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Preliminary studies on the population dynamics of African Sicklefish (*Drepane africana,* Osorio 1892) from the coast of Ghana

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ABSTRACT

Individuals of African Sicklefish (*Drepane africana*), one of Ghana's most commercially and significant marine fish species, are declining in abundance. Therefore, the study aimed to provide the first estimates of growth and mortality parameters for sustainable management of the species from the coast of Ghana. The total length (TL) of 515 individuals of African Sicklefish sampled from June 2020 to July 2021 was measured and analyzed using the FISAT II software to determine the growth, mortality, and exploitation rates. The growth equation was Lt = 27.3 (1 - exp 1.80 (t + 0.09)). The size at first capture (Lc) and maturity (Lm) were 12.3 cm and 16.3 cm TL, respectively. The total mortality rate (Z), natural mortality rate (M), and fishing mortality rate (F) were 7.34, 2.73, and 4.61 per year, respectively. The exploitation rate was assessed at 0.63, indicating that the stock is currently overexploited. The fishery risks collapsing if sustainable management measures are not implemented since the maximum sustainable yield (Emax) slightly exceeds the current exploitation rate.

Keywords: Fisheries management, Growth parameters, Length at capture, Length at maturity, Mortality parameters

Introduction

Drepane africana, characterised by a compressed body structure, has a small head, short snout, and small mouth with fleshy lips. Its upper jaw contains thin and sharp teeth in bands (Bauchot, 2003). The body of *D. africana* is coloured in silvery-grey, with a darker back and an almost white belly (Bauchot, 2003). This fish species is a benthopelagic, commonly found inhabiting the coastal waters of Canaries, Cape Verde, Senegal, Angola, and Mauritania (Desoutter, 1990).

In Ghana, this species is mostly harvested with fishing gears such as bottom trawl nets, beach seine nets, and hook and line (Segbefia et al., 2013). According to Edwards et al. (2003), the fishing season for this species spans from July to November and January to April. They are highly valued for their flesh, which is of excellent quality and greatly contributes to the nutritional security of many fishing households (Kwei & Ofori-Adu, 2005). Furthermore, the fishery of African Sicklefish contributes significantly to the economic growth of Ghana, generating approximately 1300 tonnes annually (Edwards et al., 2003).

Despite their importance to the local economy and food security, the landings of these species have decreased over time. According to FAO (2019), the landings of *D. africana* in Ghana have plummeted from 6.740 tonnes in 2008 to 32 tonnes in 2019. This alarming decline has dire consequences for the economic welfare of the communities, the livelihoods of dependent households, and food security in rural fishing communities of Ghana. Moreover, there is a significant lack of studies on the population parameters of this species from the coast of Ghana, which could lead to poor fishery management, consequently reducing its resilience in the face of overcapacity of fishing efforts (Aoki et al., 2008). This study aimed to investigate the growth, mortality, and biological reference points that could serve as indicators for sustainable management of the sampled fish species in Ghana. The information gathered from this study will also be used as a resource for future studies in Ghana since it is the first study on the population dynamics of this species.

Materials and Methods

Study Area

The study was carried out in four fishing communities along the coast of Ghana: Sekondi (4°55'45.74"N, 1°43'22.75"W), Sakumono (5°36'40.50"N, 0°2'41.13"W), Keta (5°53'34.41"N, 0°59'36.22"E) and Apam (5°16'59.24"N, 0°44'9.96"W). The main livelihoods of the people in the selected study sites include fishing and farming.

