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Growth, mortality and exploitation rates of *Lethrinus atlanticus* in the marine waters of Ghana, West Africa

[§1]Amponsah Samuel Kweku Konney, [2]Commeyn Nii, [3]Awornyom Selasi, [1]Henneh Samuel

[1]Department of Fisheries and Water Resources, University of Energy and Natural Resources, Sunyani, Ghana.

[2]ESL, Consulting, Ghana

[3]Department of Marine and Fisheries Sciences, University of Ghana, Legon, Ghana

[§]Corresponding author: samuel.amponsah@uenr.edu.gh

Abstract

Some aspects of population parameters of *L. atlanticus* in the marine waters of Ghana were studied from July 2018 to June 2019. Length based data were obtained from 473 samples and analyzed using the TropFishR package in R software. The growth parameters including asymptotic length ($L\infty$), growth (K) and growth performance index (phi) were 27.0 cm TL, was 27 cm TL, 1.73 yr-1, and 3.239 respectively, with Rn value of 0.29. The total, natural and fishing mortality rate (Z) were 5.03 yr-1, 2.08 yr-1 and 2.96 yr-1 respectively Exploitation rate (E) was slightly higher than the optimum level of 0.5, suggesting that the species is sustainably exploited.

Keywords: Ghana, exploitation rate, fishing mortality, growth performance, TropFishR.

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INTRODUCTION

Lethrinidae are native to tropical and subtropical coastal regions from the seashore to about 600m deep (Newman *et al.,* 2016). The genera Lethrinus consist of 40 fish species; only *Lethrinus atlanticus* are found in the marine aquatic space of West Africa. Lethrinids are mostly considered as scavengers; they are one of the most economically important fish species in most countries around the globe (Fabian *et al.,* 2021). Lethrinidae family of fishes are closely related to snapper and seabreams (Afrisal *et al*., 2020). The gill-membranes are broadly united with one another but free from the isthmus (Edwards *et al.,* 2001). The front teeth of the jaws are pointed and some of them are canine-like. Also, the teeth at the sides are conical and arranged in a single row (Edwards *et al*., 2001). Moreover, Lethrinidae has no teeth on the roof of it mouth. Lethrinidae has a naked head which implies absence of scales on the head region; however, there are scales on the nape and the gill-cover (Afrisal *et al*., 2020). *Lethrinus atlanticus* grows to the length of about 50cm. The colour of the skin is khaki above, brownish green on the flanks and white on its belly (Edwards *et al*., 2001). *Lethrinus atlanticus* has a darker head than the rest of its body, its mouth is pink along its edge with reddish fin, anal and caudal fine of a darker red coloration (Fabian et al., 2021). *Lethrinus atlanticus* is mostly harvested close inshore from June to September. However, the fishery for *L. atlanticus* has increased recently with approximately 250 tonnes caught in the region each year (Edwards *et al.,* 2001). In Ghana, *L. atlanticus* is documented as a commercially important species mostly harvested by the artisanal fisheries sector. Like other species that have received minimal studies on their biology and stock status, the only studies that have focused on *L. atlanticus* in Ghana have actually treated it as collective species studies (e.g. Koranteng, 2001; Nunoo and Asiedu, 2013). However, the persistent absence of research studies on the population status of *L. atlanticus* makes management of this commercially important fish ineffective.

Therefore, the study aimed at assessing some population parameters, which would provide baseline information for its sustainable management.

MATERIALS AND METHODS

Study area

The study was undertaken in five fishing communities along the coast of Greater Accra Region of Ghana. These communities are Sakumono, Tema, Nungua, Kpone and Prampram (Figure. 1). The main livelihood for most of the inhabitants of the study areas fishing related (i.e., from harvest to post harvest of fish species). Table 1 shows the geographical positions of the five sampling locations used in the study.

Figure 1. Map showing the fish landing sampling locations.

Table 1: GPS locations of the sampling areas

Sampling Location	GPS Coordinates
Nungua Beach	05°35'42.56"N, 000°04'14.57"W
Tema Canoe Beach	05°38'39.48"N, 000°00'59.50"E
Tema Inshore Fishing Harbour	05°38'23.57"N, 000°01'00.38"E
Kpone	05°41'26.84"N, 000°03'52.76"E
Prampram	05°42'17.71"N, 000°06'51.57"E

Data collection

Samples of the assessed fish species from the coastal waters of Ghana were purchased from fishermen who use nylon type of fishing gear in their activities over a period of twelve (12) months from July 2018 to June 2019. Samples collected from the field were identified in-situ using Kwei and Ofori-Adu (2005) identification keys, preserved on ice and taken to the laboratory of the Department of Marine and Fisheries Sciences, University of Ghana for analyses. Morphometric measurements including total length and weight of the individuals were taken using 100 cm graduated wooden measuring board and top pan electric scale. In all, 473 specimens of *L. atlanticus* were obtained during the study period.

