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Growth, Mortality and Exploitation rates of Lesser African threadfin, *Galeoides decadactylus* (Bloch,1795) within the coastal waters of Liberia

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Abstract
The study evaluated some population parameters of *Galeoides decadactylus* within Liberia's coastal waters. A total of 1618 samples were collected from eight coastal counties of Liberia from April, 2013 to September, 2013. Total length of individual fish samples was measured and analyzed using FiSAT II software. Von Bertalanffy parameters were estimated at asymptotic length (L_∞) = 54.08 cm, growth rate (K) = 0.19 per year, the longevity (T_{max}) = 15.8 years, theoretical age at birth (t_0) = −0.75 years and growth performance index (Φ') = 2.745. The length first capture (Lc_{50} = 9.41 cm) was lower than the length at first maturity (Lm_{50} = 13.8 cm). Mortality parameters were calculated as total mortality rate (Z) = 0.91 per year, natural mortality rate (M) = 0.49 per year and fishing mortality rate (F) = 0.42 per year. The exploitation rate (E) and maximum exploitation rate (E_{max}) were 0.46 and 0.45 respectively. *Galeoides decadactylus* fishery in Liberian coastal waters was found to be experiencing unsustainable exploitation as well as growth overfishing. Thus, to avert the consequences of growth overfishing, sustainable fisheries measures including monitoring of fishing efforts and increase in mesh size should be implemented and enforced.

Keywords: Liberia, *Galeoides decadactylus*, Growth, Mortality, Exploitation rate

Introduction

Galeoides decadactylus (Bloch, 1795), commonly known as 'Lesser African threadfin' of the family Polynemidae is primarily a demersal species, common to 30 cm total length, inhabits sandy and muddy bottoms in shallow coastal waters [1]. *Galeoides decadactylus* is well distributed from the south of Mauritania to Angola including the nearshore waters of Liberia. Its body is fusiform, grayish with two dorsal fins widely speared [2], Descriptively, the caudal fin is large and forked with the pectoral fin inserted above the lateral line and the mouth short and inferior [3], [4]. The Lesser African threadfin is carnivorous and scavenging in nature, preying on shellfish, little fish, crayfish and crabs [5], [6]. *Galeoides decadactylus* species often portray negative allometric growth, thus its length grows faster than the corresponding weight [7], [8]. Proximate analysis by [9] concluded that *Galeoides decadactylus* has higher moisture content thus vulnerable to a faster rate of post-harvest loss due to spoilage. However, one of the adopted control strategies in reducing post-harvest loss in *Galeoides decadactylus* fishery includes fermentation and drying of *Galeoides decadactylus* into lanhouin [10]. [11] defines lanhouin as a salted, fermented dried fish often consumed in southern Benin.

'Butternose' as it is locally known in Liberia is a significant marine fish resource with regards to Liberia's coastal fishing as it is well appreciated by the consumers because of the quality of its flesh. *Galeoides decadactylus* is primarily harvested by fishermen who operate with beach seines and gillnets along the nine coastal counties of Liberia. However, in Liberia, information on population parameters and population position of important commercial fishes are not readily accessible, despite the importance of fish to food security and nutrition, particularly in fishing households. Limitation of scientific information on fish population assessment renders fisheries management options geared toward sustainable exploitation of commercially important fishes in Liberia ineffective. In view of this, the objective of the study was to evaluate some population parameters of *Galeoides decadactylus*. Information gained from this study will not only fill knowledge gap but ensure sustainable management of this commercially important fish species resident in Liberia's coastal waters.

2. Materials and Methods

2.1 Study area

Liberia is a relatively small coastal state located in West Africa with geographical coordinates as 6.4281° N, 9.4295 ° W. The coastline of Liberia is 570 kilometers comprising of relatively warm waters and low nutrient contents [12]. However, the study focused on eight fish landing sampling stations within eight coastal counties along the coastline of Liberia (Figure 1). These fish landing sampling coastal counties included Maryland, Rivercess, Sinoe, Margibi, Montserrado, Grand cape Mount, GrandKru and Grand Bassa. Selection of the eight fish landing sampling sites was based on the level of fishing activity and geographical location. The main source of livelihood for the majority of the inhabitants residing within the selected eight 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.

