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Population Dynamics of Bigeye Grunt, *Brachydeuterus auritus* (Valenciennes, 1831) in Ghana and Management Implications

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Abstract

Population dynamics of *Brachydeuterus auritus* harvested from Ghana's coastal waters was assessed following previous indications that this important species is collapsing. In view of this, a total of 849 samples of *B. auritus* were collected from February 2016 to January 2017, measured for total lengths and examined using FiSAT II. The mean length was 13.7 cm with a growth pattern of 2.8. The asymptotic length (L∞) and growth rate (K) were 21.53 cm and 0.67 yr^{-1} respectively portraying that this species is a fast-growing species. The lengths at first maturity and capture were calculated as 14.4 cm and 6.02 cm respectively which indicated the presence of growth overfishing. The critical length at capture (Lc=0.28) was lower than 0.5, supporting the earlier assertion that the investigated fish species is plagued with growth overfishing. Natural mortality rate (M=1.44/yr) was higher than fishing mortality rate (F=1.22/yr) an indication that small sized fished fishes were largely harvested. The recruitment layout was unremitting throughout the year with two major peaks showing the presence of strong recruitment into the stock - a strategy to avert extinction of its species. However, the exploitation rate (E=0.46) was slightly lower than the E_{max} (0.52) showing that the biomass of the investigated stock could surpass the maximum sustainable yield (E_{max}) if necessary fishery management options are not put in place. Furthermore, using the Quadrant rule, the investigated stock was categorized as developing, hence any unsustainable increase in fishing efforts could facilitate growth overfishing leading to its collapse. Therefore, to ensure sustainable exploitation and contribution to protein requirement for coastal community households, relevant fisheries measures are advocated.

Keywords Bigeye grunt; Ghana; Yield; Growth; Mortality; Recruitment

Introduction

Globally, stock assessment options have been used by numerous marine researchers to evaluate the position of significant fish species. Knowledge from fish stock assessment studies has aided in sustainable management of key fish species. Thus, ensuring food and nutrition security mostly within households whose livelihoods and wellbeing relies on marine resources (fishes). Assessing the status of the fish stock using stock assessment models mostly involves the use of either length or age aggregated data. However, in developing countries like Ghana, where age estimation of fish data is not accessible, the length based data are mostly used in assessing the stock. Therefore, in this study, length based data was used in evaluating the position of *Brachydeuterus auritus* from the marine waters of Ghana. *Brachydeuterus auritus* which forms part of the family *Pomadasyidae* is largely scattered in Ghana's marine waters [1]. Globally, its distribution ranges between Mauritania to Angola occupying depths 30 m-80 m [2]. Species of *Brachydeuterus auritus* are in abundance chiefly during the day with preference to fingerlings including larvae of its kind as diets. In Ghana, *Brachydeuterus auritus* fish species are captured using either trawls nets, gill nets, set nets, beach seine and purse seine fishing gears making *Brachydeuterus auritus* the most harvested species of its family [3]. The bigeye grunt which is commonly known as burrito with local Ghanaian names including "Moi," "Boe boe," and "Eboe" is one of the most vital by-catch fish species in Ghanaian coastal waters [4]. Bannerman et al. [5] mentioned that the most harvested demersal fish landings by small-scale fishing crafts in Ghana are Bigeye grunt. Meanwhile, it is noteworthy that, its status as the most harvested demersal fish species was overtaken by triggerfish in the 1970s for approximately two decades down to later part of 1980s [6]. It forms part of lesser known and underutilized species in Ghana because of its dark flesh, bony nature and consumer prejudices against these species [4]. In Ghana, *Brachydeuterus auritus* are marketed as fresh, dried or salted, though harvested *Brachydeuterus auritus* are at times either used as fishmeal or discards [7]. Nonetheless, this fish species forms part of household fish species that sustains the protein requirement of most fishing households in Ghana, particularly due to its low price [3]. Furthermore [4] reported that the protein level in *Brachydeuterus auritus* is higher than found in other pelagic fishes which makes it an ideal protein supplement in the diets of infants. In cognizance of its immense contribution to coastal and national food security and nutrition, there is the need for continuous evaluation of its stock status. Again, unremitting knowledge in stock assessment for *Brachydeuterus auritus* ensures that this commercially important species is sustainably exploited.