Methods

Length frequency distribution

Length data from monthly sampling were grouped into length classes of 2 cm interval for the plotting length frequency distribution.

Length-weight relationship (LWR)

The LWR was calculated using the equation:

$$W = a*L^b \text{ (Pauly, 1984)}$$

where W is the body weight (BW, g), and L is the length (TL cm).

Growth parameters

Growth rate (K) and asymptotic length (L_∞) which are indicators of growth parameters were calculated based on the Electronic Length Frequency Analysis (ELEFAN_ GA).

Von Bertalanffy Growth Function (VBGF) was given as follows:

$$L_t = L_\infty(1 - e^{-K(t-t_0)})$$

Lt = length at time (or age) t, L_∞ = asymptotic length, K = growth rate coefficient (units are yr−1), and t_o = time or age when the average length was zero.

Longevity (Tmax) of the species was calculated following the method:

$$Tmax = 3/K \text{ (Anato, 1999)}$$

The formula provided below was to estimate the growth performance index:

$$\Phi' = 2\log L_\infty + \log K \text{ (Munro and Pauly, 1984)}$$

The age at which the length was zero (t0) was calculated as follows:

$$\text{Log } 10\,(-t0) = -0.3922 – 0.2752 \log 10\, L_\infty - 1.038 \log 10\, K \text{ (Pauly, 1979)}$$

Length at First Capture (L_{c50})

The length at first capture (Lc50), at75 and 95 percent capture which correlates with the cumulative probability at 75% and 95% respectively (Pauly 1984) were estimated using the rising section of the curve.

Length at First Maturity (Lm_{50})

The length at first maturity (Lm_{50}) followed the formula:

$$Lm_{50} = 0.8979 \text{Log}10(L_\infty) - 0.0782 \text{ (Froese and Binohlan, 2000)}$$

Mortality rates

The length catch converted (LCC) curve was applied in estimating the total mortality rate (Z) where the procedure below was followed: It is given as

$$Z = M + F \text{ (Spare and Venema, 1992).}$$

Where, Z is the instantaneous rate of total mortality, M is the instantaneous rate of natural mortality and F is the instantaneous rate of fishing mortality.

The natural mortality rate (M) was estimated as follows:

M = 4.118K0.73L∞−0.333 (Then *et al*., 2015).

Fishing mortality (F) was calculated as

Z – M (Qamar *et al*. 2016).

The exploitation rate (E) was computed using

F/Z (Georgiev and Kolarov, 1962)

Data analysis

The TropFish R package in R programming was used in assessing the population parameters (e.g., growth rates, mortality rates and exploitation rates) of the individual fish species encountered during the study period (Taylor and Mildenberger, 2017).

Results

Length frequency distribution

The mean and modal length of *L. atlanticus* was estimated as 13.9 ± 0.2 and 14.0 cm respectively (Figure 2). The minimum and maximum lengths were 6 cm and 23.3 cm respectively.

