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RESEARCH ARTICLE

Spawning Potential Ratio (SPR) in the Management of the Swordfish (*Xiphias gladius* Linnaeus, 1758) in Coastal Waters of Kenya

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Abstract

The swordfish (Xiphias gladius) is a migratory species found in sub-tropical, tropical, and temperate waters. Itmakes significant contributions to food security, nutrition, local income, and revenue for communities and countries. However, there is a lack of comprehensive information and data regarding the biological characteristics and stock status of swordfish in the nearshore marine waters of Kenya. Researchers utilize the spawning potential ratio (SPR), a proxy index commonly employed to determine the health of fish populations. This study applied length-based spawning potential ratio (SPR) to evaluate the reproductive and recruitment capacity of swordfish in the coastal fishery of Kenya. Data used in the analysis was collected from artisanal fishers between August 2015 and December 2016. FISAT (ELEFAN) and the von-Bertalanffy function were employed to analyze growth parameters, mortality rates, and asymptotic length. The SPR was calculated using the tool available at http://barefootecologist.com.au/lbspr.

The study yielded the following results: total mortality (Z) was estimated at 1.13 per year, with natural losses (M) estimated at 0.44 per year and fishing-induced mortality (F) at 0.69 per year. The rate of exploitation (E) was determined to be 0.61 per year. The length at which growth reaches infinity (L_{∞}) was measured at 208 cm, and the growth coefficient (K) was calculated as 0.28 per year. Other findings included t_o = 0.18, an SPR of 18% (ranging from 12% to 23%), an M/K ratio of 1, an F/M ratio of 1.4, an L_{50} of 129 cm LJFL, and an SL_{50} of 87.98 cm LJFL. The minimum size recorded was 68 cm LJFL, while the maximum size reached 234 cm LJFL. The study indicated that the swordfish fishery is predominantly comprised of young individuals, leading to reduction in reproductive and recruitment potential. Therefore, it is recommended to closely monitor the swordfish fishery in Kenya waters and beyond, and consider the application of SPR metrics to inform conservation and management efforts.

Keywords: Kenya, Indian Ocean, Swordfish, Mortality, Spawning Potential Ratio.

1. Introduction

The swordfish is a migratory species found in marine waters across temperate, tropical, and subtropical seas, including the Indian Ocean. It is an important catch for both artisanal and commercial fishing in the region. In 2019, approximately 32,671 metric tons of swordfish were landed in the Indian Ocean, which is close to the sustainable yield limit of 33,000 metric tons per yearswordfish were landed in 2019 (IOTC, 2020; IOTC, 2021). The catches are also above the lower limit of the sustainable yield range, which is 27,000 metric tons (IOTC, 2020). Swordfish landed

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by artisanal fishers in the Kenya waters was about 160 Metric tons in 2016 according to the report of the Ministry of Agriculture, Livestock and Fisheries (2016).

Although the IOTC Stock Assessment Report of 2021 indicates that swordfish was in stable and healthy state and that it was neither overfished nor subject to overfishing (IOTC, 2021). The current catches, being close to MSY and being below the lower limit of the MSY range, has raised concern on the status of the swordfish stock (IOTC, 2021). The IOTC Scientific Committee raised concern that any increase in the swordfish catches by 40% of the 2018 levels would drive the fish biomass to below the SB_{MSY} (IOTC, 2021). There are also concerns about localized overfishing in the Indian Ocean, particularly in the Western part, including Kenya (IOTC, 2021, Kimakwa et al., 2022; WIOMSA, 2015).

Additionally, there is a lack of biological and scientific data on swordfish and other tunas in the Indian Ocean, with most studies conducted in other seas, namely in the Mediterranean Sea, Australia, South Africa, USA, and New Zealand(Varghese et al., 2013). The swordfish fishery in the SWIO has not been studied adequately and the information on the fishery is very limited (Kimakwa et al., 2022).Stock status of most species under the IOTC management are unknown or uncertain (IOTC, 2021). For those that have been assessed, the quality of the data is scientifically unreliable, usually estimated and low in quality (IOTC, 2021).

