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Comparative study of tilapiine populations from two contrasting habitats in Ghana

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ABSTRACT

The study investigates heavy metal (Arsenic, Cadmium, Lead and Mercury) concentrations in the black chinned tilapia (Sarotherodon melanotheron) inhabiting Benya (an open lagoon) and Fosu (closed lagoon) in the Central Region of Ghana, as well as an analysis of the size –gill relations of the cichlids. The determination of heavy metal concentrations involved the use of CHRIST BETA 1 – 16 freeze drying machine to digest the fish samples which were then asprated using AAS 240fs process. The weight, standard and total lengths as well as gill length and volume of the remaining sample were determined. The results indicated that fish samples from the Fosu lagoon recorded relatively higher Cd (0.28 mg/kg) and As (0.144 mg/kg) concentrations. However, fish samples from Benya had higher concentration of Pb (0.88 mg/kg). The levels of mercury concentration in the fish from both lagoons were below detection limits (µ0.001 mg/kg). Concentrations of Cd in the fish samples from the two populations was statistically significant ($p<0.000$). However, the differences in the concentrations of Pb and As were not statistically significant ($p>0.05$). The S. melanotheron specimens from Benya lagoon were much longer than those from Fosu lagoon. There was a positive curvilinear relationship between the standard length and body weight of both populations, with the correlation coefficient being slightly higher for the Benya ($r = 0.96$) than the Fosu ($r = 0.92$). Growth was isometric in both cases ($b= 2.54$, $t= 1.2$, $P> 0.05$ for Benya; $b= 2.51$, $t = 0.92$, $P> 0.05$ for Fosu). In both populations, gill length correlated weakly with standard length in a positive linear function ($r < 0.45$) while gill volume showed a considerably strong linear relationship with body weight in the Benya population ($r = 0.70$) although this correlation was moderate for the Fosu population ($r = 0.54$).
Keywords: Tilapia, Coastal Lagoons, Heavy metals, Gill parameters, Regression.

INTRODUCTION

There are 98 lagoons along the approximately 550 km coastline of Ghana of which 78 are ‘closed’ while 20 are ‘open’ [1]. While the ‘open’ lagoons maintain contact with the sea for greater period of the year or permanently, the ‘closed’ ones get cut off from the sea by a sand bar for greater part of the year or are permanently isolated. The differences relate to the extent of tidal influence owing to the variations in the frequency of opening to the sea that makes these two lagoons differ largely in environmental characteristics. A survey conducted by [2] on some ‘closed’ and ‘open’ lagoons in Ghana indicated that not only do these differences occur in the physical environments, but also in chemical composition including heavy metal content, and these are considerably manifested in the morphological and biochemical attributes of their biotic fauna.

Like other wetland ecosystems, lagoons support a wide range of biota including birds, reptiles and mammals, with fish being the most common[3]&[4]. The lagoon fish communities are reportedly dominated by tilapias which make up 60-80% of all fish caught [5], the most abundant being the black-chinned tilapia, *Sarotherodon melanotheron*, which is the mainstay of the fisheries of many lagoons in West Africa including Ghana ([6] &[7]). This fish constitutes between 85% and 98% of tilapia catches in local subsistence fishing in various lagoons in Ghana [5].

The remarkable importance of black-chinned tilapia in coastal fisheries has made the species attract a wide range of scientific research, some of which include their fisheries [6], growth and mortality [7], genetics [8] and potential for culture [5]. Reports on the food and feeding habits of *S. melanotheron* populations have shown that the fish feeds principally on diatoms, blue-green algae, microscopic green algae and zooplankton [9], [10] & [11]. In the life of such a planktivorous fish, gills are very important organs; as they perform dual functions, both as filter-feeding apparatus and respiratory structures. Since gill development in fishes is strongly tied to their body development [12]&[13], environmental conditions of ‘closed’ and ‘open’ lagoons could have effects on the morphometry of inhabitant populations including *S. melanotheron* as well as on their gill parameters. This may consequently influence their feeding and respiratory capacities. Unfortunately, none of the researches conducted on this species explored the relationship between the body morphometry and the gill parameters, taking these two contrasting habitats into consideration.