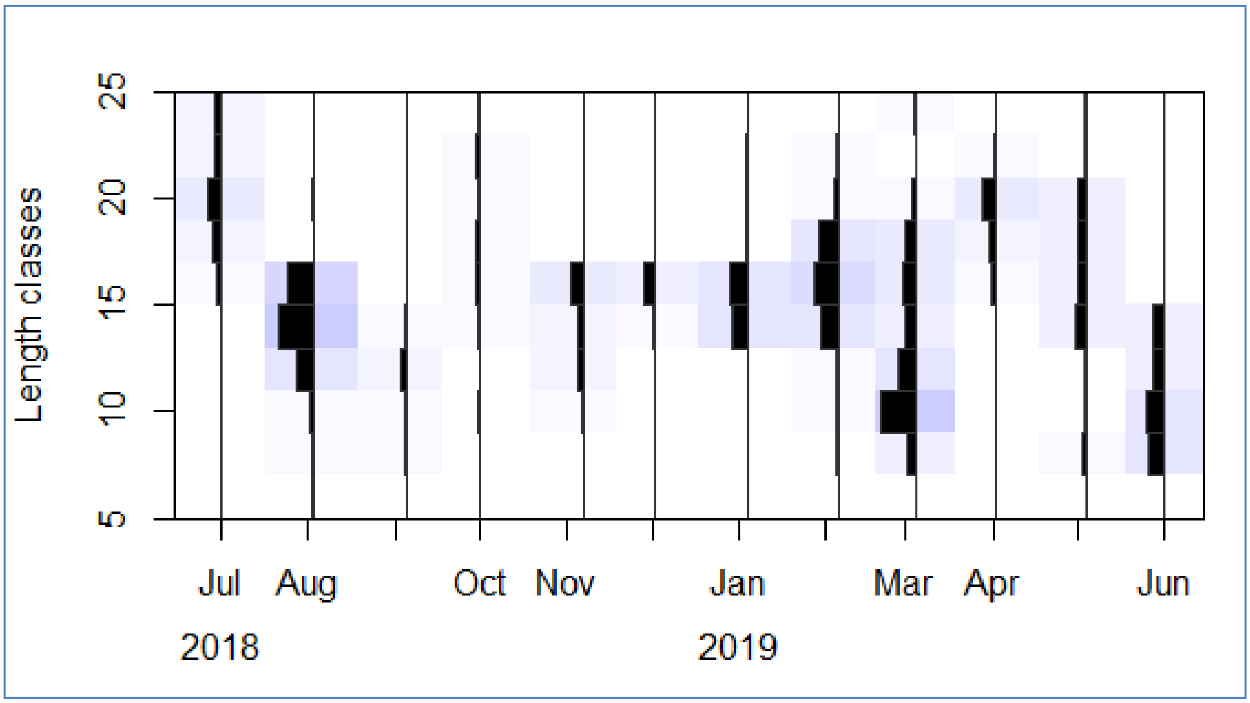

Figure 2: Length distribution for *L. atlanticus*

Length weight relationship

The estimated constant ‘a’ and ‘b’ of the length weight relationship of *L. atlanticus* was 0.0159 and 3.0 as show in Figure 3.

Growth parameters

Figure 3 shows the Powell Wetherall plot, which provides a crude estimate of L∞ as a requisite for the actual estimation using the Generic annealing option of the ELEFAN. From the Powell Wetherall plot, the crude estimate of L∞ was 27.0 ± 4 cm. Lmean is the mean length of the fish species and the Lprime is the length for which all fish of that length are no longer are under full exploitation.

Figure 4 shows the output of the Generic Annealing (GA) option of the ELEFAN for the calculation of the actual growth parameters. From the GA, L∞ and K was 26.5 cm and 1.73 yr-1 with Rn value of 0.29. The growth performance index (Φ′) was 3.239.

The length-frequency distribution reconstructed and overlaid with growth curves approximately three (3) cohorts (Figure 5).

Length at first capture

Figure 6 outlines the probability of capture of *L. atlanticus.* From, Lc50, L75 and L 95 was 11.9 cm, 13.0 cm = 14.7 cm respectively. Based on the results, the length at first capture (Lc50) was 12.8 cm with a corresponding age to be 0.35 years.

Mortality rates

The LCC curve was used in calculating the mortality rates including total, fishing and natural mortality rates. From the study, the total mortality rate (Z) was 5.03 yr^{-1} ((Figure 7). The natural mortality rate (M) and fishing mortality rate (F) was 2.08 yr^{-1} and 2.96 yr^{-1} respectively. The rate of exploitation (E) was 0.58.

