Title: Assessment of Billfish Reproductive Biology for Enhanced Sustainable Management

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Abstract

Understanding the reproductive biology of billfish in Tanzanian waters is crucial for sustainable fisheries management. This study evaluates the size at first maturity ($L50$) of billfish using morphometric methods, analyzing length and weight data from the the Deep Sea Fishing Authority (DSFA) database, FiS for neritic data sets. The results show that the estimated size at morphometric maturity is 157 cm, with a 95% confidence interval between 155 cm and 158.3 cm. The model's R-squared value of 0.68 indicates a reliable estimation, providing valuable insights for managing billfish populations in Tanzania.

Keywords: marlins, sailfish, and swordfish, Tanzania

Introduction

Billfish (families Istiophoridae and Xiphiidae), comprising marlins, sailfish, and swordfish, are among the most iconic and ecologically significant pelagic predators in the world's oceans. These species are highly prized by commercial and recreational fisheries and play a substantial role in artisanal fisheries as they fetch high prices. They also play a critical role in maintaining the balance of marine ecosystems as predatory fish. Their wide-ranging migratory patterns, extending across vast oceanic expanses, make them particularly challenging to manage, especially given overfishing and climate change pressures (Kadagi *et al.* 2022).

Billfish exploitation dates back centuries, with artisanal fisheries in many coastal communities relying on these species for subsistence and local trade. In recent decades, however, the commercialization of billfish, driven by both the fishing and tourism industries, has significantly increased the fishing pressure on these species. Various gear types, including longlines, purse seines, and artisanal fishing methods such as handlines and harpoons, target billfish (Kadagi *et al.* 2022). In Tanzania, billfish are caught in coastal waters and the open ocean, contributing to the livelihoods of thousands of fishers and supporting the country's seafood export industry.

Billfish species are apex predators, meaning they occupy the top levels of the marine food web. They regulate the populations of prey species, helping maintain the health and stability of marine ecosystems. Their predatory role and long life cycles make them particularly vulnerable to overfishing, as their population recovery rates are slow compared to other fish species. This vulnerability is exacerbated by the high demand for billfish in international markets, where they are sought after for their meat, particularly for sashimi and sport fishing, a significant tourist attraction.

Tanzania's fisheries sector is a critical component of the national economy, contributing significantly to food security, employment, and foreign exchange earnings. The country's

coastline, stretching over 1,400 kilometres along the Indian Ocean, encompasses diverse marine habitats that support a wide range of fish species, including billfish. In Tanzanian waters, billfish are caught in artisanal and industrial fisheries, with a significant portion of the industrial catch being exported to international markets by distant fishing fleets (DSFA data).

Despite the economic importance of billfish, there is limited knowledge about their population dynamics, reproductive biology, and the impact of fishing on their stocks in Tanzanian waters. The lack of comprehensive data has hindered the development of effective management strategies, leading to concerns about the sustainability of billfish fisheries in the region. Overfishing, particularly of juvenile and immature individuals, poses a significant threat to the long-term viability of billfish populations. While swordfish are most straightforward to identify, the species composition of other billfishes in artisanal and industrial fisheries is challenging, causing even uncertainties in the data quality, especially for marlins and sailfishes. This situation is further complicated by the migratory nature of billfish, making them susceptible to fishing pressure across the broader Indian Ocean region (Kadagi *et al.* 2022).

Understanding the reproductive biology of billfish is essential for informing sustainable management practices. Reproductive parameters, such as the size at first maturity ($L50$), are crucial for developing regulations that ensure that individuals have the opportunity to reproduce before being harvested. The size at first maturity is a key indicator of the health and sustainability of fish populations, and it directly influences the effectiveness of management measures such as size limits, seasonal closures, and gear restrictions.

Traditional methods for estimating $L50$ often involve the gonadosomatic index (GSI), which requires the examination of gonads to determine maturity stages. However, these methods can be labour-intensive and may not always be feasible, especially in large-scale studies or regions with logistical challenges. An alternative approach is morphometric techniques, which estimate $L50$ based on the relationship between body size and reproductive status. This method is less invasive and can be applied to a broader range of data, making it particularly useful in regions like Tanzania, where comprehensive biological sampling may be complex.

