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Standardizing Catch Per Unit Effort (CPUE) of *Coryphaena hippurus* in the Southern Java Waters Using Generalized Additive Model (GAM)

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Abstract: Improving catch data through the standardization of catch per unit effort (CPUE) is crucial in providing accurate information for fish stock assessments. This study aims to develop a CPUE standardization model for dolphinfish (*Coryphaena hippurus*) in the Southern Java Waters. The analysis is based on historical dolphinfish catch data collected between 2019 and 2023. Bias in the CPUE data was reduced using the generalized additive model (GAM) approach. The results indicate that all explanatory variables significantly influence CPUE standardization. The combination of fishing duration, location, and period parameters proved effective in standardizing CPUE. The GAM-based standardization method successfully reduced variability in nominal CPUE, producing more consistent data. These results can provide an essential scientific basis for developing a sustainable management strategy for the Indian Ocean dolphinfish.

Keywords: Catch per unit effort; *Coryphaena hippurus*; Generalized additive model; Southern Water of Java; Standardization

Introduction

Dolphinfish (*Coryphaena hippurus*) is one of Indonesia's fisheries commodities with significant economic and ecological value. This species plays a key role in controlling the food chain as an epipelagic predator inhabiting tropical and subtropical waters (Perle et al., 2020). Additionally, dolphinfish supports both commercial (Báez et al., 2020), recreational (Marín-Enríquez & Muhlia-Melo, 2017), and artisanal (Tripp-Valdez et al., 2010) fisheries, both permanently and seasonally, in several countries. It is also considered a potentially renewable resource (Hartaty & Amalia, 2015) due to its relatively fast growth and sexual maturation rates compared to other marine teleosts (Perle et al., 2020), with a growth constant (K) value ranging from 1.4 to 1.8 per year (Yonvitner et al., 2020a; Susila et al., 2020).

On the other hand, dolphinfish is a significant bycatch component in tuna fisheries (Furukawa et al., 2014; Yonvitner, et al., 2020b) that utilize purse-seine nets (Mannocci et al., 2020) as well as longlines (Arias et al., 2022), both in Indonesian Waters and internationally. It has been reported that 60% of dolphinfish are caught in the Eastern Pacific Ocean due to tuna fishing using purse-seines (Guzman et al., 2015). On the Pacific Coast of Colombia, this species is caught by shark fleets using surface nets at night. It is also captured by grouper fleets over time (Lasso & Zapata, 1999).

Based on records from the Sendang Biru-Malang Port, this species has a catch-to-natural mortality ratio of 1.73 (Yonvitner et al., 2020a). Meanwhile, the capture

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mortality and exploitation rates of dolphinfish at the Cilacap Port are 6.81 per year and 0.8 per year, respectively (Susila et al., 2020). These values are higher than the capture mortality rates of dolphinfish in the Western Indian Coast and Saurashtra Coast, which are only 0.39 and 1.28 per year, respectively (Kumar M. et al., 2017; Saroj & Mohamed Koya, 2023).

The high fishing pressure has led to the over-exploitation of dolphinfish fisheries in the Indian Ocean, particularly in the Southern Waters of Java. Since 2015, dolphinfish catch has exceeded the sustainable potential (F > 121,570 kg/year) and has continued to increase annually (Susila et al., 2020). This condition indicates a decline in the species' sustainability potential, even leading to stock depletion (Yonvitner et al., 2020b).

Nevertheless, the management of dolphinfish in Indonesia still needs to be improved. This is evident from the limited data regarding dolphinfish catch yields (Hartaty & Amalia, 2015). Furthermore, research on Dolphinfish biological resources in Indonesia is minimal (Mantiri et al., 2023).

Dolphinfish stock management is essential to maintain its productivity. One crucial aspect to consider in this effort is information on dolphinfish abundance. Accurate understanding and prediction of the species' distribution and abundance are key factors in fisheries management (Farrell et al., 2014).