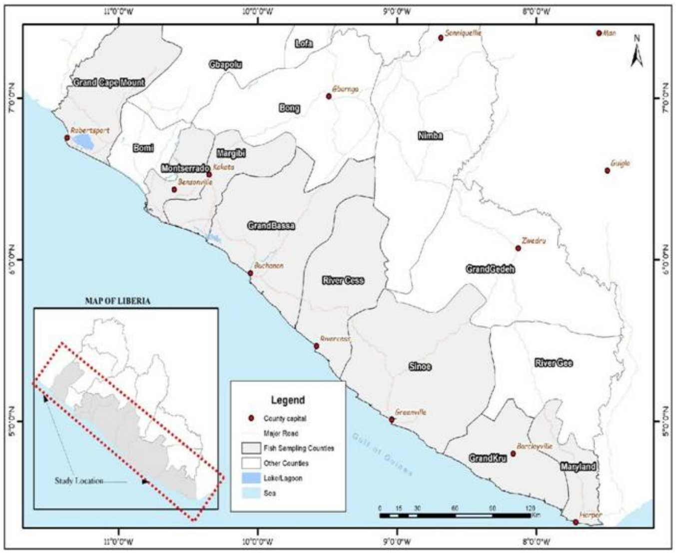

Fig. 1: Map showing the study area

2.2 Data collection

Fish samples were collected randomly from artisanal fishermen who operated with multifilament gears from the selected fish landing stations by Fisheries Enumerators of the Bureau of National Fisheries (BNF). Fish sample collection was performed from April, 2013 to September, 2013 (six months). Morphometric measurements of the obtained fish samples including total length and weights were recorded on-site. The total length was measured using the 100cm measuring board to the nearest 0.1cm whereas the weight was measured using the electronic weighing scale to the nearest 0.01g. Fish samples were identified to the species level using fish identification keys by [1]. In all, a total of 1,618 specimens of *Galeoides decadactylus* were sampled.

2.3.1 Growth parameters

The fish growth was assumed to follow Von Bertanlaffy Growth Function (VBGF) such as growth rate (K), asymptotic length ($L\infty$) and the growth performance index (Φ'). These growth parameters were obtained using the VBGF fitted in FISAT II [13]. According to VBGF as expressed below, individual fishes grow on average towards the asymptotic length at an instantaneous growth rate (K) with length at time (t) following the expression: $L_t = L_\infty \ (1\text{-}e^{-K(t\text{-}to)})$ [14]. The theoretical age at birth (t_o) was calculated using the empirical formula: $Log_{10}\ (-to) = -0.3922 - 0.275 * log_{10}L\infty - 1.038 * log_{10}K$ [14]. The longevity (T_{max}) was estimated as: $T_{max} = 3/K + to$ [15]. The growth performance index was calculated from the below expressed equation: $(\Phi') = 2logL\infty + log\ K$ [16].

2.3.2 Mortality parameters

Total mortality (Z) was computed using length converted catch curve method as fitted in FiSAT II. Natural mortality rate (M) was calculated following Pauly's empirical relationship using the expression: $Log\ M = -\ 0.0066 - 0.279\ 1og\ L_\infty + 0.6543\ log\ K + 0.4634\ log\ T$ [17], where M is the instantaneous natural mortality, L_∞ is the asymptotic length, T is the mean surface temperature at 25.5 °C and K refers to the growth rate coefficient of the VBGF. Fishing mortality (F) was calculated using the relationship: $F = Z - M$ [18], where Z is the total mortality rate, F the fishing mortality rate and M is the natural mortality rate. Limiting fishing mortality (F_{limit}) and the optimum fishing mortality (F_{opt}) which forms the precautionary target were calculated as $Fopt = 0.4*M$ [15] and $F_{limit} = (2/3) * M$ [19]. Maximum fishing mortality (F_{max}) which serves a s the biological reference point was estimated as $0.67 *K/\ (0.67 - Lc)$ [20]. The exploitation level (E) was obtained using the relationship:
$E = F/Z$ [18].