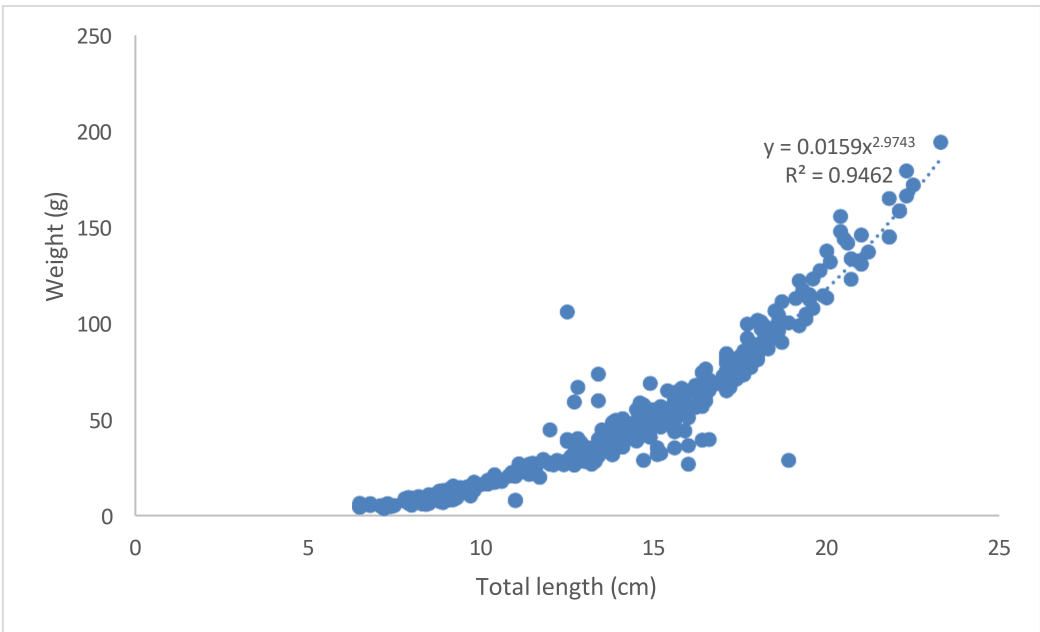

Figure 3: Length-weight relation of *Lethrinus atlanticus*

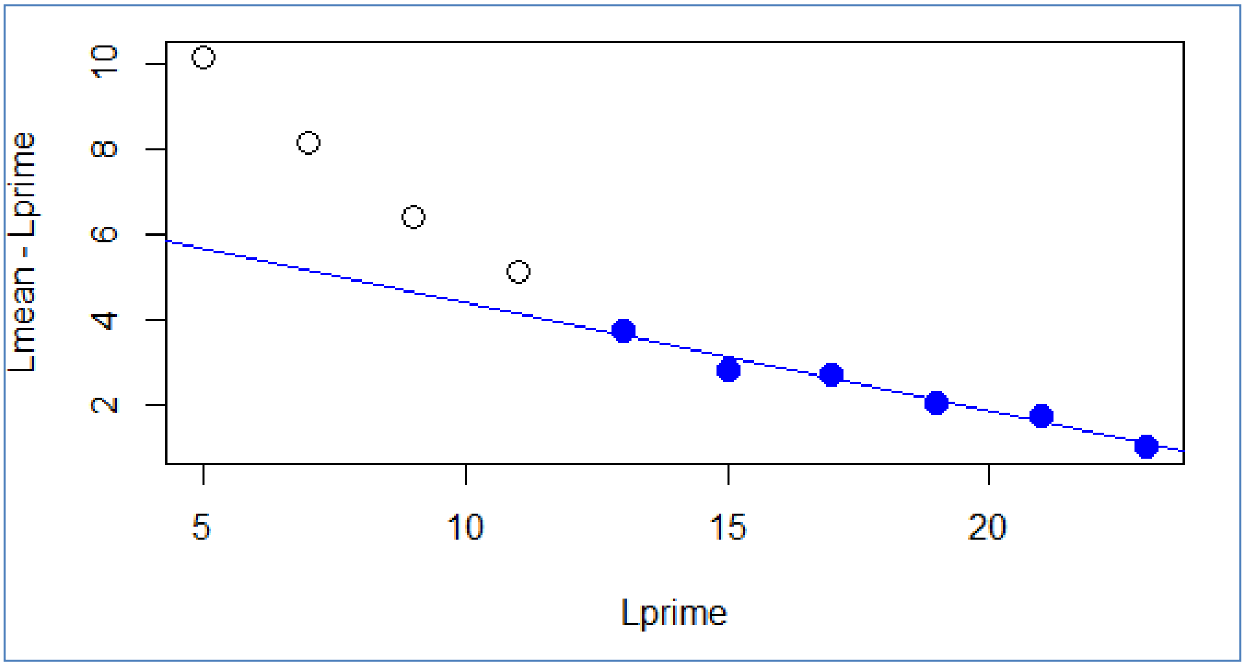

Figure 3: Powell-Wetherall plot to derive an estimate of Length at infinity of *L. atlanticus*