Catch per unit effort (CPUE) is the catch ratio to the effort expended during fishing activities (Kartini et al., 2021). This value can illustrate the decline and increase in fishery production within a particular region (Listiani et al., 2017). Furthermore, Kristiana et al. (2021) elaborated that CPUE is a potential and effective indicator of the efficiency of fishing operations. Trends in CPUE can indicate the status of fishery resource utilization in a given water body. Therefore, CPUE is considered a key piece of information in fish stock assessments and is assumed to be proportional to abundance (Hinton & Maunder, 2004).

Although nominal CPUE calculations have been widely employed in fisheries management across Indonesia, this approach exhibits several significant limitations. Nominal CPUE fails to account for the fishing effort's spatial and temporal distribution (Dimarchopoulou et al., 2023; Kunimatsu et al., 2024). Consequently, analyses based on nominal CPUE frequently produce biased and inaccurate stock abundance estimates, leading to suboptimal management decisions.

Other factors that may influence CPUE must be eliminated from the index. This process of removing the effects of these factors is commonly referred to as CPUE standardization (Rochman et al., 2021). CPUE standardization is essential for effective fisheries stock management in Indonesia. This approach facilitates more accurate comparisons among diverse fishing fleets with varying characteristics and efficiencies (Jaya et al., 2022; Dimarchopoulou et al., 2023). The effects of evolving fishing technologies can be identified and appropriately adjusted through standardization, providing a more precise representation of fish stock abundance (Maunder et al., 2006; Han et al., 2023). Additionally, standardization accounts for variations in fish distribution and fishing efforts influenced by Indonesia's distinctive geographical and oceanographic conditions (Lei et al., 2024; Kunimatsu et al., 2024). This methodological refinement ultimately contributes to more robust scientific foundations for sustainable fisheries management decisions.

Numerous methods have been developed for CPUE standardization, with the most widely used being the generalized linear model (GLM) and the generalized additive model (GAM). The functional form of GLM is designed to capture linear relationships, making it less effective in studies involving complex relationships between CPUE and explanatory variables. In contrast, GAM was developed to extend GLM, enabling more informative and accurate modeling of non-linear relationships between resource abundance and environmental factors (Hua et al., 2019).

Despite high fishing pressure and identified indications of overfishing, there has been no comprehensive CPUE standardization model for dolphinfish in the Southern Java Waters. The absence of an appropriate model results in inaccurate stock abundance estimates and could lead to management errors. Factors influencing the CPUE of dolphinfish in this region have also not been identified, making research regarding a specific CPUE standardization model for dolphinfish extremely urgent.

This study aims to develop a data standardization model for dolphinfish (*Coryphaena hippurus*) fisheries in the Southern Waters of Java. The generalized additive model (GAM) is a statistical approach to eliminating biases in fisheries data, producing more accurate and reliable estimates. The standardization of catch per unit effort (CPUE) is expected to serve as an initial step in supporting stock analysis of dolphinfish in the Indian Ocean while contributing to sustainable fisheries management.

Method

This study focuses on the Southern Waters of Java, located between coordinates 99.52°–116.67° E and 5.38°–17.82° S, as shown in Figure 1. The Southern Waters of Java are part of Indonesia's marine territory, directly connected to and influenced by the Indian Ocean, the Western Waters of Sumatra, and the Sunda Strait (Surinati & Wijaya, 2017). These waters encompass the southern maritime regions of East Java, Yogyakarta, Central Java, West Java, and Banten Provinces. According to the Indonesian Ministry of Marine Affairs and Fisheries Regulation No. 18 of 2014 on the Fisheries Management Areas of the Republic of Indonesia, the Southern Waters of Java are categorized as Fisheries Management Area 573 (WPP-NRI 573). Furthermore, this region is recognized as a migration route for large pelagic fish species (Harlyan et al., 2021).

