Peer-reviewed version available at *Fisheries and Aquatic Sciences* **2019**, 31; doi:10.1186/s41240-019-0146-z

Comparative Assessment of Age, Growth and Food Habit of the Black-Chinned Tilapia, *Sarotherodon melanotheron* (Rüppell, 1852), from Closed and Open Lagoons, Ghana

Cephas Kwesi Zuh [1], Seth Mensah Abobi [1, 2,*], Benjamin Betey Campion [3]

[1] *Universität Bremen, Fachbereich 02 Biologie/Chemie, Bremen, Germany*

[2]*Department of Fisheries and Aquatic Resources Management, University for Development Studies, Ghana*

[3]*Faculty of Renewable Natural Resources, Kwame Nkrumah University of Science and Technology, Ghana*

**Corresponding author: Universität Bremen, Fachbereich 02 Biologie/Chemie, Bremen, Germany*

Tel.: +49(0)421 238 00-183 fax*:* +49(0)421 238 00-30

E-mail addresses: abobi@uni-bremen.de, mabobi@uds.edu.gh

Abstract

The black-chinned tilapia *Sarotherodon melanotheron* is the most abundant fish species in the Nakwa (a closed lagoon) and Brenu (an open lagoon) in the Central region of Ghana. Aspects of the life history characteristics and the ecology of the fish populations in both lagoons were studied to assess the bio-ecological status of this important resource. The estimated von Bertalanffy growth parameters were $L_\infty = 12.04$ cm; $K = 2.76$ year^{-1} for the Nakwa Lagoon samples and $L_\infty = 13.44$ cm; $K = 3.27$ years^{-1} for Brenu Lagoon samples. Daily otolith incremental rate ranged from 0.01-0.03mm per day and 0.01-0.02mm per day for Nakwa and Brenu lagoons respectively. Stomach content analysis of the fish samples revealed that the species are planktivorous and the range of food varied between the lagoons. Green algae were the most prevalent food item in the stomachs of the fish samples from Nakwa with the frequency of 69% while diatoms (80.5%) were most prevalent phytoplanktonic food item in for the fish in Brenu lagoon. The results of this study of *Sarotherodon melanotheron* from the two lagoons and can be used to improve on management policies, maximize yield and to sustain the fishery resources.

Keywords: Ghana; lagoon; tilapia; otoliths; age; growth; food.

Peer-reviewed version available at *Fisheries and Aquatic Sciences* **2019**, 31; doi:10.1186/s41240-019-0146-z

1.0 Introduction

Ghana's coastline is endowed with many lagoons which support the livelihood of adjacent local communities (Dankwa et al. 2004). Cichlids, especially the tilapias, are one of the most important fish resources endemic to the aquatic ecosystems of tropical Africa (Panfili et al. 2004). They are known to be continuous spawners with multiple reproduction rates (Legendre and Ecoutin 1989, Jiménez-Badillo 2006) and feed on a range of plankton organisms and detrital matter (Kone and Teugels 2003; Ofori-Danson and Kumi 2006). Tilapias constitute an important food source, providing protein and also play a very important role in the economy of coastal inhabitants, especially during the off season for marine fishing (Blay and Asabere-Ameyaw 1993). Due to their potential to adapt and thrive in varying environmental conditions, they have either invaded or have been introduced into several water bodies in various regions around the world (Lazard 1990). The *Sarotherodon melanotheron* is a tilapia confined to brackish water in lagoons and estuaries (Myers et al. 2018). The species, though not developed for aquaculture, are important fishes in the commercial and subsistence fisheries of many West African lagoons Ekau and Blay (2000) and constitute a higher proportion of total catch of about 50 – 95% (Blay and Asabere-Ameyaw 1993; Koranteng et al. 2000; Panfili et al. 2004).

Age information is fundamental in the study of the impact of environmental factors on growth and survival, particularly of the juvenile stages of fish (Ekau and Blay 2000). Labropoulou and Papaconstantinou (2000) also posited that age information is valuable for studying population characteristics such as growth, recruitment, mortality, and reproduction, and it is often required before more detailed studies on life history strategies and ecology can be carried out. Use of otolith in ageing fish is often more reliable such that the information on age and growth is used to determine the effect of fishing on the stocks, the efficacy of management policies, to understand life history events, and to maximise yield while still ensuring the sustainability of the resource (Campana and Jones 1992). Otoliths have been widely used for estimating fish age since the first description of daily micro-increments by Pannella (1971). Examining the otolith microstructure provides a dated record of past fish growth which has been used for age determination and as a source of information on growth rate and life history (Aguilera et al. 2009). Validation of daily deposition of otolith is required before it can be used for the determination of age and growth. Many scientists have validated daily micro-increment of otolith of different fishes including horse mackerel (Waldron and Kerstan 2001), tilapias (Panfili and Tomas 2001), and tropical reef fish, *Macentrus mollucensis* (Fowler 1990).

The Nakwa and Brenu lagoons are important lagoons that support local artisanal fisheries. (Ekau and Blay 2000) found a one to one relationship between days of rearing and daily increment in the otoliths of *S. melanotheron* from Fosu and Benya lagoons and Kakum estuary of Ghana, thus verifying daily deposition. The use of otolith, however, to accurately estimate and also make a comparison of the age and growth of this important resource in, and between lagoons in Ghana with different characteristics and conditions is very limited. Fishes in their natural environment are constrained by changing environmental conditions influencing the metabolic rates and resulting in a slowing of growth rate (Gauldie 1990). Fishes show differences in growth patterns which are caused by several intrinsic and extrinsic factors such as environmental temperature, food availability, metabolic activity and reproductive activity which can subsequently produce a different budget of anabolism and catabolism reflected in the L_∞ and K parameters (Isaac 1990).

Feeding experiments conducted on different fishes revealed that food intake and food deprivation have an influence on microstructure deposition; and increment width and periodicity appear to be sensitive indicators of recent feeding history in fish larvae and juveniles (McCormick and Molony 1992; Molony 1996; Massou et al. 2002). Preliminary investigations

Peer-reviewed version available at *Fisheries and Aquatic Sciences* **2019**, 31; doi:10.1186/s41240-019-0146-z

of these two lagoons revealed differences in their characteristics and extent of the catch of the fishery resources. There is also generally limited information on age and growth of these important species which often are very important for effective management of the resources. This study, therefore, sought to use fish size, otolith size and age as a proxy to determine the age and growth of *Sarotherodon melanotheron* from the two lagoons and to assess the range of food composition of the species.

2.0 Materials and Methods

2.1 Description of the study areas

This study was carried out on the Nakwa and Brenu Lagoons in Ghana (Figure 1). The Nakwa Lagoon lies adjacent to the Ekumfi Nakwa fishing community. It is located on 5° 13' 00" N, 0° 54' 00" W. The lagoon is a relatively shallow lagoon with a surface area of about 3.6 km^2. It opens into the sea through major parts of the year and therefore under both tidal influence from the sea and freshwater discharge from the Ochie River. The mouth is frequently dredged to allow for passage of outboard motor-powered canoes. On the periphery of this lagoon are mangroves, shrubs and large tracts of marshland mostly covered with *Paspalum vaginatum*. Besides fishing in the adjacent sea, residents of Nakwa and Ekumpuano derive much of their livelihood from this lagoon. The two communities have populations of about 5,859 and 1,779 respectively (Ghana Statistical Service 2002).

Brenu lagoon, on the other hand, is located on 5° 4' 60" N, 1° 25' 0" W near Brenu Akyenim. The lagoon covers an area of 0.82 km^2. The Brenu lagoon is closed and cut off from the adjacent sea by a sand bar for the greater parts of the year and contact with the sea is re-established during the rainy season, either naturally or artificially, to prevent flooding of nearby villages and farms. Dilution is mainly from rainfall and small creeks that feed into it. Therefore, the

Peer-reviewed version available at Fisheries and Aquatic Sciences 2019, 31; doi:10.1186/s41240-019-0146-z

lagoon experiences hypersaline conditions in the dry season due to increased evaporation (Yankson 1982). It is bordered by large strands of mangroves, mostly *Avicennia* sp. and small patches of marsh. Fishing in the lagoon is seasonal. Residents of the nearby communities of Brenu Akyenim and Ampenyi-Ayensudo exploit resources from this lagoon for their livelihood mostly in the dry season when farm activities are minimal. The biggest village which is Ampeny-Ayensudo has a population size of 1,468 (Ghana Statistical Service 2002).

