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Research Article

Length-based Population Dynamics of Lesser African Threadfin (*Galeoides decadactylus*, Bloch, 1795) from the Coastal Waters of Ghana

Samuel Amponsah[1], Nii Commey Amarquaye[2], Olaniyi Alaba Olopade[3], Abdul Baset[4]

[1] *Department of Fisheries and Water Resources, University of Energy and Natural Resources, Box 214, Sunyani, Ghana*

[2] *ESL Consulting, Accra, Ghana*

[3] *Department of Fisheries, University of Port Harcourt, PMB 5323, Port Harcourt, Nigeria*

[4] *Department of Zoology, Bacha Khan University Charsadda, Pakistan*

**Email: samuelamponsah09@gmail.com*

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Abstract

The study evaluated some population parameters of *Galeoides decadactylus* in coastal waters of Ghana. A total of 567 samples were collected from some selected coastal communities along the Greater Accra region of Ghana from August 2018 to August 2019. The total length of individual fish samples was measured and analyzed using TropFish R statistical package. Von Bertalanffy parameters were estimated at asymptotic length (L_∞) = 39.6 cm, growth rate (K) = 0.19 per year, and growth performance index (Φ′) = 2.484 with an Rn value of 0.37. The length at first capture and maturity was 17.2 cm and 22.7 cm, respectively. Mortality parameters were calculated as total mortality rate (Z) = 1.49 per year, the natural mortality rate (M) = 0.36 per year, and fishing mortality rate (F) = 1.13 per year. The exploitation rate (E) was 0.76, indicating that *G. decadactylus* fishery in Ghana is overexploited. Monitoring of fishing efforts and the use of standard mesh size are some of the recommended management measures to sustain the *G. decadactylus* fishery in Ghana.

Keywords: *Galeoides decadactylus*; Population dynamics; length-weight relationship; Stock assessment; TropFish R

Introduction

Galeoides decadactylus (Bloch, 1795), commonly known as 'Lesser African threadfin' of the family Polynemidae, is primarily a demersal species that inhabits sandy and muddy bottoms in shallow coastal waters and has with a common 30 cm total length (Schneider, 1990). Its body is fusiform and greyish with two dorsal fins widely speared (Sidibé, 2010). Descriptively, the caudal fin is large and forked with the pectoral fin inserted above the lateral line and the mouth short and inferior (Edema & Osageide, 2011). The Lesser African threadfin is carnivorous and scavenging in nature, preying on shellfish, little fish, crayfish, and crabs (Aggrey-Fynn et al., 2013; Ezekiel et al., 2013). *G. decadactylus* species often portray negative allometric growth; thus, its length grows faster than the corresponding weight (Ndiaye et al., 2015).

In Ghana, *G. decadactylus* is primarily harvested by fishermen who operate with beach seines and gillnets along the coastline of Ghana. The production of *G. decadactylus* in Ghana's coastal waters has declined from 4979 tons in 1979 to 2038 tons in 2017 (FAO, 2019). In addition to the declining production of *G. decadactylus* in the coastal waters of Ghana, there is limited information on its population parameters. Limitation of such scientific data on fish population assessment renders fisheries management options geared toward sustainable exploitation of commercially important fishes ineffective. Consequently, poor management of this commercially important species can lead to the collapse of this species with severe repercussions, including malnutrition to fishing households, increased poverty severity to dependent families, loss of jobs, and low contribution to Ghana's GDP. Given the declining nature of *G. decadactylus* and the limited information of its stock status in Ghana, the study's objective was to evaluate some population parameters of *G. decadactylus*. The information gained from this study will not only fill the knowledge gap but also ensure the sustainable management of this commercially important fish species resident in Ghana's coastal waters.

Material and methods

Study area

The study focused on five fish landing sampling sites along the coast of Ghana, namely Sakumono, Tema, Nungua, Kpone, and Prampram (Fig. 1). These sampling areas were selected based on the level of fishing activity and geographical location. The primary source of livelihood for most of the inhabitants residing within the selected five fish landing sampling stations is fishing and its related activities such as fish processing and fish trade. However, a few of the indigenes are engaged in alternative forms of livelihoods, including farming, driving, and others.

