPO striped marlin $\hat{CPUE}(t)$ are computed from CPUE estimates for each year $t$ and quarter $q$ as follows (Campbell, 2015):

$$C\hat{P}UE(t) = \frac{1}{n_q}\sum_{q=1}^{n_q} d(t,q)$$

where $n_q$ is the number of quarters (i.e., $n_q = 4$)

*Model selection and diagnosis*

Akaike Information Criterion (AIC; Akaike, 1973) was used to identify which model had greater support given available data. The final model was checked for convergence and model fit was evaluated. Encounter frequencies were visualized to examine if the predicted encounter probability stayed within 95% interval, and residuals of catch rates when encountered was analyzed using quantile-quantile probability plots (Q-Q plots).

**Results and discussion**

Spatial distributions of nominal WCNPO striped marlin CPUEs for the Taiwanese distant-water longline fishery during 1995 – 2020 were shown in **Figures 1 – 2**. Catch rate data was concentrated at the eastern region of WCNPO in the early periods. Since the 2000s, the spatial distribution of the catch rate data has expanded and shifted westward.

The convergence in optimization was confirmed for each model if the Hessian matrix was positive, and the maximum gradient of each component was less than 0.0001. Based on the AIC values, the most parameterized model was used to predict the catch rate index of the WCNPO striped marlin (M-5; **Table 1**). Model diagnostics suggested the best model has good fits to the observed CPUEs between encounter rate (**Fig. 3**) and positive catch rate models (**Fig. 4**). Results indicated that the standardized catch rate of the DWLL for the WCNPO striped marlin has fluctuated overtime, and recently increased from 2018 to 2020 (**Fig. 5**). Relative scale of standardized CPUEs and CVs were summarized in **Table 2**.

**Reference**

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Grüss, A., Walter III, J. F., Babcock, E. A., Forrestal, F. C., Thorson, J. T., Lauretta, M. V., and Schirripa, M. J. (2019). Evaluation of the impacts of different treatments of spatio-temporal variation in catch-per-unit-effort standardization models. Fisheries Research, 213, 75-93.

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Table 1. Model selection information for the VAST model of stripe marlin caught by Taiwanese distant-water longline fishery in the Western and Central North Pacific Ocean during 1995 – 2020.

| ID | Model structure | Deviance | AIC | ΔAIC | Maximum gradient |
|---|---|---|---|---|---|
| M1 | Year | 61290.28 | 61396.27 | 8482.31 | <0.0001 |
| M2 | Year + Knot | 57134.58 | 57252.58 | 4338.62 | <0.0001 |
| M3 | Year + Knot + Year-Knot | 54261.74 | 54383.73 | 1469.77 | <0.0001 |
| M4 | Year + Knot + Year-Knot + Vessel | 52863.84 | 52989.84 | 75.88 | <0.0001 |
| M5 | Year + Knot + Year-Knot + Vessel + Quarter | 52775.96 | 52913.96 | 0 | <0.0001 |

Table 2. Standardized relative CPUE and CV for stripe marlin caught by Taiwanese distant-water longline fishery in the Western and Central North Pacific Ocean during 1995 – 2020.

| Year | Std. CPUE | CV | Year | Std. CPUE | CV |
|---|---|---|---|---|---|
| 1995 | 1.25 | 0.26 | 2008 | 0.95 | 0.16 |
| 1996 | 0.77 | 0.20 | 2009 | 0.66 | 0.16 |
| 1997 | 0.72 | 0.22 | 2010 | 0.81 | 0.17 |
| 1998 | 1.12 | 0.31 | 2011 | 0.93 | 0.17 |
| 1999 | 0.93 | 0.26 | 2012 | 1.01 | 0.19 |
| 2000 | 0.46 | 0.21 | 2013 | 1.67 | 0.18 |
| 2001 | 0.90 | 0.19 | 2014 | 0.63 | 0.18 |
| 2002 | 1.00 | 0.22 | 2015 | 0.60 | 0.17 |
| 2003 | 1.73 | 0.18 | 2016 | 0.54 | 0.15 |
| 2004 | 1.87 | 0.14 | 2017 | 1.00 | 0.16 |
| 2005 | 1.77 | 0.13 | 2018 | 0.68 | 0.15 |
| 2006 | 1.14 | 0.15 | 2019 | 0.72 | 0.14 |
| 2007 | 0.99 | 0.14 | 2020 | 1.14 | 0.13 |