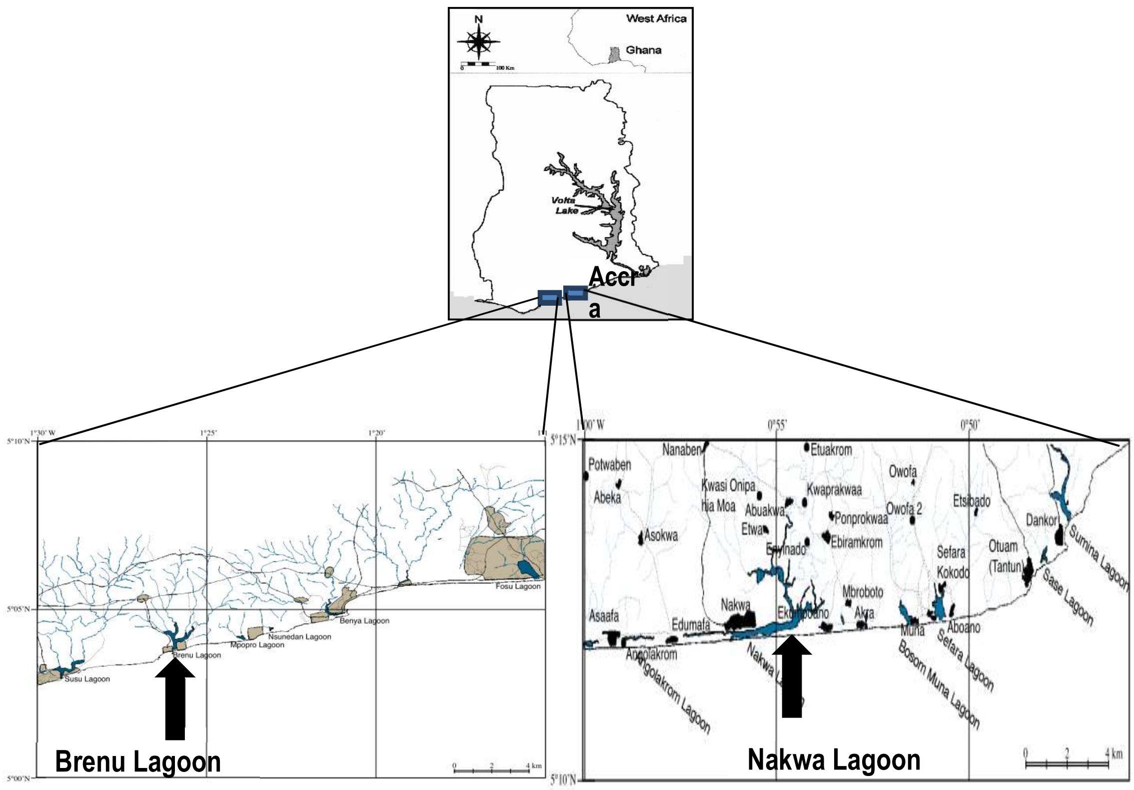


Figure 1. Map of Ghana's coastline showing Brenu and Nakwa lagoons

2.2 Data Collection

Fish samples from the two lagoons were bought from fishermen immediately they were landed. Fish samples from both lagoons were collected between September 10 and October 26, 2010. The samples were kept chilled in sealed poly bags to reduce digestion of stomach contents to the minimum while transporting them to the laboratory. In the laboratory, total lengths (TL) of

Peer-reviewed version available at Fisheries and Aquatic Sciences 2019, 31; doi:10.1186/s41240-019-0146-z

the fish specimens were measured from the tip of the snout (mouth closed) to the extended tip of the caudal fin. Standard length (SL) was measured from the tip of the snout to the caudal peduncle. The lengths were taken with measuring board to the nearest 0.1cm. Body weights of individual fishes were measured to the nearest 0.01g with an electronic balance after wiping the water and other particles from the body surface. A total of 402 fish samples from both lagoons were measured, comprising 209 from Nakwa lagoon and 176 from Brenu lagoon.

After length and weight measurements, fishes were then gutted for examination of stomach contents. The extracted stomachs were stored in 10% formalin to preserve the food items. At the Biolab of Center for Tropical Marine Ecology, the samples were removed from the formalin solution, split open on a petri dish and contents examined using a binocular microscope. With the help of identification manuals, organisms in the stomach were identified and grouped into broad categories of food items. From each of the lagoons, forty-two (42) stomachs were analysed.

Pairs of sagittal otoliths of the fish were extracted using instruments from dissection kit. This involved completely removing the heads of the specimen and then dividing it horizontally to separate the head into upper and lower sections. Otoliths were extracted with forceps after carefully teasing off the flesh, cleaned in 70% alcohol, dried and stored in capped vials for preparation and examination. One hundred and thirty-eight pairs were sorted for examination and 110 samples were used for analysis.

Simon et al. (2010) found no difference in shape and size between left and right otoliths and therefore samples of right-sided otoliths of the 138 pairs were sorted under the dissecting microscope and used for the ageing and growth assessment. Otolith samples were weighed to the nearest 0.1mg with an electronic balance and the length on the longest axis measured to the nearest 0.001 mm using a dissecting microscope at x250. Measured otoliths were embedded in

Peer-reviewed version available at Fisheries and Aquatic Sciences 2019, 31; doi:10.1186/s41240-019-0146-z

epoxy resin block, and sectioned with a linear precision saw (Buehler Isomet 4000). Sectioned otoliths were mounted on microscope slides with a transparent glue, ground on wet waterproof silicon carbide abrasive paper (FEPA P # 1000, 1200, 2400 and 4000 grits) with intermittent monitoring under the light microscope till the nucleus was reached, polished with Buehler Cerium oxide polishing compound and etched with 2% ethylenediamine tetra acetate (EDTA) for 5 minutes and then rinsed with distilled water. This process enhanced the visibility of growth rings making them more readable under the microscope.

The otoliths were analysed under the microscope and photographed with a digital microscope camera (AxioCam ICc 1) and AxioVision 4.8 software. Daily increment counts were carried out on the photographed images using the Image-Pro Plus analysis software (version 5). Daily growth increment consisted of light and dark zones visible as the area from the beginning of a dark band to the beginning of the next dark band (Geffen 1982) and these increment counts were used to estimate the age of the fishes. Growth increments were counted from the nucleus to the edge of the otolith. Otolith readings were carried out thrice, without reference to the length and weight of the fishes, to minimise errors and also eliminate biases that might be introduced during reading.

2.3 Statistical Analysis

The length-weight relationship of the fish species was analysed using the equation: $\mathbf{W = aL^b}$, where W = weight (g), L = standard length (cm), a = constant, b = growth exponent. The condition factor, to estimate the wellbeing of the fishes, was calculated with the equation $\mathbf{K = 100*W/(L^b)}$ where K = condition factor, W = body weight, L = standard length and b = length exponent (slope). For each species, the slopes of length-weight regressions were compared to 3 using student's t-test to determine whether species grew isometrically. The von Bertalanffy growth model of the form: $\mathbf{L_t=L_\infty (1-e^{-k (t-to)})}$, where $\mathbf{L_t}$ is the asymptotic length, **k** is the growth coefficient and $\mathbf{t_o}$ being the age at length zero, was used to analyse the relations between length and age of the fish samples from the two lagoons. Estimation of $\mathbf{t_o}$ was performed using the von Bertallanffy plot. An error level of 0.05 was used for all statistical tests. The percentage occurrence method was used to analyse the stomach content of the fish specimen. All statistical analyses were performed in the R environment for statistical computing (R Core 2018).