Materials and Methods

Study area

The study focused on six fishing communities along the coastline of Ghana. A two-stage stratified sampling strategy including geographical

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isolation and fishing methods was used in selecting the study areas. In that regards, the six selected fishing communities were Tema, Apam, Sekondi, Elmina, Half Assini and Dzelukope (Figure 1).

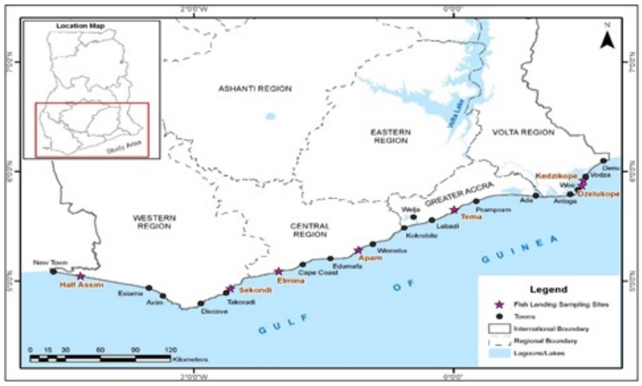

Figure 1: Map showing the sampling sites.

Data collection

Fish samples were purchased from February, 2016 to January 2017. Obtained specimen was weighed to the 0.01 g with the total length recorded to 0.1 cm using the 100 cm measuring board. Identification of species was done following identification keys by [2,7]. In all, 849 species of *Brachydeuterus auritus* were assessed during the study period.

Methods

Growth parameters: Growth rate (K), asymptotic length (L∞) and the growth performance index (ϕ) were estimated using the Von Bertanlaffy Growth Function (VBGF). The Z/K ratio was calculated using Powell-Wetherall Plot [8]. The theoretical age at birth (to) was estimated using: $\log10(-t_o)=-0.3922-0.275^* \log_{10}L\infty-1.038^* \log_{10}K$ [9]. Longevity (t_{max}) was calculated as $t_{max}=3/K+t_o$ [10]. Growth performance index was generated from the equation: $(\phi)=2\log L\infty+\log K$ [11].

Mortality parameters: The length-converted catch curve was used to estimate the total mortality rate (Z). Natural mortality rate (M) was calculated as: $\log_{10}M=-0.0066-0.279 \log_{10} L\infty+0.6543 \log_{10}K+0.4634 \log_{10}T$ [12], where M=natural mortality, T=surface temperature of 25.7°C and K refers to the growth rate. Fishing mortality (F) was computed as Z-M [13].

Length at first capture: The probability of capture of was estimated by graphing the cumulative probability of capture against mid-length. From the resultant curve, the length at first capture (Lc_{50}) correlated to cumulative probability at 50%.

Recruitment pattern: Recruitment pulse reconstructed from a time series of length-frequency distribution was used to identify the pulses per year and the relative strength of each pulse [14]. The length at first recruitment (L_r) was taken as the midpoint of the smallest length class [15].

Length at first maturity (Lm_{50}): This is the length at which the fish is able to increase stock population. The length at first maturity (Lm_{50}) was computed as: $Lm_{50}=(2^*L\infty)/3$ [16].

Length weight relationship: Length weight relationship was evaluated using the expression: $W=aL^b$, where 'W' is the body weight and 'L' is the corresponding total length [8].

Exploitation rates (E_{max}, $E_{0.1}$ and $E_{0.5}$): E_{max} which correlates to exploitation at maximum yield production, $E_{0.1}$ for marginal increase of Y'/R at 10% of its virgin stock with $E_{0.5}$ as exploitation rate of reducing stock to half its virgin biomass were estimated.

Yield isopleth: Yield isopleth was plotted to identify the impact of changes in exploitation ratio (E) on yield (critical length ratio (Lc)= $Lc_{50}/L\infty$).

Data analysis

The length frequency data was pooled into groups with 1cm length interval and analysed using the FiSAT II (FAO-ICLARM Stock Assessment Tools) software [17]. The length at age was graphed using the Yield software package [18].