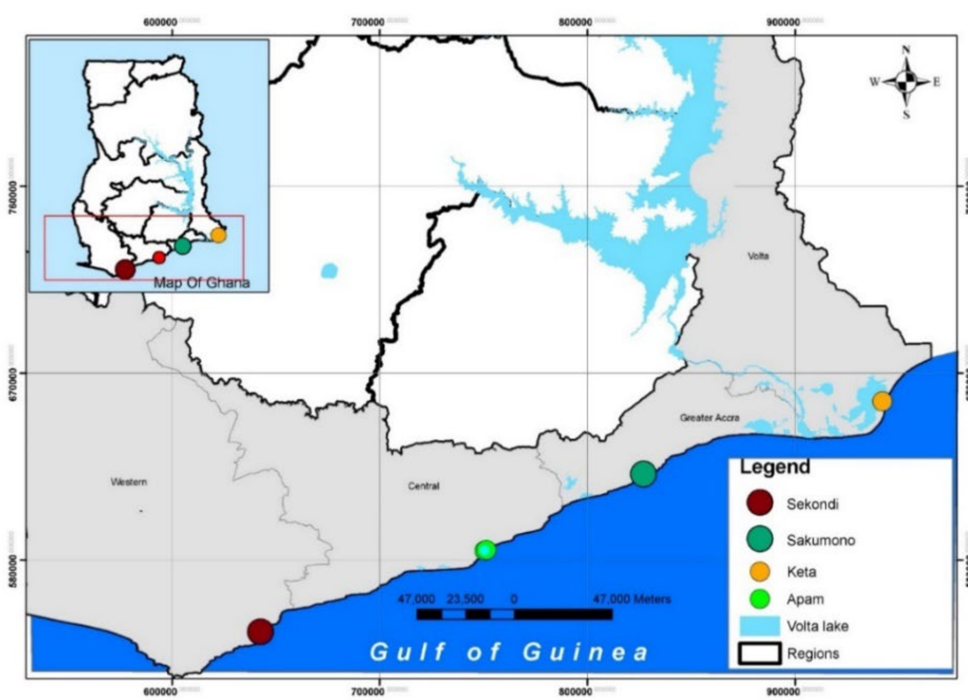

Figure 1. Map showing the sampling locations for the study

Data Collection

Between June 2020 and July 2021, 515 samples of *D. africana* from the coast of Ghana were purchased monthly from local fishermen. Samples obtained were measured to the nearest centimetres for total length (TL) with a wooden measuring board and weighed to the nearest gram using an electronic balance. The samples were identified to the species level using identification keys (Kwei & Ofori-Adu, 2005).

Growth Parameters

Electronic Length Frequency Analysis (ELEFAN) option of FiSAT II Tool, was used to estimate the growth parameters following the Von Bertalanffy Growth Function (VBGF) by Pauly (1980): $TL_t = TL_\infty\left(1 - e^{-K(t - t_o)}\right)$,

L_t is the average length at the time (or age), $L\infty$ is the asymptotic length, K is the growth rate, and t_o represents the age when the average length was zero.

The longevity (T_{max}) was determined as T_{max}=3/K (Pauly, 1983).

The growth performance index was estimated as 2logL∞ + log K (Pauly & Munro, 1984).

The theoretical age at length zero (t_0) was calculated as Log_{10} (-t0) = -0.3922 – 0.2752 log_{10} L∞ —1.038 log_{10} K (Pauly, 1979).

Length at First Capture

The downward left portion of the length-converted catch curve was applied to calculate the lengths at capture. These include Lc_{25}, Lc_{50}, and Lc_{75}, which correlate with the cumulative probability at 25%, 50%, and 75%, respectively (Pauly, 1984).

Length at First Maturity

The length at first maturity (Lm_{50}) was determined as Log Lm_{50} = 0.8979*Log_{10} (L∞) - 0.0782 (Froese & Binohlan, 2000).

Mortality Parameters

The total mortality rate (Z) was determined from the length converted catch curve (LCC). The natural mortality rate (M) at a temperature of 28.9°C was computed using the empirical formula by Pauly (1980): ln M = – 0.0152 - 0.279 * ln L∞ + 0.6543 * ln k + 0.463 * ln T

where M is natural mortality in a given stock and the value of T is the seawater's annual mean temperature (in °C).

The fishing mortality coefficient (F) was computed as F = Z–M (Pauly, 1983).