Despite the importance of billfish to both the ecosystem and the economy, there has been a lack of focused research on their reproductive biology in the region, including within Tanzania. The absence of such critical information has made it difficult to develop effective management strategies to ensure billfish stocks' long-term sustainability. This study addresses this gap by identifying important gear types involved in billfish fishery and also estimated the size at first maturity ($L50$) for billfish in the neritic waters of Tanzania, using a morphometric approach. The findings will provide valuable insights into gears that contribute to billfish catch and into the reproductive dynamics of billfish in this region, as well as contribute to developing more effective conservation and management measures.

Materials and Methods

Study Area

The study was conducted in Tanzania's neritic waters, where artisanal fisheries commonly catch billfish. The region is characterized by various marine habitats, including coral reefs, seagrass beds, and open oceanic waters, providing suitable environments for billfish.

Data Collection

Length and weight data for billfish were obtained from the Deep Sea Fishing Authority (DSFA) database, FIS. These data were collected over several fishing seasons using various gear types, including longlines, gillnets, and handlines. The data set included measurements from many billfish species, focusing on those most commonly caught in Tanzanian waters.

Size at First Maturity (L50) Estimation

The size at first maturity (*L*50) represents the length at which 50% of the individuals in the population are sexually mature. In this study, we estimated *L*50 using a morphometric approach, which is based on the relationship between body size and reproductive status, rather than the traditional gonadosomatic index. The morphometric method involves analyzing the length at which a randomly chosen individual has a 50% chance of being mature, as Torrejon-Magallanes (2020) described.

Results

The length-weight analysis showed varying R values, with a greater proportion of the relationships above 0.7, indicating strong correlations between length and weight for billfish caught with varying gear types. However, some gear types showed weaker correlations, possibly due to the misidentification of species, resulting in mixed data being categorized as billfish.

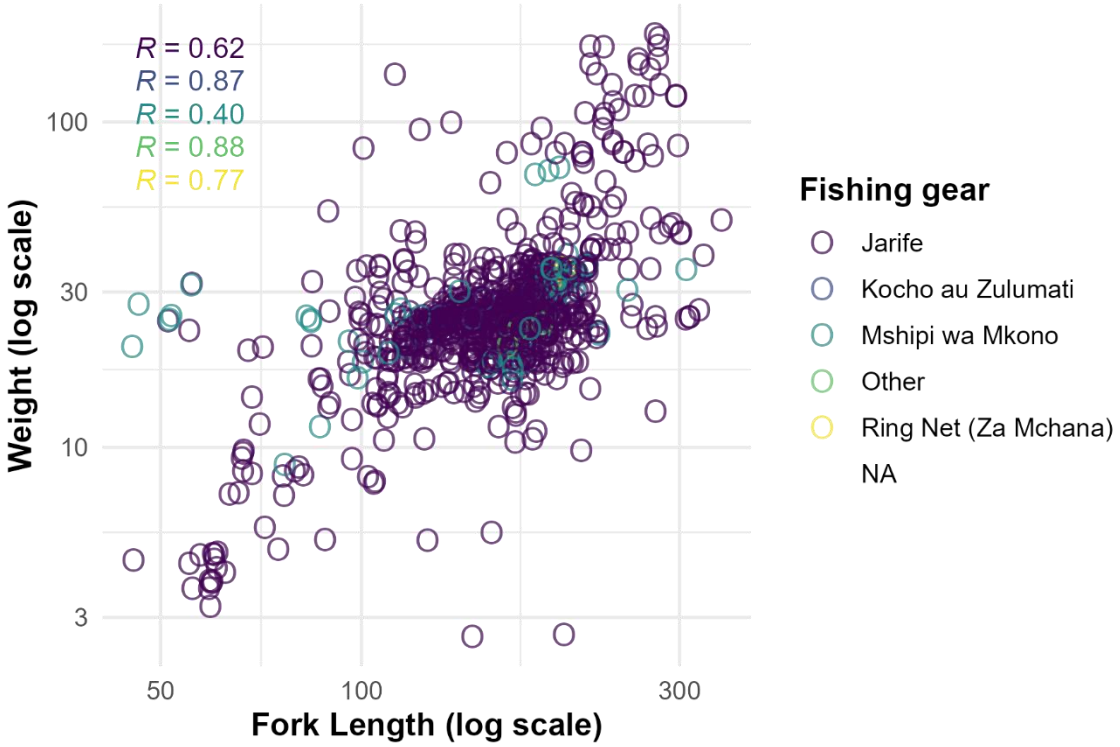

Figure 1; Relationship of legnth and weight of Billfish by gears type. Colure pattern are used to distinguish catches from varying gear type as elustrated in the legend.

