Further observations on the use of length conversion equations to address length data deficiencies for swordfish (*Xiphias gladius),* Indo-Pacific sailfish (*Istiophorus platypterus*), black marlin (*Istiompax indica*) and blue marlin (*Makaira nigricans*) in the Indian Ocean, using images of billfish caught by Sri Lanka's artisanal and semi- industrial multi-day fishing vessels.

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Abstract

Accurate length data are essential for billfish stock assessments, yet obtaining standard morphometric measurements is challenging in Sri Lanka due to common dressing practices that remove key body parts before landing. This study evaluated the use of Pectoral Second Dorsal Length (PDL) and Pectoral Anus Length (PAL) as proxies for Lower Jaw Fork Length (LJFL) in swordfish (Xiphias gladius), Indo-Pacific sailfish (*Istiophorus platypterus*), black marlin (I*stiompax indica*), and blue marlin (*Makaira nigricans*). Morphometric data were collected from artisanal and semi-industrial multi-day fishing vessels using field measurements and image-based analysis. Results showed strong linear relationships between LJFL and both PDL and PAL for swordfish, sailfish, and black marlin ($R^2 > 0.85$), confirming their reliability for length estimation. In contrast, blue marlin exhibited weaker correlations, with PDL moderately related to LJFL ($R^2 = 0.73$) and PAL poorly correlated ($R^2 = 0.46$), indicating higher variability in body proportions. These findings demonstrate that PDL and PAL provide robust conversion tools for most billfish species in the Indian Ocean, but highlight the need for additional sampling and refinement before their application to blue marlin. However, the relationship between LJFL and PDL can be considered reliable, and therefore PDL can be used to derive LJFL. The same approach can be recommended for other fisheries that face issues similar to those encountered by Sri Lanka in billfish stock assessments. However, species-specific validation is also essential when applying morphometric proxies to address data deficiencies in billfish fisheries.

Key Words: Billfish, Indian Ocean, Stock assessment, Morphometric data, Fisheries Management

Introduction

The Sri Lankan billfish fishery which is not a major fishery in Sri Lanka primarily targets pelagic species such as swordfish (*Xiphias gladius*), black marlin (*Istiompax indica*), blue marlin (*Makaira nigricans*), striped marlin (*Tetrapturus audax*), and Indo-Pacific sailfish (*Istiophorus platypterus*). In some instances, billfishes are also caught beyond the Exclusive Economic Zone (EEZ) as bycatch in tuna fisheries. However the fishery logbook records suggesting that billfishes are typically caught as bycatch in Sri Lankan Fisheries sector (DFAR, 2025). Figure 01 illustrates the distribution of billfish catches by Sri Lankan fishers in 2024. The harvested catch is utilized both for domestic consumption and export markets (Creech et al., 2024). Longline fishing gear constitutes the primary method of targeting billfish, although they are also incidentally captured in gillnets to a lesser extent (Haputhantri & Perera, 2015; IOTC, 2013).

Billfish catches in Sri Lanka show marked seasonal variation, with peaks during the monsoon periods when migratory patterns bring these species closer to coastal waters (Dissanayake & Sigurdsson, 2005). Comparable seasonal trends have been reported across the Indian Ocean, reflecting the strong influence of environmental drivers on billfish availability (Velayudham et al., 2012). To support effective management, the Indian Ocean Tuna Commission (IOTC) Resolution 15/02 requires member states and cooperating parties to systematically collect and submit size-frequency data for tuna, billfish, and other IOTC-managed species (IOTC, 2021). This includes the standardized reporting of morphometric measurements, forming the basis for length–weight data submissions.