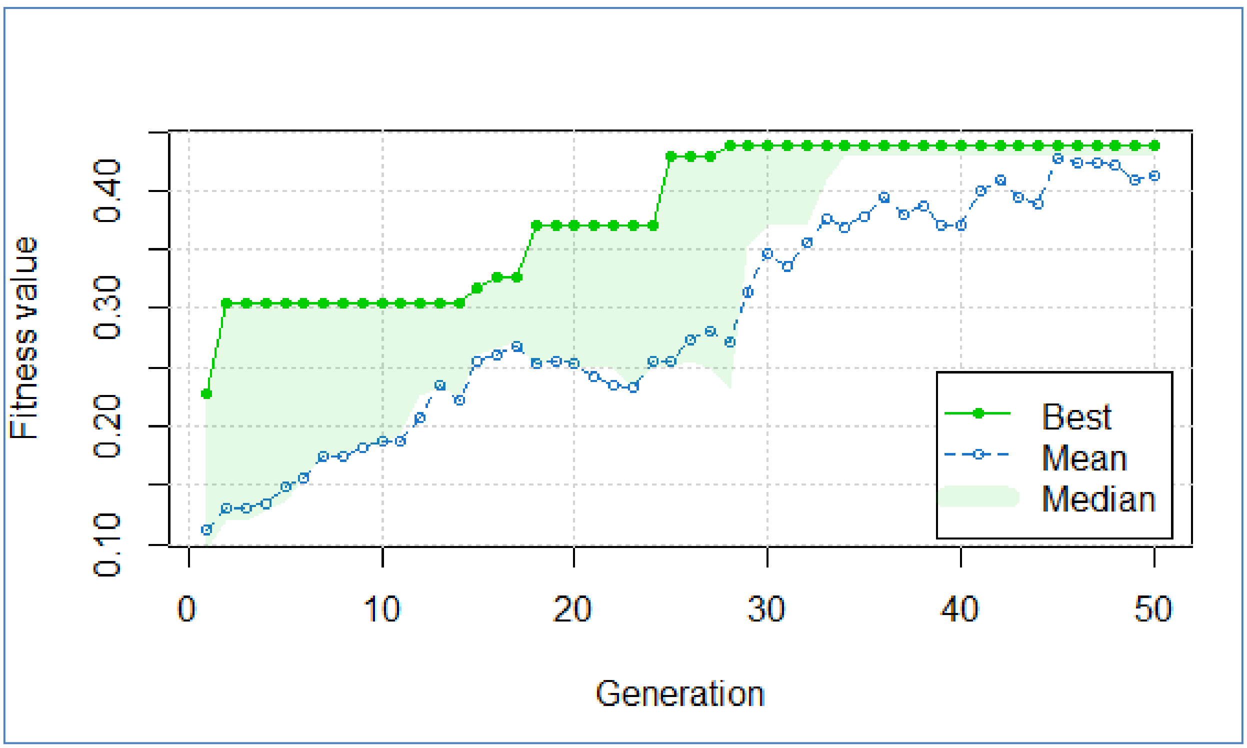

Figure 4: Generic Annealing (GA) option of the ELEFAN for attaining the actual growth parameters