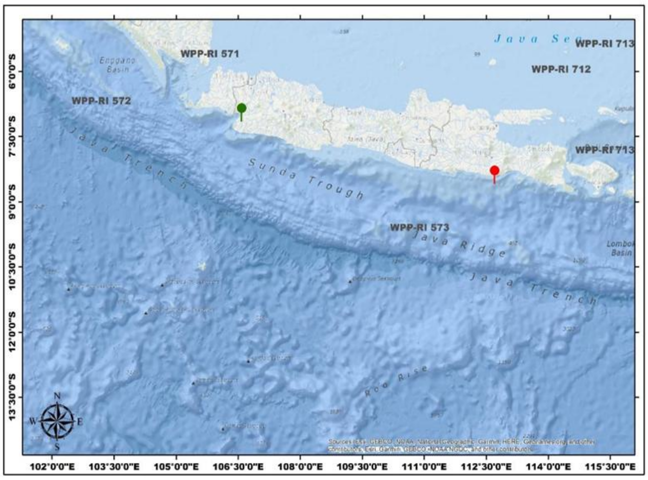

Figure 1. The map of the study area in Southern Waters of Java. The red dot shows the location of PPP. Pondokdadap, while the green dot shows the location of PPN. Palabuhanratu.

Data Collecting

This study utilizes historical fishing data of dolphinfish from the Southern Waters of Java, including catch coordinates, fishing and landing dates, and the catch's weight and species composition. The fisheries data were obtained from recapitulating fishing logbooks from Pondokdadap and Palabuhanratu Harbors. Data collection was conducted from January 2019 to December 2023, resulting in 4,034 observations.

Data Analysis

The data analysis workflow in this study is illustrated in Figure 2.

(1) CPUE Calculation

Fish stock abundance can be estimated using a simple calculation of catch per unit effort (CPUE) (Sutono Hs. et al., 2021). In this context, fishing effort can be represented by the days at sea (Easton et al., 2023). The calculation of CPUE in this study follows the guidelines Schaefer (1957) outlined by (Gulland, 1983). The following equation represents the calculation of catch per unit effort for Dolphinfish:

$$CPUE = \frac{c}{f} \quad (1)$$

The CPUE represents the total catch per unit effort (kg/day), where c denotes the total catch (kg), and f indicates the fishing effort (days).

(2) CPUE Standardization

The standardization of CPUE aims to eliminate unintentional estimation bias from fisheries data (Sihombing et al., 2023). This standardization process utilizes nominal CPUE data as the primary dataset alongside explanatory variables. At this stage, nominal CPUE values are adjusted to derive standardized CPUE indices. Standardized CPUE represents an index value derived from explanatory variables significantly influencing the data. Explanatory variables in fishing efforts encompass the tactics and strategies employed by fishing fleets (Rochman et al., 2021). These variables may include fishing year, fishing month, fishing coordinates, and others (Mondal et al., 2021). In this study, CPUE standardization is conducted using the generalized additive model (GAM) with a gamma distribution implemented through the RStudio software version 2024.04.2+764 integrated with R software version 4.4.1. The following equation, adapted from Hua et al. (2019), represents the model used in this analysis.

$$Log(CPUE + k) = \mu + (n)day + year + month + s_1(longitude) + s_2(latitude) + \epsilon \quad (2)$$

CPUE represents the catch per unit of nominal fishing effort (kg/day), where (n)day denotes the duration of fishing activities (days), k represents the indicator of the average nominal catch with a constant value of 0.1, μ denotes the intercept, s_n represents the smoothing function of each predictor, and $\in$ denotes the normally distributed variable with a mean of zero.

The best model selection can be evaluated based on the deviance explained (DE) value (Puspita et al., 2023). The DE value measures the proportion of total deviation explained by a given model (Hidayat et al., 2021). A significant model is characterized by a higher DE value (Sasmito et al., 2022).

The final stage of this analysis is the development of standardized CPUE. Dolphinfish CPUE values can be predicted using the predict.gam function (Wood, 2023) within the mixed GAM computation vehicle (MGCV) package version 1.9-1 (Zhu et al., 2024). This process involves covariates similar to those used in building the model (Setiawati et al., 2014). The following command can execute the prediction function (Puspita et al., 2023).

predict.gam(object, NewData, type = 'response') (3)

Object represents the GAM object generated by the gam() function, NewData refers to the dataset containing the covariate values for the model, and type

= 'response' returns the predicted values on the response scale.