2.3.3 Length at first capture (L_{c50}) and maturity (L_{m50})

The ascending left part of the length converted catch curve within in FiSAT II tool was applied in calculating the probability of length at first capture (L_{c50}) in addition to the length at both 25 and 75 captures which corresponded to the cumulative probability at 25% and 75% respectively [21]. The length at first maturity (L_{m50}) was estimated using the expression: $Log\ (L_{m50}) = 0.8776\ log\ L\infty - 0.38$ [22]. The length at optimum yield (L_{opt}) was estimated as follows: $Lopt = (3/\ (3 + M/K)) * L\infty$ [23].

2.3.4 Recruitment pattern

The recruitment pattern was computed following the method described in the FiSAT routine [24]. The length at first recruitment (Lr) was estimated as the midlength of the smallest length interval [25].

2.3.5 Relative Yield per Recruit (Y'/R)

The relative biomass per recruit (B'/R) was estimated as $B'/R = (Y'/R)/F$. E_{max} which depicts exploitation rate producing maximum yield, $E_{0.1}$ highlighting exploitation rate at which the marginal increase of Y'/R is 10% of its virgin population with $E_{0.5}$ implying exploitation rate under which the population is reduced to half its virgin biomass were computed using the procedure incorporated using the Knife-edge option fitted in the FiSAT II Tool [24].

2.3.6 Yield Isopleth

The yield isopleth shows the interplay between the maximum exploitation rate and the critical length at first capture ($Lc = Lc_{50}{:}L_\infty$). Yield isopleth was estimated using categorization chart by [26].

2.4 Data Analysis

The length frequency data were pooled into groups with 1cm length intervals. Then the data were analyzed using the FiSAT II (FAO-ICLARM Population Assessment Tools) software [26].

3. Results

3.1 Growth parameters

From the restructured length frequency with superimposed growth curves in Figure 2. The asymptotic length (L_∞) was 54.08 cm. *Galeoides decadactylus* grew at a growth rate (K) of 0.19 per year with a long-life span (T_{max}) of 15.8 years. Growth performance index (Φ') and theoretical age at birth (t_o) were estimated as 2.745 and - 0.75 per year respectively. The VBGF for length at time (t) was expressed as: $L_t = 54.08\ (1 - e^{-0.19(t+0.75)})$ for *Galeoides decadactylus.* The Z/K ratio using the Powell Wetherall plot was 1.46 (Figure 2).

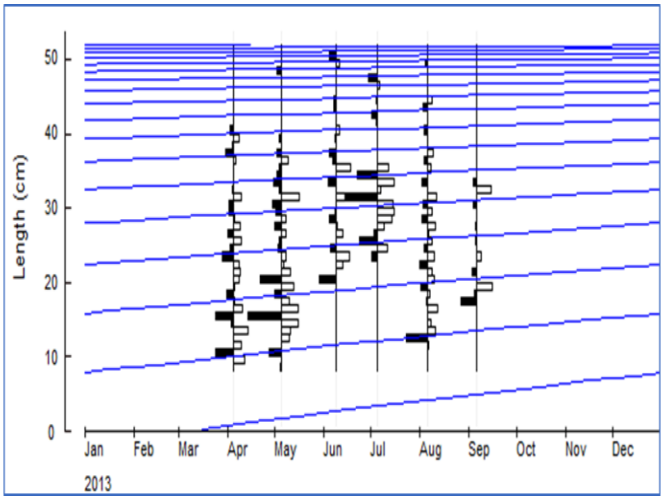

Fig 2: Reconstructed length frequency distribution superimposed with growth curve