3. Results

The standard lengths of the fish samples were in a range of 3.0 - 8.6cm and 4.2 - 9.9cm for Nakwa and Brenu lagoons respectively (Figure 2). The length frequency plot shows that the most abundant size class from Nakwa lagoons is 3.6 - 4.0cm but size classes of 4.1 - 4.5, 4.6 - 5.0, 5.1 - 5.5 and 5.6 – 6.0cm constitute some substantial proportions of the population of the catch. Percentage frequency of the fish samples decreases with increasing size classes from 3.5 - 4.0cm. Fishes samples with sizes between 5.1 cm and 9.0cm were observed to constitute quite a substantial proportion of the fish caught in the Brenu lagoon. The results also show that fishes from Brenu lagoon (mean ± SD = 6.86 ± 1.16cm) are generally of bigger sizes compared with the population from Nakwa lagoon (mean ± SD = 4.62 ± 0.95cm).

Peer-reviewed version available at Fisheries and Aquatic Sciences 2019, 31; doi:10.1186/s41240-019-0146-z

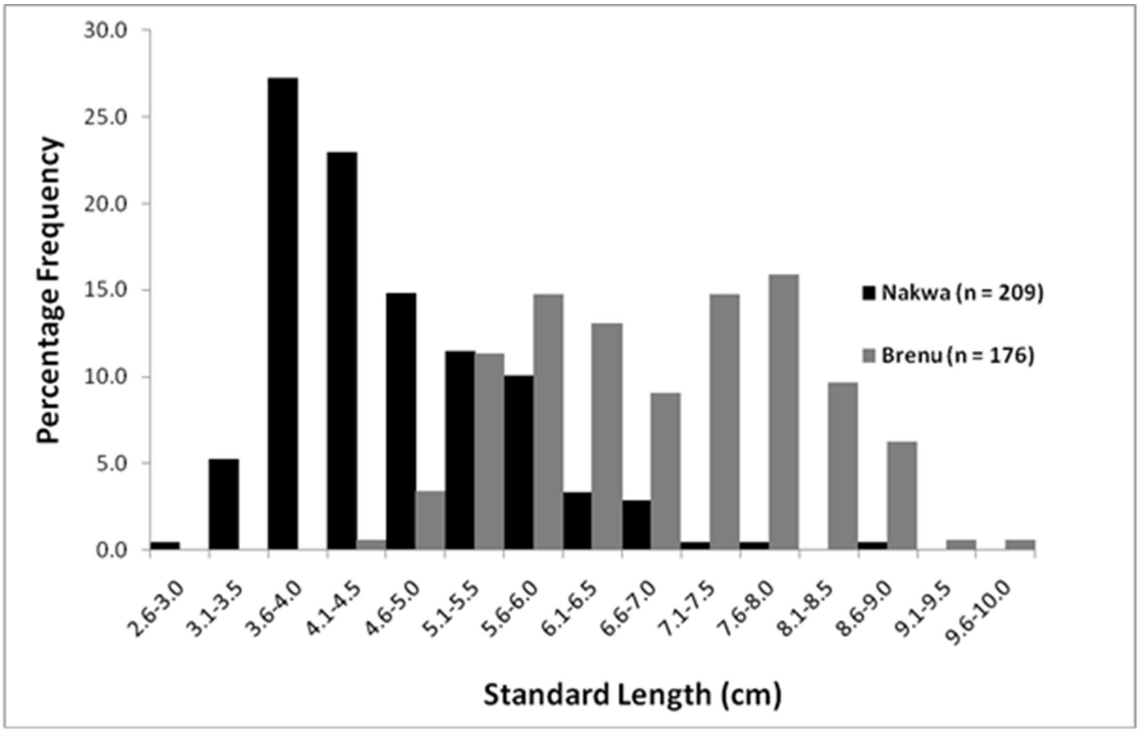


Figure 2. Length frequency distribution of *Sarotherodon melanotheron* from Nakwa and Brenu lagoons

The length-weight relationship for fish samples from the two lagoons (Figure 3) showed very high coefficients of determination, with $r^2 = 0.971$ for Nakwa and 0.968 for Brenu lagoons. The values of the length exponent 'b' of the length-weight relationship of the fish samples, which give an indication of the increase in fish size in relation to body weight, were found to be 3.002 for Nakwa and 2.839 for Brenu lagoons. The b value of the relationship for the population at Brenu was statistically different from 3 (t-test: $p<0.001$), indicating the predominance of the allometric relationship of weight and standard length. This relationship was negatively allometric (i.e., $b<3$), while the population at Nakwa lagoon exhibited an isometric growth pattern (t-test: $p>0.05$) (Table 1). The length-weight relationships of fish samples from the two lagoons were significantly different at $p< 0.05$.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 February 2019 doi:10.20944/preprints201902.0106.v1

Peer-reviewed version available at *Fisheries and Aquatic Sciences* **2019**, 31; doi:10.1186/s41240-019-0146-z

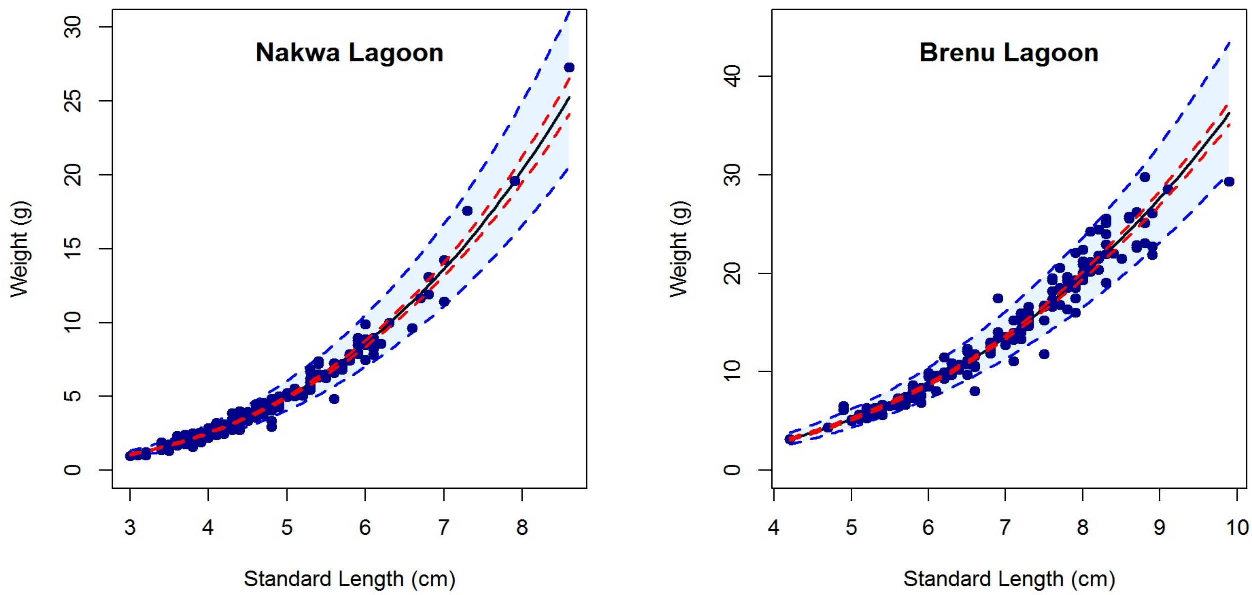


Figure 3. Length-weight data with the best-fit models (solid lines), 95% confidence bands (red dashed lines) and 95% prediction bands in the blue zones for *Sarotherodon melanotheron* from Nakwa and Brenu lagoons

Table 1. Length-weight, otolith length-otolith weight, and otolith length-standard length relationships of *Sarotherodon melanotheron* from Nakwa and Brenu Lagoons

Models	**Nakwa**	**Brenu**
Length-weight relationship: $FW=aSL^b$	$0.039SL^{3.002}$	$0.054SL^{2.839}$
a (Cl95%a)	0.035-0.044	0.046-0.062
b (Cl95%b)	2.93-3.07	2.76-2.92
r^2	0.971	0.968
Growth Type	Isometric	Allometric (-)
N	209	176
Otolith length and otolith weight: $OW=aOL^b$	$0.1724OL^{2.70}$	$0.2547OL^{2.50}$
a (Cl95%a)	0.1577-0.2016	0.2176- 0.2981

b (Cl95%b)	2.56-2.84	2.35-2.66
r^2	0.9507	0.9498
Otolith length and standard length: $SL = aOL^b$	$1.8327OL^{0.9815}$	$0.8611OL^{1.6598}$
a (Cl95%a)	1.6743-2.0060	0.7756-0.9560
b (Cl95%b)	0.8814-1.0816	1.5554-1.7642
r^2	0.8245	0.9495

FW: Fish weight; SL: Standard length; OL: Otolith length; OW: Otolith length

The condition factor of fish samples from Brenu lagoon (5.40 ± 0.48) was significantly higher than the value found for samples from Nakwa lagoon (3.96 ± 0.39) ($p<0.05$) (Table 2). The condition factor for fish samples from Nakwa lagoon, however, showed very minimal changes across the fish sample sizes. The mean values ranged between 3.85 ± 0.31 at a length of 6.5cm to 4.27 ± 0.00 at the size of 8.5cm.

