

Preliminary study of standardized catch per unit efforts (CPUE) of blue shark (*Prionace glauca*) in the Eastern Indian Ocean

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Abstract

Catch per unit effort (CPUE) standardization is important for accurate stock assessments of highly migratory species like blue shark (*Prionace glauca*), particularly in the longline fishery. Moreover, biases from spatiotemporal heterogeneity, seasonal variations, and gear configurations can mislead abundance trends. This study standardizes CPUE data from 2005 to 2025 using a generalized linear model (GLM) with negative binomial distribution including categorical covariates: year (20 levels), quarter (4 levels), area (tropical vs. temperate), number of hooks between floats (NHBF: shallow, intermediate, deep), and length of float lines (LFL: short vs. long), offset by $\log(\text{effort})$. The GLM analysis showed significant temporal increases in standardized CPUE relative to the 2005 baseline (lowest at 1 catch/1,000 hooks), highest in 2023 (9 catches/1,000 hooks), with mixed differences during years. There was no seasonal effect on blue shark catch ($p > 0.05$), while tropical areas exhibited lower CPUE ($p < 0.05$) than temperate zones. Intermediate NHBF maximized selectivity ($p < 0.05$), and longer LFL enhanced efficiency ($p < 0.05$). Nominal and standardized series closely mirrored each other and reached the peak in 2023. These findings indicate blue shark stock resilience and GLM analysis usefulness in generating indices for stock assessments.

Keywords: standardized CPUE, GLM analysis, blue shark, number of hooks between floats (NHBF), length of float line (LFL).

Introduction

Blue shark (*Prionace glauca*) is a highly migratory pelagic species with a broad distribution across tropical, subtropical, and temperate waters of the Atlantic, Indian, and

Pacific Oceans (Collette & Nauen, 1983). The species' ability to inhabit a wide range of depths and environmental conditions makes it a versatile but challenging target for fishers, necessitating precise fishing strategies to optimize catch efficiency (Queiroz et al., 2012). Understanding the ecological and behavioural characteristics of blue shark in the Eastern Indian Ocean is critical for developing sustainable fishery practices tailored to regional conditions.

In longline fishery, catch per unit effort (CPUE) provides an important index of relative stock abundance for informing stock assessments and management strategies (Maunder et al., 2006). However, unstandardized raw CPUE is highly susceptible to biases arising from technology and different fishing effort that can doubt true population trends and lead to miss estimation of stock status (Walter et al., 2014).

Standardization techniques, such as generalized linear models (GLMs) or delta-lognormal approaches, address these issues by modelling key covariates (Chang et al., 2011). These include vessel characteristics, seasonal patterns, hook depth configurations, and oceanographic factors, which generate indices that more accurately represent abundance (Obradovich, 2018).

This is especially important in pelagic longline operations with bycatch of blue shark (*P. glauca*). The objective of this study is to standardize catch per unit effort (CPUE) data from longline fishery. This study will provide better information of stock assessments and management decisions of blue shark in the Indian Ocean.

Methods

Data collection

Data were collected by trained scientific observers aboard commercial tuna longline vessels primarily based at Benoa Harbor, Bali, Indonesia, from August 2005 to December 2025. Fishing trips ranged in duration from 3 weeks to 3 months, targeting blue shark (*P. glauca*) in the Eastern Indian Ocean, spanning coordinates 76°–130° E longitude and 0°–34° S latitude (Figure 1). Observers recorded daily fishing operation data, including the number of hooks between floats (NHBF), the length of the float line (LFL), the total number of hooks deployed per set, and the number of blue shark caught per set. These parameters were selected based on their influence on hook depth and fishing efficiency, which are critical for targeting depth-specific species like blue shark (Beverly et al., 2003; Bigelow et al., 2006). All data were logged using standardized protocols to ensure consistency across vessels and trips.