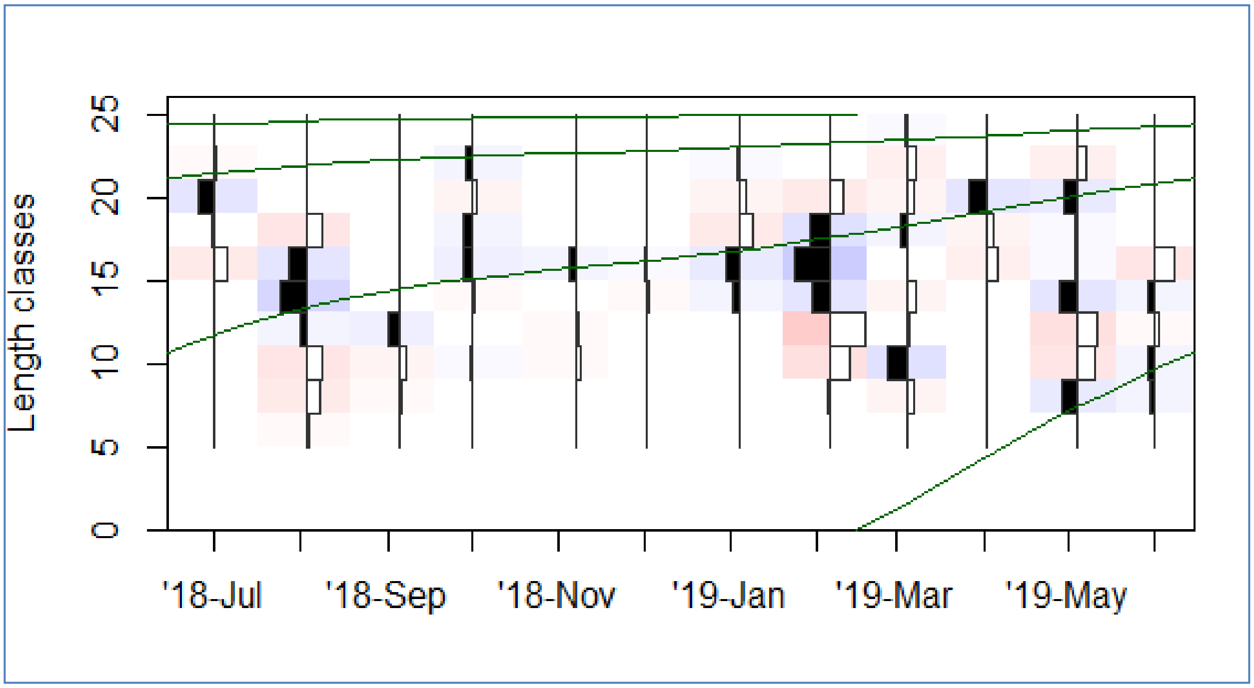

Figure 5: Length frequency distribution reconstructed for *L. atlanticus*, overlaid with growth curves.