The exploitation rate (E) was estimated as E= F/Z (Pauly, 1983).

Relative Yield Per Recruit (Y/R)' and Relative Biomass Per Recruit (B/R)'

The data of Lc/Linf and M/K values were used to estimate exploitation at maximum yield (Emax), 10% of yield ($E_{0.1}$), and 50% of yield ($E_{0.5}$).

Data Analysis

Length measurement data was pooled together at 5 cm intervals and analysed for population parameters using FAO-ICLARM Stock Assessment Tool (FiSAT) II software (Gayanilo et al., 1988).

Results and Discussion

Length Distribution

The mean length of 515 individuals of *D. africana* obtained during the study was 14.5 ±0.18 cm (Figure 2). The minimum and maximum lengths obtained were 3.90 cm and 27.0 cm, respectively.

Growth Parameters

The calculated Von Bertalanffy growth function (VGBF) parameters of *D. africana* were L∞= 27.3 cm, K = 1.80 $year^{-1}$ (Figure 3), t_0 = -0.09, and Ø' = 3.128, while the estimated goodness of fit of model was Rn = 0.36.

Mortality Parameters

The total, natural and fishing mortality rates for *D. africana* were Z = 7.34 $year^{-1}$ (Figure 4), 2.73 $year^{-1}$ and 4.61 $year^{-1}$ respectively. The exploitation rate (E) was 0.63.

Probability of Capture

The capture probability was 11.3 cm, 12.3 cm, and 13.3 cm at 25%, 50%, and 75%, respectively (Figure 5). Therefore, the length at first capture was 12.3 cm. The length at first sexual maturity was estimated at 16.3 cm.

Yield Per Recruit Analysis

The exploitation rates at the 10 and 50 %, and maximum levels were 0.567, 0.348, and 0.657, respectively (Figure 7).