Data collection

Samples of *G. decadactylus* were purchased from randomly selected fishers who used gillnet (multifilament) fishing gears with mesh sizes ranging from 0.5 – 1.5 inches (diagonal stretch). Samples were obtained from August 2018 to July 2019. Samples collected were preserved on ice and transported to the Department of Marine and Fisheries Sciences, University of Ghana laboratory. At the laboratory, samples were identified to the species level using appropriate keys (i.e., Kwei & Ofori-Adu, 2005). Length (i.e., the minimum length was 4.0 cm) of the samples was recorded to the nearest 0.1 cm using a 100 cm graduated wooden measuring board. In all, 560 individuals of the assessed fish species were obtained and assessed.

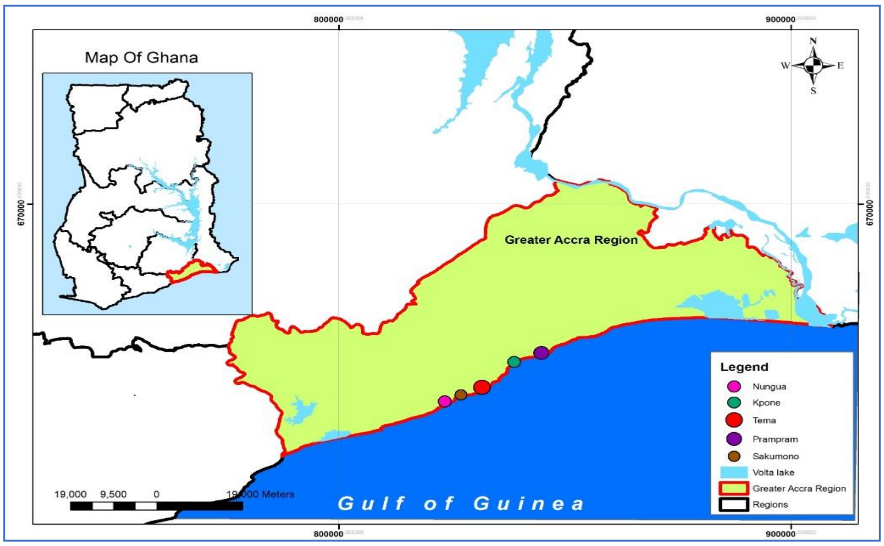

Figure 1. Map showing the fish landing sampling locations

Length-weight relationship

A regression analysis was conducted to ascertain the relationship between total length and bodyweight of the fish species, following the formula:

$$W= aTL^b$$

W is the weight in grams, and TL is the total length in cm (LeCren, 1957).

Growth Parameters

Tropical fishes are assumed to follow the Von Bertalanffy Growth Function (VBGF), such as growth rate (K), asymptotic length (L_∞), and the growth performance index (Φ'). These growth parameters were obtained using the VBGF equation.

According to VBGF, as expressed below, individual fishes grow on average towards the asymptotic length at an instantaneous growth rate (K) with length at the time (t) following the expression:

$$L_t = L_\infty (1- e^{-K(t-to)}) \text{ (Pauly, 1984)}$$

The theoretical age at length zero (to) was calculated according to the equation below:

$$\text{Log}_{10} (-t_0) = -0.3922 – 0.2752 \log_{10} L_\infty - 1.038\log_{10} K \text{ (Pauly 1984)}$$

The longevity (T_{max}) was estimated as

$$T_{max} = 3/K + t_0 \text{ (Pauly, 1983)}$$

The growth performance index was calculated from the below-expressed equation:

$$(\Phi') = 2\log L_\infty + \log K \text{ (Munro and Pauly, 1983)}$$

The length at optimum yield (L_{opt}) was estimated as follows:

$$L_{opt} = (3/ (3 + M/K)) * L_\infty \text{ (Beverton, 1992)}$$

Mortality Parameters

Total mortality (Z) was computed using Linearized length converted catch curve fitted (Gayanilo et al., 2005). The natural mortality rate (M) was calculated using the 'Then Method'. Fishing mortality (F) was calculated by subtracting the natural mortality from the total mortality, F = Z-M (Gulland, 1971). Exploitation rate (E) was calculated as

Fishing mortality / Total mortality rate (Gulland, 1971).

The optimum fishing mortality (F_{opt}), which forms the precautionary target, was calculated as

$$F_{opt} = 0.4*M \text{ (Pauly, 1983)}$$

The limiting fishing mortality (F_{limit}) was calculated as

$$F_{limit} = (2/3) * M$$ (Patterson, 1992)

Maximum fishing mortality (F_{max}), which serves as the biological reference point, was estimated as

$$0.67 * K / (0.67 - Lc)$$ (Hoggarth et al., 2006).

