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Exploring the vulnerability of a commonly exploited fish stock, *Galeoides decadactylus* in the artisanal mixed capture fisheries of Sierra Leone

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Abstract

Galeoides decadactylus is a commonly exploited fish stock in Sierra Leone, and the study of its vulnerability to capture in the artisanal mixed fisheries of Sierra Leone has not gained the needed attention of researchers, for which the present study has come in handy particularly when such information is critical for sustainable management of the stock. The study utilized length-frequency data obtained from 865 specimens as input datasets of analytical models inscribed for the FAO Fish Stock Assessment Tool (FiSAT II) software. Vulnerability indices for this study were the Length Structured Virtual Population Analysis (LVPA) and the Probability of Capture (PC). Results revealed minimum and maximum total length of 11cm and 36cm respectively for the study species, and LVPA showed highest catch (in numbers) for the length range, 20 cm (n = 94, 0000) - 21 cm (n = 100, 000). Also, the probability of capture evinced greater selection probability (p = 0.9) of the larger sizes (17cm - 22 cm (mean, 19.5 cm TL) at a maximum mesh size of 8cm of bottom drift net utilised by the fishers. The results of LVPA implied that the smaller length groups of the assessed stock (TL ≤ 11 cm) are less vulnerable to fishing mortality, but most susceptible to natural mortality, and the probability of capture indicated that the gill nets used by the artisanal fishers for this study were highly selective to allow greater number (n = 4.8×10^6) of the smaller length group escape capture. In conclusion, *G. decadactylus* was efficiently exploited in the artisanal mixed fisheries. However, stringent measures on capture input and output controls are advised for the assessed stock.

Keywords: Biomass, Fisheries, probability of capture, stock, survival, virtual population

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INTRODUCTION

Galeoides decadactylus (Bloch, 1795) is commonly referred to as the Lesser African threadfin fish of the Polynemidae family with major records in marine waters ranging from Morocco to Angola, and sparsely exist in the North and Southern regions of the African Continent (Wehye and Amponsah, 2017). *G. decadactylus* is typically salt tolerant, and conglomerate at depths range of 10 m -70 m (Carpenter *et al.,* 2015). Occurs over sandy and muddy bottoms in brackish habitats and estuaries (Daget and Njock, 1986).

The artisanal fishery of Sierra Leone operates in estuaries and inshore waters extending from the shoreline to a depth of 20–40 m (MFMR, 2020). This is sector is eulogized as a significant source of fish protein to the vast majority of Sierra Leoneans alongside its critical support to employment and rural income (Neiland *et al.,* 2016; Konoyima *et al.,* 2020). The artisanal fisheries of Sierra Leone are characterized by varying types of canoes such as (a) small dug-out canoes (commonly called Kru canoes) of length ranging from 4–6 m and moulded depth of 0.6m; (b) the standard canoes (usually planked and of length ranging from 5–10 m) with a crew of 1-3 men, 3-5men or 5-10men (c) the Ghana-type canoe (either dug-out or planked) with a length of about 12 m (Ndomahina and Chaytor, 1991; Thorpe *et al.,* 2009) as given in Figure 5.

The Lesser African threadfin fish is a commercially viable stock that contributes vastly to the diet of Sierra Leoneans, as well as to national economy. Besides, *G. decadactylus* accounted for 48.5% (0-30 m), 10.9% (31-50 m), 37.1% (51-100 m) and 3.5% (101-200 m) depth zones of ten commercially important demersal fish stocks in Sierra Leone (Seisay, 2014). However, despite its critical contribution to national food security through capture from the industrial sector, *Galeoides decadactylus* is one of most commonly exploited fish stocks in the artisanal mixed fisheries of Sierra Leone which vulnerability to capture by the artisanal fishery sector has yet to gain scientific attention for analysis, more so when the said fishery is notorious of its unscrupulous fishing methods such as the use of illegal mesh sizes of fishing nets that may subsequently results into growth overfishing, and hence, dampen sustaianabily of the stock.

The present study aimed at evaluating the vulnerability of *G. decadactylus* to capture in the artisanal mixed fisheries. This aspect of analysis has hardly attracted the attention of academics in Sierra Leone, and the information provided could foster the enhancement of existing management strides for such a commonly exploited economically viable fish stock of Sierra Leone, in concordance with postulates of other scholars (Asadollah *et al.,* 2017; Wehye *et al.,* 2017; Konoyima and Seisay, 2020).

MATERIALS AND METHODS

Study Site

Sierra Leone lies between latitudes 7°10′ N and longitudes 10°14′ W on the west coast of Africa, covering an area of 71 740 km^2 (Coutin and Payne, 1989), and a continental shelf area of about 30 000 km^2 (Neiland *et al.,* 2016). There are two distinct climate systems: the dry season (November-April) and the monsoonal rainy season (May-October, Coutin and Payne, 1989).