Data collection programmes are usually costly and many developing coastal and island states are experiencing challenges with gathering, collating and analysing data to inform policy for improved fisheries management and stock sustainability (IOTC, 2020). Noting that the quality of data for billfishes,including swordfish, in the IOTC area is of low quality and there is paucity of information on most of the species, fisheries management and conservation measures can benefit from approaches and models that analysefisheries with limited data (Yonvitner et al., 2021).

One approach that can be beneficial in analyzing fisheries with limited data is the spawning potential ratio (SPR)as described by Prince (2015) and Hordyk et al. (2015), which assesses the reproductive capacity of a fishery based on fish length data.

The SPR model uses life history strategies, size structure and size at first maturity ratios of the fishery that is being studied. SPR in this respect is the ratio of induced mortality due tofishing operations (F) to mortality due to natural losses (M) which is represented as F/M, and as a ratio of mortality due to natural losses (M) and the coefficient of growthaccording to von Bertalanffy (K) which is M/K, and also the ratio of thesize at first maturity to length at infinity (L_m/L_∞).

Spawning potential ratio is an indicative proxy of thereproductive capacity of a fishery that is being fished when compared with the unfished one. A fish population that is unfished is usually referred to as having maximum reproductive capacity ($SPR_{100\%)}$. Fishing removes individuals from the population, especially the breeding adults, which reduces productive capacity ($SPR100_{-x\%}$). Fisheries scientists have established the reference point for SPR to assist in diagnosing the health of the fish stocks. $SPR_{20\%}$ has been set as the limit below which the reproductive capacity of any given fish stocks is impaired, and consequently resulting in depletion and possible collapse of the fishery.

The SPR model can provide valuable information on the health of fish stocks, with SPR of 20% being the limit below which the reproductive capacity is impaired. The application of the SPR methodology on swordfish as an indicator of reproductive capacity and health of stocks based on length-based measurements in Kenya hasn't been studied (Yonvitner et. al., 2021; Yonvitner et al., 2021). This paper presents the results of life history strategies, mortality and exploitation rates and SPR for the swordfish fishery sampled in five landing sites along the Kenyan coast (Figure 1). This paper aims to contribute to the scientific knowledge on swordfish and the application of SPR approaches in the management of tunas in Kenyan coastal waters and the Indian Ocean.

2. Materials and Methods

The study sites comprised of Five (5) fish landing sites along the Kenyan coast. These sites wereMalindi (Shella), Lamu (Amu),Mombasa (Old Town) and Mnarani (Kilifi) (Fig.1).

