A **draft paper**

Spatial and Temporal Variation in the Catch Rates and Size of Swordfish (*Xiphias gladius*) in the Tanzanian EEZ

Ranwel N. Mbukwah[1], Mathew O. Silas[2], Saleh A. Yahya[3]
[1]Deep Sea Fishing Authority, Zanzibar, Tanzania
[2]Tanzania Fisheries Research Institute (TAFIRI), Dar es Salaam, Tanzania
[3]University of Dar es Salaam, Zanzibar, Tanzania

Corresponding author: ranwel.mbukwah@dsfa.go.tz

Abstract

We analyzed geo-referenced longline catch data and size–frequency information for Swordfish (*Xiphias gladius*) from Tanzania's Exclusive Economic Zone (EEZ) to assess spatial and temporal patterns in catch rates, size distribution, spawning potential, and preliminary stock indicators. Data spanning March 2013–December 2024 revealed strong seasonality, with highest catch rates occurring during the northeast monsoon (October–February). A sample of 211 individuals was analyzed for length–frequency patterns, yielding a mean size of 149 cm and a spawning potential ratio (SPR) of 0.65, indicating that two-thirds of the catch consists of mature individuals. Length-based growth modeling using the von Bertalanffy growth function (VBGF) and Pauly's empirical formula estimated natural mortality at $M \approx 0.23$ yr^{-1}. Gear selectivity analysis suggested 50% vulnerability at 115 cm, slightly below the biological L_{50} of 126 cm. Results suggest that the Tanzanian Swordfish stock is not severely truncated toward younger fish and retains a relatively healthy spawning biomass, though gear modifications could further protect immature individuals. Environmental variables, particularly sea surface temperature (SST) and chlorophyll-a concentration, showed strong associations with catch variability. These findings provide baseline information to guide ecosystem-based management of the Tanzanian Swordfish fishery.

1. Introduction

Swordfish (*Xiphias gladius*) is an important target species in the Indian Ocean longline fishery and contributes significantly to Tanzania's EEZ landings. Understanding spatial–temporal patterns of catch rates, size distribution, and reproductive potential is critical for managing sustainable harvest levels.

Tanzania's EEZ extends from 4.3°S to 10.3°S and 39.5°E to 43.5°E (Figure 1). The region experiences two distinct monsoon seasons — the northeast monsoon (NEM: October–April) and southeast monsoon (SEM: May–September) — which strongly influence oceanographic conditions and fishing activity. Longline operations primarily occur during the NEM due to calmer seas and higher fishing efficiency (Sheghude et al., 2020).

This study aims to (1) describe spatial and seasonal catch rate variability, (2) evaluate size structure and maturity composition, (3) estimate natural mortality and relative fishing mortality, and (4) provide insights into the influence of environmental drivers on Swordfish catch in Tanzania's EEZ.