Specimens were collected at Funkia Wharf, Goderich community located in the far West End of the capital Freetown as indicated in Figure 1.

Data Collection

Monthly fish samples were collected between January and December 2020 using randomized data collection techniques from five semi-industrial fishing boats that mainly employed surface drift nets and bottom drift nets of varying mesh sizes ranging from 4 cm – 8 cm. Fish specimens were identified to the least taxonomic level using identification guide by FAO (2010) whereby *G. decadactylus* has nine dorsal spines, 13-14 dorsal soft rays , body moderately elongate and compressed, snout very short, blunt and prominent; mouth inferior; posterior edge of maxillary only slightly expanded, barely reaching past eye; two widely separated dorsal fins, second dorsal fin and anal fin bases barely equal; pectoral fin inserted low on body; scales ctenoid; head and unpaired fins partly covered with small scales, body uniformly silvery, upper part greyish and belly white; a large rounded black spot, about equal to eye diameter, generally visible under lateral line, behind opercle (Daget, 2003).

Specimens were then preserved in ice boxes and taken to the laboratory of the Institute of Marine Biology and Oceanography (IMBO), Fourah Bay College, University of Sierra Leone for analysis.

Figure 1. Location of Data Collection Site

Morphometric measurements of fish samples included total length (TL) and somatic weight. The total length was measured to the nearest 1cm using a 1m fish measuring board graduated in centimeters, whereas the weight was measured using an electronic top-pan weight scale (ADAM-ACBPlus600H) to the nearest 1 g. Overall, a total of 865 specimens of *G. decadactylus* were collected using randomized sampling procedures, avoiding disproportionate representation of a particular size of the assessed species in line with recommended best practices (Pauly, 1980).

Statistical analysis

The present study utilized time series length frequency data grouped by constant class size. Analysis of growth parameters followed methods fitted in the FAO-ICLARM Fish Stock Assessment software (FiSAT II) for PCs (Gayanilo *et al*., 2005).

Parameters estimation

Estimating asymptotic length (L_∞) and growth rate (K)

The asymptotic length (L_∞), Mean and cutoff lengths of the assessed species were computed from the Powell-Witherall method (Powell, 1979; Wetherall, 1986; Pauly, 1993) as fitted in the FiSAT II routine (Gayanilo *et al*., 2005) using least-square regression coefficients (a and b) estimated following the least square regression relationship by (Pauly, 1983; 1984):

$W = aL^b$ ……… (1) (Where W = Somatic weight (g), L = total length (cm), b = growth exponent/slope and a = intercept).

The Instantaneous growth rate (K) was estimated by method of K-Scan in ELEFAN 1 as implemented in the FiSAT II routine, using L_∞ as input parameter.

Estimating mortality parameters

The instantaneous total mortality rate (Z) was computed using method of length converted catch curve as implemented in the FiSAT II routine (Gayanilo *et al*., 2005). The Pauly's empirical relationship was employed in the estimation of the instantaneous natural mortality rate (M) at a mean surface temperature (T) of 28°C thus: $LogM = -0.0066 - 0.279\ log\ L\infty + 0.6543\ log\ K + 0.4634\ log\ T$………… (2), using L∞, mean surface temperature (T°C) and K as input parameters (Pauly, 1980).

The Instantaneous fishing mortality (F) was calculated by the formula:

$F = Z – M$ ………… (3) (Gulland, 1971), whereas the most favourable fishing effort (F_{opt}) representing Terminal Fishing effort (Ft) from this assessment ($F_{opt} = F_t$), was estimated using the expression, $F_{opt} = 0.4M$……… (4) (Pauly, 1984).

Length-structured virtual population analysis (LVPA)

The LVPA employed the modified method by Jones and van Zalinge (1981). Input parameters were L_∞ and K.

The terminal population (Nt) was first estimated by the function:

$N_t = C_t \cdot (M + F_t)/F_t$……… (5)

where C_t is the terminal catch. Successive values of 'F' were estimated by the relation:

$C_i = N_{i+\Delta t} \cdot (F_i/Z_i) \cdot (exp(Z_i \cdot \Delta t_i)-1)$… (6) where $\Delta t_i = (t_{i+1} - t_i)$……….. (7)

$t_i = t_0 - (1/K) \cdot ln(1-(L_i/L_\infty)$…….. (8), were population sizes (N_i) were computed from the relation:

$N_i = N_{i+t} \cdot exp\ (Z_i)$………. (9)

Estimating probability of capture

The length-converted catch curve fitted in the FISAT II routine (Pauly, 1984; Gayanilo *et al*., 2005) provides an extended methodology for estimating the probability of capture of selected length groups (L25, L50 and L75) using the following relationships:

