Relative condition factor and parasites of the Bigeye grunt, *Brachydeuterus auritus* (Valenciennes, 1831) inhabiting the coastal waters off Tema, Ghana

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Abstract

The marine ray-fined *Brachydeuterus auritus* is one of the most exploited and heavily consumed fishes of the tropical and sub-tropical waters of the eastern-central Atlantic. Fish microbial studies have raised awareness of parasites that can impact fish health, growth, survival, reproduction, and the possible transmission of fish-to-humans situations. The study assessed the well-being of this economically important fish and the prevalence of parasites that they harbour which potentially is of public health interest.. This cross-sectional study involved sampling of fish from June to December, 2016. A total of 424 *B. auritus* were collected of which 228 were males, 157 females and 39 being hermaphrodites. Data on their length and weight were taken and condition factors determined. Ectoparasites were isolated for identification using a compound light microscope by direct smear of mucous scraped from the skin, fins and mouth, whereas endoparasites were isolated from the gut. The length of *B. auritus* ranged from 9.70 to 22.20 cm, and weighed between 13.51 to 149.92 g. The correlation coefficient (r) between the log of total length and body depth of the sexes ranged from 0.960 - 0.970. *Brachydeuterus auritus* in this part of the coastal waters of Ghana showed negative allometric growth for both sexes. Most of the parasites isolated were parasitic crustaceans, such as *Achtheres* sp., *Clinostomum* sp., *Cymothoa* sp., *Ergasilus* sp., and *Rhabdochona* sp. which were recovered from the gills and mouth. Parasite density was higher in males than in females. Samples of intermediate sizes had the highest parasite prevalence, and also had the least parasite intensity. This study has contributed to the knowledge on the parasitic infestations associated with this economically important fish species and their potential roles and dangers in the fish-to-human transmissions. More education on proper handling and cooking of fish be given to farmers, traders and consumers, as well as control of piscivorous birds is to maximize profitability in fish farming.

Keywords: *Brachydeuterus auritus*, coastal waters, condition factor, length-weight relationship, parasites

Introduction

Fish serve as food and their by-products provides innumerable benefits to humans (Olsen et al., 2014). Fish consumption reduces the risk of stroke, depression, Alzheimer's disease and other chronic conditions (Huang et al., 2005; Thaipisuttikul and Galvin, 2012). Fish also provide income and employment to many developing regions and in low-income food-deficit countries (LIFDCs). Accordingly, the health of fish is paramount not only to the fish but also to those who depend on it for livelihood and nutrition. The Bigeye grunt, *Brachydeuterus auritus* (Valenciennes, 1831) is a species of marine ray-finned fish of the family Haemulidae. This fish is distributed in the tropical and sub-tropical waters of the eastern-central Atlantic from Morocco to Angola, and occurs at depths of 10 to 100 m (Chunlei et al., 2022). At least five species of this fish family occur in the coastal waters of Ghana (Amponsah, et al., 2016). The Bigeye grunt is the smallest of all the family members, yet the most commercially exploited species in terms of abundance and quality (Aggrey-Fynn and Sackey-Mensah, 2012; Amponsah, et al., 2016). Besides its heavy consumption, limited studies have focused on the condition factor as well as the parasites of the Bigeye

grunt, commonly called Burrito.

Fish microbial studies have raised the awareness of parasites that can impact on fish fitness, as well as the possibility of pathogen spill-overs from fish to humans through consumption (Onyedineke et al., 2010). Parasites such as Anisakis, have been reported in fishes and humans (Kolodziejczyk et al., 2020; Mercken et al., 2021). Parasite communities can be ecologically important as they are used to distinguish distinct populations of the same fish species co-habiting a region (Locke et al., 2013; Allam et al., 2023). Parasitic infections are known to impair courtship dance of some fish species thereby impacting on their breeding (Mikheev et al., 2010). The death of host means same for the parasites, but not all parasites want to keep their hosts alive, as those with multistage life cycles, such as some tapeworms make some fish more buoyant and behave in such a way that a predatory bird, which is the definitive host can prey on infected fish(Weinersmith et al. 2023).