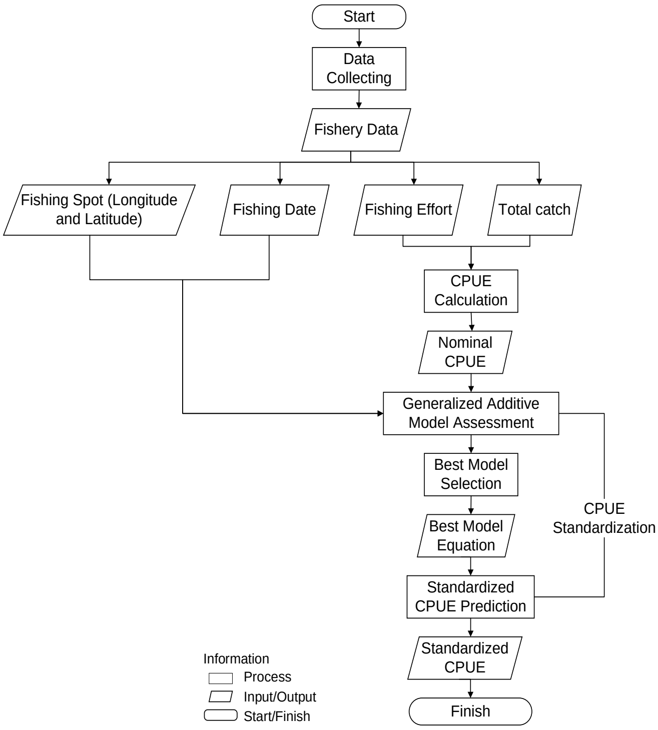

Figure 2. Research flow diagram for the standardization of dolphinfish CPUE in Southern Java Waters.

Result and Discussion

Nominal CPUE of Dolphinfish

The dolphinfish is one of the bycatch species from tuna, mackerel, and skipjack fishing activities in the Southern Waters of Java. Most dolphinfish catches in this area are made using handline fishing fleets, although trolling lines and tuna longlines are also utilized, particularly in the Palabuhanratu Waters during 2019-2020. These findings align with those reported by Susila et al. (2020) and Chodrijah & Nugroho (2016), who stated that dolphinfish can be caught using purse seines, pole-and-line, longlines, and handlines.

The duration of *C. hippurus* fishing in the Southern Waters of Java varies depending on the type of vessel and fishing gear used, the fishing season, and weather conditions. Based on fishing records, fishermen in Pondokdadap typically undertake trips lasting 7–14 days (weekly) using vessels with capacities below 30 GT. In contrast, fishermen in Palabuhanratu conduct trips lasting 30–90 days (monthly) per trip, utilizing vessels with capacities exceeding 30 GT.

The *C. hippurus* fishing activities during the 2019–2023 period are illustrated in Figure 3. Fishing efforts occurred year-round, with an average of 191 monthly fishing days. Higher fishing intensity was observed in 2019, 2020, and 2023, with a peak in May 2023, reaching 695 fishing days. Conversely, *C. hippurus* fishing efforts in 2021 and 2022 declined compared to other years. During this period (2021–2022), fishing intensity fluctuated and did not exhibit a consistent seasonal pattern. This decline is likely associated with the shift from trolling line and tuna longline fleets to handline fishing in Palabuhanratu. The lowest fishing intensity was recorded in May 2022, with six fishing days.

The peak of *C. hippurus* fishing activities each year occurs during the first transitional season (March-May) and the eastern season (June–August). In contrast, a consistent decline in fishing efforts is observed during the western season (December–February). Weather conditions influence fluctuations in fishing intensity. During periods of strong winds and high waves, fishermen tend to avoid going to sea and instead focus on repairing fishing gear onshore. Conversely, fishing intensity increases under favourable conditions (Lintang et al., 2012). These findings are supported by Saleh et al. (2022), who stated that intensive fishing from March to November is attributed to favourable environmental conditions. Meanwhile, during the western season (December–February), fishermen are more likely to reduce or postpone fishing activities due to strong waves and currents that hinder fishing operations.