Length at First Capture (Lc_{50}) and Maturity (Lm_{50})

From Gayanilo et al. (2005), the ascending left component of the length converted catch curve was used in calculating the probability of length at first capture (Lc_{50}). Further to this, lengths at both 75 and 95 capture corresponding to 75%, and 95% respectively were estimated.

The length at first maturity (Lm_{50}) was estimated using the empirical formula below for unsexed fishes by Froese and Binohlan (2000):

$$\log_{10} Lm_{50} = 0.8979 * \log_{10}(L\infty) - 0.0782.$$

Recruitment Pattern

The recruitment pattern was identified based on the procedure described by Gayanilo et al. (2005). The length at first recruitment (Lr_{50}) was estimated as the smallest length interval (Gheshlaghi et al, 2012).

Data analysis

The length-frequency data were pooled into groups with 1cm length intervals. Then the data were analyzed using the TropFish R package in R statistical tool to assess the population parameters.

Results

Length frequency

The mean length for *G. decadactylus* was 16.4 ± 0.2 cm, with a range of 4.0 cm – 33.5 cm (Figure 2). The modal length class for *G. decadactylus* was 17 - 18 cm TL (Figure 2).

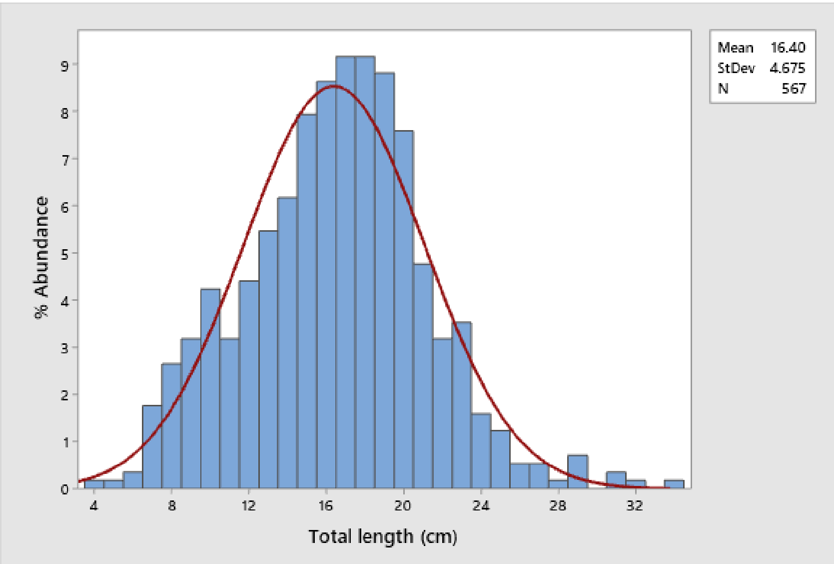

Figure 2. Length frequency distribution of *Galeoides decadctylus*

Length-weight relationship

From Figure 3, the length-weight relationship estimated for *G. decadactylus* was

$$W = 0.0088TL^{3.0536}.$$

The growth pattern *(b)* from the length-weight relationship was 3.05, indicating that *G. decadactylus* is exhibiting isometric growth.

Growth parameters

The restructured length frequency of *G. decadactylus* superimposed growth curves are shown in Figure 4. The asymptotic length (L_∞) was 39.6 cm, with a growth rate (K) of 0.19 per year. Theoretical age at length zero (to) was estimated as -0.82 per year. The VBGF for *G. decadactylus* was

$$L_t = 39.6\ (1\text{- } e^{-0.19\ (t + 0.82)})$$

The length at optimum yield (L_{opt}) was estimated at 24.2 cm. The growth performance index (Φ′) was 2.484 per year. The longevity (T_{max}) was calculated as 14.98 years with an Rn value of 0.37.