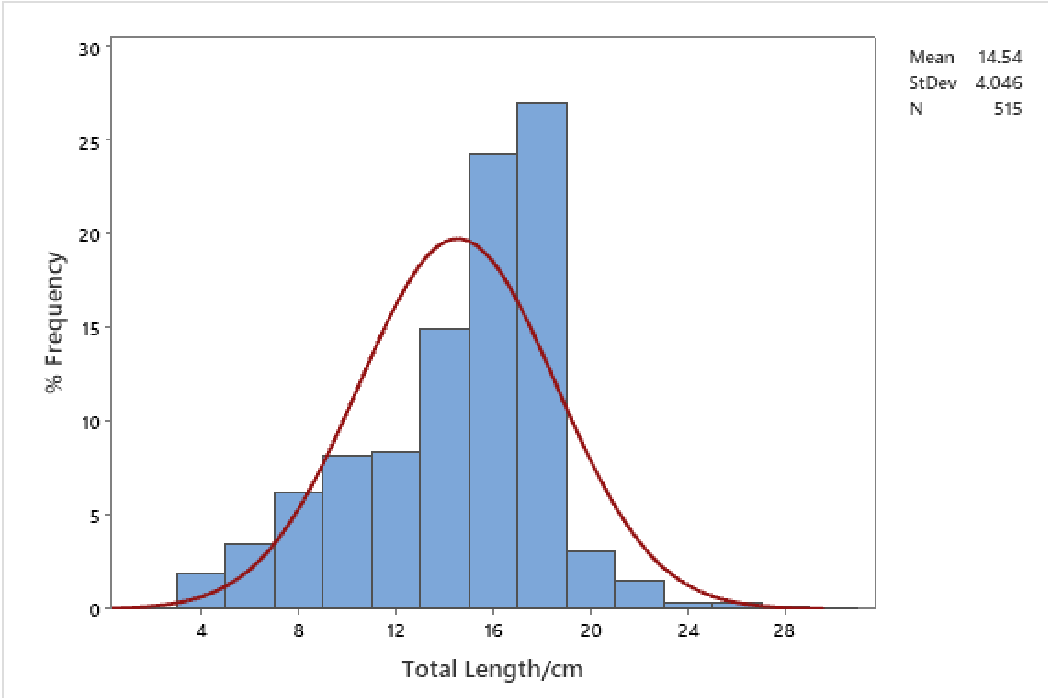

Figure 2. Length distribution of *D. africana* from the coast of Ghana

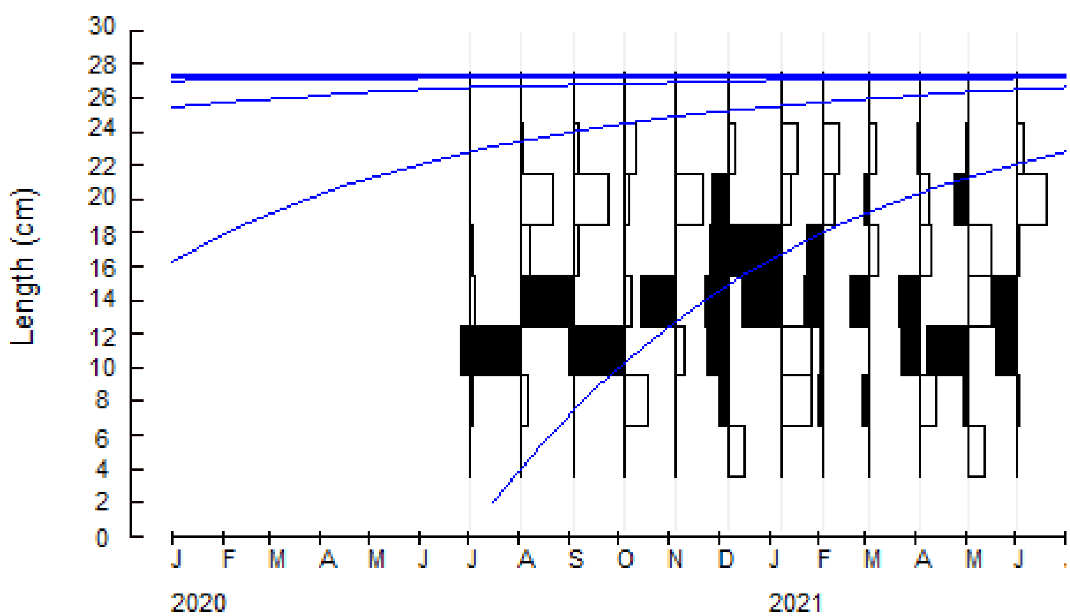

Figure 3. Length-frequency distribution data and growth curves estimated using the ELEFAN method for *D. africana*