2.1 Sites of Study

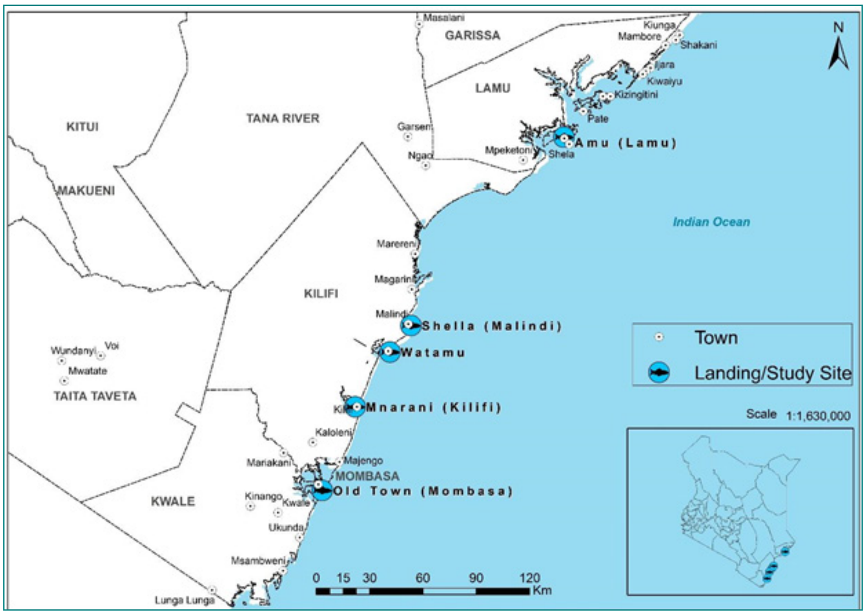

Figure 1. *The swordfish fishery study sites along the Kenya coast.*

2.2 Data Collection

Swordfish samples were obtained from the catches made by artisanal fishers over a span of 17 months, ranging from August 2015 to December 2016. Samples were collected continuously for 10 consecutive days each month. The fishers utilized different fishing gears, including handlines, gillnets, and longlines. To identify the fish species, various identification keys such as Anam et al. (2012) and Smith and Heemstra (1995) were used. Individual swordfish were weighed using a digital scale, rounded to the nearest kilogram (Kg). The Lower-Jaw Fork Length (LJFL) and Total Length (TL) of each fish in the sample were measured using a measuring tape, rounded to the nearest centimeter (cm). Information such as the landing site name, county located, type of fishing vessel (boat), fishing gear used, crew members on each vessel, duration of fishing trip, and the length and weight of each individual fish were recorded using data collection forms based on the biological sampling template for tunas adapted from IOTC. The collected data was then entered into a spreadsheet (Excel), organized, cleaned, and subjected to various analyses.

3. Data Analyses

The data was subjected to various analyses as follows;

3.1 Length-Frequency Structure

The combined length-frequency data obtained from different sites and gear combinations was analysed using FISAT and the von-Bertalanffy method (Gayanilo *et al.,* 1994). Catch curves were created based on the length distribution data. The parameters of growth, mortality rates, and exploitation were determined using the length-weight relationship.

3.2 Parameters of Growth

To estimate the length at infinity (L_∞) and the coefficient of growth (K), FISAT II (Gayanilo *et al*., 1994) and ELEFAN 1 (Pauly, 1987) were utilized. The analysis was conducted using a seawater temperature of 26 °C. The Response Surface Analysis routine was employed to determine the best combination of growth parameters, considering the array of values for length at infinity (L_∞), growth coefficient (K), starting length, and fixed starting point (SS). The data was fitted to the Von Bertalanffy Growth Function (VBGF) as follows (Sparre and Venema, 1998):

$$L_Y = L_\infty\,(1-\exp(-K(Y-Y_0)))$$

Where:

L_∞ represents the length at infinity,

K denotes the von Bertalanffy growth coefficient,

Y_0 corresponds to the theoretical age at length zero,

L_Y indicates the length at age Y.

Furthermore, the following equation was used to estimate the index of growth performance (φ') (Pauly and Munro, 1984):

$$\Phi' = \mathrm{Log}(K) + 2\,\mathrm{Log}(L_\infty)$$

3.3 Estimating the Rates of Swordfish Mortality

By applying the length-converted linearized catch curve method described by Pauly (1983, 1984), estimates were made for the total mortality rate (Z), length at infinity (L_∞), and the von Bertalanffy growth coefficient (K). The calculation involved the following equation:

$$\ln(Ni/\Delta Ti) = X + Y * Ti$$

Where:

N represents the total number of individuals in length class i,

ΔT is the estimated time required for fish to grow to length class i,

T corresponds to the estimated age at the midpoint of class i,

Y, with a sign change, is an estimation of Z (total mortality rate).

Using indirect methods and the relationship described by Pauly (1980) in the following equation, mortality rates of swordfish due to natural causes (M) were estimated:

$$\log M = -0.007 - 0.28 * \log L\infty + 0.6543 * \log K + 0.4634 * \log t$$

Where:

M represents the mortality rate due to natural causes,

L_∞ is the length at infinity,

T denotes the estimated mean surface temperature of tropical waters at 26 °C,

K stands for the von Bertalanffy growth coefficient (VBGF).

Furthermore, by applying the relationship F = Z – M (Gulland, 1971), the mortality rate due to fishing operations (F) was estimated, where:

Z represents the total mortality rate,

M represents the mortality rate due to natural losses.