Consequently, commercially exploited species such as *B. auritus*, when infected with parasites may have consumer preference challenges (Petersen et al., 1993). In addition, knowledge of parasite ecology of fishes is essential for implementing a multispecies approach to fisheries management (Astles and Cormier, 2018). A moderate number of parasites have been reported to infect fishes in Africa including *B. auritus* (Omeji et al., 2011; Ogbon et al., 2023). Knowledge of parasites of this fish species is very vital so as to determine their physiological well-being or state in their coastal aquatic environment.

Morphometric analyses describe the relationship between length and weight, so that one of the parameters can be converted into the other. This helps with measuring the variation from expected weight-for-length of individual fish, which is used in calculating the relative condition factor – a measure that expresses the physiological well-being or fitness of fishes in different environments, thereby giving indication about the conducive nature of the environment in which the fish lives and develops. The relevance of this study reported is to contribute to achieving food security, improving nutrition, ensuring healthy lives, promoting well-being and sustainable economic growth, productive employment and decent work for all (SDGs 2, 3 & 8) (United Nations, The 17 goals). Specifically, the aim of the study was to identify and estimate the prevalence of parasites of *B. auritus* and determine the length-weight relationships and relative condition factor of this fish species. collected from the coastal waters off Tema, Ghana.

Materials and Methods

Study site

Fresh samples of *B. auritus* were randomly collected from catches of artisanal fishermen at the Tema Fishing Harbour. This site is the biggest fishing harbour in Ghana and is operated by the Ghana Ports and Harbours Authority. It lies at $5^{0}40'0"$N, $0^{0}0'0"$E and covers an area of 1.7 million square metres (Figure 1) (Botwe et al., 2017).

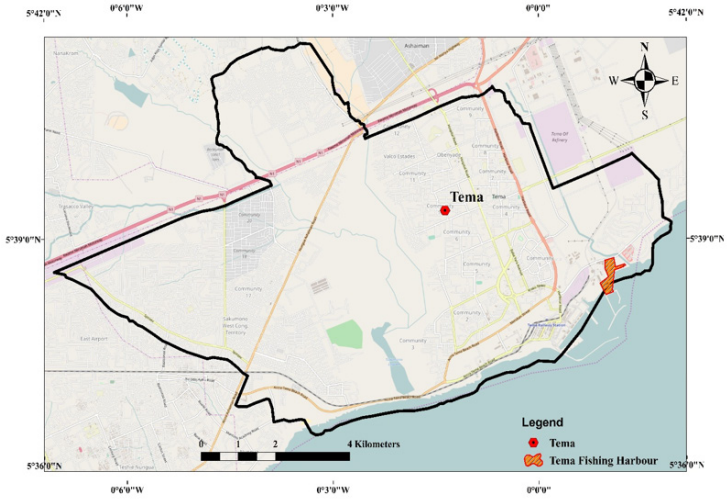

Figure 1 Map of the coastal area of Tema showing the Fishing Harbour

Fish sampling

This was a cross-sectional study and sampling was done once every month from June to December, 2016. The samples included different age classes of *B. auritus*. The study was approved by the Department of Animal Biology and Conservation Science. Fresh samples of the Bigeye grunt were purchased from fishermen at the landing beach of the Tema Fishing Harbour, and identification done with the aid of the FAO Fish Identification Guide for Fishery Purposes (Carpenter and DeAngelis, 2014). The fish were preserved on ice at a temperature of 4^0C, in a clean ice chest and immediately transported to the research laboratory of the Department of Animal Biology and Conservation Science, University of Ghana.