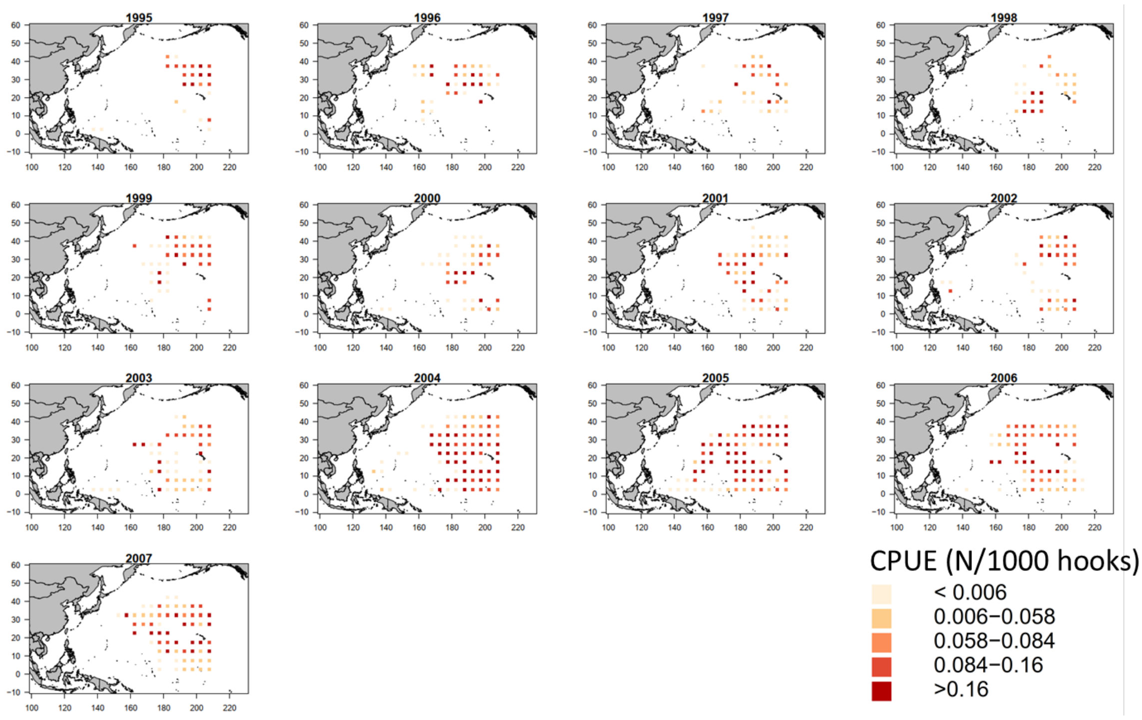


Figure 1. Distributions of nominal CPUEs (number of fish caught per 1,000 hooks) of striped marlin caught by the Taiwanese distant-water tuna longliners (DWLL) in the Western and Central North Pacific Ocean during 1995 – 2007.