Table 2. Condition Factor of *Sarotherodon melanotheron* from Nakwa and Brenu Lagoons

Standard Length (cm)	Nakwa		Brenu	
	Mean ± SD	Confidence Limits	Mean ± SD	Confidence Limit
2.6-3.0	3.55 ± 0.00			
3.1-3.5	3.74 ± 0.54	3.376, 4.094		
3.6-4.0	4.05 ± 0.39	3.947, 4.153		
4.1-4.5	3.89 ± 0.37	3.788, 4.001	5.37 ± 0.00	
4.6-5.0	3.97 ± 0.43	3.814, 4.128	5.85 ± 0.78	4.955, 6.753
5.1-5.5	4.07 ± 0.32	3.933, 4.203	5.28 ± 0.29	5.143, 5.416
5.6-6.0	3.90 ± 0.36	3.739, 4.066	5.27 ± 0.36	5.122, 5.415
6.1-6.5	3.76 ± 0.21	3.561, 3.951	5.48 ± 0.37	5.316, 5.638
6.6-7.0	3.76 ± 0.31	3.372, 4.151	5.38 ± 0.66	5.019, 5.745

Peer-reviewed version available at Fisheries and Aquatic Sciences 2019, 31; doi:10.1186/s41240-019-0146-z

7.1-7.5	4.50 ± 0.00		5.34 ± 0.47	5.151, 5.534
7.6-8.0	3.96 ± 0.00		5.52 ± 0.41	5.357, 5.683
8.1-8.5			5.56 ± 0.47	5.315, 5.809
8.6-9.0	4.3 ± 0.00		5.20 ± 0.53	4.829, 5.575
9.1-9.5			5.39 ± 0.00	
9.6-10.0			4.37 ± 0.00	

Otoliths of fish samples from the two lagoons, used for analysis, ranged in size from 1.70 - 3.72mm (n = 82) for Nakwa lagoon and 2.49 - 4.67mm (n = 28) for Brenu lagoon. A high correlation was found between Otolith size and otolith weight and also between otolith size and fish size (Figure 4a and b). Allometric growth coefficients were found to be 2.5043 (Brenu) and 2.7003 (Nakwa) for otolith size - otolith weight, and 1.6598 (Brenu) and 0.9815 (Nakwa) for otolith size - fish size relationships respectively (Table 1).

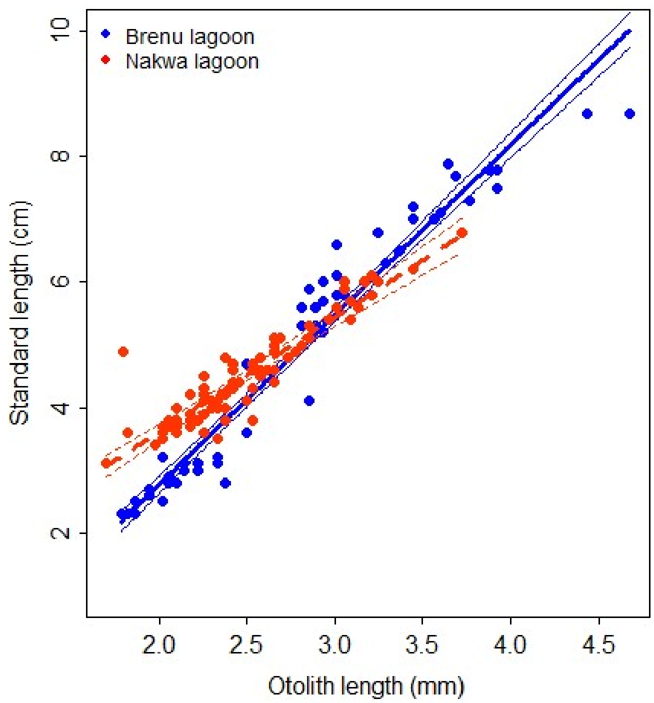


Figure 4a. Relation of otolith length and standard length of *Sarotherodon melanotheron* from Nakwa and Brenu lagoons

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 February 2019 doi:10.20944/preprints201902.0106.v1

Peer-reviewed version available at *Fisheries and Aquatic Sciences* **2019**, 31; doi:10.1186/s41240-019-0146-z

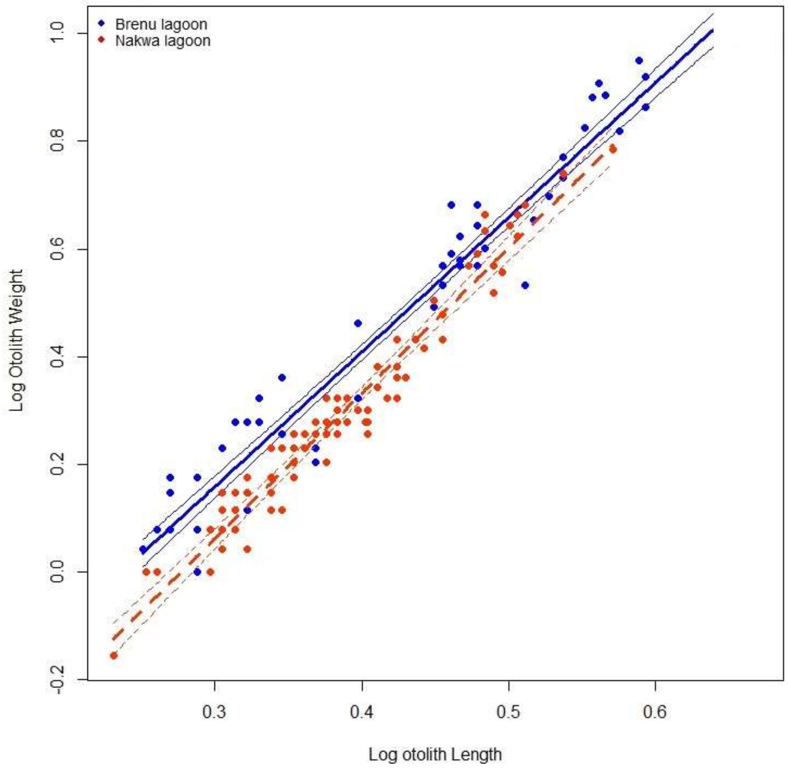


Figure 4b. Relation of (a) otolith length and otolith weight of *Sarotherodon melanotheron* from Nakwa and Brenu lagoons