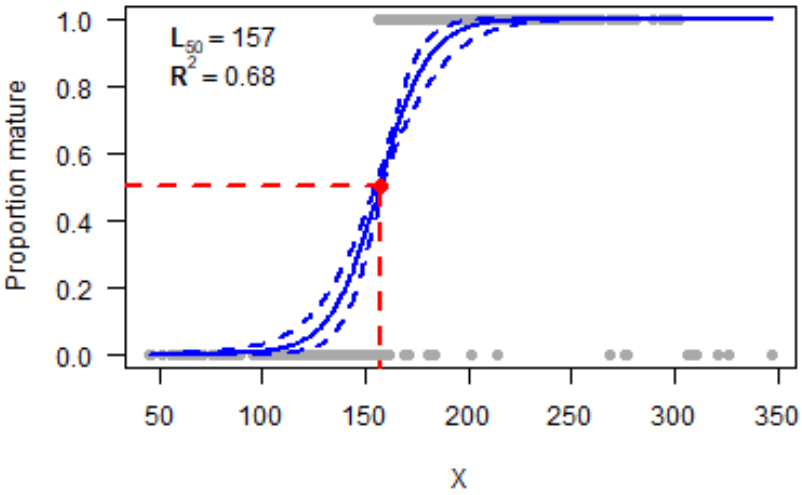

Figure 2; The estimated size at morphometric maturity for the billfish population was determined to be 157 cm. The analysis provided a 95% confidence interval ranging from 155 cm to 158.3 cm, indicating high precision in the estimation. The model's R-squared value was 0.68, suggesting that the model explained 68% of the variation in the morphometric data.

Discussion

The estimated size at first maturity for billfish in Tanzanian waters, determined to be 157 cm, is consistent with findings from other regions. This consistency suggests that 157 cm represents a critical threshold for reproductive maturity across different billfish populations. The robustness of the morphometric method employed in this study is underscored by the high R-squared value of 0.68, which indicates a strong fit between the observed data and the model. Additionally, the narrow confidence interval (155 cm to 158.3 cm) further strengthens the reliability of this estimate, providing a solid basis for its application in fisheries management.

The study also highlights the significant variation in length-weight relationships observed across different gear types. This variation emphasizes the importance of species-specific data collection, as inaccuracies in species identification can lead to the mixing of different species within the dataset. Such misidentification can result in considerable errors in biological assessments, potentially compromising the effectiveness of management strategies. Therefore, there is a critical need for improved species identification protocols during data collection to enhance the accuracy and reliability of biological data.

Given these findings, several recommendations emerge. First, there is a need to implement more accurate species identification methods during data collection. This will help minimize the risk of species mixing in datasets, thereby improving the reliability of biological assessments. Second, the estimated size at morphometric maturity (157 cm) should be utilized as a key parameter in developing size-based regulations, such as minimum landing sizes. Such regulations would ensure that billfish populations are given the opportunity to reach reproductive maturity before being harvested, contributing to the sustainability of these populations.

Moreover, continued monitoring of billfish populations in Tanzanian waters is essential. A focus on reproductive biology will be particularly important to track changes over time and adapt management strategies as needed. Lastly, regional collaboration between Tanzania and neighboring countries should be fostered. Given the migratory nature of billfish, sharing data and management practices across borders will be crucial for the effective management and conservation of these species.

In conclusion, this study successfully estimates the size at morphometric maturity for billfish in Tanzanian waters, providing a critical benchmark for fisheries management. The findings underscore the importance of accurate data collection and species identification in ensuring sustainable fishing practices. By implementing the recommended management strategies, Tanzania can enhance the sustainability of its billfish fisheries and contribute to the long-term conservation of these important species.

Reference

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