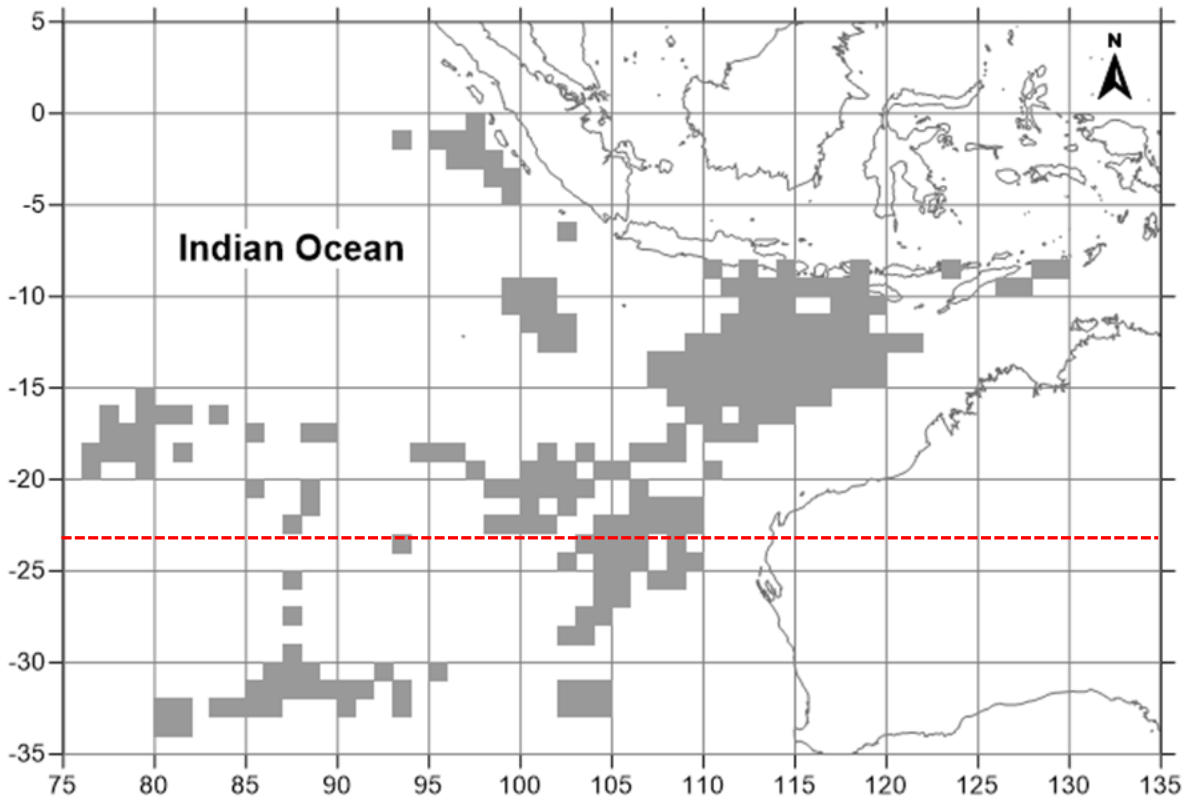


Figure 1. Fishing ground of the longline tuna in this study. The red dash-line is 23.5° latitude that separating tropical and temperate area.

CPUE calculation

Catch rate was calculated as the catch per unit effort (CPUE), defined as the number of blue shark caught in a single fishing set divided by the total number of hooks deployed in that set, multiplied by 1,000 to express the rate as a percentage. This metric provides a standardized measure of fishing efficiency, accounting for variations in effort across sets and vessels (Bigelow et al., 2006). Only sets targeting blue shark were included in the analysis to minimize confounding effects from multi-species targeting.

Data categorization

All variables were treated as categorical factors to account for discrete variations in fishing effort. The year factor covered 20 levels, from the period of 2005 to 2025 for the catch of temporal trends (no data in 2022). The quarter factor included four levels, corresponding to seasonal periods (e.g., January–March, April–June, July–September, and October–December). Spatial stratification was included in area factor, with two levels distinguishing tropical and temperate zones based on latitude thresholds of 23.5° (Val et al., 2005). The number of hooks between floats (NHBF) factor was modelled as a three-level factor shallow, intermediate, and

deep (modification from (Sadiyah et al., 2012)). The length of floats line (LFL) factor contained two levels, short and long (Table 1).

Table 1. Variables used in the GLM analysis.

Factor	Level	Category	Type
Year	20	2005-2025	Categorical
Quarter	1	Jan-Mar	Categorical
	2	Apr-Jun	
	3	Jul-Sep	
	4	Oct-Dec	
Area	tropical	< 23.5°	Categorical
	temperate	>= 23.5°	
NHBF	shallow	< 11 hooks	Categorical
	intermediate	11-14 hooks	
	deep	> 14 hooks	
LFL	short	<= 25 m	Categorical
	long	> 25 m	

Statistical analysis

Standardization of CPUE was performed using a generalized linear model (GLM) with a negative binomial distribution to account for over-dispersion inherent in count-based catch data using this equation:

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glm.nb(formula = num_bsh ~ year + quarter + area + NHBF + LFL + offset(log(effort)),
link = log)
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The model regressed on fixed effects for year, quarter, area, NHBF, and LFL, with an offset term for log(effort) to normalize for varying hook numbers across sets. Model fitting was conducted in R using the “MASS” package for GLM analysis (Ripley et al., 2013) and “dplyr” for data manipulation (Rathod et al., 2023). Standardized CPUE was derived as the ratio of predicted expected catch to effort, producing adjusted rates per 1,000 hooks. Approximate 95% confidence intervals for standardized CPUE were computed assuming normality, using standard errors, and aggregated annually by mean for trend analysis.