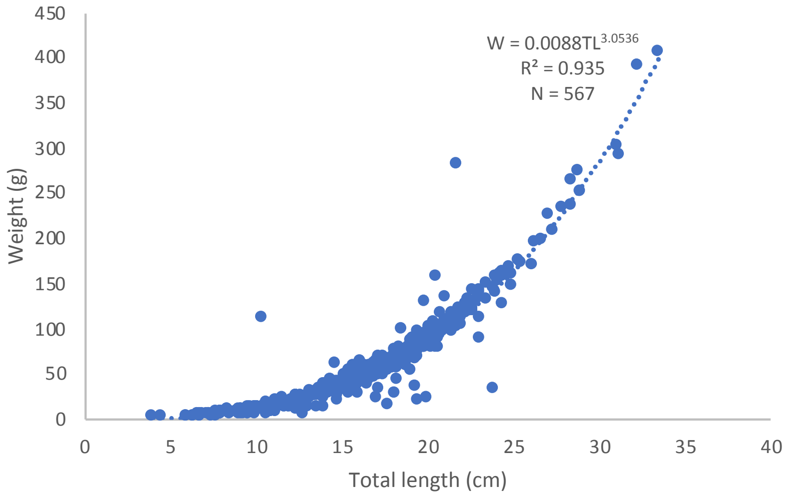

Figure 3. Length-weight relationship for *G. decadctylus*

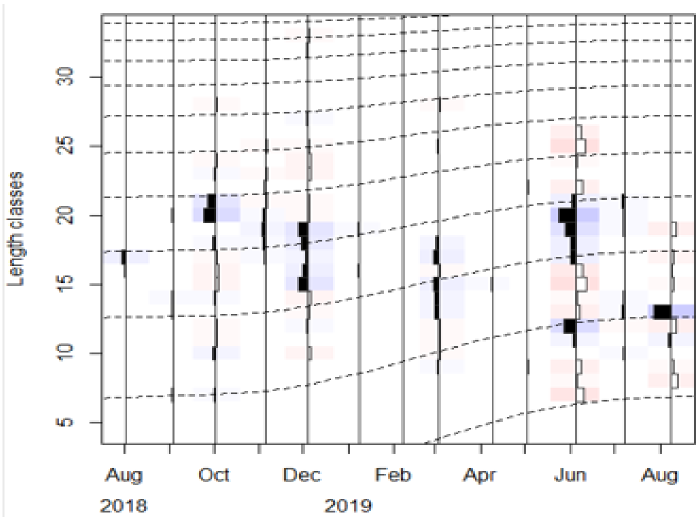

Figure 4. Length-frequency histograms with the growth curves (dashed lines) obtained through the bootstrapped ELEFAN with SA analysis superimposed for *G. decadactylus*. The bars represent the restructured length frequency data, where black bars indicate positive peaks and white bars represent negative peaks. The method tries to maximize the number of positive peaks hit. The faint blue and red colors emphasize positive and negative peaks, respectively.

Length at first capture and first maturity

Figure 5 shows the probability of capture of *G. decadactylus*. The probabilities of capture were estimated as: L_{50} = 17.2 cm, L_{75} = 18.7 cm and L_{95} = 21.1 cm (Figure 5). The probability of capture was estimated as t_{50} = 3.00 years, t_{75} = 3.37 years, and t_{95} = 4.00 years (Figure 5). Therefore, the length and age at first capture (Lc_{50}) were 17.2 cm and 3.00 years, respectively. The length at first maturity (Lm_{50}) was estimated at 22.7 cm.

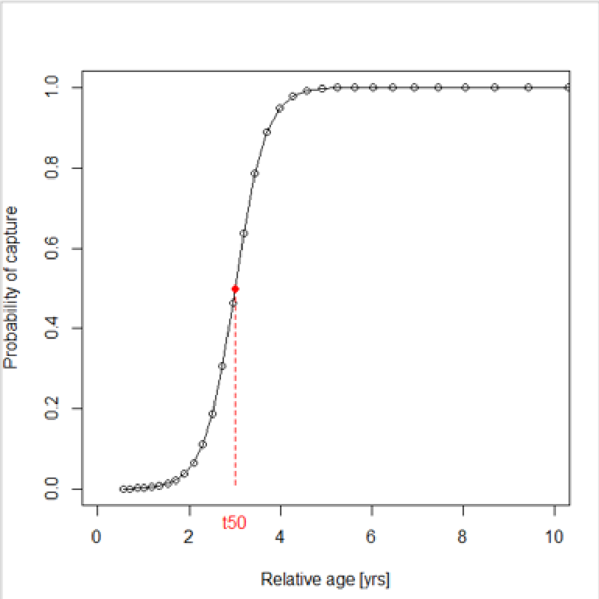

Figure 5. Probability of capture of *G. decadactylus*.