In addition, lagoons in Ghana have reportedly come under increasing threat of pollution [14] with a resultant accumulation of high levels of heavy metals in the inhabitant consumable fish biota such as *S. melanotheron* in the Sakumo lagoon [15] and some bivalves in the Sakumo, Benya and Ningo lagoons [2]. Consequently, it has become pertinent to rigorously assess the concentrations of heavy metals in the flesh of the populations from both lagoons to determine the levels of toxicity since this species is one of the highly exploited and consumed fish by local communities in the country.

This study therefore investigates the size distribution, standard length/body weight - gill parameter relationships and levels of arsenic, cadmium, lead and mercury in the black chinned tilapia populations in the Benya and Fosu lagoons in the Central Region of Ghana.

MATERIALS AND METHODS

Study areas

These are Benya (open) and Fosu (closed) lagoons in the Central Regions of Ghana (Lat. 5°5¹N and 5°6¹; Long 1°15¹W and 1°20¹W). These water bodies have been described by [16].

Fish samples collection

Fresh samples of *Sarotherodon melanotheron* were collected from Benya and Fosu lagoons in April, 2011. These were scaled and gutted. In the case of the Benya samples, the opecula were also removed in accordance with the way the fish is prepared before cooking. The specimens were frozen fresh and sent to the Ghana atomic Energy Commission (GAEC) laboratory for the determination of the heavy metals.

Determination of As, Cd, Pb and Hg concentrations in fish samples

Fresh fish Samples were frozen dried for two days using CHRIST BETA 1 – 16 freeze drying machine. The samples were then milled into powder and about 0.5 g of each weighed into a labelled 100 ml polytetraflouroethylene (PTFE) Teflon bombs. Exactly 6.0 ml of concentrated HNO_3 (65 %) and 1 ml H_2O_2 (30 %) were added to each sample in a fume chamber. The samples were then loaded on a microwave carousel. Each complete assembly of the samples was microwave-irradiated for 22 minutes using Milestone microwave Lab station ETHOS 900.MLS – 1200 MEGA. The data for microwave digestion is given in Table 1.

After digestion of the samples, the Teflon bombs mounted on the microwave carousel were cooled in a water bath to reduce internal pressure and allow volatilized material to re-stabilize. Reference Standard (from FLUKA ANALYTICAL Sigma Aldrich Chemie GmbH) for the elements of interest blanks and repeats or duplicates of the samples were digested the same way as the actual fish samples. These served as internal positive controls. The digested samples were made to 20 ml with distilled water and assayed for the presence of arsenic (As), cadmium (Cd), lead (Pb), and mercury (Hg) using VARIAN 240FS atomic absorption spectrometer in an acetylene air flame. Arsenic and mercury were measured in the hydride form.

Table 1: Data for microwave digester

STEP	TIME /min	POWER	PRESSURE	TEMP^{o}C (1)	TEMP^{o}C (2)
1	1	250	100	400	500
2	1	0	100	400	500
3	5	250	100	400	500
4	5	400	100	400	500
5	5	650	100	400	500

Measurement of standard and total lengths of *S. melanotheron*

The total length (TL) of each specimen was determined as the distance from the tip of the snout to the end of the caudal fin. The standard length (SL) of the fish was obtained by measuring the length of the fish from the tip of the snout to the base of the caudal fin. The length parameters were measured to the nearest 0.1cm using the fish measuring board. The body weight (BW) of each specimen was measured to the nearest 0.01g using FEL-500S electronic balance.

Determination of gill length and volume

The gills of each specimen were carefully removed with the aid of a pair of scissors and forceps. The length of gill was determined by measuring the curvature of the gill by means of a thread. The thread was then stretched on a meter rule to obtain the actual gill length. The volume of each gill was determined by the displacement method using a 100 ml measuring cylinder, containing a known volume of water ([13]).

Determination of Condition index

The condition index (CI) of each specimen was calculated using the formula:

$$CI = \frac{W \times 100}{L^3} \qquad [17]$$

Where W = weight (g), and L = total length (cm)

Statistical analysis

The data from this study were subjected to statistical analysis using GenStat (Discovery Edition 3) software. The data were explored using Levene test of normality method. The average heavy metal concentrations in the fish samples were compared using independent t-test method. The correlation coefficients, coefficient of determination and regression analysis were performed using the GenStat software. Spearman's Rho correlation analysis method was employed for the non-parametric portion of the data.