$ln((1/PL)-1) = S1 - S2 * L$ …… (10) (Where PL is the probability of capture for length L, and;

$L25 = \frac{(ln(3)-S1)}{S2}$…… (11)

$L50 = SI/S2$……….. (12)

$L75 = \frac{(ln(3)+S1)}{S2}$….. (13) (Where L_{25} = length at which 25% of the fish were vulnerable to capture; L_{50} = length at which 50% of the fish entering the trawl net were retained by the gear (Pauly, 1984) was taken to be equivalent to mean length of the fish at first capture (L_{c50}); L_{75} = length at which 75% of the fish were vulnerable to capture by the fleet; S1 and S2 = variables used for estimating the probability of capture under the logistic model).

RESULTS

Length-structured virtual population analysis

Results revealed minimum and maximum total length of 11cm and 36cm respectively for the study species. The Length Structured Virtual Population Analysis (LVPA) revealed highest catch (in numbers) for the length range of 20 cm ($n = 94 \times 10^4$) - 21 cm ($n = 10 \times 10^4$) with corresponding fishing mortality of 0.68 yr^{-1} and 0.62 yr^{-1} (Table 1; Figure 2), and the number of specimens that survived gill net capture steadily decreased with increase in length (Figure 2). Besides, natural death of the population of the assessed stock decreased with increase in total length (Figure 2).

Table 1 shows further, the relative steady state biomass of the population of *G. decadactylus* drawn from the artisanal mixed fishery, and the greatest biomass (22.02 t) was obtained for the length of 21cm- 22cmTL.

Probability of capture

The normal distribution plot (Figure 3) evinced greater selection probability (*p* 0.9) of the length range of 17 cm - 22 cm (mean of 19.5 cm TL) in the mixed mesh sizes employed by the fishers.

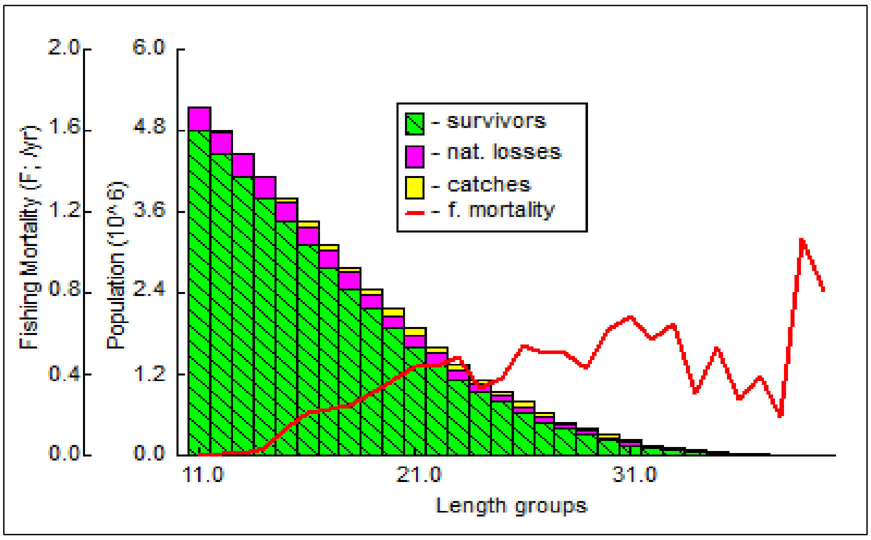

Figure 2. Length-Structures Virtual Population Analysis of *G. decadactylus*

Table 1. Steady state biomass of the population of *G. decadactylus*

Mid-Length (cm)	Catch (numbers)	Steady-state Biomass (t)
11.0	1000.00	7.12
12.0	3000.00	8.71
13.0	4000.00	10.43
14.0	15000.00	12.26
15.0	50000.00	14.08
16.0	76000.00	15.80
17.0	76000.00	17.41
18.0	75000.00	18.90
19.0	87000.00	20.19
20.0	94000.00	21.17
21.0	100000.00	21.76
22.0	89000.00	22.02
23.0	88000.00	21.95
24.0	53000.00	21.79
25.0	54000.00	21.56
26.0	66000.00	20.71
27.0	51000.00	19.45
28.0	43000.00	18.07
29.0	31000.00	16.65
30.0	36000.00	14.91
31.0	31000.00	12.72
32.0	20000.00	10.65
33.0	17000.00	8.71
34.0	6000.00	7.19
35.0	8000.00	5.85
36.0	3000.00	4.60