Results

Length frequency distribution

The mean length was 13.7 cm with the maximum and minimum lengths at 26.5 cm and 5.5 cm respectively (Figure 2).

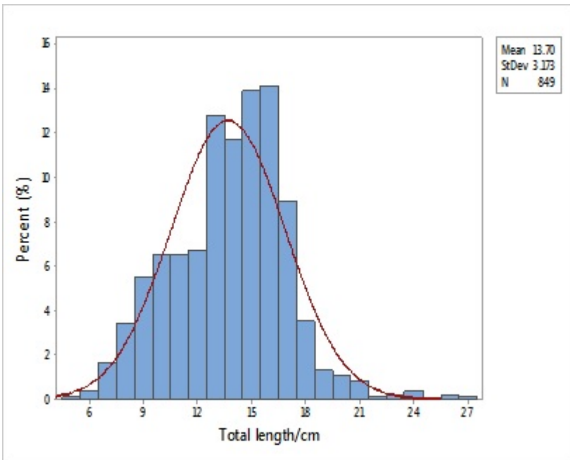

Figure 2: Length frequency distribution.

Length weight relationship

The estimated growth pattern (b) and the constant (a) were 2.8 and 0.0211 respectively (Figure 3).

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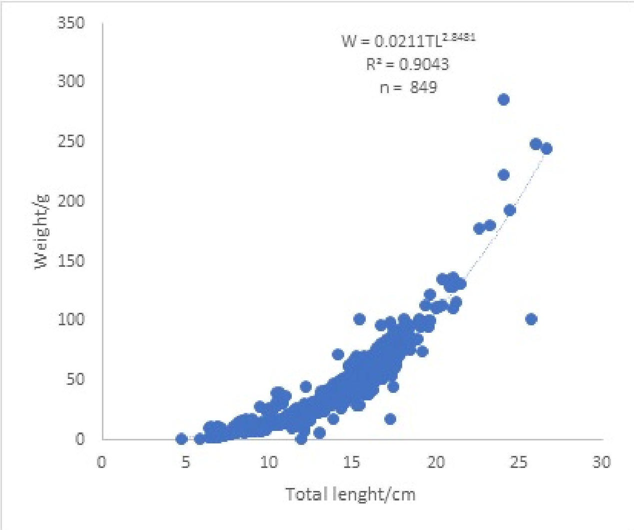

Figure 3: Length weight relationship.

Growth parameters

Asymptotic length (L∞) and growth rate (K) were 21.53 cm TL and 0.67/yr respectively. The growth curve revealed four cohorts (Figure 4a). The Von Bertanlaffy Growth Function (VBGF) was L_t=21.53 (1-$e^{-0.26\ (t-(-0.67))}$) with a growth performance index of 1.849. The estimated Z/K ratio was 1.47 (Figure 4b). The theoretical age at birth (t_o) and longevity (t_{max}) were -0.26 and 4.2 years respectively (Figure 4c).

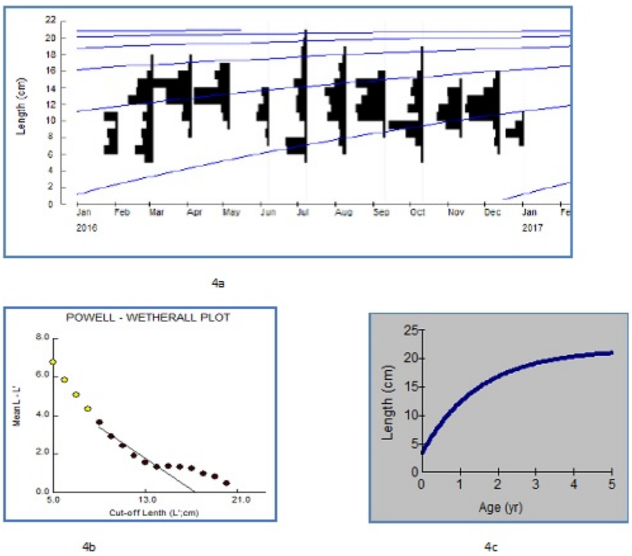

Figure 4: (a) Length frequency distribution superimposed with growth curve; (b) Powell-Wetherall plot for Z/K ratio; (c) Length at age plot.