RESULTS AND DISCUSSION

Heavy metal concentrations in fish samples

Results of the heavy metal concentration analysis (Figure 1) indicated that the Fosu lagoon sample had higher concentrations of Cd (0.28 mg/kg) and As (0.144 mg/kg) while samples from Benya had relatively higher concentration of Pb (0.88 mg/kg). The lower cadmium values in the Benya fish may be attributed to a higher salt content of the lagoon since salt-water organisms are known to be more resistant to cadmium poisoning than freshwater organisms [22].

According to [21], the greatest sources of cadmium in humans are seafoods and meats. The Cd levels found in both populations were higher than the reported levels in the Sakumo lagoon population [15] where the maximum value recorded was 0.045 mg/kg, but falls within the permissible contamination limit set by some countries such as Denmark, Colombia and Brazil [24], and above the maximum limit of other countries such as Poland and Bulgaria. The level of mercury concentration in the fish samples from both lagoons were below detection limits (0.001 mg/kg), and far below the WHO maximum permissible limits of 0.005 mg/kg [23].

The results of the independent t-test comparison (Table 1), revealed that, the difference in Cd concentrations in the fish samples from the two populations studied was statistically significant ($p<0.000$) implying a significantly higher levels of Cd in the Fosu lagoon than Benya. However, the differences in the concentrations of Pb and As were not statistically significant ($p>0.05$). The weak correlations ($p>0.05$) between the Cd, Pb and As in each sampling site fish samples suggest that the elements might come from different sources as also reported by [18].

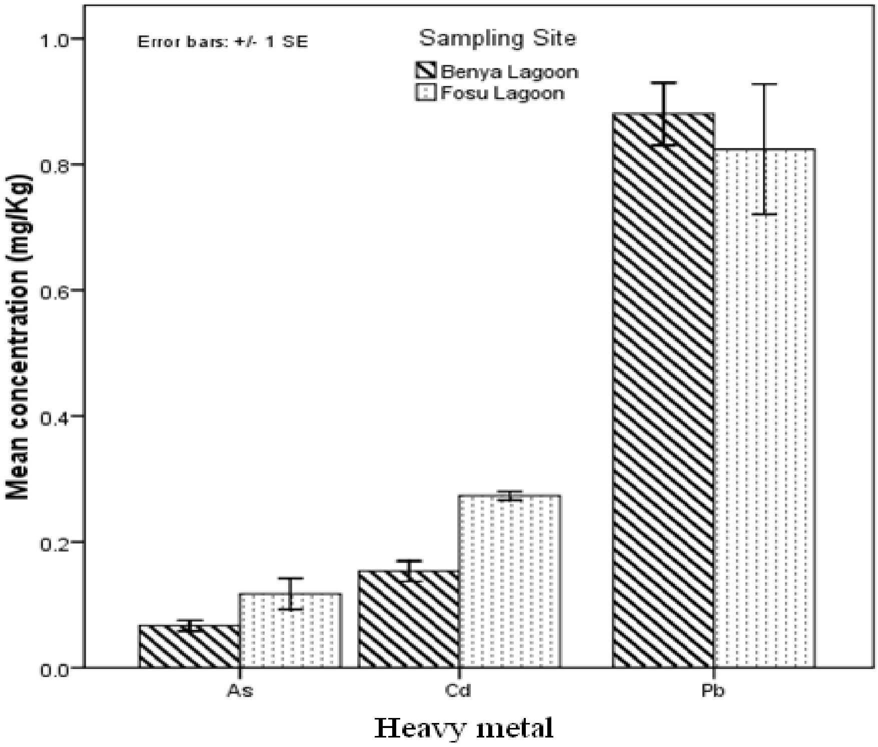

Figure 1: Variations of heavy metal concentrations across sampling sites

Table 2. Descriptive statistics and t-test results of heavy metal concentrations in fish samples