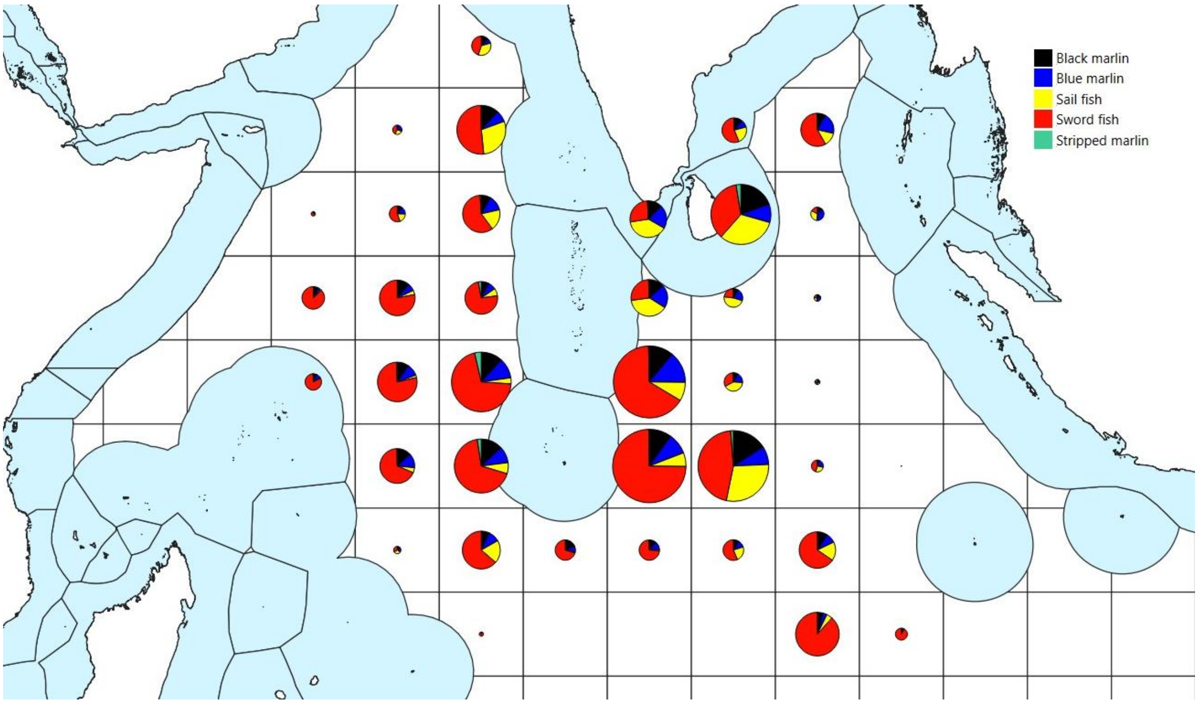

Figure 01. Spatial catch distribution of billfish catches by Sri Lankan fishers in 2024

The IOTC specifies that upper jaw fork length (UJFL) should be used as the standard metric for reporting. In cases where UJFL is not available, lower jaw fork length (LJFL) should be recorded. In addition, the full body weight of each specimen should be documented. If only dressed weight is available (for example, when the fish has been gutted or the head removed) the report must include details of the conversion procedure used to estimate the round weight (Mejuto et al., 2008). Reported values should be validated against expected regional size distributions in order to minimize errors in species identification and size reporting to ensure data accuracy (IOTC, 2021; Brodziak, 2013).

The majority of Sri Lankan longline and gillnet vessels are less than 24 meters in length (Kariyawasam, 2010). Due to limited onboard storage capacity, billfishes are often gutted prior to landing. Consequently, it is difficult to obtain whole-fish measurements at landing sites. According to Prager et al. (1995), ten methods are commonly used for dressing billfishes (*Istiophoridae*) at sea. Among these, Sri Lankan fishers most frequently employ the methods illustrated in subfigures 9 and 10 of their study(Figure 02). Typically, fish are cut into two or three sections prior to landing, which complicates precise estimation of both length and weight during port sampling. This presents challenges for collecting comprehensive biological data on billfish (Haputhantri & Perera, 2014, 2015; Jayasinghe et al., 2024).

To address these difficulties, this study proposes an alternative approach for collecting morphometric information on billfishes. Specifically, we examine the correlations between billfish body weight and different length measurements. These derived relationships can serve as conversion factors for estimating standard lengths such as total length (TL), fork length (FL), and lower jaw fork length (LJFL). In line with the IOTC technical standards for length and weight data collection, these conversion factors may be applied to enhance data quality and consistency in national submissions to the IOTC (IOTC, 2021).

Methodology

Several trips to the field were conducted to the Negombo fish market on September 2025, where fish dressing from guts was observed. Ten methods of dressing fish were described by Prager et al. (1995). The ninth and tenth methods closely resemble Sri Lankan dressing practices (Figure 02). However, another common dressing was observed during the field visit (Figure 03).