Results

The GLM analysis reveals significant temporal trends in standardized blue shark CPUE, with most years from 2006 to 2025 showing positive and highly significant coefficients in recent years relative to the 2005 baseline ($p < 0.05$). Seasonal effects are not noticeable, as catch

rates are relatively similar in all seasons ($p>0.05$). Spatial heterogeneity is evident, with tropical areas showing markedly lower CPUE than temperate area highlighting latitudinal influences on distribution ($p<0.05$). Gear configuration of number of hooks between floats (NHBF) significantly impacts selectivity, where intermediate depths yield the highest CPUE relative to the deep baseline and shallow sets showed low value ($p<0.05$). For the length of floats line (LFL), shorter LFL correlate with lower CPUE compared to longer ones ($p<0.05$) (Table 2).

Table 2. Summary of the GLM model for blue shark (*P. glauca*).

Coefficients:	Estimate	Std. Error	z value	Pr(> z)	
(Intercept)	0.717441	0.216379	3.316	0.000914	***
year2006	0.555914	0.184726	3.009	0.002618	**
year2007	0.24531	0.182674	1.343	0.17931	
year2008	-0.072902	0.285624	-0.255	0.79854	
year2009	-0.06803	0.237167	-0.287	0.774233	
year2010	0.16053	0.206209	0.778	0.436285	
year2011	-0.264275	0.531935	-0.497	0.619318	
year2012	0.424259	0.190514	2.227	0.025953	*
year2013	0.376937	0.294552	1.28	0.200652	
year2014	0.16655	0.223226	0.746	0.455605	
year2015	0.436886	0.200081	2.184	0.028996	*
year2016	0.706332	0.916148	0.771	0.440719	
year2017	0.19325	0.200512	0.964	0.335154	
year2018	0.412066	0.184786	2.23	0.02575	*
year2019	0.440228	0.213687	2.06	0.039384	*
year2020	0.605464	0.23251	2.604	0.009213	**
year2021	0.3115	0.227847	1.367	0.17158	
year2023	1.835659	0.306935	5.981	2.22E-09	***
year2024	1.034396	0.247894	4.173	3.01E-05	***
year2025	1.260572	0.24693	5.105	3.31E-07	***
quarter2	0.002372	0.106413	0.022	0.982213	
quarter3	-0.082672	0.109577	-0.754	0.450574	
quarter4	-0.120511	0.112308	-1.073	0.283254	
areatropical	-0.520603	0.080184	-6.493	8.44E-11	***
NHBFintermediat	e -0.150506	0.07487	-2.01	0.044406	*
NHBFshallow	-0.097249	0.136988	-0.71	0.47776	
LFLshort	0.144251	0.066368	2.174	0.029742	*
Signif. codes:	0 '***'	0.001 '**'	0.01 '*'	0.05 '.'	0.1 ''

From 2005 to 2025, both the nominal and standardized CPUE showed similar fluctuating patterns over time. The catch per unit effort (CPUE) of blue shark showed relatively low and slightly fluctuating values during the 2005–2021 period, around 2 catches/1,000 hooks. Then, increase was observed in the later years of the time series, with CPUE reaching its highest level in 2023 at approximately 9 catches/1,000 hooks (Figure 2).