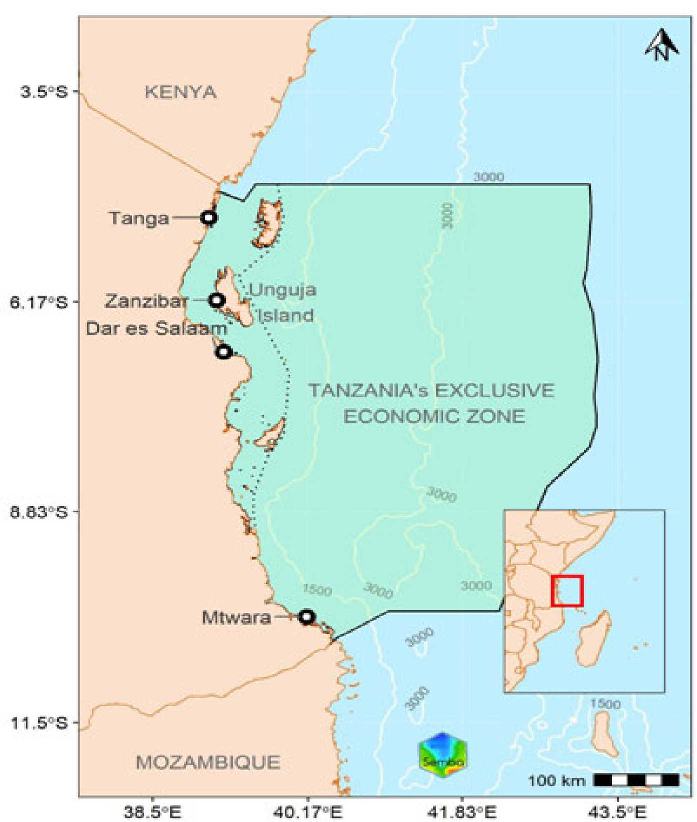

Figure 1. The map of the Exclusive Economic Zone of Tanzania

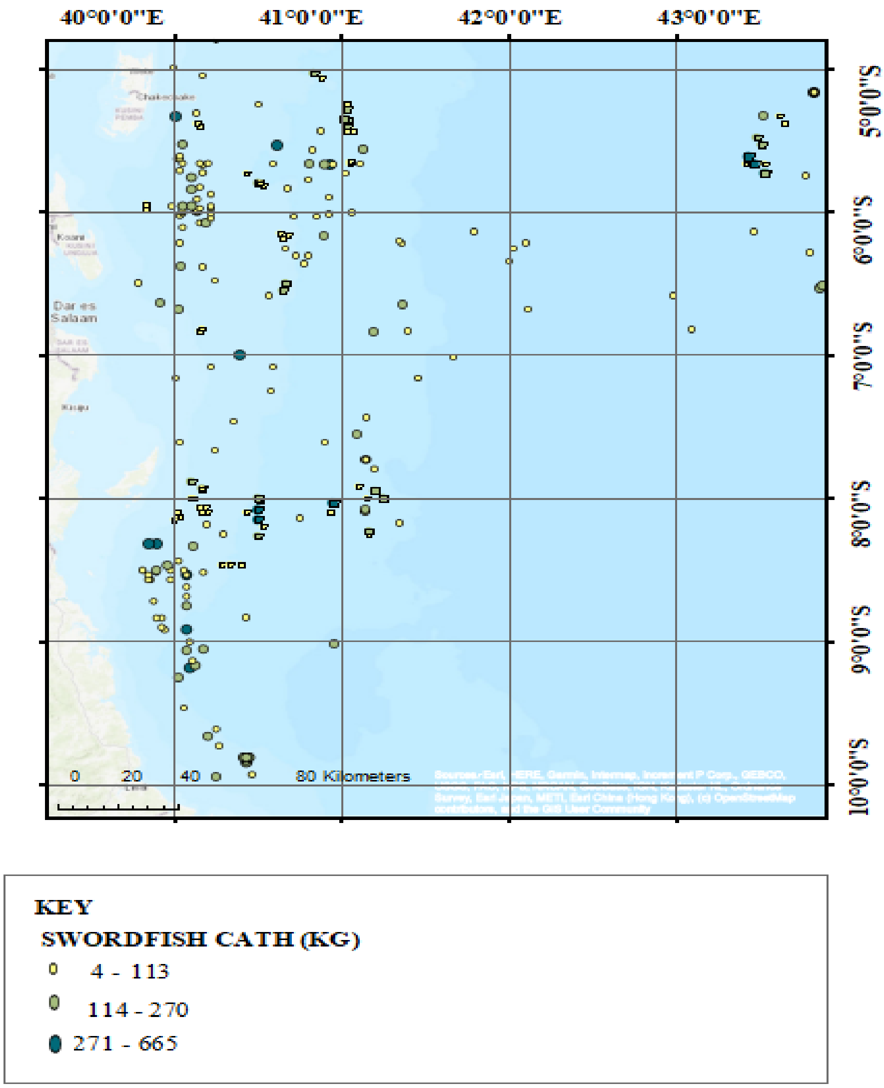

Figure 2: Spatial distribution of Swordfish catches between 2013 -2024 in the EEZ of Tanzania

2. Materials and Methods

2.1 Data Sources

Catch data were obtained from commercial longliner logbooks from March 2013 to December 2024. Each record included date, geographic coordinates, number of hooks deployed, and catch weight (kg). Only operations within the Tanzanian EEZ were retained.