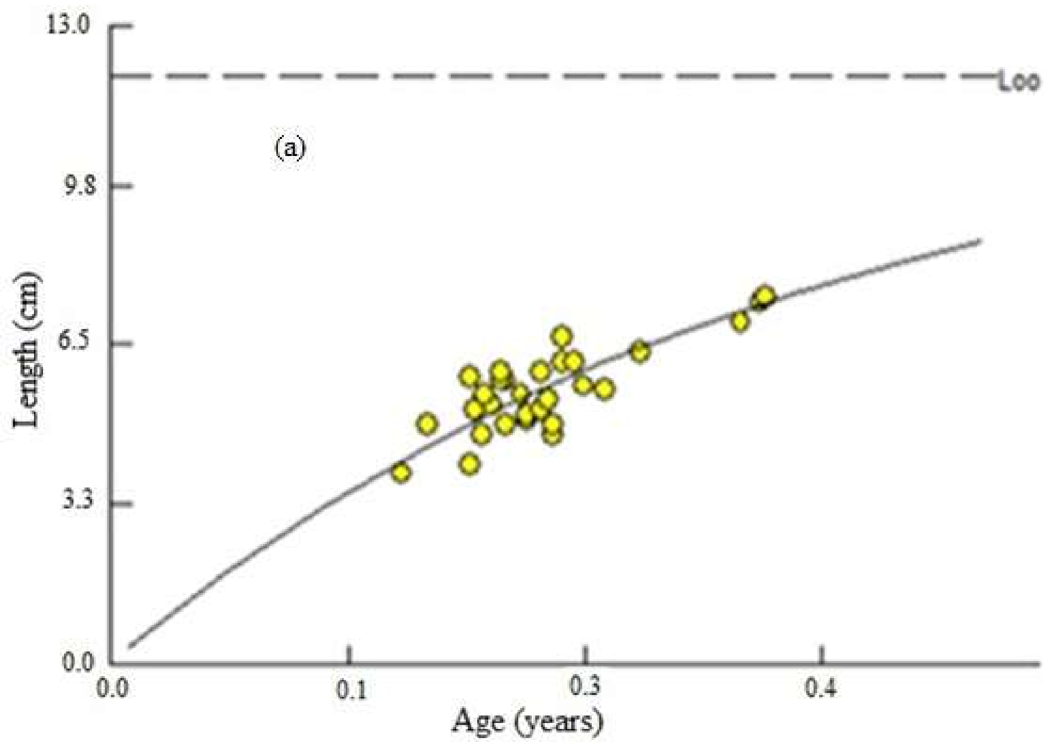
Out of the 110 samples of otoliths prepared for age estimation, 40 (Nakwa = 29; Brenu = 11) were selected for analysis. The rest were rejected due to preparation errors, inability to visualise and counts the rings and also inconsistency in all the otolith readings. Otoliths accepted showed clear zones with each zone consisting of opaque and translucent bands. The estimated growth parameters for samples from both lagoons were L_∞ = 12.04 and 13.44cm TL, t_o = -0.02 and 0.02 year, K = 2.76 and 3.27 years-1 from Nakwa and Brenu Lagoons respectively (Table 3, Figure 5).

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 February 2019 doi:10.20944/preprints201902.0106.v1

Peer-reviewed version available at *Fisheries and Aquatic Sciences* **2019**, 31; doi:10.1186/s41240-019-0146-z

Table 3. Estimates of the parameters of the von Bertalanffy growth equation of *Sarotherodon melanotheron* from Nakwa and Brenu Lgoons and their estimated standard errors

Samples	**Parameters**	**Estimates**	**S. E**
Nakwa Lagoon	L_∞	12.04 cm	10.07
	K	2.76 year^{-1}	4.62
	t_o	-0.02 year	-
Brenu Lagoon	L_∞	13.44 cm	25.91
	K	3.27 year-^{1}	15.89
	t_o	0.02 year	-



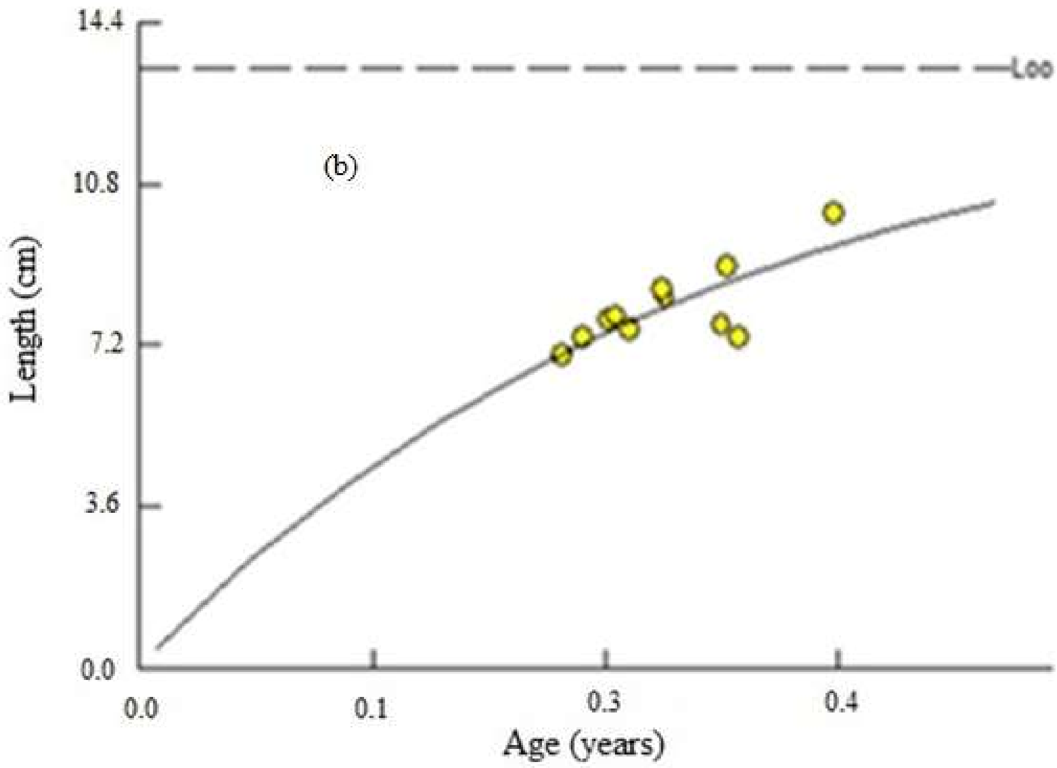


Figure 5. Length-at-age plot for *Sarotherodon melanotheron* from (a) Nakwa and (b) Brenu lagoons respectively

The daily increment rates of *S. melanotheron* ranged between 0.01 and 0.03mm day^{-1} in Nakwa lagoon and 0.01 to 0.02mm day^{-1} in Brenu lagoon (Figure 6). In both lagoons, there was an initial increase in the daily increment rings over the first 20 days. In Nakwa lagoon, increment remained constant over the next 50 days and then increased over the 60th day. An unstable pattern characterised the increment over the rest of the days with the highest increment occurring over the 120th day. In Brenu lagoon, however, there was a rise over the 60th day and a fall on the 90th day. Increment rose to the maximum near the 100th day and became relatively stable to the last day.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 February 2019 doi:10.20944/preprints201902.0106.v1

Peer-reviewed version available at *Fisheries and Aquatic Sciences* **2019**, 31; doi:10.1186/s41240-019-0146-z