Nominal vs Standardized Mean CPUE

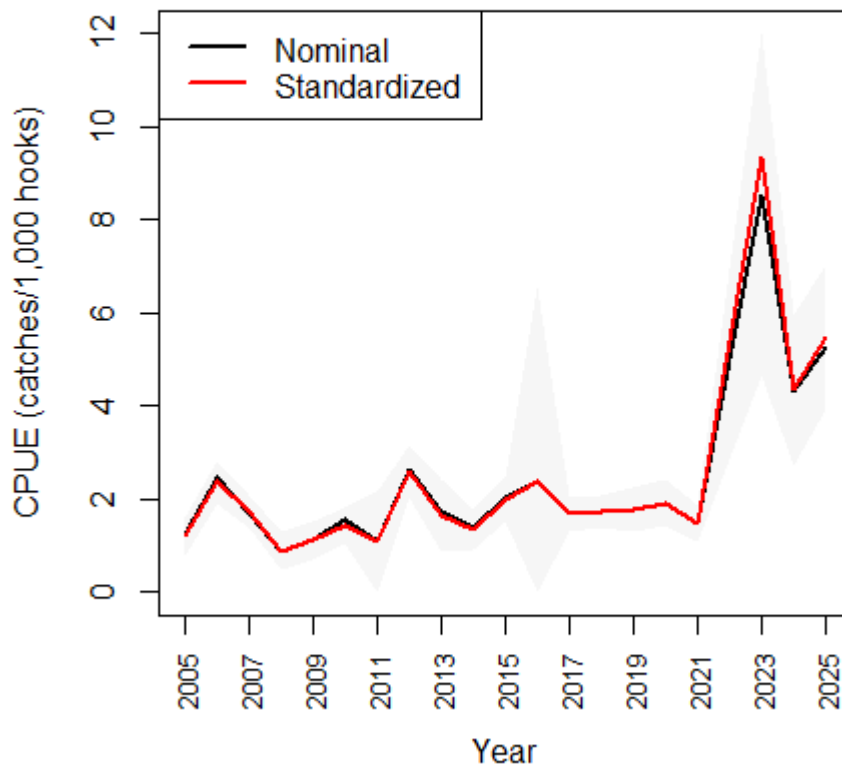


Figure 2. Nominal and standardized CPUE (catches/1,000 hooks) of blue shark (*Prionace glauca*).

References

- Beverly, S., Chapman, L., & Sokimi, W. (2003). *Horizontal longline fishing methods and techniques: a manual for fishermen*. Secretariat of the Pacific Community Nouméa, New Caledonia.
- Bigelow, K., Musyl, M. K., Poisson, F., & Kleiber, P. (2006). Pelagic longline gear depth and shoaling. *Fisheries Research*, 77(2), 173-183. <https://doi.org/10.1016/j.fishres.2005.10.010>
- Chang, S.-K., Hoyle, S., & Liu, H.-I. (2011). Catch rate standardization for yellowfin tuna (*Thunnus albacares*) in Taiwan's distant-water longline fishery in the Western and Central Pacific Ocean, with consideration of target change. *Fisheries Research*, 107(1-3), 210-220.
- Collette, B. B., & Nauen, C., E. (1983). FAO Species Catalogue, Vol. 2 Scombrids of the world: An annotated and illustrated catalogue of tunas, mackerels, bonitos, and related species known to date. In F. a. A. Organization (Ed.), *FAO Fisheries Synopsis* (Vol. 2, pp. 137). Rome, Italy: Food and Agriculture Organization.
- Maunder, M. N., Sibert, J. R., Fonteneau, A., Hampton, J., Kleiber, P., & Harley, S. J. (2006). Interpreting catch per unit effort data to assess the status of individual stocks and communities. *ICES Journal of Marine Science*, 63(8), 1373-1385.

- Obradovich, S. G. (2018). *Evaluating key assumptions of a hook-based relative abundance index derived from the catch of bottom longlines* University of British Columbia].
- Queiroz, N., Humphries, N. E., Noble, L. R., Santos, A. M., & Sims, D. W. (2012). Spatial dynamics and expanded vertical niche of blue sharks in oceanographic fronts reveal habitat targets for conservation. *PLoS One*, 7(2), e32374.
- Rathod, S., Kumar, A. T., & Haripriya, S. (2023). Data Manipulation using R Tidyverse. *Statistical Procedures for Analyzing Agricultural Data using R*, 17.
- Ripley, B., Venables, B., Bates, D. M., Hornik, K., Gebhardt, A., Firth, D., & Ripley, M. B. (2013). Package 'mass'. *Cran r*, 538(113-120), 822.
- Sadiyah, L., Dowling, N., & Prisantoso, B. I. (2012). Developing recommendations for undertaking CPUE standardisation using observer program data. *Indonesian Fisheries Research Journal*, 18(1), 19-33.
- Val, A. L., De Almeida-Val, V. M. F., & Randall, D. J. (2005). Tropical environment. *Fish physiology*, 21, 1-45.
- Walter, J. F., Hoenig, J. M., & Christman, M. C. (2014). Reducing bias and filling in spatial gaps in fishery-dependent catch-per-unit-effort data by geostatistical prediction, I. Methodology and simulation. *North American Journal of Fisheries Management*, 34(6), 1095-1107.