Element	Sampling site	Mean (mg/kg)	Std. Dev.	t	p-value	df
Cd	Benya Lagoon	0.153	0.039	-6.903	0.000	10
	Fosu Lagoon	0.273	0.016			
Pb	Benya Lagoon	0.880	0.121	0.488	0.640	10
	Fosu Lagoon	0.824	0.254			
As	Benya Lagoon	0.067	0.021	-1.949	0.098	10
	Fosu Lagoon	0.117	0.060			

Size distribution of the two populations

The *S. melanotheron* specimens from Benya lagoon were bigger, and ranged from 5.3 cm to 12.2 cm SL while those from Fosu lagoon ranged from 3.7 cm to 6.3 cm SL, with body weight ranging from 6.77 g – 57.40 g and 1.95 g - 8.93 g respectively. As shown in Figure 1, both populations had unimodal length distribution, with the Benya samples dominated by individuals of 7.0-7.9 cm SL class (40.0%) followed by 6.0-6.9 cm SL class (22.2%), while specimens measuring 4.0-4.9 cm SL (49.1%) and 5.0-5.9 cm SL (39.8%) dominated the Fosu catches. The smaller size of the Fosu population could be ascribed to overfishing resulting in stunting as reported in a previous study [6].

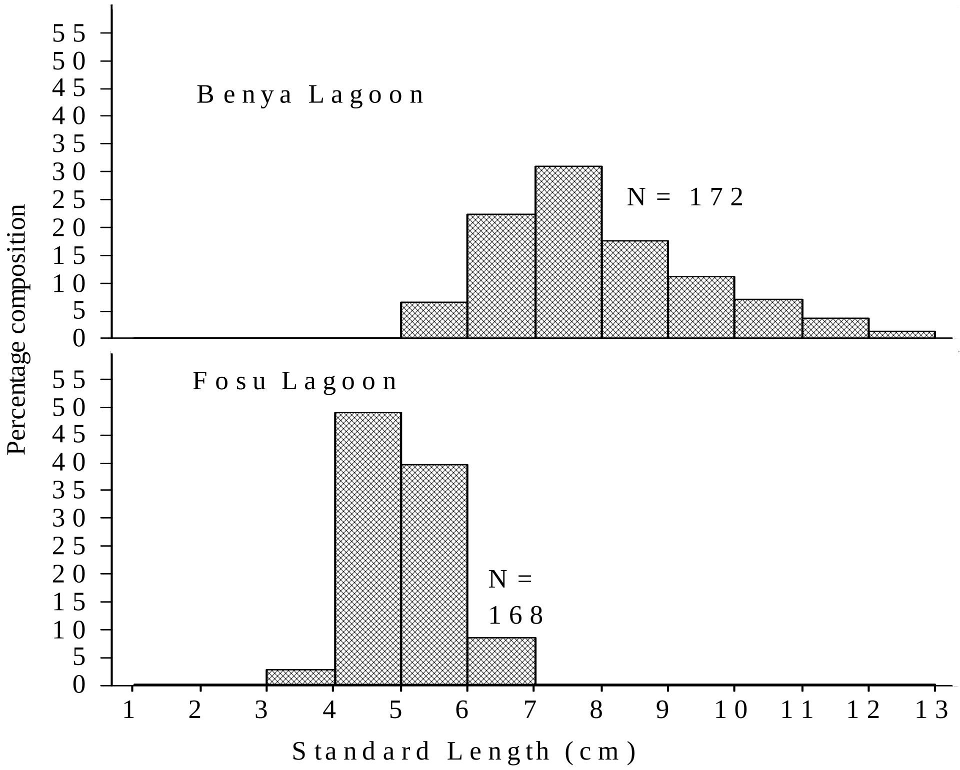

Figure 2: Length-frequency distribution of *S. melanotheron* from two lagoons in Ghana

Relationships between total length, standard length and body weight

There was a very strong positive linear correlation between the standard length and total length of both populations (Figure 2) although the coefficient for Benya sample (r = 0.98) was slightly higher than that of Fosu (r = 0.96). The relations were defined by the linear equations TL (cm) = 1.196 SL (cm) + 0.464 and TL (cm) = 1.306 SL (cm) - 0.14 for the Benya and Fosu population populations, respectively. Fish total length and standard length are strongly correlated in a linear function [13], hence the similarity of these relations in the two populations of the same species is expected.