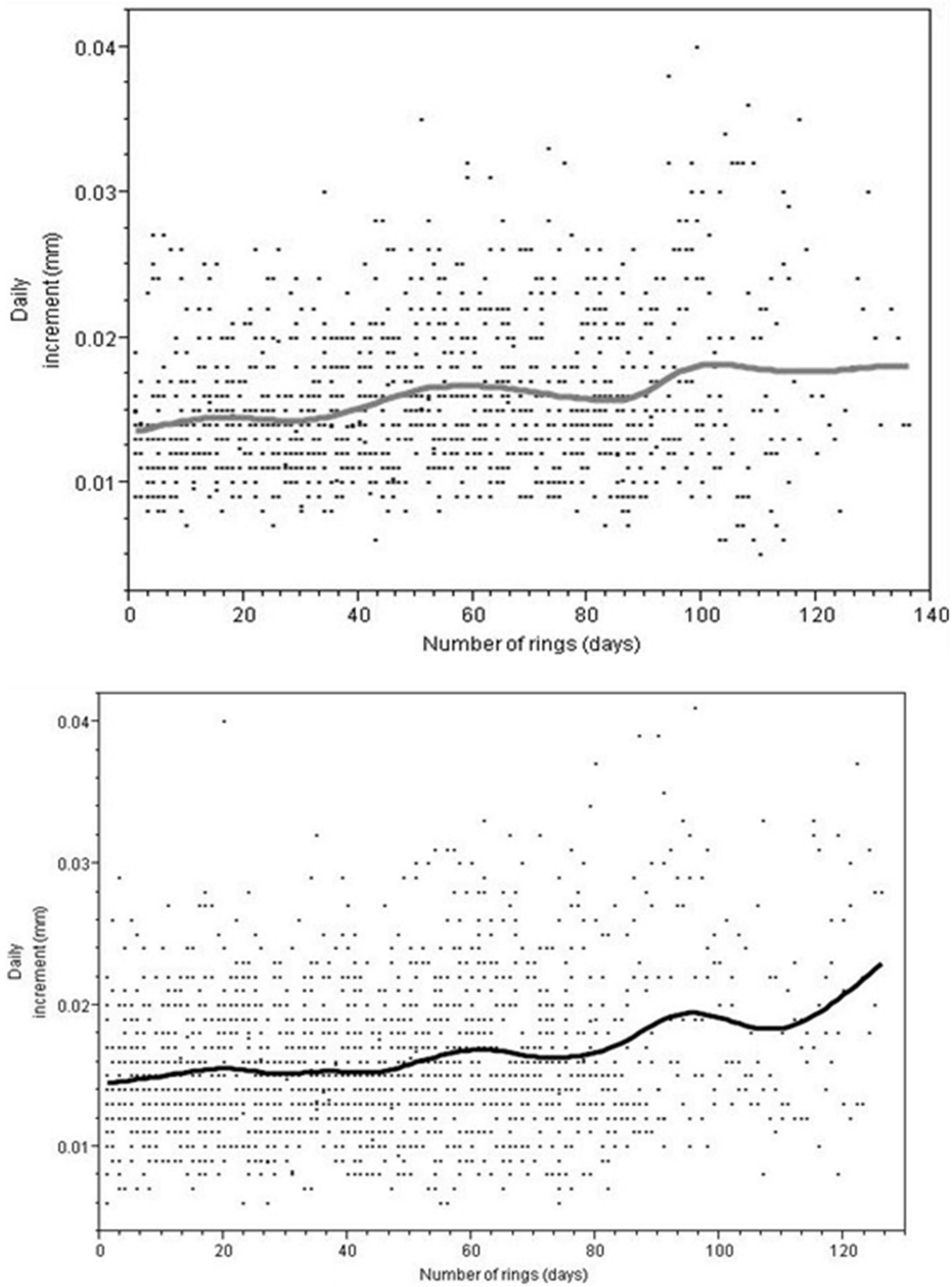


Figure 6. Relationship between daily otolith increment (mm) and number of rings (days) for *Sarotherodon melanotheron* from (a) Nakwa lagoon (n = 20) and (b) Brenu lagoon (n = 11)

A total of 83 stomachs were examined for categories of food items (Table 4). This comprised 42 and 41 stomachs of fish samples from Nakwa and Brenu lagoons respectively. Green algae were the commonest phytoplankton food items that occurred in the stomachs of fish samples from Nakwa lagoon (69.0 %), compared to Brenu lagoon (26.8%). *Spirogyra* sp., *Geminella* sp. and *Mougeotia* sp. were mostly encountered in the fish samples from Nakwa while few species of *Euglena*, *Microspora*, *Chrysoccocus,* and *Treubaria* were also seen (Table 3). *Elakatrothrix* and *Oocystis* spp. were seen in samples from Brenu lagoon in addition to *Microspora, Spirogyra* and *Euglena* spp. Phytoplankton food items that were most common in the stomachs of fish samples from Brenu lagoon were the diatoms, (80.5%). The diatoms mostly present were the *Navicula* spp. and few species of *Gyrosigma*, *Flagilaria*, *Coscinodiscus* and *Merismopedia*. Species of *Diatoma, Striatella, Tabellaria, Rhizosolena,* and *Surirella* in addition to *Flagillaria*, *Gyrosigma* and *Navicula* formed 61.9% of phytoplankton food that occurred in stomachs of fish samples from Nakwa lagoon. About 51.2% and 35.7% of the blue-green algae occurred in the stomachs of fish samples from Brenu and Nakwa lagoons respectively. Species of *Lyngbya*, and *Anabaena* were mostly encountered with species of *Spirulina*, *Gloeotrichia, Nodularia*, *Oscillatoria*, and *Gomphospheria* constituting little to proportions of food in stomachs of fish samples from Brenu. *Gloeotrichia*, S*pirulina*, *Oscillatoria*, *Lyngbya* together with *Aphanizomenon* spp. were seen in the stomachs of fish samples from Nakwa lagoon. About the same amount of desmids were eaten by fishes from both lagoons. There were also *Closterium* and *Pleurotaenium* spp in the stomachs of fish samples from Nakwa lagoon whilst *Closterium*, *Pleurotaenium*, *Desmidium* and *Microsterias* were found in the fish samples from Brenu lagoon. The detrital matter is always present in food ingested by fishes from the two lagoons whiles sand particles represented 59.5% and 97.6% of food items ingested by fish samples from Nakwa and Brenu respectively. Animal food organisms such as rotifers made up more than 40% of food in stomachs of fish from Nakwa but

Peer-reviewed version available at Fisheries and Aquatic Sciences 2019, 31; doi:10.1186/s41240-019-0146-z

only about 15% food in stomachs of fish from Brenu lagoons. Sand particles and unidentified organisms constituted 59.5% and 90.5% respectively in stomachs of fish from Nakwa lagoon compared to 97.6% of sand particles and 82.9% of unidentified organisms ingested by fish from Brenu lagoon.

Table 4. Percentage frequency of occurrence values of various food categories in the stomachs of *Sarotherodon melanotheron* from Nakwa and Brenu Lagoons

Food items	Species	Nakwa	Brenu
Diatoms		61.9	80.5
	Navicula		
	Gyrosigma		
	Flagilaria		
	Coscinodiscus		
	Merismopedia		
	Diatoma		
	Striatella		
	Tabellaria		
	Rhizosolena		
	Surirella		
Desmids		38.1	39.0
	Closterium		
	Pleurotaenium		
	Desmidium		
	Microsterias		
Green algae		69.0	26.8
	Spirogyra sp		
	Geminella sp		
	Mougeotia sp		
	Euglena		
	Microspora		
	Chrysoccocus		
	Terubaria		
	Elakatrothrix		
	Oocystis		

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 12 February 2019 doi:10.20944/preprints201902.0106.v1

Peer-reviewed version available at Fisheries and Aquatic Sciences 2019, 31; doi:10.1186/s41240-019-0146-z

Blue-green algae		35.7	51.2
	Lyngbya		
	Anabaena		
	Spirulina		
	Gloeotrichia		
	Nodularia		
	Oscillatoria		
	Gomphospheria		
	Aphanizomenon		
Cladocerans		2.4	4.9
Rotifers		40.5	14.6
Calanoids		2.4	17.1
Unidentified Organisms.		90.5	82.9
Detritus		100.0	100.0
Sand particles		59.5	97.6
Fish scales		-	7.3
Fish eggs		4.8	7.3
Insects		2.4	-

4.0 Discussion

Fish samples collected from these lagoons showed a difference in their sizes. Fish samples from Brenu lagoon are of significantly bigger sizes (Mean ± SD) with a maximum length of 12.8cm compared to fishes from Nakwa lagoon (Mean ± SD) with a maximum length of 11.5cm. In Nakwa lagoon, uni-modal size class of fish samples was observed. In Brenu lagoon, however, three different size classes are evident in the fish samples. The estimated 'b' values derived from the allometric length-weight relationship of the fish samples from the two lagoons showed that weights of fish samples from Brenu lagoon are lighter for their lengths. This means that the 'b' values for fish samples from this lagoon are significantly different ($p>0.05$) from 3. A proportional relationship between length and weight of fish samples from Nakwa lagoon was observed, implying that fishes in this lagoon grow isometrically. This is in agreement with

Peer-reviewed version available at *Fisheries and Aquatic Sciences* **2019**, 31; doi:10.1186/s41240-019-0146-z

findings on *S. melanotheron* from Ologo Lagoon, Lagos (Ndimele et al. 2010); from Eleiyele Lake in Southwestern Nigeria (Ayoade and Ikulala 2007). Other studies found isometric and allometric growth in different cichlids in the same waterbody (Abowei et al. 2009) and among different fishes from the same environment (Kumolu-Johnson and Ndimele 2010).