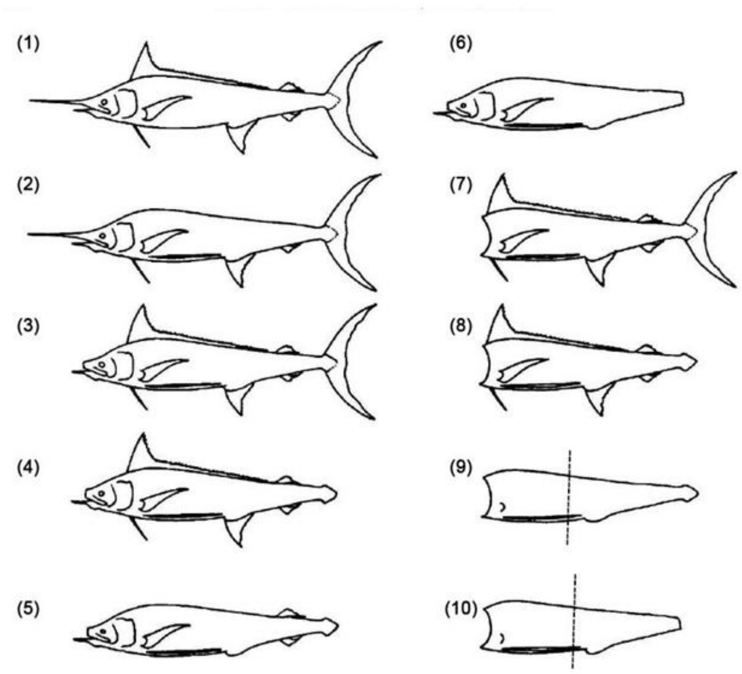

Figure 02. Methods of dressing billfishes at sea as described by Prager et al. (1995). In Sri Lanka, methods 9 and 10 are most commonly used by fishers. Because length measurements are typically taken on dressed carcasses, conversion to standardized length metrics is required for consistent data collection.

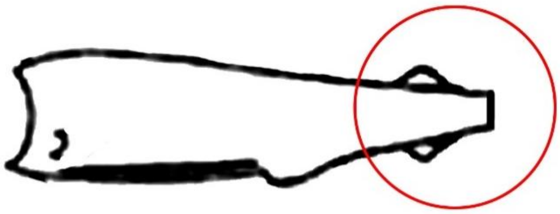

Figure 03: The common dressing method observed in field visits

In the observed dressing, fish are normally gutted from above the dorsal fin to a point between caudal and second dorsal fin. Second dorsal fins and the second anal fins are clearly visible in gutted carcasses. Between the second dorsal fin and caudal fin point is not consistent among fishermen and no specific point of cutting exists in that region (Figure 04).

Figure 04. Examples of dressed swordfish and billfish carcasses landed in Sri Lanka. Cuts are generally made from above the dorsal fin to a point between the second dorsal and caudal fins, although the exact cutting point varies among fishers, complicating standardized measurement.

Therefore, Pectoral Second Dorsal Length (PDL) and Pectoral Anus Length (PAL) turned out to be reliable morphometric measures that could also directly be measured from gutted fish. All standard measurements are illustrated in Figure 05, where PDL and PAL are used for this study. Subsequently, in 2025, morphometric measures of sailfish and billfish were acquired from longline and gillnet fisheries. Here, an observer program based on crews was implemented in collecting data by directing observers to photograph the entire specimen with a scale. These photos were then pre-processed in such a way that these lengths were extracted: Pectoral Anus Length (PAL), Pectoral Second Dorsal Length (PDL), and Lower Jaw Fork Length (LJFL). Regression models were employed to each species for determining the best-fit model to estimate Lower Jaw Fork Length (LJFL) from Pectoral Anus Length (PAL) and Pectoral Second Dorsal Length (PDL). Then routine field visits to Negombo harbour were made by directly measuring Pectoral Anus Length (PAL) and Pectoral Second Dorsal Length (PDL) on landing sites in order to test the model.