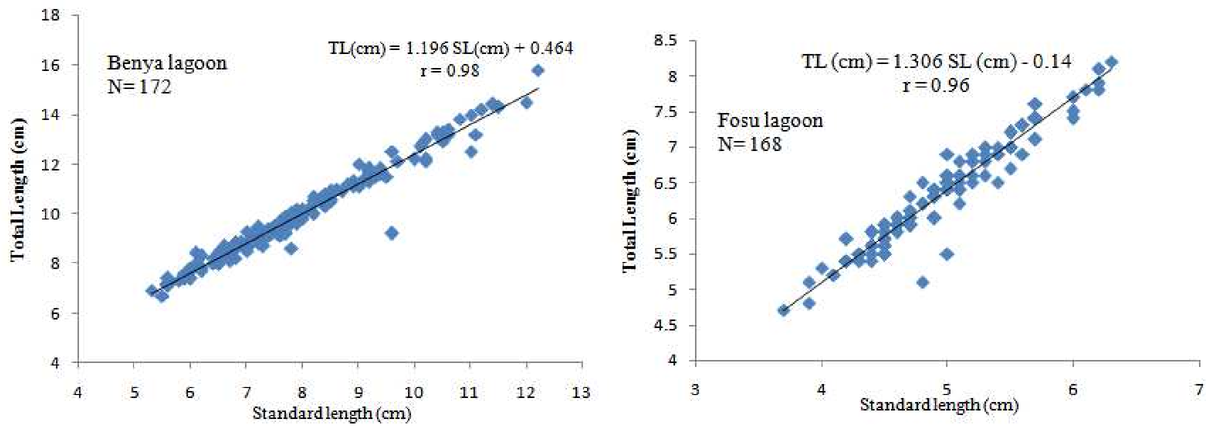

Figure 2: Relationship between total length and standard length of *S. melanotheron* from two lagoons in Ghana

As illustrated in Figure 3, the standard length of both populations correlated strongly with the body weight in a positive curvilinear relationship, given by the power relations BW (g) = 0.098SL $(cm)^{2.54}$ and BW (g) = 0.077SL $(cm)^{2.51}$ for the Benya and Fosu populations respectively, with the correlation coefficient being slightly higher for the former (r = 0.96) than the latter (r = 0.92). However, the regression coefficient (b) did not differ significantly from the isometric growth value of 3.0 in both cases (b= 2.54, t= 1.2, P > 0.05 for Benya; and b= 2.51, t = 0.92, P > 0.05 for Fosu). This indicates that despite the differences in body size, both populations are growing isometrically, with highly minimal effects of the differences in their environmental conditions on the proportional development of their body parts.