Although fish samples from Brenu lagoon show negative allometric growth, their condition factors are significantly higher (5.398 ± 0.479) than fish samples from Nakwa lagoon (3.955 ± 0.389) ($p<0.05$). Abowei et al. (2009) stated that the condition factor of a fish reflects, through its variations, information on the physiological state of the fish in relation to its welfare. Saliu (2001) reported that condition factor might be influenced by both biotic and abiotic factors such as feeding regimes and state of gonadal development. No much variation was observed in the condition factor over sizes of fish samples in Nakwa lagoon but condition factor was high in small fish sizes and low is the bigger fish sizes. Though the time period for the study was short and data collection carried out in the minor raining season, the results showed that the condition factor of the fish samples varied between the lagoons. The mean condition factors for S. *melanotheron* from both lagoons are greater than 1 and this shows that the fish samples are above average condition in their environment (Wade 1992). The difference in growth may be due to the relatively lower aeration and higher salinity levels in the Brenu Lagoon. The Lagoon bottom is very muddy due to deposition of fine allochthonous material which could increase the biological oxygen demand and thus, the reduced dissolved oxygen concentration. Also, there is very little or no mixing of the water as the sand bar cuts of the sea water from entering the lagoon which may be the cause of the decreased oxygen and relatively higher salinity levels. The lagoon itself is being used by the locals for salt production. Low fishing activities in addition to strict adherence to off fishing days in the lagoon could also contribute significantly to the observed results. Nakwa lagoon, on the other hand, has vibrant fishing activities taking

Peer-reviewed version available at *Fisheries and Aquatic Sciences* **2019**, 31; doi:10.1186/s41240-019-0146-z

place in it. The mouth of the lagoon is the landing site for the marine fishermen and the exposure to the sea coupled with riverine influence are factors that could explain the high oxygen levels in Nakwa.

Otolith size – otolith weight relationship analysed with the power equation showed high correlations with growth coefficients of fish samples from both lagoons approaching isometric growth. The relationship between otolith size and fish size (standard length) from both lagoons are also highly correlated but with small allometric growth coefficients. This means that both otolith weight and standard length of *S. melanotheron* can be estimated if data on the fish otolith length is available.

Results of otolith age determination showed that for *S. melanotheron* from both lagoons with a size range between 3.9 – 7.9cm and 7.0 – 10.2cm, estimated ages of 56 – 166 days and 85 – 150 days were seen for Nakwa and Brenu lagoons respectively. The mean ages of fish samples were significantly different between the two lagoons ($p<0.05$). Fish samples from Brenu lagoon showed a higher condition factor; $K \pm$ Se value of 3.27 ± 15.8932 compared with the value of 2.76 ± 4.6202 for samples from Nakwa lagoon (Table 2). The difference observed in the condition factors may be due to variation in environmental conditions in the lagoons. (Panfili et al. 2004) observed a reduction in growth rate with the corresponding reduction in size at maturity of *S. melanotheron* with increasing salinity. They concluded that the observation in the reduction in size at maturity may be due to the reduction of growth but also to an earlier maturity. From this study, however, it has been found that the growth rate in Brenu lagoon, with high salinity, is higher with increased size at maturity and comparatively low growth rate in Nakwa lagoon with reduced size at maturity. They thus tend to approach length at infinity faster than fish samples from Nakwa lagoon (Figure 5). The high asymptotic length calculated from fish samples from Brenu lagoon may be as a result of the large fish sizes in the samples (13.44

Peer-reviewed version available at Fisheries and Aquatic Sciences 2019, 31; doi:10.1186/s41240-019-0146-z

± 25.9103). Asymptotic lengths of *S. melanotheron* from this study fall in range of asymptotic lengths computed for this species in other lagoons: 11.5cm (Densu delta), 12.5cm (Muni lagoon), 12.5cm (Sakumo Lagoon), 12.4cm (Songhor Lagoon), and 17.5cm (Keta Lagoon) along the coast of Ghana (Entsua-Mensah et al. 2000). The comparatively low growth rate and asymptotic length of fish samples from Nakwa lagoon could be due to the high variability in salinity which may impact their physiology and also the high level of fishing activities which continually take out bigger sizes of fish from the stock.

The daily increment of otolith rings per day of the species in both lagoons did not show a pronounced difference (Figure 6). This could be due to the fact that temperature which is the main factor impacting metabolic activities in fishes did not show much difference between the lagoons since the lagoons experienced similar illumination.

The range of food present, how well fishes make use of food in their environment in addition to the existing physicochemical conditions affects their growth and well-being. Food present in the stomach of fish samples from Nakwa lagoon was less varied than that in fishes of Brenu lagoon. Results of the food habit of the *S. melanotheron* agreed with other findings that showed that the species are planktivorous (Ofori-Danson and Kumi 2006; Ayoade and Ikulala 2007; Ndimele et al. 2010). Also present in the stomachs of fish samples from both lagoons are high proportions of detritus and sand particles. This suggests that the fish samples from both lagoons feed mostly on the substratum.

5.0 Conclusion

Nakwa and Brenu lagoons are very important lagoons along the coast of Ghana that support artisanal fisheries of the most abundant fish species, *S. melanotheron*. The estimated ‘b’ values derived from the length-weight relationship of the species indicated that the *S. melanotheron* population from Nakwa lagoon grows isometrically and the samples from Brenu lagoon grow

Peer-reviewed version available at Fisheries and Aquatic Sciences 2019, 31; doi:10.1186/s41240-019-0146-z

allometrically but are in better condition compared to species from Nakwa lagoon. The species are fast growing as indicated by the rate at which the species approach the length at infinity. Food habits of the species showed that they are omnivorous and are bottom feeders, having detritus and sand in their food.

The study provides the basis for further work on this important species in these lagoons and other lagoons for better management of the resources. It is recommended that further studies be carried out during the two major seasons in the country to obtain knowledge of seasonal differences in the growth and conditions of the species in the lagoons. Otolith analysis proved to be successful in aging the fishes but with much difficulty for the adults, in terms of preparation of samples. Further work should focus on juvenile otoliths since they are most sensitive to conditions in their environment.

Peer-reviewed version available at *Fisheries and Aquatic Sciences* **2019**, 31; doi:10.1186/s41240-019-0146-z

References

1. Abowei J, Davies O, Eli A. 2009. Study of the length-weight relationship and condition factor of five fish species from Nkoro River, Niger Delta, Nigeria. *Current Research Journal of Biological Sciences* 1:94-98. http://www.airitilibrary.com/Publication/alDetailedMesh?docid=20410778-200910-201009060065-201009060065-94-98.
2. Aguilera B, Catalán IA, Palomera I, Olivar MP. 2009. Otolith growth of European sea bass (Dicentrarchus labrax L.) larvae fed with constant or varying food levels. *Scientia Marina* 73:173-182. https://doi.org/10.3989/scimar.2009.73n1173.
3. Ayoade A, Ikulala A. 2007. Length weight relationship, condition factor and stomach contents of Hemichromis bimaculatus, Sarotherodon melanotheron and Chromidotilapia guentheri (Perciformes: Cichlidae) in Eleiyele Lake, Southwestern Nigeria. *Revista de biologia tropical* 55:969-977. https://www.redalyc.org/articulo.oa?id=44912352020.
4. Blay J, Asabere-Ameyaw A. 1993. Assessment of the fishery of a stunted population of the cichlid, Sarotherodon melanotheron (Rüppel), in a “closed” lagoon in Ghana. *Journal of Applied Ichthyology* 9:1-11. https://doi.org/10.1111/j.1439-0426.1993.tb00382.x

5. Campana S, Jones C. 1992. Analysis of otolith microstructure data. In ‘Otolith Microstructure Examination and Analysis’.(Eds DK Stevenson and SE Campana.) pp. 73–100. *Canadian Special Publication of Fisheries and Aquatic Sciences*. 117.
6. Dankwa H, Shenker J, Lin J, Ofori-Danson P, Ntiamoa-Baidu Y. 2004. Fisheries of two tropical lagoons in Ghana, West Africa. *Fisheries Management and Ecology* 11:379-386. https://doi.org/10.1111/j.1365-2400.2004.00406.x.
7. Ekau W, Blay J. 2000. Validation of daily increment deposition and early development in the otoliths of Sarotherodon melanotheron. *Journal of fish biology* 57:1539-1549. https://doi.org/10.1111/j.1095-8649.2000.tb02230.x

8. Entsua-Mensah M, Ofori-Danson P, Koranteng K. 2000. Management issues for the sustainable use of lagoon fish resources. pp. 24-27 Biodiversity and sustainable use of fish in the coastal zone, ICLARM Conference Proceedings.