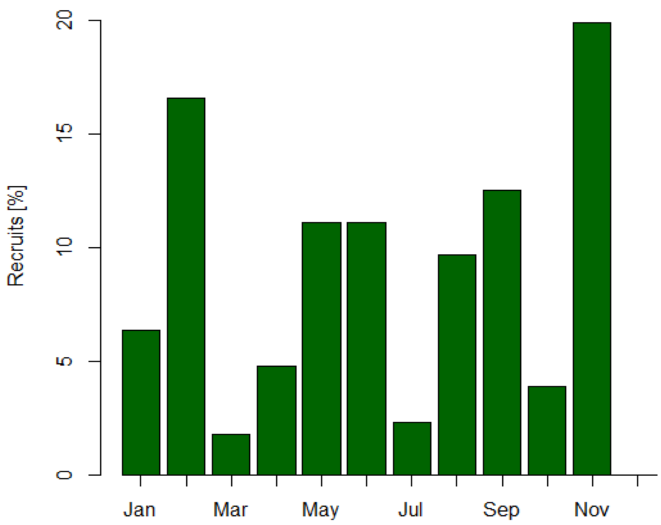

Figure 6. Recruitment pattern of *G. decadactylus*

Recruitment pattern

From Figure 6, two peaks – major and minor peaks were identified with the major peak of recruitment occurring in November with 19.9 % recruits, while the minor peak occurred in February with 16.6 % recruits. The length at first recruitment (Lr_{50}) was 4.5 cm.

Mortality parameters

The Linearized length-converted catch curve was used to estimate instantaneous total mortality (Z), as shown in Figure 7. The total mortality rate (Z) was calculated as 1.49 $year^{-1}$. The natural and fishing mortality rates were estimated at M = 0.36 $year^{-1}$ and F = 1.13 $year^{-1}$, respectively. The current exploitation rate (E) was obtained at 0.76. Limiting fishing mortality (F_{limit}) and the optimum fishing mortality (F_{opt}) were calculated as 0.53 per year and 0.15 per year, respectively. Maximum fishing mortality (F_{max}) was estimated at 0.24 per year.

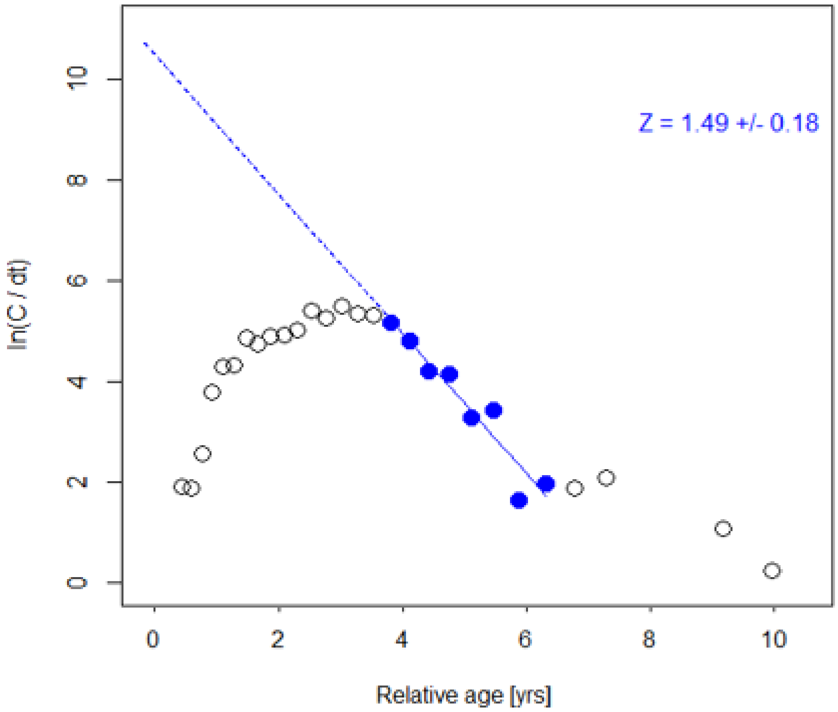

Figure 7. Linearized length-converted catch curve for *G. decadactylus*

Discussion

Length frequency distribution

The mean length of *G. decadactylus* from the current study was 16.4 ± 0.2 cm TL with a modal length class of 17 cm TL. The modal length class from the present study was the same as recorded by Sossoukpe et al. (2016) from Benin, which was 16 cm – 18 cm. However, it was lower than estimates by Longhurst (1965), who recorded a range of 20.7 cm – 39 cm in Nigeria. Furthermore, the modal length record by Lazar (2017) for both trawl (30 cm TL) and beach seine (20 cm TL) catches from the western coastline of Ghana was higher than the modal class length from the current study. The use of fishing gear with a small mesh size could be the reason for the lower length estimates from the current study as compared to the aforementioned studies. Furthermore, this observation implies that *G. decadactylus* in Greater Accra, Ghana, is facing a high rate of depletion. Again, the mean length was lower than the legal minimum landing size of *G. decadactylus* in Ghana (i.e., 18 cm TL). This could be an indication of non-compliance to the fishing regulations enshrined in Ghana's Fisheries Act 625.