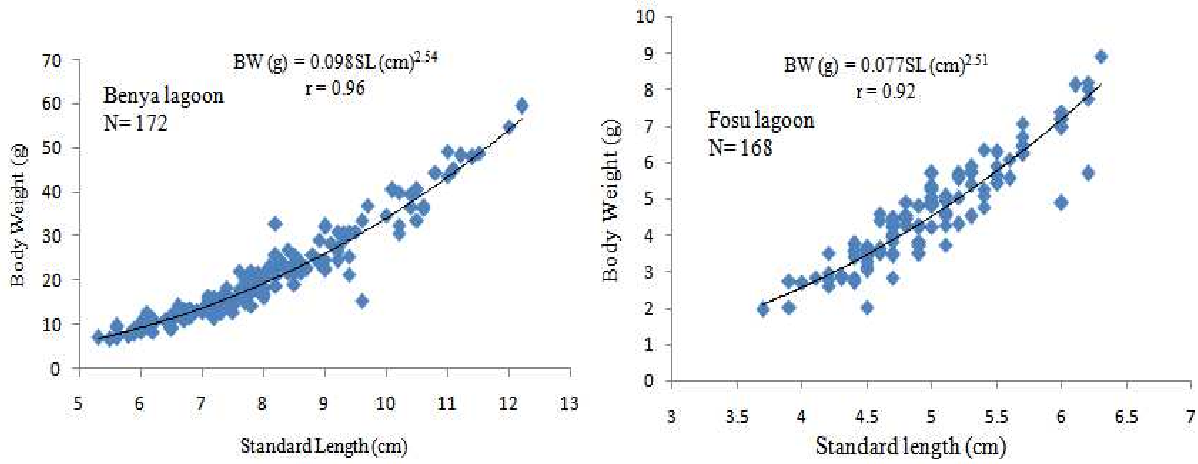

Figure 3: Length-weight relationship of *S. melanotheron* from Benya and Fosu lagoons in Ghana

The instantaneous condition index (K) for the Benya population was found to 3.89 and that of the Fosu population was 3.68. This could imply that both populations were in good condition at the time of sampling. However, a study over a longer period in the future would give a broader understanding of the dynamics of the condition of the populations during the year.

Relationship between standard length, gill length and gill volume

In both populations, there was a weak positive linear correlation between standard length and gill length (r < 0.45) (Figure 4) in equations given as G L (cm) = 0.49 SL (cm) + 0.934 and GL (cm) = 0.539SL (cm) + 1.69 for Benya and Fosu samples, respectively. However, gill volume showed appreciable positive linear correlation with standard length (Figure 5), with the correlation being somehow stronger in the Benya population (r = 0.71) than the Fosu population (r = 0.67). The relations were defined by GV (cm^3) = 0.437SL (cm) - 1.870 for the former population and GV (cm^3) = 0.258 BW (g) - 0.857 for the latter. The linear relations suggest that gill length and volume of the species increases with increase in fish length. ([19], [20] and [13]) have all made a similar finding that longer fish specimens have larger gill length and volume. This is in line with what is expected, since bigger fishes require more dissolved oxygen for respiration and feeding: the two main functions of the gill of a fish. However, the present study has additionally shown that increase in fish length has a stronger effect on the gill volume than the gill length.

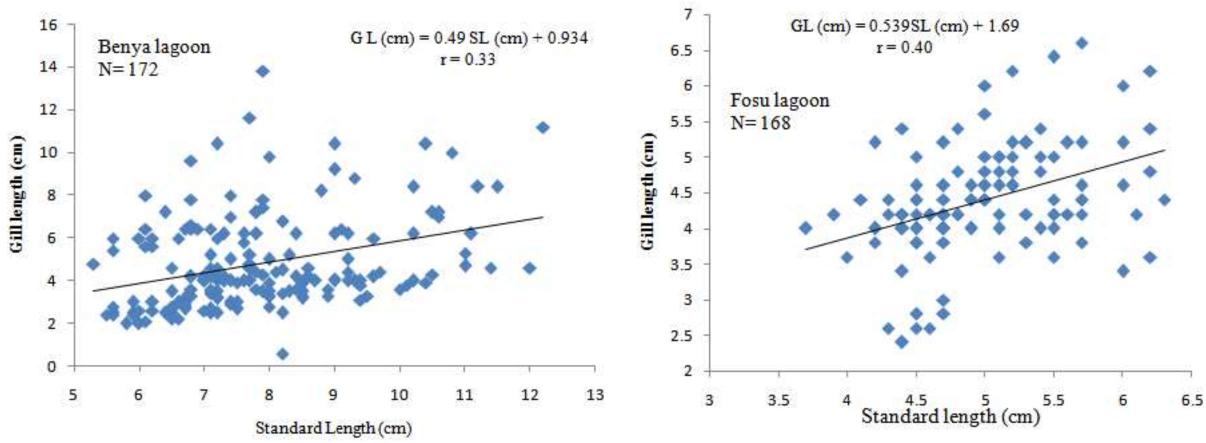

Figure 4: Standard length- gill length relationship of *S. melanotheron* from Benya and Fosu lagoons in Ghana