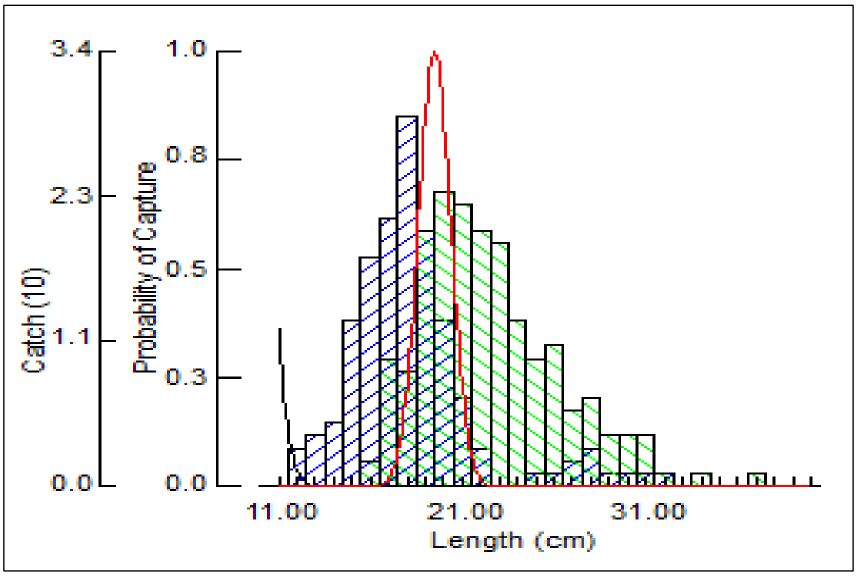

Figure 3. Probability of Capture of *G. decadactylus*

DISCUSSION

The length-structured virtual population analysis from this study depicted that the smaller length groups of the assessed stock (TL ≤ 11 cm), to a larger extent, survived fishing mortality amidst a seemingly exerted fishing pressure probably owing to some unique manoeuvring or protection strategy. It could also be that the gill nets used by the fishermen were highly selective to allow the young specimens escape net capture, though highly susceptible to natural causes of death, and suspected limiting factors to surplus production could be linked to proliferation of their predators and/or pollutants, for which pollution debarring measures are strongly advised by the authors. Retrospectively, the most capture-vulnerable length groups of *G. decadactylus* obtained from this study (17 cm-22 cm) coincided with the length at first capture (L_{c50} = 17.2 cm) and

Further, the probability of capture from this study portrayed an increase in capture vulnerability with increase in size of *G. decadactylus*, also suggesting high selectivity in the gill nets of local fishers that allowed greater number (n = 4.8 x 10^6) of the smaller length group (TL ≤ 11 cm) escape capture, inter alia. Low capture of the larger sized individuals (> 27 cm) could, however, also imply that these could easily fight their way out of the gill net utilized by the artisanal mixed fisheries or could easily escape fishing grounds. Concurrently, several authors have suggested

maturity (L_{m50} = 22.7 cm) of the same stock recorded by Amponsah *et al.* (2021) from the Ghanaian Coastal Waters. However, the inference of growth overfishing in *G. decadactulus* proffered by Amponsah *et al.* (2021) was in contravention to the present analysis that portrayed colossal likelihood of selecting mostly the larger-sized individuals of the assessed stock by local fishing nets. Such discrepancy depicted clearly the regional differences in stock status and management, fishing methods and study sample sizes. Slightly lower L_{c50} values (L_{c50} = 13.9 cm and 15.4 cm) have also been observed by Wehye and Amponsah (2017) and Sossoukpe *et al.* (2016) from the Liberian and Benin jurisdictional marine zones respectively. Growth overfishing occurs when smaller length classes of a fish stock become the dominant population in catches (Amponsah *et al.,* 2016, 2017; Wehye *et al.,* 2017)

that appropriate fishing nets could allow escapement of young fishes and enhance optimal spawning stock biomass of a fishery (Mehanna *et al.,* 2012; Ghanbarzadeh *et al.,* 2015; Amponsah *et al.,* 2016, 2017; Wahye *et al.,* 2017).

CONCLUSION

The study depicted that the smaller length groups of the assessed stock (TL ≤ 11 cm) were less vulnerable capture by local fishing nets, owing to high selectivity in gill nets utilized by the artisanal fishers for the stock to allow greater number (n = 4.8 x 10^6) of the smaller length group escape capture averse to the larger sized (> 21cm) specimens. Notwithstanding, natural death was eminent for the young individuals.

The authors however recommend stringent input and output control measures on the exploitation of the assessed stock to ensuring sustainability in the spawning stock biomass and optimal production. Ensuring good habitat quality is also essential in minimizing natural cause of death in the study species, and is strongly recommended.

Conflict of interest

The authors declare that there is no conflict of interest that should in any way hamper the outcome of this paper

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