Length weight relationship

The growth pattern *(b)* of *G. decadactylus* from the current study was 3.05, which signifies that the species grows isometrically where the shape does not change despite the rate of growth of both the length and weight. Fiogbé et al. (2003) and Lazar (2017) reported similar growth patterns (i.e., *b* = 3.02 and 3.03, respectively) from the coastal waters of Benin and Ghana. However, both Emmanuel et al. (2010) and Ezekiel et al. (2013) from Nigeria reported negative allometric growth. Similarly, Aggrey-Fynn et al. (2012) from Ghana also documented a negative allometric grow pattern for *G. decadactylus* (Table 2). Nonetheless, Konan et al. (2012) and Njock (1990) from the coastal waters of Ivory Coast and Cameroon respectively reported a positive allometric growth (Table 2). The variation in growth patterns in relationship to other studies could be linked to factors such as sex, season, maturity stage and abundance of feed item (Sossoukpe et al. 2016). Furthermore, there is the potential of environmental parameters affecting the growth pattern of fish species (Kundsen, 1962).

Table 1. Length-weight Relationship reported in other studies.

Studies	Location	a	b	Growth type
Current study	Ghana	0.009	3.05	Isometric
Lazar (2017)	Ghana	0.010	3.03	Isometric
Sossoukpe et al. (2016)	Benin	0.012	2.96	Negative allometric
Aggrey-Fynn et al. (2013)	Ghana	0.011	2.99	Negative allometric
Ezekiel et al. (2013)	Nigeria	0.264	1.97	Negative allometric
Konan et al. (2012)	Ivory Coast	0.007	3.15	Positive allometric
Emmanuel et al. (2010)	Nigeria	1.695	2.80	Negative allometric
Fiogbé et al. (2003)	Benin	0.010	3.02	Isometric
Njock (1990)	Cameroon	0.004	3.15	Positive allometric

Growth parameters

Growth rate of *G. decadactylus* from the current study was 0.19 per year. The growth rate from the current study was lower than indicated by others researchers (e.g., Konan et al., 2012; Sossoukpe et al., 2016; Longingue & Dave, 2016; Lazar, 2017) with the exception of Wehye and Amponsah (2017) who reported a similar growth rate (K = 0.19 per year) as shown in Table 2. Regarding the asymptotic length (L_∞), the value of the present study was in variance to results reported by some researchers (e.g., Njock, 1990, Konan et al., 2012, Longingue & Dave, 2016, Wehye & Amponsah, 2017). The possible reasons for variation in growth rate (K) and asymptotic length (L_∞) could be due to geographical locations, the data analysis method used, and the size classes obtained (Sossoukpe et al., 2016). Assefa et al. (2018) related spatial changes in growth parameters to stock variations, ecological conditions, diet composition and feeding habits, and climatic conditions. The growth rate (K) obtained from the current study suggested that *G. decadactylus* in Ghana is a slow-growing fish species (Kienzle, 2005). To support this claim, Lazar (2017) also documented that *G. decadactylus* in Ghana is a slow-growing fish species with a growth rate of 0.47 per year (Table 2). The growth performance index from the current study (Φ = 2.484 per year) was close to estimates from other studies (e.g., Sossoukpe et al., 2016, Wehye & Amponsah, 2017), which shows that they are of a similar taxonomic family. However, the growth performance index from the current study was lower than the estimates by Lazar (2017). He reported a growth performance index of 3.031 per year from the western coastline of Ghana (Table 2). According to Sossoukpe et al. (2016), variations in growth performance index may be due to the availability of food and change in the chemistry of the marine environment.