Length and age at first capture (Lc50)

The probability of capture routine (L_{50}) was 6.02 cm (Figure 5). Further, the estimates for L_{25} and L_{75} were 2.78 cm and 9.20 cm respectively. Therefore, the length-at-first capture (Lc_{50}) and age at first capture (tc) were at 6.02 cm and 0.27 years respectively.

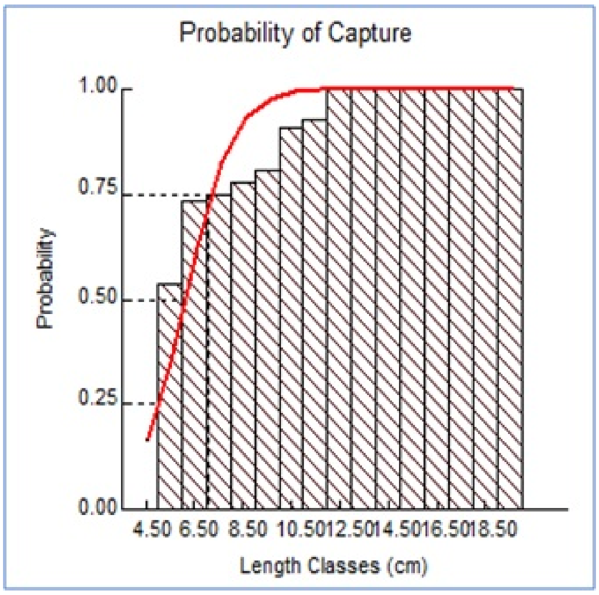

Figure 5: Probability of capture.

Length and age at first maturity (Lm_{50})

The length at first maturity (Lm_{50}) and age at first maturity (tm) were obtained at 14.4 cm and 1.34 years respectively.

Recruitment pattern

Two peaks of recruitment during one year were observed (Figure 6). The minor peak was observed in May while the major peak was in September. The length at first recruitment (Lr_{50}) and age at first recruitment (tr) were 5.5 cm and 0.18 years respectively.

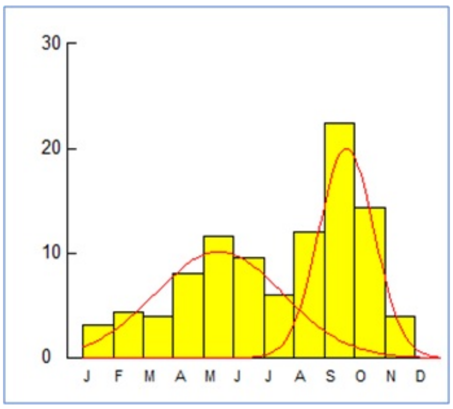

Figure 6: Recruitment pattern.

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Mortality

The mortality rates including Total (Z), natural (M) and fishing (F) mortality rates were at 2.66 per year, 1.44 per year and 1.22 per year respectively (Figure 7). The exploitation ratio (E) was estimated at 0.46.

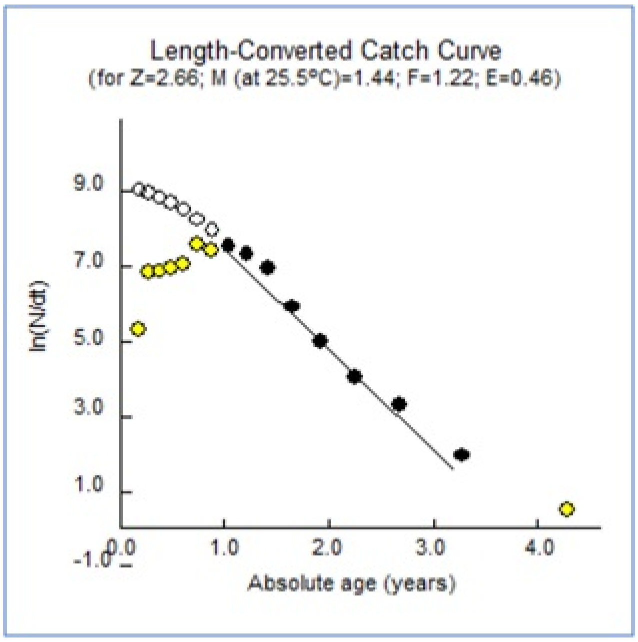

Figure 7: Length converted catch curve plot.

Relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R)

The maximum exploitation rate (E_{max}) was 0.52 (Figure 8). The marginal exploitation rate ($E_{0.1}$) and economic exploitation rate ($E_{0.5}$) were estimated to be 0.42 and 0.30 respectively.

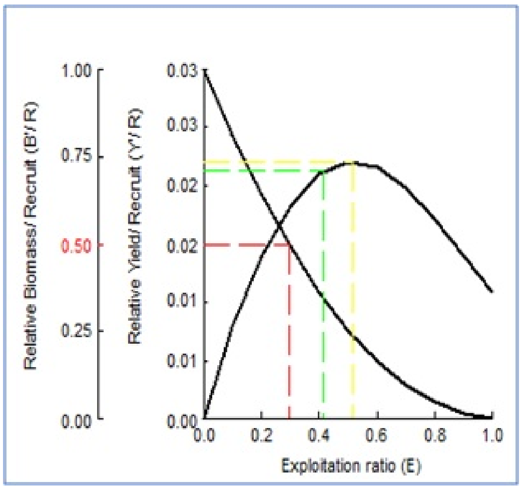

Figure 8: Relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R).

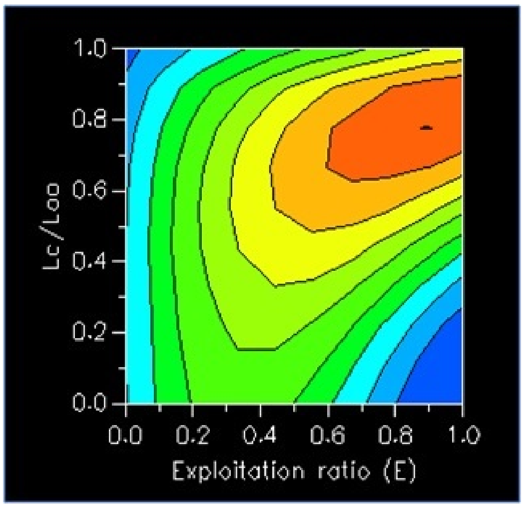

Figure 9: Yield isopleth diagram.

Yield isopleth

The yield isopleths shown in Figure 9 envisage the response of Lc=0.28 and E=0.46. As a result, the stock status of the investigated fish species fell in quadrant B (eumetric category/developing stage).

Discussion

The growth pattern observed from the study was lower than the ideal value of 3, implying that *Brachydeuterus auritus* from the coast of Ghana exhibits negative allometric growth. Negative allometric growth indicates the length growing faster than the weight [19]. Konan et al. [1,19] from Nigerian and Ivorian coastal waters respectively reported a similar observation. On the contrary [20] from Benin coastal waters recorded a positive allometric growth of 3.36. Potential causes for changes in growth pattern include availability of feed, environmental condition, gender of the species and the maturity stage [12]. Evidently [21] observed a negative allometric growth for female *Brachydeuterus auritus* species and positive allometric growth for male *Brachydeuterus auritus* species.

The calculated length at infinity was relatively higher than estimated by [3,5] while the growth rate (K) was lower than estimated by [3,5]. Meanwhile from the Ivorian waters, [1] estimated a lower growth rate. Thus, the changes in length at infinity and growth rate could be due to computation protocol, length classes obtained and the geographical locations [22]. The growth performance index estimated was relatively lower than estimates by other scientists [1,3,5]. Potential causes include the nature of inputs used in computation as well as chemical and physical dynamics of the marine environment.

The length at first capture (Lc_{50}) estimated from this study was lower than estimates by other researchers [3,5]. The observed differences within coastal waters of Ghana implies that fishermen in Ghana are now deploying smaller and smaller mesh sized fishing gears. However, [1] from the coastal waters of Ivory Coast estimated a relatively higher length at first capture which could mean that fishers in Ivory Coast are using fishing gear of bigger mesh sizes. Critical length at capture (Lc) was far below 0.5 which shows that the fishery comprises of small sized species [10]. This finding lends credence to earlier work done by [3,5] who reported similar observation. More so, Lc lower than 0.5 is known to be indicative of growth overfishing [3]. The length at first capture was lesser than the minimum legal landing size, inferring that the investigated stock is under protected by the relevant regulations preserved in Ghana Fisheries Act 625 [22].