The rate of exploitation (E) was then estimated by dividing the mortality due to fishing operations (F) by the total mortality rate (Z) using the following relationship:

$$E = F / Z.$$

3.4 Selectivity of the Fishing Gears

The logistic equation and approach outlined by Pauly (1984a, 1984b, and 1990) were employed to estimate selectivity at 25%, 50%, and 75%. This was accomplished using the following formula:

$$\ln((1/P_L) - 1) = S1 - S2L$$

Here, P_L represents the probability of capture for length L. The values for L_{25}, L_{50}, and L_{75} were determined as follows:

$$L_{25} = (\ln(3) - S1) / S2$$

$$L_{50} = S1 / S2$$

$$L_{75} = (\ln(3) + S1) / S2$$

3.5 Length-Based Spawning Potential Ratio (LB - SPR)

The spawning potential ratio (SPR) based on length (LBS-SPR) was computed by dividing the mortality due to fishing (F) with the mortality due to natural losses (M) as the ratio F/M. Additionally, two other ratios, M/K and Lm/L_∞, which are associated with life history strategies, were considered (Prince, 2015; Hordyk *et al*., 2015). To estimate the LBS-SPR, the software application barefoot ecologist was utilized, taking into account the aforementioned parameters.

In this context:

M represents mortality due to natural losses.

L_∞ corresponds to the asymptotic length (length at infinity).

L_m denotes the size at first maturity.

K signifies the Von Bertalanffy Growth Coefficient (VBGF).

F represents the mortality rate caused by fishing.

4. Results

4.1 Length-Frequency Structure

The collected data included swordfish samples with sizes ranging from 68 cm Lower Jaw Fork Length (LJFL) to 234 cm LJFL (Fig. 2). The majority of the sampled individuals fell within the range of 90 cm to 150 cm LJFL. The graph clearly illustrates three distinct length categories: 68 cm to 90 cm LJFL, 91 cm to 150 cm LJFL, and over 150 cm LJFL.

4.2 Swordfish g Parameters of Growth

The growth parameters of swordfish were determined using pooled data from various sampling sites. The estimated parameters of growth based on this data were as follows: the Von Bertalanffy coefficient of growth (K) was 0.28 $year^{-1}$, the length at infinity (L_∞) was 208 cm, the theoretical age at length zero (t_0) was 0.18, and the growth performance index (φ) was 4.08 (Kimakwa *et al.,* 2022).

4.3 Rates of Mortality

Based on the analysis of the combined data, the total mortality rate (Z) for swordfish was estimated to be 1.13 per year, with a mortality rate due to natural losses

(M) of 0.44 per year and a mortality rate due to fishing (F) of 0.7 per year. The rate of exploitation (E), which indicates the level of fishing pressure, was calculated to be 0.61 per year. The analysis was conducted using a water surface temperature of 26 °C (Fig. 3). The findings indicate that the swordfish population experienced significant losses primarily due to fishing activities (F). Furthermore, the rate of exploitation in this fishery was relatively high, exceeding the average value of 0.5 per year (Kimakwa *et al.,* 2022).