Table 2. Comparison of growth rates estimates with other studies

Parameters	Current study	Lazar (2017)	Wehye &Amponsah (2017)	Sossoukpe et al. (2016)	Longingue & Raffaeli (2016)	Konan et al. (2012)	Amiye & Erondu (2010)	Njock (1990)
Location	Ghana	Ghana	Liberia	Benin	Cameroon	Ivory Coast	Nigeria	Nigeria
$L\infty$ (cm)	39.6	47.78	54.08	26.3	54.5	50.7	*	41.2
K (per year)	0.19	0.47	0.19	0.80	0.41	0.53	0.93	0.20
Φ (per year)	2.484	3.031	2.75	2.741	*	2.85	*	*

Length at first capture (Lc_{50})

The estimated length at first capture from the present study was 17.2 cm. The length at first capture of *G. decadactylus* in Liberia by Wehye and Amponsah (2017) and Sossoukpe et al. (2016) was lower than the current study. Wehye and Amponsah (2017) and Sossoukpe et al. (2016) documented a length at first capture of 13.9 cm from Liberia and 15.4 cm from Benin, respectively. The differences in the mesh size of fishing gears used in fishing may have accounted for the observed variation in length at first capture in relation to previous studies. Possibly fishing gears with large mesh size are likely to capture fishes of larger sizes and vice versa. The length at first capture from the current study (Lc_{50} = 17.2 cm) was slightly lower than instituted in Ghana's fisheries regulation Act 625, which is 18.0 cm TL (GFM, 2010). The use of fishing gears with small mesh size may have resulted in landed species having length lower the minimum legal size. The mesh of fishing gears legally enshrined for set net fishing in Ghana in the Fisheries Act 625 is 5 cm or 1.96 inches (Akongyuure et al., 2015). However, most fishers using gillnet in Ghana's marine waters use mesh size between 0.1 inches – 1.5 inches. As a result, it shows that fishermen in Ghana are not complying to the laws surrounding the minimum legal landing size of fish species in Ghana. The critical length at capture (Lc) from the study was estimated to be 0.43, slightly lower than 0.5, which suggests that the harvested catch was composed of more juveniles (Wehye & Amponsah, 2017). This observation shows that the fishery of *G. decadactylus* in Ghana is experiencing growth overfishing.

Recruitment pattern

The recruitment pattern from the study showed a continuous pattern for *G. decadactylus*. This form of recruitment pattern indicates that the fishery of *Galeoides decadactylus* is far from recruitment overfishing (Wehye & Amponsah, 2017). The two peaks of recruitment occurred mostly after both the minor (December - February) and major upwelling (June – August) periods. Lazar (2017) from the western coastline of Ghana documented a continuous recruitment pattern with most of the requirements occurring from February to May and a peak in April. The changes in recruitment patterns, including the recruitment peaks, could be due to the continental shelf's depth. Watson et al. (1996) documented that the depth of the continental shelf, increases gradually with distance from the nearshore areas used by juveniles, before they recruit into the fishery. This relatively simple bathymetry, may facilitate a steady migration offshore into the fishery with increasing age or size. Furthermore, the two peaks exhibited by the assessed fish species conform to Pauly's (1987) findings that tropical fish species portray two recruitment peaks. All year-round recruitment pattern could be as a result of the high number of deaths, particularly from the fishing mortality rate (Abowei et al., 2010). The length at first recruitment for the *G. decadactylus* from the current study was 4.5 cm. This was lower than the length at first capture (17.2 cm) and the length at first maturity (22.7 cm), which was estimated from the current study. The lower length at first recruitment implies that individuals of *G. decadactylus* get recruited into the stock before becoming vulnerable to fishing gears (Kings, 2005).

Consequently, it supports the claim that the fishery of *G. decadactylus* in Ghana is far from recruitment overfishing. The amplitude of seasonal growth oscillation (C) observed during the study indicated that *G. decadactylus* experienced seasonality growth. This may imply these species are 'k-selected species' with life-history traits such as slow growth, late reproductive maturity, low natural mortality rates, and relatively long-life span, suggestive of a density-dependent spawner recruit relationship (Abowei et al., 2010).