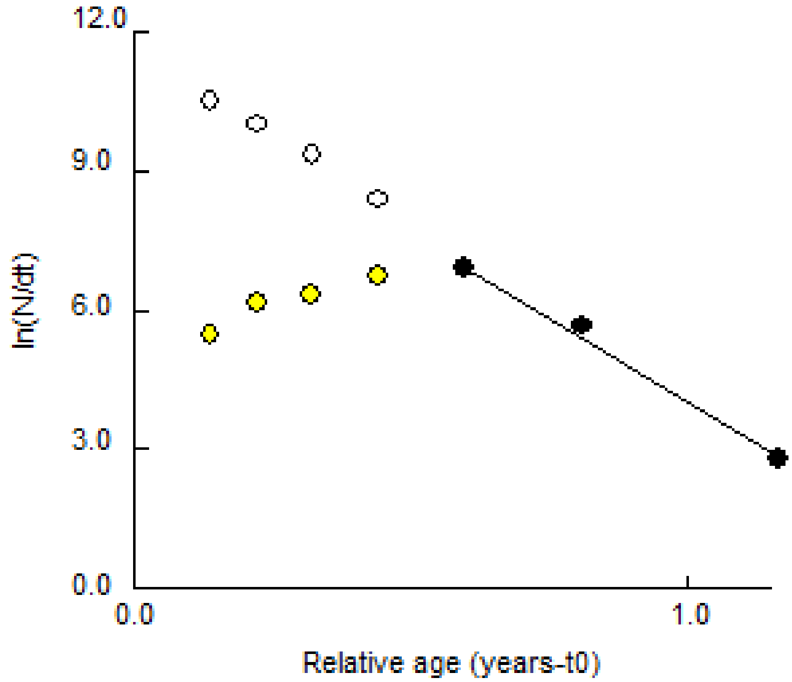

Figure 4. Estimation of 'Z' by length converted catch curve method for *D. africana*