2.2 Catch Rate Calculation

Catch rates were standardized per 1,000 hooks using:

CR=WT1000CR = \frac{WT}{1000}

where CR = catch rate (kg/1,000 hooks) and WT = total Swordfish weight per set.

2.3 Environmental Data

Monthly sea surface temperature (SST) and chlorophyll-a (Chl-a) data (4 km resolution) were obtained from NASA MODIS-Aqua and ESA MERIS products, archived at TAFIRI e-Station. SST and Chl-a were extracted at fishing locations and dates, then linked to catch rates.

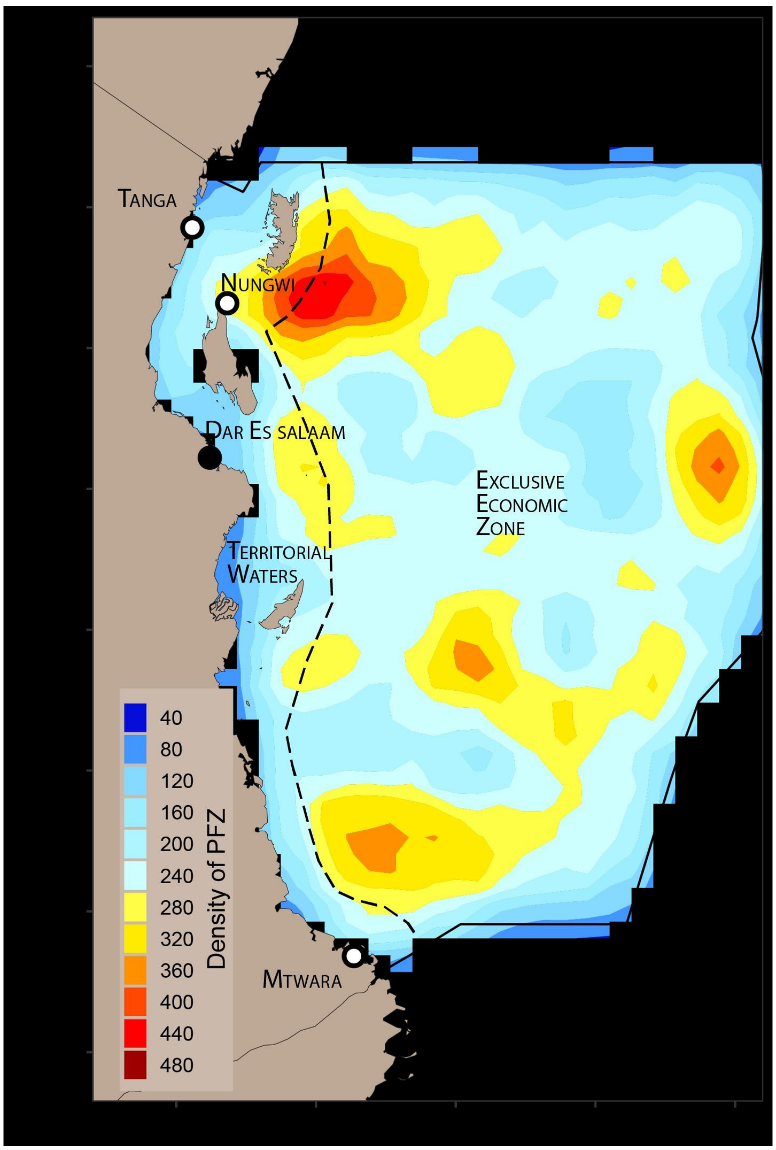

Figure3. Illustrate the potential fishing ground for Swordfish fishery in the EEZ of Tanzania

2.4 Length–Frequency Data

A total of 211 Swordfish were measured (fork length, cm) from landings between 2021–2023. Data were grouped into 5 cm size intervals to construct a size–frequency histogram. L_{50} (length at 50% maturity) was assumed to be 126 cm based on morphometric data.