Length at first maturity (Lm_{50})

Sinovcic and Zorica (2006) reported that sexual maturity size is a parameter closely related to habitat conditions of the species in each region, for which probably food availability, climatic conditions, and trophic parameters are important factors. From the study, the length at first maturity was found to be 22.7 cm. The length at first at maturity in fish is useful in monitoring whether enough juveniles will enter the exploited stock and spawn. Lazar (2017) reported the length at frost maturity for *G. decadactylus* from the western coastline to be 27.5 cm, which slightly higher than estimated from the current study. The variation in length at first maturity regarding findings by Lazar (2017) may be due to differences in the ecological ecosystem existing at the western (i.e., sampling area for Lazar (2017) and the eastern coastline of Ghana (i.e., sampling area for the present study). Falimi et al. (2009) asserted that local environmental conditions, life history, and flexibility to fishing are essential factors in determining the differences in size at maturity. Again, *G. decadactylus* from the current study mature at an earlier size than in the western coastline by Lazar (2017) due to the heavy fishing pressure (Stevens et al., 2000). Nonetheless, the approach used by Lazar (2017) may have been conservative, thus providing higher estimates than with the usual methods (Freitas et al., 2016). However, the length at first maturity documented by Wehye and Amponsah (2017) from Liberia's coastal waters was 18.5 cm, highly lower than estimated from the current study. Changes in the length at first maturity could be reliant on the growth rate of the species. For instance, species with a fast growth rate ($K > 0.5$ per year) are known to mature earlier than species with a slow growth rate ($K < 0.5$ per year). The length first maturity (22.7 cm) from the current study was higher than the estimated length at first capture (17.2 cm), highlighting that the fishing gears capture most of the individuals of *G. decadactylus* before reaching the matured stage where they can add juveniles to stock to ensure continuity in the marine environment. In the absence of proper management measures, the continued exploitation of immature *G. decadactylus* species may lead to recruitment failure in the future and, subsequently, possible collapse as well.

Mortality parameters

The fishing mortality, total mortality, and natural mortality rates recorded from the study were 1.13 per year, 1.49 per year, and 0.36 per year, respectively. These estimates of mortality rate from the current study were lower than the estimates by Lazar (2017) (Table 3). In Ghana, the main mortality form contributing to the decline of *G. decadactylus* is fishing activities. This is because the fishing mortality rate (1.12 per year) was higher than the natural mortality rate (0.36 per year). Lazar (2017) also reported a similar observation from Ghana (Table 3).

On the contrary, Wehye and Amponsah (2017) and Sossoukpe et al. (2016) revealed that the natural mortality rate is a critical contributor to the decline of *G. decadactylus* in Liberia and Benin, respectively (Table 3). This shows that the influence of natural and fishing mortality rates, on the decline of fish stock varies spatially. From the study, the fishing mortality rate (1.13 per year) was higher than the optimum fishing mortality rate (F_{opt} = 0.15 per year), limit fishing reference point (F_{limit} = 0.33 per year), and maximum fishing mortality rate (F_{max} = 0.24 per year). These findings imply that the assessed fish species is experiencing high fishing pressure, which tends to distort its stock status if proper measures are not implemented. To buttress this claim, the exploitation rate estimated from the present study (E = 0.76) was higher than 0.5, depicting that the *G. decadactylus* in the Ghanaian coastal waters (particularly the eastern coastline) is underexploited. Lazar (2017) also reported that *G. decadactylus* from the western coastline of Ghana, is overexploited (Table 2). The overexploitation of *G. decadactylus* in Ghana may be linked to the high intensity of fishing. Nonetheless, other researchers (e.g., Sossoukpe et al., 2016, Amiye & Erondu, 2010) also obtained a relatively lower exploitation rate from their study areas (Table 2). This shows that fishing intensity along the West Africa coast is higher in Ghana.

Table 3. Comparison of mortality rates with other studies

Parameters	Current study	Lazar (2017)	Sossoukpe et al. (2016)	Amiye & Erondu (2010)	Wehye & Amponsah (2017)
Z (per year)	1.49	2.16	1.88	2.45	0.91
M (per year)	0.36	0.61	1.64	1.96	0.49
F (per year)	1.13	1.55	0.24	0.49	0.42
E	0.76	0.72	0.13	0.20	0.45

Conclusion

The study aimed at assessing the stock status of *G. decadactylus* from the coastal waters of Ghana based on certain population parameters. The assessed fish species was found to be a slow-growing species with continuous recruitment patterns from the study. The length at first maturity (22.7 cm) was higher than the length at first capture (17.2 cm), which when unsolved, may result in recruitment failure in the future. The exploitation rate of 0.76 indicated *G. decadactylus* from the eastern coastline of Ghana is highly overexploited. As part of the recommendation, there should be stringent management measures such as mesh size regulation and extended closed fishing seasons.

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