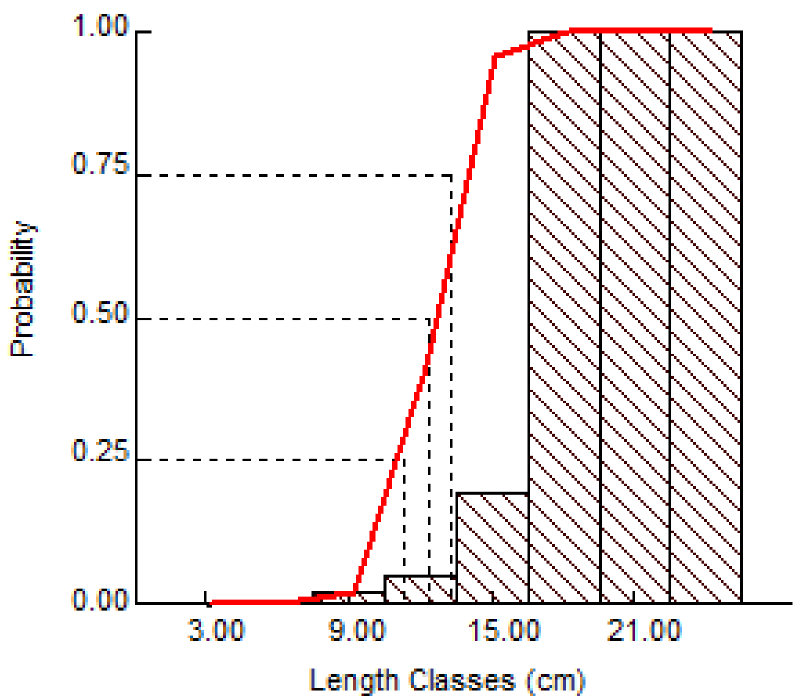

Figure 5. Probability of capture of *D. africana*

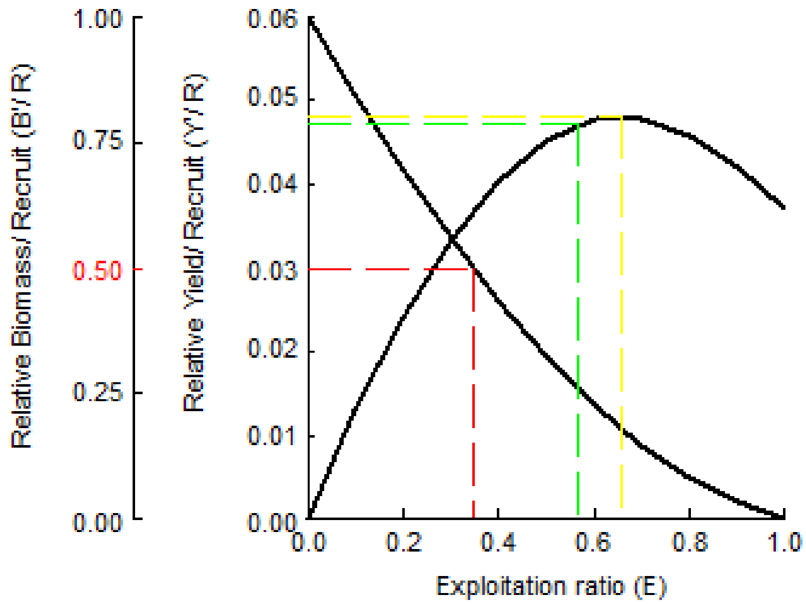

Figure 7. Yield per recruit analysis of *D. africana* in the present study

This is the first study on the population dynamics of *D. africana* from the coast of Ghana. Hence, little information exists for effective comparison. As such, the information gained will serve as preliminary scientific resources for managing this species from the coast of Ghana. Growth parameters are essential to estimate the stock size, recruitment, and mortality of fish population (Shojaen et al., 2007). The asymptotic length recorded from the study was lower than the estimate that Thiam (1988) recorded from the waters of Senegal (51.4 cm). Nonetheless, the growth rate of 1.80 per year in the present study was higher than that of Thiam (1988), who reported a growth rate of 0.15 per year. The variation in asymptotic length and growth rate reveal the presence of small-sized individuals of stock within the coast of Ghana than in other regions, potentially due to the high, unsustainable fishing pressure exerted by fishermen along the coast of Ghana (Amponsah et al., 2019; Arizi et al., 2022). According to Pinsky and Byler (2015), fishes with a fast growth rate are three times more likely to experience a population collapse. This implies that the individuals of the sampled fish species are highly vulnerable to collapse, especially in absence of proper management measures.

The length at first capture (Lc) from the current study was lower than estimate from Thiam (1988), who reported 19.0 cm as the length at first capture. This comparison confirms that individuals of *D. africana* landed along the coast of Ghana are largely of a small size. This is also characterised by the length at capture to asymptotic length ratio being lower than 0.5 (Pauly & Soriano, 1986). This potentially reflects the existence of growth overfishing within the fishery of species. According to Ben-Hasan et al. (2021), poor management of fish species occasions the presence of small-sized individual fish species fishes.

The length at first catch (Lc) from the current study was less than length at first maturity (Lm), suggesting that the species becomes vulnerable to capture before reaching sexual maturity. The presence of immature small-sized individuals from the study may be attributed to artisanal fishermen using small mesh-sized fishing gear (Zhai et al., 2019). Furthermore, high fishing pressure will result in a high likelihood of decline in spawning biomass to the point where recruitment is impaired (i.e. recruitment overfishing) when exploitation is unsustainably high (Ben-Hasan et al., 2021).

From the present study, the fishing mortality rate was higher than the natural mortality rate, indicating that the decline in the population of the fish species is hugely accounted for by fishing-related activities (Aheto et al., 2019). Furthermore, the fishing mortality rate from the study was higher than the value (F = 0.73 per year) Thiam (1988) reported. This suggests that the sampled fish species is experiencing high fishing pressure, evinced by the significant drop in landings (FAO, 2019).

According to Gulland (1971), an exploitation ratio (E) at 0.5 reveals a sustainable level of fishing, while a value above 0.5 signals that the species is in an over-exploited state. This shows that with an exploitation rate of 0.63, the species from the coast of Ghana is over-exploited. Nonetheless, the exploitation rate from the current study favoured the finding by Thiam (1988), who documented an exploitation rate of 0.63. Compared to the exploitation at maximum sustainable yield (Emax), the current exploitation rate (E) was slightly lower than the Emax, a condition that may result in a reduction of the stock from the coast of Ghana.

Conclusion

The current study sheds light on the population dynamics of the *D. africana* from the coast of Ghana. According to the study, *D. africana* exhibited signs of fast growth, with individuals becoming susceptible to capture before they reach maturity. The stock was overexploited and marginally below the maximum exploitation rate, placing it at risk of future depletion. Revision of mesh size regulation and lowering fishing capacity are some of the measures needed to protect the resources from further depletion.

Compliance with Ethical Standards

Conflict of interest: The author(s) declare no actual, potential, or perceived conflict of interest for this article.

Ethics committee approval: Not applicable

Data availability: Data will be made available on request.

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Disclosure: -

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