Length-weight relationships (LWRs)

Fish length measurements such as standard length and total length were measured and recorded to the nearest 0.01 cm. In addition, weight with its stomach content was measured to the nearest 0.01 g, with an electronic tabletop weighing scale (Philip Harris, Novara House, Ashby Park, Ashby de la Zouch, Leics. LE651NG) after blot drying the fish with a piece of clean hand towel. The exponential equation of fish length and weight relationship (W = aLb) by King (1992) which is usually log transformed was then used for the computations;

$$W = aLb$$
$$\text{Log } W = \text{Log } a + b \text{ Log } L$$

where w = weight of fish in g
L = standard length of fish in cm
b = exponent of growth

The growth of the fish was analyzed and identified as allometric growth (b < 3) or isometric (b = 3) (King, 1992; Imam et al., 2010). The correlation (r^2) between the length and weight was computed from the linear regression analysis: $R = r^2$.

Relative condition factor (Kn)

The physiological well-being (condition factor) of this fish species was determined through estimation of their monthly mean condition factor (K).

$$\text{Condition factor (K)} = \frac{weight\ of\ fish\ (g)}{cube\ of\ length\ of\ fish\ (cm)} \times 100 \qquad \text{(Equation 1)}$$

The relative condition factor was used to assess the condition of the fish species, and was defined as W_o/W_c, where W_o is the observed weight, and W_c is the calculated weight (Le Cren, 1951). Good condition of the fish is deduced when Kn≥1, whilst the organism is in poor growth condition compared to an average individual with the same length when Kn<1.

Isolation and identification of parasites

A total of 424 individual samples of *B. auritus* were collected over a five-month period of which 228 were males, 157 females and 39 being hermaphrodites (Table 1). The skin, fins and mouth of each specimen were observed with the aid of a hand lens for both ecto- and endo-parasites. Wet mounts of mucous were prepared by scraping the dorso-lateral surface of the fish with the blunt side of a scalpel blade. Slides of this preparation were examined for parasites using 100x and 400x magnification of a compound light microscope. The gills were removed and placed in a petri dish with physiological saline and then observed under a dissecting microscope. The specimens were then cut open and their guts removed. The gut

TABLE 1
Correlation between Total length and Body depth of *Brachydeuterus auritus*

	Constants		Correlation	
Sex	**a**	**b**	**coefficient (r)**	**Number of fish (%)**
Male	-1.631	2.826	0.985	228 (53.77)
Female	-1.631	2.833	0.980	157 (37.03)
Hermaphrodite	-1.643	2.839	0.984	39 (9.20)

contents were flushed out with physiological saline into a petri dish and observed under dissecting microscope for endoparasites. Portions of the gut were slit open, and the walls observed for parasites that may be attached to the intestinal walls. Isolated parasites were photographed for identification with the help of guides and taxonomic keys to fish parasites and invertebrates (Bruno et al., 2006). Other parasites were identified by matching photographs and descriptions to existing records obtained from Food and Agriculture Organization (1981). The following formulae were used to estimate parasitological indices.

$$\text{Prevalence} = \frac{Number\ of\ fishes\ infected}{Total\ number\ of\ fishes\ examined} \times 100 \quad \text{(Equation 2)}$$

$$\text{Men intensity of parasites} = \frac{Number\ of\ parasites\ recovered}{Total\ number\ of\ fishes\ infected} \quad \text{(Equation 3)}$$

$$\text{Mean intensity (\%)} = \frac{number\ of\ parasites}{total\ number\ of\ infected\ fish} \times 100 \quad \text{(Equation 4)}$$

$$\text{Mean density of parasites} = \frac{Number\ of\ parasites\ recovered}{Total\ number\ of\ fishes\ examined} \quad \text{(Equation 5)}$$

$$\text{Density} = \frac{number\ of\ parasites}{number\ of\ fish\ examined} \quad \text{(Equation 6)}$$

Statistical analysis

ANOVA was used to evaluate the statistical significance of the regression model detected when $P < 0.05$ (Gökçe et al., 2010). Student t-test comparison was performed to verify if b for each species is significantly different from the predictions assigned for isometric growth ($b = 3$). Whilst a statistically significant difference of b from 3 implies an allometric growth either positive or negative ($P < 0.05$), an isometric growth is assigned when b is not statistically different from 3 ($P > 0.05$) as described by Yilmaz et al. (2012).