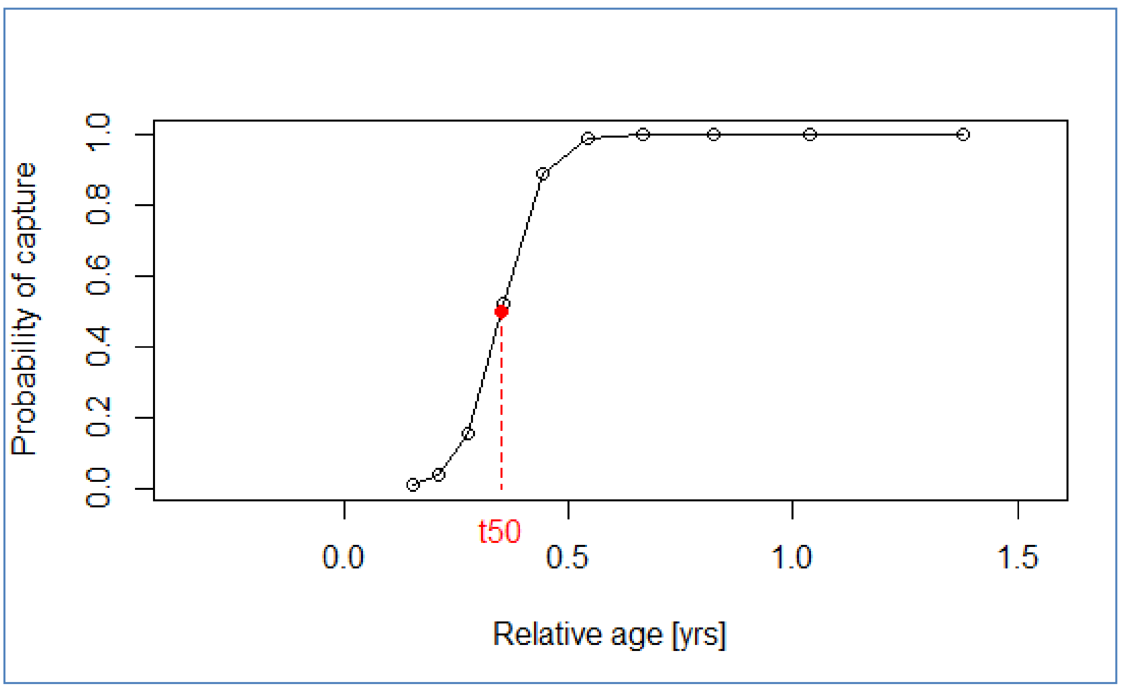

Figure 6: Age at first capture for *L. atlanticus*

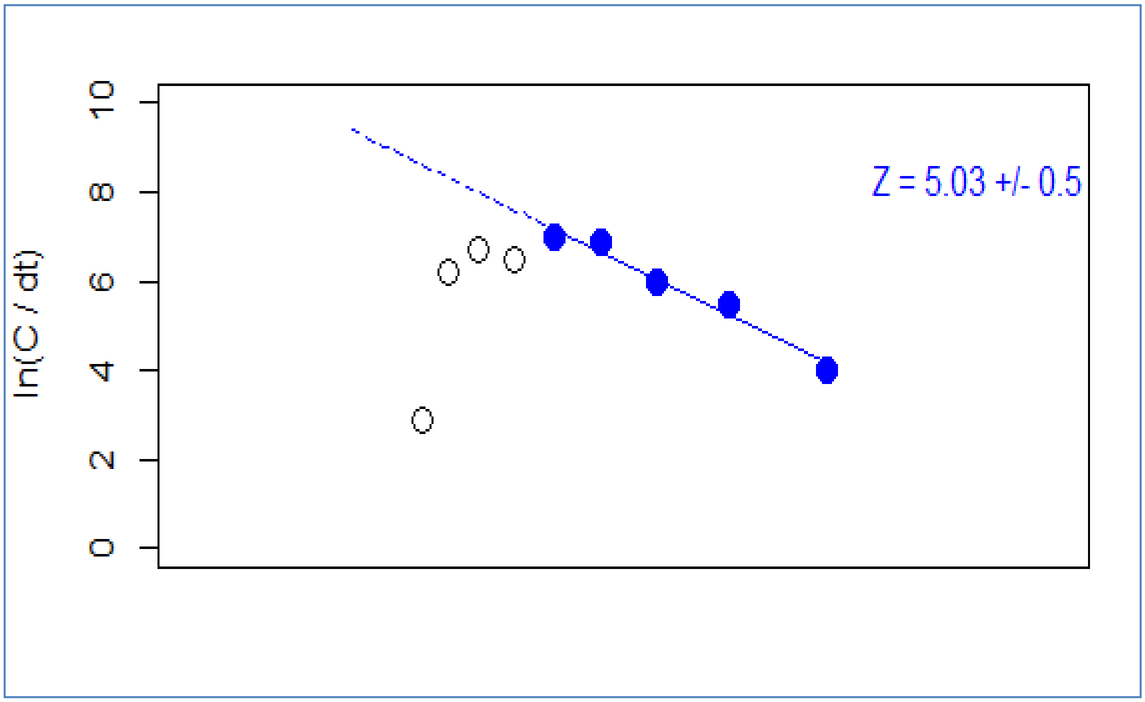

Figure 7: Length converted catch (LCC) curve for the estimation of total mortality rate (Z) of *L. atlanticus*

DISCUSSION

In Ghana, population parameters of commercially important marine species including *L. atlanticus* are lacking. Therefore, information from the current study will aid in sustainable management the fishery resources. The growth pattern 'b' recorded by Kulmiye *et al*. (2002) and Lidour *et al*. (2018) for *L. harak* and *L. nebulosus* from the Kenyan and Akab waters respectively was favorable with estimate obtained from the current study. The growth pattern 'b' estimated from the study indicated the assessed species exhibited a slightly negative allometric growth (Lidour *et al.,* 2018).

The estimated range of K and growth performance index recorded by Kaunde-Arara and Rose (2006) from Kenya (i.e. 0.57 per year – 0.77 per year and 2.65 – 3.13) was lower than the estimate recoded from the study. However, the estimated asymptotic length from the current study was slightly below the range published by Kaunde-Arara and Rose (2006). In addition, for *L. nebulosus*, Motlagh *et al.* (2010), Mehanna *et al.* (2012) and Al-Qishwe *et al.* (2017) from the waters of Iran and Oman recorded lower growth rates and higher asymptotic lengths than the recorded from the current study. The variation in growth parameters maybe aligned to the level of fitness of the growth curve to the length-frequency progressions (Kaunde-Arara and Rose, 2006). Nonetheless, the higher growth rate of the *L. atlanticus* could be alluded to conducive environmental conditions for its growth in the Ghanaian coastal waters. Again, growth parameters differences may be linked to variations in environmental conditions, especially temperature, physiological conditions, food availability, fishing pressure and sampling limitations (Al-Qishwe *et al*., 2017). For instance, the absence of obtaining large-sized individuals during the sampling period could have resulted in the low length at infinity estimated from the study (Midway *et al*., 2018). Sparre (1992) reported that the lower the growth coefficient (K), the longer the time needed to achieve its asymptotic length (L∞) and vice versa. From the study, the estimated growth rate was 1.70 per year, which categorizes the species as fast growth type (Kienzle, 2005).