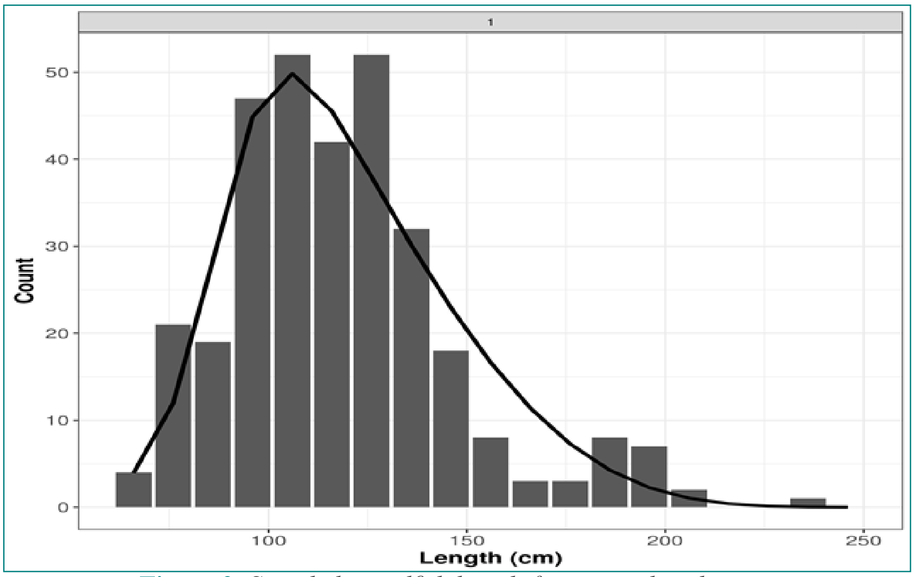

Figure 2. *Sampled swordfish length-frequency distribution.*

4.4 Growth Parameters, Selectivity and Spawning Potential Ratio (SPR)

The results of the analysis for swordfish growth, selectivity, and spawning potential ratio (SPR) are presented in Table 1. The length at which swordfish reach first maturity (L_{50}) was estimated to be 129 cm LJFL, while the length at which 95% of individuals were mature (L_{95}) was estimated to be 142 cm LJFL. The lengths at which 50% (SL_{50}) and 95% (SL_{95}) of the selected swordfish population were found were estimated to be 87.9 cm LJFL and 111.23 cm LJFL, respectively. According to Fishbase (2023), the size at first maturity for swordfish is estimated to be 221 cm. These findings indicate that the swordfish sampled from the artisanal catches were predominantly young individuals.

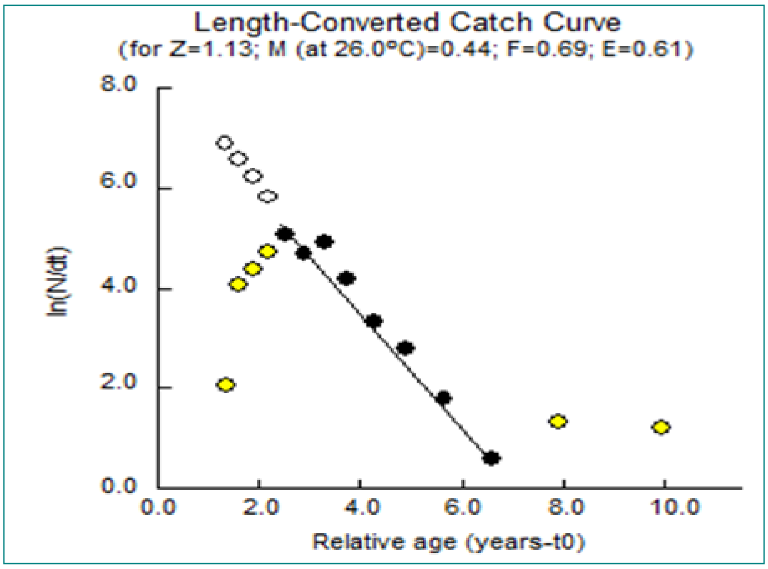

Figure 3. *Swordfish mortality against age based on the length converted catch curve (Source: Kimakwaet al., 2022)*

The ratios of natural mortality rate (M) to the Von Bertalanffy growth coefficient (K) and fishing mortality rate (F) to natural mortality rate (M) were estimated at 1.0 and 1.4, respectively, suggesting the presence of young individuals in the sample. The average spawning potential ratio (SPR) calculated in this study was 0.18, with a range of 0.12 to 0.23. These results indicate low recruitment in the fishery, posing a risk of collapse (Kimakwa *et al.,* 2022).