Length-weight relationships

The total length of the fish ranged from 9.70 cm to 22.20 cm and standard length ranged from 8.00 cm to 20.00 cm. The total weight of the fish samples ranged from 13.51 g to 149.92 g, head width from 1.19 cm to 3.52 cm and the body depth ranged from 1.00 cm to 2.99 cm. The constants for the estimation of the correlation coefficient are displayed in Table 1 and Table 2. The correlation coefficient (r) between the log of total length and weight for males, females and combined sexes were 0.99, 0.98 and 0.98 respectively (Figure 2). Other morphometric analyses between standard length versus. total length, body length vs. body weight, and head length vs. head width were 0.95, 0.87 and 0.12 respectively (Figure 2).

Relative condition factor (Kn)

The mean condition factor for females ranged from 1.42 to 1.54 whereas that of the males ranged from 1.37 to 1.53 (Table 3). There was an initial gain in condition, reaching a peak in September followed by a decline in October. Of the months sampled, the least condition factor was recorded in May for both sexes (Table 3).

Parasite prevalence and intensity

Out of the 94 males examined, 29 were infected whereas 28 females were infected out of the 96 examined (Figure 3). Total parasite prevalence was 30% (Table 4). Fish with sizes ranging above 15 cm were the most infected nonetheless the highest mean intensity was found in sizes below 10 cm (Table 4). With respect to the density of parasites, it was observed that a density of 0.511 was recorded for males while 0.469 was recorded for females. Among the collected parasite species, three

TABLE 2

Correlation between Log Total Length and Log Width of *Brachydeuterus auritus*

Independent variable	Dependent variable	Coefficient(b) ± SE	Constant (a)	Correlation coefficient (r)	Number (n) of fish
Total Length	Standard Length	0.905 ± 0.014	-1.278	0.953	424
Body Length	Body Width	0.153 ± 0.004	0.191	0.874	424
Head Length	Head Width	2.051 ± 0.892	-6.271	0.122	424