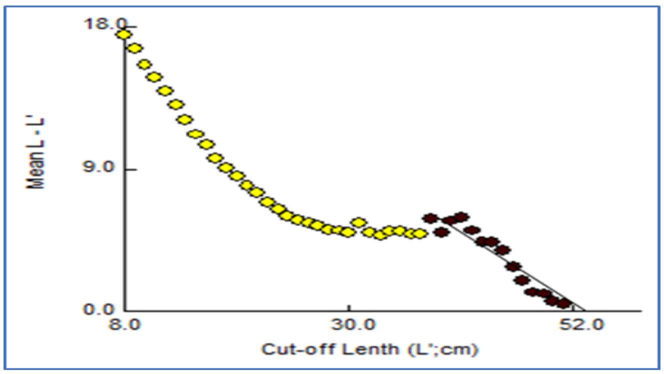

Fig 3: Z/K ratio of *Galeoides decadactylus* using the Powell Wetherall Plot from FISAT output

3.2 Mortality Coefficients and Current Exploitation Rate

The estimate of the total mortality (Z) from the length converted catch curve was 0.91 (Figure 4). The natural mortality rate (M) and fishing mortality rate (F) were 0.49 per year and 0.42 per year respectively. The current exploitation rate was estimated as E = 0.46. The optimum fishing rate (F_{opt}) and the limiting fishing rate (F_{limit}) was 0.20 per year and 0.33 per year respectively. The maximum fishing rate (F_{max}) was calculated at 0.25 per year.

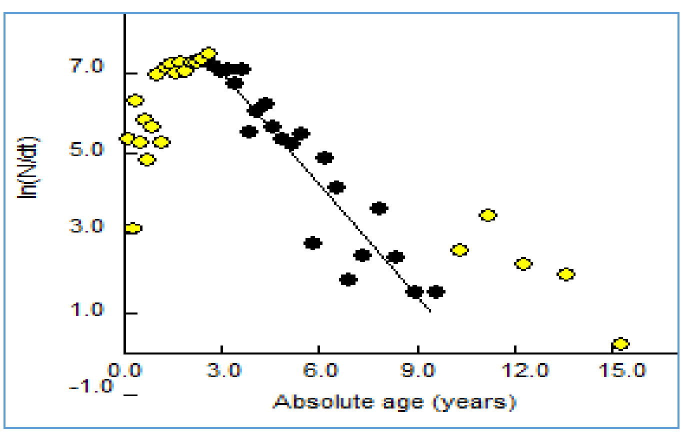

Fig 4: Linearized length-converted catch curve for estimation of instantaneous total mortality (Z)

3.3 Length at first capture (Lc_{50}) and Length at first maturity (Lm_{50})

The probability of capture as output from FiSAT II were estimated as: L_{25}= 8.13 cm, L_{50}= 9.41 cm and L_{75}= 16.49 cm (Figure 5). Therefore, the length at first capture (L_{c50}) was 9.41 cm. Length at first maturity (L_{m50}) and optimum length were calculated at 13.8 cm and 29.1 cm respectively.

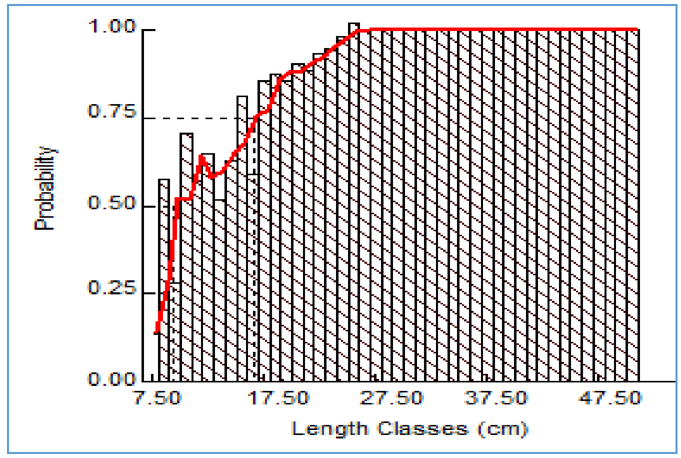

Fig 5: FiSAT II output of probability of capture for *Galeoides decadactylus*.