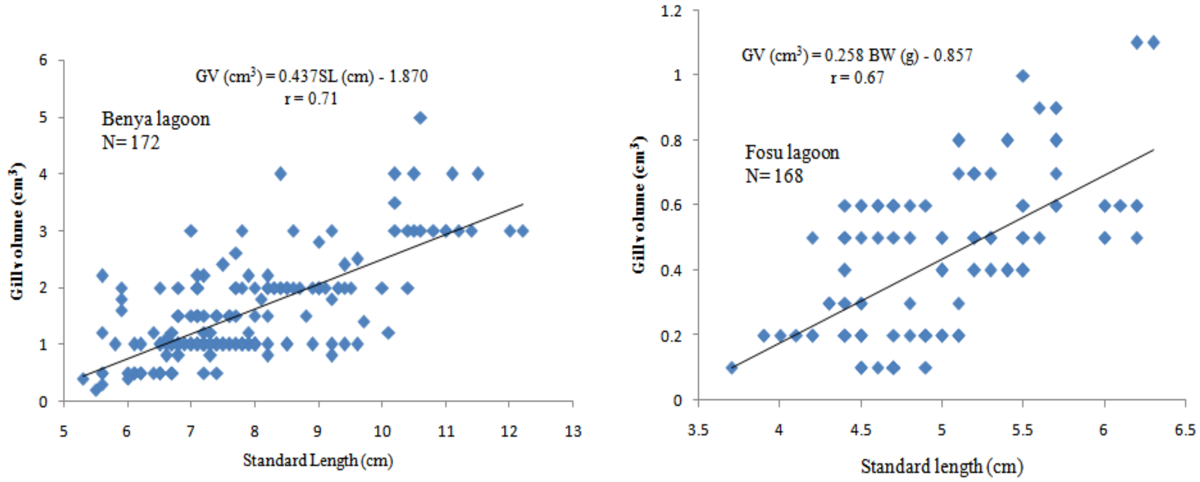

Figure 5: Standard length- gill volume relationship of *S. melanotheron* from Benya and Fosu lagoons in Ghana

Relationship between body weight, gill length and gill volume

Gill length correlated weakly with body weight also ($r < 0.5$) (Figure 6). The relationship as linear, described as GL (cm) = 0.077BW (g) + 3.27 for the Benya lagoon population and GL (cm) = 0.184BW (g) + 3.532 for the Fosu lagoon population. Gill volume on the other hand, showed a considerably strong linear relationship with body weight in the Benya lagoon population [GV cm^3 = 0.060SL (cm) + 0.364; r = 0.70] (Figure 7) but this correlation tended to be moderate for the Fosu lagoon population [GV (cm^3) = 0.093 BW (g) + 0.05; r = 0.54].

According to [25] gills grow in fish in proportions to powers of their body weight ranging from 0.5 to 0.9. Although this power relation was not observed in the present populations, the stronger correlation between body weight and gill volume as well as standard length and gill volume buttresses the point that fish growth has a larger influence on the volume of the gill than the length. This may be an adaptation to enhance respiratory and feeding activities.