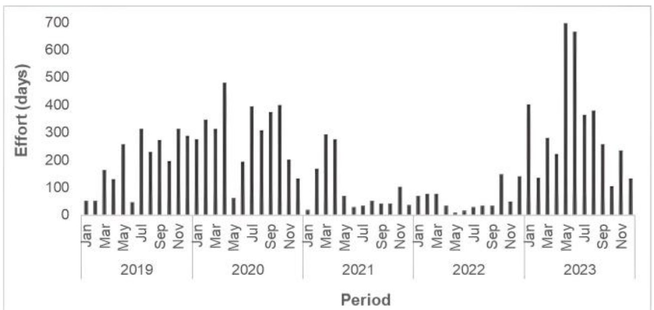

Figure 3. Variability of Dolphinfish Fishing Efforts in the Southern Java Waters from 2019 to 2023

The *C. hippurus* landings at PPP Pondokdadap and PPN Palabuhanratu are illustrated in Figure 4. According to fishing records, the average monthly dolphinfish catch was 3,771.02 kg. The highest catch was recorded in November 2021, weighing 11,573 kg, while the lowest catch occurred in May 2022, weighing 162 kg. Dolphinfish catches increased from 2019 (56,049 kg) to 2020 (64,757 kg), representing a 16% growth. However, a decline was observed in 2021 (38,118 kg), reaching the lowest annual catch in 2022 (17,361 kg), with a 54% decrease. Subsequently, the catch rebounded in 2023, reaching 49,976 kilograms, with an increase of 188%.

Catch performance is closely associated with changes in environmental conditions (Farrell et al., 2014). During the 2021–2022 period, these parameters exhibited a significant decline. This is presumed to be related to the weak La Niña event in 2020–2021 (Sambah et al., 2023) and the negative Indian Ocean Dipole (IOD) in 2022 (Ratnawati et al., 2024).

Dolphinfish are available year-round, with two peak fishing seasons. The first peak typically occurs from the end of the eastern season (July) through the second transitional season (November). The second peak appears from the end of the western season (January) to the early first transitional season, as seen in March and April. Conversely, low catch periods often occur at the end of the first transitional season (May) to the beginning of the eastern season (June) and at the start of the western season (December). This pattern is similar to the fishing season for bigeye tuna in the Western Waters of Sumatra, which also has two peak seasons in March-May and October (Nugroho et al., 2018). Other studies suggest that fish catches stabilize during the eastern season, characterized by dry air that warms Indonesian Waters (Anggara et al., 2023).

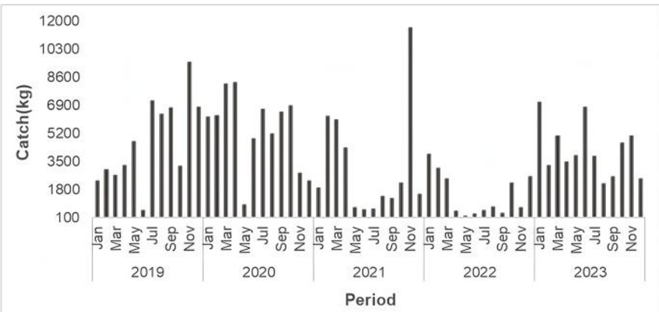

Figure 4. Variability of Dolphinfish Catch in the Southern Waters of Java from 2019 to 2023

The relationship between fishing effort and catch is illustrated in Figure 5. The bar chart represents the total catch, while the red line indicates the dolphinfish fishing effort in the Southern Waters of Java using handline fishing gear. Based on the observed pattern, there is a general tendency for increased fishing effort to be followed by an increase in catch. However, there are instances where increased fishing effort does not necessarily result in a higher catch, such as in May 2023. During this period, fishing efforts reached 695 days, yet the total catch amounted to only 3,851 kg. Additionally, an anomaly was observed in November 2021, where the total catch was exceptionally high (11,573 kilograms) despite relatively low fishing effort (100 days).