Table1. *Input and estimated parameters for swordfish that are used to calculate the spawning potential ratio*

Parameter	Value	Description
Input parameters		
M/K	1	Mortality due to natural losses (M) to the Von Bertalanffy Growth Coefficient K) ratio.
L_∞	208	Average length at infinity of the population of swordfish that is not fished.
CVL_∞	0.1	Length at infinity variation across the different cohorts in the sample.
L_{50}	129	The average length atfirst maturity.
L_{95}	142	Average length at which 95% of the fish in the population is in mature state.
Estimated parameters		
F/M	1.43 (1.05 - 1.81)	Ratio of mortality rate due to fishing operations (F) to mortality due to natural losses (M)
SL_{50}	87.98 (82.68 - 93.28)	Average length at which 50% of the individuals of fish in any given population is captured/ selected.
SL_{95}	111.23 (101.77 - 120.69)	Average length at which 95% of the individuals of fish in any given population is captured/selected.
SPR	0.18 (0.12 - 0.23)	SPR is the spawning potential ratio. It is calculated based on the input and estimates of the parameters of growth and selectivity.

4.5 Selectivity and Maturity

Figure 4 shows the maturity and selectivity curve for the swordfish encountered in the sample. The findings reveal that 50% (L_{50}) and 95% (L_{95}) of the fish population reached maturity at an approximate length of 129 cm LJFL and 142 cm LJFL, respectively. These results imply that a significant portion of the landed swordfish were below the desired size, indicating a predominance of young individuals.

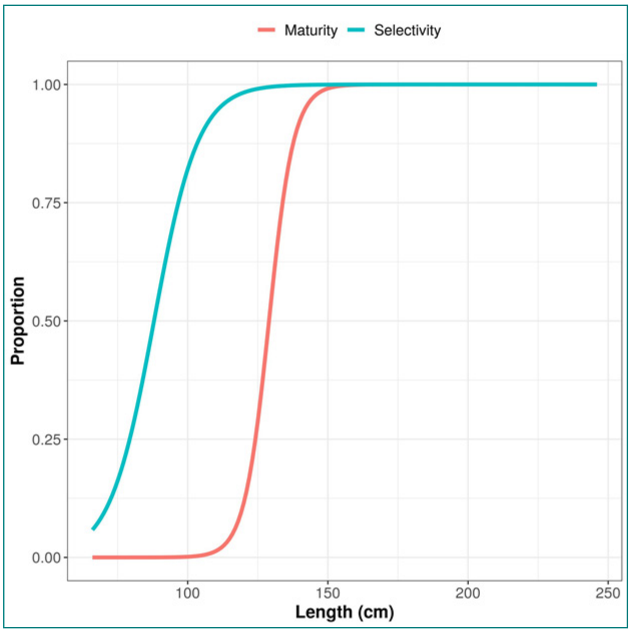

Figure 4. *Swordfish proportion at 50% maturity andselectivity.*

5. Discussion

5.1 Size Structure

In this study, the swordfish encountered displayed a range of lengths, spanning from 68 cm to 234 cm LJFL (Fig. 2). The majority of the captured individuals fell within the size range of 90 cm to 150 cm LJFL. The length distribution revealed three distinct size classes: 68 cm to 90 cm, 91 cm to 150 cm, and over 151 cm. These findings are consistent with previous studies conducted by different researchers. For example, Su et al. (2021) reported swordfish sizes in the Atlantic Ocean ranging from 119 cm LJFL to 190 cm LJFL. Setyadji et al. (2016) documented swordfish landed in the Eastern Indian Ocean with lengths ranging from 50 cm to 254 cm LJFL and an average size of 129 cm LJFL. Minimum landing sizes for swordfish catches were reported as 51 cm in the Aegean Sea and 53 cm in the Northern Ionian Sea (De Metro, 1995). In the Eastern Mediterranean Sea, the minimum recorded length was 52.5 cm (Alicli and Oray, 2001). Other studies reported swordfish lengths ranging from 87 cm to 289 cm LJFL in Reunion Island (Poisson and Fauvel, 2009; Abid and Idrissi, 2010).

The observed variations in swordfish sizes can be attributed to various factors, including the size and sex of individual fish, environmental conditions, gear types and sizes, as well as selectivity (Kimakwa *et al*., 2022; Poisson and Fauvel, 2009; Arocha, 2007; Di Natale *et al*., 2006). The probability of capturing a specific fish is influenced by factors such as age, size, sex, condition, gear type, and size (Ingolfsson *et al*., 2017; Tuda *et al*., 2016). Gear selectivity is greatly influenced by the size structure of the targeted stocks and individual fish (Erzini *et al*., 2003; Maunder *et al*., 2006).