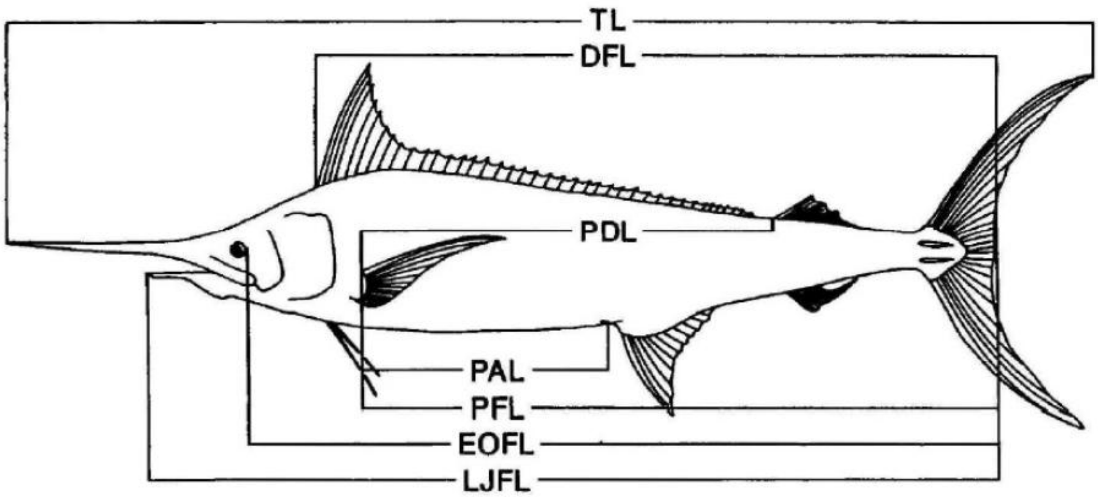

Figure 05: Length measures used for recording lengths of bill fishes (Istiophoridae) landed in commercial and recreational harvests. TL, total length; DFL, Dorsal-fork length; PDL, Pectoral second dorsal length; PAL, pectoral-anus length; PFL; pectoral-fork length; EOFL, eye orbit-fork length; UFL, lower jaw-fork length (Prager et al, 1995; Creech et al, 2024).

Table 1: Length measurements used for the present study

Common name	**Scientific name**	**Sampling size**	**Mean length (Cm) ± standard deviation**		
			LJFL	**PDL**	**PAL**
Swordfish	*Xiphias gladius*	194	138± 38	80±25	48±12
Blue marlin	*Makaira nigricans*	37	186±26	101±17	67±12
Black marlin	*Istiompax indica*	130	171±37	194±34	106±19
Indo-pacific sailfish	*Istiophorus platypterus*	110	175±38	176±30	103±18

For each species is model is validated separately to obtain appropriate equations. Linear regression was used to estimate the morphometric correlations of billfishes & Swordfish length-length (Sedgwick, 2012). The quality of the linear regressions was assessed using the determination coefficient (r). Every statistical analysis was evaluated at the 5% significance level ($p<0.05$). Minitab (Minitab® 19) statistical software was used for the analysis.

Results and Discussion

The correlations between LJFL ,PAL and PDL were shown in Table 1. Results indicated that PDL has significant linear relationships ($r>0.8$, $p>0.05$) with the LJFL for all species. Significant linear relationship ($r>0.8$, $p>0.05$) between PAL and LJFL for all species (except blue marlin) indicated that PDL can be used as a reliable measurement. Swordfish, sailfish, and black marlin show consistently strong correlations: both PDL and PAL are reliable predictors of LJFL. For blue marlin, a distinct pattern was observed: LJFL demonstrates a strong and statistically robust correlation with PDL ($r = 0.854$), whereas its association with PAL is comparatively weaker ($r = 0.680$). Additionally, PDL and PAL exhibit only a weak correlation ($r = 0.515$), indicating greater variability in body proportions.

Table 2: Pearson correlation metrixes for Swordfish, Blue marlin, Indo-Pacific sail fish and Black Marlin

	Swordfish		**Blue marlin**		**Indo- pacific sail fish**		**Black marlin**	
	LJFL	**PDL**	**LJFL**	**PDL**	**LJFL**	**PDL**	**LJFL**	**PDL**
PDL	0.982		0.854		0.971		0.968	
PAL	0.96	0.963	0.68	0.515	0.926	0.953	0.88	0.915

For swordfish, sailfish, and black marlin, the current analysis shows strong linear relationships between PDL and LJFL, with coefficients of determination (R2) exceeding 0.93 (Figure 06). Regression was statistically significant, and the sample size (N = 37) was adequate to establish a relationship between PDL and LJFL. These findings show that PDL is a valid morphometric proxy for LJFL in gutted specimens of these species, supporting its usefulness for size estimation where standard measurements are unavailable for blue marlin. The lower R2 (0.73), however, indicates that the dataset is currently insufficient for reliable predictive modeling. To increase the stability and dependability of the model for this species, more sampling and cautious handling of outliers are needed. Consequently, while PDL-based models appear robust for swordfish, sailfish, and black marlin, additional sampling and refinement are required for blue marlin before the method can be applied with confidence.