The anomaly observed in May 2023 reflects the complexity within the dynamics of *C. hippurus* fisheries in the Southern Java Waters. Several interrelated factors influenced this phenomenon. May 2023 marked the onset of the El Niño phase, characterized by increased sea surface temperature anomalies in the eastern Pacific, while the Indian Ocean Dipole (IOD) remained in a neutral phase but began to exhibit a positive trend (Badan Meteorologi, Klimatologi, dan Geofisika, 2023). The transition from La Niña conditions in 2020-2021 and negative IOD in 2022 to the early El Niño phase and trending toward positive IOD in 2023 is hypothesized to have altered the migration patterns and feeding behavior of dolphinfish, subsequently causing a shift in fish concentration areas away from traditional fishing grounds.

This anomaly case also indicates that the fishing intensity of dolphinfish has exceeded the environmental carrying capacity, suggesting the potential vulnerability of dolphinfish stocks in the Southern Java Waters. High fishing intensity risks stock depletion (Yonvitner et al., 2019). This condition occurs because fishing effort directly impacts fish biomass (Pratiwi et al., 2019). Similar patterns have been observed in other fish species in Indonesian waters, where significant increases in fishing efforts have resulted in declining productivity (Purwanto et al., 2014; Zairion et al., 2020; Erwansyah et al., 2023).

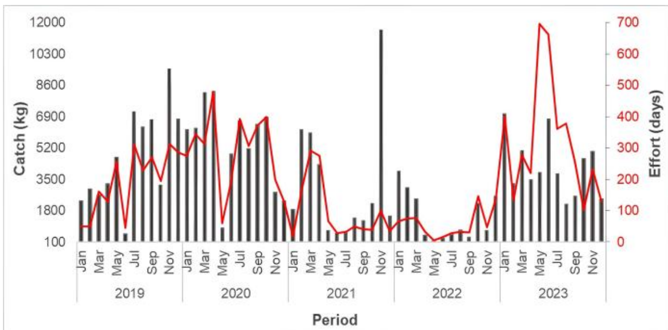

Figure 5. Relationship Between Fishing Effort and Dolphinfish Catch in the Southern Waters of Java from 2019 to 2023

The development of nominal CPUE for dolphinfish in the Southern Waters of Java is presented in Figure 6. Higher nominal CPUE values were recorded in 2021, with a monthly average of 41.6 kg/day. Conversely, lower CPUE values were observed in 2023, with a monthly average of 16.94 kg/day. The peak nominal CPUE occurred in November 2021, reaching 115.73 kg/day, while the lowest value was recorded in May 2023 at 5.54 kg/day. Overall, the nominal CPUE pattern exhibited inconsistent variation throughout the observation period.

The abundance of dolphinfish shows an increasing trend during the second transitional period (September–November) through the western season (December–February). In contrast, CPUE values decline gradually during the first transitional period (March-May) and the eastern season (June–August). The decrease in CPUE values indicates that a corresponding increase in catch does not accompany increased fishing effort. Furthermore, the decline in CPUE also suggests a reduction in the availability of fish resources in the wild, which, if not addressed, could lead to the risk of over-exploitation (Oktaviyani et al., 2015). This change underscores the importance of long-term monitoring of marine environmental conditions to understand dolphinfish distribution and abundance better.