3.4 Recruitment pattern

Figure 6 shows the recruitment pattern of *Galeoides decadactylus* with two main recruitment peaks (major and minor). The major peak of recruitment occurred in June with recruitment strength of 21.9% whereas the minor peak occurred in October producing a recruitment strength of 12.8% (Figure 8). The length at first recruitment (Lr) was 8.5 cm.

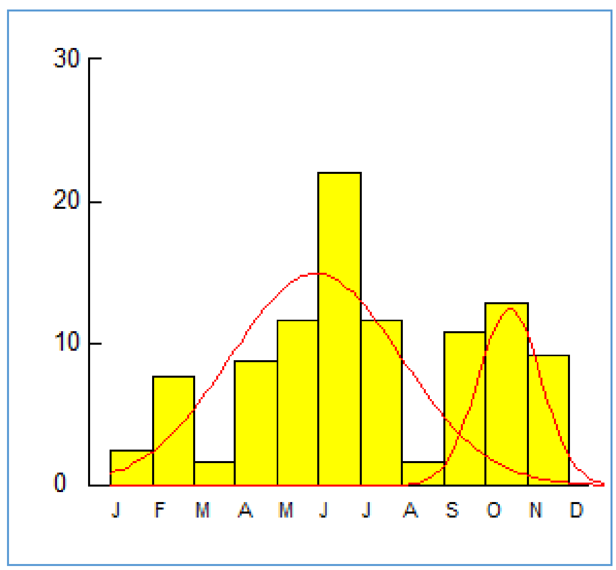

Fig 6: Recruitment pattern from FISAT output for *Galeoides decadactylus.*

3.5 Relative Yield per Recruit (Y'/R)

From Figure 7, the Beverton and Holt relative yield per recruit model showed that the indices for sustainable yield were 0.10 for optimum sustainable yield ($E_{0.5}$), 0.45 for the maximum sustainable yield (E_{max}) and 0.42 for economic yield target

($E_{0.1}$). From Figure 8, the yield isopleth diagram placed the fishery of *Galeoides decadactylus* in quadrant B.

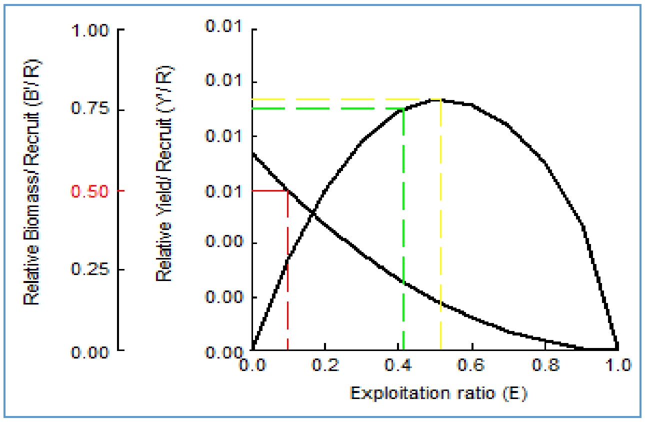

Fig 7: Beverton and Holt's relative yield per recruit and average biomass per recruit models from FISAT output for *Galeoides decadactylus*

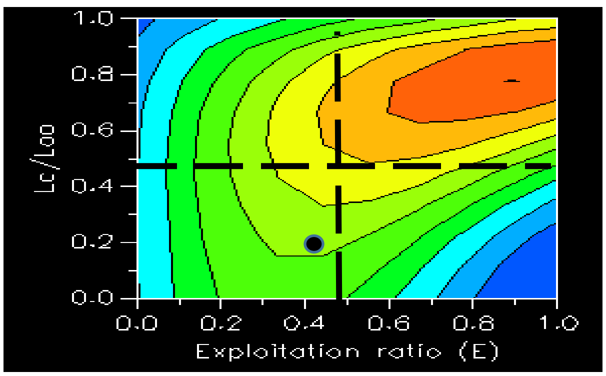

Fig 8: Yield isopleth of *Galeoides decadactylus* from FISAT output.