Clear interspecific variations in predictive strength were found in the regression analysis between PDL and LJFL (Figure 07). Strong linear relationships between Indo-Pacific sailfish and swordfish (R2 = 0.86 and 0.92, respectively) suggest that PDL can be a good stand-in for LJFL in gutted specimens of these species. Although they were somewhat more variable than swordfish and sailfish, black marlin also displayed a comparatively high correlation (R2 = 0.77). Blue marlin, on the other hand, showed a weak correlation (R2 = 0.46), and the data was highly scattered. This implies that a robust regression model cannot be produced with the current sample size and/or variability in body proportions for this species. While highlighting the need for additional improvement for blue marlin, these findings generally support the use of PDL-based models for length estimation in swordfish, sailfish, and black marlin. This emphasizes how crucial species-specific validation is when using morphometric proxies in studies on billfish fisheries.

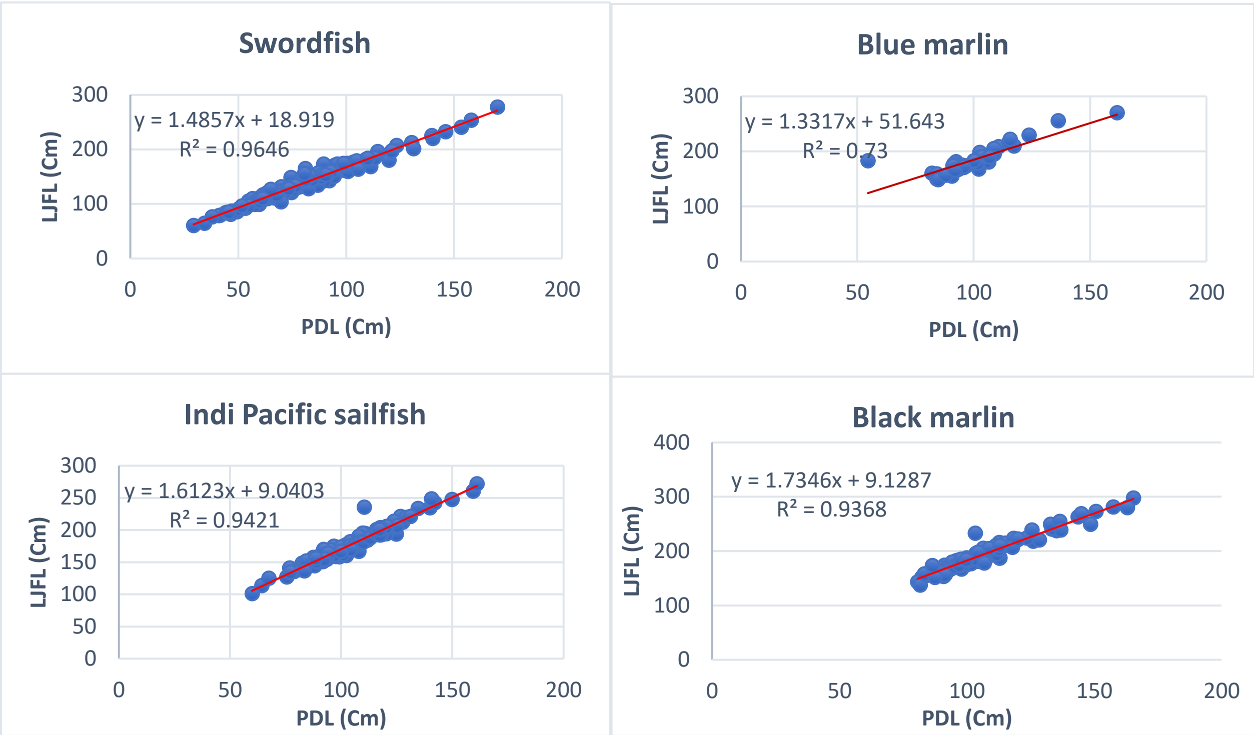

Figure 06 : Regression analysis between LJFL and PDL

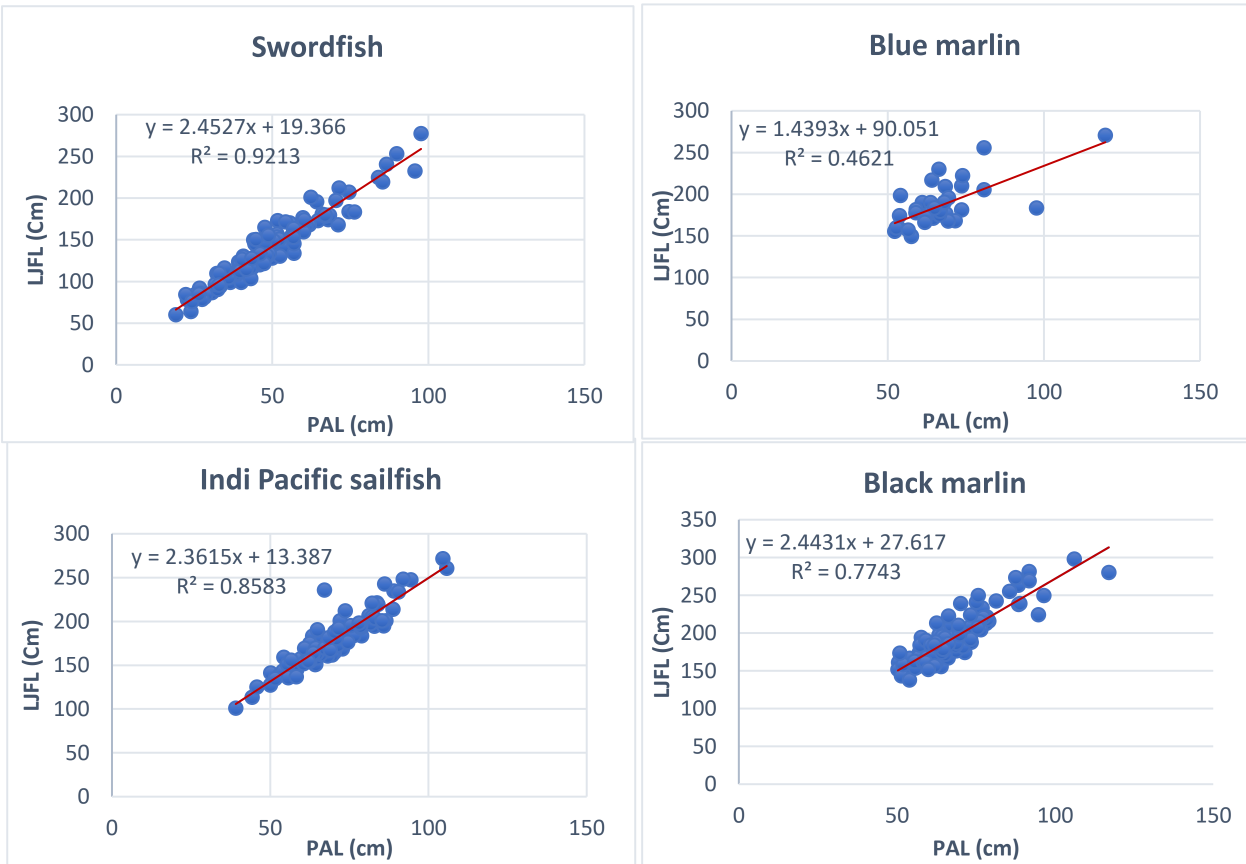

Figure 07: Regression analysis between LJFL and PAL

Conclusion

The findings demonstrate that PDL and PAL are accurate measures of length in swordfish, Indo-Pacific sailfish, and black marlin since they are strong predictors of LJFL in these species. On the other hand, the relationships between blue marlin and LJFL are weaker and more inconsistent, with PAL showing a poor correlation and PDL only a moderate correlation. This suggests that although models based on PDL and PAL are reliable for most species, more information and improvement are required before they can be used with confidence for blue marlin though.

However, the relationship between LJFL and PDL can be considered robust and reliable, indicating that PDL can serve as a practical proxy for deriving LJFL where direct measurements may be limited or unavailable. This approach not only increase the level of data availability, but also improves the consistency and accuracy of stock assessments. Accordingly, the same methodology can be recommended for other fisheries experiencing similar challenges to those encountered by Sri Lanka in the assessment of billfish stocks, particularly in cases where complete length data are difficult to obtain due to the dressing of billfish onboard. Implementing such a strategy could enhance the comparability of data across regions and support more informed management decisions for billfish populations

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