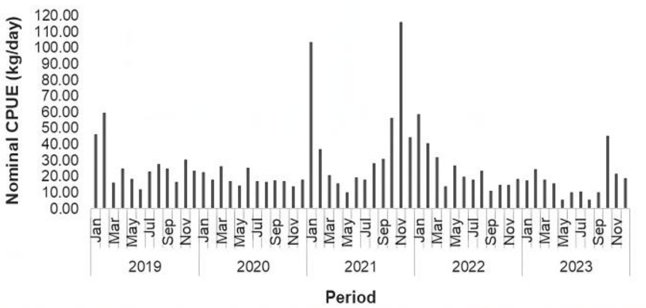

Figure 6. Nominal Catch per Unit Effort (CPUE) of Dolphinfish in the Southern Waters of Java, 2019-2023

CPUE Standardization Model

This study employed a generalized additive model (GAM) with a gamma distribution, which is considered more effective in explaining the variation of parameters within the model. The Gamma distribution was chosen because it is specifically designed to model continuous variables and can effectively handle slight overdispersion in the data (Félix-Salazar et al., 2024). The model generated a deviance explained (DE) value of 11-20%, indicating a moderate fit to the analyzed data. This range is commonly observed in fisheries data with complex ecological systems influenced by various environmental and anthropogenic factors (Schiller et al., 2024). In general linear models (GLM) studies, higher DE values (up to 52.4%) can be achieved for well-defined target species such as *Aristeus antennatus*. In contrast, for bycatch species like *Nephrops norvegicus*, lower DE values (maximum 13%) are more typical (Maynou et al., 2003). Despite the relatively low DE value, this model remains acceptable for providing valuable insights into fisheries management, and a positive deviation approach can be utilized to study successful fisheries management interventions by analyzing 'positive deviations' or outliers that demonstrate better-than-expected results (Schiller et al., 2024).

Table 1. presents the model variables and the significance values of each explanatory factor in the GAM analysis using a Gamma distribution. The effort variable represents the duration of fishing activities, while the month 1–12 variable corresponds to the fishing months from January to December. The year 1–5 variable represents the fishing years from 2019 to 2023. The longitude and latitude variables describe the fishing locations. The month and year variables are categorical, whereas longitude, latitude, and effort are numerical variables.

The results for month 1 and year 1 are not displayed in the table as they were selected as the baseline (reference), with the effects of other categories calculated relative to this baseline. Consequently, the values for month 1 and year 1 can be considered part of the intercept, as the baseline does not exhibit additional deviation.

All environmental variables included in the GAM analysis with a gamma distribution demonstrated high significance ($p < 0.035$). The combination of fishing effort, year and month of fishing, and geographical coordinates (longitude and latitude) at the fishing locations (Model 2) produced the most effective model in explaining data variation. This combination of five parameters yielded the highest deviance explained (DE) value of 20.4%, as presented in Table 2. These findings indicate that variations in these variables are likely to be accompanied by changes in CPUE over a time series (Rochman et al., 2021).

These results are consistent with previous studies (Mondal et al., 2021; Sihombing et al., 2023), which indicated that the explanatory variables are sufficiently representative for standardizing the abundance index of fish in a given waterbody. Furthermore, the observation year variable significantly affects CPUE, which can be attributed to changes in fishing strategies, shifts in fishing areas, and annual variations in environmental conditions (Rochman et al., 2021).

Table 1. Summary Model GAM Gamma

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	4.175128	0.095805	43.579	< 2e-16 ***
Effort	-0.018043	0.003036	-5.944	3.00e-09 ***
Month2	-0.221657	0.104233	-2.127	0.033513 *
Month3	-0.344715	0.102384	-3.367	0.000767 ***
Month4	-0.582738	0.099848	-5.836	5.72e-09 ***
Month5	-0.714382	0.123912	-5.765	8.71e-09 ***
Month6	-0.458690	0.122623	-3.741	0.000186 ***
Month7	-0.683499	0.108564	-6.296	3.35e-10 ***
Month8	-0.436241	0.111831	-3.901	9.73e-05 ***
Month9	-0.411252	0.104564	-3.933	8.52e-05 ***
Month10	-0.676230	0.100218	-6.748	1.70e-11 ***
Month11	-0.270937	0.100431	-2.698	0.007008 **
Month12	-0.316561	0.107757	-2.938	0.003323 **
Year2	-0.265087	0.070047	-3.784	0.000156 ***
Year3	-0.279087	0.092309	-3.023	0.002514 **
Year4	-0.523424	0.094355	-5.547	3.07e-08 ***
Year5	-0.466639	0.080240	-5.816	6.47e-09 ***
	edf	Ref.df	F	p-value
s(Longitude)	8.659	8.965	7.198	<2e-16 ***
s(Latitude)	8.684	8.965	31.874	<2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 2. CPUE Standardization Model