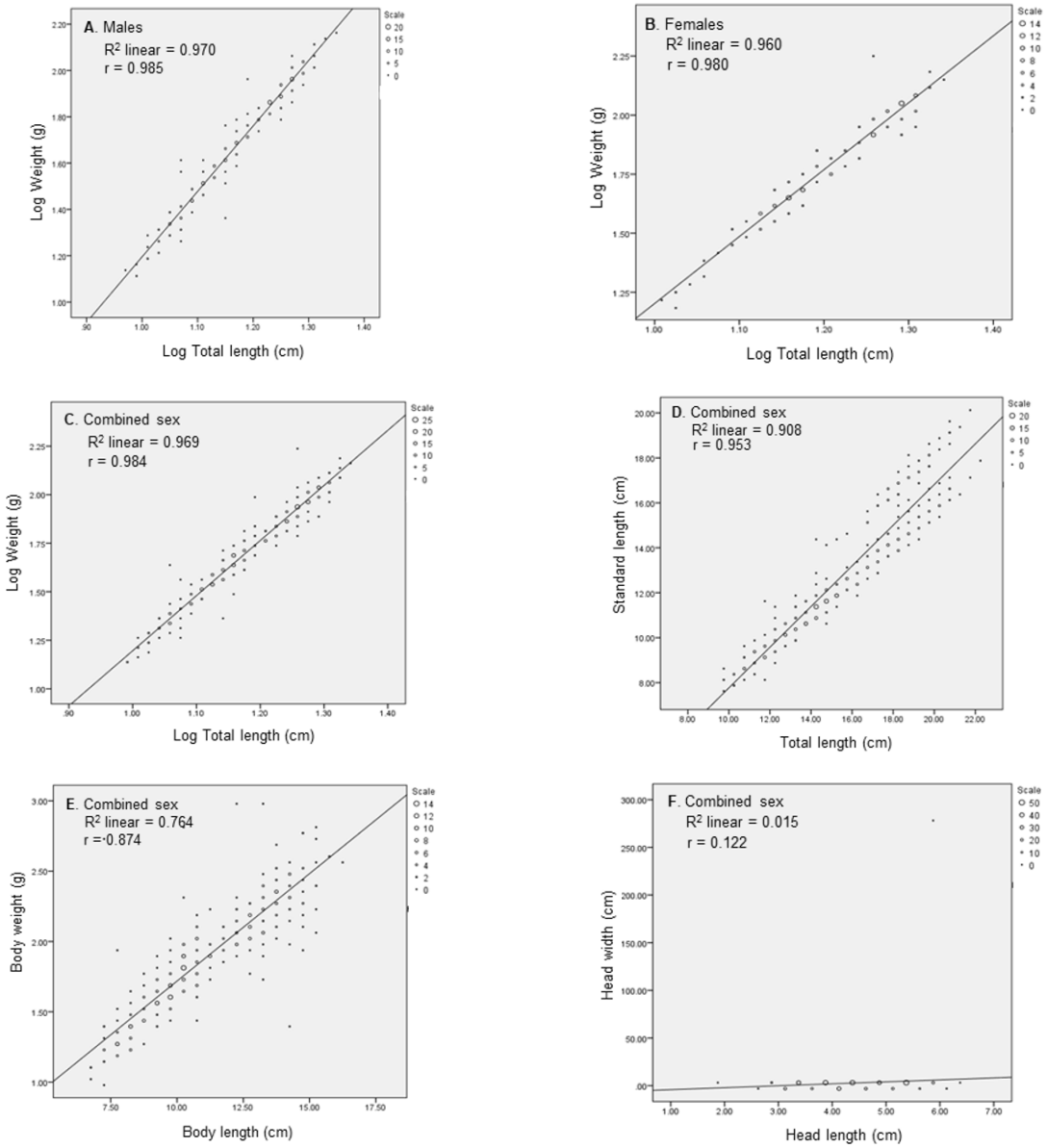

Figure 2 Morphometric analyses of Brachydeuterus auritus in the coastal waters off Tema, Ghana

were crustaceans (*Ergasilus* sp., *Achtheres* sp., *Cymothoa* sp.) which were collected from the mouth and gills. Monogeneans of the sub-group Polyopisthocotylea, one digenea trematode (*Clinostomum* sp.) were recovered from the gills and one nematode (*Rhabdichoma* sp.) from the gut.

Discussion

During the study period, 424 individual samples of *B. auritus* were collected, of which the majority were males. Earlier studies have reported varying percentages in terms of the sex ratios. For instance, a study done by Asabere-

TABLE 3
Mean condition factor (K) for the sexes of *Brachydeuterus auritus*

Month	Female	Male
May	1.424	1.374
September	1.539	1.526
October	1.463	1.463
November	1.504	1.437
December	1.498	1.534

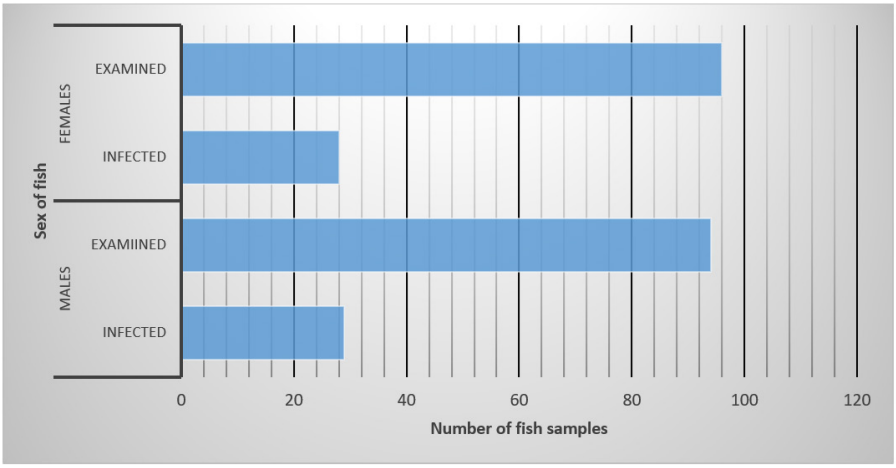

Figure 3 Number of fish examined and infected with parasites

TABLE 4

Parasite prevalence, mean intensity and condition factor of *Brachydeuterus auritus* based on age group