Regarding maturity, the estimated length at first maturity (Lm_{50}) was higher than the values documented by [3,23]. Probable causes for the observed variation include geographical locations, genetic makeup and environmental factors [24]. More so, in relation to the length at first maturity, lower length at first capture revealed that the juveniles are harvested before adding to the biomass of the stock which is a feature of growth overfishing. The estimated age at first maturity (tm) suggested that juveniles become matured at the end of the first year a feature of short-lived or fast-growing species [25].

The age at first maturity (tm) was greater than the age the first capture (tc) which supports the above-mentioned claim that the species is beset with growth overfishing. In support of this assertion, about 55% of the catch had total lengths lower than the length at first maturity (Lm_{50}). The estimated age at fist recruitment (tr) indicated that its juveniles enter into the stock shortly after birth, approximately two months after birth while the age at first capture (tc) showed that these juveniles become exposed to capture approximately a month after recruitment into the stock. The early recruitment could be a survival strategy adopted in response to the existing high fishing burden, which when neglected could lead to collapse of its species. However, the closeness of the age at recruitment (tr) to age at capture (tc) may result in recruitment failure in the future if fishing pressure is not sustainably regulated.

The two observed recruitment peaks from the study agreed with the suggestion by [12] that tropical fish species exhibit two recruitment peaks. Possible reasons for the exhibited peaks of recruitment include advantageous environmental situations, availability of feed and the presence of matured *Brachydeuterus auritus* species [26,27]. Continuous recruitment may be linked to the presence of more females than males as well as the geographical location [28]. The position of the major recruitment peak was in line with traditional knowledge of local fishermen. Furthermore, the strong presence of recruits evinced by the recruitment pattern suggests that recruitment within *Brachydeuterus auritus* stock is still functional [24].

The calculated Z/K ratio was greater than 1, suggesting that the stock is highly subjected to mortality [29]. This observation could be due to the presence of more juveniles as they are more prone to both natural and fishing mortality situations. However, the estimated M/K ratio was within the range 1.5 to 2.5 for fishes which suggests the presence of relatively conducive marine environment [30,31].

In comparison to fishing mortality rate, higher natural mortality rate maybe as a result of high percentage of juveniles within the stock. Ecologically small sized fishes or juveniles are more vulnerable to unfavourable environmental conditions and unbalanced predator-prey relationships [32]. The exploitation ratio was approximately at the ideal level of 0.5 revealing optimal exploitation of the investigated stock [8]. However, the exploitation ratio was slightly lower than the E_{max}, which indicates that the investigated species is heavily fished and could surpass the maximum sustainable yield (E_{max}) if necessary management options are not put in place.

The interception of Lc and E fell in quadrant B, implying that the *Brachydeuterus auritus* stock is at the eumetric stage which implies small sized fishes are caught at a low fishing effort [33]. Amponsah et al. [3] mentioned that investigated fish species in 2014/2015 was at the developing stage following a possible collapse in the past. Though as management intervention nothing should be done, in the wake of growing fishing effort in Ghana and the use of small mesh size fishing gears, fishing effort should be minimized. Further, to reduce the fishing heaviness on this commercially important species, value addition to harvested species should be identified and implemented.

Conclusion

Brachydeuterus auritus is a fast-growing species and possess a short lifespan, early sexual maturity, year-round recruitment and high natural mortality to asymptotic length ratio. Though optimally exploited, the stock of *Brachydeuterus auritus* is heavily fished. The continuous existence of recruits reveals strong recruitment into the stock and the absence of recruitment overfishing. The fishery of the investigated stock currently resides in the developing stage which demands reduction in fishing efforts. Taking cognizance of *Brachydeuterus auritus* contribution to food security within coastal communities in Ghana, effective fisheries management measures are urgently required to avert possible collapse in the near future.

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