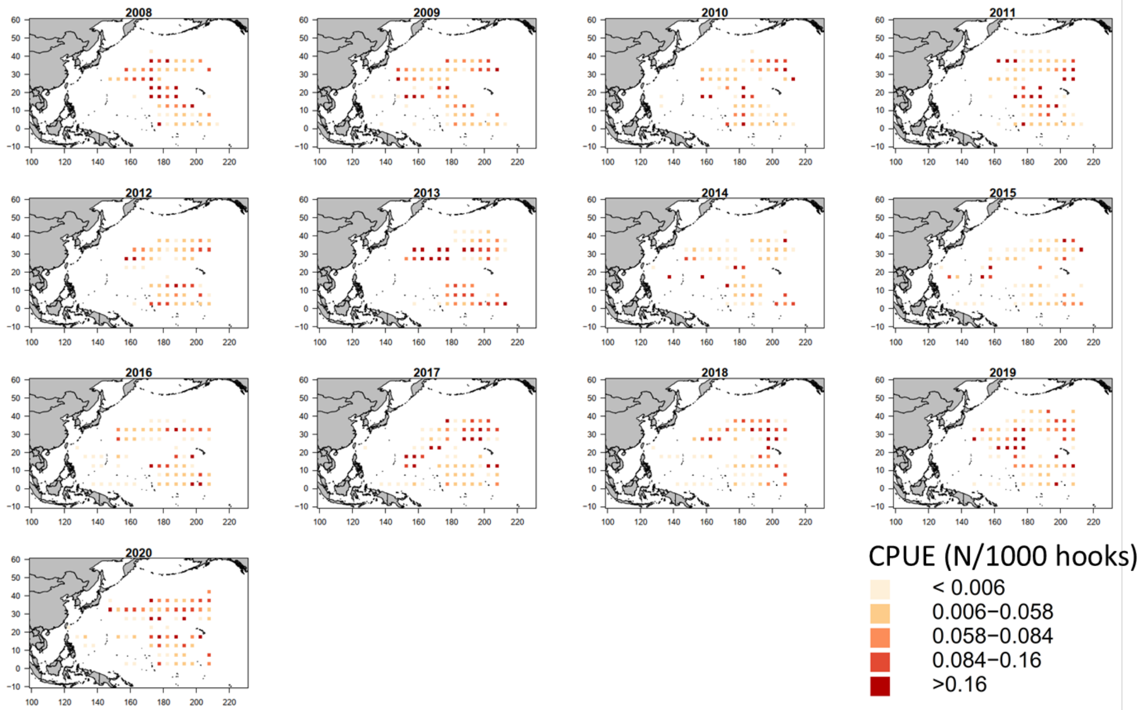


Figure 2. Distributions of nominal CPUE (number of fish caught per 1,000 hooks) of striped marlin caught by the Taiwanese distant-water tuna longliners (DWLL) in the Western and Central North Pacific Ocean during 2008 – 2020.

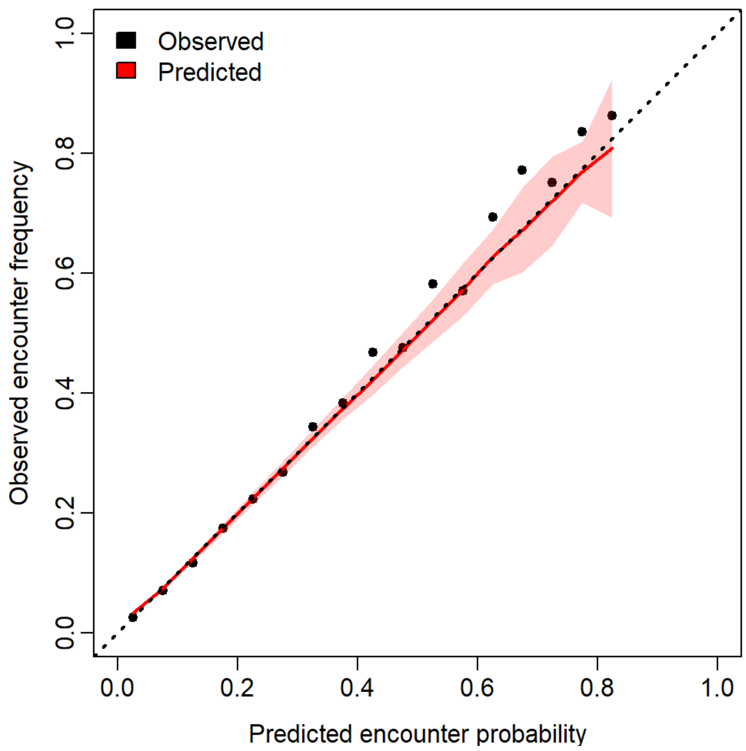


Figure 3. Observed (black points) and predicted (red shading) encounter probability of Western and Central North Pacific Ocean striped marlin for Taiwanese distant-water tuna longliners (DWLL) during 1995 – 2020.