Length groups (cm)	Number of fishes		Prevalence (%)	No. of parasites recovered	Mean intensity unit	Density
	Examined	Infected				
<10	20	7	35	13	1.86	0.65
10-14.9	154	44	28.57	72	1.64	0.47
>15	16	6	37.5	8	1.33	0.50
Total	190	57	30	93	1.63	0.49

Ameyaw (2001) on the artisanal commercial fishery occurring off Cape Coast, Ghana, observed that females outnumbered the males. Similarly, a study done in the coastal waters of Senegal showed there were more females than males (Samb, 2003). This happens to be a reproductive strategy of preponderance of females over males that have been observed in many other fish species (Dadzie et al., 2000). However, a study by Ikusemiju et al. (1979) in Nigeria recorded more males than females, as observed in the study reported in this paper. In fish populations, sex ratio is determined by a number of factors. This includes differences in mortality or longevity between the sexes, and size dimorphism that could lead to differences in their catchability (Arra et al., 2018).

For length-weight relationship, all the cases had the slope typically below 3, the value for the fish growth to be assumed as allometric. According to Tesch (1971) the slope is often nearly constant throughout the year or a series of different environments for the same species. The intercepts, by contrast, often vary based on season and between habitats. The slope for that matter offers a more objective method for analysing growth in fishes while the intercept reflects on changes in the fish condition (Tesch, 1971). The general expectation is that the longer the fish the heavier it should be in terms of weight. On the contrary, this was not observed in our study, since weight varied in fish of the same length. These observations might be due to differences in sex, stomach contents and gonad weights (Le Cren, 1951; Akter et al., 2019).

It was observed that the females were relatively longer and weightier than the males. Such observations may be attributed to the high gonad weights in the females which adds to the weight of the fish (Zorica et al., 2011; Akter et al., 2019). Studies have shown that the ideal growth pattern of fish is isometric, where the value of b is equal to or does not depart significantly from 3 (Carlander, 1969). In such cases, the fish increases in all dimensions at the same rate. In some cases, growth was allometric, and that is when the

value of b departs significantly from 3. In the study presented in this paper, the average value of b, the slope of relationship was 2.8. With this value it can be suggested that growth of *B. auritus* in this part of the off-shore waters of Ghana shows negative allometric growth since b<3.0. This implies that the fish becomes slenderer as it increases in weight. On the contrary, other fishes display positive allometric growth with b values greater than 3.0, where in that case such fish becomes relatively stouter or deeper-bodied as it increases in length (Hamid et al., 2015).

Studies such as that of Adebiyi (2012) have observed a negative allometric growth with b value of 2.68 for *B. auritus* in Nigeria. This was similar to the result obtained in the study reported in this paper, which indicates that growth in body length was not proportionate to growth in body weight. Samb (2003) in Senegal observed that male *B. auritus* had positive allometric growth (b=3.115) whereas the females had negative allometric growth (b=2.908). This is contrary to the results obtained for this study, where both male and female *B. auritus* had allometric growth.