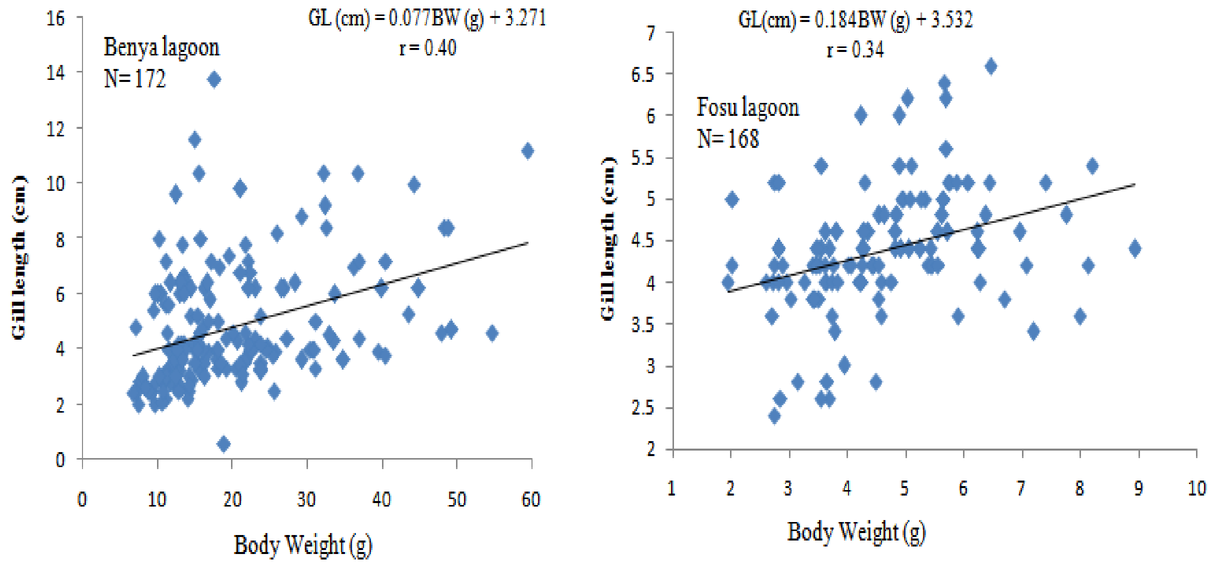

Figure 6: Body weight- gill length relationship of *S. melanotheron* from two lagoons in Ghana

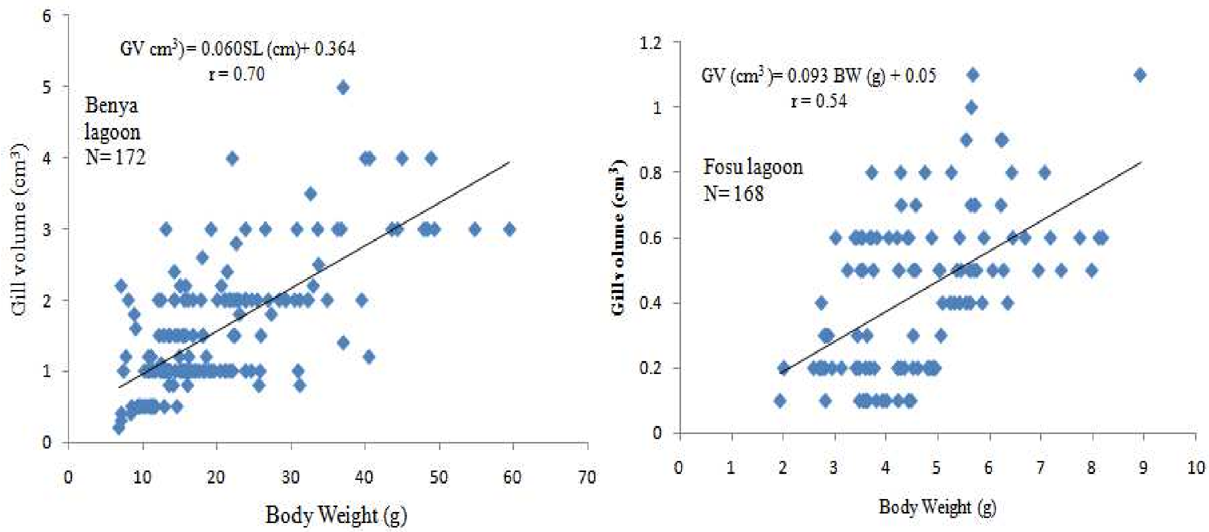

Figure 7: Body weight- gill volume relationship of *S. melanotheron* from two lagoons in Ghana

CONCLUSION

In conclusion, in spite of the generally bigger sizes of *S. melanotheron* in the Benya (open) lagoon than the Fosu (closed) lagoon, both populations exhibited isometric growth. Minimal differences were observed in the standard length/body weight - gill parameter relationships in both populations suggesting that differences in the environments of 'open' and 'closed' lagoons have no significant effects on the morphological development of the inhabitant black-chinned tilapia. Standard length and body weight of the fish were more correlated with gill volume than gill length. The results also revealed that sample from Fosu lagoon had higher concentrations of Cd and As while that from Benya had relatively higher concentration of Pb. The Cd levels found in both populations fall within the permissible contamination limit set by some countries and above that of others, while mercury concentrations were far below the WHO maximum permissible limits It is envisaged that the findings of this study will enrich the understanding of how aquatic organism could be affected due to habitat disturbances as a result of anthropogenic activities.

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