Analysis of the structure of fish population requires at least 1500 fish samples collected over a period of six months [27]. This criterion validates the use of 1618 samples of *Galeoides decadactylus* sampled within a period of six months to evaluate some aspect of its population parameters. The present study is the preliminary studies on *Galeoides decadactylus* from Liberian waters. Hence information gained will serve as a launchpad for further research on this commercially important species within Liberian coastal waters.

The observed asymptotic length was greater than estimated by [28] and [29] (Table 1). Further, the growth rate was relatively favorable with the estimate by [28] but lower than estimates by [29-32]. Potential causes for the observed variation in estimates for the asymptotic length ($L\infty$) and growth rate (K) in comparison with other studies include environmental condition, size classes obtained and the computational procedures [30]. Estimated growth rate (K) was found to be lower than 0.34, demonstrating that *Galeoides decadactylus* is a slow growing fish species, evinced by the estimated long lifespan [34]. Growth performance index (Φ') from the study was favourable with [29] in Table 1, indicating that both treated species are of the same family [32]. Contra wise, the growth performance index was slightly lower than the estimate by [31], possibly due to the difference in $L\infty$ and K computational procedure [36]. [13] highlighted that juveniles of fish species with negative age at birth (t_o) values grow faster than adults while juveniles with positive age at birth values grow slowly. From the study, the estimated age at birth (to) implied that juveniles grow faster than the predicted growth curve for adults [37]. This could be due to the fact that chemical energy obtained during feeding is mostly channeled into growth while in adults, the obtained energy is channeled into reproduction hence the reduced growth.

4. Discussion

Table 1: Comparison of population estimates from the present study and other studies

Parameters	Current study	Njock (1990)	Sossoukpe *et al.* (2016)	Amiye & Erondu (2010)	Longingue & Raffaeli (2016)	Konan *et al* (2012)
$L\infty$ cm	54.08	41.2	26.25	*	54.5	50.7
K /year	0.19	0.2	0.8	0.93	0.41	0.53
to years	-0.758	*	-0.21	*	*	-0.24
Φ /year	2.745	*	2.741	*	*	2.85
Lc_{50} cm	9.41	12.0	15.43	*	*	*
Lm_{50} cm	13.8	*	*	*	0.82	*
Z /year	0.91	*	1.88	2.45	0.74	*
M/year	0.49	*	1.64	1.96	0.08	*
F/year	0.42	*	0.24	0.49	*	*
Ecurrent	0.46	*	0.13	0.20	*	*

The estimated length at first capture was lower than the corresponding length at first maturity. This suggests the presence of growth overfishing because fish were caught before reaching the matured stage and eventually adding to the biomass of the population. Growth overfishing is mostly characterized by small sized fish species within the catch [35]. From the study, the ratio of $Lc_{50}/L\infty$ was estimated as 0.17, relatively lower than 0.5, which signifies the presence of small sized *Galeoides decadactylus* within the catch [26]. This observation confirms the earlier assertion that growth overfishing is present within the population of *Galeoides decadactylus*. Nonetheless, harvesting of small sized *Galeoides decadactylus* could be a function of the mesh size, thus bigger mesh size mostly harvests large sized fish species whereas small sized mesh captures small sized fishes. In support of this, the length at first capture (Lc_{50}) from the study was relatively lower than estimates by [28] and [29] in Table 1, suggesting that mesh size of fishing gears should be increased upon relevant scientific assessment. The observed recruitment pattern conformed to the finding by [17] that tropical fish species mostly exhibit double recruitment pulses. The presence of recruitment through the year indicated that recruitment is continuous, thus recruitment overfishing was found to be absent within the population of *Galeoides decadactylus*. Evidently, the length at first recruitment was lower than the length at capture, implying that juveniles get recruited into the population before becoming vulnerable to capture by any fishing gears [38]. The highest recruitment occurred in June which was within the upwelling season - a period of cold temperatures and abundant plankton. This suggests that abundance of plankton and cold temperatures during the upwelling seasons favours recruitment of juveniles into the population. Hence changes in temperatures or shift in upwelling period due to climate change could severely impact the strength of recruitment into the *Galeoides decadactylus* population negatively. Further, finding by [40] buttressed the observed recruitment peaks from the study by highlighting that species such as *Galeoides decadactylus* exhibits recruitment peaks between June and October.