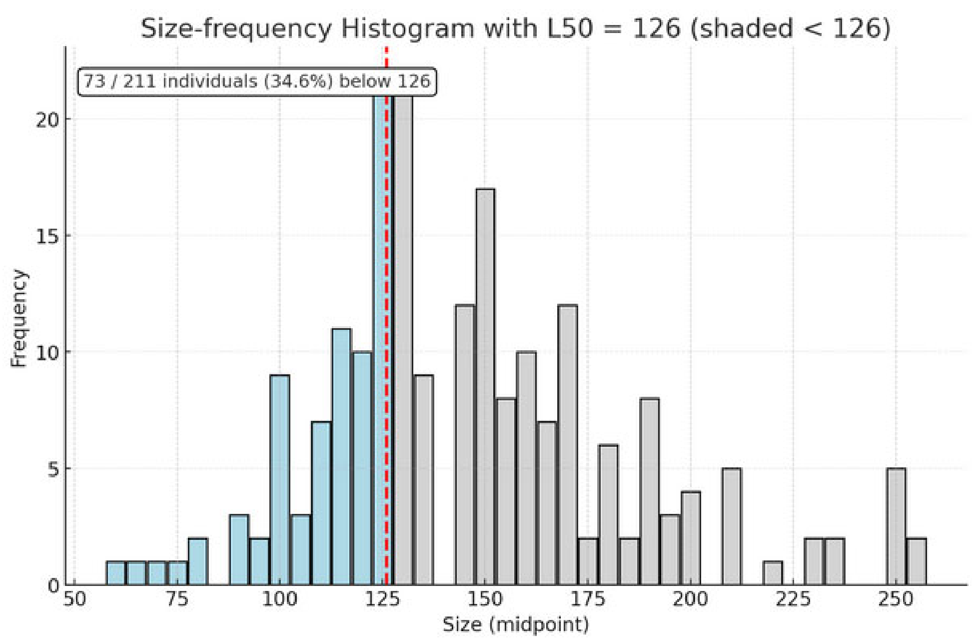

Figure4: Size frequency for Swordfish caught by longline fishing vessels in EEZ of Tanzania 2021-2023

2.5 Growth Model and Mortality

The von Bertalanffy growth function (VBGF) was applied with assumed parameters (L_∞ = 270 cm, k = 0.12 yr^{-1}, t_0 = −0.5). Natural mortality (M) was estimated using Pauly's (1980) empirical equation: log 10M=−0.0066−0.279log 10L∞+0.6543log 10k+0.4634log 10T\log_{10} M = -0.0066 - 0.279 \log_{10} L_\infty + 0.6543 \log_{10} k + 0.4634 \log_{10} T

where T = 25°C.