However, this study did not collect data on the gear sizes used by artisanal fishers. Further research is needed in this area, as the IOTC Scientific Committee has recommended gathering more accurate information on swordfish stocks in the Indian Ocean waters (IOTC, 2020). Understanding the size structure of fish is crucial for stock assessment, as various models such as Virtual Population Analysis (VPA) and Spawning Potential Ratio (SPR) utilize size composition and distribution to assess stocks and comprehend population dynamics (Prince, 2015; Pauly, 1990; King, 1995; Hordyk *et al.,* 2015).

5.2 Mortality Rates and Growth Parameters

Mortality rates, growth parameters, and sexual maturity are key factors influencing the recruitment and sustainability of fish stocks (King, 1995; Yonvitner *et al*., 2021). Using a Length-Based model, the ratio of fish mortality due to natural losses (M) to the coefficient of growth (K) (i.e., M/K) and the ratio of mortality due to fishing (F) to mortality due to natural losses (M) (i.e., F/M) were estimated as 1.0 and 1.4, respectively, for swordfish. By employing a length-converted catch curve (Fig. 3), the mortality rates for swordfish were determined as follows: total mortality (Z) = 1.13 Year-1, mortality due to natural losses (M) = 0.44 Year-1, and mortality due to fishing operations (F) = 0.69 Year-1. The exploitation rate (E) was estimated at 0.61 Year-1 (Kimakwa *et al.,* 2022).

This study provides clear evidence that mortality resulting from fishing operations (F) exceeded the mortality caused by natural factors (N). Furthermore, the reported exploitation rate in this study was above 0.5 $Year^{-1}$, which is considered optimal.

According to Kimakwa et al. (2022), the length at infinity (L_∞) for swordfish was estimated at 208 cm LJFL, while the Von Bertalanffy coefficient of growth (K) was determined as 0.28 $Year^{-1}$. The values of t_0 and the growth performance index (φ) were 0.18 and 4.08, respectively. Based on these growth parameters, the M/K and F/M ratios for swordfish were estimated as 1.57, indicating relatively low ratios. These results suggest a high proportion of young individuals in the swordfish sample and, consequently, in the population distribution area. This indicates that the fishery is experiencing significant fishing pressure. The SPR model and others assume that species with low M/K values consist mainly of unfished individuals, resulting in a left-skewed curve representing a population composition dominated by young individuals (Hordyk *et al*., 2015; Prince, 2015).

5.3 Selectivity and Maturity

In this study, swordfish of various sizes were observed. The average length at first maturity (L_{50}) was estimated to be 129 cm. According to Fishbase (2023), the length at first maturity for swordfish is generally considered to be 221 cm, ranging from 156 cm to 250 cm. This indicates that individuals below this size range are considered juveniles or young swordfish. Therefore, the sampled individuals in this study were below the maturity threshold. Previous studies have reported varying sizes at first maturity for swordfish, ranging from 87 cm to 189 cm. These differences can be attributed to factors such as sexual dimorphism, environmental conditions, and variations in the methods used to estimate maturity status (Arocha, 2007). For example, Poisson and Fauvel (2009) estimated the length at first maturity for male and female swordfish as 120 cm and 170 cm, respectively. Alicli et al. (2012) also reported sexual dimorphism in swordfish, with females reaching maturity between 87 cm and 188.5 cm, while males ranged from 99 cm to 161 cm.

The dominance of juvenile swordfish in catches has been reported in various regions, including the Mediterranean Sea (FIRMS, 2016; Oceana, 2016). To protect and prevent depletion of the swordfish fishery in the Atlantic Ocean, the International Commission for the Conservation of Atlantic Tunas (ICCAT) has implemented size restrictions. Landing of swordfish is restricted to a minimum slot size of 125 cm LJFL (ICCAT, 2011).

Regular monitoring and analysis of the sizes of landed fish over time can help identify changes in fishing patterns, fishing efforts, and population dynamics, aiming to prevent depletion of the fishery (Ward and Elscot, 2000).