Fast growth nature of the species also indicates that in the event of heavy exploitation, the fast-rebuilding nature will guard theory stock size against extinction.

Compared to studies by Mehanna *et al* (2012) and Al-Qishwe *et al* (2017), the estimated length at first capture was highly lower than the estimates provided by these researchers (i.e. 31-9 cm – 32.3 and 22.4 cm respectively). The difference in estimated length at first capture may be reliant on variation in locality, depth of water column inhabited by the species, distribution of the species and the variation in maximum length recorded (Mehanna *et al*., 2017; Muflikhah *et al*., 2006). Furthermore, the highly reduced length at first capture from the current study suggests that individuals of the species are highly exploited with fishing gears of very small mesh sizes. Given this, Lappalainen *et al.* (2016) reported that L50 is a potential indicator of fishing pressure in fish stocks.

According to Williams *et al*. (2006), formulation and implementation of minimum legal sizes are often implemented in a fishery based on size at first maturity (Lm_{50}) information. Therefore, carrying out studies on reproductive biology of fishes has important implications for fisheries management. From the study, the size at first maturity was highly lower than estimates by Kulmiye *et al.* (2002) who recorded Lm_{50} range of 24.2 cm to 26.2 cm. Furthermore, the length at first maturity from study was outside the ranged of 25 cm – 31 cm for *L. nebulosus* from FAO Area 51 (Motlagh *et al.,* 2010). The changes in length at first maturity as compared to the current study might be due to inherent genetic differences among the populations, effects of temperature, turbidity or other environmental factors (Allsop and West, 2003).

The size at which capture of the species commenced (Lc50) was below the size at first maturity (Lm_{50}) of 15.8 cm. Generally, having the Lc is lower than the Lm, has the propensity of causing overexploitation of the fish stock. Furthermore, in a fishery where species reach maturity at a larger size due to variations in maturity schedules than the length at which they become vulnerable to capture may result in recruitment overfishing (Froese and Binohlan, 2000; Williams *et. al.,* 2006). This is because the subpopulations of the species will not have the opportunity to conduct their spawning activity in order to sustain the recruitment process. Therefore, to sustain the subpopulations of the species, there is the need to revise and apply the maximum legal-size limit of the stock.

The estimated total and fishing mortality rates from the study highly greater than estimates by Motlagh *et al*. (2019) for *L. nebulosus,* Younis *et al.* (2020) for *L. Letjan* and Mrombo *et al*. (2019) for *L. Letjan*. The difference in growth parameters used and the fluctuations in environmental parameters could seriously affect the computed mortality rates (Younis *et al*., 2020; Tserpes and Tsimenidis, 2001). The rate at which species die due to natural causes (M) was slightly lower than the fishing mortality rate. This condition was also observed in other studies (e.g. Younis *et al.,* 2020) and it shows that the death of most of the individuals because of intense fishing activity. However, the higher rate of fishing mortality than natural mortality conforms to the earlier findings that the balance between F and M is always impossible, as species are likely to be influenced by either F or M. The exploitation rate recorded for the species from the current study was similar exploitation rates reported for other species of Lethrinidae from different geographical areas (e.g. Mrombo *et al,* 2019; Motlagh *et al.,* 2010; Younis *et al*., 2020). Furthermore, the exploitation rate (E) was marginally higher than the optimum level of 0.5, which suggests that the species from the coast of Ghana is slightly overexploited (Pauly, 1984). In order to sustain the stock of the species, there is the need to institutionalize some management measures such as reducing fishing efforts and increasing the duration of the closed season or fishing holidays

CONCLUSION

From the study, the *L. atlanticus in* coast of Ghana is a fast-growing species with species harvested before reaching the maturity stage. The species is highly susceptible to potential recruitment failure if relevant fishing measures are not in place. Based on the exploitation rate, the species is optimally exploitation hence the need to enhance voluntary compliance to existing management measures such as closed fishing season, reduction in the fishing efforts, use of appropriate fishing gears and reduced engagement in illegal fishing practices. Nonetheless, it is worthy to note that, due to the absence of literature on the assessed species from the coast of Ghana, findings from the study were compared to results from different geographical locations published on species of the same Genus, *Lethrinus*. Therefore, information from the current study should be used cautiously.

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Conflict of interest

None to declare.

Author contribution:

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