Fulton's condition factor (K) reflects the health of a fish and it is used to measure the relative plumpness of a fish (Datta et al., 2013). In numerical terms it measures the variation from the expected weight for the length of a fish. For the study reported in this paper, the condition factor ranged from 1.374 to 1.539. The condition factor dipped in the month of May while peaking in September, with females having higher conditions than the males. The results of the condition factor suggested that the habitat for *B. auritus* was optimum. A study carried out in Nigeria recorded a range between 0.76-3.20 for males 0.75-3.07 for females (Adebiyi, 2012). The males had higher condition factor than the females. This was in contrast with the results obtained for *B. auritus* in this study were females had higher condition factor than the males. In Ivory Coast, the condition factor, K for males ranged from 0.95 to 2.12 (mean = 1.69 ± 0.01) and was significantly lower than that of females which ranged from 0.90 to 3.02 (mean = 1.78 ± 0.01) (Sylla et al., 2016). The condition factor for the combined sexes ranged from 0.9 to 3.02 with a mean value of 1.73 ± 0.01 (Sylla et al., 2016). Our observation implies that on the average females showed better condition than males or the females were plumper in nature than the males. Dadzie et al. (2000) posited that highest condition factor is exhibited when the gonads are developing, and thus maximum condition would precede maximum spawning seasons for many fishes. This could also be due to female fishes better adapted to the environment or engaged in less activity and thus channeled most of their energy from food into growing and reproducing (Enberg et al, 2011). There is also the possibility of environmental factors such as dissolved oxygen, food, shelter, temperature, disease and predators favouring the females of *B. auritus* than the males (Domenici et al., 2007).

Parasite prevalence of 30% was observed from the study. Most of the parasites isolated were parasitic crustaceans, a combination of organisms from copepods and isopods, recovered from the gills and mouth. Parasites identified from the study includes digenean trematode (*Clinostomum* sp.), *Ergasilus* sp., *Cymothoa* sp., *Achtheres* sp., *Rhabdochona* sp., monogenean and other unidentified. Only the female *Ergasilus* sp. are parasitic, producing eggs in favourable environmental conditions where there is the absence of high subtropical temperature, coupled with depletion of dissolved oxygen and elevated salinity (Fajer-Avila et al., 2006). Their presence in *B. auritus* suggests that the coastal waters of Tema is suitable for their survival and could be used as an indicator of the environmental conditions in case of fluctuations. Although no observed damage of gills was recorded for *B. auritus*, higher incidence of ergasilids attached to gill filaments produce small foci of erosion which may consequently lead to irritation and obstruction of the branchial blood vessels (Abowei et al., 2011).

Achtheres sp. is a lernaepodid copepod and is reported to have been introduced with its host *Micropterus salmoides* (a type of fish) in South Africa (Fryer, 1968a). Copepods of

the family lernaeidae are opportunistic species infecting fish of many taxonomic Families. Female copepods are permanently attached to the inner surface of the host gill arches by specially modified leg (Abowei et al., 2011). It probably seized the opportunity to be in the gill of the Bigeye grunt and they could be confined to it as is the case of *Micropterus salmoides* (Fryer, 1968a). *Cymothoa* sp. were recovered from the mouth and gills of the Bigeye grunt. This species of isopod may be either highly host specific, opportunistic in their host choice or facultative parasite (Sikkel & Welicky, 2019). However, *Cymothoa* sp. is known to parasitize eight species in two orders and four families of fishes including that of the Bigeye grunt, Haemulidae (Williams and Bunkley-Williams, 2003).

According to Fryer (1968a), host specific isopods are the least harmful to their hosts and with respect to observations from the study, no visible signs of damage were seen on the gills or in the mouth. Nevertheless, higher infestation causes the host to be underweight (Iyaji et al., 2009). The presence of other parasites such as monogenean (Polyopisthocotylea), digenean fluke (*Clinostomum* sp.), nematode (*Rhabdochona* sp.) and the other unidentified parasites recovered from the gills and gut could be attributed to certain factors such as the feeding habit of the host, mobility of the host through its lifetime, parasites' host specificity and life cycle of the parasite (Williams and Bunkley-Williams, 2019).