Model	DE	Link Function
Catch ~ s(Longitude) + s(Latitude) + Month + Year	17.3%	log
Catch ~ Effort + s(Longitude) + s(Latitude) + Month + Year	20.4%	log
Catch ~ s(Longitude) + s(Latitude) + Month + Year + offset(log(Effort))	11.6%	log

Standardized CPUE of Dolphinfish

Fishing data in developing countries is abundant and continuously available (Setiawati et al., 2014). Therefore, this study utilizes dolphinfish catch data to indicate fish stock abundance. However, this fishing data has several limitations, such as variations in catch capacity influenced by operational time and oceanographic conditions at the fishing site. Thus, standardization is necessary to eliminate confounding factors in the fishing data (Félix-Salazar et al., 2024).

The standardized catch per unit effort (CPUE) of dolphinfish ranged between 17.747 and 1,743.339 kg/day, with an average of 61 kg/day, as illustrated in Figure 7. In 2020, the standardized CPUE showed lower values, with a monthly average of 28.1 kg/day. Conversely, the standardized CPUE exhibited higher values in 2023, reaching a monthly average of 172.53 kg/day. The lowest standardized CPUE value was recorded in May 2022 (17.75 kg/day), while the highest value occurred in September 2023 (1,743.34 kg/day), representing a sharp increase compared to other months.

The GAM standardization method employed in this study has proven effective in reducing variability in nominal CPUE, consistent with the findings of Hua et al. (2019). The standardized CPUE provides a more consistent representation of fish stock availability compared to nominal CPUE (Shi et al., 2023) and is expected to enhance predictive capacity (Zhou et al., 2022). This data will subsequently serve as the foundation for further investigations into identifying dolphinfish in the Southern Java Waters.

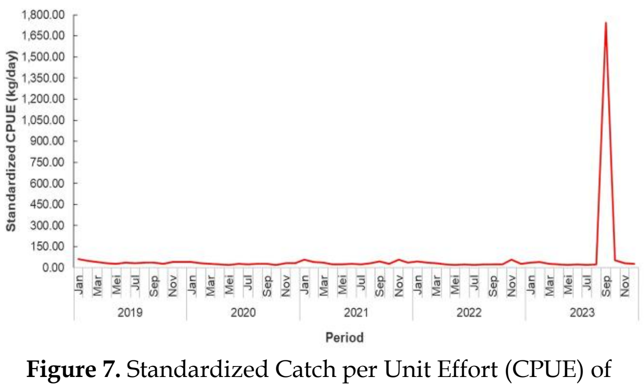

Figure 7. Standardized Catch per Unit Effort (CPUE) of Dolphinfish in the Southern Waters of Java, 2019-2023.

Conclusion

This study provides novel insights into the standardization of CPUE for dolphinfish fisheries in Indonesian Waters. The five explanatory variables significantly influenced the CPUE standardization of dolphinfish in the Southern Java Waters. The combination of fishing duration, year and month of fishing, and latitude and longitude effectively reduced variability in nominal CPUE. The resulting standardized CPUE offers a more consistent representation of fish stock availability than nominal CPUE.

This study represents an initial investigation presenting the concept of CPUE standardization for dolphinfish in the Southern Java Waters. While it provides a fundamental overview, the study has certain limitations, offering opportunities for further development, particularly regarding the variables used in the model. Researchers recommend incorporating oceanographic dynamics data, such as sea surface temperature, chlorophyll-a, salinity, ocean current, etc., to improve the robustness of the standardization model.

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Author Contributions

All authors have made a real contribution to completing this manuscript.

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Conflicts of Interest

The authors declare no conflict of interest

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