The estimated Z/K ratio for *Galeoides decadactylus* from the present study was found be greater than 1, depicting that the population of the targeted species is mortality dominated [39]. However, for a mortality dominated-population, a Z/K ratio less than or approximately close to 2 indicates that the population of the targeted species is lightly exploited [43]. As a result, the population of *Galeoides decadactylus* is lightly exploited. The calculated total mortality rate from the present study was greatly lower than the estimated by [28] in Table 1. The observed disparity in estimates of total mortality rates (Z) could be due to the high estimates of natural mortality (M) as well as the computation procedure applied in the estimation of other inputs (parameters). The computed fishing mortality rate (F) was lower than the corresponding natural mortality rate (M) from the present study, hence *Galeoides decadactylus* population is more prone to naturally induced mortality situations than fishing gears [38]. This relates to the fact that accessed catch consists of more juvenile fishes than adults. Again, the obtained fishing mortality was relatively higher than the optimum fishing rate, limit fishing rate and the biological reference point. This observation illustrates the exertion of intense fishing pressure on *Galeoides decadactylus* population [14], [19].

The current exploitation rate (E) estimated approximately at 0.5 highlighted that the *Galeoides decadactylus* population is currently at the optimum level of exploitation [41]. Additionally, it indicates that the fishery of *Galeoides decadactylus* is not overexploited [36]. However, with estimated E slightly higher than the maximum exploitation rate (E_{max}), it illustrates the presence of unsustainable exploitation due to intense fishing pressure on the targeted population. Thus, supporting the earlier assertion that the investigated fish species is experiencing intense fishing pressure. Therefore, any increase in fishing effort could breed recruitment failure within the population in the absence of effective management interventions.

Biomass per recruits below 30% of the unexploited biomass is indicative of recruitment overfishing [42]. From Figure 7, the relative biomass per recruit at $E_{0.5}$ and E_{max} were all lower than 30%. This finding reveals the likelihood of recruitment failure within the population and subsequent collapse of the *Galeoides decadactylus* fishery in the future [37].

Following the quadrant rule by [26], the critical length at capture (Lc) and estimated maximum exploitation rate fell within quadrant B. This shows that the fishery of *Galeoides decadactylus* is currently at the developing stage with fishermen catching small sized *Galeoides decadactylus* specimen at the lower fishing effort. Thus, as management intervention, nothing should be done concerning the effort [26]. However, with increasing number of fishing effort in the form of increasing number of local and migrant fishermen as well as the introduction of motorized fishing vessels, there is the need to regulate fishing efforts along with the introduction of mesh size regulation measures.

5. Conclusion

Galeoides decadactylus population within Liberia's coastal waters is currently at the developing stage amidst intense fishing pressure. Further, *Galeoides decadactylus* fishery in Liberia is currently exhibiting growth overfishing signs with severe implications on population size and food security within vulnerable fishing households in the future. Therefore, urgent management interventions not limited to monitoring fishing efforts and mesh size regulation are needed to safeguard this commercially important fish species from possible collapse in the future.

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Conflicts of Interest: The authors declare no conflict of interest.

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