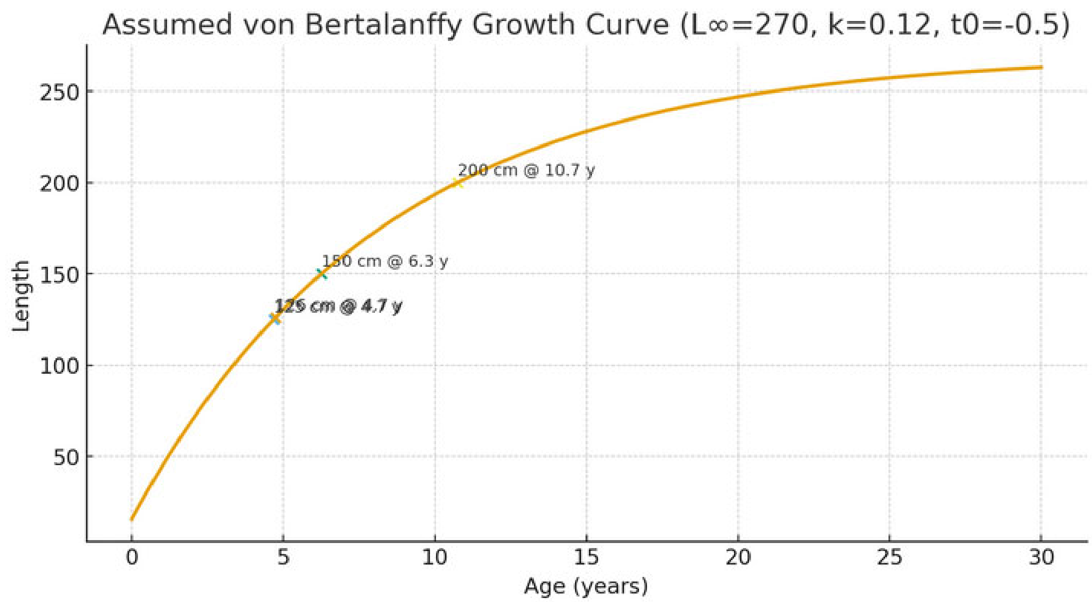

Figure 5: Swordfish growth curve using von Bertalanffy growth function

Total mortality (Z) was estimated using a length-converted catch curve (Boettiger et al., 2012), and fishing mortality (F) was derived as F = Z − M. Exploitation rate was calculated as E = F/Z.

2.6 Gear Selectivity and Spawning Potential

Selectivity ogives were derived from normalized frequencies to determine size at 50% vulnerability (L_{50}-selectivity). The spawning potential ratio (SPR) was calculated as the proportion of individuals ≥ L_{50}.

3. Results

3.1 Catch Rate Variability

Catch rates exhibited strong seasonality, peaking between October–February and declining sharply during the SEM months (May–September). Annual variability reflected differences in environmental conditions including Sea Surface temperature, Chl-a, NEM and SEM winds in the area. Whereas interannual variability in catch rates may be caused by both differences in fishing effort and environmental condition variability.

3.2 Length–Frequency Structure

Fish ranged from 60–255 cm FL, with a mode at 125–135 cm .

- Mean length = 149.1 cm
- Proportion ≥ 126 cm = 65.4%
- SPR = 0.65

This indicates that most fish caught are mature and contributing to the spawning stock.

3.3 Growth and Mortality

The VBGF growth curve predicted maturity around 6–7 years. Natural mortality was estimated at $M \approx 0.23\ yr^{-1}$. The length-converted catch curve indicated $Z \approx 0.33\ yr^{-1}$, yielding $F \approx 0.10\ yr^{-1}$ and an exploitation rate $E \approx 0.30$, suggesting moderate fishing pressure.

3.4 Gear Selectivity

L_{50}-selectivity ≈ 115 cm, slightly below L_{50} maturity. This means that some pre-mature fish are harvested, but the majority of catch consists of mature individuals.

3.5 Environmental Correlates

Catch rates were positively associated with moderate SST (24–27°C) and intermediate Chl-a concentrations, suggesting a preference for productive frontal zones with favorable thermal conditions.

4. Discussion

The results indicate that Swordfish caught in Tanzania's EEZ are predominantly mature, with a healthy spawning potential ratio (SPR = 0.65). This is above common biological reference points (SPR30–40), suggesting the population is not severely overexploited.

The slight mismatch between selectivity and maturity size implies room for management improvement. Adjusting gear specifications (e.g., hook size or depth) could shift selectivity above L_{50} and further enhance spawning biomass.

Environmental variability strongly drives catch rates, consistent with studies linking pelagic species abundance to oceanographic drivers such as SST, Chl-a, and thermocline depth (Semba et al., 2019).

5. Conclusions

- **Seasonality:** Highest catch rates during NEM (Oct–Feb), driven by favorable ocean conditions.
- **Population Structure:** Majority of individuals caught are above L_{50} (126 cm).

- **Stock Status:** SPR (0.65) suggests a healthy spawning stock; moderate fishing mortality indicates no immediate overfishing risk.
- **Management Implication:** Slight gear modification could protect immature individuals and maximize yield-per-recruit.
- **Environmental Influence:** SST and Chl-a are key predictors of catch rates, highlighting the need for ecosystem-based management.

References

- Pauly, D. (1980). On the interrelationships between natural mortality, growth parameters, and mean environmental temperature across fish species. *J. Conseil*, 39: 175–192.
- Boettiger, C. et al. (2012). Using time series to estimate population dynamics. *Methods in Ecology and Evolution*, 3(3): 478–488.
- Semba, M. et al. (2019). Influence of monsoon winds on pelagic fisheries. *Indian Ocean Tuna Commission Proceedings*.
- Sheghude, S. et al. (2020). Seasonal variability in longline fisheries. *Western Indian Ocean J. Mar. Sci.*