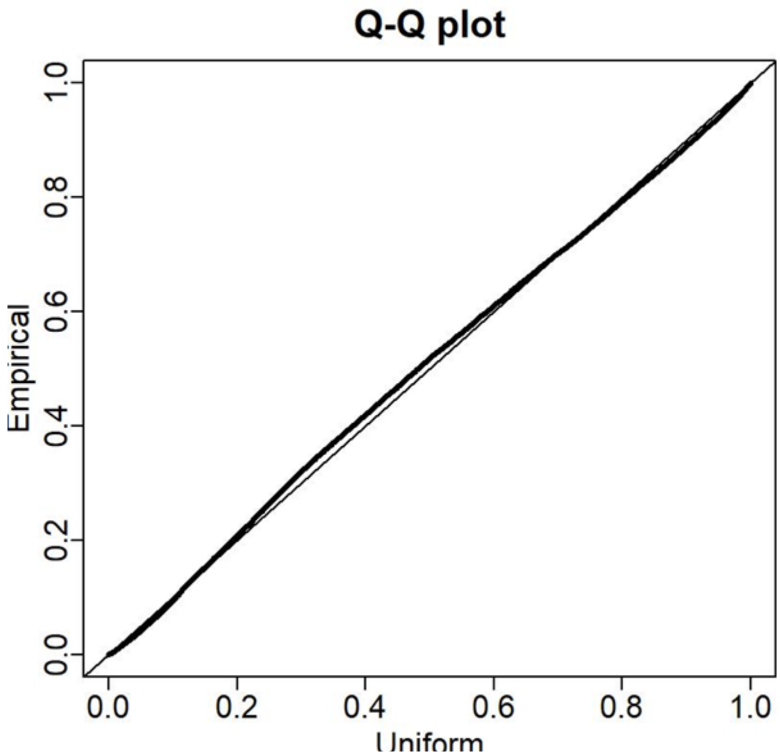


Figure 4. Normal Q-Q plot of positive catches component of Western and Central North Pacific Ocean striped marlin for Taiwanese distant-water tuna longliners (DWLL) during 1995 – 2020.

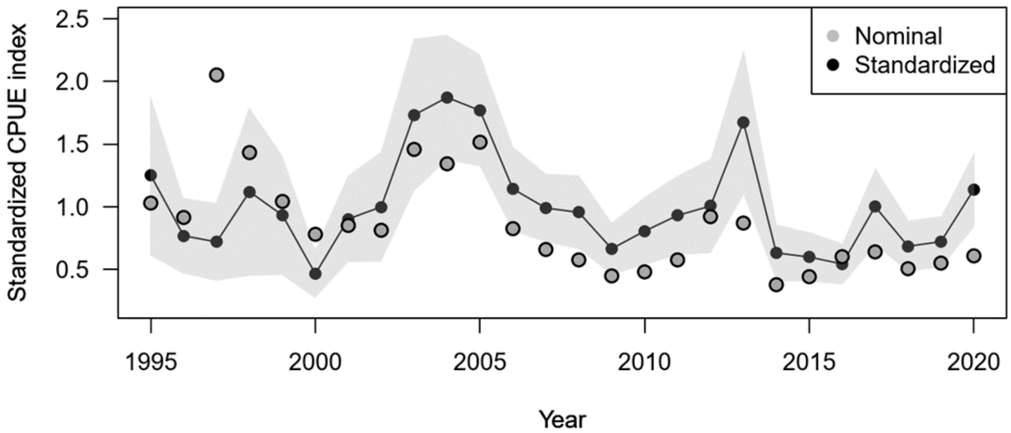


Figure 5. Relative scales (centered to mean) of the nominal (total numbers of fish caught/total number of hooks) and standardized indices for the WCNPO striped marlin caught by Taiwanese distant-water tuna longliners (DWLL) during 1995 – 2020. Shaded area indicates the 95% confidence intervals.