9. Fowler AJ. 1990. Validation of annual growth increments in the otoliths of a small, tropical coral reef fish. *Marine Ecology Progress Series*. 25-38. https://www.int-res.com/articles/meps/64/m064p025.pdf.
10. Gauldie R. 1990. A measure of metabolism in fish otoliths. Comparative Biochemistry and Physiology Part A: *Physiology* 97:475-480. https://doi.org/10.1016/0300-9629(90)90113-7.
11. Geffen A. 1982. Otolith ring deposition in relation to growth rate in herring (Clupea harengus) and turbot (Scophthalmus maximus) larvae. *Marine Biology* 71:317-326. https://link.springer.com/article/10.1007/BF00397048.
12. Isaac VJ. 1990. The accuracy of some length-based methods for fish population studies. WorldFish.
13. Jiménez-Badillo L. 2006. Age-growth models for tilapia Oreochromis aureus (Perciformes, Cichlidae) of the Infiernillo reservoir, Mexico and reproductive behaviour. *Revista de biología tropical* 54:577-588. https://revistas.ucr.ac.cr/index.php/rbt/article/view/13923.
14. Kone T, Teugels GG. 2003. Food habits of brackish water tilapia Sarotherodon melanotheron in riverine and lacustrine environments of a West African coastal basin. *Hydrobiologia* 490:75-85. https://link.springer.com/article/10.1023/A:1023410528580.
15. Koranteng K, Ofori-Danson P, Entsua-Mensah M. 2000. Fish and fisheries of the Muni lagoon in Ghana, West Africa. *Biodiversity and Conservation* 9:487-499. https://link.springer.com/article/10.1023/A:1008903813222.
16. Kumolu-Johnson C, Ndimele P. 2010. Length-weight relationships and condition factors of twenty-one fish species in Ologe Lagoon, Lagos, Nigeria. *Asian Journal of Agricultural Sciences* 2:174-179.
17. Labropoulou M, Papaconstantinou C. 2000. Comparison of otolith growth and somatic growth in two macrourid fishes. *Fisheries Research* 46:177-188. https://doi.org/10.1016/S0165-7836(00)00144-2
18. Lazard J. 1990. Transferts de poissons et développement de la production piscicole: exemple de trois pays d'Afrique subsaharienne.
19. Legendre M, Ecoutin J-M. 1989. Suitability of brackish water tilapia species from the Ivory Coast for lagoon aquaculture. I–Reproduction. *Aquatic Living Resources* 2:71-79. https://doi.org/10.1051/alr:1989009

Peer-reviewed version available at *Fisheries and Aquatic Sciences* **2019**, 31; doi:10.1186/s41240-019-0146-z

20. Massou A, Panfili J, Laë R, Baroiller J-F, Mikolasek O, Fontenelle G, Bail PY. 2002. Effects of different food restrictions on somatic and otolith growth in Nile tilapia reared under controlled conditions. *Journal of Fish Biology* 60:1093-1104. https://doi.org/10.1111/j.1095-8649.2002.tb01706.x.
21. McCormick M, Molony B. 1992. Effects of feeding history on the growth characteristics of a reef fish at settlement. *Marine Biology* 114:165-173. https://link.springer.com/article/10.1007/BF00350866.
22. Molony B. 1996. Episodes of starvation are recorded in the otoliths of juvenile Ambassis vachelli (Chandidae), a tropical estuarine fish. *Marine Biology* 125:439-446. https://link.springer.com/article/10.1007/BF00353256
23. Myers P, Espinosa R, Parr CS, Jones T, Hammond GS, Dewey TA. 2018. The Animal Diversity Web (online). Accessed at http://animaldiversity.org. Accessed 30/10/2018.
24. Ndimele P, Kumolu-Johnson C, Aladetohun N, Ayorinde O. 2010. Length-weight relationship, condition factor and dietary composition of Sarotherodon melanotheron, Rüppell, 1852 (Pisces: cichlidae) in Ologe Lagoon, Lagos, Nigeria. *Agriculture and Biology Journal of North America* 1:584-590. https://www.cabdirect.org/cabdirect/abstract/20103236560.
25. Ofori-Danson P, Kumi GN. 2006. Food and Feeding Habit of Sarotherodon melanotheron, Rüppell, 1852 (Pisces: Cichlidae) in Sakumo Lagoon, Ghana. *West African Journal of Applied Ecology* 10:9-18. http://dx.doi.org/10.4314/wajae.v10i1.45692
26. Panfili J, Tomas J. 2001. Validation of age estimation and back-calculation of fish length based on otolith microstructures in tilapias (Pisces, Cichlidae). *Fishery Bulletin* 99:139-139.
27. Panfili J, Mbow A, Durand J-D, Diop K, Diouf K, Thior D, Ndiaye P, Laë R. 2004. Influence of salinity on the life-history traits of the West African black-chinned tilapia (Sarotherodon melanotheron): comparison between the Gambia and Saloum estuaries. *Aquatic Living Resources* 17:65-74. https://doi.org/10.1051/alr:2004002.
28. Pannella G. 1971. Fish otoliths: daily growth layers and periodical patterns. *Science* 173:1124-1127. http://science.sciencemag.org/content/173/4002/1124.

 doi:10.20944/preprints201902.0106.v1

Peer-reviewed version available at *Fisheries and Aquatic Sciences* **2019**, 31; doi:10.1186/s41240-019-0146-z

29. Saliu J. 2001. Observation on the condition factor of Brycinus nurse (Pisces: Cypriniformes, Characidae) from Asa Reservoir, Ilorin, Nigeria. *Tropical Freshwater Biology* 10:9-17. http://dx.doi.org/10.4314/tfb.v10i1.20837.
30. Ghana Statistical Service. 2002. 2000 population and housing census.
31. R Core T. 2018. R: A Language and Environment for Statistical Computing.
32. Simon K, Mazlan A, Samat A, Zaidi C, Aziz A. 2010. Size, growth and age of two congeneric archer fishes (Toxotes jaculatrix Pallas, 1767 and Toxotes chatareus Hamilton, 1822) inhabiting Malaysian coastal waters. *Sains Malaysiana* 39:697-704. http://journalarticle.ukm.my/7392/1/01_Md_Yeaminhossain.pdf.
33. Wade J. 1992. The relationship between temperature, food intake and growth of brown trout, Salmon trutta (L.) fed natural and artificial pelleted diet in earth ponds. *Journal of aquatic sciences* 7:59-71.
34. Waldron ME, Kerstan M. 2001. Age validation in horse mackerel (Trachurus trachurus) otoliths. ICES Journal of Marine Science *58*:806-813. https://doi.org/10.1006/jmsc.2001.1071.
35. Yankson K. 1982. Gonad maturation and sexuality in the West African bloody cockle, Anadara senilis (L.). *Journal of Molluscan Studies* 48:294-301. https://doi.org/10.1093/oxfordjournals.mollus.a065651.