5.4 Spawning Potential Ratio (SPR)

The swordfish fishery in the Southwest Indian Ocean (SWIO) has not received sufficient research attention, resulting in limited information about the fishery (Kimakwa *et al*., 2022). There is a significant lack of biological and scientific data on swordfish species in Kenya (KMFRI, 2018). Most of the research on swordfish has been conducted in other regions, such as the Mediterranean Sea, Australia, South Africa, the USA, and New Zealand (Varghese *et al*., 2013).

In fisheries where data collection is challenging, the Spawning Potential Ratio (SPR) methodology by Prince (2015) and Hordyk et al. (2015) serves as a valuable tool to assess fisheries and determine their recruitment and productive capacity. SPR, as a proxy indicator for sustainable recruitment and reproductive capacity of fish stocks, is gaining recognition (Prince, 2015). The findings of this study indicate that the average SPR for the artisanal swordfish fishery in Kenya waters was 18%, ranging from 12% to 23% (Table 1). This average SPR falls below the recommended range of 20% to 50%, considered a good indicator for a healthy stock by fisheries scientists (Caddy and Mahon, 1995; Goodyear, 1993). Hordyk et al. (2015) proposed a limit reference point (LRP) of 40% for SPR. An SPR value below the LRP signifies low reproductive capacity and recruitment potential, while a value higher than the LRP suggests a fishery with greater reproductive capacity, recruitment potential, and resilience to fishing pressure (Caddy and Mahon, 1995; Goodyear, 1993).

These findings reveal that the fishery is experiencing low recruitment potential and reproductive capacity, posing a high risk of collapse unless immediate corrective measures are implemented.

Length-based approaches, which utilize the size structure of the fish population, provide valuable insights into the health and condition of the stock, offering useful information for decision-making to improve stock sustainability (Klaer *et al.,* 2012). This methodology is also cost-effective, as length measurements are inexpensive and easy to collect, unlike age-related data, which require substantial financial resources and technical expertise (Quinn and Deriso, 1999). Fisheries management authorities should consider incorporating SPR as one of the metrics to establish reference points for swordfish, complementing existing stock assessment models rather than replacing them. This approach would contribute to ensuring and sustaining the reproductive capacity and enhancing the stock sustainability of the swordfish fishery.

6. Conclusion and Recommendations

In data-deficient fisheries, low-cost data collection systems like Size Structure, Spawning Potential Ratio (SPR) can serve as a useful proxy to assess the stock status and performance. This methodology can be easily adapted by local fishing communities and fisheries managers, providing an estimate of recruitment and reproductive capacity.This study indicates that the average SPR of swordfish, at 0.18 (18%), falls below the recommended lower limit of 0.2 (20%)suggested by fisheries scientists (Hordyk et al., 2015). This suggests low recruitment in the fishery. It should be noted that the sample size used in the analysis was relatively small (319 individuals), and the SPR results should be considered preliminary. The results of this study reveal that fishing mortality outweighs natural mortality for swordfish. The exploitation rate of 0.8 per year exceeds the threshold of 0.5 per year, indicating overfishing in the swordfish fishery. The observed ratio of natural mortality (M) to the coefficient of growth (K) (M/K) of 1.0 and the length distribution (with most individuals ranging from 90 cm to 150 cm) of the sampled swordfish indicate the presence of many young individuals being caught with uncontrolled gear sizes. This suggests that the fishery is experiencing growth overfishing, posing a significant risk of collapse unless immediate management measures are taken.

In view of the above, the study proposes the following recommendations:

1. The fisheries management authorities should consider incorporating SPR as one of the metrics to establish reference points for managing the swordfish fishery, promoting the sustainability of reproductive capacity and stock.
2. A comprehensive study with a view to introducingregulations and management measures such as restrictions on fishing gear sizes and establishment of a Minimum Landing Slot Size for the swordfish fishery in the Indian Ocean region should be undertaken.
3. More comprehensive data collection and monitoring plan to detect changes in size and

population structure over a longer timeframe is necessary to identify future trends for management considerations.

Acknowledgement

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