Some species of *Clinostomum* are fish-borne zoonotic parasites transmitted when fish is consumed raw or undercooked (Park et al. 2009; Kim et al. 2019). However, the rest of the parasites identified on the fish can only result in adverse effects on the growth and reproduction of the fish, as the parasites are not known to infect humans (Moravec et al. 2012). *Cymothoa* sp. for instance would enter the gills of the fish, eat the tongue of its host, and then replacing the tongue with itself, thereby affecting the growth of the fish (Eman et al., 2012; Al-Zubaidy & Mhaisen, 2013). They are also not known to be present in the flesh of the fish and cooking would usually kill these parasites (Murugami et al., 2018).

Although previous study reported that female fishes were generally more liable than males to infections with parasites (Abd-ELrahman et al., 2023), this observation was however different from ours. There was no significant difference in the prevalence of parasite in reference to the sex of the fish. Parasite density were higher in males than they were in females in this study. Although these values vary slightly, there was no significant difference in both the prevalence and density of parasites recorded for both sexes of *B. auritus*. From the numbers recorded for both males and females of *B. auritus*, an observed ratio of 1:1.02 was obtained which was approximately equal to the expected ratio of 1:1. A chi square test of homogeneity revealed that there was no significant difference between these ratios ($\chi^2 = 9.488$; d.f. = 4; $P < 0.05$). This suggests that during the period of study, there were equal numbers of males and females in the coastal waters of Tema.

Brachydeuterus auritus were categorized in three groups according to their body size or length: <10 cm, 10-14.9 cm and >15 cm. It was observed that the fishes of intermediate size had the highest parasite prevalence, which agrees with the observations made by Abd-ELrahman et al. (2023). This observation could be attributed to the intermediate sized groups being the most sampled. On the other hand, this group recorded the least parasite intensity. Al-Zubaidy (2009) reported that the prevalence of infection was positively correlated with the host length and results from this study agrees with his finding. This could be ascribed to the fact that larger fishes have larger surface areas and lived longer and have a higher probability of encountering parasites during their life span than smaller and shorter-lived fish species (Al-Zubaidy, 2009).

Conclusion

The average value of b, which is the slope of relationship suggests a negative allometric growth of *B. auritus* in the coastal waters of

Ghana. The female fish had higher condition factor than the males, thus, females were more physiologically well as compared to the males. Most of the parasites isolated were parasitic crustaceans recovered from the gills and mouth. This included Clinostomum sp., Ergasilus sp., Cymothoa sp., Achtheres sp., Rhabdochona sp., monogenean. Parasite density were higher in males than they were in females. Samples of intermediate size had the highest parasite prevalence, yet this group recorded the least parasite intensity. Continuous encouragement to key stakeholders in the fish farming industry, such as farmers, traders and consumers in terms of proper handling and cooking fish is recommended to avoid infestation with zoonotic parasites. Additionally, control of piscivorous birds is encouraged to maximize the profitability of fish farming.

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Ethical responsibilities of authors

All Authors have read, understood and have complied as applicable with the statement on "Ethical responsibilities of Authors" as found in the Instructions for Authors.

Consent to publish

All Authors have consented to the publication of this manuscript.

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Ethical approval

The study received express approval from the Department of Animal Biology and Conservation Science after review of scientific and technical content of the proposal.

Competing interest

The authors declare no competing interests.

Data availability statement

All relevant data are within the paper.

Author Contributions

Stephen Dadzie, Angela Manekuor Lamptey, Bethel Kwansa-Bentum and Juliet Ewool conceived and designed the experiments. Daniel DeGraft Sey, Japhet Kwame Baah, Juliet Ewool, Bethel Kwansa-Bentum and Angela Manekuor Lamptey performed the experiments. Bethel Kwansa-Bentum, Juliet Ewool, Maxwell Kelvin Billah analysed the data. Bethel Kwansa-Bentum, Juliet Ewool, Maxwell Kelvin Billah, Angela Manekuor Lamptey and Stephen Dadzie contributed reagents/materials/analyses tools. Bethel Kwansa-Bentum put the texts of the manuscript together with contributions from all other authors.

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